Designation: D7315 – 17 (Reapproved 2023)

Standard Test Method for
Determination of Turbidity Above 1 Turbidity Unit (TU) in Static Mode[1]

This standard is issued under the fixed designation D7315; 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 test method covers the static determination of turbidity in water. Static refers to a sample that is removed from its source and tested in an isolated instrument. (See Section 4.)

1.2 This test method is applicable to the measurement of turbidities greater than 1.0 turbidity unit (TU). The upper end of the measurement range was left undefined because different technologies described in this test method can cover very different ranges. The round robin study covered the range of 0 to 4000 turbidity units because instrument verification in this range can typically be covered by standards that can be consistently reproduced.

1.3 Many of the turbidity units and instrument designs covered in this test method are numerically equivalent in calibration when a common calibration standard is applied across those designs listed in Table 1. Measurement of a common calibration standard of a defined value will also produce equivalent results across these technologies.

1.3.1 In this test method calibration standards are often defined in NTU values, but the other assigned turbidity units, such as those in Table 1 are equivalent. For example, a 1 NTU formazin standard is also a 1 FNU, a 1 FAU, a 1 BU, and so forth.

1.4 This test method does not purport to cover all available technologies for high-level turbidity measurement.

1.5 This test method was tested on different natural waters and wastewater, and with standards that will serve as surrogates to samples. It is the user's responsibility to ensure the validity of this test method for waters of untested matrices.

1.6 Depending on the constituents within a high-level sample, the proposed sample preparation and measurement methods may or may not be applicable. Those samples with the highest particle densities typically prove to be the most difficult to measure. In these cases, and alternative measurement method such as the process monitoring method can be considered.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]
D1129 Terminology Relating to Water
D1193 Specification for Reagent Water
D2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D19 on Water
D4411 Guide for Sampling Fluvial Sediment in Motion
D5847 Practice for Writing Quality Control Specifications for Standard Test Methods for Water Analysis
D6855 Test Method for Determination of Turbidity Below 5 NTU in Static Mode
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *Other Referenced Standards:*
U.S. EPA Method 180.1 Methods for Chemical Analysis of Water and Wastes, Turbidity[3]
ISO 7027 Water Quality—Determination of Turbidity[4]

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[1] This test method 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.

Current edition approved Nov. 1, 2023. Published December 2023. Originally approved in 2007. Last previous edition approved in 2017 as D7315 – 17. DOI: 10.1520/D7315-17R23.

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

[3] Available from United States Environmental Protection Agency (EPA), William Jefferson Clinton Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, http://www.epa.gov.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

TABLE 1 Summary of Known Instrument Designs, Applications, Ranges, and Reporting Units

Design and Reporting Unit	Prominent Application	Key Design Features	Typical Instrument Range	Suggested Application Ranges
Nephelometric non-ratio (NTU)	White light turbidimeters. Comply with U.S. EPA Method 180.1 for low level turbidity monitoring.	Detector centered at 90° relative to the incident light beam. Uses a white light spectral source.	0.0–40	0.0–40 Regulatory
Ratio White Light turbidimeters (NTRU)	Complies with ISWTR regulations and Standard Method 2130B. Can be used for both low and high level measurement.	Used a white light spectral source. Primary detector centered at 90°. Other detectors located at other angles. An instrument algorithm uses a combination of detector readings to generate the turbidity reading.	0–10 000	0–40 Regulatory 0–10 000 other
Nephelometric, near-IR turbidimeters, non-ratiometric (FNU)	Complies with ISO 7027. The wavelength is less susceptible to color interferences. Applicable for samples with color and good for low level monitoring.	Detector centered at 90° relative to the incident light beam. Uses a near-IR (780 nm–900 nm) monochromatic light source.	0–1000	0–40 Regulatory (non-US) 0–1000 other
Nephelometric near-IR turbidimeters, ratio metric (FNRU)	Complies with ISO 7027. Applicable for samples with high levels of color and for monitoring to high turbidity levels.	Uses a near-IR monochromatic light source (780 nm–900 nm). Primary detector centered at 90°. Other detectors located at other angles. An instrument algorithm uses a combination of detector readings to generate the turbidity reading.	0–10 000	0–40 Regulatory 0–10 000 other
Surface Scatter Turbidimeters (NTU)	Turbidity is determined through light scatter from or near the surface of a sample.	Detector centered at 90° relative to the incident light beam. Uses a white light spectral source.	10–10 000	10–10 000
Formazin Back Scatter (FBU)	Not applicable for regulatory purposes. Best applied to high turbidity samples. Backscatter is common with but not all only probe technology and is best applied in higher turbidity samples.	Uses a near-IR monochromatic light source in the 780 nm–900 nm range. Detector geometry is between 90° and 180° relative to the incident light beam.	100–10 000+	100–10 000
Backscatter Unit (BU)	Not applicable for regulatory purposes. Best applied for samples with high level turbidity.	Uses a white light spectral source (400 nm–680 nm range). Detector geometry is between 90° and 180° relative to the incident light beam.	10–10 000+	100–10 000+
Formazin attenuation unit (FAU)	May be applicable for some regulatory purposes. This is commonly applied with spectrophotometers. Best applied for samples with high level turbidity.	Detector is geometrically centered at 0° relative to incident beam (attenuation). Wavelength is 780 nm–900 nm.	20–1000	20–1000 Regulatory
Light attenuation unit (AU)	Not applicable for some regulatory purposes. This is commonly applied with spectrophotometers.	Detector is geometrically centered at 0° relative to incident beam (attenuation). Wavelength is 400 nm–680 nm.	20–1000	20–1000
Nephelometric Turbidity Multibeam Unit (NTMU)	Is applicable to EPA regulatory method GLI Method 2. Applicable to drinking water and wastewater monitoring applications.	Detectors are geometrically centered at 0° and 90°. An instrument algorithm uses a combination of detector readings, which may differ for turbidities varying magnitude.	0.02–4000	0–40 Regulatory 0–4000 other

USGS National Field Manual for the Collection of Water Quality Data[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 *attenuation, v*—the amount of incident light that is scattered and absorbed before reaching a detector, which is geometrically centered at 0° relative to the centerline of the incident light beam.

