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Standard Guide for The Use of Various Turbidimeter Technologies for Measurement of Turbidity in Water[1]

This standard is issued under the fixed designation D7726; 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 guide covers the best practices for use of various turbidimeter designs for measurement of turbidity in waters including: drinking water, wastewater, industrial waters, and for regulatory and environmental monitoring. This guide covers both continuous and static measurements.

1.1.1 In principle there are three basic applications for on-line measurement set ups. The first is the bypass or slipstream technique; a portion of sample is transported from the process or sample stream and to the turbidimeter for analysis. It is then either transported back to the sample stream or to waste. The second is the in-line measurement; the sensor is submerged directly into the sample or process stream, which is typically contained in a pipe. The third is in-situ where the sensor is directly inserted into the sample stream. The in-situ principle is intended for the monitoring of water during any step within a processing train, including immediately before or after the process itself.

1.1.2 Static covers both benchtop and portable designs for the measurement of water samples that are captured into a cell and then measured.

1.2 Depending on the monitoring goals and desired data requirements, certain technologies will deliver more desirable results for a given application. This guide will help the user align a technology to a given application with respect to best practices for data collection.

1.3 Some designs are applicable for either a lower or upper measurement range. This guide will help provide guidance to the best-suited technologies based given range of turbidity.

1.4 Modern electronic turbidimeters are comprised of many parts that can cause them to produce different results on samples. The wavelength of incident light used, detector type, detector angle, number of detectors (and angles), and optical pathlength are all design criteria that may be different among instruments. When these sensors are all calibrated with the sample turbidity standards, they will all read the standards the same. However, samples comprise of completely different matrices and may measure quite differently among these different technologies.

1.4.1 This guide does not provide calibration information but rather will defer the user to the appropriate ASTM turbidity method and its calibration protocols. When calibrated on traceable primary turbidity standards, the assigned turbidity units such as those used in Table 1 are equivalent. For example, a 1 NTU formazin standard is also equivalent in measurement magnitude to a 1 FNU, a 1 FAU, and a 1 BU standard and so forth.

1.4.2 Improved traceability beyond the scope of this guide may be practiced and would include the listing of the make and model number of the instrument used to determine the turbidity values.

1.5 This guide does not purport to cover all available technologies for high-level turbidity measurement.

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

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.*

1.8 *This guide 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. Refer to the MSDSs for all chemicals used in this procedure.*

1.9 *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.*

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[1] This guide is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.07 on Sediments, Geomorphology, and Open-Channel Flow.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water

D3977 Test Methods for Determining Sediment Concentration in Water Samples

D6698 Test Method for On-Line Measurement of Turbidity Below 5 NTU in Water (Withdrawn 2023)[3]

D6855 Test Method for Determination of Turbidity Below 5 NTU in Static Mode

D7315 Test Method for Determination of Turbidity Above 1 Turbidity Unit (TU) in Static Mode

2.2 *Other References:*

USGS National Field Manual for the Collection of Water Quality Data[4]

Wagner's Field Manual Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting[5]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this standard, refer to Terminology D1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *calibration drift, n*—the error that is the result of drift in the sensor reading from the last time the sensor was calibrated and is determined by the difference between cleaned-sensor readings in calibration standards and the true, temperature-compensated value of the calibration standards.

3.2.2 *calibration turbidity standard, n*—a turbidity standard that is traceable and equivalent to the reference turbidity standard to within statistical errors; calibration turbidity standards include commercially prepared 4000 NTU Formazin, stabilized formazin, and styrenedivinylbenzene (SDVB).

3.2.2.1 *Discussion*—These standards may be used to calibrate the instrument.

3.2.3 *calibration-verification standards, n*—defined standards used to verify the accuracy of a calibration in the measurement range of interest.

3.2.3.1 *Discussion*—These standards may not be used to perform calibrations, only calibration verifications. Included verification standards are opto-mechanical light-scatter devices, gel-like standards, or any other type of stable-liquid standard.

3.2.4 *continuous, adj*—the type of automated measurement at a defined-time interval, where no human interaction is required to collect and log measurements.

3.2.4.1 *Discussion*—Measurement intervals range from seconds to months, depending on monitoring goals of a given site.

3.2.5 *design, n*—a more detailed technology description that will encompass all of the elements making up a technology, plus any inherent criteria used to generate a specific turbidity value.

3.2.5.1 *Discussion*—The design will typically translate into a specific make or model of an instrument.

