



Designation: B170 – 99(Reapproved 2010)<sup>ε1</sup>

## Standard Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes<sup>1</sup>

This standard is issued under the fixed designation B170; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

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

<sup>ε1</sup> NOTE—Sections 2 and 6 editorially corrected in March 2011.

### 1. Scope

1.1 This specification establishes the requirements for two grades of oxygen-free electrolytic copper wire bars, billets, and cakes produced without the use of metallic or metaloidal deoxidizers.

1.2 Oxygen-free copper, as described herein, is defined as copper containing oxygen not in excess of 0.0010 % (10 ppm).

1.2.1 Grade 1 copper (UNS C10100) corresponds to the designation OFE in Classification B224.

1.2.2 Grade 2 copper (UNS C10200) corresponds to the designation OF in Classification B224.

1.2.3 Grade 2 copper may be used to produce OFS designation coppers corresponding to UNS C10400, C10500, and C10700.

1.3 Although this specification includes certain UNS designations as described in Practice E527, these designations are for cross reference only and are not specification requirements. In case of conflict, Specification B170 shall govern.

1.4 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only, except for analytical measurements where SI units are the norm.

1.5 The following hazard caveat pertains only to Section 13 and Annex A1, of this specification. *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.*

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.07 on Refined Copper.

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### 2. Referenced Documents

2.1 *ASTM Standards*:<sup>2</sup>

B5 Specification for High Conductivity Tough-Pitch Copper Refinery Shapes

B193 Test Method for Resistivity of Electrical Conductor Materials

B224 Classification of Coppers

B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper

B846 Terminology for Copper and Copper Alloys

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E50 Practices for Apparatus, Reagents, and Safety Considerations for Chemical Analysis of Metals, Ores, and Related Materials

E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry

E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)<sup>3</sup>

E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

### 3. Terminology

3.1 *Definitions*:

3.1.1 Definition of terms used shall be that found in Classification B224 and Terminology B846.

### 4. Ordering Information

4.1 Orders for material shall include the following information:

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

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

- 4.1.1 ASTM designation and year of issue,
- 4.1.2 Grade,
- 4.1.2.1 Grade 1 copper, (UNS C10100), corresponds to the designation OFE in Classification **B224**,
- 4.1.2.2 Grade 2 copper (UNS C10200), corresponds to the designation OF in Classification **B224**,
- 4.1.3 Shape and size, and
- 4.1.4 Quantity.

4.2 The following options are available and should be specified at time of order when required:

- 4.2.1 Certification,
- 4.2.2 Test reports,
- 4.2.3 Piece identification,
- 4.2.4 The amount of silver required in troy oz/short ton for silver bearing (OFS) coppers,
  - 4.2.4.1 The addition of silver up to an average of 30 troy oz/short ton (0.102 %) will be considered within the specification, with no individual silver analysis to exceed 35 troy oz/short ton (0.12 %), and
  - 4.2.4.2 Copper with added silver corresponds to the designation OFS as shown in Classification **B224** and to coppers UNS C10400, C10500, and C10700 as defined by the agreed silver content.

## 5. Chemical Composition

5.1 The composition of each grade shall be in accordance with the requirements of **Table 1**.

5.2 By agreement between purchaser and supplier, analysis may be required and limits established for elements not specified in **Table 1**.

## 6. Physical Properties

### 6.1 Electrical Resistivity:

6.1.1 The maximum mass resistivity for Grade 1 is 0.15176  $\Omega$  g/m<sup>2</sup> (conductivity 101 %, minimum, International Annealed Copper Standards, (IACS)).

6.1.2 The maximum mass resistivity for Grade 2 is 0.15328  $\Omega$  g/m<sup>2</sup> (conductivity 100 %, minimum, IACS).

### 6.2 Embrittlement Test:

6.2.1 Grade 1 shall withstand ten *reverse* bends without breaking, in accordance with Test Method D of Test Methods **B577**.

6.2.2 Grade 2 shall withstand eight *reverse* bends without breaking in accordance with Test Method D of Test Methods **B577**.

## 7. Dimensions, Mass, and Permissible Variations

7.1 *Standard Shapes and Sizes*—The copper shall be supplied in the form of wire bars, cakes, and billets (**Note 1**).