3.2.1.1 *Discussion*—Attenuation is inversely proportional to transmitted signal.

Attenuated Turbidity = Absorbed Light + Scattered Light

The application of attenuation in this test method is as a distinct means of measuring turbidity. When measuring in the FAU or AU mode, the turbidity value is a combination of scattered (attenuated) plus absorbed light. The scattered light

is affected by particle size and is a positive response. The absorption due to color is a negative. The sum of these two entities results in the turbidity value in the respective units.

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 (see 9.2.3), and styrenedivinylbenzene (SDVB) (see 9.2.4).

3.2.2.1 *Discussion*—These standards may be used to calibrate the instrument. Calibration standards may be instrument design specific. Calibration standards that exceed 10 000 turbidity units are commercially available.

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 standards are opto-mechanical light scatter devices, gel-like standards, or any other type of stable liquid standard. Calibration verification standards may be instrument design specific.

3.2.4 *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.

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

3.2.5 *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 incident light fluctuation, stray light, instrument noise, or sample color.

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

3.2.6.1 *Discussion*—All other standards are traced back to this standard. The reference standard for turbidity is formazin (see 9.2.2).

3.2.7 *seasoning, v*—the process of conditioning labware with the standard to be diluted to a lower value.

3.2.7.1 *Discussion*—The process reduces contamination and dilution errors.

3.2.8 *stray light, n*—all light reaching the detector other than that which is scattered by the sample.

3.2.8.1 *Discussion*—For example: ambient light leakage, internal reflections and divergent light in optical systems. For this test method, stray light is likely to be negligible. The instrument design is intended to reduce or eliminate stray light.

3.2.9 *surface scatter turbidimeter, n*—an instrument that determines the turbidity through incident light scatter that occurs at or slightly below the surface of a water sample with a detection angle that is at 90° relative to the incident light beam.

3.2.9.1 *Discussion*—Interferences are not as substantial as nephelometric non-ratio measurements.

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

3.2.10.1 *Discussion*—The detected light is quantitatively converted to a numeric value that is traced to a light-scatter standard. See Table 1 for examples of designs.

3.2.11 *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.

3.2.11.1 *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 Test Method

4.1 The optical property expressed as turbidity is measured by the scattering effect that constituents within a sample have on light; the higher the quantity of scattered or attenuated incident light, the higher the turbidity. In samples containing particulate material, light scatter and attenuation will vary *(1)* due to size, shape and composition of the particles in the water, and *(2)* the wavelength of the incident light.

4.2 This test method is based upon a comparison of the amount of light scattered or attenuated by the sample with the amount of light scattered or attenuated by a reference suspension. Lower turbidity values are typically determined by a nephelometer, which measures light scatter from a sample in a direction that is at 90° with respect to the centerline of the incident light path. High-level turbidity determination can be performed using many different technologies. It is critical when reporting the measurement, traceability to the type of technology be used. Turbidity measurements are not often consistent among differing technologies.

5. Significance and Use

5.1 Turbidity at the levels defined in the scope of this test method are often monitored to help control processes, monitor the health and biology of water environments and determine the impact of changes in response to environmental events (weather events, floods, etc.). Turbidity is often undesirable in drinking water, plant effluent waters, water for food and beverage processing, and for a large number of other water-dependent manufacturing processes. Removal is often accomplished by coagulation, sedimentation, and various levels of filtration. Measurement of turbidity provides an indicator of contamination, and is a vital measurement for monitoring the characteristics and or quality within the sample's source or process.

5.2 This test method does overlap Test Method D6855 for the range of 1 to 5 TU. If the predominant measurement falls below 1.0 TU with occasional spikes above this value, Test Method D6855 may be more applicable. For measurements that are consistently above 1 TU, this test method is applicable.

5.3 This test method is suitable to turbidity such as that found in all waters that measure above 1 NTU. Examples include environmental waters (streams, rivers, lakes, reservoirs, estuaries), processes associated with water pollution

control plants (wastewater treatment plants), and various industrial processes involving water with noticeable turbidity. For measurement of cleaner waters, refer to Test Method D6855.

5.4 The appropriate measurement range for a specific technology or instrument type that should be utilized is at or below 80 % of full-scale capability for the respective instrument or technology. Measurements above this level may not be dependable.

5.4.1 Dilutions of waters are not recommended, especially in the case of samples with rapidly settling particles (that is, sediments). It is recommended that an appropriate instrument design that covers the expected range be selected to avoid the need to perform dilutions.

5.5 Technologies described in this standard may not measure all aspects (absorption and scatter) of a sample. Some of the properties of the water, the suspended material, or both may interfere with the certain measured property of the sample, such as the scattering of light that the particular instrument is measuring.

5.6 Several different technologies are available for use in the measurement of high-level turbidity. Some technologies may be better suited for specific types of samples, depending on the application and measurement criteria. Please refer to Table 1 and Appendix X1 which is a flow chart to help assist in selecting the best technology for the specific application.

5.6.1 When measuring high levels of turbidity the samples will often contain significant interferences such as that from absorbing particles, absorbance in the matrix, and rapidly settling particles. These may have a significant impact on how one measurement technology responds to changes in turbidity. Often times it will be prudent to run a series of linear dilutions to determine if the measured response was expected relative to the dilution. In cases where the response to dilution ratio is linear, the technology may be adequately accounting for the interferences. If the response is not expected, another technology should be considered to determine if a more accurate measurement could be obtained.

