



Designation: D 3559 – 03

Standard Test Methods for Lead in Water¹

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

1. Scope*

1.1 These test methods cover the determination of dissolved and total recoverable lead in water and waste water by atomic-absorption spectrophotometry² and differential pulse anodic stripping voltammetry. Four test methods are included as follows:

| | Concentration Range | Sections |
|---|-----------------------------|----------|
| Test Method A—Atomic Absorption, Direct | 1.0 to 10 mg/L | 7 to 15 |
| Test Method B—Atomic Absorption, Chelation-Extraction | 100 to 1000 $\mu\text{g/L}$ | 16 to 24 |
| Test Method C—Differential Pulse Anodic Stripping Voltammetry | 1 to 100 $\mu\text{g/L}$ | 25 to 35 |
| Test Method D—Atomic Absorption, Graphite Furnace | 5 to 100 $\mu\text{g/L}$ | 36 to 44 |

1.2 Test Method B can be used to determine lead in brines. Test Method D has been used successfully with reagent water, lake water, well water, filtered tap water, condensate from a medium Btu coal gasification process, waste treatment plant effluent, and a production plant process water.

1.3 It is the user's responsibility to ensure the validity of these test methods for waters of untested matrices.

1.4 *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 specific hazards statements, see 10.4.1, Note 2, 11.2, 11.3, 21.7, 21.8, 21.11, 23.7, 23.10, 32.2.1, and 33.1.

2. Referenced Documents

2.1 ASTM Standards:

D 858 Test Methods for Manganese in Water³

¹ These test methods are under the jurisdiction of ASTM Committee D19 on Water and are the direct responsibility of Subcommittee D19.05 on Inorganic Constituents in Water.

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² Platte, J. A., and Marcy, V. M., "A New Tool for the Water Chemist," *Industrial Water Engineering*, May 1965.

Brown, E., Skougstad, M. W., and Fishman, M. J., "Methods for Collection and Analysis of Water Samples for Dissolved Minerals and Gases," *Techniques of Water-Resources Investigations of the U. S. Geological Survey*, Book 5, Chapter , 1970, p. 115.

³ *Annual Book of ASTM Standards*, Vol 11.01.

- D 1066 Practice for Sampling Steam³
D 1068 Test Methods for Iron in Water³
D 1129 Terminology Relating to Water³
D 1192 Specification for Equipment for Sampling Water and Steam in Closed Conduits³
D 1193 Specification for Reagent Water³
D 1687 Test Methods for Chromium in Water³
D 1688 Test Methods for Copper in Water³
D 1691 Test Methods for Zinc in Water³
D 1886 Test Methods for Nickel in Water³
D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water³
D 3370 Practices for Sampling Water from Closed Conduits³
D 3557 Test Methods for Cadmium in Water³
D 3558 Test Methods for Cobalt in Water³
D 3919 Practice for Measuring Trace Elements in Water by Graphite Furnace Atomic Absorption Spectrophotometry³
D 4841 Practice for Estimation of Holding Time for Water Samples Containing Organic and Inorganic Constituents³
D 5810 Guide for Spiking into Aqueous Samples³
D 5847 Practice for the Writing Quality Control Specifications for Standard Test Methods for Water Analysis³
E 60 Practice for Photometric and Spectrophotometric Methods for Chemical Analysis of Metals⁴
E 275 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers⁵

3. Terminology

3.1 *Definitions*—For definition of terms used in these test methods, refer to Terminology D 1129.

3.2 *total recoverable lead*—an arbitrary analytical term relating to the recoverable forms of lead that are determined by the digestion method which are included in the procedure.

4. Significance and Use

4.1 The test for lead is necessary because it is a toxicant and because there is a limit specified for lead in potable water in the National Interim Primary Drinking Water Regulations. This

⁴ *Annual Book of ASTM Standards*, Vol 03.05.

⁵ *Annual Book of ASTM Standards*, Vol 03.06.

*A Summary of Changes section appears at the end of this standard.

test serves to determine whether the lead content of potable water is above or below the acceptable limit.

5. Purity of Reagents

5.1 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.⁶ Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

5.2 Unless otherwise indicated, references to water shall be understood to mean reagent water conforming to Specification **D 1193**, Type I. Other reagent water types may be used provided it is first ascertained that the water is of sufficiently high purity to permit its use without adversely affecting the bias and precision of the test method. Type II water was specified at the time of round-robin testing of this test method.

