

**METHODS FOR
EMISSION SPECTROCHEMICAL
ANALYSIS
1977 SUPPLEMENT**



**GENERAL PRACTICES
NOMENCLATURE
STANDARD METHODS
PROPOSED METHODS
SUGGESTED METHODS**

METHODS FOR EMISSION SPECTROCHEMICAL ANALYSIS

1977 SUPPLEMENT



① / **Sponsored by
ASTM COMMITTEE E-2
on Emission Spectroscopy**

**GENERAL PRACTICES
NOMENCLATURE
STANDARD METHODS
PROPOSED METHODS
SUGGESTED METHODS**

1977

List Price: \$10.75

03-502077-39

AMERICAN SOCIETY FOR TESTING AND MATERIALS

1916 Race St., Philadelphia, Pa. 19103

Editorial Staff

Robert P. Lukens, Managing Standards Editor
Pamela A. Shenker, Assistant Standards Editor
Joan L. Cornillot, Senior Assistant Editor
Stephanie M. Greco, Assistant Editor
Leona W. Greenhill, Indexer
Margaret W. Haines, Assistant Editor
Diane Montgomery, Assistant Editor
Roberta A. Priemon, Assistant Editor

Albert L. Batik, Deputy Managing Director
for Publications and Marketing
Irene C. Moore, Manager, Production and Purchasing

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in these standards. Users of these standards are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

Reprinted from the *Annual Book of ASTM Standards*
© BY AMERICAN SOCIETY FOR TESTING AND MATERIALS
Printed in Easton, Md., U. S. A.
May 1977

FOREWORD

This compilation is sponsored by ASTM Committee E-2 on Emission Spectroscopy. The preceding edition, the sixth, was published in 1971 and is entitled *Methods for Emission Spectrochemical Analysis*. This volume is published as a supplement and companion volume to the 1971 edition, and includes spectrochemical practices, methods, and nomenclature produced by Committee E-2 since 1971.

Spectrochemical methods are developed by a number of ASTM committees and are published in various parts of the *Annual Book of ASTM Standards*; all standards and proposed methods of Committee E-2 appear in Part 42. Copies of individual ASTM standards are available from ASTM Headquarters. Many ASTM standards are also ANSI standards, having been approved by the American National Standards Institute.

For many years Committee E-2 has had an active program of developing *suggested* methods and practices. Suggested methods and practices (designated E-2 SM) are based on the experience of the submitters, bear the names of the submitters, and are published as information. They have no official status in the Society and should not be referred to as ASTM methods or practices. All suggested methods, however, have been approved by the chairman of Committee E-2, by the editorial subcommittee, and by a letter ballot of the responsible subcommittee. This compilation is the medium for publication of these suggested methods, and also includes some ASTM standard methods.

Committee E-2 publishes these compilations to provide current practices and methods in the fields of atomic absorption, flame, X-ray, and optical emission spectroscopy, for use in analytical laboratories. The subcommittees of Committee E-2 listed in the Appendix have the direct responsibility for developing these practices and methods, as well as definitions and selected bibliographies.

The activities of Committee E-2 are restricted to its official scope as follows:

1.1 Review and coordination of all methods for spectrochemical analysis by atomic emission, atomic absorption and atomic fluorescence spectroscopy. The areas of emission spectroscopy to be covered include optical emission spectroscopy, X-ray emission spectroscopy, flame emission photometry, and electron emission spectroscopy. Formulation and evaluation of methods for spectrochemical analysis of metals and of other materials where agreed upon by the technical committee which establishes chemical analysis requirements. Methods include sampling and test procedures used in determining composition. The formation of methods for the analysis of metals and metal bearing ores employing flame photometry and atomic absorption spectroscopy is specifically excluded from this scope.