5.7 When reporting the measured result, appropriate units should also be attached. The units are reflective of the technology used to generate the measurements. The intention is to provide traceability for the technology used to generate the measured result, and if necessary, provide more adequate comparison to historical data. Section 7 describes technology that each type of traceable reporting units is based.

5.7.1 Table 1 contains the list of technologies and respective reporting units that will be traceable to that technology.

5.7.1.1 The methods in Table 1 can be broken down into two distinct groups of designs which are based on the type of incident light source used. These are broad-band white light source or light sources that provide a spectral output in the 400 nm to 680 nm range. These include polychromatic light sources, such as those that are necessary to comply with regulatory method U.S. EPA Method 180.1, but also can include mono-chromatic light sources if the respective wavelength falls within the specified range. The second group of instruments uses a near IR monochromatic light source that is

in the range of 780 nm to 900 nm. These designs are distinguishable in the reporting units and will always begin with the letter F.

5.7.1.2 For a specific design that falls outside of these reporting ranges, the turbidity should be reported in turbidity units (TU) with a subscripted wavelength value to characterize the light source that was used. See 7.4.3.

5.7.1.3 Those designs listed in Table 1 cover those that were currently identified by the ASTM subcommittee. Future designs that are not covered in this document may be incorporated into a future revision after review by the method subcommittee.

5.7.1.4 See Section 7 for more details regarding instrument designs.

5.7.1.5 Section 16 contains precision and bias data that incorporates the different classifications of technologies. The precision and bias section includes the overall data set of all laboratories and smaller segments of this data set to provide comparisons across distinguishing technological features that are exhibited by those technologies that are represented in this test method.

5.8 This test method covers the measurement of samples collected from waters and analyzed using typical laboratory based or portable-based instruments.

6. Interferences

6.1 Bubbles, although they cause turbidity, may result in interferences in measured turbidity as determined by this test method. Bubbles cause a positive interference and color typically causes a negative interference. Dissolved material that imparts a color to the water may cause errors in pure nephelometric readings, unless the instrument has special compensating features to reduce these interferences. Certain turbulent motions also create unstable reading conditions of nephelometers.

6.2 Color is characterized by absorption of specific wavelengths of light. If the wavelengths of incident light are significantly absorbed, a negative interference will result unless the instrument has special compensating features. Depending on the application color may or may not be considered as an interference. Some instrument designs are intended to remove the effect that color imparts on a turbidity measurement. Other designs do not remove the effects of color.

6.2.1 Those designs where color effects can be reduced or eliminated include nephelometric-based designs with incident light sources in the 780 nm to 900 nm range. Those designs that have additional detectors, such as ratioing instruments also help to reduce the effects of color regardless of the light source. Single detector systems with light sources below 780 nm will be more impacted by the effects of color in the sample, that is, color visible to the naked eye. Color can have a significant impact on attenuation-based instruments if it has absorption spectrum that overlaps the spectral output of the incident light source.

6.3 Scratches, finger marks, or dirt on the walls of the sample cell may give erroneous readings, especially at lower turbidity levels. Sample cells should be kept scrupulously clean

both inside and outside and discarded when they become etched or scratched. The sample cells must not be handled where the light strikes them when positioned in the instrument well.

6.4 Sample cell caps and liners must also be scrupulously clean to prevent contamination of the sample. Seasoning of the sample cells should be performed each time a new sample is measured.

6.5 The optical quality and geometry of the sample cells can also impact results. At all turbidity levels, sample cells that are not optically consistent can result in error. Errors greater than 10 % relative to the turbidity value can be reduced through indexing or replacement of the cells. See Section 16 for additional information.

6.5.1 Sample cells should be optically matched or a single cell should be used to perform calibrations and measurements.

6.6 Particle size and distribution will also impact turbidity and is sensitive to the different types of technologies used. Typically, small particles will more effectively scatter light in the nephelometric direction (at 90° relative to the incident light beam) than larger particles. Overall, however, it is the net aggregate scatter and attenuation of the available incident light by all particles that in the sample that contribute to the measurement.

6.7 The path-length of the sample cell or equivalent will impact the sensitivity of measurements. A shorter path length will extend the range and reduce the interference proportionally. However, use of a shorter path-length will reduce the sensitivity of the measurement.

6.8 Ideally, the same indexed sample cell should be used first for standardization followed by unknown (sample) determination. If this is not possible, then sample cells must be matched. Refer to the instrument manual or the standard's manufacturer for instructions regarding the matching of sample cells.

NOTE 1—Indexing of the sample cell to the instrument well is accomplished by placing a mark on the top of the sample cell and a similar mark on the upper surface of the well so that the sample cell can be placed in the well in an exact position each time.

6.9 Condensation on optical elements or sample cells can lead to severe errors in measurement.

6.10 Rapidly settling particles are also an interference. Particles such as sand can settle rapidly and cause false high or false low turbidity readings. The user of this test method must use care to ensure particles are suspended in solution the instant that the measurement is taken.

7. Apparatus

7.1 There are several technologies that are capable of measuring turbidity that exceeds 1.0 turbidity unit. A summary of these technologies is provided in Table 1. Within this table, suggested reporting units, which are representative to the technology, are included.

7.2 Several technologies for measuring high-level turbidity are discussed in this test method. They include nephelometer-based instruments (see Figs. 1-3), backscatter based instruments (see Fig. 4), and attenuation-based instruments (see Fig. 5). These are all discussed in more detail.

7.2.1 Nephelometers include the Photoelectric Nephelometer, Ratio Photoelectric Nephelometer with single beam design, and ratio photoelectric nephelometer in the dual beam design. The correlation between detector response and increasing turbidity levels is positive.

