



Standard Test Method for On-Line Measurement of Turbidity Below 5 NTU in Water¹

This standard is issued under the fixed designation D6698; 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 is applicable to the on-line measurement of turbidity under 5 nephelometric turbidity units (NTU) in water.

1.2 It is the user's responsibility to ensure the validity of this test method for waters of untested matrices.

1.3 In this test method calibration standards are defined in NTU values, but other assigned turbidity units are assumed to be equivalent.

1.4 This test method assigns traceable reporting units to the type of respective technology that was used to perform the measurement. Units are numerically equivalent with respect to the calibration standard. For example, a 1 NTU formazin standard is also equal to a 1 FNU (formazin nephelometric units) standard, a 1 FNRU (formazin nephelometric ratio units) standard, and so forth.

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

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

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](#)

[D3370 Practices for Sampling Water from Closed Conduits](#)

¹ This test method is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.03 on Sampling Water and Water-Formed Deposits, Analysis of Water for Power Generation and Process Use, On-Line Water Analysis, and Surveillance of Water.

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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.

[D3864 Guide for On-Line Monitoring Systems for Water Analysis](#)

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

2.2 Other Standards:

[EPA 180.1 Methods for Chemical Analysis of Water and Wastes, Turbidity](#)³

[GLI Method 2](#)⁴

[Hach Method 8195 Determination of Turbidity by Nephelometry EMMC Format](#)⁴

[ISO 7027 Determination of Turbidity](#)⁵

[Standard Method 2130B](#)⁶

2.3 Other Documents:

[U.S. Patent 4,283,143 Patterson, James A. 1981. Optical Characterization of a Suspension. United States Patent 4,283,143, filed November 19, 1979, and issued August 11, 1981.](#)⁷

[U.S. Patent 4,291,980 Patterson, James A. 1981. Styrene-Divinylbenzene Copolymer and Method of Manufacturer. United States Patent 4,291,980, filed August 14, 1978, and issued September 29, 1981.](#)⁷

[U.S. Patent 5,777,011 Sadar, Michael J. 1998. Stabilized Formazin Composition. United States Patent 5,777,011, filed December 1, 1995, and issued July 7, 1998.](#)^{4,8}

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology [D1129](#).

3.2 *Definitions of Terms Specific to This Standard:*

³ Available from United States Environmental Protection Association (EPA), Ariel Rios Bldg., 1200 Pennsylvania Ave., NW, Washington, DC 20460, <http://www.epa.gov>.

⁴ Available from Hach Company, P.O. Box 389, Loveland, CO, 80539-0389, <http://www.hach.com>.

⁵ Available from International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

⁶ Available from Standard Methods for the Examination of Water and Wastewater, 21st Edition, American Public Health Association, Washington, DC, 2005, <http://www.standardmethods.org>.

⁷ Available from AMCO Clear, P.O. Box 245, Powell, OH, 43065, <http://www.amcclear.com>.

⁸ This document is covered by a patent. Interested parties are invited to submit information regarding the identification of alternatives to the ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend.

3.2.1 *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).

3.2.1.1 *Discussion*—These standards may be used to calibrate the instrument. Calibration standards may be instrument specific.

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

3.2.2.1 *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. Calibration verification standards may be instrument specific.

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

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

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 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.

3.2.7 *seasoning, v*—the process of conditioning labware with the standard that will be diluted to a lower value to reduce contamination and dilution errors. See [Appendix X2](#) for suggested procedure.

3.2.8 *slip stream nephelometer, n*—an on-line turbidimeter that determines the turbidity of a sample as the sample flows through a sampling chamber.

3.2.8.1 *Discussion*—The sample is drawn from the source into the turbidimeter, analyzed and then transported to drain.

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

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 Test Method [D7315](#).

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 suspended solids have on light; the higher the intensity of scattered light, the higher the turbidity. In samples containing particulate matter, the manner in which the particulate matter interacts with light transmittance is related to the size, shape and composition of the particles in the water, and also to the wavelength of the incident light.

4.2 This test method is based upon a comparison of the intensity of light scattered by the sample with the intensity of light scattered by a reference suspension. Turbidity values are determined by a nephelometer, which measures light scatter from a sample in a direction that is at 90 degrees with respect to the centerline of the incident light path.

5. Significance and Use

5.1 Turbidity is 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 of suspended matter is accomplished by coagulation, settling, and filtration. Measurement of turbidity provides a rapid means of process control to determine when, how, and to what extent the water must be treated to meet specifications.

5.2 This test method is suitable for the on-line monitoring of turbidity such as that found in drinking water, process water, and high purity industrial waters.

5.3 The instrumentation used must allow for the continuous on-line monitoring of a sample stream.

NOTE 1—See [8.2](#) for discussion on signal spikes resulting from bubbles.

5.4 When reporting the measured result, appropriate units should also be reported. The units are reflective of the technology used to generate the result, and if necessary, provide more adequate comparison to historical data sets.

5.4.1 [Table 1](#) describes technologies and reporting results. Those technologies listed are appropriate for the range of measurement prescribed in this test method are mentioned, though others may come available.

