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Standard Test Method for Analysis of Aluminum and Aluminum Alloys by Spark Atomic Emission Spectrometry¹

This standard is issued under the fixed designation E1251; 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 U.S. Department of Defense.

1. Scope

1.1 This test method describes the analysis of aluminum and its alloys by atomic emission spectrometry. The aluminum specimen to be analyzed may be in the form of a chill cast disk, casting, foil, sheet, plate, extrusion, or some other wrought form or shape. The elements covered in the scope of this method are listed in the table below.

| Element | Tested Concentration Range (Wt %) |
|------------|--------------------------------------|
| Antimony | 0.001 to 0.003 |
| Arsenic | 0.001 to 0.006 |
| Beryllium | 0.0004 to 0.24 |
| Bismuth | 0.03 to 0.6 |
| Boron | 0.0006 to 0.009 |
| Calcium | 0.0002 to – |
| Chromium | 0.001 to 0.23 |
| Cobalt | 0.4 to – |
| Copper | 0.001 to 5.5 |
| Gallium | 0.02 to – |
| Iron | 0.2 to 0.5 |
| Lead | 0.04 to 0.6 |
| Lithium | 0.0003 to 2.1 |
| Magnesium | 0.03 to 5.4 |
| Manganese | 0.001 to 1.2 |
| Nickel | 0.005 to 2.6 |
| Phosphorus | 0.003 to – |
| Silicon | 0.07 to 16 |
| Sodium | 0.003 to 0.02 |
| Strontium | 0.03 to – |
| Tin | 0.03 to – |
| Titanium | 0.001 to 0.12 |
| Vanadium | 0.002 to 0.022 |
| Zinc | 0.002 to 5.7 |
| Zirconium | 0.001 to 0.12 |

NOTE 1—The concentration ranges given in the above scope were established through cooperative testing (ILS) of selected reference materials. The range shown for each element does not demonstrate the actual usable analytical range for that element. The usable analytical range may be extended higher or lower based on individual instrument capability, spectral characteristics of the specific element wavelength being used, and the availability of appropriate reference materials.

NOTE 2—Mercury (Hg) is intentionally not included in the scope. Analysis of Hg in aluminum by spark atomic emission spectrometry (Spark-AES) is not recommended. Accurate analysis of Hg using this technique is compromised by the presence of an intense iron interference. Inaccurate reporting of Hg due to these interference effects can jeopardize the current designation of aluminum production as a ~~mercury-free~~ mercury-free process. To demonstrate compliance with legislated Hg content limits, use of an alternate method capable of analysis with a minimum reporting limit of 0.0001% or lower is recommended. Suitable techniques include but are not limited to glow discharge mass spectrometry, XRF, and cold vapor AA.

1.2 This test method is suitable primarily for the analysis of chill cast disks as defined in Practices E716. Other forms may be analyzed, provided that: (1) they are sufficiently massive to prevent undue heating, (2) they allow machining to provide a clean, flat surface, which creates a seal between the specimen and the spark stand, and (3) reference materials of a similar metallurgical condition and chemical composition are available.

¹ This test method is under the jurisdiction of ASTM Committee E01 on Analytical Chemistry for Metals, Ores, and Related Materials and is the direct responsibility of Subcommittee E01.04 on Aluminum and Magnesium.

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1.3 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use. Specific safety and health statements are given in Section 10.

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

2. Referenced Documents

2.1 ASTM Standards:²

E135 Terminology Relating to Analytical Chemistry for Metals, Ores, and Related Materials

E158 Practice for Fundamental Calculations to Convert Intensities into Concentrations in Optical Emission Spectrochemical Analysis (Withdrawn 2004)³

E172 Practice for Describing and Specifying the Excitation Source in Emission Spectrochemical Analysis (Withdrawn 2001)³

E305 Practice for Establishing and Controlling Atomic Emission Spectrochemical Analytical Curves

E406 Practice for Using Controlled Atmospheres in Spectrochemical Analysis

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E716 Practices for Sampling and Sample Preparation of Aluminum and Aluminum Alloys for Determination of Chemical Composition by Spark Atomic Emission Spectrometry