NOTE 1—For available shapes and sizes consult the manufacturer's published list.

7.1.1 Wire bars covered by this specification do not conform in dimension to Specification **B5**.

### 7.2 Wire Bars:

7.2.1 A variation of 5 % in weight, or

7.2.2 A variation of 1/4 in. (6.4 mm) in height, or width, or both, or

7.2.3 A variation of 1 % in length from the purchaser's specification shall be considered good delivery.

### 7.3 Cakes:

7.3.1 A variation of 5 % in weight, or

7.3.2 A variation of 1/4 in. (6.4 mm) in height or width, or both, from the purchaser's specification shall be considered good delivery.

7.3.3 Cakes may vary by 3 % from any listed or specified dimension greater than 8 in. (203 mm).

### 7.4 Billets:

7.4.1 For billets up to 6 in. (152.4 mm) in diameter, a variation of 5 % in weight and  $\pm 1/16$  in. (1.6 mm) in diameter from the purchaser's specification shall be considered good delivery.

7.4.2 For billets 6 in. (152.4 mm) and over in diameter, the diameter tolerance shall be  $+1/16$ ,  $-1/8$  in. (+1.6 mm, -3.2 mm) for good delivery.

7.4.3 By agreement between the manufacturer and the purchaser a diameter tolerance of +0 in.,  $-3/16$  in. (+0 mm, -4.8 mm) may be specified for billets 6 in. and over in diameter.

7.4.4 Billets varying in length by  $\pm 2$  % from the listed or specified length shall be considered good delivery.

7.4.5 Billets shall be straight within 1/4 in. (6.4 mm) in 4 ft (1.22 m) as measured at the center of the billet.

7.4.6 Billets shall not be cupped except by specific agreement at time of purchase.

## 8. Workmanship, Finish, and Appearance

8.1 *Wire Bars, Billets, and Cakes*—Shall be substantially free of shrink holes, porosity, cracks, cold sets, pits, inclusions, and similar defects.

## 9. Sampling

9.1 For routine sampling, the method of sampling shall be at the discretion of the sampler.

**TABLE 1 Chemical Composition<sup>A</sup>**

Element	Grade 1	Grade 2
Copper, min %	99.99 <sup>B</sup>	...
Copper (including silver), min %	...	99.95
	ppm, max	ppm, max
Antimony	4	...
Arsenic	5	...
Bismuth	1	...
Cadmium	1	...
Iron	10	...
Lead	5	...
Manganese	0.5	...
Nickel	10	...
Oxygen	5	10
Phosphorus <sup>C</sup>	3	...
Selenium	3	...
Silver	25	...
Sulfur	15	...
Tellurium	2	...
Tin	2	...
Zinc	1	...

<sup>A</sup> Analytical uncertainty is not incorporated into the specified limits.

<sup>B</sup> Copper is determined by the difference of impurity total from 100.

<sup>C</sup> Refer to Section **13**.

9.2 In the case of special requirements specified in the purchase order or contract, the method of sampling shall be as agreed upon between the producer, or supplier, and the purchaser.

9.3 In case of dispute, a sampling lot shall consist of all pieces in a shipment manufactured during a single production period as defined and recorded by the manufacturer.

9.4 *Chemical Composition*—In case of dispute concerning chemical composition, each party shall select two pieces from the lot to be investigated.

9.4.1 Each of the four selected pieces shall be sampled in the presence of both parties by drilling five holes, approximately ½ in. (12.7 mm) in diameter, at points equally spaced between the ends of the pieces.

9.4.2 For wire bars or billets, these holes shall be along an approximate center line, and with cakes, along an approximate diagonal line between opposite corners.

9.4.3 The drilling shall be completely through each piece. Surface drillings shall be rejected.

9.4.3.1 The drill bit used shall be thoroughly cleaned prior to use. The bit shall be made from a noncontaminating material.

9.4.3.2 No lubricant shall be used, and the drill shall not be forced sufficiently to cause oxidation of the drillings.

9.4.4 In case of a section more than 5 in. (125 mm) in thickness, drillings may be made from opposite sides for a depth of not less than 2 in. (51 mm) in each direction instead of completely through each piece, but, in other respects, the drillings shall be conducted as previously described.

