



Standard Terminology Relating to Optical Fiber Sensing Systems¹

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1. Scope

1.1 This terminology standard is a compilation of definitions of technical terms related to optical fiber sensing systems, used in the various sections of standards under the jurisdiction of ASTM Committee F36.

1.2 Where possible definitions are stated as a single sentence, with necessary supplementary information as a Discussion. This approach is used to simplify explanations of the meanings of technical terms for the benefit of those not conversant with them, to facilitate a precise understanding and interpretation of F36 ASTM standards.

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

2. Referenced Documents

2.1 ASTM Standards:²

[F2233 Guide for Safety, Access Rights, Construction, Liability, and Risk Management for Optical Fiber Networks in Existing Sewers](#)

[F2303 Practice for Selection of Gravity Sewers Suitable for Installation of Optical Fiber Cable and Conduits](#)

[F2304 Practice for Sealing of Sewers Using Chemical Grouting](#)

[F2349 Practice for Operation and Maintenance of Integrated Natural Gas Pipelines and Optical Fiber Systems](#)

[F2350 Practice for Selection of Natural Gas Pipelines Suitable for Installation of Optical Fiber Systems](#)

[F2414 Practice for Sealing Sewer Manholes Using Chemical Grouting](#)

[F2454 Practice for Sealing Lateral Connections and lines from the mainline Sewer Systems by the Lateral Packer Method, Using Chemical Grouting](#)

[F2462 Practice for Operation and Maintenance of Sewers](#)

¹ This terminology is under the jurisdiction of ASTM Committee F36 on Technology and Underground Utilities and is the direct responsibility of Subcommittee F36.91 on Terminology.

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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.

[with Optical Fiber Systems](#)

[F2550 Practice for Locating Leaks in Sewer Pipes By Measuring the Variation of Electric Current Flow Through the Pipe Wall](#)

[F2551 Practice for Installing a Protective Cementitious Liner System in Sanitary Sewer Manholes](#)

3. Significance and Use

3.1 Definitions in this standard are to be regarded as correct for the terms found in other ASTM standards of Committee F36. Certain terms may be found in more than one standard issued under the jurisdiction of this committee and many of these terms have been placed in this standard.

4. Terminology

absorption, n —the loss of some or all of the energy contained in an electromagnetic wave to the medium in which it is propagating, usually converted to heat.

acceptance angle, n —the maximum angle, measured from the optical fiber centerline to an incident light ray, within which the incident ray will be accepted for transmission by total internal reflection along the fiber.

DISCUSSION—If the incident angle is greater than the acceptance angle, total internal reflection will not occur and the incident ray will be lost by leakage.

access rights, n —agreements between various parties to obtain temporary and permanent access to property for the purpose of constructing, maintaining, or changing optical fiber networks. **F2233**

accuracy, n —the closeness of the measured value to the true or the ideal value of the parameter being measured and is affected by both bias and precision.

acoustic wave, n —longitudinal waves propagated by means of adiabatic compression and decompression.

acousto-optics, n —the science and technology of the interactions between sound waves and light waves passing through material media, especially as applied to the modulation and deflection of laser beams by ultrasonic waves.

acrylamide, n —organic solid of white, odorless, acrylic resinous material available in flake-like crystals and in liquid form. The greatest use of acrylamide is as a coagulant aid in

drinking water treatment. Other major uses of acrylamide are in soil stabilization, in grout for repairing sewers and in acrylamide gels used in biotechnology laboratories. **F2414**

acrylate, *n*—a general term applied to various water-soluble acrylic resinous materials. **F2414**

adit, *n*—*in tunneling*, a tunnel driven from ground surface to provide access to or drainage from underground workings; a length of tunnel driven for an exploration-exploration adit.

advance, *n*—*in tunneling*, the forward progress in the construction of a tunnel, usually measured by the length created, or the rate of segment positioning in terms of a number per hour/day or some other timescale.

ambient temperature, *n*—the temperature of the surrounding environment or air. **F2304**

Angstrom, A, *n*—a unit of length equal to 10^{-1} nanometer (10^{-1} nm), 10^{-4} micron (10^{-6} mm), and 10^{-10} meter (10^{-10} m).

annulus, *n*—*in tunneling*, a ring-shaped opening, generally bounded by the outside diameter of excavated tunnel and the exterior of the final tunnel liner. **F2304**

aperture, *n*—*in optics*, a hole or an opening through which light travels.

attenuation, *n*—the decrease in optical power of a signal, or light wave, from interaction with the propagation medium, for example, absorption, reflection, diffusion, scattering, deflection, dispersion or resistance.

attenuation budget, *n*—the maximum cumulative one-way or two-way optical power loss between the interrogator and the measurement point that allows a measurement with a specified performance.

attenuation range, *n*—total cumulated optical loss (one way loss; expressed in decibels (dB)) tolerated by the DRS system without affecting the specified measurement performance more than a given factor at a given location, spatial resolution, and measurement time.

DISCUSSION—Part of the total cumulative loss can be the fiber attenuation, point defect losses introduced by components such as connectors, splices, kink in the fiber, attenuators, etc.

authorized inspector, *n*—the person(s) contracted or approved by the owner or owner's representative to do inspections. **F2414**

backfill, *n*—*in tunneling*, a material used to replace excavated soil.

bandwidth, *n*—the range of frequencies that a device is capable of handling.

beam splitter, *n*—an optical device for dividing a light beam into two separated beams.

bench, *n*—*in tunneling*, in situ ground at the lower face of a tunnel undergoing staged excavation.

bend loss, *n*—optical power loss in an optical fiber because signal radiation escapes through its bends, with the magnitude of optical power loss being proportional to the bending radius.

bending radius, *n*—the radius of a bend measured in a fiber optic cable.

bentonite, *n*—clay composed mainly of clay mineral 'montmorillonite,' used for synthetic reasons, due to its expanding properties when in contact with water, for example, drilling mud, binder, absorbent, groundwater barrier, etc.

bias, *n*—the difference between the measured results after averaging, less the true value.

birefringence, *n*—the separation of a light beam into two components to form two rays propagating at different velocities in the medium.

bolt pocket, *n*—*in tunneling*, a pre-formed recess in tunnel segment to accommodate bolts which hold segments together.

bore, *n*—*in tunneling*, the internal diameter of a pipe or other cylinder, single tunnel, for example, twin bore.

borehole, *n*—a hole driven into the ground to get information about the strata, or to release water pressure by vertical sand drains, or to obtain water, oil, gas, etc.

borings/bored, *n*—making a hole in the ground by means of rotating auger.

box jack/jacked box, *n*—*in tunneling*, a fully constructed structure that is thrust into final position from an adjacent jacking point.