3.2.6 *detection angle, n*—the angle formed with its apex at the center of the analysis volume of the sample, and such that one vector coincides with the centerline of the incident light source's emitted radiation and the second vector projects to the center of the primary detector's view.

3.2.6.1 *Discussion*—This angle is used for the differentiation of turbidity-measurement technologies that are used in this guide.

3.2.6.2 *attenuation-detection angle, n*—the angle that is formed between the incident light source and the primary detector, and that is at exactly 0 degrees.

(1) Discussion—This is typically a transmission measurement.

3.2.6.3 *backscatter-detection angle, n*—the angle that is formed between the incident light source and the primary detector, and that is greater than 90 degrees and up to 180 degrees.

3.2.6.4 *nephelometric-detection angle, n*—the angle that is formed between the incident light source and the detector, and that is at 90 degrees.

3.2.6.5 *forward-scatter-detection angle, n*—the angle that is formed between the incident light source and the primary detector, and that is greater than 0 degrees but less than 90 degrees.

(1) Discussion—Most designs will have an angle between 135 degrees and 180 degrees.

3.2.6.6 *surface-scatter detection, n*—a turbidity measurement that is determined through the detection of light scatter caused by particles within a defined volume beneath the surface of a sample.

(1) Discussion—Both the light source and detector are positioned above the surface of the sample. The angle formed between the centerline of the light source and detector is typically at 90 degrees. Particles at the surface and in a volume below the surface of the sample contribute to the turbidity reading.

3.2.7 *fouling, v*—the measurement error that can result from a variety of sources and is determined by the difference between sensor measurements in the environment before and after the sensors are cleaned.

3.2.8 *in-situ nephelometer, n*—a turbidimeter that determines the turbidity of a sample using a sensor that is placed directly in the sample.

3.2.8.1 *Discussion*—This turbidimeter does not require transport of the sample to or from the sensor.

3.2.9 *metadata, n*—the ancillary descriptive information that describes instrument, sample, and ambient conditions under which data were collected.

3.2.9.1 *Discussion*—Metadata provide information about

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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.

[3] The last approved version of this historical standard is referenced on www.astm.org.

[4] Available from United States Geological Survey (USGS), USGS Headquarters, 12201 Sunrise Valley Drive, Reston, VA 20192, http://www.usgs.gov/FieldManual/Chapters6/6.7.htm.

[5] Wagner, R. J., et al, *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting*, USGS Enterprise Publishing Network, 2005, available from: http://pubs.usgs.gov/tm/2006/tm1D3.

data sets. An example is the useful background information regarding the sampling site, instrument setup, and calibration and verification results for a given set of turbidity data (especially when data are critically reviewed or compared against another data set).

3.2.10 *nephelometric-turbidity measurement, n*—the measurement of light scatter from a sample in a direction that is at 90° with respect to the centerline of the incident-light path.

3.2.10.1 *Discussion*—Units are NTU (Nephelometric Turbidity Units). When ISO 7027 technology is employed units are FNU (Formazin Nephelometric Units).

3.2.11 *pathlength, n*—The greatest distance that the sum of the incident light and scattered light can travel within a sample volume (cell or view volume).

3.2.11.1 *Discussion*—The pathlength is typically measured along the centerline of the incident-light beam plus the scattered light. The pathlength includes only the distance the light and scattered light travel within the sample itself.

3.2.12 *ratio-turbidity measurement, n*—the measurement derived through the use of a nephelometric detector that serves as the primary detector, and one or more other detectors used to compensate for variation in incidentlight fluctuation, stray light, instrument noise, or sample color.

3.2.13 *reference-turbidity standard, n*—a standard that is synthesized reproducibly from traceable raw materials by the user.

3.2.13.1 *Discussion*—All other standards are traced back to this standard. The reference standard for turbidity is formazin.

3.2.14 *seasoning, v*—the process of conditioning labware with the standard that will be diluted to a lower value to reduce contamination and dilution errors.

3.2.15 *slipstream, n*—an on-line technique for analysis of a sample as it flows through a measurement chamber of an instrument.

3.2.15.1 *Discussion*—The sample is transported from the source into the instrument (for example, a turbidimeter), analyzed, and then transported to drain or back to the process stream. The term is synonymous with the terms "on-line instrument" or "continuous monitoring instrument."