9.4.5 The drillings from each of the four pieces are individually mixed and divided into three approximately equal portions.

9.4.5.1 Each portion shall be placed in a sealed, noncontaminating, package, and

9.4.5.2 The twelve portions shall be individually identified, and

9.4.5.3 Divided into three groups of four portion each, one portion from each of the original four pieces; one group each for the manufacturer, the purchaser, and the umpire, if necessary.

9.4.6 Sampling of individual pieces weighing over 1000 lb (453 kg) shall be by agreement between manufacturer and the purchaser.

9.5 *Oxygen*—In case of dispute concerning oxygen content, each party shall select two pieces from the lot to be investigated.

9.5.1 Each of the four selected pieces shall be sampled in the presence of both parties. A single piece of adequate size shall be cut from each of the four pieces by mutually agreeable means.

9.5.2 Each piece shall be cut into three approximately equal portions. The twelve portions thus obtained shall be individually identified.

9.5.3 The twelve portions shall be divided into three groups of four portions each, one from each of the original four pieces; one group each for the manufacturer, the purchaser, and the umpire, if necessary.

9.6 *Resistivity*—In case of dispute concerning mass resistivity, each party shall select two pieces from the lot.

9.6.1 In the presence of both parties, and by mutually agreeable means, a single sample of adequate size shall be cut from each of the four pieces and fabricated into a wire.

9.6.2 Each coil shall be cut into three portions of approximately equal length, and the twelve portions thus obtained shall be individually identified.

9.6.3 The twelve wires shall be divided into three groups of four wires each, one from each of the four original selected pieces; one group each for the manufacturer, the purchaser, and the umpire, if necessary.

9.7 *Embrittlement*—In case of dispute concerning freedom from embrittlement, sampling shall be described in 9.6.

9.8 *Variation in Weights or Dimensions*—In case of dispute concerning weights or dimensions, the representative of the manufacturer and purchaser shall inspect all pieces where physical defects or variations in weights are claimed. If such inspection is not practical, or if agreement is not reached, the question of fact shall be submitted to a mutually agreeable umpire.

## 10. Number of Tests and Retests

### 10.1 *Number of Tests:*

10.1.1 The chemical composition, except for oxygen, shall be determined as the mean of the observations from three replicate analyses of each of the four portions.

10.1.2 The oxygen content shall be determined as the mean of the results from the four test specimens.

10.1.3 The mass resistivity shall be determined as the mean of the results from the four test specimens.

10.1.4 The freedom from embrittlement shall be determined as the mean of the results from the four test specimens.

### 10.2 *Retest:*

10.2.1 In case of dispute one retest may be made by the manufacturer or the purchaser or both, under the conditions of 10.1.

### 10.3 *Umpire Test:*

10.3.1 In the case where the retest does not settle the dispute, a second retest may be made by a third qualified laboratory agreeable to the manufacturer and the purchaser. The second retest shall be made on the samples set aside for this purpose.

10.3.2 The umpire provision does not preclude other arrangements, by agreement or contract.

## 11. Specimen Preparation

### 11.1 *Oxygen:*

11.1.1 The test specimen shall originate as a single piece of appropriate size cut from a bar, cake, or billet from which a 0.25-in. (6.4-mm) test cube specimen is fabricated by means agreeable to the manufacturer and the purchaser.

11.1.2 The test specimen shall be etched with a solution of nitric acid (HNO<sub>3</sub>) (1+1) for a time sufficient to produce a visible reaction.

11.1.3 The test specimen is removed from the acid with stainless steel, or platinum tipped, tongs, or forceps, and rinsed four times with distilled or deionized water.

11.1.4 The test specimen is covered with concentrated hydrochloric acid (HCl) for 5 min, rinsed four times with water, blotted dry, dipped in acetone, and allowed to air dry.

11.1.5 The test specimen is weighed to the nearest 0.1 mg and analyzed in a properly calibrated oxygen analyzer.

#### 11.2 *Resistivity:*

11.2.1 Each test specimen shall originate as a single piece of appropriate size cut from a bar, cake, or billet. The specimen shall be forged or hot rolled.