Bragg cell, *n*—an acousto-optic device that is capable of modulating light waves to produce an output light wave with an imposed frequency equal to the frequency of the input signal.

Brillouin optical time domain analysis, BOTDA, *n*—double ended access to the light source and detection system for long sensing lengths combined with high strain and temperature resolution for up to 31 miles (50 km) without signal regeneration.

Brillouin optical time domain reflectometer, BOTDR, *n*—a single ended access to the source and detection system, which provides a Brillouin gain-loss-based distribution sensor much like the standard OTDR sensors which use Rayleigh scattering to the same effect. See **optical time domain reflectometer**.

Brillouin scattering, *n*—light in a medium interacts with time-dependent optical density variations and changes its frequency and path.

DISCUSSION—The density variations may be due to acoustic modes, such as phonons, or magnetic modes, such as temperature gradients. As described in classical physics, when the medium is compressed its index of refraction changes, and a fraction of the traveling light wave, interacting with the periodic refraction index variations, is deflected as in a three-dimensional diffraction grating. Since the sound wave, too, is traveling, light is also subjected to a Doppler shift, so its frequency changes.

cable, *n*—a group of insulated light conductors that are bound together, usually with a durable cable jacket.

cable jacket, *n*—the outer protective covering over insulated conductors that are bound together.

caisson, *n*—*in tunneling*, a watertight retaining structure, that can be used as a support of excavation for a shaft structure.

canopy tube, *n*—*in tunneling*, a metal tube drilled into the tunnel face above the ground to be excavated, the tube is pumped full of grout once in place; the canopy is created using multiple adjacent tubes to reduce the risk of crown failure.

catalyst, *n*—substance which markedly speeds up the cure of an adhesive when added in small quantities as compared to the amounts of primary reactants. **F2414**

caulking, *n*—one of several different processes to seal joints or seams in various structures and piping. **F2454**

character-separated value file format, CSV, *n*—synonymous with “comma separated value file,” stores tabular data (numbers and text) in a sequence of characters, with no data that has to be interpreted, separated by some character or string, for example, comma or tab.

characteristic frequency and/or wavelength at reference temperature (Brillouin technologies), *n*—the frequency and/or wavelength that characterizes the sensor response at reference temperature as monitored by the interrogator.

DISCUSSION—As Brillouin frequency varies with wavelength of the light source, this also changes the temperature and strain coefficients for various sensing fibers. Therefore, characteristic frequency and the wavelength at a specified reference temperature and at zero strain are usually provided by the complete system producers.

chemical grout, *n*—injection repair media other than cementitious grout that may be multicomponent, with or without additives, and based on either polyurethane resin or acrylic resin. **F2414**

circumferential joint, *n*—*in tunneling*, a joint (typically between segments) which runs circumferentially relative to the tunnel bore.

cladding, *n*—*in optics*, optical transparent material over the core of the optical fiber, with a refractive index lower than that of the core, to provide total internal reflectance.

coherence length, *n*—the coherence time of a light beam multiplied by the velocity of the light.

coherence time, *n*—if t is the time a light beam takes to become coherent, and $t + \Delta t$ is the time at which the light beam loses its coherent properties, Δt is the coherence time.

coherent light, *n*—light which has predictable parameters at any point in time or space, for example, laser light.

combined sewers, *n*—sewers that carry both wastewater and storm or surface water. **F2303**

compensation grouting, *n*—*in tunneling*, a method of reversing ground settlements by injecting grout into the ground.

competent person, *n*—a person properly trained in the safety aspects of an activity. **F2233**

conductor, *n*—a transparent medium that is capable of transmitting or conveying light waves by total internal reflection.

conduit, *n*—plastic tubing used to house optical fiber cable that is connected to, but not inside of, a pipeline. **F2349, F2462**

confined space, *n*—an enclosed area that is large enough and so configured that a person can bodily enter and has the following characteristics: its primary function is something other than human occupancy; has restricted entry and exit. (Restricted entry and exit is a physical configuration which requires the use of hands or contortion of the body to enter into or exit from the confined space.) **F2233**

connector, *n*—coupling device attached to the end of a fiber so that it can be mechanically connected to equipment or mated with another connector to join two fibers together by aligning their cores to minimize signal loss.

connector insertion loss, *n*—the power loss due to the insertion of a connector between two elements.

constructability, *n*—the term used to denote the condition of a completed set of plans and specifications for an optical fiber network and its impact to the host utility, which have been prepared with an analysis of practical, feasible methods of construction. **F2233**

contractor, *n*—usually, the entity in charge of construction of the new tunnel or other infrastructure that may impact the utility. **F2551**

control agent, *n*—substance added which controls the viscosity or flow properties of the material it is added to. **F2414**

convergence, *n*—*in tunneling*, a measurement of the inward movements of tunnel walls, often monitored to provide information on the performance of the lining during construction.

conveyor, *n*—*in tunneling*, used to remove excavated material from a tunnel face or shaft.

core, *n*—the primary light-conducting region of an optical fiber. The refractive index of the core is higher than its cladding, the condition necessary for total internal reflection.

coupler, *n*—a mechanical connector that is used to interconnect two or more optical fibers.

coupler 3-dB, *n*—a coupler that splits the optical energy in an optical waveguide into two equal parts and couples each part into a separate waveguide; ideally distributes 50 % of the input optical power to each of the output channels.

coupling, *n*—the connection between elements, whether physical or across a gap, where energy from one element is transferred to one or more other elements.

coupling loss, *n*—the power loss caused by the coupling.

coupling ratio, *n*—the ratio of the output power to the input power.

covered tasks, *n*—an activity, identified by the operator, that is performed on a pipeline; is an operations and maintenance

task; is performed as a requirement of this part and affects operation or integrity of the pipeline. **F2349**

critical angle, *n*—measured angle between the incident ray and the normal to the reflecting surface where total internal reflection begins.