6. Sampling

6.1 Collect the samples in accordance with Practice **D 1066**, Specification **D 1192**, and Practices **D 3370**, as applicable.

6.2 Samples shall be preserved with HNO_3 (sp gr 1.42) to a pH of 2 or less immediately at the time of collection, normally about 2 mL/L of HNO_3 . If only dissolved lead is to be determined, the sample shall be filtered through a 0.45- μm membrane filter before acidification.

TEST METHOD A—ATOMIC ABSORPTION, DIRECT

7. Scope

7.1 This test method covers the determination of dissolved and total recoverable lead in most waters and wastewaters.

7.2 The test method is applicable in the range from 1.0 to 10 mg/L of lead. The upper limits of detectability can be increased to concentrations greater than 10 mg/L by dilution of the sample.

8. Summary of Test Method

8.1 Lead is determined by atomic absorption spectrophotometry. Dissolved lead is determined by aspirating the filtered and preserved sample directly with no pretreatment. Total recoverable lead is determined by aspirating the sample following hydrochloric-nitric acid digestion and filtration. The same digestion procedure may be used to determine total recoverable cadmium (Test Methods **D 3557**), chromium (Test Methods **D 1687**), cobalt (Test Methods **D 3558**), copper (Test Methods **D 1688**), iron (Test Methods **D 1068**), manganese (Test Methods **D 858**), nickel (Test Methods **D 1886**), and zinc (Test Methods **D 1691**).

⁶ *Reagent Chemicals, American Chemical Society Specifications*, 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. Pharmaceutical Convention, Inc. (USPC), Rockville, MD.

9. Interferences

9.1 Other metals usually do not interfere in the determination of lead by increasing or decreasing the amount of absorbed radiation. The most common interference is caused by a chemical reaction in the flame that prevents conversion of the lead to the atomic state.

9.2 High concentrations of calcium, such as those connected with the coal industry, will give lead concentrations higher than which actually exist. This can be corrected by using a background correction technique, or by the chelation-extraction procedure (Test Method B).

9.2.1 The equipment manufacturer's instructions for use of specific correction technique shall be followed.

10. Apparatus

10.1 *Atomic Absorption Spectrophotometer*, for use at 283.3 nm.

NOTE 1—The manufacturer's instructions shall be followed for all instrumental parameters. Wavelengths other than 283.3 nm may be used if they have been determined to be equally suitable.

10.2 *Lead Light Source*, hollow-cathode lamps or electrodeless-discharge lamps have been found satisfactory.

10.3 *Oxidant*:

10.3.1 *Air*, which has been passed through a suitable filter to remove oil, water, and other foreign substances, is the usual oxidant.

10.4 *Fuel*:

10.4.1 *Acetylene*—Standard, commercially available acetylene is the usual fuel. Acetone, always present in acetylene cylinders, can affect analytical results. The cylinder should be replaced at 50 psig (345 kPa).

10.4.1.1 **Warning**—"Purified" grade acetylene containing a special proprietary solvent rather than acetone should not be used with poly(vinyl chloride) tubing as weakening of the walls can cause a potential hazardous situation.

10.5 *Pressure-Reducing Valves*—The supplies of fuel and oxidant shall be maintained at pressures somewhat higher than the controlled operating pressure of the instrument by suitable valves.

11. Reagents

11.1 *Hydrochloric Acid (sp gr 1.19)*—Concentrated hydrochloric acid (HCl).

NOTE 2—If the reagent blank concentration is greater than the method detection limit, distill the HCl or use a spectrograde acid. **Caution**—When HCl is distilled, an azeotropic mixture is formed (approximately 6 N HCl is formed). Therefore, whenever concentrated HCl is used in the preparation of a reagent or in the procedure, use double the volume specified if distilled HCl is used.

11.2 *Lead Solution, Stock (1 mL = 1 mg lead)*—Dissolve 1.5999 g of lead nitrate ($\text{Pb}(\text{NO}_3)_2$) in a mixture of 10 mL of HNO_3 (sp gr 1.42) and 100 mL of water. Dilute to 1 L with water. **Warning**—Lead salts are toxic. Handle with care and avoid personal contamination.