5.4.2 For a specific design that falls outside of the reporting ranges in [Table 1](#), the turbidity should be reported in turbidity units (TU) with a subscripted wavelength value to characterize the light source that was used.

6. Safety

6.1 Wear appropriate personal protection equipment at all times.

6.2 Follow all relevant safety guidelines.

TABLE 1 Technologies and Reporting Results

Design and Reporting Unit	Prominent Application	Key Design Features	Typical Instrument Range	Suggested Application
Nephelometric non- ratio (NTU)	White light turbidimeters comply with EPA 180.1 for low-level turbidity monitoring.	Detector centered at 90° relative to the incident light beam. Uses a white light spectral source.	0.020 to 40	Regulatory reporting of clean water
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.	0.020 to 10 000	Regulatory Reporting of clean water
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 (780-900 nm) monochromatic light source.	0.012 to 1000	0–40 ISO 7027 Regulatory reporting
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 (780–900 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.	0.012 to 10 000	0–40 ISO 7027 Regulatory reporting
Formazin Nephelometric Multi-beam Unit (FNMU)	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°. Uses a near-IR light source (780–900 nm) monochromatic light source. An instrument algorithm uses a combination of detector readings, which may differ for turbidities varying magnitude.	0.012 to 4000	0–40 Reporting for EPA and ISO compliance
mNTU	Is applicable to reporting of clean waters and filter performance monitoring. Very sensitive to turbidity changes in low turbidity samples.	Nephelometric method involving a laser-based light source at 660 nm and a high sensitivity photo-multiplier tube (PMT) detector for light scattered at 90°. 1000 mNTU = 1 NTU	5 to 5000 mNTU	0–5000 mNTU, for EPA compliance reporting on drinking water systems

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

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

7. Interferences

7.1 Bubbles, color, and large suspended particles may result in interferences. Bubbles cause positive interference and color causes negative interference. Dissolved material that imparts a color to the water may cause errors in pure photoelectric nephelometric readings (versus ratio photoelectric nephelometric readings) unless the instrument has special compensating features. Certain turbulent motions also create unstable reading conditions of nephelometers.

7.2 Scratches, finger marks, or dirt on any part of an optical component through which light must travel to reach the sample, or through which scattered light leaves the sample to a detector, may give erroneous readings. Keep these surfaces scrupulously clean and replace damaged (etched or scratched) components.

8. Apparatus

8.1 The sensor used for the on-line monitoring of turbidity is designed for continuous monitoring of the turbidity of the sample stream.

8.2 The instrument design should eliminate signal spikes resulting from bubbles present in samples through the use of either internal or external bubble rejection chambers (traps), sample pressurization, or electronic rejection methods, or a combination thereof.

8.3 The sensor must be designed to be calibrated. The calibration should be performed by following the manufacturer’s recommended procedures. If a calibration algorithm for the instrument is used, it should be derived through the use of a reference or calibration turbidity standard.

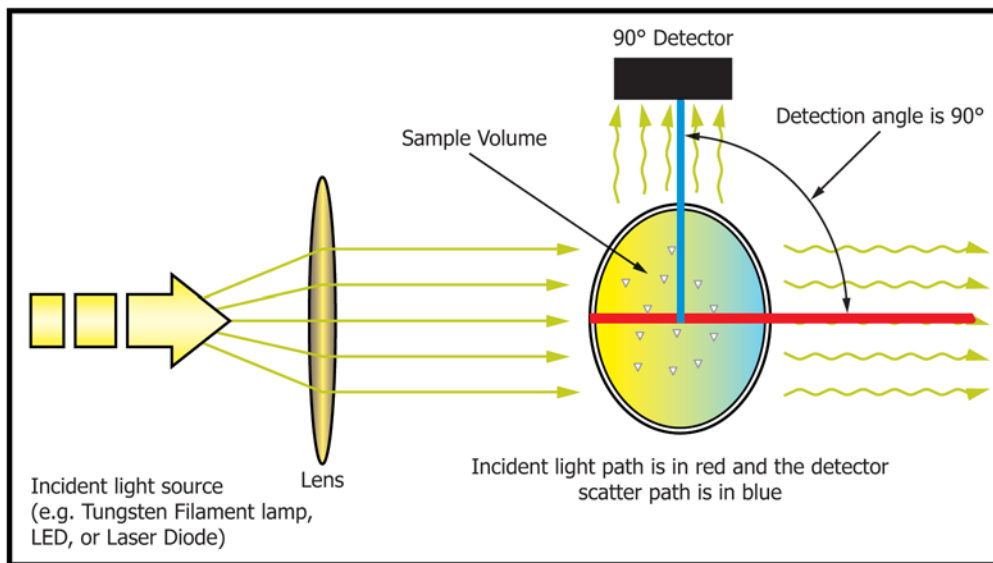
8.4 The resolution of the instrument should permit detection of turbidity differences of 0.01 NTU or less in waters having turbidities of less than 1.00 NTU. The instrument should permit detection of turbidity differences of 0.10 NTU or less in waters with turbidity between 1.0 and 5.0 NTU.

8.5 *Instrument Types*—Two types of instruments are available for the nephelometric turbidity method, the nephelometer and ratio nephelometer.