11.2.2 The external oxide shall be removed and the specimen cold drawn into a wire approximately 0.080 in. (2.03 mm) in diameter.

11.2.3 The wire shall be annealed in an inert atmosphere at approximately 500°C (932°F) for 30 min and cooled to ambient temperature in the same inert atmosphere.

#### 11.3 *Embrittlement (Bend):*

11.3.1 Each specimen shall originate as a single piece of appropriate size cut from a selected bar, cake, or billet. The specimen shall be forged or hot rolled.

11.3.2 The external oxide shall be removed and the specimen cold drawn into a wire approximately 0.080 in. (2.03 mm) in diameter.

11.3.3 The wire shall be annealed in an atmosphere containing not less than 10 % hydrogen for 30 min at  $850 \pm 25^\circ\text{C}$  (1517 to 1607°F) and cooled to ambient temperature in the same atmosphere.

## 12. Test Methods

12.1 For routine analysis, the analytical test method shall be at the discretion of the analyst.

12.2 In the case of special requirements specified in the purchase order or contract, the methods of analysis used shall be as agreed upon between the producer, or the supplier, and the purchaser.

12.3 In case of dispute concerning the chemical composition of Grade 1, except for phosphorus, oxygen, and sulfur, the method of analysis shall be by electrothermal atomization atomic absorption spectrometer with background correction capability as described in the annex.

12.4 In case of dispute concerning the copper content of Grade 1, copper shall be determined by difference of “impurity total” from 100 %.

12.4.1 *impurity total*—defined as the sum of antimony, arsenic, bismuth, cadmium, iron, lead, manganese, nickel, oxygen, phosphorus, silver, selenium, sulfur, tellurium, tin, and zinc.

12.5 Phosphorous is normally determined by the optical emission spectroscopy technique. Therefore, in case of dispute concerning the phosphorous content, reference material for instrument calibration shall be by agreement between the producer, or the supplier, and the purchaser in the absence of suitable standard reference materials from the National Institute of Standards and Technology.

12.6 In case of dispute concerning the oxygen content of Grade 1 or Grade 2, the method of analysis shall be by the conductometric method, the vacuum fusion method, or the inert gas fusion technique, described in the annex.

12.7 In case of dispute concerning the sulfur content of Grade 1, the method of analysis shall be by induction furnace combustion and infrared detection instrumentation in accordance with the test method described in the annex, or by agreement between the manufacturer or supplier and the purchaser, or by the direct combustion method described in Test Methods E76.

12.8 In case of dispute concerning copper content of Grade 2, the method of analysis shall be the electrolytic determination of copper method in Test Methods E53.

12.9 *Resistivity*—In case of dispute concerning the electrical resistivity, the test method shall be in accordance with Test Method B193.

12.10 *Embrittlement*—As required in 6.2, freedom from embrittlement shall be determined by lightly clamping each of the four test specimens, individually, between jaws having a radius of 0.200 in. (5.1 mm).

12.10.1 The specimen shall then be bent by hand over one edge through an angle of 90° and returned to its original position, this constitutes one bend.

12.10.2 The specimen shall then be bent in the reverse direction through 90° and returned to its original position, this constitutes a second bend.

12.10.3 Each successive bend shall be made in the opposite direction of the previous bend until the test is completed.

## 13. Significance of Numerical Limits

13.1 For purposes of determining conformance with this specification, an observed value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the limiting value in accordance with Practice E29.

## 14. Inspection

14.1 The manufacturer shall inspect and make tests necessary to verify that the product furnished, conforms to the specified requirements.

14.2 The manufacturer and the purchaser, by mutual agreement, may accomplish the final inspection simultaneously.

## 15. Rejection and Rehearing

### 15.1 *Rejection:*

15.1.1 Product that fails to conform to the specification requirements when tested by the purchaser or purchaser’s agent may be rejected.

15.1.2 Rejection shall be considered as follows:

15.1.2.1 Chemical composition, embrittlement, or resistivity by lot,

15.1.2.2 Variation in weight, dimensions, and workmanship by individual pieces,

15.1.3 Rejection shall be reported to the manufacturer or supplier promptly, and in writing, and

15.1.4 In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer or supplier may make claim for a rehearing.

15.2 *Rehearing*—As a result of product rejection, the manufacturer or supplier may make claim for a retest to be conducted by the manufacturer or supplier and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified therein, or alternatively, upon agreement by both parties, an independent laboratory may be selected for the test(s) using the test methods specified in the specification.