11.3 *Lead Solution, Standard (1 mL = 0.1 mg lead)*—Dilute 100.0 mL of stock lead solution to 1 L with HNO_3 (1 + 499). Store all solutions in polyethylene bottles. **Warning**—Lead

salts are toxic. Never pipet by mouth. Pipet with the end of a suction device or employ other conventional means of quantitative measurement.

11.4 *Nitric Acid (sp gr 1.42)*—Concentrated nitric acid (HNO₃).

NOTE 3—If the reagent blank concentration is greater than the method detection limit, distill the HNO₃ or use a trace metal grade acid.

11.5 *Nitric Acid (1 + 499)*—Add 1 volume of HNO₃(sp gr 1.42) to 499 volumes of water.

12. Standardization

12.1 Prepare 100 mL each of a blank and at least four standard solutions to bracket the expected lead concentration range to be analyzed by diluting the lead standard solution (11.3) with HNO₃(1 + 499). Prepare the standards each time the test is to be performed.

12.2 When determining total recoverable lead, add 0.5 mL of HNO₃(sp gr 1.42) to each blank and standard solution and proceed as directed in 13.2 through 13.4. After the digestion of the blank and standard solutions has been completed in 13.4, return to 12.3 to complete the standardization for total recoverable determinations. When determining dissolved lead, proceed with 12.3.

12.3 Aspirate the blank and standards and record the instrument readings. Aspirate HNO₃(1 + 499) between standards.

12.4 Prepare an analytical curve by plotting the absorbance versus the concentration for each standard on linear graph paper. Alternatively, read directly in concentration if this capability is provided with an instrument.

13. Procedure

13.1 Measure 100.0 mL of a well-mixed acidified sample into a 125-mL beaker or flask.

NOTE 4—If only dissolved lead is to be determined, start with 13.5.

13.2 Add 5 mL of HCl (sp gr 1.19) to each sample.

13.3 Heat the samples on a steam bath or hot plate in a well-ventilated hood until the volume has been reduced to 15 to 20 mL, making certain that the samples do not boil.

NOTE 5—For samples having appreciable amounts of suspended matter or dissolved matter, the amount of reduction in volume is left to the discretion of the analyst.

13.4 Cool and filter the samples through a suitable filter such as fine-textured, acid washed, ashless paper, into 100-mL volumetric flasks. Wash the filter paper two or three times with water and adjust to volume.

13.5 Aspirate each filtered and acidified sample and determine its absorbance or concentration at 283.3 nm. Aspirate HNO₃(1 + 499) between samples.

14. Calculation

14.1 Calculate the concentration of lead in each sample, in milligrams per litre, using the calibration curve established in 12.4.

TABLE 1 Determination of Bias, Direct

| Amount Added, mg/L | Amount Found, mg/L | S _r , mg/L | S _o , mg/L | Bias, % | Statistically Significant (95 % Confidence Level) |
|-------------------------|--------------------|-----------------------|-----------------------|---------|---|
| Reagent Water, Type II | | | | | |
| 1 | 1.01 | 0.08 | 0.04 | +1.00 | no |
| 6 | 6.01 | 0.28 | 0.14 | +0.17 | no |
| 8 | 8.02 | 0.34 | 0.14 | +0.25 | no |
| Selected Water Matrices | | | | | |
| 1 | 1.00 | 0.00 | 0.06 | 0.00 | no |
| 6 | 6.11 | 0.25 | 0.16 | +1.83 | yes |
| 8 | 7.99 | 0.36 | 0.23 | -0.13 | no |

15. Precision and Bias ⁷

15.1 Fourteen operators from nine laboratories participated in this study. One operator performed the analysis in quadruplicate, twelve in triplicate and one in duplicate at each concentration level.

15.2 The bias of this test method for lead is listed in Table 1.

15.3 These data may not apply to waters of other matrices.

15.4 This section on precision and bias conforms to Practice D 2777 – 77 which was in place at the time of collaborative testing. Under the allowances made in 1.4 of D 2777 – 98, these precision and bias data do meet existing requirements of interlaboratory studies of Committee D19 test methods.

16. Quality Control

16.1 In order to be certain that analytical values obtained using these test methods are valid and accurate within the confidence limits of the test, the following QC procedures must be followed when analyzing lead.

