



Designation: D-1889—99^{ε1} 1889 – 00

Standard Test Method for Turbidity of Water¹

This standard is issued under the fixed designation D 1889; 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.

This standard has been approved for use by agencies of the Department of Defense.

^{ε1} ~~NOTE—An editorial correction was made in Section 7.2 in April 2000.~~

1. Scope

1.1 This test method covers the determination of turbidity in water and wastewater.

1.2 This test method is applicable to the measurement of turbidities in the range from ~~0.05~~ 1.0 to 40 nephelometric turbidity units (NTU).

1.3 Higher turbidities may be measured using this test method by serial dilution to applicable range.

1.4 This test method was tested on municipal drinking water and final effluent discharges. It is the user's responsibility to ensure the validity of this test method for waters of untested matrices.

1.5 *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. For a specific hazard statement, see Note 5. Refer to all material safety data sheets (MSDS) prior to preparing or using standards and before calibrating or performing instrument maintenance.*

2. Referenced Documents

2.1 *ASTM Standards:*

¹ This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.07 on Sediments, Geomorphology, and Open-Channel Flow.

Current edition approved ~~Dec. 10, 1999~~, 2000. Published ~~February~~ October 2000. Originally published as D 1889 – 61. Last previous edition D 1889 – 94^{ε1}.

- D 1129 Terminology Relating to Water²
- D 1192 Specification for Equipment for Sampling Water and Steam in Closed Conduits²
- D 1193 Specification for Reagent Water²
- D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water²
- D 3370 Practices for Sampling Water from Closed Conduits²

2.2 *EPA Standard:*

~~EPA 600/4-79-202 Methods for Chemical Analysis~~

EPA 180.1 Determination of Water and Wastes Turbidity by Nephelometry³

3. Terminology

3.1 *Definitions:* The terms turbidity, and nephelometric turbidity are defined in Terminology D 1129. For definitions of other terms used in this test method, refer to Terminology D 1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *turbidity*— 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. (Turbidity of water is caused by the presence of suspended and dissolved matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes.)

4. Summary of Test Method

4.1 *Nephelometric Turbidity:*

4.1.1 *Photoelectric Nephelometer*—The photoelectric nephelometer operation is based on instrumental comparison of the intensity of light scattered by the contained static water sample under defined conditions to the intensity of light scattered by a reference standard in the sample container. The higher the intensity of scattered light, the higher the turbidity of sample.

4.1.2 *Calibrated Slit Turbidimeter*—The calibrated slit turbidimeter operation is based on a visual comparison of the intensity of light scattered by the contained static water sample under defined conditions to the intensity of light scattered by a reference sample in the same container, the higher the intensity of scattered light the higher the turbidity of sample.

4.1.3 *Nephelometric Turbidity Standards:*

4.1.3.1 ~~AEPA-1 s~~Styrene-divinylbenzene (SDVB) polymer standard (see Section 12). These standards are used as received from the manufacturers or distributor.

4.1.3.2 Formazin polymer preparation and dilution methods are given in 8.2.2-8.2.4.

5. Significance and Use

5.1 Turbidity in water is caused by the presence of suspended and dissolved particles of gas, liquid or solids of organic or inorganic matter. 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 for when, how, and to what extent the water must be treated to meet specifications. Methodology for the correlation of a sample NTU to the number or volume of suspended particles is now under evaluation. Specific gravity estimates would then give rapid NTU correlation to the weight concentration of suspended matter.

5.2 This test method is suitable for 1.0 to low and medium 40.0 NTU turbidity such as that found in drinking water and process water.

6. Interferences

6.1 Floating or suspended large particles and entrained air bubbles will give false or unstable readings. Certain turbulent motions also create unstable reading conditions of nephelometers.

6.2 Dissolved material that imparts a color to the water may cause serious errors in nephelometric reading unless the instrument has special compensating features.