DISCUSSION—Total internal reflection continues for all angles greater than the critical angle.

critical radius, *n*—the radius of curvature of an optical fiber containing an axially propagated light wave at which microbend losses begin to occur.

cross passage, *n*—*in tunneling*, a small tunnel used to connect between adjacent tunnel bores in a multiple-bore tunnel.

cross-sensitivity, *n*—the unwanted change of measured result due to the influence of physical factors other than the measured parameters.

crow, *n*—*in tunneling*, the highest point of the internal curved surface of a tunnel cross section.

culvert, *n*—small channel or drain used to carry water beneath an obstacle.

cured-in-place pipe, CIPP, *n*—a trenchless rehabilitation method used to repair existing pipelines.

DISCUSSION—The cured in place lining process consists of a flexible resin-saturated felt tube made of polyester or another resin, fiberglass cloth or a number of other materials suitable for resin impregnation, which is inverted or pulled into a damaged pipe. Little to no digging is involved in this trenchless process, which potentially allows this method to be more cost-effective and less disruptive than traditional “dig and replace” pipe repair methods. Once flexible resin impregnated lining is installed in damaged pipe, hot water, UV light, ambient cured or steam is used to cure the resin and form a tight-fitting, jointless and corrosion-resistant replacement pipe.

cutterhead, *n*—*in tunneling*, the head at the front of a tunnel boring machine used for cutting into the ground.

DISCUSSION—The cutterhead is designed for specific soil types, for example, hard rock, soft ground, high pressure, etc.

cut and cover tunnel, *n*—*in tunneling*, a method of tunnel construction involving excavating a trench, installing the structure and covering it over, generally used for shallow tunnels.

data link, *n*—a communication link suitable for transmission of data, which does not include the data source and the data sink.

decibel, dB, *n*—a gain or attenuation factor, measured as 10 times the log of a power ratio.

delay distortion, *n*—in a waveform or signal that contains two or more different frequencies, that is, different wavelengths, such as that occurs in the spectral width of an optical pulse, distortion caused by the difference in arrival times of the frequencies at the output of a transmission system, for example, as at the end of a fiber optic link.

demodulation, *n*—the extraction of the original signal from the carrier.

designated control point, DCP, *n*—specific documented locations in the pipeline system where the operations plan designates the control of gas. **F2349**

detector, *n*—a device that responds to a signal and reproduces the signal in a new form, usually in a form that is easier to process.

dewatering, *n*—the removal of water from soils, normally carried out with well points alone, or in combination with an impermeable cut-off wall.

diaphragm wall, *n*—a concrete retaining wall (usually reinforced) constructed by installing adjacent panels of concrete underground, using the following method: excavate panel opening under pressure from drilling mud; lower reinforcement cage into place (if applicable); pour concrete into the hole, displacing the drilling mud.

diffraction, *n*—the bending of radio, sound, or light waves around an edge; typically aperture edges.

diffuse reflectance spectroscopy, DRS, *n*—non-invasive technique that measures the characteristic reflectance spectrum produced as light passes through a medium, by measuring absorption and scattering.

discharge hose, *n*—a flexible tubing that facilitates outflow through which the hot water or steam condensate is released after flowing through the CIPP liner that is being cured.

discrete thermal elements, *n*—temperature monitoring components that are not continuous.

dispersion, *n*—*in optics*, wavelength dependent time-of-flight of an optical signal resulting from the fact that the index of refraction of a fiber is wavelength dependent, that is, if the refractive index, *n*, of a medium on the wavelength, *l*, then dispersion = dn/dl .

distance measurement range, *n*—maximum distance (specified in length units) from the DTS output connector along the fiber optic sensor within which the instrument measures a temperature with specified measurement performance under defined conditions.

DISCUSSION—This supporting parameter is closely related to the attenuation range of the instrument. In test cases used to prove or verify the reported specifications, the total fiber length shall be equal to or greater than the specified distance measurement range (equal to or greater than twice the distance measurement range in the loop configuration).

distortion, *n*—*in electronics*, to reproduce or amplify (a signal) inaccurately by changing the frequencies or unequally changing the delay or the amplitude of the components of the output wave.

distributed acoustic sensing, DAS, *n*—a system using fiber optic cables to provide distributed strain sensing over its entire length.

distributed optical fiber sensing system, DOFSS, *n*—a system using optical fiber cable as a sensor, without discrete elements such as wound mandrels or fiber Bragg gratings,

that is sensitive over its entire length to deliver spatially continuous and resolvable data on the desired measured parameters.

distributed temperature gradient sensing, DTGS, *n*—a system using optical fiber cable to measure temperature temporal and spatial gradients using thermal strain and thermo-optic effects.

distributed temperature sensing, DTS, *n*—devices which measure temperatures by means of optical fibers function as liner sensors, temperatures are measured along the optical sensor cable to provide a continuous profile.

distribution lines, *n*—a pipeline other than a gathering or transmission line. **F2349**

drift, *n*—a slow change in time of the monitoring characteristics of the measurement system.

drill and blast, *n*—*in tunneling*, the excavation of a tunnel, shaft, or cavern in rock using explosive charges placed in holes drilled in the face.

durability, *n*—a quality of a manufactured component of a measurement system or of the entire measurement system measured by how well it withstands a sustained period of specified operation.

earth pressure balance machine, EPBM, *n*—*in tunneling*, a type of tunnel boring machine which retains a prescribed amount of excavated soil in the cutterhead, in an effort to equal the pressure in front of the machine, this method reduces the risk of soil running into the machine causing excessive settlements above.

electromagnetic interference, EMI, *n*—the interference caused in a circuit by radiation through coupling.

electrostriction, *n*—*in optics*, physical mechanism that accounts for a material density change induced by an electric field in an isotropic body.