7.2.2 Backscatter turbidimeters typically employ similar light sources used in the photoelectric photometer but utilize a detection angle that is capable of detecting backscattered light from a sample. The correlation between detector response and increasing turbidity levels is positive.

7.2.3 Attenuation-based turbidimeters employ a detection angle that is 0° relative to the incident light beam.

7.3 The resolution of the instruments should permit detection of differences of at least 1 % of the range in which it is used. See Section 14 for rounding the reporting values of turbidity.
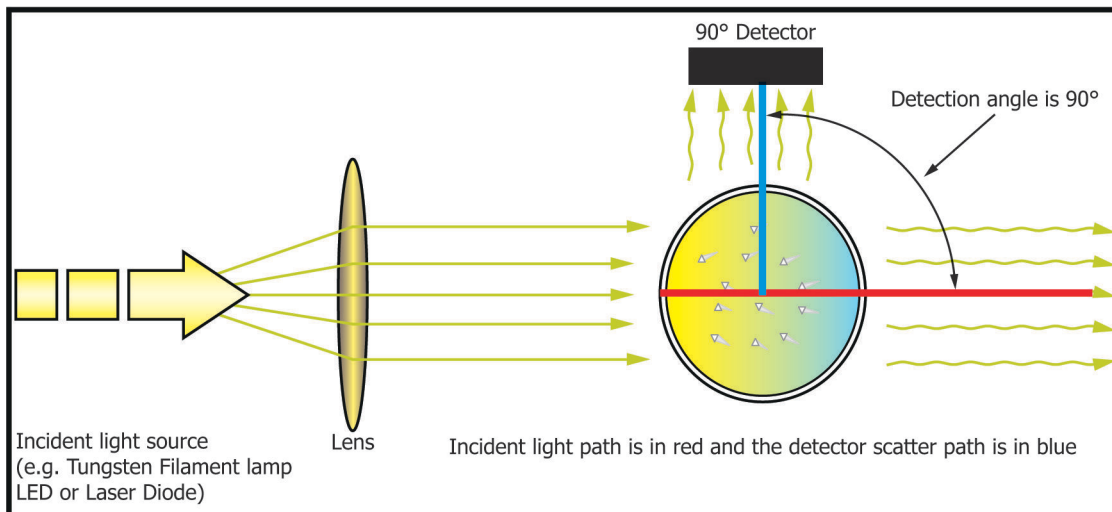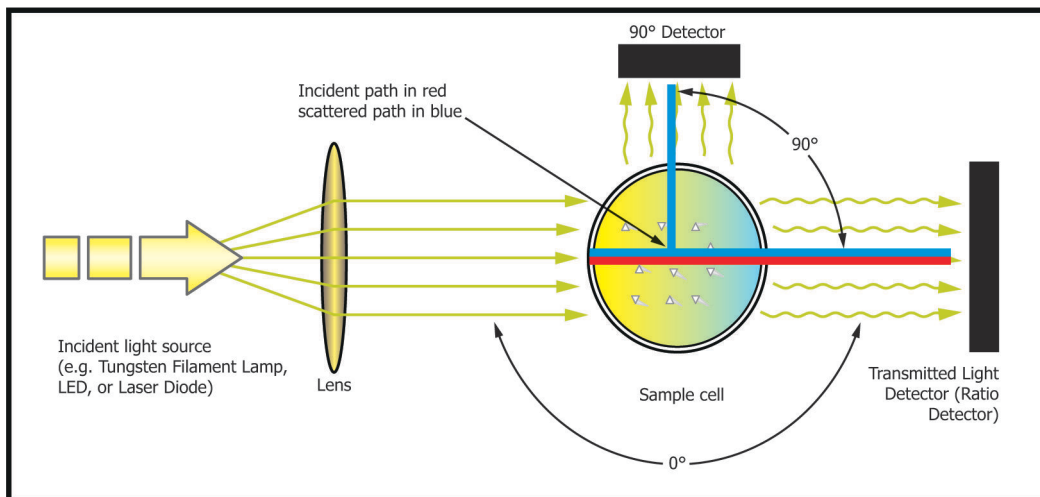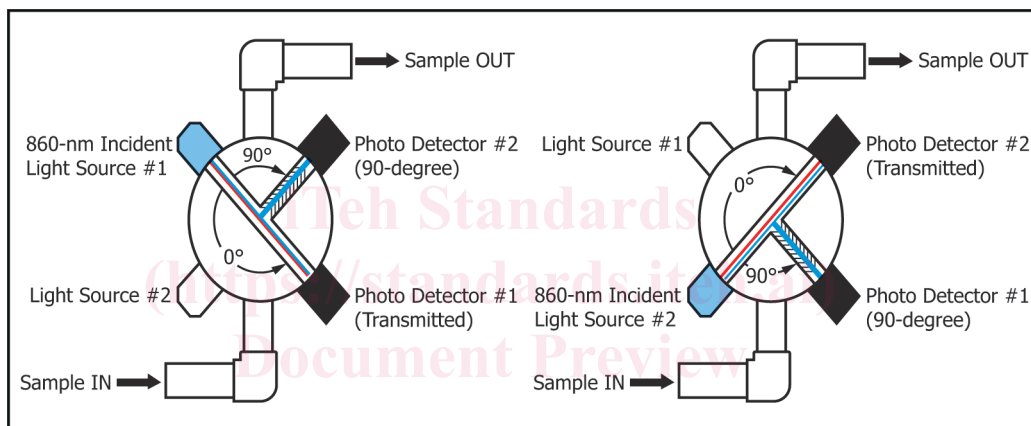

FIG. 1 Typical Nephelometer

FIG. 2 Ratio Nephelometer (Single Beam Design)

NOTE 1—The blue traces show the path of the scattered light.