8.5.1 *The Photoelectric Nephelometer*—(See Fig. 1.) This instrument uses a light source for illuminating the sample and a single photo-detector with a readout device to indicate the intensity of light scattered at 90° to the centerline of the path of the incident light. The photoelectric nephelometer should be so designed 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 should be a Tungsten lamp operated at a color temperature between 2200 and 3000 K. Light Emitting Diodes (LEDs) and laser diodes in defined wavelengths ranging from 400-900 nm may also be used. If LEDs or laser diodes are used, then the LED or laser diode should be coupled with a monitor detection device to achieve a consistent output. The total distance traversed by incident light and scattered light within the sample is not to exceed 10 cm. Angle of light acceptance to the detector: centered at 90° to the centerline of the incident light path and not to exceed ±10° from the 90° scatter path center line. The detector must have a spectral response that is sensitive to the spectral output of the incident light used.

8.5.1.1 Differences in physical design of photoelectric nephelometers will cause slight 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 design is not recommended. To minimize initial differences, observe the following design criteria:

8.5.2 *Ratio Photoelectric 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 sense 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, or sample color, or combination 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 and 3000 K. LEDs and laser diodes in defined wavelengths ranging from 400 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 center line. The detector must have a spectral response that is



NOTE 1—The pathlength through the sample is shown in red and the shortest scattered light path is in blue. The longer this distance, the better the measurement sensitivity.

FIG. 1 Technology Diagram of a Nephelometric Non-Ratio Technology

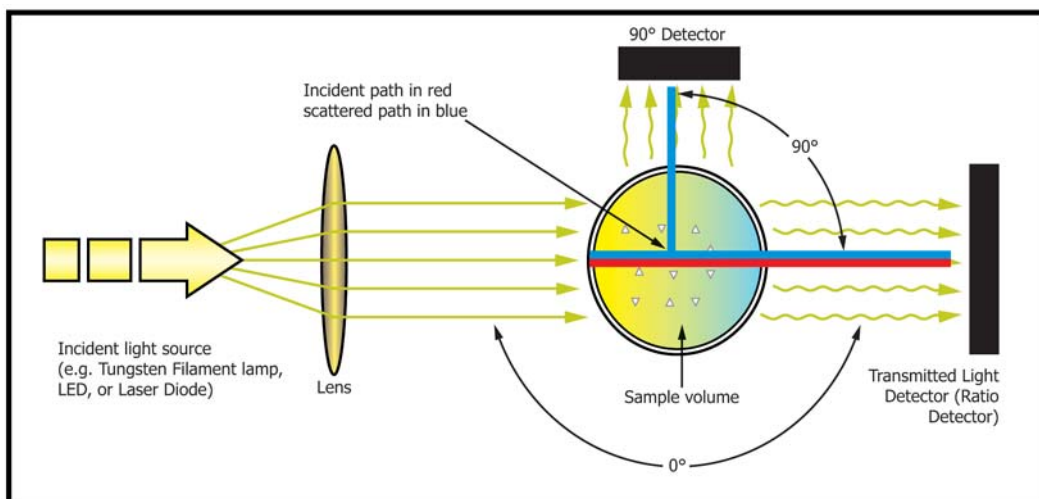
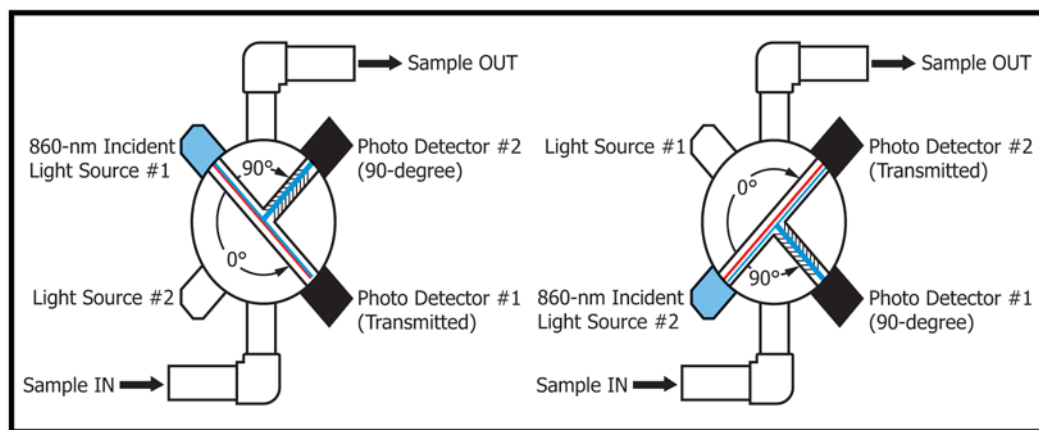


FIG. 2 Technology Diagram of a Nephelometric Ratio Technology



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

FIG. 3 Diagram of a Multi-Beam Ratio Technology

sensitive to the spectral output of the incident light used. The instrument calibration (algorithm) must be designed such that the scalable reading is from the nephelometric detector(s), and other detectors are used to compensate for instrument variation described in 3.2.5.

8.5.2.1 Differences in physical design of ratio photoelectric nephelometers will cause slight 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. Examples of ratio nephelometers are shown in Figs. 2 and 3.