DISCUSSION—Electrostrictive pressure is the result of electrostriction, an acoustic wave created by the propagation of the two light waves, specifically the Stokes (probe) wave and the pump wave.

electro-optic device, *n*—a device that converts electronic signals to optical signals or optical signals to electronic signals.

emergency incident, *n*—an emergency incident may involve fire, damage to underground facilities, explosion, gas leak, injury, death, gas outage, district pressure problems, hazardous or toxic material spills, or response by fire, police, or other agencies. **F2349**

engineer, *n*—the licensed professional engineer registered in the state where the work is being done designated by the owner/operator of the utility or the tunnel, to represent the owner's/operator's interests during the ground movement monitoring process or pipe renovation process. **F2303**

environmental temperature repeatability, *n*—difference of the measured constant fiber optic sensor temperature at a specified instrument temperature (for example, nominal

operating temperature) before and after temperature cycling of the instrument across the entire instrument operating temperature range.

environmental temperature stability, *n*—difference of the measured constant fiber optic sensor temperature before, during and after temperature cycling of the DTS instrument across the entire instrument operating temperature range.

DISCUSSION—Worst case environmental temperature effect, high/low environmental temperature effect, and environmental temperature repeatability are derived from this definition.

evanescent wave, *n*—the wave radiating away from the fiber at sharp bends in the optical fiber where the radius of the bend is less than the critical bending radius.

exfiltration, *n*—leaking or weeping to the external areas outside the barrier from a source inside the barrier. **F2414**

expanded gasket procedure, EGP, *n*—the sealing of joints, cracks, or holes by soaking dry, oil-free oakum with chemical grout and forcing the oakum/resin plug into the opening until it sets. **F2414**

expanded lining, *n*—*in tunneling*, primary lining that consists of segments that are expanded circumferentially against the surrounding ground.

extrados, *n*—the outside face of a structure element.

eye, *n*—*in tunneling*, the start of a tunnel, normally at a junction between a shaft and a tunnel.

Fabry Perot interferometer, *n*—a high resolution multiple beam interferometer especially sensitive to linear motion of the mirrors.

face dowel, *n*—*in tunneling*, a rod of steel or fiberglass inserted into the tunnel face to provide temporary support and assist in limiting face movement.

face loss, *n*—*in tunneling*, the loss of material from the face of a tunnel.

failure criteria of the sensor, *n*—the measurement uncertainty due to overstressing, overheating, and other factors leading to results or data that are unreliable.

fault, *n*—*in geology*, a crack in the earth's crust resulting from the displacement of one side with respect to the other on the scale of observation.

fiber, *n*—optical: any type of optical fiber.

fiber loss, *n*—power loss in an optical fiber, usually expressed in dB/km.

fiber optic, *n*—pertaining to optical fiber systems, such as sensors and communication systems.

fiber optic array, *n*—device that connects optical fibers to optical waveguide devices which are necessary for wavelength division multiplexing applications.

fiber optic cable, *n*—optical fibers incorporated into a cable.

fiber optic data link, *n*—a data link consisting of a modulated light source, a fiber optic cable, and a photo-detector.

fiber optic sensor, *n*—a sensor in which light is modulated by a specified environmental variable.

fiber optic sensor cable, *n*—cable formed using one or more strands of optical fiber to sense physical or other parameters of interest and/or transmit data.

fiber optic sheath, *n*—an outer protective covering over an optical fiber, or a cable.

fiber optic splice, *n*—a non-separable junction, usually formed by fusing the end of one optical to another.

fiber optics, FO, *n*—the theories and practices of using the technologies for control and guidance of optical power.

fiber to the x, FTTX, *n*—a generic term for any broadband network architecture using optic fiber to provide all or part of the local loop used for last mile communications.

frequency-division multiplexing, FDM, *n*—multiplexing in which the transmission frequency range is divided into narrow bands, each used as a separate channel.

fusion splicing, *v*—is the process of fusing or welding together two fibers, usually by an electric arc.

gas, *n*—*utilities*, natural gas. **F2350**

gauge length, GL, *n*—is the length of the measured structure over which the sensor gathers information. For example, if the sensor is anchored at two fixed points L cm apart, then the GL is L . If a sensor of length l is continuously-fixed in or to a measured structure of length L , then GL depends on the method of attachment to the measured structure and is a function of the mechanical properties of both the sensor and its surrounding; it is generally longer than l but shorter than, L .

graded-index fiber, *n*—an optical fiber with a refractive index that gets progressively lower as the distance increases along the normal to the fiber axis.

greenfield settlement, *n*—vertical downward movement of the ground solely due to the loss of soil caused by tunneling.

groundwater, *n*—water beneath the surface of the ground.

grout, *n*—*in soil and rock grouting*, a material injected into a soil or rock formation to change the physical characteristics of the formation, usually made of sand, water, and cement.

grout, *n*—*in tunneling*, a construction material used to improve ground conditions, fill voids in the ground or embed reinforcing bars, as well as fill the annulus between the excavated tunnel and the exterior of the final tunnel liner, usually made of sand, water, and cement.

heat differential, *n*—measurement of small temperature differences reliably performed by detecting the phase difference with the interference light and using a thermally symmetric configuration.

heterodyne detection, *n*—signal detection based on the mixing of two frequencies.

heterodyning, *n*—the mixing of an electromagnetic wave of one frequency with a wave of another frequency to produce a beat, usually for demodulation.

high/low environmental temperature effect, *n*—difference of the measured constant fiber optic sensor temperature at the high and low temperature limit of the instrument temperature operating range.

high-pressure distribution system, *n*—a distribution system in which the gas pressure in the main is higher than the pressure normally provided to the customer (that is, higher than utilization pressure). **F2350**

homodyne detection, *n*—signal detection based on the use of only one frequency.