6.3 Scratches, finger marks, or dirt on the walls of the sample cell may give erroneous readings. Cells should be kept scrupulously clean both inside and outside and discarded when they become etched or scratched. The cells must not be handled where the light strikes them when indexed in the instrument well. ~~NOTE 1—The same indexed cell should be~~

6.4 Cuvette used must be indexed first for standardization followed by unknown-determination.

~~NOTE 2—Indexing of the sample cell or tube to the instrument well is accomplished by placing a mark on the top of the glass cell and a similar mark on the upper surface of the well so that the cell can (sample) determination. Indexing should be placed in the well in an exact position each time. done according to manufacturers' recommendations.~~

7. Apparatus

7.1 Two types of instruments are available for the nephelometric method, the photoelectric nephelometer and the calibrated slit

² Annual Book of ASTM Standards, Vol 11.01.

³ Available from Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, OH 45268.

turbidimeter (Fig. 1 and Fig. 2). Both give a greater precision and sensitivity than the Jackson candle turbidity, within their applicable range from 0.05 to 40.0 NTU, to ranges as low as 0.05 to 1.00 NTU.

7.2 The sensitivity of the instruments should permit detection of differences of 0.1 NTU or less in waters having turbidities between 1.0 and 10.0 NTU. The instruments should measure the ranges from 1.0 to 10.00 NTU and 1.0 to 40.0 NTU. Linear calibration charts should be made with the additional ranges from 0.05 to 0.10 and 0.05 to 10.0 NTU if possible. Either of the two accepted standards, SDVB or Formazin, (8.2.1 or 8.2.2) can be used for this calibration. See 11.1 for calibration instruments.

7.3 Photoelectric Nephelometer:

7.3.1 This instrument uses a light source for illuminating the sample and one or more photoelectric detectors with a readout device to indicate the intensity of light scattered at right angles (90°) to the path of the incident light. The photoelectric nephelometer should be so designed that little stray light reaches the detector(s) in the absence of turbidity and should be free from significant drift after a short warm-up period.

7.3.2 Differences in physical design of photoelectric nephelometers will cause differences in measured values for turbidity, as will aging of a turbidimeter, even though the same suspension is used for calibrations. To minimize initial differences, the following design criteria should be observed (see Fig. 1).

7.3.2.1 *Light Source*— Tungsten lamp operated at a color temperature between 2200 and 3000 K.

7.3.2.2 Distance traversed by incident light and scattered light within the sample, total not to exceed 10 cm.

7.3.2.3 *Angle of Light Acceptance to the Detector*—Centered at 90° to the incident light path and not to exceed ±30° from the 90° scatter path center line.

7.3.3 The sample tube used in calibration and sample measurement must be the following:

7.3.3.1 Clear, colorless glass, be kept scrupulously clean, both inside and out, and discarded when it becomes etched or scratched.

7.3.3.2 Index marked so that repeated exact placements into the instrument cuvette well for measurement can be made.

7.3.3.3 Handled where the light path does not pass during measurement. Provision should be made in design to give the tube a proper place in which to handle the tube during calibration or sample measurement procedure. Instrument and sample tube design criteria are given in EPA-600/4-79-202-180.1.

7.4 Calibrated Slit Turbidimeter:

7.4.1 This instrument uses principles based on the Tyndall effect. A beam of light passing up through the sample is compared to the light scattered upward by suspended particles in the turbid solution which has been illuminated from the side at 90°.

7.4.2 As shown in Fig. 2, light from the bulb, B, is reflected to illuminate the turbid solution in the cell, T, from the side. Light scattered upward by the suspended particles in the solution is seen through an eye piece as the outer portion of a circular split field (as in Fig. 3). Light also passes through a dial operated adjustable slit, S, and is reflected upward through the sample. In the eye piece this light is seen as the center circular field. Depending on the amount of light permitted through the adjustable slit, the center field will appear higher or darker than the outer portion, as shown in Fig. 3(a) and Fig. 3(c). The operator turns the dial controlling the slit until the entire field is of uniform brightness as shown in Fig. 3(b). Dial calibration charts should be based on at least five concentration levels, (across the 0.05 1.0 to 40 NTU range) of prepared ~~AEPA-1 SDVB~~ or in-house fresh preparations and dilutions of Formazin. 40 NTU has been selected by EPA as the maximum concentration or turbidity that is the upper limit of linearity for measuring instruments even though there are some instruments that are linear above 40 NTU.