8.6 Examples of applicable nephelometers include: photoelectric nephelometer, ratio photoelectric nephelometer with a single beam design, and ratio photoelectric nephelometer in the dual beam design. In these designs, the correlation between detector response and increasing turbidity is positive.

9. Purity of Reagents

9.1 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.

9.2 Standard dilution, reagent and rinse waters shall be prepared by filtration of Type III water, or better, through a 0.22 microns or smaller membrane or other suitable filter within 1 hour of use to reduce background turbidity. Reverse osmosis (RO) water is acceptable and preferred in this test method. (See Specification D1193.)

10. Reagents

10.1 Reagent, dilution, and final rinsing water, see 9.2.

10.2 *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. Preparation of

formazin standards shall be performed by skilled laboratory personnel with experience in quantitative analysis. Close adherence to the instructions within Section 10 is required in order to accurately prepare low-level turbidity standards.

10.2.1 Equivalent, commercially-available, calibration standards may be used. These standards, such as stabilized formazin and SDVB, have a specified turbidity value and accuracy. Such standards must be referenced (traceable) to formazin. Follow specific manufacturer's calibration procedures.

NOTE 4—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 3 times with rinse water as defined in 9.2. Reference formazin turbidity standard (4000 NTU) is synthesized on the bench.

10.2.1.1 Dissolve 5.000 grams of ACS grade hydrazine sulfate (99.5 % + purity) ($N_2H_4 \cdot H_2SO_4$) into approximately 400 mL of dilution water (see 9.2) contained in a 1-litre Class A volumetric flask.

10.2.1.2 Dissolve 50.000 grams of ACS grade hexamethylenetetramine (99 % + purity) in approximately 400 mL of dilution water (see 9.2) contained in another flask. Filter this solution through a 0.2- μ m filter.

10.2.1.3 Quantitatively pour the filtered hexamethylenetetramine solution into the flask containing the hydrazine sulfate. Dilute this mixture to 1 litre using dilution water (see 9.2). Stopper and mix for at least 5 minutes, and no more than 10 minutes.

10.2.1.4 Allow the solution to stand for 24 hours at $25 \pm 1^\circ C$. The 4000 NTU formazin suspension develops during this time.

10.2.1.5 This suspension, if stored at $20\text{--}25^\circ C$ in amber polyethylene bottles, is stable for 1 year; it is stable for 1 month if stored in glass at $20\text{--}25^\circ C$.

10.2.2 Stabilized formazin turbidity standards 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. (See Hach Method 8195 and U.S. Patent 5,777,011.)

10.2.3 SDVB polymer turbidity standards are prepared stable suspensions which are used as received from manufacturer or distributor. These standards exhibit calibration performance characteristics that are specific to instrument design. (See U.S. Patents 4,283,143 and 4,291,980.)

10.2.4 *Formazin Turbidity Suspension, Standard (40 NTU)*—All labware shall be seasoned (see Appendix X2). Invert 4000 NTU stock suspension 25 times to mix (1 second 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.

10.2.4.1 This suspension serves as the highest calibration standard that may be used with this test method.

10.2.5 *Dilute Formazin Turbidity Suspension Standard (1.0 NTU)*—Prepare this standard dilution daily by inverting the 40

NTU stock suspension 25 times to mix (1 second inversion cycle) and immediately pipetting a volume of the 40.0 NTU standard (10.2.4). All labware shall be seasoned (see Appendix X2).

NOTE 5—The instructions below result in the preparation of 200 mL of 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.

10.2.5.1 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.

10.2.5.2 Using the cleaned glassware, pipette 5.00 mL of mixed 40.0 NTU formazin suspension (10.2.4) into the 200 mL flask and dilute to volume with the dilution water. Stopper and invert 25 times to mix (1 second inversion cycle). The turbidity of this prepared standard is 1.0 NTU.

10.2.6 *Miscellaneous Dilute Formazin Turbidity Suspension Standard*—Prepare all turbidity standards with values below 40.0 NTU daily. All labware shall be seasoned (see Appendix X2). Standards with values above 40.0 NTU have a useful life of one week. Use Class A glassware that has been cleaned in accordance with the instructions in 10.2.5.1 and prepare each dilution by pipetting the volume of 40 NTU (10.2.4) into a 100-mL volumetric flask and diluting to mark with dilution water (9.2). For example, prepare 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.

11. Instrument Installation, Sample Lines, and Sampling

NOTE 6—In principle, there are two ways for on-line measurement set ups: (1) The in-line measurement the sensor is brought directly into the process (see Fig. 5). (2) The bypass sample technique involves a portion of sample that is transported via sample lines from the process (source) and into the measurement apparatus. It is then either transported back to the process or to waste (see Fig. 6).

11.1 Bypass Sample Technique:

11.1.1 *Instrument Installation*—Proper location of the sensor and the instrument will help assure accurate results. Assuring that the sensor sees a flowing, bubble free and representative sample is essential for accurate results. Refer to the instrument manufacturer for proper instrument set-up and installation; also see Practices D3370.

11.1.1.1 Locate the sensor as close to the sample location as possible to minimize sample response time. Additionally, locate the instrument for safe, easy access for maintenance and calibration.