E826 Practice for Testing Homogeneity of a Metal Lot or Batch in Solid Form by Spark Atomic Emission Spectrometry

E876 Practice for Use of Statistics in the Evaluation of Spectrometric Data (Withdrawn 2003)³

E1329 Practice for Verification and Use of Control Charts in Spectrochemical Analysis

E1507 Guide for Describing and Specifying the Spectrometer of an Optical Emission Direct-Reading Instrument

3. Terminology

3.1 *Definitions*—For definitions of terms used in this Standard, refer to Terminology **E135**.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *alloy-type calibration*—calibration curves determined using calibrants from alloys with similar compositions.

3.2.2 *binary-type calibration*—calibration curves determined using binary calibrants (primary aluminum to which has been added one specific element).

3.2.3 *global-type calibration*—calibration curves determined using calibrants from many different alloys with considerable compositional differences.

3.2.3 *alloy-type calibration*—calibration curves determined using calibrants from alloys with similar compositions.

3.2.4 *two-point drift correction*—the practice of analyzing a high and low standardant for each calibration curve and adjusting the counts or voltage values obtained back to the values obtained on those particular standardants during the collection of the calibration data. The corrections are accomplished mathematically and are applied to both the slope and intercept. Improved precision may be obtained by using a multi-point drift correction as described in Practice **E1329**.

3.2.5 *type standardization*—mathematical adjustment of the calibration curve's slope or intercept using a single standardant (reference material) at or close to the nominal composition for the particular alloy being analyzed. For best results, the standardant being used should be within $\pm 10\%$ of the composition (for each respective element) of the material being analyzed.

4. Summary of Test Method

4.1 A unipolar triggered capacitor discharge is produced in an argon atmosphere between the prepared flat surface of a specimen and the tip of a semi-permanent counter electrode. The energy of the discharge is sufficient to ablate material from the surface of the sample, break the chemical or physical bonds, and cause the resulting atoms or ions to emit radiant energy. The radiant energies of the selected analytical lines and the internal standard line(s) are converted into electrical signals by either photomultiplier tubes (PMTs) or a suitable solid state detector. The detector signals are electrically integrated and converted to a digitized value. The signals are ratioed to the proper internal standard signal and converted into concentrations by a computer in accordance with Practice **E158**.

4.2 Three different methods of calibration defined in ~~3.2.1~~3.2.2, ~~3.2.2~~3.2.3, and ~~3.2.3~~3.2.1; are capable of giving the same precision, accuracy, and detection limit.

4.2.1 The first method, *binary calibration*, employs calibration curves that are determined using a large number of high-purity binary calibrants. This approach is used when there is a need to analyze almost the entire range of aluminum alloys. Because binary

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

³ The last approved version of this historical standard is referenced on www.astm.org.

calibrants may respond differently from alloy calibrants, the latter are used to improve accuracy by applying a slope and/or intercept correction to the observed readings.

4.2.2 The second method, *global calibration*, employs calibration curves that are determined using many different alloy calibrants with a wide variety of compositions. Mathematical calculations are used to correct for both alloy difference and inter-element effects. Like the method above, specific alloy calibrants may be used to apply a slope and/or intercept correction to the observed readings.

4.2.3 The third method, *alloy calibration*, employs calibration curves that are determined using different alloy calibrants that have similar compositions. Again, specific alloy calibrants may be used to apply a slope and/or intercept correction to the observed readings.

5. Significance and Use

5.1 The metallurgical properties of aluminum and its alloys are highly dependent on chemical composition. Precise and accurate analyses are essential to obtaining desired properties, meeting customer specifications, and helping to reduce scrap due to off-grade material.

5.2 This test method is applicable to chill cast specimens as defined in [Practice Practices E716](#) and can also be applied to other types of samples provided that suitable reference materials are available. Also, other sample forms can be ~~melted-down~~ melted down and cast into a disk, using an appropriate mold, as described in [Practice Practices E716](#). However, it should be noted that some elements (for example, magnesium) readily form oxides, while some others (for example, sodium, lithium, calcium, and strontium) are volatile, and may be lost to varying degrees during the melting process.