16.2 *Calibration and Calibration Verification:*

16.2.1 Analyze at least three working standards containing concentrations of lead that bracket the expected sample concentration, prior to analysis of samples, to calibrate the instrument. The calibration correlation coefficient shall be equal to or greater than 0.990. In addition to the initial calibration blank, a calibration blank shall be analyzed at the end of the batch run to ensure contamination was not a problem during the batch analysis.

16.2.2 Verify instrument calibration after standardization by analyzing a standard at the concentration of one of the calibration standards. The concentration of a mid-range standard should fall within ±15 % of the known concentration.

16.2.3 If calibration cannot be verified, recalibrate the instrument.

16.3 *Initial Demonstration of Laboratory Capability:*

16.3.1 If a laboratory has not performed the test before, or if there has been a major change in the measurement system, for example, new analyst, new instrument, etc., a precision and bias study must be performed to demonstrate laboratory capability.

⁷ Supporting data are available from ASTM Headquarters. Request RR:D 19-1030.

16.3.2 Analyze seven replicates of a standard solution prepared from an Independent Reference Material containing a mid-range concentration of lead. The matrix and chemistry of the solution should be equivalent to the solution used in the collaborative study. Each replicate must be taken through the complete analytical test method including any sample preservation and pretreatment steps. The replicates may be interspersed with samples.

16.3.3 Calculate the mean and standard deviation of the seven values and compare to the acceptable ranges of bias in **Table 1**. This study should be repeated until the recoveries are within the limits given in **Table 1**. If a concentration other than the recommended concentration is used, refer to Practice **D 5847** for information on applying the *F* test and *t* test in evaluating the acceptability of the mean and standard deviation.

16.4 Laboratory Control Sample (LCS):

16.4.1 To ensure that the test method is in control, analyze a LCS containing a known concentration of lead with each batch or 10 samples. If large numbers of samples are analyzed in the batch, analyze the LCS after every 10 samples. The laboratory control samples for a large batch should cover the analytical range when possible. The LCS must be taken through all of the steps of the analytical method including sample preservation and pretreatment. The result obtained for a mid-range LCS shall fall within $\pm 15\%$ of the known concentration.

16.4.2 If the result is not within these limits, analysis of samples is halted until the problem is corrected, and either all the samples in the batch must be reanalyzed, or the results must be qualified with an indication that they do not fall within the performance criteria of the test method.

16.5 Method Blank:

16.5.1 Analyze a reagent water test blank with each batch. The concentration of lead found in the blank should be less than 0.5 times the lowest calibration standard. If the concentration of lead is found above this level, analysis of samples is halted until the contamination is eliminated, and a blank shows no contamination at or above this level, or the results must be qualified with an indication that they do not fall within the performance criteria of the test method.

16.6 Matrix Spike (MS):

16.6.1 To check for interferences in the specific matrix being tested, perform a MS on at least one sample from each batch by spiking an aliquot of the sample with a known concentration of lead and taking it through the analytical method.

16.6.2 The spike concentration plus the background concentration of lead must not exceed the high calibration standard. The spike must produce a concentration in the spiked sample that is 2 to 5 times the analyte concentration in the unspiked sample, or 10 to 50 times the detection limit of the test method, whichever is greater.

16.6.3 Calculate the percent recovery of the spike (*P*) using the following formula:

$$P = 100 [A(V_s + V) - B V_s] / C V \quad (1)$$

where:

- A* = analyte concentration (mg/L) in spiked sample,
- B* = analyte concentration (mg/L) in unspiked sample,
- C* = concentration (mg/L) of analyte in spiking solution,
- V_s* = volume (mL) of sample used, and
- V* = volume (mL) added with spike.

16.6.4 The percent recovery of the spike shall fall within the limits, based on the analyte concentration, listed in Guide **D 5810**, Table 1. If the percent recovery is not within these limits, a matrix interference may be present in the sample selected for spiking. Under these circumstances, one of the following remedies must be employed: the matrix interference must be removed, all samples in the batch must be analyzed by a test method not affected by the matrix interference, or the results must be qualified with an indication that they do not fall within the performance criteria of the test method.

NOTE 6—Acceptable spike recoveries are dependent on the concentration of the component of interest. See Guide **D 5810** for additional information.