3.2.16 *sonde, n*—a monitoring instrument that contains two or more measurement sensors that share common power, transmitting, and data logging.

3.2.16.1 *Discussion*—A sonde usually has one end that contains the measurement sensors, which are in close proximity to each other and together are submerged in a sample.

3.2.17 *stray light, n*—all light reaching the detector other than that contributed by the sample.

3.2.18 *technology, n*—a general classification of a turbidimeter design that incorporates the type and wavelength of the incident-light source, detection angles, and the number of detectors used to generate a turbidity measurement and its defined reporting unit.

3.2.18.1 *Discussion*—In ASTM turbidity test methods, the technology is based on type and number of light sources, and their respective wavelength, detector angle(s), and number of detectors used in the technology to generate the turbidity value.

3.2.19 *turbidimeter, n*—an instrument that measures light scatter caused by particulates within a sample and converts the measurement to a turbidity value.

3.2.19.1 *Discussion*—The detected light is quantitatively converted to a numeric value that is traced to a light-scatter standard. See Test Method D7315.

3.2.20 *turbidity, n*—an expression of the optical properties of a sample that causes light rays to be scattered and absorbed rather than transmitted in straight lines through the sample.

3.2.20.1 *Discussion*—Turbidity of water is caused by the presence of matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes.

4. Summary of Practice

4.1 This guide is to assist the user in meeting and understanding the following criteria with respect to turbidity measurements:

4.1.1 The selection of the appropriate technology for measurement of a given sample with implied characteristics.

4.1.2 Help in the selection of a measurement technology that will help meet the scope of requirements (goals) for use of the data.

4.1.3 Assist in the selection of a technology that is best suited to withstand the expected environmental and sample deviations over the course of data collection. Examples of deviations would be expected measurement range and interferences.

4.1.4 Understand both the general strengths and limitations for a given type (design) of technology in relation to overcoming known interferences in turbidity measurement.

4.1.5 Provide general procedures that can be used to determine whether a given technology is suitable for use in a given sample or a given application.

4.1.6 Understand the need for the user to include critical metadata related to turbidity measurement.

4.1.7 This guide will help the user select the appropriate technology for regulatory purposes.

5. Significance and Use

5.1 Turbidity is a measure of scattered light that results from the interaction between a beam of light and particulate material in a liquid sample. Particulate material is typically undesirable in water from a health perspective and its removal is often required when the water is intended for consumption. Thus, turbidity has been used as a key indicator for water quality to assess the health and quality of environmental water sources. Higher turbidity values are typically associated with poorer water quality.

5.1.1 Turbidity is also used in environmental monitoring to assess the health and stability of water-based ecosystems such as in lakes, rivers and streams. In general, the lower the turbidity, the healthier the ecosystem.

5.2 Turbidity measurement is a qualitative parameter for water but its traceability to a primary light scatter standard allows the measurement to be applied as a quantitative measurement. When used as a quantative measurement, turbidity is typically reported generically in turbidity units (TUs).

5.2.1 Turbidity measurements are based on the instruments' calibration with primary standard reference materials. These reference standards are traceable to formazin concentrate (normally at a value of 4000 TU). The reference concentrate is linearly diluted to provide calibration standard values. Alternative standard reference materials, such as SDVB co-polymer or stabilized formazin, are manufactured to match the formazin polymer dilutions and provide highly consistent and stable values for which to calibrate turbidity sensors.

5.2.1.1 When used for regulatory compliance reporting, specific turbidity calibration standards may be required. The user of this guide should check with regulatory entities regarding specifics of allowable calibration standard materials.

5.2.2 The traceability to calibrations from different technologies (and other calibration standards) to primary formazin standards provides for a basis for defined turbidity units. This provides equivalence in the magnitude of the turbidity unit between the different measurement technologies when they are all calibrated on standards that are traced to primary formazin. This means that a TU is equivalent in its magnitude to a nephelometric turbidity unit (NTU), and all other units as described in this guide. See Table 1.

5.2.3 Turbidity is not an inherent property of the sample, such as temperature, but in part is dependent on the technology used to derive the value. Even though the magnitude of turbidity units are equivalent and are based on turbidity standards, the units do not maintain this equivalence when measurement of samples is practiced. Turbidity standards are generally free of interferences and samples are not. Depending on the type of technology employed for measurement, the magnitude of the different interferences on a given sample can differ significantly with respect to the different measurement technologies. The user of a turbidity technology should expect to observe a lack of measurement equivalence across different turbidity measurement designs when common samples are analyzed. See Section 6 on interferences.