6. Recommended Analytical Lines and Potential Interferences

6.1 [Table 1](#) lists the analytical lines commonly used for aluminum analysis. Other lines may be used if they give comparable results. Also listed are recommended concentration ranges, background equivalent concentrations (BEC), detection limits, useful linear ranges, and potential interferences. The values given in this table are typical; actual values obtained are dependent on instrument design.

NOTE 3—The BEC and detection limits listed in [Table 1](#) have been attained with a spectrometer that has a reciprocal dispersion of 54 nm/mm and a working resolution of 3.5 nm, using an entrance slit width of 25 μm and exit slit widths of 50 μm .

7. Apparatus

7.1 Specimen Preparation Equipment:

7.1.1 *Sampling Molds*, for aluminum and the techniques of pouring a sample disk are described in [Practice Practices E716](#). Chill cast samples, poured and cast as described within [Practice Practices E716](#), shall be the recommended form in this test method.

7.1.2 *Lathe*, capable of machining a smooth, flat surface on the reference materials and samples. A variable speed cutter, a cemented carbide or polycrystalline diamond tool bit, and an automatic ~~cross-feed~~ cross feed are highly recommended. Proper depth of cut and desired surface finish are described in [Practice Practices E716](#).

7.1.3 *Milling Machine*, a milling machine can be used as an alternative to a lathe.

NOTE 4—It is strongly recommended that the same preparation machinery used to prepare the standards is also used to prepare the samples. Differences in surface characteristics may influence the analysis.

7.2 *Excitation Source*, capable of producing a unipolar, triggered capacitor discharge. In today's instrumentation, the excitation source is computer controlled and is normally programmed to produce: (1) a high-energy pre-spark (of some preset duration), (2) a spark-type discharge (of some preset duration), (3) an ~~arc-type~~ arc-type discharge (of some preset duration), and (4) a spark-type discharge, during which, ~~time-resolved~~ time-resolved measurements are made for improved detection limits (this may be optional on some instruments).

7.2.1 Typical parameters and exposure times are given in [Table 2](#). It should be emphasized that the information presented is given as an example only and parameters may vary with respect to instrument model and manufacturer. For details on describing and specifying an excitation source, please refer to [Practice E172](#).

7.3 *Excitation Chamber*, shall be designed with an upper plate that is smooth and flat so that it will mate (seal) perfectly with the prepared surface of the sample specimen. The seal that is formed between the two will exclude atmospheric oxygen from entering the discharge chamber. The excitation chamber will contain a mounting clamp to hold the counter electrode. The excitation stand assembly will also have some type of clamp or device designed to hold the sample firmly against the top plate. Some manufacturers may provide for the top plate to be liquid cooled to minimize sample heat-up during the excitation cycle. The excitation chamber will also be constructed so that it is flushed automatically with argon gas during the analytical burn cycle. The excitation chamber's design should allow for a flow of argon gas to prevent the deposition of ablated metal dust on the inner-chamber quartz window(s). The excitation chamber will be equipped with an exhaust system that will safely dispose of the argon gas and the metal dust created during the excitation cycle. For reasons of health and cleanliness, the exhausted gas and dust should not be vented directly into the laboratory. To help with this situation, manufacturers have designed their instruments with some type of exhaust/filter system to deal with this problem. The exhaust can then be vented into an efficient hood system.