## 16. Certification

16.1 When specified in the purchase order or contract, the purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and the requirements have been met.

16.2 When specified in the purchase order the certificate of compliance shall include the statement, “The material furnished on this purchase order does not contain functional mercury in any form.”

## 17. Test Report

17.1 When specified in the contract or purchase order, a report of test results shall be furnished.

## 18. Product Marking

18.1 Each wire bar, billet, and cake shall be stamped with the manufacturer’s brand and with an identifying number.

## 19. Packaging and Package Marking

19.1 The manufacturer shall arrange rail car loads, truck loads, or other shipping units so that, as far as possible, each shipping unit shall contain pieces bearing a single identifying lot number.

19.2 In case of dispute, a lot shall consist of all pieces of the same shape and size bearing the same identifying number.

## 20. Keywords

20.1 billets; cakes; oxygen free; refinery shapes; silver containing; wire bars

### ANNEX

(Mandatory Information)

## A1. TEST METHODS FOR DETERMINATION OF COMPLIANCE WITH CHEMICAL COMPOSITION REQUIREMENTS OF SPECIFICATION B170 FOR OXYGEN-FREE ELECTROLYTIC COPPER-REFINERY SHAPES

### A1.1 Scope

A1.1.1 These test methods cover the chemical analysis of oxygen-free electrolytic copper for the elements with the specified limiting value stated in **Table 1** of Specification B170.

A1.1.2 *These test methods may involve hazardous materials, operations, and equipment. These test methods do not purport to address all of the safety concerns associated with their use. It is the responsibility of the user of these test methods to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to their use.* Special hazard statements are given in **A1.11**, **A1.24**, and **A1.36**.

A1.1.3 These test methods are arranged as follows:

	Sections
Antimony, Arsenic, Bismuth, Cadmium, Iron Lead,	A1.7-A1.17
Manganese, Mercury, Nickel, Selenium, Silver, Tellurium, Tin, and Zinc by Electrothermal Atomization	
Atomic Absorption Spectrometry	
Oxygen by Inert Gas Fusion Principle and Ther- mal	A1.18-A1.30
Conductivity or Infrared Detector	
Sulfur by Combustion and Infrared Detector	A1.31-A1.42

### A1.2 Significance and Use

A1.2.1 These test methods are primarily intended to test oxygen-free copper for compliance with chemical composition requirements of Specification B170. It is assumed that all who use these test methods will be trained analysts capable of performing common laboratory procedures skillfully and safely. It is expected that work will be performed in a properly equipped laboratory.

### A1.3 Apparatus

A1.3.1 Apparatus required for each determination are listed in separate sections preceding the procedure.

### A1.4 Reagents and Material

A1.4.1 Reagents and materials required for each test method are listed in a separate section in the test method.

### A1.5 Sampling

A1.5.1 In the absence of specific specification requirements, sampling shall be in accordance with Practice **E255**.

### A1.6 Rounding Calculated Values

A1.6.1 Calculated values shall be rounded to the desired number of places as directed in Practice **E29**.

**TEST METHOD FOR ANTIMONY, ARSENIC, BISMUTH, CADMIUM, IRON, LEAD, MANGANESE, NICKEL, SELENIUM, SILVER, TELLURIUM, TIN, AND ZINC BY ELECTROTHERMAL ATOMIZATION ATOMIC ABSORPTION SPECTROSCOPY**

**A1.7 Scope**

A1.7.1 This test method covers the determination of antimony, arsenic, bismuth, cadmium, iron, lead, manganese, nickel, selenium, silver, tellurium, tin, and zinc in oxygen-free electrolytic copper.

**A1.8 Summary of Test Method**

A1.8.1 The test sample is dissolved in HNO<sub>3</sub> and the solution diluted to a known volume. An aliquot is introduced into an electrothermal atomic absorption spectrometer with background correction capability. The absorption of the resonance line energy from the spectrum of the element is measured and compared with that of calibration solutions of the same element in a matched matrix.