1.1 Preparation of recommended practices for emission, atomic absorption, and atomic fluorescence spectroscopy.

1.3 Establishment of nomenclature and definitions relating to emission and atomic absorption spectroscopy.

1.4 Cooperation with agencies concerned with preparation and distribution of standard reference materials.

1.5 Advancement of the field of emission and atomic absorption spectroscopy by promoting the collection and exchange of information through surveys, cooperative test programs, publication of suggested methods and practices, meetings, and symposia.

1.6 The formulation and evaluation of standard spectrochemical methods shall be confined to those materials considered to be within the scope of ASTM but not included in the scope of other ASTM committees, except by mutual agreement.

1.7 These activities will be coordinated with those of other relevant ASTM committees and other organizations.

1.7.1 Methods for sampling metals and methods of analysis for metals involving extensive chemical pretreatment shall be developed and evaluated in close cooperation with Committee E-3.

1.7.2 Nomenclature activities shall be coordinated with the Committee on Terminology.

1.7.3 Committee E-2 will maintain close liaison with the A and B materials (metals) committees in

FOREWORD

providing emission spectroscopy methods employing techniques other than flame photometry and atomic absorption spectroscopy. It will initiate methods under the jurisdiction of other committees, if they so desire.

1.7.4 Liaison will be maintained with the Society for Applied Spectroscopy, the Optical Society of America, and the Spectroscopy Society of Canada.

1.7.5 Liaison with other ASTM groups and national and international groups for standardization will be encouraged.

It is not practical to include here all ASTM spectrochemical standards, but this volume is particularly valuable because it contains a list of all ASTM spectrochemical methods published in the *Annual Book of ASTM Standards*.

This supplement comprises 21 new suggested methods, 3 new proposed methods, and 15 new or revised standard methods. Standards that have been reapproved without revision are not included.

Suggestions or constructive criticisms concerning this publication are solicited and should be forwarded to the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

The E-2 subcommittees are interested in receiving contributions of new practices and methods. Contributors are urged to use the *Form and Style for ASTM Standards* and the appropriate style guide prepared by Committee E-2 which are available from the secretary of the committee. Current guides cover spectrographic, X-ray spectrometric, and atomic absorption methods.

This compilation is the result of voluntary cooperative effort of Committee E-2 members. Particular recognition should be given to the Editorial Subcommittee, under the chairmanship of Norma L. Bottone, who were largely responsible for editing the material in this supplement. Overall organization and direction of the committee work was provided by Chairman W. R. Kennedy. Special credit should be given to Roberta A. Priemon, ASTM Assistant Editor, for her contributions to the work of Committee E-2; to Leona W. Greenhill, ASTM Indexer, for the Index; and to D. C. Spindler, the designated Publications Editor for Committee E-2.

Finally, special thanks and recognition go to J. F. Woodruff for his leadership of Committee E-2 editorial activities. The magnitude and quality of his contributions have been invaluable. Additionally he has inspired and trained others to carry out their editorial functions. Among his many honors in ASTM was his designation as Honorary ASTM Editor. The committee is most appreciative of his talents and inspiration.

January 1977

CONTENTS

METHODS FOR EMISSION SPECTROCHEMICAL ANALYSIS—1977 SUPPLEMENT

A detailed subject index begins on p. 231

The methods in this book are arranged in alphanumeric sequence. The standards appear first, followed by the proposed methods and then the suggested methods.