16.7 Duplicate:

16.7.1 To check the precision of sample analyses, analyze a sample in duplicate with each batch. If the concentration of the analyte is less than five times the detection limit for the analyte, a matrix spike duplicate (MSD) should be used.

16.7.2 Calculate the standard deviation of the duplicate values and compare to the precision in the collaborative study using an *F* test. Refer to 6.4.4 of Practice **D 5847** for information on applying the *F* test.

16.7.3 If the result exceeds the precision limit, the batch must be reanalyzed or the results must be qualified with an indication that they do not fall within the performance criteria of the test method.

16.8 Independent Reference Material (IRM):

16.8.1 In order to verify the quantitative value produced by the test method, analyze an Independent Reference Material (IRM) submitted as a regular sample (if practical) to the laboratory at least once per quarter. The concentration of the IRM should be in the concentration mid-range for the method chosen. The value obtained must fall within the control limits established by the laboratory.

TEST METHOD B—ATOMIC ABSORPTION, CHELATION-EXTRACTION

17. Scope

17.1 This test method covers the determination of dissolved and total recoverable lead in most waters and brines.

17.2 This test method is applicable in the range from 100 to 1000 μ g/L of lead. The range may be extended upward by dilution of the samples.

18. Summary of Test Method

18.1 Lead is determined by atomic absorption spectrophotometry. The element, either dissolved or total recoverable, is chelated with pyrrolidine dithiocarbamic acid and extracted with chloroform. The extract is evaporated to dryness, treated with hot HCl and diluted to a specified volume with water. The resulting solution is then aspirated into the air-acetylene flame of the spectrophotometer. The digestion procedure summarized

in 8.1 is used for total recoverable lead. The same chelation-extraction procedure may be used to determine total recoverable cadmium (Test Methods [D 3557](#)), cobalt (Test Methods [D 3558](#)), copper (Test Methods [D 1688](#)), iron (Test Methods [D 1068](#)), nickel (Test Methods [D 1886](#)), and zinc (Test Methods [D 1691](#)).

19. Interferences

19.1 See Section [9](#).

20. Apparatus

20.1 All apparatus described in Section [10](#) are required.

21. Reagents

21.1 *Bromphenol Blue Indicator Solution (1 g/L)*—Dissolve 0.1 g of bromphenol blue in 100 mL of 50 % ethanol or 2-propanol.

21.2 *Carbon Disulfide (CS₂)*.

21.3 *Chloroform (CHCl₃)*.

21.4 *Hydrochloric Acid (sp gr 1.19)*—Concentrated hydrochloric acid (HCl).

21.5 *Hydrochloric Acid (1 + 2)*—Add 1 volume of HCl (sp gr 1.19) to 2 volumes of water.

21.6 *Hydrochloric Acid (1 + 49)*—Add 1 volume of HCl (sp gr 1.19) to 49 volumes of water.

21.7 *Lead Solution, Stock (1.0 mL = 200 µg lead)*—Dissolve 0.3198 g of lead nitrate (Pb (NO₃)₂) in water containing 1 mL of HNO₃(sp gr 1.42) and dilute to 1 L with water. **Warning**—Lead salts are toxic. Handle with care and avoid personal contamination.

21.8 *Lead Solution, Intermediate (1.0 mL = 2.0 µg lead)*—Dilute 10 mL of lead stock solution and 1 mL of HNO₃(sp gr 1.42) to 1 L with water. **Warning**—Lead salts are toxic. Never pipet by mouth. Pipet with the end of a suction device or employ other convenient means of quantitative measurement.

21.9 *Lead Solution, Standard (1.0 mL = 0.2 µg lead)*—Immediately before use, dilute 10.0 mL of lead intermediate solution and 1 mL of HNO₃(sp gr 1.42) to 100 mL with water. This standard is used to prepare working standards at the time of analysis.

21.10 *Nitric Acid (sp gr 1.42)*—Concentrated nitric acid (HNO₃).

21.11 *Pyrrolidine Dithiocarbamic Acid-Chloroform Reagent*—Add 36 mL of pyrrolidine to 1 L of CHCl₃. Cool the solution and add 30 mL of CS₂ in small portions, swirling between additions. Dilute to 2 L with CHCl₃. The reagent can be used for several months if stored in a cool, dark place. **Warning:** All components of this reagent are highly toxic. Carbon disulfide is also highly flammable, prepare and use in a well-ventilated hood. Avoid inhalation and direct contact.