**A1.9 Significance and Use**

A1.9.1 This test method is intended to test oxygen-free electrolytic copper for compliance with antimony, arsenic, bismuth, cadmium, iron, lead, manganese, nickel, selenium, silver, tellurium, tin, and zinc requirements of this specification.

**A1.10 Interferences**

A1.10.1 Elements normally present in oxygen-free electrolytic copper do not interfere.

**A1.11 Hazards**

**A1.11.1 Warning:**

A1.11.1.1 The ultraviolet radiation must be shielded at all times to prevent eye damage.

A1.11.1.2 Arsenic trioxide (As<sub>2</sub>O<sub>3</sub>) is a hazardous reagent and may be fatal if swallowed. Avoid inhalation and prolonged or repeated skin contact.

A1.11.1.3 Cadmium and cadmium compounds are potentially hazardous reagents. Avoid ingestion or inhalation.

A1.11.1.4 Tellurium and tellurium compounds are hazardous reagents and may be fatal if ingested. Avoid inhalation and prolonged or repeated skin contact.

A1.11.1.5 Selenium and selenium compounds are potentially hazardous reagents. Avoid ingestion, inhalation, or prolonged and repeated skin contact.

A1.11.1.6 For other specific hazards refer to Practices E50

**A1.11.2 Technical Hazards:Warning:**

A1.11.2.1 It is essential that acids and water be carefully checked for purity to avoid contamination from this source.

A1.11.2.2 Laboratory glassware should be thoroughly cleaned, soaked in HNO<sub>3</sub> (1 + 10) for several hours, and rinsed, prior to use. Avoid previously etched glassware.

A1.11.2.3 Effects of nonspecific absorption and light scattering must be compensated by matrix matching of calibration solutions and background correction.

A1.11.2.4 Matrix modifiers: The copper matrix reduces loss for most elements during the char step. Modifiers such as magnesium nitrate may be found useful to further stabilize elements like cadmium, nickel, and tin and ammonium hydroxide for manganese.

A1.11.2.5 Should lack of homogeneity be suspect in the test material, a 10 g sample, weighed to the nearest 1 mg should be taken and diluted to 1 L with the appropriate amount of acid.

A1.11.2.6 The lower limit of elemental determination is affected by the residual level of the element in the copper.

A1.11.2.7 Optimum settings for operating parameters vary instrument to instrument, and must be experimentally established for a particular instrument.

**A1.12 Apparatus**

A1.12.1 *Atomic Absorption Spectrometer and Electrothermal Atomizer*—The instrument shall be equipped with a background corrector and high-speed read-out electronics, or a high-speed recorder, or both. The instrument should be capable of using single-element hollow cathode lamps or electrodeless discharge lamps. Follow the manufacturer's manual for installation and system operation.

A1.12.2 *Graphite Tubes*—Pyrolytically coated graphite tubes and I'vov platforms for use in the electrothermal atomizer.

A1.12.3 *Micropipets*—5 to 250 μL.

A1.12.3.1 The analytical lines are:

Element	Wavelength, nm
Antimony	217.6
Arsenic	193.9
Bismuth	223.0
Cadmium	228.8
Iron	248.3
Lead	283.3
Manganese	279.5
	232.0
Selenium	196.0
Silver	321.8
Tellurium	214.3
Tin	224.6
Zinc	213.8

A1.12.4 *Operating Parameters*—Determine the sample size and optimum electrothermal atomizer parameters for the type of atomizer used as recommended by the instrument manufacturer.

**A1.13 Reagents and Materials**

**A1.13.1 Reagents:**

A1.13.1.1 *Acids*—acids, hydrochloric (HCl) and nitric (HNO<sub>3</sub>), should be carefully checked for purity to ensure they do not contaminate the analysis.

A1.13.1.2 *Water*—The quality of the water should be carefully checked for purity to ensure it does not contaminate the analysis.

A1.13.1.3 *Argon*—purity: 99.98 %, minimum.

A1.13.1.4 *Copper Solution (1 mL = 50 mL Cu)*—Transfer 10 g of certified high purity copper (National Institute of Standards and Technology, Standard Reference Material,