	PAGE
*E 50-75	Rec. Practices for Apparatus, Reagents, and Safety Precautions for Chemical Analysis of Metals (Excerpt only)
	1
*E 129-74	Spectrographic Analysis of Thermionic Nickel Alloys by the Powder Technique
	8
*E 130-73	Rec. Practice for Designation of Shapes and Sizes of Graphite Electrodes
	13
*E 131-75	Def. of Terms and Symbols Relating to Molecular Spectroscopy
	19
*E 135-76	Def. of Terms and Symbols Relating to Emission Spectroscopy
	23
*E 414-71	Spectrographic Analysis of Electrolytic Copper by the Briquet Technique
	30
*E 483-74	Spectrographic Analysis of Nickel Alloys by the Silver Chloride-Lithium Fluoride Carrier Technique
	35
*E 484-73	Optical Emission Spectrometric Analysis of Steel by the Solution-Reservoir Cup Technique
	40
*E 485-73	Optical Emission Vacuum Spectrometric Analysis of Blast Furnace Iron by the Point-to-Plane Technique
	48
*E 486-73	Spectrographic Analysis of Admiralty Metal by the Cast Pin and Point-to-Plane Techniques
	52
*E 504-74	Rec. Practice for Selection of Electrode Material Used in Optical Emission Spectroscopy Based on Physical Properties
	56
*E 520-74	Rec. Practice for Describing Detectors in Emission and Absorption Spectroscopy
	67
*E 528-74	Rec. Practices for Grounding Basic Optical Emission Spectrochemical Equipment
	74
*E 539-75	X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy
	77
*E 572-76	X-Ray Emission Spectrometric Analysis of Stainless Steel
	83
E-2 P7	Proposed Method for Spectrographic Analysis of Cartridge Brass
	89
E-2 P8	Proposed Method for Spectrographic Analysis of Unalloyed Copper by the Briquet Technique
	93
E-2 P9	Proposed Practices for Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis
	99
E-2 SM 5-16	Suggested Method for Spectrographic Analysis of Copper by the Copper Fluoride-Carrier Technique
	103
E-2 SM 6-49	Suggested Method for Spectrographic Analysis of Gold, Silver, and Platinum by the Copper Fluoride-Carrier Technique
	107
E-2 SM 6-50	Suggested Method for Spectrographic Analysis of Thorium Oxide by the Gallium Oxide-Carrier Technique
	113
E-2 SM 6-51	Suggested Method for Spectrographic Analysis of Gallium Arsenide
	118
E-2 SM 6-52	Suggested Method for Optical Emission Spectrometric Analysis of Plutonium Dioxide by the Silver Chloride-Lithium Fluoride-Carrier Technique
	124
E-2 SM 7-20	Suggested Practice for Casting and Evaluating Aluminum and Aluminum Alloy Spectrochemical Reference Materials
	128
E-2 SM 8-21	Suggested Method for Optical Emission Spectrometric and Spectrographic Analysis of Molybdenum
	135
E-2 SM 8-22	Suggested Method for Optical Emission Spectrometric and Spectrographic Analysis of Tungsten
	140
E-2 SM 8-23	Suggested Method for Spectrographic Determination of Hafnium in Zirconium Dioxide
	145
E-2 SM 9-42	Suggested Method for X-Ray Emission Spectrometric Analysis of Standard Ferromanganese
	148
E-2 SM 10-27	Suggested Method for Spectrographic Analysis of Sodium Chloride and Other Sodium Compounds by the Solution Residue Technique
	153

CONTENTS

	PAGE
E-2 SM 10-28	Suggested Method for Flame Emission Determination of Sodium and Potassium in Raw Materials and By-Products of Portland Cement Plants 160
E-2 SM 10-29	Suggested Method for X-Ray Emission Spectrometric Analysis of Calcite Soda-Lime Glass 168
E-2 SM 10-30	Suggested Method for Neutron Activation Analysis of Dry-Process Portland Cement Raw Mix 175
E-2 SM 10-31	Suggested Method for Atomic Absorption Analysis of Glass 181
E-2 SM 10-32	Suggested Method for Atomic Absorption Determination of Sodium and Potassium in Portland Cement Raw Materials and Kiln Dust 187
E-2 SM 10-33	Suggested Method for X-Ray Emission Spectrometric Analysis of Aluminosilicate Raw Materials and Refractories by the Lithium Tetraborate-Lanthanum Oxide-Fusion Technique 193
E-2 SM 10-34	Suggested Method for X-Ray Emission Spectrometric Analysis of Portland Cement by the Energy-Dispersive Technique 197
E-2 SM 11-22	Suggested Method for Semiquantitative Spectrographic Analysis of Miscellaneous Materials by the Graphite Dilution Technique 202
E-2 SM 11-23	Suggested Method for Semiquantitative Spectrographic Analysis of Miscellaneous Materials by the Lithium Fluoride-Graphite Dilution Technique 210
E-2 SM 11-24	Suggested Method for Atomic Absorption Analysis of Slags and Sinters by the Lithium Tetraborate-Fusion Technique 214
APPENDIXES	
Appendix I	Selected Reference on Analysis of Metals Using Emission Spectroscopy 221
Appendix II	Selected References on Analysis of Glass, Ceramics, Alkalies, and Cementitious Materials Using Atomic Emission and Absorption Analysis 222
Appendix III	Selected References on Analysis of Organic Materials Using Atomic Emission and Absorption Spectroscopy 223
Appendix IV	Related Publications 227
Officers of Committee E-2 and Its Subcommittees	228
Index	231
ASTM Membership Application Blank	249