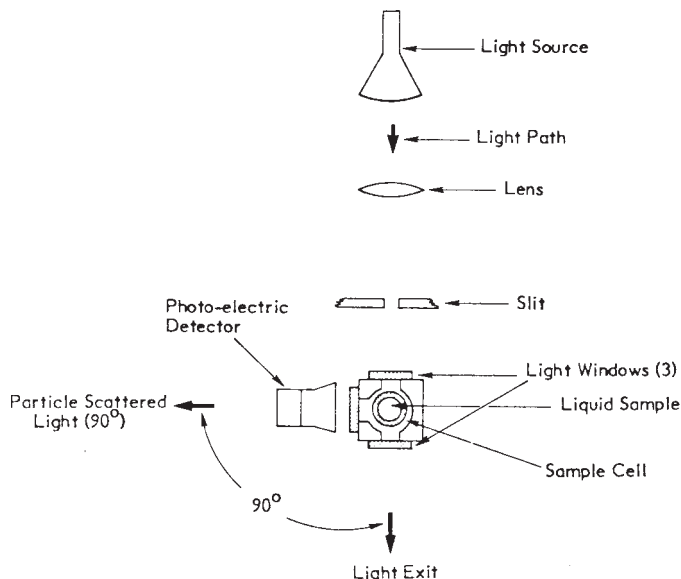
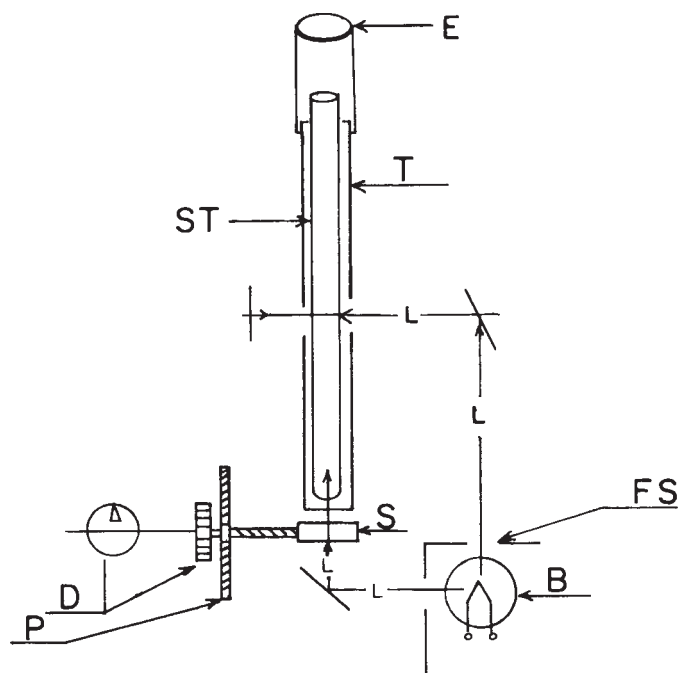


FIG. 1 Photoelectric Nephelometer



- B—bulb
- T—cell
- S—slit
- D—dial
- P—calibrated plate
- ST—sample cell
- E—eye piece
- FS—fixed slits
- L—light paths

FIG. 2 Calibrated Slit Turbidimeter

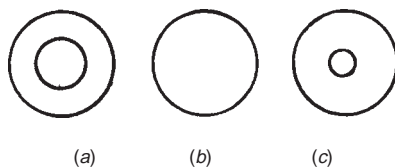


FIG. 3 Eye Piece Fields (Calibrated Slit)

NOTE 3—1—**Caution:** Care should be exercised if Formazin standardization is used as Formazin has a rapid settling rate, so sample should be remixed at least every 15 min.

7.4.2.1 From this prepared chart slit dial reading can be translated into NTU values. Prior to unknown water sample determination, a single standard point determination should be made to check cell cleanliness and other instrument optics, such as lamp operation.

7.4.2.2 Because the eye is used to detect the null-point, the observer can compensate and disregard the presence of sample color and extraneous debris.