11.1.1.2 Locate the instrument so external interferences such as vibration, ambient light, humidity, and extreme conditions are minimized.

11.1.1.3 Position the instrument so it is level and stable to ensure the sample stream is consistent and adequate over long periods of time.

11.1.2 *Sample Lines*—Refer to the instrument manufacturer for recommended sampling procedures for the respective instrument.

11.1.2.1 Sample inlet lines should be a minimum of 4 mm inner diameter, rigid or semi-rigid tubing to allow easy passage of large particles and to minimize the possibility of air lock.

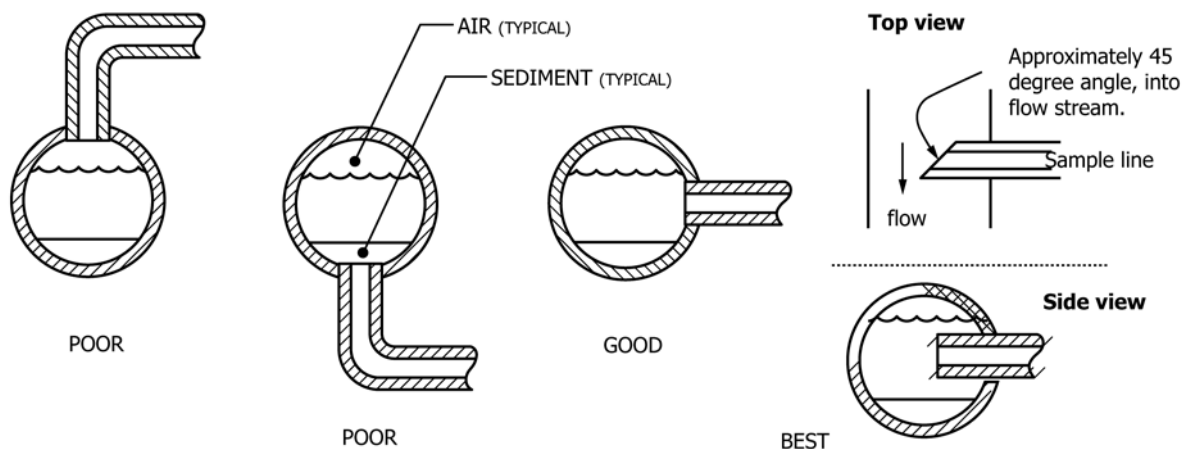


FIG. 4 Illustration of Proper and Improper Sampling Techniques

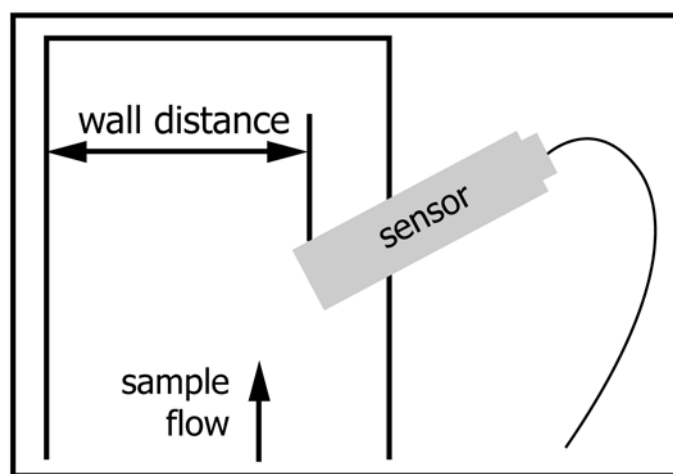


FIG. 5 Principle Set-Up for Inline Turbidity Measurement

(1) Examples of tubing that can be used for sample lines include but are not limited to: polyethylene, nylon, polypropylene, or Teflon⁹-lined tubing.

(2) Soft or porous tubing that could harbor the growth of micro-organisms or contribute turbidity to the sample should not be used.

11.1.3 Sampling:

11.1.3.1 A sample tap should project into the center of the pipe to minimize interference from air bubbles or pipeline bottom sediment. See Fig. 4 for proper sample taps or review instrument manual.

11.1.3.2 Run sample lines directly from the sample point to the turbidimeter sensor to minimize sample flow lag time (response time) or refer to instrument manual.

11.1.3.3 Adjust the flow rate to minimize particle fallout in the sample lines while maximizing bubble removal so bubbles are not carried through the sensor or refer to instrument manual.

(1) Refer to the instrument installation procedures from the manufacturer for optimization of sample flow rates through the instrument.

11.1.4 The use of either internal or external bubble removal devices (bubble traps) prior to performing measurement of the sample is recommended. Reference Practices D3370 and Guide D3864.

11.2 In-Line Measurement:

11.2.1 The principle set up for an in-line turbidity measurement is shown below.

11.2.2 For proper set-up and installation of sensor and transmitter refer to the instrument manufacturer. Some general recommendations for the installation should be followed:

11.2.2.1 The sensor should be mounted into process lines so that the sample stream is consistent and adequate to minimize interference from air bubbles or pipeline bottom sediment.

11.2.2.2 Install sensor surface under an angle with respect to medium flow so that flow increases self cleaning effects of optical parts and repels air bubbles.