LIST BY SUBJECTS

METHODS FOR EMISSION SPECTROCHEMICAL ANALYSIS - 1977 SUPPLEMENT

(Methods that are shown in *italic type* appear in the 1971 edition.)

A detailed subject index appears on p. 231

NOMENCLATURE

	PAGE
<i>Definitions of Terms and Symbols Relating to:</i>	
*E 131 - 75 Molecular Spectroscopy	19
*E 135 - 76 Emission Spectroscopy	23

COMPUTATIONS - GENERAL

Recommended Practices for:

- E 29 - 67 (1973) *Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values*
- *E 158 - 66 (1972) *Spectrochemical Computations*
- *E 177 - 71 *Use of Terms Precision and Accuracy as Applied to Measurements of a Property of a Material*
- *E 178 - 75 *Dealing with Outlying Observations*

Suggested Practice for:

- E-2 SM 2-4 *Use of Statistical Methods in Spectrochemical Analysis*

GENERAL PRACTICES

Laboratory Installation, Safety

Recommended Practices for:

- *E 50 - 75 Apparatus, Reagents, and Safety Precautions for Chemical Analysis of Metals (Excerpt Only)
- *E 416 - 71 *Planning and Safe Operation of a Spectrochemical Laboratory*
- *E 528 - 74 Grounding Basic Optical Emission Spectrochemical Equipment (formerly E-2 P2)

Sampling and Sample Preparation

Recommended Practices for:

- E 311 - 67 (1975) *Sampling and Sample Preparation Techniques in Spectrochemical Analysis*
- *E 401 - 70 (1975) *Bonding Thin Spectrochemical Samples and Standards to a Greater Mass of Material*

Proposed Practice for:

- E-2 P9 Sampling Aluminum and Aluminum Alloys for Spectrochemical Analysis .. 99

Suggested Practice for:

- E-2 SM 7-20 Casting and Evaluating Aluminum and Aluminum Alloy Spectrochemical Reference Materials

* Approved as **American National Standard** by the American National Standards Institute.

LIST BY SUBJECTS

PAGE

Atomic Absorption Spectroscopy—General

Proposed Practice for:

E-2 P1 Atomic Absorption Spectrometry

Flame Spectroscopy—General

Suggested Practice for:

†E-2 SM 2-5 Flame Photometric Methods of Spectrochemical Analysis

Equipment Specifications

Recommended Practices for:

*E 130 - 73	Designation of Shapes and Sizes of Graphite Electrodes	13
*E 172 - 67 (1973)	Describing and Specifying the Excitation Source in Emission Spectrochemical Analysis	
*E 356 - 68	Describing and Specifying the Spectrograph	
*E 409 - 71	Description and Performance of Microphotometer	
*E 504 - 74	Selection of Electrode Material Used in Optical Emission Spectroscopy Based on Physical Properties (formerly SM 4-3)	56

Excitation Conditions

Recommended Practice for:

E 406 - 70 (1975) Using Controlled Atmospheres in Spectrochemical Analysis

Photographic Processing and Photometry

Recommended Practices for:

*E 115 - 71	Photographic Processing in Spectrochemical Analysis
*E 116 - 70a	Photographic Photometry in Spectrochemical Analysis
*E 305 - 67 (1972)	Establishing and Controlling Spectrochemical Analytical Curves

SPECTROCHEMICAL ANALYSIS—GENERAL

Suggested Methods for Spectrochemical Analysis of:

E-2 SM 11-2	Unknown Materials by the Powder D-C Arc Semiquantitative Technique	
E-2 SM 11-16	Miscellaneous Materials—Semi-Quantitative Analysis	
E-2 SM 11-19	Miscellaneous Materials by the Powder A-C Arc and Pellet Spark Technique	
E-2 SM 11-22	Semiquantitative Spectrographic Analysis of Miscellaneous Materials by the Graphite Dilution Technique	202
E-2 SM 11-23	Semiquantitative Spectrographic Analysis of Miscellaneous Materials by the Lithium Fluoride-Graphite Dilution Technique	210

SPECTROCHEMICAL ANALYSIS OF METALS

Aluminum and Aluminum Alloys

Methods for Spectrochemical Analysis of:

*E 101 - 67 (1972)	Aluminum and Aluminum-Base Alloy by the Point-to-Plane Spark Technique
*E 227 - 67 (1972)	Aluminum and Its Alloys by the Point-to-Plane Technique Using an Optical Emission Spectrometer

Proposed Method for Spectrochemical Analyses of:

E-2 P5	Aluminum and Its Alloys by the Point-to-Plane, Nitrogen Atmosphere, Spark Technique Using an Optical Emission Spectrometer
--------	--

Suggested Methods for Spectrochemical Analysis of:

E-2 SM 7-2	Aluminum-Base Alloys by the Powder D-C Arc Technique
†E-2 SM 7-9	Aluminum and Its Alloys by the Pin-to-Pin Spark Technique
†E-2 SM 7-12	Aluminum and Its Alloys by the Point-to-Plane Spark Technique Using a Clock-Indicating Photoelectric Spectrometer
†E-2 SM 7-14	Aluminum-Base Alloys by the Solution Rotating Disk-Spark Technique
E-2 SM 7-15	Aluminum-Base Alloys Using an X-Ray Fluorescence Technique
E-2 SM 7-18	Aluminum Alloys for Copper, Magnesium and Zinc Using an Atomic Absorption Spectrometer

† These methods were published in the 1971 edition of *Methods for Emission Spectrochemical Analysis*, but are no longer considered valid.