FIG. 3 Ratio Nephelometer (Multiple Beam Design)

7.3.1 Consult the manufacturer to determine that your instrument meets any of the designs that are discussed in this test method.

7.4 *The Nephelometer:*

7.4.1 This instrument uses a light source for illuminating the sample and a single photodetector with a readout device to indicate the intensity of light scattered at right angle(s) (90°) to the centerline of the path of the incident light. The photoelectric nephelometer should be designed so that minimal stray light reaches the detector in the absence of turbidity and should be free from significant drift after a short warm-up period. The light source shall be a tungsten lamp operated at a color temperature between 2200 K and 3000 K (U.S. EPA Method 180.1). Light-emitting diodes (LEDs) or laser diodes in defined wavelengths ranging from 400 nm to 680 nm and 780 nm to 900 nm may also be used if accurately characterized to be equivalent in performance to tungsten using the same type of calibration and calibration verification standards. It is important to note that new technologies may not be covered by this test method. If LEDs or laser diodes are used, then the LED or laser diode should be coupled with a monitor detection device to achieve a constant output. LEDs and laser diodes should be characterized by a wavelength of between 400 nm and 900 nm with a bandwidth of less than 60 nm. The total distance traversed by incident light and scattered light within the sample is not to exceed 10 cm. The angle of light acceptance to the detector shall be centered at 90° to the centerline of the incident light path and shall not exceed ±10° from the 90° scatter path centerline. The detector must have a spectral response that is sensitive to the spectral output of the incident light used.

7.4.2 Differences in physical design of nephelometers may cause differences in measured values for turbidity even though the same suspension is used for calibrations. Comparability of measurements made using instruments differing in optical and physical designs is not recommended. To minimize initial differences, the following design criteria should be observed (see Fig. 1).

7.4.3 Report in units of NTU if a white light source was used or in units of FNU if a 780 nm to 900 nm light source was used.
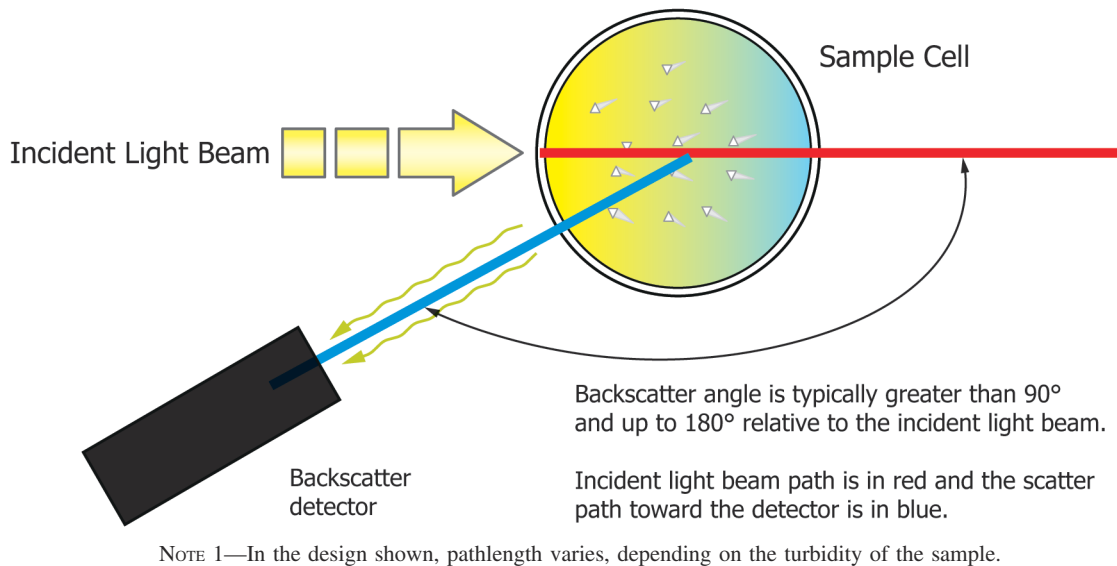
7.5 *Ratio Nephelometer:*

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NOTE 1—In the design shown, pathlength varies, depending on the turbidity of the sample.

FIG. 4 Geometric Diagram of a Backscatter Measurement (<90°)

NOTE 1—The scatter and attenuation path is the same as the incident light path.
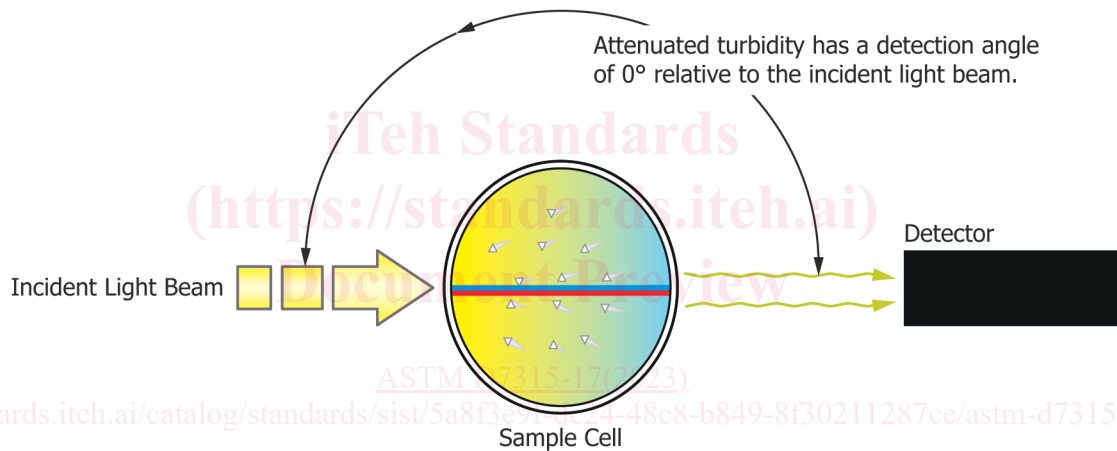
FIG. 5 Technology Diagram of an Attenuation Technology