8. Reagents

8.1 Dilution and final rinsing water, see 9.2.

8.2 *Turbidity Standards:*

8.2.1 SDVB turbidity standards are prepared sealed stable suspensions of styrene divinylbenzene which are opened and used as received from the manufacturer.

NOTE 4—2—Sealed or solid samples will not standardize nephelometers for the turbidity measurement of water or waste. These two methods (sealed or solid examples) neglect the zeroing out of sample tube (cuvette) prior to making water measurement in the tube.

8.2.2 *Formazin Turbidity Suspension, Stock*—A stock turbidity suspension for Formazin polymer is prepared by reacting hydrazine sulfate with hexamethylenetetramine under carefully controlled conditions. (See EPA-600/4-79-202-180.1.)

8.2.2.1 *Solution I*—Dissolve 1.00 g of hydrazine sulfate [(NH₂)₂H₂SO₄] in dilution water and dilute to mark in a 100-mL volumetric flask. **Note 5—Warning:** Formazin stock turbidity suspension contains residual hydrazine sulfate (NH₂)₂H₂SO₄, a known carcinogenic material. See Appendix X1.

8.2.2.2 *Solution II*— Dissolve 10.0 g of hexamethylenetetramine (practical grade, ACS grade not available) in dilution water and dilute to mark in a 100-mL volumetric flask.

8.2.2.3 Into a third 100-mL volumetric flask, pipet 5.00 mL of Solution I and with a clean pipet add 5.00 mL of Solution II. Mix the two solutions and allow to stand for 24 h at 25 ± 3°C. After reaction, dilute to mark with water and mix. The freshly mixed turbidity of this solution is 400 NTU. This 400 NTU stock has to be prepared monthly.

8.2.3 *Formazin Turbidity Suspension, Standard (40 NTU)*—Pipet 10.0 mL of mixed 400 NTU stock into a 100-mL volumetric flask and dilute with water to mark. The turbidity of this suspension is defined as 40 NTU. This 40 NTU suspension has to be prepared weekly.

8.2.4 *Dilute Formazin Turbidity Suspension Standard*—Prepare dilute turbidity suspension below 4.0 NTU daily. Those above 4.0 NTU have a useful life of one week. Prepare each dilution by pipetting the volume of 40 NTU into a 100-mL volumetric flask and diluting to mark with water; 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.

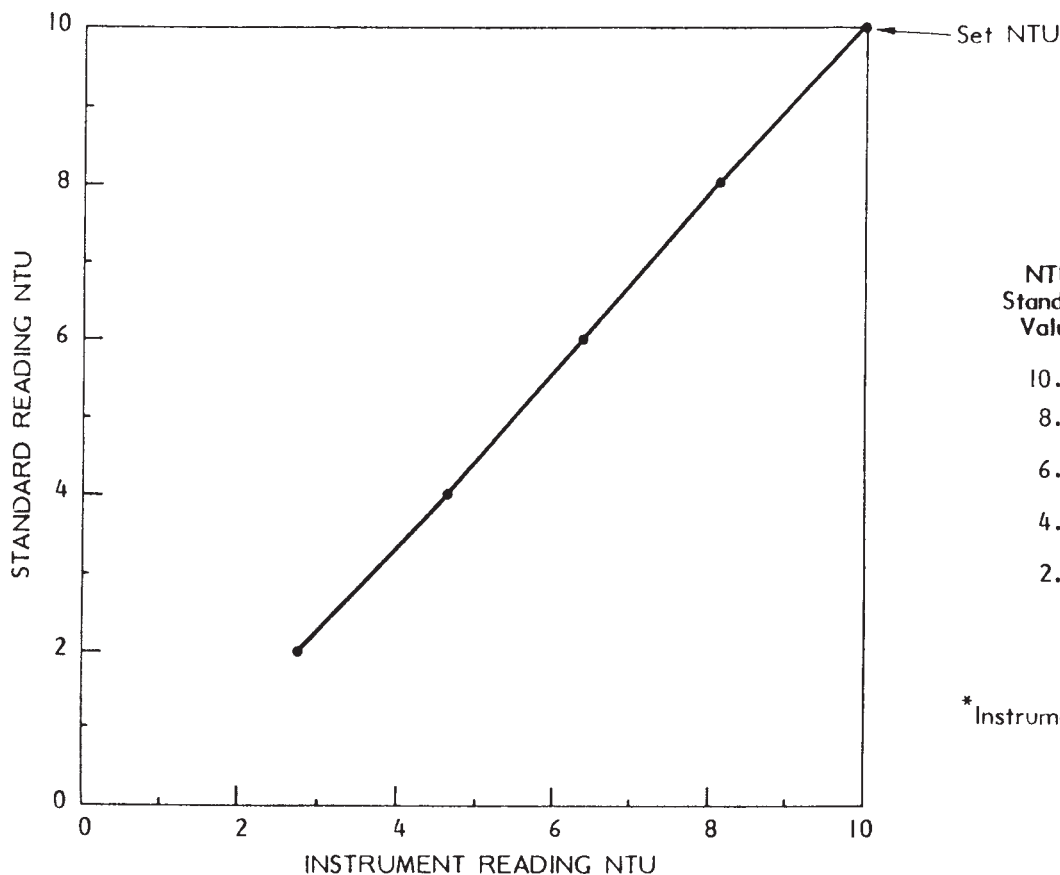
8.2.4.1 To prepare dilute suspensions having turbidities of less than 1.0 NTU use an appropriate volume of 4.0 NTU suspension in a 100-mL volumetric flask and dilute to mark. Prepare dilutions below 4.0 NTU daily.