5.2.4 Depending on the application, some instruments are calibrated on a sample that has been characterized (or defined) by some independent means. The calibration may include one or more samples that have been characterized with respect to the application of its use. See Test Methods D3977.

5.3 Turbidity is not a quantative measure of any chemical or physical property of water. Different expected interactions between a given measurement technology and a given sample with a unique combination of interferences can significantly impact the final turbidity result. As stated in 5.3, depending on the technology used, the result will differ. It is imperative to provide a linkage of metadata that is reflective of the design type (that is, technology) used to generate the turbidity values. In all ASTM standards, the measurement units are reflective of the design criteria and the information is presented in Table 1.

5.3.1 The actual reporting units, signified by a two to four-letter code, are based upon distinguishing design criteria for each of the common measurement technologies. The intent of attaching the measurement unit to the determined turbidity value is to indicate the type of technology used.

5.3.2 Even though various instrument designs may be grouped by technology type (that is, FNU, NTU, FBU, etc., and refer to Table 1), instruments within a group should not be considered to be identical nor it is proposed that sample values obtained will be alike. Instruments within each technology may still have other design differences whereby samples give different results. For example, pathlength differences between two instruments with the same reporting units can impact measurements and the relative difference in results.

5.4 *Discussion of Table 1:*

5.4.1 Table 1 provides a summary of technologies and their respective reporting units that are in the different ASTM test methods. The reporting unit is a two to four letter-code that has been assigned to a unique type of technology. The reporting unit follows every reported turbidity measurement and serves as metadata to the respective measurement.

5.4.2 The key design features are based on three criteria: (*1*) type of light source used, (*2*) primary detector angle with respect to the incident light beam, and (*3*) number of detectors used.

5.4.2.1 If the measurement unit begins with an "F" then the light source is a near-IR wavelength. Most designs will encompass a light source that is in the 860 ± 60 nm range. The strength of this wavelength is that most natural colors do not absorb at this level, which reduces or eliminates color interference. Two things that interfere at the near-IR are carbon black and copper sulfate. Second, the incident light beams are easily collimated, which extends the overall operational range. Third, the output of the light source can be regulated to provide a stable output over time. The weakness is that longer wavelengths are less sensitive to smaller particles with respect to response at very low turbidities.

5.4.2.2 If the measurement unit either begins with an "N" or is a two-letter unit (for example, BU, AU), the incident light source will be in the 400–680-nm range. The strength of this wavelength range is increased sensitivity to smaller particles when compared to longer wavelengths (such as those in the near infared (IR) range). The weakness of this wavelength range is that color that absorbs at the same wavelengths, as those that are emitted by light source will cause a negative interference. Second, if the source is an incandescent light source, additional optics is required to maintain collimation and stability over time. The light source will typically need to periodic replacement over the life of an instrument.

5.4.2.3 If the measurement unit includes an "R" it is a nephelometric method that utilizes a 90-degree detector plus one other detector. This is referred to as a ratio metric technique and helps to compensate for color interference, regardless of the wavelength of the incident light source. The technique also helps to linearize the response to turbidity at higher levels and can provide an extended measurement range. The technique can also help to stabilize measurement outputs. The technique is the most flexible across different applications because of the combination of sensitivity to low turbidity ranges and the ability can measure very high turbidity levels.

5.4.2.4 If the measurement unit has a "B" it indicates a backscatter technique. These techniques typically have a wide range, but are not sensitive at low turbidities. They are also more susceptible to color and particulate absorbance interferences.

5.4.2.5 If the measurement unit has an "A" it indicates an attenuation or absorbance measurement. The measurement is a combination of light that is attenuated and absorbed, in combination. Color is a significant interference, except for applications that require color to be considered part of the overall turbidity measurement. The method is very sensitive to wavelength and thus, the reporting unit should also include the wavelength of the incident light beam.

5.4.2.6 If the measurement unit contains an "M" it indicates a technology in which at least two incident light beams and two detectors are employed. The method also encompasses a ratio technique. These designs are very similar to ratio techniques as are the advantages and limitations.

5.4.2.7 *Other Units:*

(a) mNTU—The technology indicates a monochromatic incident light source in visible wavelength range and a nephelometric technique. The technology design allows for an improved limit of detection over conventional light sources. Its primary use for low turbidity measurements, such the monitoring for membrane breaches and ultra-purification processes.