TABLE 1 Recommended Analytical Lines

| Element | Wavelength in Air (nm) ^A | Recommended Concentration Range, % | Background Equivalent, % ^B | Calculated Detection Limit, % ^{C,D} | High Concentration Index, % ^E | Interferences Element, λ(nm) and k, % ^F |
|------------|---|--|---|--|--|---|
| Aluminum | I 256.799 | 70-100 | | | | |
| | I 266.039 | 70-100 | | | | |
| | I 237.208 | 70-100 | | | | |
| Antimony | I 231.147 | 0.001-0.5 | 0.17 | 0.0002 | | Co 231.166 0.6 |
| | I 259.806 | 0.001-0.5 | | 0.0002 | | Fe 259.837 Mn 259.817 0.01 |
| Arsenic | 234.984 | 0.005-0.1 | | | | |
| Beryllium | I 234.861 | 0.0001-0.05 | 0.001 | 0.00003 | | |
| | II 313.042 | 0.0001-0.05 | 0.0035 | 0.00001 | | |
| | 332.134 | 0.0001-0.05 | | 0.00001 | | |
| Bismuth | I 306.772 | 0.001-0.7 | 0.04 | 0.0002 | | |
| Boron | I 249.773 | 0.0001-0.05 | 0.002 | 0.0001* | | Fe 249.782 0.001 Mn 249.778 0.007 |
| | I 249.678 | 0.0001-0.05 | | | | |
| | I 208.959 | 0.0001-0.05 | | | | Mo 208.952 0.13 |
| Cadmium | I 228.802 | 0.001-1 | 0.05 | <0.0001 | | As 228.812 |
| | I 479.992 | 0.005-2 | 0.15 | 0.003 | | |
| Calcium | II 393.367 ^G | 0.001-0.05 | 0.001 | 0.00005 | | Fe 393.361 |
| Chromium | I 425.435 | 0.001-1 | 0.015 | <0.0001 | | |
| | II 267.716 | 0.001-1 | 0.004 | 0.0005* | | |
| | II 276.654 ^G | 0.005-1 | | | | |
| Cobalt | I 345.351 | 0.0001-2 | | <0.0001 | | |
| Copper | I 327.396 | 0.001-1.5 | 0.005 | <0.0001 | 0.7 | |
| | I 324.754 | 0.001-0.5 | | | | |
| | I 296.117 | 0.05-20 | 0.40 | 0.01* | >20 | Fe 296.128 |
| | II 224.700 | 0.01-5 | 0.03 | 0.0005* | 5 | |
| | I 510.554 | 0.05-20 | 0.32 | 0.01* | >20 | |
| Gallium | I 294.364 | 0.001-0.05 | 0.015 | <0.0001 | | |
| | I 417.206 ^G | 0.001-0.05 | | | | Fe 417.213 Ti 417.190 Cr 417.167 |
| Iron | II 238.204 | 0.001-1.5 | 0.015 | 0.0008 | 1.0 | |
| | II 259.940 | 0.001-1.5 | 0.005 | 0.0004 | | |
| | I 259.957 | | | | | |
| | II 273.955 | 0.01-3.5 | | | | |
| | I 374.949 ^G | 0.001-3.5 | | 0.0001 | | |
| | I 441.512 | 0.01-3.5 | | 0.0004 | | |
| | I 438.355 | 0.005-3.5 | | | | |
| Lead | I 405.782 | 0.002-0.7 | 0.04 | 0.0001 | | Mn 405.792 0.01 Mg 405.763 0.001 |
| Lithium | I 283.306 | 0.002-0.7 | 0.07 | 0.002 | | |
| | I 610.364 | 0.0001-3 | | | | |
| | I 670.784 | 0.0001-0.02 | 0.0005 | <0.0005 | | |
| | I 323.261 | 0.01-3 | | | | Fe 323.279 Sb 323.250 |
| Magnesium | II 279.553 | 0.0005-0.3 | 0.0006 | 0.00003 | 0.04 | |
| | I 285.213 | 0.0005-0.3 | 0.008 | <0.0001 | 0.25 | |
| | I 277.669 | 0.05-11 | 0.08 | 0.01 | >11 | |
| | I 383.231 ^G | 0.01-11 | 0.015 | 0.002* | >11 | |
| | I 383.826 | 0.1-11 | | | | |
| | I 518.362 | 0.01-11 | 0.02 | 0.002* | >11 | |
| Manganese | I 403.076 ^G | 0.001-0.1 | 0.028 | 0.0001* | | |
| | II 259.373 | 0.0005-0.5 | 0.004 | 0.00005 | 0.2 | |
| | II 293.306 | 0.001-2 | 0.006 | 0.0002* | >1.1 | |
| | II 346.033B | 0.01-2 | | | | |
| Nickel | I 341.476 | 0.001-2 | 0.02 | <0.0001 | >2.5 | Zr 341.466 0.01 |
| | I 310.188 | 0.005-4 | 0.05 | 0.001* | >5 | |
| | II 231.604 | 0.001-2 | 0.015 | 0.0005* | <2.5 | |
| Phosphorus | I 178.231 ^H | 0.0001-0.1 | 0.084 | 0.0001 | | |
| Silicon | I 288.158 | 0.001-1.5 | 0.01 | 0.0001 | 1.5 | Cr 288.123 |
| | I 251.612 | 0.001-1.5 | 0.006 | 0.0001 | 1.5 | |
| | I 390.553 ^G | 0.05-24 | 0.25 | 0.01 | >24 | Cr 390.566 0.09 |
| | I 212.415 | 0.05-24 | 0.5 | 0.05 | >24 | |
| Silver | I 328.068 | 0.0005-0.1 | | | | |
| | I 338.289 | 0.0001-0.1 | | | >10 | |
| | I 466.848 | 0.05-1.5 | | | | |
| Sodium | I 588.995 | 0.0001-0.05 | 0.0015 | <0.0001 | | |
| Strontium | II 421.552 ^G | 0.0001-0.1 | 0.0004 | 0.0001 | | |
| | I 460.733 | 0.0005-0.06 | | | | |
| Tin | I 317.502 | 0.001-7.5 | 0.04 | 0.0001 | >10 | |
| Titanium | II 334.904 | 0.0005-0.5 | 0.004 | <0.0001 | | |
| | II 337.280 | 0.001-0.5 | 0.002 | <0.00010 | | |
| | I 363.545 | 0.0005-0.05 | 0.030 | 0.003* | | |