NOTE 3—Standards below 1.0 NTU are difficult to prepare accurately. Refer to specific manufacturer instructions to determine if such a standard is needed.

9. Purity of Reagents

9.1 Reagent grade chemicals 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.⁴ 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.

⁴Parents 4,283,143



Table

NTU Standard Value	NTU Instrument Reading
10.0	10.0*
8.0	8.1
6.0	6.3
4.0	4.7
2.0	2.8

* Instrument adjusted to read this value

FIG. 4 Linear Calibration LC-10

9.2 Unless otherwise indicated references to water shall be understood to mean reagent water conforming to reagent water Type III Specification D 1193.

9.2.1 Standard dilution waters of Type III shall be prepared by filtration of Type III through a 0.2 to 0.22 μm membrane or other suitable filter within 1 h of use to reduce background turbidity to less than 0.05 NTU.

10. Sampling and Sample Preservation

10.1 *Collection of Sample*—Collect the sample in accordance with the applicable standard, Specification D 1192 and Practices D 3370 or EPA-600/4-79-202 180.1 for EPA compliance.

10.2 *Storage of Sample*—Determine the turbidity on the day the sample is taken. If this is not feasible, store the sample in the dark for up to 24 h and refrigerate at 4°C if possible, but do not freeze. Prolonged storage is not recommended because of irreversible changes.

10.3 *Preparation of Sample*—Bring the sample to room temperature and shake sample vigorously for at least 1 min. Let the sample stand 2 to 3 min to allow air bubbles to disappear, then gently invert the sample several times or swirl mix before examination.

11. Calibration

11.1 Follow the manufacturer's operating instructions. Calibrate the instrument range of interest with standards (see ~~EPA-I SDVB~~ and Formazin standards). If the instrument control dial, meter, or output digital reading is already in NTUs, this procedure and curve will check the accuracy of the instrument output. Use at least three standard concentrations (NTU) to calibrate each instrument range. Photoelectric nephelometers have a calibration adjustment. Set this adjustment to equal the high value of standard for the range of interest. Read the standards used for the calibration of the range in the same tube as was the high level adjustment. Note and graph the instrument value for each standard (instrument reading versus standard value). See Fig. 4 as an example. For daily use of the instrument, one standard in the use range will be all that is required to set the calibration adjustment at the graph reading for that value. The aging drift characteristics of each instrument will determine the recalibration requirement.

11.1.1 Clean the cell after filling with turbidity standard or test water samples as follows:

11.1.1.1 Rinse the clean dry cell twice with the suspension with which it is to be filled.

11.1.1.2 Fill the cell to a level to where the top air-liquid interface will not interfere with the subsequent reading. Check manufacturer recommendations as to cell filling.