(b) SSU—The "SS" portion of the unit indicates a surface scatter technique is being used. The technique positions both the light source and detector that are in the same horizontal plane above the sample. Light that is scattered by particles at or very near the surface and detected at an angle that is at 90 degrees to the centerline of the incident light beam. The system has a high detection range, but low sensitivity. It is also susceptible to color interferences, but to a lesser degree than techniques that pass light completely through the sample. The technique is valuable for applications where it is desirable for the sample not to touch the optics of the instrument.

5.4.3 The table provides information regarding to the most prominent applications and discusses interference concerns. This information is based on technologies that are in the field at the time this guide was written, but does not constitute endorsement to any given manufacture of a given technology. In some cases, a design can be successfully used outside of the stated applications in Table 1. The user should perform testing to ensure the technology meets limit of detection, sensitivity, and range requirements that insure representative data can be acquired.

TABLE 1 Summary of Known Commercialized Technologies, Key Design Features, Prominent Sample Applications, Ranges, and Reporting Units for Turbidity Measurements

Turbidity Reporting Unit Used in ASTM Test Methods	Turbidity Reporting Unit Used in ASTM Test Methods	Prominent Application and Major Interference Concerns	Suggested Application and Operating Range Ranges
Nephelometric Non-Ratio (NTU)	The detector is centered at 90º relative to the incident light beam. The incident light source is a tungsten filament lamp that is operated at a color temperature between 2200 and 3000 K.	White light turbidimeters. These designs comply with EPA 180.1 for low level turbidity monitoring. Color is a major negativeinterference and optical variations cannot be compensated with this technique.	Regulatory for drinking water. The optimal operating range is 0.0 to 40 units if the sample has no color. Best comparability will be at turbidities below 5 TU.
Ratio White LightTurbidimeters (NTRU)	This technology applies the same light source as the EPA 180.1 design but uses several detectors in the measurement. A primary detector centered at 90° relative to the incident beam plus other detectors located at other angles. An instrument algorithm uses a combination of detector readings to generate the turbidity reading.	Complies with the USEPA Interim Enhanced Surface Water Treatment Rule regulations and Standard Methods 2130B. Can be used for both low and high level measurement. Color interference (negative) is reduced and lamp variations are compensated for with this technique.	Regulatory for drinking water and wastewater (0–40 units). The technology can potentially measure up to 10 000 units.
Nephelometric, Near- IR Turbidimeters, Nonratiometric (FNU)	This technology uses a light source in the near IR range (860 ± 60 nm). The detector is centered at 90º relative to the incident light beam.	The instrument design is compliant with ISO 7027. The wavelength is less susceptible to color interferences. The light source is very stable over time because its output can be highly controlled. This technique is applicable for samples with color and for low level monitoring. Only highly samples that absorb light above 800 nm can result in negative interference.	Regulatory compliance in Europe for drinking water and wastewater (0–40 units). The technology can measure up to 1000 units or more, depending on pathlength.
Nephelometric Near-IR Turbidimeters, Ratio Metric (FNRU)	This technology applies the same light source that is required by ISO 7027. The design uses several detectors in the measurement. A primary detector is centered at 90° relative to the incident beam and other detectors are located at other angles. An instrument algorithm uses the combination of detector readings to generate the turbidity value.	Complies with ISO 7027. This technique is applicable for samples with high levels of color and for monitoring to high turbidity levels. Samples that absorb light above 800 nm will result in some negative interference.	Regulatory compliance monitoring in Europe for drinking water and wastewater (0–40 units). The technology can potentially measure up to 10000 units.
Surface Scatter Turbidimeters (SSU)	The technology uses the same white light source as in EPA 180.1. The detector centered at 90º relative to the incident light beam. Both the detector an incident light source is mounted in a fixed position in the same plane that is immediately above the sample.	Turbidity is determined through light scatter from a defined volume of sample beneath the surface of a sample. Negative color interferences are reduced when compared to the non-ratio nephelometric method.	Sample flows through the instrument. This is a good watershed monitoring instrument and can measure from 0.5 to 10,000 units.