homogeneous curing, *n*—equal curing rate in all directions and positions of a material.

host pipe, *n*—*in reference to CIPP*, the original damaged pipe containing the installed CIPP liner.

hot spot, *n*—length of fiber optic sensor (ΔL) which is exposed by a measurable temperature change ΔT which is significantly bigger than the instrument temperature repeatability and which is confirmed by reference temperature devices in the two thermal chambers.

hot tapping, *n*—a procedure for cutting or tapping into a gas pipeline under pressure. **F2349**

hydrophilic grout, *n*—grout that will absorb and react with the water it comes into contact with. **F2414**

hydrophobic grout, *n*—grout that will repel water. **F2414**

incident ray, *n*—a ray of light that strikes the surface of an object.

incident wave, *n*—a wave that impinges on a discontinuity, particle, or body, or on a medium having different propagation characteristics.

index-matching material, *n*—a light-conducting material used to reduce optical power losses, usually in connectors.

innerduct, *n*—plastic tubing used to house optical fiber cable inside a natural gas pipeline. **F2349**

installer, *n*—*in fiber optics*, the person(s) or body installing the optical fiber system. **F2303**

intensity sensor, *n*—*in fiber optics*, a fiber optic sensor in which the optical intensity of a light beam varies with an environmental signal.

interface temperature, *n*—the temperature at the interface between the inner surface of the pipe wall of the host pipe and the outer surface of the CIPP liner wall.

interferometer, *n*—an instrument in which the interference effects of light waves are used for the purpose of measurement.

interferometric sensor, *n*—a sensor that employs the principles of interferometry to perform a sensing function.

interferometry, *n*—the study of electromagnetic wave interference for precise measurements of parameters, such as wavelength and index of refraction.

internal reflection, *n*—a reflection at an outside surface from the inside such that an incident wave is reflected wholly or in part back into the element itself.

intrinsic fiber loss, *n*—optical power loss in an optical fiber or coupling.

isotropic material, *n*—a substance that exhibits the same property when tested along an axis in all directions.

Kerr cell, *n*—a substance, usually liquid, with a refractive index change proportional to the square of an applied electric field. The cell can provide a means of modulating the light in the optical path.

laser, *n*—a coherent-light source used to generate an intense, highly directional, narrow beam of electromagnetic energy.

lateral, *n*—*in sewers*, sewer pipe connecting the common sewer collection system to the user. **F2550**

liability, *n*—the exposure to claims for damage to another party's health, well being, or property; in the event that a bond is considered from a liability perspective, furnishing a bond will guarantee performance or payment of all bills, or both. **F2233**

life expectancy, *n*—a period of time during which the measuring system or its components are expected to operate according to its specifications for defined conditions.

light backscatter, *n*—a gradual attenuation of light due to Rayleigh, Raman or Brillouin scattering.

light ray, *n*—a line perpendicular to the wave front of a light wave indicating direction of propagation.

light source, *n*—any device that produces light.

light-emitting diode, LED, *n*—a diode without lasing action, having a spectral width of about 10 times that of a laser.

limiting conditions, *n*—the extreme conditions that a measuring instrument is required to withstand without damage, needing to switch off or degradation of specified characteristics when it is subsequently operated under its rated operating conditions.

linearity, *n*—*in fiber optic sensing*, the tolerance to which the transfer response characteristics of a measurement system (scale factor) approximates a straight line over the sensor range of the system.

DISCUSSION—For Brillouin sensors, it means that the range of temperature or strain should be within the Brillouin frequency which is linearly proportional to the strain or temperature.

link budget, *n*—accounting of all of the gains and losses from the transmitter, through the medium to the receiver.

local distribution company, LDC, *n*—the owner/operator of the natural gas piping system within a specific geographic area. **F2350**

location, *n*—*in fiber optic sensing*, optical distance (specified in length units) from the DTS output connector to a desired temperature sample point along the fiber optic sensor.

DISCUSSION—In the case of a loop configuration test setup, no measurements should be reported at a location beyond one half of the total fiber length. The furthest location from DTS output connector for the particular test is quantified as Z km and is often chosen to be the same as the distance measurement range for purposes of comparing the measurement results with quoted specifications.

location accuracy, *n*—the estimated location of a measurement or other system output, such as a detection report, minus the true location of the stimulus that generated the measurement or output.

loss, *n*—*in fiber optic sensing*, optical power loss in a fiber system.

low-pressure distribution system, *n*—*in utilities*, a distribution system in which the gas pressure in the main is substantially the same as the pressure provided to the customer.

Mach-Zehnder interferometer, *n*—an interferometer in which the light wave is split, and then recombined at a photo-detector.

magneto-optic, *n*—pertaining to the action of a magnetic field on light waves.

magneto-optic modulator, *n*—a modulator that uses a magnetic field to modulate a light wave.

main, *n*—*in utilities*, a distribution line that serves as a common source of supply for more than one service line. **F2350**

mainline, *n*—*in utilities*, pipe that is part of the common sewer collection system. **F2550**

manhole, MH, *n*—*in utilities*, vertical shafts intersecting a utility that allows entry for cleaning, inspection, and maintenance, sometimes referred to as “maintenance hole.” **F2303**

maximum allowable operating pressure, MAOP, *n*—*in utilities*, the maximum pressure that occurs in a utility during normal operations over a period of one year. **F2350**

measurement range, *n*—a set of values, the extent to which, or the limits between which measurement is possible for a given parameter.

measuring spatial resolution, *n*—the minimum distance over which the DOFSS is able to detect the value of the measured parameter, such as strain or temperature, averaged over this minimum distance, within the specified uncertainty.

measuring time, *n*—the required time interval needed to obtain a measurement within the specified uncertainty, the spatial resolution, and the system range, including any time required for data post-processing required by the DOFSS.

DISCUSSION—This parameter includes acquisition time and processing time for measured data. This parameter is selectable by the user typically in some limited fashion. Multiple independent temperature measurements may be averaged together to provide an overall measurement time.