11.1.1.3 After the cell is filled, tissue is then used to remove all traces of dirt or fingerprints. Tissue alone does not clean very dirty cells and one of the common nonabrasive glass cleaners may be necessary.

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

11.2 *Calibration Steps:*

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

11.2.2 Rinse a clean, dry, scratch-free index marked cell with the highest concentration of the standard for the instrument range setting or range of interest, and then fill. Always clean the exterior of the cell after filling in any of the following procedures.

11.2.3 Place the cell in the instrument in an oriented manner ready for reading of turbidity.

11.2.4 For photoelectric nephelometrics, set the calibration adjustment for the labeled value of ~~EPA-I SDVB~~ turbidity standard or the diluted value of Formazin standard. For slit type nephelometers plot the adjusted dial reading at null or uniform field brightness versus NTU value of turbidity standard.

11.2.5 Remove the sample cell and discard the first turbidity standard. Rinse and fill the cell with a second value different concentration of turbidity standard and place the cell in the instrument in an oriented manner. Without moving the photo-electric calibration adjustment, make a reading. Plot this instrument NTU reading against the NTU value of the turbidity standard. For the slit type nephelometer again plot the adjusted dial reading at null versus NTU value of the turbidity standard.

11.2.6 Repeat for at least one more turbidity standard NTU value which should cover the turbidity range of interest. The greater the number of turbidity standard values used, the greater the reliability of the calibration.

11.2.7 Make the plot of instrument reading or dial setting versus turbidity standard NTU value to where any instrument reading or dial setting within the range calibrated is corrected to values relative to the turbidity standard values. The plot of instrument reading or dial setting versus turbidity standard value is a range calibration curve. Calibration curves for each usable range should be made. See Fig. 4 for an example of a linear calibration curve.

12. Procedure

12.1 Standardize the instrument with one value (NTU) of turbidity standard in the measurement range of interest.

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

12.1.2 Rinse a clean, dry, scratch-free index marked (a felt pen dot) cell with a turbidity standard (~~EPA-I SDVB~~ or Formazin) with a value (NTU) in the range of interest. Fill the cell with this turbidity standard. Clean the cell's exterior.

⁴ "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and 4,291,980, available from, Advanced Polymer Systems, Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., 3696 Haven Ave., Redwood City, CA 94063, have been found satisfactory for this purpose. New York, NY, and the "United States Pharmacopeia."

TABLE 1 Final Statistics^A

True concentration, C	0.92	4.50	18.66
Mean response, \bar{X}	0.972	4.410	18.57
Bias, $\bar{X} - C$	0.052	-0.090	-0.09
Total standard deviation, S_T	0.091	0.361	0.292
Single-operator standard deviation, S_o	0.044	0.174	0.181

^A Represent three concentrations of NTU.

TABLE 2 Bias Results

True concentration, C	0.92	4.50	18.66
Mean response, \bar{X}	0.972	4.410	18.57
Bias = $\bar{X} - C$	0.052	-0.090	-0.09
Total standard deviation, S_T	0.091	0.361	0.292
Number of lab/operators contributing usable data, n	8	8	8
Student's t -value, $t = bias / S_T / \sqrt{n}$	1.62	0.71	0.87
Critical t -value from Table X3.8 of Practice D 2777	2.365	2.365	2.365
Is bias significant, is $t >$ critical t ?	no	no	no

12.1.3 Place the filled clean cell in an indexed manner in the instrument and read the value. It will be an NTU reading for photoelectric types and a dial reading for slit types nephelometers.

12.1.4 From the calibration curve for this instrument's range, determine the required reading for the turbidity standard in cell.

12.1.4.1 Move calibration adjustment to give the photoelectric nephelometer the required NTU reading.

12.1.4.2 The slit dial reading determined from the calibration curve for the turbidity standard in the cell should be within 5 % of the dial reading. If not, reclean the cell and recalibrate.

12.2 Measurement of Water Turbidity:

12.2.1 Turbidity Less Than 40 NTU—Shake the sample to thoroughly disperse the solids. Allow air bubbles to disappear, then proceed.