⁹ Teflon is a trademark of E.I. du Pont de Nemours and Company, Wilmington, DE, 19898.

Sample Bypass or Slipstream Measurement Technique

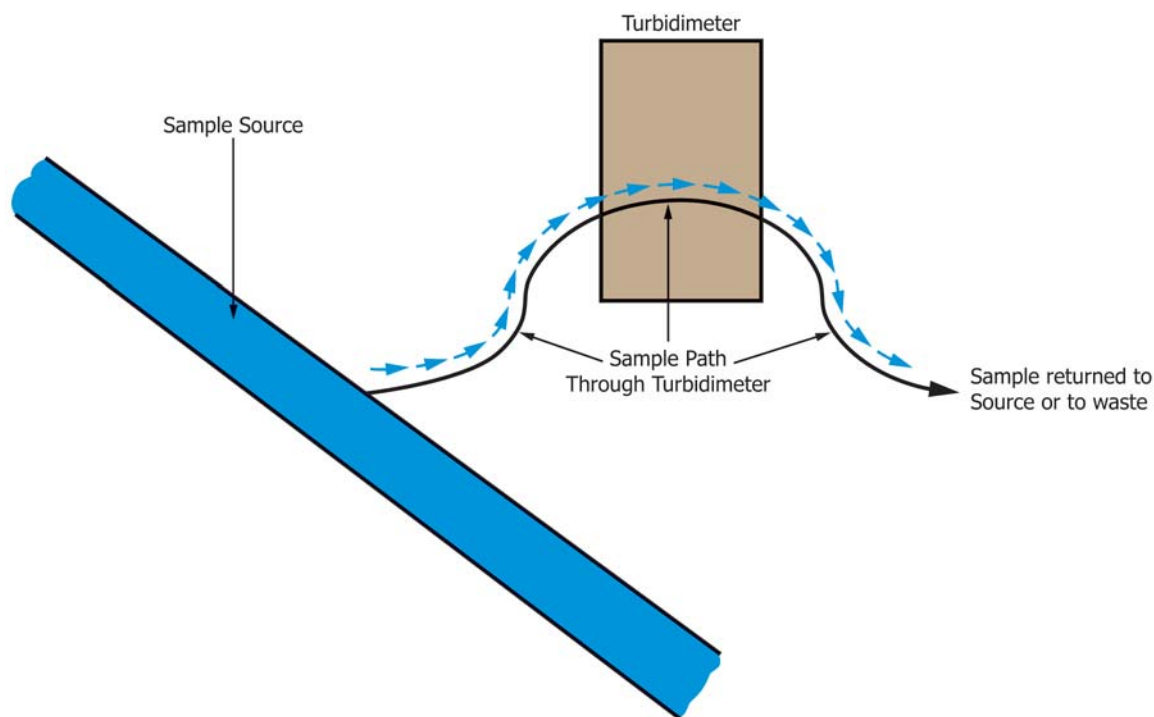


FIG. 6 The Bypass or Slip-Stream Sample Technique

11.2.2.3 The sensor should be installed with maximized wall distance to reduce backscattered or reflective signal (see Fig. 5).

11.2.2.4 Locate transmitter and sensor so that there is easy access for maintenance or calibration.

11.2.2.5 Adjust the flow rate to minimize particle fallout in the sample lines while maximizing bubble removal.

11.2.2.6 Measurement should be done under pressure to avoid degassing.

12. Calibration and Calibration Verification

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

12.2 Follow the manufacturer's instructions for calibration and operation. Calibrate the instrument to assure proper operation for the range of interest with appropriate standards.

NOTE 7—Close adherence to the calibration procedure and to the rinsing/seasoning techniques is very important to ensure the data remains consistent across all locations with all of the turbidimeters.

12.2.1 Formazin-based calibration standards should be re-suspended through inversion (1 second inversion cycle) 25 times followed by a 2–10 minute wait to allow for bubble removal. Standards of 40 NTU or below will remain suspended

for up to 30 minutes; standards greater than 40 NTU may require re-suspension more frequently.

12.2.2 The relationship between turbidity and nephelometric light scatter is known to be linear up to 40 NTU; therefore, calibration standards ranging up to 40 NTU may be used for this test method. Verify linearity in the range of interest (or as close to the measurement range of interest as possible) using defined calibration or calibration verification standards with a known accuracy. (Consult manufacturer's recommendations for guidance associated with verification methods and devices.) In case of verification failure, clean the instrument to reduce stray light levels or contamination. Follow with a recalibration according to manufacturer's calibration instructions, or at a minimum on a quarterly basis.

12.3 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 manufacturer's recommendations for guidance associated with verification methods and devices.)

NOTE 8—Close adherence to the calibration procedure and to the rinsing/seasoning techniques is very important to ensure the data remains consistent across all locations with all of the turbidimeters.

13. Procedure

13.1 Warm up the instrument according to the manufacturer's instructions.

13.1.1 Identify the type of technology and the appropriate reporting unit (see 5.4).

13.2 Verify the flow rate is within the manufacturer's guidelines. If it is not, perform adjustments to the flow to meet these guidelines.