21.12 *Sodium Hydroxide Solution (100 g/L)*—Dissolve 100 g of sodium hydroxide (NaOH) in water and dilute to 1 L.

22. Standardization

22.1 Prepare a blank and sufficient standards from 0.0 to 1000 µg/L lead from the lead standard solution ([21.9](#)) by making appropriate dilutions in water. Prepare standards immediately prior to use.

22.2 When determining total recoverable lead use 125-mL beakers or flasks, add 0.5 mL HNO₃(sp gr 1.42) and proceed as directed in [23.2](#) thru [23.15](#). When determining dissolved lead use 250-mL separatory funnels and proceed as directed in [23.5](#) thru [23.15](#).

22.3 Construct an analytical curve by plotting the absorbances of standards versus micrograms of lead. Alternatively, read directly in concentration if this capability is provided with the instrument.

23. Procedure

23.1 Measure a volume of a well-mixed acidified sample containing less than 100 µg lead (100-mL maximum) into a 125-mL beaker or flask and adjust the volume to 100 mL with water.

NOTE 7—If only dissolved lead is to be determined, measure a volume of filtered and acidified sample containing less than 100 µg of lead (100-mL maximum) into a 250-mL separatory funnel, and start with [23.5](#).

23.2 Add 5 mL of HCl (sp gr 1.19) to each sample.

23.3 Heat the samples on a steam bath or hot plate in a well-ventilated hood until the volume has been reduced to 15 to 20 mL, making certain that the samples do not boil.

NOTE 8—When analyzing brines and samples containing appreciable amounts of suspended matter, the amount of reduction in volume is left to the discretion of the analyst.

23.4 Cool and filter the samples through a suitable filter such as fine-textured, acid-washed, ashless paper, into 250-mL separatory funnels. Wash the filter paper two or three times with water and bring to approximately a 100-mL volume.

23.5 Add 2 drops of bromphenol blue indicator solution and mix.

23.6 Adjust the pH by addition of NaOH (100 g/L) solution until a blue color persists. Add HCl (1 + 49) by drops until the blue color just disappears; then add 2.5 mL of HCl (1 + 49) in excess. The pH at this point should be 2.3.

NOTE 9—The pH adjustment in [23.6](#) may be made with a pH meter instead of using an indicator.

23.7 Add 10 mL of pyrrolidine dithiocarbamic acid-chloroform reagent and shake vigorously for 20 min (**Warning**—See [21.11](#)).

23.8 Plug the tip of the separatory funnel with cotton, allow the phases to separate, and drain the chloroform phase into a 100-mL beaker.

23.9 Repeat the extraction with 10 mL of chloroform and drain the chloroform layer into the same beaker.

NOTE 10—If color still remains in the CHCl₃ extract, reextract the aqueous phase until the chloroform layer is colorless.

23.10 Place the beaker on a hot plate at low heat and evaporate just to near dryness. Remove beaker from heat and allow residual solvent to evaporate without further heating.

Warning—Perform in a well-ventilated hood.

23.11 Hold the beaker at a 45° angle and slowly add dropwise 2 mL of HNO₃(sp gr 1.42), rotating the beaker to effect thorough contact of the acid with the residue.

23.11.1 If acid is added to the beaker in a vertical position, a violent reaction will occur accompanied by high heat and spattering.

23.12 Place the beaker on a hot plate at low heat and evaporate just to dryness.

23.13 Add 2 mL of HCl (1 + 2) to the beaker and heat while swirling for 1 min.

NOTE 11—If a precipitate appears when the HCl (1 + 2) is added to the dried residue, obtain a fresh supply of pyrrolidine which has a different lot number or redistill the pyrrolidine just before preparing the pyrrolidine dithiocarbamic acid-chloroform reagent.

23.14 Cool and quantitatively transfer the solution to a 10-mL volumetric flask and bring to volume with water.

23.15 Aspirate each sample and record the scale reading or concentration.

24. Calculation

24.1 Determine the weight of lead in each sample by referring to 22.3. Calculate the concentration of lead in micrograms per litre as follows:

$$\text{Lead, } \mu\text{g/L} = (1000/A) \times B \tag{2}$$

where:

A = volume of original sample, mL, and

B = weight of lead in sample, μg .