TABLE 1 *Continued*

| Element | Wavelength in Air (nm) ^A | Recommended Concentration Range, % | Background Equivalent, % ^B | Calculated Detection Limit, % ^{C,D} | High Concentration Index, % ^E | Interferences Element, λ(nm) and k, % ^F |
|-----------|-------------------------------------|------------------------------------|---------------------------------------|--|--|--|
| Vanadium | I 318.341 | 0.001-0.15 | 0.06 | 0.0003* | | |
| | I 437.924 | 0.001-0.25 | | | | |
| | II 310.230 | 0.001-0.15 | 0.014 | <0.0001 | | |
| Zinc | I 213.856 | 0.0005-0.1 | 0.035 | 0.0001* | 0.05 | |
| | I 334.502 | 0.001-10.0 | 0.065 | 0.0004 | >8 | |
| | I 481.053 | 0.01-10 | 0.07 | 0.001* | >10 | |
| | I 472.216 | 0.01-10 | 0.26 | 0.0015 | >10 | |
| Zirconium | II 339.198 | 0.001-1 | 0.02 | 0.001* | | |
| | II 349.621 ^G | 0.001-1 | 0.006 | <0.0001 | | |

^A I = atom line, II = ion line. Second (2nd) indicates that the second order shall be used, where available.

^B *Background Equivalent Concentration (BEC)*—The concentration at which the signal due to the element is equal to the signal due to the background.

^C In this test method, the *calculated detection limit* was measured by calculating the standard deviation of ten consecutive burns on a specimen with element concentration(s) at levels *below* ten times the expected detection limit.

^D See footnote C. For values marked with an asterisk (*) the available data were for a concentration greater than ten (10) times but less than a hundred (100) times the expected detection limit.

^E *High Concentration Index*—The concentration at which the slope of the calibration curve drops below 0.75.

^F *Interference Factor, k*—The apparent increase in the concentration of the element being determined, expressed in percent, due to the presence of 1.0 % of the interfering element.

^G Useful analytical lines with improved signal to background ratios due to the complete removal of C-N background by the argon atmosphere.