13.3 If bubbles are interfering, perform adjustments to minimize bubbles. These adjustments might include pressurizing the measuring chamber, installing bubble traps and ensuring they are working properly, or changing the flow rate, or a combination thereof.

13.4 Measurement of Water Turbidity:

13.4.1 Determine the frequency of sample data that is being logged into an appropriate data base. If no data base is to be used, define the procedure for logging data from the instrument.

13.4.1.1 Data should be logged at defined intervals to determine when a change to the on-line sample has occurred.

14. Results

14.1 Report results as follows:

NTU (or Appropriate Reporting Unit)	Report to Nearest (NTU or Appropriate Reporting Unit)
<1.00	0.01
≥1.0	0.1

15. Precision and Bias

15.1 In Practice D2777, an exemption from the requirement to conduct a typical interlaboratory study is specifically granted for test methods involving continuous sampling or measurement, or both, such as this one. However, results from independent intra-laboratory studies make the following precision and bias statements possible:

Turbidity Standard	# of Standards Analyzed per Lab	# Labs	# Operators per Lab	Precision as %RSD	Bias, %
0.1 NTU, Inst. A	10	2	1	12	2.9
0.1 NTU, Inst. B	10	2	1	7.3	13
4.0 NTU	20	1	1	0.9	-0.1

NOTE 9—Because an interlaboratory study is not possible with on-line turbidity measurement, the data provided above should be considered only as examples of the precision and bias that have been achieved using this test method. Because this test method covers a wide range of turbidity measuring technologies, the precision and bias characteristics associated with any specific instrument, compliant with this test method, will also vary amongst varying technologies. Referencing manufacturers specifications and third party technology verification reports will assist the user of this test method in better understanding the performance characteristics that can be expected from a specific instrument.

16. Keywords

16.1 calibration; calibration verification; continuous; formazin; measurement; monitoring; nephelometer; nephelometric; on-line; standard; styrenedivinylbenzene; turbidimeter; turbidity; turbidity standards

APPENDIXES

(Nonmandatory Information)

X1. STABILITY OF FORMAZIN

X1.1 Stability studies of low level and high level formazin standards were conducted by ASTM members to support the formazin preparation instructions set forth in this test method.

X1.1.1 Table X1.1 summarizes the stability data collected

for low-level formazin standards.

X1.1.2 Table X1.2 summarizes the stability data collected for high-level formazin standards.

TABLE X1.1 Summary of Low Level Formazin Stability^A

NTU Standard	%Change in the Measured Value Vs Time Since Preparation									
	0.1 Days	1 Day	2.2 Days	7.3 Days	13.1 Days	21 Days	28 Days	47 Days	61 Days	81.3 Days
0.10	-0.92	-1.61	0	-2.99	-5.06	-6.70	-8.05	-14.0	-20	-32.4
0.30	-0.74	0	3.31	3.23	-3.23	-5.38	-6.45	-14.8	-22.9	-44.5
0.50	-1.70	-1.70	-0.94	-2.21	-6.97	-5.53	-6.38	-8.50	-11.3	-11.4
20.0	0.00	-0.77	-0.51	-2.05	-4.60	-3.07	-3.07	-4.60	-4.86	-6.39

^A ASTM Low-Level Formazin Stability Study. ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

TABLE X1.2 Summary of High Level Formazin Stability^A

	Formazin 20 NTU					
	Day 0.08	Day 1.00	Day 1.92	Day 6.92	Day 13.92	Day 28.79
Average	19.67	19.47	19.31	19.12	18.80	18.12
Std Dev	0.5630	0.5227	0.5250	0.5766	0.5891	0.6034
% Error vs Theoretical	-1.650	-2.650	-3.425	-4.375	-5.975	-9.375
	Formazin 0.60 NTU					
	Day 0.08	Day 1.00	Day 1.92	Day 6.92	Day 13.92	Day 28.79
Average	0.610	0.592	0.591	0.586	0.569	0.533
Std Dev	0.0176	0.0175	0.0190	0.0190	0.0170	0.0221
% Error vs Theoretical	1.091	-1.267	-1.523	-2.417	-5.183	-11.23

^A ASTM High-Level Formazin Stability Study. ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

X2. PROCEDURE FOR SEASONING GLASSWARE WHEN PREPARING CALIBRATION STANDARDS

X2.1 Introduction

X2.1.1 Seasoning is a procedure in which glassware is conditioned immediately prior use in the preparation of turbidity standards. Seasoning will reduce contamination and volumetric dilution errors and is a common practice in volumetric quantitative analysis. The process involves rinsing the glassware twice with the specific standard that will be diluted to prepare a standard of lower value. Seasoning should be used when preparing any standard from the stock 4000 NTU formazin standard. It is of primary importance to season pipets used to prepare low-level turbidity standards. Seasoning should be performed immediately before performing the actual volumetric dilution. Below is the general procedure that should be used for seasoning a pipet. A similar practice should be applied when filling sample cells with sample immediately before analysis.

X2.2 Procedure

X2.2.1 Prepare the solution that is to be diluted. For formazin, this involves mixing the standard immediately prior to use.

X2.2.2 Rinse a small beaker with a small portion of the standard. Discard the rinsing to waste. Repeat this a second time.