Michelson interferometer, *n*—an interferometer in which an electromagnetic wave is split and recombined so that displacement measurements can be made by fringe counting.

microbend, *n*—a bend in the optical fiber with a radius equal to or smaller than the critical radius causing light waves in the core to penetrate into the cladding and leak from the fiber.

microbend loss, *n*—the signal attenuation caused by microbending.

microbend sensor, *n*—a sensor that converts mechanical movement to fiber bending so that the output light wave intensity is proportional to the mechanical movement.

micron, *n*— 10^{-6} meter, synonymous with micrometer.

mode, *n*—the characteristic state of a specific light beam traveling in a fiber, determined as function of the core diameter, the index of refraction of the core and cladding, the wavelength of the light.

modulation, *n*—the impressed variations of a carrier wave that correspond to an input signal.

modulator, *n*—a device that modulates a carrier.

moving grating sensor, *n*—a sensor consisting of both a fixed and moveable grating so that the intensity of light passing through the gratings is modulated according to the motion of the movable grating.

multimode fiber, *n*—an optical fiber waveguide that will support more than one mode.

multiplexing, *n*—a method of transmitting several signals on the same channel.

nanometer, nm, *n*— 10^{-9} meter.

nanosecond, ns, *n*— 10^{-9} second.

noise, *n*—the random variation in the measurement result unrelated to the measured parameter, primarily affecting the precision of measurement, causing degradation or masking of the desired signal.

numerical aperture, NA, *n*—a measure of the light-accepting ability of an optical fiber.

oakum, *n*—loose hemp or jute fiber, sometimes treated with resin or grout, used chiefly for caulking seams in structures and boats as well as packing pipe joints. **F2414**

operating temperature range of the measurement unit, *n*—the range of temperatures over which, the measurement unit can collect data on the parameters of interest, without losing its capacity for performance and reliability.

operator, *n*—the firm usually hired by the owner to operate and maintain the tunnel or the utility. **F2349**

operator qualification program, *n*—the minimum requirements for operator qualification of individuals performing covered tasks. **F2349**

optical fiber, *n*—an optical waveguide usually consisting of a glass core and glass cladding.

optical fiber cable, *n*—cable formed of one or more strands of optical fiber for transmission of data, video, audio, voice, and other information. **F2303, F2462**

optical fiber cable owner, *n*—the entity holding legal rights to, and responsible for the operation and maintenance of, the optical fiber cable and any components associated with the optical fiber system. **F2304, F2462**

optical fiber coating, *n*—a protective material this is put over the cladding to help protect the glass fiber from mechanical damage.

optical fiber conduit, *n*—fully-supported tubes suitably affixed to or suitably incorporated into the monitored structure. **F2303**

optical fiber jacket, *n*—a material used to cover an optical fiber, whether or not it is clad or coated.

optical fiber loss, *n*—the signal attenuation in an optical fiber, usually expressed in dB/km.

optical fiber network, *n*—telecommunications cable from central office to user. **F2233**

optical fiber sensing cable, *n*—cable formed using one or more strands of optical fiber to sense physical parameters and/or transmit data.

optical fiber sensor, *n*—composed of one or more optical fiber sensing cables and the associated light signal processing equipment as pertinent to DOFSS.

optical fiber system, *n*—the complete set of installed optical fiber components including cable, conduit, and attachment components. **F2303, F2462**

optical power budget, *n*—*in a fiber optic system*, the power for each element of the system that is required to keep the signals above specified distortion limits or error rates.

optical power dynamic range, *n*—is the ratio between the largest and smallest possible values of a changeable quantity in light signals. It is measured as a ratio, or as a base-10 (decibel) or base-2 (doublings, bits or stops) logarithmic value.

optical repeater, *n*—a signal amplification, processing, and re-transmitting device.

optical sensor, *n*—a sensor in which light is modulated by a specified environmental variable.

optical time domain reflectometry, OTDR, *n*—based on Rayleigh scattering, the elapsed time and intensity of light reflected in optical fiber is measured using an optical time domain reflectometer, which computes the distance to attenuations and/or breaks in the fiber.

owner/operator, *n*—the person(s) or governing body charged with construction, operation and maintenance of the underground utility or tunnel system. **F2303**

owner’s representative, *n*—*in construction*, the individual or body that has been contracted to act on behalf of the owner for project planning and supervision. **F2414**

partnering, *n*—*in construction*, teaming between the owner, engineer, contractor, and other involved parties. **F2233**

pdf file format, PDF, *n*—abbreviation for “Portable Document Format,” a format used to represent digital documents in a manner independent of application software, hardware, and operating system.

phase modulation, PM, *n*—modulation of the carrier wave phase angle to follow an environmental signal.

photo-detector, PD, *n*—a device that produces an electrical signal output proportional to the amplitude of the incoming light.

point defect, *n*—local deviation of a fiber optic sensor from its nominal optical and mechanical properties occurring at a single location, or over a length substantially less than the DTS spatial resolution.

DISCUSSION—The definition of a point defect encompasses a wide range of situations, which may produce similar effects on the temperature trace. Examples include: a point loss, such as a bad fiber splice; a back reflection, such as may arise from a fiber connector; a localized region of high loss, such as a bend or kink in the fiber; a physical discontinuity in the fiber, such as a splice between two fibers of different core diameters.

point defect temperature offset, *n*—difference between the average values of the temperature sample points in two zones on the temperature trace, one each side of a point defect, where the actual fiber optic sensor temperatures are the same.