LIST BY SUBJECTS

	PAGE
Antimony and Antimony Alloys	
<i>Suggested Method for Spectrochemical Analysis of:</i>	
E-2 SM 6-16 <i>Antimony by the Point-to-Plane Spark Technique</i>	
Beryllium and Beryllium Alloys	
<i>Suggested Method for Spectrochemical Analysis of:</i>	
E-2 SM 8-19 <i>Beryllium Metal by Stannic Oxide-Barium Hydroxide-Graphite Carrier Technique</i>	
Cadmium and Cadmium Alloys	
<i>Suggested Methods for Spectrochemical Analysis of:</i>	
E-2 SM 6-10 <i>Bismuth-Cadmium Eutectic Alloy by the Powder D-C Arc Technique</i>	
E-2 SM 6-11 <i>Tin-Cadmium Eutectic Alloy by the Powder D-C Arc Technique</i>	
E-2 SM 6-13 <i>Cadmium Metal by the Solution Residue D-C Arc Technique</i>	
E-2 SM 6-14 <i>Cadmium Metal by the Point-to-Point A-C Arc Technique</i>	
Copper and Copper Alloys	
<i>Methods for Spectrochemical Analysis of:</i>	
*E 414 - 71 <i>Electrolytic Copper by the Briquet D-C Arc Technique</i>	30
*E 486 - 73 <i>Spectrographic Analysis of Admiralty Metal by the Cast Pin and Point-to-Plane Techniques</i>	52
<i>Proposed Methods for Spectrochemical Analysis of:</i>	
E-2 P7 <i>Spectrographic Analysis of Cartridge Brass</i>	89
E-2 P8 <i>Spectrographic Analysis of Unalloyed Copper by the Briquet Technique</i>	93
<i>Suggested Methods for Spectrochemical Analysis of:</i>	
E-2 SM 5-2 <i>Wrought Copper Alloys by the D-C Arc Technique</i>	
E-2 SM 5-3 <i>Bronze by the Solution-Porous Cup-Spark Technique</i>	
E-2 SM 5-4 <i>Tin Bronze by the Cast Pin-Spark Technique</i>	
E-2 SM 5-7 <i>70-30 Cupro-Nickel by the Cast Pin-Spark Technique</i>	
†E-2 SM 5-9 <i>Copper Alloys by the Point-to-Plane Spark Technique</i>	
E-2 SM 5-11 <i>Beryllium-Copper Alloys by the Solution-Rotating Disk-Spark Technique</i>	
E-2 SM 5-12 <i>Copper-Base Alloys by the Powder D-C Arc Technique</i>	
E-2 SM 5-15 <i>Copper by the Oxidized Globule D-C Arc Technique</i>	
E-2 SM 5-16 <i>Spectrographic Analysis of Copper by the Copper Fluoride-Carrier Technique</i>	103
Gallium and Gallium Alloys	
<i>Suggested Methods for Spectrochemical Analysis of:</i>	
E-2 SM 6-21 <i>Indium-Gallium Alloys by the Solution-Graphite Spark Technique</i>	
E-2 SM 6-36 <i>Gallium Metal by the Solution Residue D-C Arc Technique</i>	
E-2 SM 6-46 <i>High-Purity Gallium Metal by the D-C Arc Technique</i>	
E-2 SM 6-51 <i>Spectrographic Analysis of Gallium Arsenide</i>	118
Gold and Gold Alloys	
<i>Suggested Methods for Spectrochemical Analysis of:</i>	
E-2 SM 6-24 <i>Gold-Antimony Alloys by the Solution Residue-Graphite Spark Technique</i>	
E-2 SM 6-26 <i>Gold Alloys by the Solution-Rotating Disk-Spark Technique</i>	
E-2 SM 6-33 <i>Gold-Gallium Alloys by the D-C Arc Technique</i>	
E-2 SM 6-38 <i>Gold by the Pellet D-C Arc Technique</i>	
E-2 SM 6-39 <i>Gold by the Solution Residue D-C Arc Technique</i>	
E-2 SM 6-40 <i>Gold-Phosphorus Alloys for Phosphorus by the Solution Residue D-C Arc Technique</i>	
E-2 SM 6-49 <i>Spectrographic Analysis of Gold, Silver, and Platinum by the Copper Fluoride-Carrier Technique</i>	107
Indium and Indium Alloys	
<i>Suggested Methods for Spectrochemical Analysis of:</i>	
E-2 SM 6-20 <i>Indium Alloys by the Solution-Porous Cup-Spark Technique</i>	
E-2 SM 6-22 <i>Indium Metal by the Powder D-C Arc Technique</i>	

LIST BY SUBJECTS

PAGE

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|-------------|--|--|
| E-2 SM 6-23 | Indium Metal by the Point-to-Plane Condensed Arc Technique | |
| E-2 SM 6-27 | Indium and Its Alloys by the Point-to-Plane Condensed Arc Technique Using an Optical Emission Spectrometer | |

Iron and Iron Alloys

Methods for Spectrochemical Analysis of:

- | | | |
|--------------------|---|----|
| *E 212 - 66 (1972) | Plain-Carbon and Low-Alloy Steel by the Rod-to-Rod Spark Technique | |
| *E 225 - 66 (1972) | Cast Iron for Magnesium by the Solution-Rotating Disk-Spark Technique | |
| *E 281 - 67 (1972) | Carbon and Low-Alloy Steel by the Pellet Technique | |
| *E 282 - 67 (1972) | Plain-Carbon and Low-Alloy Steel by the Point-to-Plane Technique | |
| *E 293 - 68 (1972) | Low-Alloy Steel and Cast Irons Using an X-Ray Fluorescence Spectrometer | |
| E 327 - 68 (1974) | Stainless Type 18-8 Steels by the Point-to-Plane Technique Using an Optical Emission Spectrometer | |
| *E 403 - 70 (1975) | Plain-Carbon and Low-Alloy Steel by the Point-to-Plane Technique Using an Optical Emission Spectrometer | |
| *E 404 - 70 (1975) | Plain-Carbon and Low-Alloy Steel for Boron by the Point-to-Plane Arc Technique | |
| *E 415 - 71 | Carbon and Low-Alloy Steel Using a Vacuum Optical Emission Spectrometer | |
| *E 421 - 71 | High-Purity Iron for Silicon and Aluminum | |
| *E 484 - 73 | Optical Emission Spectrometric Analysis of Steel by the Solution-Reservoir Cup Technique (formerly SM 9-33) | 40 |
| *E 485 - 73 | Optical Emission Vacuum Spectrometric Analysis of Blast Furnace Iron by the Point-to-Plane Technique (formerly SM 9-35) | 48 |
| *E 572 - 76 | X-Ray Emission Spectrometric Analysis of Stainless Steel | 83 |

Proposed Method for Spectrochemical Analysis of:

- | | | |
|--------|---|--|
| E-2 P3 | Low-Alloy and Carbon Steel for Antimony Using an X-Ray Spectrometer | |
|--------|---|--|

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|-------------|--|-----|
| E-2 SM 9-26 | Simultaneous Sampling of Molten Ferrous Alloys for Routine Control of Composition by Spectrochemical and Chemical Analysis | |
| E-2 SM 9-27 | Low-Alloy Steel for Acid-Insoluble Aluminum by the Solution-Porous Cup-Spark Technique | |
| E-2 SM 9-30 | Carbon and Low-Alloy Steel by the Rod-to-Rod Technique Using an Optical Emission Spectrometer | |
| E-2 SM 9-32 | Iron-Base Materials Using a Spectroscope | |
| E-2 SM 9-36 | Sampling Molten Blast Furnace Iron for Spectrochemical Analysis | |
| E-2 SM 9-37 | Preparing Sheet Steel Samples for Point-to-Point Spectrochemical Analysis | |
| E-2 SM 9-38 | Carbon and Low-Alloy Steels by Argon Atmosphere, Point-to-Plane Spark Technique Using an Optical Emission Spectrometer | |
| E-2 SM 9-39 | Non-Metallic Inclusions Extracted from Steel | |
| E-2 SM 9-40 | Preparation of Disk Specimens of Steel and Iron for Spectrochemical Analysis by Remelting | |
| E-2 SM 9-42 | X-Ray Emission Spectrometric Analysis of Standard Ferromanganese | 148 |

Suggested Practices for:

- | | | |
|-------------|--|--|
| E-2 SM 9-31 | Sampling Molten Steel to Obtain Pin Specimens for Spectrochemical Analysis | |
| E-2 SM 9-41 | Sampling Low-Alloy and Stainless Steel to Obtain Flat Specimens for Spectrochemical Analysis | |

Lead and Lead Alloys

Method for Spectrochemical Analysis of:

- | | | |
|--------------------|--|--|
| *E 117 - 64 (1976) | Pig Lead by the Point-to-Plane Spark Technique | |
|--------------------|--|--|