12.2.2 Turbidity Exceeding 40 NTU—Dilute the sample with one or more equal volumes of reagent water until turbidity is below 40 NTU after mixing and degassing. Then treat this less than 40 NTU turbidity in accordance with 12.2.1. The turbidity of the original sample can then be computed based on dilution data and original sample volume (variations of particle size can affect dilution).

12.2.3 After calibration check or adjustment, empty the cell (do not change cells for measurement) of turbidity standard and rinse the empty cell with the water sample to be tested.

12.2.3.1 The measured NTU value of the water sample is determined using the instrument value and the appropriate calibration curve.

13. Report

13.1 Report results as follows:

NTU	Report to Nearest (NTU)
0.05–1.00	—0.05
1.00–10.0	0.1
10.0–40	1.0
40–100	5.0
100–400	10
400–1000	50
>1000	100

14. Precision and Bias

14.1 Round-robin⁵

14.1 Under the allowances made in 1.5 of Practice D 2777–86, these precision and bias data do not meet existing requirements for interlaboratory studies of Committee D19 test methods.

14.2 Round-robin data for this test method were obtained by the use of A-EPA-I SDVB standards. EMSL (Environmental Monitoring and Support Laboratory, EPA, Cincinnati, Ohio) examined this data for its statistical significance. For other matrices, these data may not apply.

⁵—“Reagent Chemicals, American Chemical Society Specifications,” Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see “Reagent Chemicals and Standards,” by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the “United States Pharmacopeia.”

⁶ Supporting data are available from ASTM Headquarters. Request RR: D19-1129.

14.23 Formazine was not used in the round-robin test because of its short term stability. Formazine can be used as a fresh short-term calibration mixture but the results might not be applicable to this collaborative test study.

14.3 Polymer suspensions of styrene-divinylbenzene

14.4 SDVB are stable and can be accurately quantitated by gravimetric procedures. Linear calibration of each instrument was performed prior to collaborative study, involving ten laboratories and three nephelometric turbidity unit (NTU) levels.

14.45 Table 1 shows the required statistical treatment of the turbidity round-robin test for nine laboratories and three concentrations of NTUs and one laboratory's results were statistically rejected.

14.56 Table 2 shows that the bias of all NTU levels is insignificant for the round-robin test.

15. Keywords

15.1 calibration; measurement; nephelometric turbidity; turbidity standards

APPENDIX

(Nonmandatory Information)

X1. RESIDUALS OF HYDRAZINE SULFATE FOUND IN FORMAZIN

X1.1 The following information was collected from various state health agencies:

X1.1.1 The maximum amount of $(\text{NH}_2)_2\text{H}_2\text{SO}_4$ that can be ingested, inhaled, or injected per day by a human without deleterious effects is $0.2\ \mu\text{g}$ — $0.2 \times 10^{-6}\ \text{g}$ at a concentration of 4000 NTU.

X1.1.2 Formazin contains 318.7 ppm of $(\text{NH}_2)_2\text{H}_2\text{SO}_4$ or $318.7 \times 10^{-6}\ \text{g}$ at a concentration of 4000 NTU.⁶ This is 1593.5 times the maximum daily allowable amount of $(\text{NH}_2)_2\text{H}_2\text{SO}_4$ if all the formazin was ingested.

X1.1.3 For each gram of $(\text{NH}_2)_2\text{H}_2\text{SO}_4$ used to formulate 10 mL of 4000 NTU formazin, $318.7 \times 10^{-6}\ \text{g}$ is residual in the concentrated solution.

X1.2 Refer to the following sources for the information contained in X1.1:

X1.2.1 Hydrazine Sulfate TRS#14881, Department of Health Services, California Occupational Health Program (COHP), 2151 Berkeley Way, Room 504, Berkeley, CA 94704.

X1.2.2 Hazardous Substance Fact Sheet—Hydrazine Sulfate, New Jersey Department of Health, CAS Number 10034-93-2, TRK Substance Number 2360.

X1.2.3 Occupational Safety and Health Guideline for Hydrazine—Potential Human Carcinogen, U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Standards Development and Technology Transfer.

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