DISCUSSION—The point defect temperature offset may be positive, negative or zero.

polarimetric sensor, *n*—a sensor in which the environmental signal alters the polarization of a light wave in an optical fiber.

polarization, *n*—the property of a radiated electromagnetic wave that describes the time-varying direction and amplitude of the electric field vector.

polarization modulation, *n*—the modulation of a carrier wave by changing the direction, amplitude, and/or phase of the electric field vector of an information-bearing input signal.

polarization multiplexing, *n*—multiplexing by using two or more polarization modes in the same transmission medium at the same time with the same frequency, each mode being a separate channel.

polymerization, *n*—a chemical process that combines several monomers to form a polymer or polymeric compound.

polyurethane resin, *n*—any of various polymer resins containing the urethane radical; a wide variety of synthetic forms

are made and used as adhesives, plastics, foams, paints, or rubber-like materials. **F2414**

post-curing, *n*—a process of exposing a part or mold to elevated temperatures to speed up the curing process and to maximize some of the material’s physical properties.

power budget, *n*—the allocation of available power in a system to the various functions that need to be performed.

precision, *n*—describes how repeatable a measurement result is, measured by the estimated standard deviation of a specified series of measurements.

probe wave, *n*—see **Stokes wave**.

pump laser, *n*—*in optics*, laser creating optical pump wave.

pump wave, *n*—see **incident wave**.

Raman effect, *n*—the inelastic scattering of a photon causing a change in the wavelength of light that occurs when a light beam is deflected by molecules.

range, *n*—the extent to which, or the limits between which, variation is possible.

Rayleigh scattering, *n*—the elastic scattering of light or other electromagnetic radiation by particles much smaller than the wavelength of the light.

reflected ray, *n*—a ray representing the light wave leaving a reflective surface and indicating the path at reflection.

reflection, *n*—the return of a light wave from a surface.

refractive index, *n*—the ratio of the velocity of light in a vacuum to the velocity of the same light in a new medium is the refractive index of the new medium.

repeatability, *n*—the closeness of the agreement between the results of successive measurements of the same measured parameter carried out under the same conditions of measurement.

report, *n*—the official written work product or project deliverable that contains a description of the scope of work done, data collected and presented in various forms, interpretation of the data, finding and recommendations for further action.

reproducibility, *n*—the quality of being reproducible. See **repeatability**.

resin, *n*—an artificial chemical substance which hardens irreversibly.

resolution, *n*—the smallest change in the measured parameter that can be indicated by the measurement system, not to be confused with precision, often called the “quantization interval” of the measurement system.

responsivity, *n*—the change in the response (output signal) of a complete measurement system to the corresponding change in the stimulus (input signal).

risk management, *n*—the process of identifying the risk on a construction project, and assigning the risks to the parties most capable of controlling the risks. **F2233**

safety, *n*—physical and mental activities that protect the health, well-being, and life of workers and third-party people, and activities that protect the property of all parties. **F2233**

Sagnac interferometer, *n*—an interferometer in which a light wave is split and passed in opposite directions through a coil to measure angular acceleration.

sag, *n*—to sink, droop or settle under self-weight.

sampling interval, *n*—distance between two points of measurement along the optical fiber sensor, sometimes referred to as “sample spacing.”

sanitary sewers, *n*—sewers that carry wastewater from users to the treatment plant. **F2303**

scale factor, *n*—the ratio of a measured change to the corresponding stimulus.

scale factor at reference conditions, *n*—the ratio of the measured input parameter’s engineering units to the output parameter’s units.

scattering, *n*—the deflection of electromagnetic waves caused by all the influences within a medium.

sensor, *n*—any device that responds to an environmental signal and produces an output signal that can be used as a measure of the environmental signal.

sensor array, *n*—a spatial distribution of sensors.

sensor range, *n*—range between the smallest and largest allowable value of the measured parameter.

service lateral, *n*—*in utilities*, see **lateral**. **F2303**

single-mode fiber, *n*—an optical fiber that supports the propagation of one mode, usually a low-loss optical waveguide with a very small core.

sliding pipe plug, *n*—*in utilities*, device that blocks flow through a pipe and at the same time can be pulled through a pipe. **F2550**

sonde, *n*—electro-scan electrode placed in a monitored structure used for testing various physical conditions. **F2550**

source, *n*—the part of a system from which signals or messages originate.

space-division multiplexing, *n*—use of spatial separation to obtain channel isolation.

spatial resolutions, *n*—the minimum distance between two step transitions of the measured parameter in time domain that can be independently observed with a specified performance.

spatial sampling interval, Δx , *n*—the spatial distance along the optical fiber between two adjacent outputs of the DOFSS.

DISCUSSION—Usually controlled by the high-rate temporal sampling interval of the optical detector, dt , and the speed of light in the fiber, cf , using $dx = dt*cf/2$. The spatial sampling interval shall be at least one-half of the spatial resolution.

spatial temperature uncertainty, *n*—uncertainty of location of temperature data in a single temperature trace expressed by twice the standard deviation of a specified number of adjacent temperature sample points, with the fiber optic sensor held at constant temperature.

splice, *v*—to join or connect two fibers together.

splitter, *n*—used to split the fiber optic light into several parts at a certain ratio.

step-index fiber, *n*—a fiber manufactured with a fixed index of refraction for the core and cladding, with the cladding index being less than that of the core.

stimulated Brillouin scattering, SBS, *n*—acoustic waves are intentionally created in a fiber through electrostriction using wave propagation, these waves cause Brillouin scattering, therefore it is stimulated Brillouin scattering.

stimulus, *n*—something causing or considered to be causing a response.

Stokes laser, *n*—*in optics*, laser creating optical Stoke wave.

Stokes wave, *n*—progressive periodic waves of permanent form.

storm sewers, *n*—sewers that carry storm or surface water away from roadways or structures to waterways. **F2303**

strain, *n*—rate of change of the length of the stressed element in a particular direction.

system distance range, *n*—the length of fiber over which the measurement can be performed within the stated precision, or the system can achieve its stated performance, for example, probability of detection, location accuracy.

temperature dead zone, *n*—limited zone of a temperature trace, where the temperature sample points deviate from the undisturbed parts of the trace by a specified limit due to a point defect.

temperature measurement error, *n*—maximum difference between a moving average of the measured temperature and a reference temperature for all data points of the fiber optic sensor over the full operating temperature range and all acquisition times.

temperature repeatability, *n*—precision of temperature data between successive temperature traces at a given location expressed by twice the standard deviation of corresponding temperature sample points in each temperature trace, with the fiber optic sensor held at constant temperature.

temperature sample point, *n*—measured temperature value associated with a single point at a known location along a fiber optic sensor.