TABLE 1 *Continued*

Turbidity Reporting Unit Used in ASTM Test Methods	Turbidity Reporting Unit Used in ASTM Test Methods	Prominent Application and Major Interference Concerns	Suggested Application and Operating Range Ranges
Formazin Back Scatter (FBU)	This design applies a near-IR monochromatic light source in the (860 ± 60 nm) nm range as the incident light source. The scattered light detector is typically positioned at 30 ± 15° relative to the incident light beam. However, some designs may have a detection angle that is approximately 0° relative to the incident light beam.	This technology is not applicable for most regulatory purposes. It is best applied to samples with high turbidity and is commonly used in trending applications. Absorbance and color above 800 nm will result in negative interference	This technology is best suited for in-situ measurement, in which a probe is placed in a sample for continuous monitoring purposes. It is best applied to turbidities in the range of 100–10 000+ unit range.
Backscatter Unit (BU)	The design applies a white light spectral source (400–680 nm range). The detector geometry is between 90 and 180° relative to the incident light beam.	This technology is not applicable for most regulatory purposes. It is best applied to samples with high turbidity. The measurement will be susceptible to any visible color and particle absorbance that will result in a negative interference.	This technology is best suited for in-situ measurements in which sample color is part of the turbidity measurement. It is best applied to turbidities in the 100–10 000+ unit range.
Formazin Attenuation Unit (FAU)	The incident light beam is at a wavelength of (860 ± 60 nm) nm. The detector is geometrically centered at 0° relative to the incident light beam. This is typically an attenuation measurement.	The design may be applicable for some regulatory purposes. The measurement is commonly performed with spectrophotometers. It is best suited for samples with high-level turbidity. Particle absorption is a prominent interference.	This measurement is part of the ISO 7027 regulation. The optimal turbidity range is between 20 and 1000 units.
Light Attenuation Unit (AU)	The wavelength of the incident light is in the 400–680 nm range. The light scatter detector is geometrically centered at 0º relative to incident beam. This is an transmission measurement.	This design is not applicable for some regulatory applications. This is commonly performed with spectrophotometers. Color and absorption are prominent interferences if their respective absorptive spectrum is the same as the output spectrum of the incident light.	This is best applied to samples in which color is part of the turbidity measurement. The best application is to samples in the turbidity range of 20 to 1000 units.
Nephelometric Turbidity Multibeam Unit (FNMU)	The technology consists of two light sources and two detectors. The light sources comply with ISO 7027. The detectors are geometrically centered at 90° relative to each incident light beam. The instrument measures in two phases in which the detectors are either at 90 or 180º relative to the incident light beam, depending on the phase. An instrument algorithm uses a combination of detector readings to calculate the reported value.	This technology is compliant to the EPA Regulatory Method GLI Method 2 and ISO 7027. It is applicable to regulatory monitoring for drinking water, wastewater, and industrial monitoring applications. The technology is very stable. This technology will be immune to color absorbance below 800 nm. Above 800 nm, color and particle absorbance interferences will be reduced.	Regulatory monitoring at low turbidity levels in the 0.02 to 40 unit range. The technology can measure up to 4000 units.
Laser Turbidity Units (mNTU)	The technology consists of an incident laser light source at 660 nm and a detector that is a high-sensitivity PMT design. The detector is centered at 90º relative to the incident light beam.	This technique complies with the EPA-approved Hach Method 10133. The application is for the monitoring of filter performance and breakthrough. Color interference can occur it absorbs the same wavelength of light that is emitted by the incident light source. However, color is typically significant in filtered samples.	Regulatory monitoring of drinking water effluent and membrane systems. The range is about 7 to 5000 mNTU. 1 NTU = 1000 mNTU.
Forward Scatter Ratio Unit (FSRU)	The technology encompasses a single light source and two detectors. Light sources can vary from single wavelength to polychromatic sources. The detection angle for the forward scatter detector is between 0 and 90º relative to the centerline of the incident light beam. More commonly, the forward scatter detection angle will be between 15 and 45º. The second detector is at exactly 0º.	The technology is sensitive to turbidities as low as 1 TU. The ratio technology helps to compensate for color interference and fouling.	The measurement of ambient waters such as streams, lakes, rivers. The range is typically from about 1–800 FSRU, depending on the manufacturer.

5.4.4 *Range of Measurement*—Table 1 provides guidance on the estimated range of use for the different measurement technologies. A key design criterion is the pathlength of measurement. This is the actual distance that light travels through a sample to generate the scatter that ultimately becomes detected. It encompasses both the incident light distance and the receive angles for the scattered light detectors. The longer the pathlength, the lower the measurement ranges,