7.5.1 *Ratio Nephelometer* (see Fig. 2 for single beam design; see Fig. 3 for multiple beam design)—This instrument uses 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 incident light fluctuation, stray light, instrument noise, or sample color. As needed by the design, additional photodetectors may be used to detect the intensity of light scattered at other angles. The signals from these additional photodetectors may be used to compensate for variations in incident light fluctuation, instrument stray light, instrument noise, sample color, or combinations thereof. The ratio photoelectric nephelometer should be so designed that minimal stray light reaches the detector(s), and should be free from significant drift after a short warm-up period. The light source should be a tungsten lamp, operated at a color temperature between 2200 K and 3000 K (U.S. EPA Method 180.1). LEDs and laser diodes in defined wavelengths ranging from 400 nm to 900 nm may also

be used. If an LED or a laser diode is used in the single beam design, then the LED or laser diode should be coupled with a monitor detection device to achieve a consistent output. The distance traversed by incident light and scattered light within the sample is not to exceed 10 cm. The angle of light acceptance to the nephelometric detector(s) should be centered at 90° to the centerline of the incident light path and should not exceed ±10° from the scatter path centerline. The detector must have a spectral response that is sensitive to the spectral output of the incident light used. The instrument calibration (algorithm) must be designed such that the scaleable reading is from the nephelometric detector(s), and other detectors are used to compensate for instrument variation described in 7.4.1.

7.5.2 Differences in physical design of ratio photoelectric nephelometers may cause differences in measured values for turbidity even when the same suspension is used for calibrations. Comparability of measurements made using instruments differing in optical and physical design is not recommended. To

minimize initial differences, the following design criteria should be observed (see Figs. 2 and 3).

7.5.3 Report in the appropriate units using Table 1 as guidance.

7.5.3.1 FNRU, and FNMU signify the use of an incident light wavelength between 780 nm to 900 nm. NTRU and NTMU signify the use of an incident light in the wavelength range of 400 nm to 680 nm for a ratio technology.

7.6 *Backscatter Turbidimeters:*

7.6.1 The instrumentation contains a light source that meets or exceeds the criteria specified in 7.4.1 for illumination of the sample.

7.6.2 The response curve of the detector should be such that it overlaps the output of the light source.

7.6.3 The detection angle for backscatter is between 90° and 180° relative to the centerline of the incident light beam. See Fig. 4.

7.6.4 When reporting turbidity, report in units that best fit the light source and detector in Table 2. Report in BU (white light source) or FBU (if a 780 nm to 900 nm light source was used).

7.7 *Attenuation-Based Turbidimeters:*

7.7.1 The instrument contains a light source that meets or exceeds the criteria specified in 7.4.1 for illumination of the sample. Examples include monochromatic light such as those generated in spectrophotometers.

7.7.2 The detector response curve should overlap the incident light source.

7.7.3 The detection angle for attenuation is to be set at 0° relative to the centerline of the incident light beam. See Fig. 5.

7.7.4 When reporting turbidity, report in units that best fit the light source and detector in Table 1. Report in AU (white light source) or FAU (if a 780 nm to 900 nm light source was used).

7.8 *Sample Cells* (if used with typical benchtop or portable instruments):

7.8.1 The sample cells used in calibration and sample measurement must be the following:

7.8.1.1 Clear, colorless glass or optically clear plastic, be kept scrupulously clean, both inside and out, and discarded when it becomes etched or scratched (see non-mandatory Appendix X3 for sample cell cleaning procedure).

7.8.1.2 Index marked so that repeated exact placements into the instrument sample cell compartment for measurement can be made. The location of the index mark should be such that

the window of movement is less than 10° of rotation where the measurement is consistent. See 11.4.2.1.

7.8.1.3 Cells should be handled where the light path does not pass during measurement. Provision should be made in design to give the sample cell a proper place in which to handle the cell during calibration or sample measurement procedure.

7.8.1.4 The outside surface of a glass sample cell may be oiled, using silicone oil and a soft cloth, or a lint free laboratory tissue to minimize imperfections that could cause light to scatter off the surface of this sample cell, or wiped with alcohol. See the manufacturer's recommendations for sample cell preparation.

7.8.1.5 Preferably matched sample cells that provide consistent readings to within 10 % on filtered DI water should be used.

7.9 *Sample Chambers:*

7.9.1 For those instruments not using sample cells, the sample is placed directly into the sample chamber. For those units, the sample chamber must be the following:

7.9.1.1 Sample chambers should be kept scrupulously clean. Scratches, fingerprints and dirt on the walls of the sample chamber may give erroneous results. See the manufacturer's recommendations for sample chamber maintenance.

7.9.1.2 Sample chambers should be designed in such a way as to negate any influence from external light sources, and to minimize stray light interference with readings.

8. Purity of Reagents

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. All reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.[6]

8.1.1 ACS grade chemicals of high purity (99+ %) shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available. Other grades may be used providing it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

NOTE 2—Refer to product MSDS for possible health exposure concerns.

8.2 Reverse osmosis (RO) water is acceptable and preferred in this test method. Standard dilution waters and rinse waters should be prepared by filtration through a 0.22 µm or smaller membrane filter or any other suitable filter within 1 h of use to reduce background turbidity. Type III water is also acceptable (see Specification D1193). These types of water should be used in preparation of turbidity standards for calibration or verification.

TABLE 2 Reporting of Results for High Level Static Turbidity Measurements

NOTE 1—New developments in technologies may allow instruments to extend beyond range.