DISCUSSION—Due to thermodynamic effects the measured value represents the temperature along a very small section of the fiber optic sensor which includes the point.

temperature trace, *n*—set of temperature sample points, distributed along a fiber optic sensor and spaced by the sample spacing.

DISCUSSION—All the sample points are associated with a common time of measurement, often called the trace timestamp. The measured values represent the temperature during a period which includes the timestamp. All the sample points in a temperature trace are measured values produced by the DTS, and not interpolated or smoothed values produced by subsequent processing outside the instrument.

tensile load capacity, *n*—the maximum tensile load a homogeneous or composite material can be subjected to without damage.

tensile strength, *n*—the strength of a material when loaded in tension.

tester, *n*—the person or the entity responsible for carrying out the evaluation of the impact of tunneling or utility construction.

thermal molecular vibrations, *n*—thermal energy associated with the vibrations of molecules about the equilibrium position.

thermistors, *n*—a resistor whose action depends upon changes of its resistance with changes in temperature.

thermocouple, *n*—is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit.

thermographic image (3D Plot), *n*—the 3D view visualizes the temperature data over the time interval in a thermographic image. The values are displayed through a rainbow table color scheme for a clear distinction between different curing stages.

thermographic view, *n*—allows one to see variations in temperature.

thermocouple sensor, *n*—a temperature-measuring sensor consisting of two dissimilar conductors that contact each other at one or more spots.

time-division multiplexing, TDM, *n*—the use of spatial separation to obtain channel isolation.

total fiber length, *n*—distance (specified in length units) from the DTS output connector to the final end of the fiber optic sensor.

DISCUSSION—Final end of the fiber optic sensor can either be a purposefully cut or terminated end of the fiber physically far from the instrument (in a single-ended configuration), or the end of a loop consisting of a connector that is connected to the same instrument (in a loop configuration). This parameter is either equal to or greater than the distance measurement range if performance is specified in a single-ended configuration, or twice the distance measurement range in a loop configuration.

total internal reflection, *n*—reflection that occurs in a medium when the incidence angle of a light ray striking a boundary of the medium is greater than the critical angle and the entire energy of the ray is reflected back into the medium.

transducer, *n*—a device that converts variations in a physical quantity, such as brightness, into an electrical signal, or vice versa.

true value, *n*—obtained either by measuring a reference standard maintained by the national standard organizations or by using a traceable measuring instrument. The result of a measurement that would be obtained by a perfect measurement with no precision or bias error.

updating time, *n*—the time interval between updates of the measured value of all channels of the DOFSS; the same as the temporal sampling interval for systems other than multi-channel or those that provide data incrementally.

vault, *n*—*in utilities*, a manhole, hand hole, or other buried enclosure used to store slack-loops of cable, fiber cable splices, or provide access to the sewer for maintenance and inspection, or a combination thereof. **F2349, F2462**

DISCUSSION—Vaults designated only for optical fiber systems may be located within the street or off-street. Sewer vaults are typically located in the street and, as approved by sewer pipeline operator, may serve the dual purpose of also housing optical fiber systems.

warm-up time, *n*—the duration from the time power is turned on until the system performs in accordance with all specifications.

waveguide, *n*—any structure capable of confining and supporting the energy of an electromagnetic wave.

waveguide delay distortion, *n*—the distortion of the signal that is caused by the different velocities for each wavelength.

waveguide dispersion, *n*—the part of the total dispersion attributable to the dimensions of the waveguide.

wavelength, *n*—the length of a wave measured from any point on a wave to the corresponding point on the next cycle of the wave.

wavelength of operation, *n*—the range of wavelengths of optical radiation the sensor uses to provide the required data.

wavelength-division multiplexing, WDM, *n*—the multiplexing of light waves in a single transmission medium, such that different wavelengths are responsible for the channel separation.

worst case environmental temperature effect, *n*—maximum difference of the measured constant fiber optic sensor temperature at different locations along the sensor during a complete temperature cycling of the DTS instrument across the entire instrument operating temperature range.

5. Symbols, Abbreviations, and Acronyms

5.1 Acronyms:

BOTDA, *n*—Brillouin optical time domain analysis or analyzer

BOTDR, *n*—Brillouin optical time domain reflectometer

CFR, *n*—code of federal regulators

CIPP, *n*—cured in place pipe

CW, *n*—continuous wave

DAS, *n*—distributed acoustic sensing

DCP, *n*—designated control point

DOFSS , <i>n</i> —distributed optical fiber sensing system	OTDR , <i>n</i> —optical time domain reflectometer
DPP , <i>n</i> —differential-pulse-pair	PD , <i>n</i> —photo detector
DRS , <i>n</i> —diffuse reflectance spectroscopy	PDF , <i>n</i> —portable document format
DTGS , <i>n</i> —distributed temperature gradient sensing	PM , <i>n</i> —phase modulation
DTS , <i>n</i> —distributed temperature sensing	RCP , <i>n</i> —reinforced concrete pipe
EGP , <i>n</i> —expanded gasket procedure	SBS , <i>n</i> —stimulated Brillouin scattering
EMI , <i>n</i> —electromagnetic interference	TDM , <i>n</i> —time-division multiplexing
EPB , <i>n</i> —earth pressure balance machine	WDM , <i>n</i> —wavelength-division multiplexing
FDM , <i>n</i> —frequency-division multiplexing	Δx , <i>n</i> —spatial sampling interval
FO , <i>n</i> —fiber optics	<i>5.2 Abbreviations:</i>
FTTX , <i>n</i> —fiber to the x	A —Angstrom
GL , <i>n</i> —gauge length	dB —decibels
LDC , <i>n</i> —local distribution company	km —kilometers
LED , <i>n</i> —light-emitting diode	nm —nanometers
MAOP , <i>n</i> —maximum allowable operating pressure	ns —nanoseconds
MH , <i>n</i> —manhole	O&M —operations and maintenance
NA , <i>n</i> —numerical aperture	

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