X2.2.3 Fill the beaker with enough standard to accommodate at least three times the volume required to prepare the dilution. For example, if a 10 mL dilution volume is to be used, then at least 30 mL of standard should be placed in the beaker.

X2.2.4 Draw a small amount of the standard from the beaker into the pipet. Swirl the standard around the pipet, making sure it contacts all internal surfaces up to the draw line. Then, discard this to waste.

X2.2.5 Draw up a second amount of standard from the beaker up slightly past the fill line. Immediately discard to waste.

X2.2.6 The pipet is now ready for volumetric draw of the standard. There should be enough standard left in the beaker to use. This volumetric draw of the standard should take place immediately after the seasoning.

X3. SELECTION CRITERIA FLOWCHART FOR TURBIDIMETERS

X3.1 Introduction

X3.1.1 The criteria was developed as a cooperative effort between ASTM and the United States Geological Survey.¹⁰

¹⁰ United States Geological Survey (USGS), "National Field Manual for the Collection of Water Quality Data," 12201 Sunrise Valley Drive, Reston, VA, 20192, <http://www.usgs.gov>.

X3.2 The technologies listed in this flowchart include many that may not be suited for low-level process measurements. However, the chart does serve to provide guidance for selection of a technology that will be best suited for the sample type and conditions.

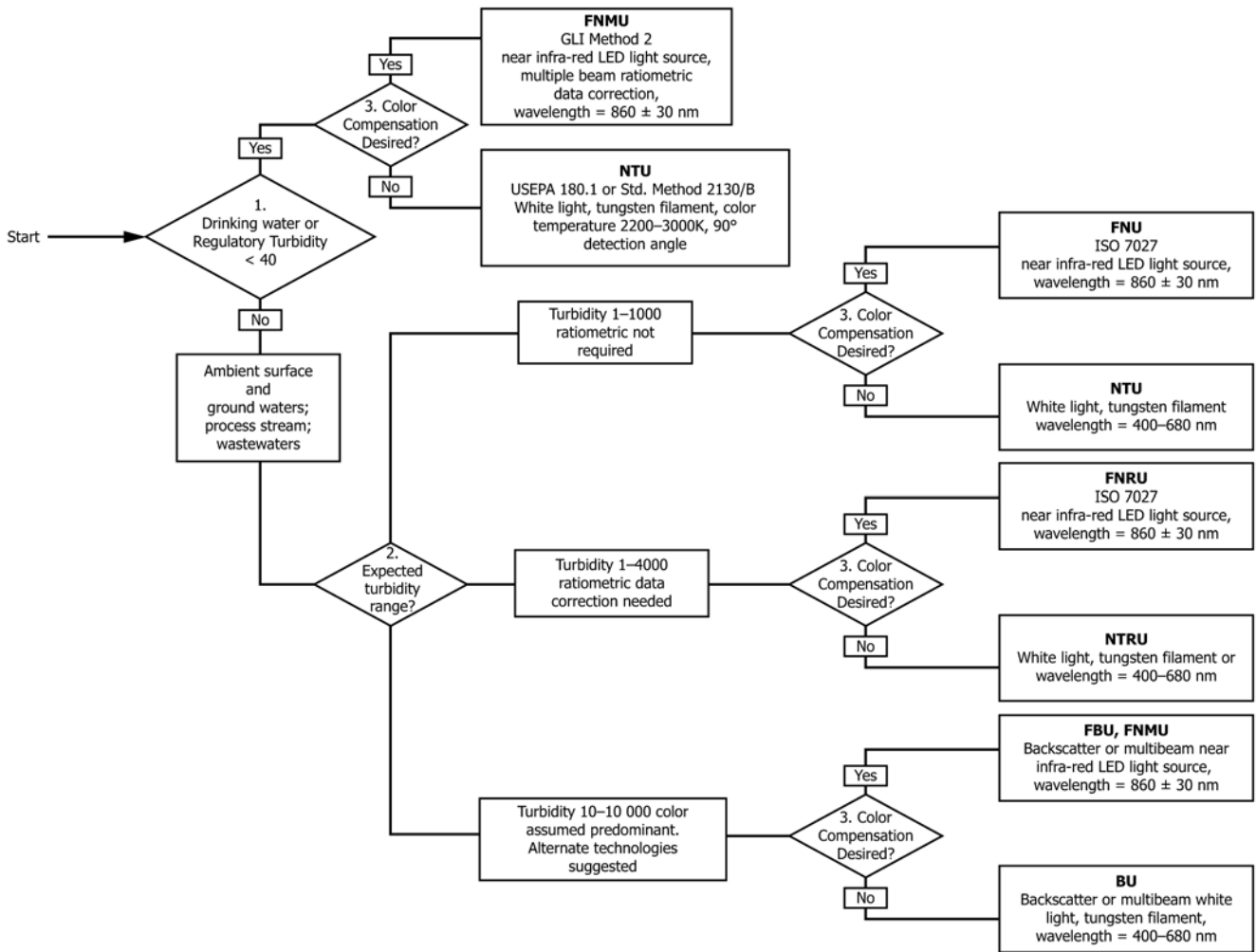


FIG. X3.1 Selection Criteria Flowchart for Turbidimeters

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