Measured Value In Appropriate Units	Report to Nearest
1.0* < 9.9	0.1
10 < 99	1
100–999	5
1000<	50

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[6] *ACS Reagent Chemicals, Specifications and Procedures for Reagents and Standard-Grade Reference Materials*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

9. Reagents

9.1 *Dilution and Final Rinsing Water,* see 8.2.

9.2 *Turbidity Standards:*

NOTE 3—A standard with a turbidity of 1.0 NTU is the lowest formazin turbidity standard that should be produced on the bench. Skilled laboratory personnel with experience in quantitative analysis shall perform preparation of formazin standards. Close adherence to the instructions within this section is required in order to accurately prepare low-level turbidity standards.

NOTE 4—Equivalent, commercially available, calibration standards may be used. These standards, such as stabilized formazin (StablCal[7]) and styrenedivinylbenzene (SDVB), have a specified turbidity value and accuracy. Such standards must be referenced (traceable) to bench-synthesized formazin (see 9.2.2). Follow specific manufacturer's calibration procedures.

9.2.1 All volumetric glassware must be scrupulously clean. The necessary level of cleanliness can be achieved by performing all of the following steps: washing glassware with laboratory detergent followed by 3 tap water rinses; then rinse with portions of 1:4 HCl followed by at least 3 tap water rinses; finally, rinse with rinse water as defined in 8.2.

9.2.2 *Reference Formazin Reference Turbidity Standard, 4000 NTU*—This standard is synthesized in the lab.

9.2.2.1 Quantitatively transfer 5.000 g of reagent grade hydrazine sulfate (99.5 %+ purity) ($N_2H_4 \cdot H_2SO_4$) into approximately 400 mL of dilution water (see 8.2) contained in a 1 L Class A volumetric flask; stopper and completely dissolve by swirling.

NOTE 5—To quantitatively transfer this powdered reagent, transfer the hydrazine sulfate into the flask containing the dilution water. Rinse the weighing bowl with dilution water, adding the rinsings to the flask. Repeat the rinsing again adding the second rinsings to the flask.

9.2.2.2 Quantitatively transfer 50.000 g of reagent grade hexamethylenetetramine (99 %+ purity) in approximately 400 mL of dilution water (see 8.2) contained in a clean flask; stopper and completely dissolve by swirling. Filter this solution through a 0.2 μm filter into a clean flask.

9.2.2.3 Quantitatively transfer the filtered hexamethylenetetramine into the flask containing the hydrazine sulfate. Dilute this mixture to 1 L using dilution water (see 8.2). Stopper and mix for at least 5 min, and no more than 10 min.

NOTE 6—To quantitatively transfer this liquid mixture, transfer the hexamethylenetetramine into the flask containing the hydrazine sulfate. Rinse this flask two times using 50 mL aliquots of dilution water, adding each rinsing to the flask containing the hydrazine sulfate.

9.2.2.4 Allow the solution to stand for at least 24 h at 25 °C ± 1 °C. The 4000 NTU Formazin suspension develops during this time.

NOTE 7—This suspension, if stored at 20 °C to 25 °C in amber polyethylene bottles, is stable for 1 year; it is stable for 1 month if stored in glass at 20 °C to 25 °C.

9.2.3 Stabilized formazin turbidity standards (StablCal) are prepared stable suspensions of the formazin polymer. Preparation is limited to inverting the container to re-suspend the formazin polymer. These standards require no dilution and are used as received from the manufacturer.

9.2.4 SDVB standards are prepared stable suspensions of copolymer microspheres which are used as received from the manufacturer or distributor. These standards exhibit calibration performance characteristics that are specific to instrument design.

NOTE 8—Sealed or solid samples should not be used to standardize turbidimeters for the turbidity measurement of water or waste; they may only be used for calibration verification. These two methods (sealed or solid examples) neglect the zeroing out of the sample cell prior to making water measurement in the cell.

9.2.5 *Formazin Turbidity Suspension, Standard (40 NTU)*—This is an example on how to prepare a calibration standard of a specific turbidity value. All labware shall be seasoned (see Appendix X3). Invert 4000 NTU stock suspension 25 times to mix (1 s inversion cycle); immediately pipette, using a Class A pipette, 10.00 mL of mixed 4000 NTU stock into a 1000 mL Class A volumetric flask and dilute with water to mark. The turbidity of this suspension is defined as 40 NTU. This 40-NTU suspension must be prepared weekly.

9.2.6 *Other Formazin Calibration Standards*—Using a similar procedure as in 9.2.5, prepare the appropriate standards as required to calibrate the instrument as instructed by the instrument calibration protocol.

9.2.7 *Dilute Formazin Turbidity Suspension Standard (1.0 NTU)*—Prepare this standard daily by inverting the 40 NTU (9.2.5) stock suspension 25 times to mix (1 s inversion cycle) and immediately pipet a volume of 40 NTU standard. All glassware shall be seasoned (see Appendix X3).

NOTE 9—The instructions below result in the preparation of 200 mL of a formazin standard. Users of this test method will need different volumes of the standard to meet their instrument's individual needs; glassware and reagent volumes shall be adjusted accordingly.

9.2.7.1 Within one day of use, rinse both a glass Class A 5.00 mL pipette and a glass Class A 200 mL volumetric flask with laboratory glassware detergent or 1:1 hydrochloric acid solution. Follow with at least ten rinses with rinse water. Cap and store in a clean environment until use.

9.2.7.2 Using the cleaned glassware, pipet 5.00 mL of well-mixed 40.0 NTU formazin suspension (9.2.5) into the 200 mL flask and dilute to volume with the dilution rinse water. Stopper and invert (1 s inversion cycle) 25 times to mix. The turbidity of this standard is 1.0 NTU.