25. Precision and Bias

25.1 Seven operators from six laboratories participated in this study. Five operators performed the analysis in triplicate and two in duplicate at each concentration level.

25.2 The bias of this test method for lead is listed in Table 2.

25.3 These data may not apply to waters of other matrices.

25.4 This section on precision and bias conforms to Practice D 2777 – 77 which was in place at the time of collaborative testing. Under the allowances made in 1.4 of D 2777 – 98, these precision and bias data do meet existing requirements of interlaboratory studies of Committee D19 test methods.

26. Quality Control

26.1 In order to be certain that analytical values obtained using these test methods are valid and accurate within the confidence limits of the test, the following QC procedures must be followed when analyzing lead.

26.2 Calibration and Calibration Verification:

26.2.1 Analyze at least three working standards containing concentrations of lead that bracket the expected sample concentration, prior to analysis of samples, to calibrate the

instrument. The calibration correlation coefficient shall be equal to or greater than 0.990. In addition to the initial calibration blank, a calibration blank shall be analyzed at the end of the batch run to ensure contamination was not a problem during the batch analysis.

26.2.2 Verify instrument calibration after standardization by analyzing a standard at the concentration of one of the calibration standards. The concentration of a mid-range standard should fall within $\pm 15\%$ of the known concentration.

26.2.3 If calibration cannot be verified, recalibrate the instrument.

26.3 Initial Demonstration of Laboratory Capability:

26.3.1 If a laboratory has not performed the test before, or if there has been a major change in the measurement system, for example, new analyst, new instrument, etc., a precision and bias study must be performed to demonstrate laboratory capability.

26.3.2 Analyze seven replicates of a standard solution prepared from an Independent Reference Material containing a mid-range concentration of lead. The matrix and chemistry of the solution should be equivalent to the solution used in the collaborative study. Each replicate must be taken through the complete analytical test method including any sample preservation and pretreatment steps. The replicates may be interspersed with samples.

26.3.3 Calculate the mean and standard deviation of the seven values and compare to the acceptable ranges of bias in Table 2. This study should be repeated until the recoveries are within the limits given in Table 2. If a concentration other than the recommended concentration is used, refer to Practice D 5847 for information on applying the *F* test and *t* test in evaluating the acceptability of the mean and standard deviation.

26.4 Laboratory Control Sample (LCS):

26.4.1 To ensure that the test method is in control, analyze a LCS containing a known concentration of lead with each batch or 10 samples. If large numbers of samples are analyzed in the batch, analyze the LCS after every 10 samples. The laboratory control samples for a large batch should cover the analytical range when possible. The LCS must be taken through all of the steps of the analytical method including sample preservation and pretreatment. The result obtained for a mid-range LCS shall fall within $\pm 15\%$ of the known concentration.

26.4.2 If the result is not within these limits, analysis of samples is halted until the problem is corrected, and either all the samples in the batch must be reanalyzed, or the results must be qualified with an indication that they do not fall within the performance criteria of the test method.

26.5 Method Blank:

26.5.1 Analyze a reagent water test blank with each batch. The concentration of lead found in the blank should be less than 0.5 times the lowest calibration standard. If the concentration of lead is found above this level, analysis of samples is halted until the contamination is eliminated, and a blank shows no contamination at or above this level, or the results must be qualified with an indication that they do not fall within the performance criteria of the test method.

TABLE 2 Determination of Bias, Chelation-Extraction

| Amount Added, $\mu\text{g/L}$ | Amount Found, $\mu\text{g/L}$ | S_T , $\mu\text{g/L}$ | S_o , $\mu\text{g/L}$ | Bias, % | Statistically Significant (95 % Confidence Level) |
|-------------------------------|-------------------------------|-------------------------|-------------------------|---------|---|
| Reagent Water Type II | | | | | |
| 100 | 86.1 | 17.7 | 8 | -13.9 | yes |
| 400 | 364 | 55 | 27 | -9.0 | yes |
| 800 | 674 | 124 | 24 | -15.8 | yes |
| Selected Water Matrices | | | | | |
| 100 | 83 | 20 | 6.5 | -17 | yes |
| 400 | 352 | 51 | 21 | -12 | yes |
| 800 | 669 | 78 | 50 | -16 | yes |