^H If phosphorus is to be determined, the most sensitive line appears to be the 178.231 nm in the second order which requires either a vacuum or a gas filled spectrometer. The vacuum spectrometer should be operated at a pressure of 25 microtorr or less. The gas filled spectrometer will be charged with nitrogen to a positive pressure of slightly over one atmosphere (101 k pa). Optimum results are obtained by using a background channel that has been profiled “off peak” of the first order 178.231 nm phosphorus line as the internal standard. The ratio of P 178.231 nm (2nd) / background near the 178.231 nm (1st) is plotted against % phosphorus. Even with this compensation for variability in background, alloys with highly different compositions of major alloying elements, particularly silicon, require separate reference materials and analytical curves.

TABLE 2 Typical Excitation Source Electrical Parameters

| Parameter | High Energy Pre-spark | Spark | Arc |
|-----------------|-----------------------|-------|-----|
| Resistance, Ω | 4 | 4 | 45 |
| Resistance, Ω | 1 | 1 | 15 |
| Inductance, μH | 30 | 130 | 30 |
| Volts, V | 400 | 400 | 400 |
| Frequency, Hz | 300 | 300 | 300 |
| Capacitance, μF | 12 | 3 | 5 |
| Time, s | 10 | 5 | 5 |

ASTM E1251-17

<https://standards.iteh.ai/catalog/standards/sist/17a7c627-f669-4662-9b7b-bd97a2c8f7f9/astm-e1251-17>

7.4 *Gas Flow System*, will be designed so that it can deliver pure argon gas to the excitation chamber. The purity of the argon gas will affect the precision of the results. Generally, precision improves as the purity of the argon gas gets higher. Argon gas with a minimum purity of 99.995 % has been found to be acceptable. The gas shall be delivered by a flow system as described in Practice E406. The argon gas source can be from high-purity compressed gas cylinders, a cryogenic-type cylinder that contains liquid argon or possibly from a central supply (liquid only). It is essential that only argon gas meeting the minimum purity of 99.995 % be used. A lower purity grade of argon, such as a “welding grade,” should not be used. The delivery system shall be composed of a two-stage type (high/low pressure) regulator of all-metal construction with ~~two-pressure~~ two pressure gages. Delivery tubing must not produce any contamination of the argon stream. ~~Refrigerator grade~~ Refrigerator-grade copper tubing is recommended. The gages on the regulator will allow for the adjustment of the gas pressure to the instrument. Delivery pressure specifications will vary with instrument manufacturer. Please note that the delivery tube connections should be made with ~~all-metal~~ all-metal seals and the delivery tubing itself should be kept as short as possible (Note 5). Argon supply shall be sufficient to support required flow during analysis and bleed during idle periods. All connections must be leak-free.

NOTE 5—~~All-metal~~ All-metal connections are strongly recommended because the discharge is adversely affected by organic contamination, or by as little as 2 ppm of oxygen or a few ppm of water vapor.

7.5 *Spectrometer*—For details on specifying the spectrometer please refer to Guide E1507.

7.6 *Measuring and Control System* of the instrument consists of either photomultiplier and integrating electronics or solid-state photosensitive arrays (CCD or CID) that convert observed light intensities to a digitizable signal. A dedicated computer and/or microprocessor is used to control burn conditions, source operation, data acquisition, and the conversion of intensity data to concentrations. Data should be accessible to the operator throughout all steps of the calculation process. Concentration data may be automatically transferred to a site mainframe computer or server for further data storage and distribution. The instrument’s control software should include functions for routine instrument drift correction (standardization), type standardization, and the application of these functions to subsequent analyses.

8. Materials

8.1 ~~Counter-Electrode~~—Counter Electrode—The ~~counter-electrode~~ counter electrode and specimen surface are the two terminus points of the spark discharge. The counter electrode should be made from thoriated tungsten or silver and have a pointed end. The gap distance between the specimen surface and the tip of the counter electrode is specified by the manufacturer. The diameter and geometry of the counter electrode is also application and vendor dependent. If different designs and/or configurations are offered, it is recommended that the prospective purchaser test each design to determine which one performs the best for the intended analytical task. The counter electrode configuration and auxiliary gap distance must not be altered subsequent to spectrometer calibration or calibration adjustments. Electrode maintenance (frequent brushing of the counter electrode) to maintain its configuration, gap distance, and minimize surface contamination are critical to accurate, precise analytical results. It is recommended that the instrument purchaser order several spare counter electrodes so that they can be replaced when necessary.