9.2.8 *Miscellaneous Dilute Formazin Turbidity Suspension Standard*—Prepare all turbidity standards with values below 40 NTU daily. Standards ≥ 40 NTU have a useful life of one week. All labware shall be seasoned (See Appendix X3). Use Class A glassware that has been cleaned in accordance with the instructions in 9.2.1 and prepare each dilution by pipetting the volume of 40 NTU (9.2.5) into a 100-mL volumetric flask and diluting to mark with dilution water (8.2). For example, prepare the solution so that 50.0 mL of 40 NTU diluted to 100 mL is 20.0 NTU and 10.0 mL of 40 NTU diluted to 100 mL is 4.00 NTU.

9.2.8.1 Prepare standards at the turbidity concentrations that are required to meet the specific calibration requirements for the instrument that is to undergo calibration.

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[7] StablCal is a trademark of Hach Company, Loveland, CO, 80538.

9.2.9 Stable turbidity standards are commercially available. These standards, such as stabilized formazin and styrenedivinylbenzene (SDVB), have a specific turbidity value and accuracy. Such standards must be traceable to the reference turbidity standard.

10. Safety

10.1 Wear appropriate personal protection equipment at all times.

10.2 Follow all relevant safety guidelines.

10.3 Refer to instrument manuals for safety guidelines when installing, calibrating, measuring or performing maintenance with any of the respective instrumentation.

10.4 Refer to all Material Safety Data Sheets (MSDSs) prior to preparing or using standards and before calibrating or performing instrument maintenance.

11. Sampling and Sample Preservation

11.1 *Collection of Sample*—Collect the sample in accordance with the applicable standard, specification and practices. See Guide D4411 for the collection of samples in moving waters.

11.2 *Storage of Sample*—Analyze the sample immediately. Do not store the sample.

11.3 *Sample Handling*—Samples should be measured expeditiously after collection to prevent changes in particle characteristics due to temperature changes and settling. Temperature can effect particles either by changing their behavior or creating new particles, if precipitates are created. Dilution water may dissolve particles or change their characteristics. Operators should draw samples only when turbidimeters are ready for operation. Do not draw a sample and allow it to sit while the turbidimeter is being readied.

11.4 *Other Important Sampling Techniques:*

11.4.1 Minimize agitation of samples as particles can be altered or air may be entrained into the sample. Gentle agitation or swirling is recommended to reduce particle settling. Swirling may not be appropriate for rapidly settling particles.

11.4.2 Sample cells should only be used with the instrumentation for which they were intended.

11.4.2.1 Prior to each measurement inspect the filled sample cell and ensure that there are no bubbles in the sample, and that the cell is free of scratches.

NOTE 10—If degassing is necessary, a non-intrusive procedure for removing bubbles can be used. Examples include the application of a vacuum or the use of an ultra-sonic bath. Caution must be exercised not to alter the composition of the samples.

11.4.2.2 Sample cells should be evaluated with a low turbidity water (after cleaning) to determine if cells remain matched. If the evaluation determines that a cell is corrupted, discard the cell. This check should be performed on a weekly basis.

11.4.2.3 If a sample cell's condition is questionable, discard the cell and replace with a new sample cell.

11.5 *Sample Preparation for Measurement:*

11.5.1 Rinse the clean sample cell or chamber twice with the sample that is to be measured, and discard the rinsings.

11.5.2 Fill the sample cell or chamber to a level at which the top air/liquid interface will not interfere with the subsequent reading. Follow manufacturer recommendations as to sample cell or chamber filling.

11.5.3 After the sample cell is filled, use a lint-free tissue to remove all traces of dirt or fingerprints. Tissue alone does not clean dirty sample cells and one of the common nonabrasive glass cleaners may be necessary.

11.5.4 The cleaned sample cell is handled by its very top and placed in an indexed manner in the instrument.

12. Calibration and Calibration Verification

12.1 Determine if the instrument requires any maintenance such as cleaning the sample cell or sample chamber, etc. Follow the manufacturer's instructions for any required instrument maintenance prior to calibration.

12.2 *Calibration:*

12.2.1 Follow the manufacturer's instructions for calibration and operation. Calibrate the instrument to assure proper operation for the range of interest with appropriate standards. See standard or instrument manufacturers for the preparation and use of calibration or verification standards.

12.2.2 Formazin-based calibration standards should be resuspended through inversion (1 s inversion cycle) 25 times followed by a 2 min to 10 min wait to allow for bubble removal. Standards of 40 NTU or below will remain suspended for up to 30 min; standards greater than 40 NTU may require more frequent re-suspension.

NOTE 11—A Calibration Turbidity Standard is a turbidity standard that is traceable and equivalent to the reference turbidity standard to within statistical errors, including commercially prepared 4000 NTU Formazin, stabilized formazin, and styrenedivinylbenzene (SDVB). These standards may be used to calibrate the instrument.

12.2.3 Verify instrument calibration accuracy in the expected measurement area using a calibration verification standard. The calibration verification standard used should have a defined value with known accuracy. The calibration verification standard should allow the instrument to perform to within its defined performance specifications. Verification should be conducted at timely intervals between calibrations. (Consult instrument manufacturer's recommendations, standard's manufacturers recommendations, or both for guidance associated with verification methods and devices.)

NOTE 12—Some regulatory agencies may have specific requirements or guidelines regarding the calibration of turbidimeters. Consult those authorities if reporting to specific regulatory agencies.

12.2.4 In case of verification failure clean the instrument to reduce stray light levels or contamination. Follow with a recalibration (instrument adjustment) according to manufacturer's calibration instructions, using a calibration standard (see 3.2.2), or at a minimum on a quarterly basis.

12.2.5 Close adherence to the calibration procedure and to the rinsing/seasoning techniques is very important to ensure data quality.

12.2.6 Proper sample handling and preparation procedures must be followed to assure data quality (see Section 11).