9. Reference Materials

9.1 *Calibrants*—All calibrants shall be homogeneous and free of cracks or porosity. These materials should also possess a metallurgical condition that is similar to the material(s) that are being analyzed. The calibrants shall be used to produce the analytical curves for the various elements being determined.

9.1.1 It is recommended that a calibration curve for any particular element be composed of a minimum of four calibrants. The concentrations of these calibrants should be fairly evenly spaced over the calibrated analytical range so that a mathematically valid calibration curve can be established using all of the points.

9.1.1.1 The calibrants used shall be of sufficient quality, purchased from a recognized reputable source, and have certified values to the required accuracy for the anticipated analytical tasks to be performed. A few ~~SRM's~~ SRMs are available from the National Institute of Standards and Technology (NIST). Also, there are other commercial sources for aluminum reference materials.

9.1.2 For trace elements, reference materials that contain variable concentrations of the trace element in a typical alloy of constant or nearly constant composition are available. These reference materials can be used for establishing the analytical curve, but will not reveal potential interferences from nearby lines of other elements, or matrix effects that change instrument response or background. For optimum usefulness, several of the calibrants should have concentrations for the other elements that vary over the expected ranges in the specimen to be analyzed.

NOTE 6—Atomic emission analysis is a comparative technique that requires a close match of the metallurgy, structure, and composition between the reference material and the test material. Differences in structure, such as result from the sodium modification of high silicon alloys, or differences in metallurgical history, due to extruding, rolling, or heat treating, induce a variety of effects that can influence the analytical results. To ensure analytical accuracy, care must be taken to match the characteristics of the reference material to that of the test material or suitable corrections to adjust for these influences must be established.

9.2 Standardants:

9.2.1 *Standardants for Drift Correction*—Both ~~high- and low-concentration~~ high-purity standardants are available from several commercial sources. The low standardant is usually ~~high-purity~~ high-purity (smelter grade) aluminum. The high standardant(s) should have concentrations near or above the median concentration for the calibrated range of each spectral line. The commercially available standardants are tested for homogeneity and reproducibility of spectral response but are not necessarily certified for composition of individual elements. Composition certification is not required because these materials are only used to adjust intensity ratios back to those obtained during the initial calibration of the instrument. Care should be exercised when replacing depleted standardants with new ones that are from different heats or lots, since the actual concentration of the individual element(s) may be different from the standardant currently in use. Whenever standardants are replaced, appropriate procedures must be followed to reference the intensities obtained from the new standardant to the intensities obtained from the standardant being replaced. See 14.3 for details.

9.2.2 *High-Purity Standardants*—These shall be homogeneous and shall consist of aluminum with the lowest available concentration of the elements being determined. These materials are used to establish the background readings of the spectrometer for most elements. Their exact compositions need not be known.

9.2.3 *Blank Standardants*—These materials shall be homogeneous and of similar composition to the alloy type calibrants as described in 9.1 but will contain the lowest available concentrations of the trace elements being determined. They may be used if the lowest concentration of the element being determined is within ten times the detection limit of that element.

9.2.4 *Type Standardants*—Standardization Materials—~~Type standardants are certified~~ standardization materials should be reference materials that are traceable to a recognized certification agency such as NIST. These materials are certified for composition and homogeneity, or equivalent materials that closely match the metallurgical history and composition of the unknown(s). In use, a type ~~standardant~~ standardization material usually provides a nominal ~~concentration~~ mass fraction reference point which the instrument's computer software can use to calculate a slope and/or intercept correction to the observed readings to fine-tune the instrument's calculated response for each element of interest. This correction is then applied to each subsequent analysis. When using this approach it is assumed that the composition(s) of the unknown(s) will be essentially similar to the composition of the type ~~standardant~~ standardization material.