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|-------------|--|--|
| E-2 SM 6-1 | Lead-Base Alloys by the Powder D-C Arc Technique | |
| E-2 SM 6-2 | Pig Lead by the Pellet D-C Arc Technique | |
| E-2 SM 6-5 | Lead-Tin Solders by the Powder D-C Arc Technique | |
| E-2 SM 6-6 | Antimonial-Lead Alloys by the Point-to-Plane Spark Technique | |
| E-2 SM 6-7 | Lead-Base Bearing Alloys by the Cast Pin-Spark Technique | |
| E-2 SM 6-8 | Type Metal Alloys by the Point-to-Plane Spark Technique | |
| E-2 SM 6-19 | Lead and Its Alloys by the Point-to-Plane Condensed Arc Technique Using a Recording Photoelectric Spectrometer | |
| E-2 SM 6-25 | Lead and Its Alloys by the Point-to-Plane Argon Atmosphere, Spark Technique Using an Optical Emission Spectrometer | |

LIST BY SUBJECTS

PAGE

Suggested Methods for Spectrochemical Analysis of:

- E-2 SM 6-28 *Gallium-Lead and Antimony-Lead Alloys by the Solution-Porous Cup-Spark Technique*
 E-2 SM 6-45 *Tin-Lead Solder by the Point-to-Plane Spark Technique*
 E-2 SM 6-47 *Tin and Lead Alloys by the Point-to-Plane Spark Technique*

Magnesium and Magnesium Alloys

Method for Spectrochemical Analysis of:

- *E 226 - 67 (1974) *Magnesium Alloys for Calcium by Flame Photometry*

Suggested Methods for Spectrochemical Analysis of:

- E-2 SM 7-13 *Magnesium-Base Alloys by the Point-to-Plane Spark Technique*
 †E-2 SM 7-16 *Magnesium and Its Alloys by the Pin-to-Pin Spark Technique Using an Optical Emission Spectrometer*
 E-2 SM 7-17 *Magnesium and Its Alloys by the Point-to-Plane Spark Technique Using an Optical Emission Spectrometer*
 E-2 SM 7-19 *Magnesium Alloys for Zinc, Manganese, and Copper Using an Atomic Absorption Spectrometer*

Molybdenum and Molybdenum Alloys

Suggested Methods for Spectrochemical Analysis of:

- †E-2 SM 8-16 *Molybdenum by the Powder D-C Arc Technique*
 E-2 SM 8-21 *Optical Emission Spectrometric and Spectrographic Analysis of Molybdenum* 135

Nickel and Nickel Alloys

Methods for Spectrochemical Analysis of:

- *E 129 - 74 *Spectrographic Analysis of Thermionic Nickel Alloys by the Powder Technique* 8
 E 383 - 69 (1974) *Nickel-Tungsten Alloys for Tungsten Using an X-Ray Spectrometer*
 *E 483 - 74 *Spectrographic Analysis of Nickel Alloys by the Silver Chloride-Lithium Fluoride Carrier Technique (formerly E-2 P4)* 35

Suggested Method for Spectrochemical Analysis of:

- E-2 SM 5-10 *Nickel-Base High-Temperature Alloys by the Point-to-Plane Spark Technique*

Palladium

Suggested Methods for Spectrochemical Analysis of:

- E-2 SM 6-31 *Palladium by the Pellet-Spark and D-C Arc Technique*
 E-2 SM 6-48 *Palladium by the D-C Arc Technique*

Platinum

Suggested Methods for Spectrochemical Analysis of:

- E-2 SM 6-35 *Platinum by the Pellet D-C Arc Technique*
 E-2 SM 6-49 *Spectrographic Analysis of Gold, Silver, and Platinum by the Copper Fluoride-Carrier Technique* 107

Plutonium

Suggested Method for Spectrochemical Analysis of:

- E-2 SM 6-37 *Plutonium by the Ion Exchange-Graphite Spark Technique*

Rhenium

Suggested Method for Spectrochemical Analysis of:

- E-2 SM 8-17 *Rhenium by the Solution Residue-D-C Arc Technique*

Rhodium

Suggested Method for Spectrochemical Analysis of:

- E-2 SM 6-32 *Rhodium by the Pellet Technique*

Silver

Method for Spectrochemical Analysis of:

- E 378 - 68 (1972) *Silver by the Powder-D-C Arc Technique*

LIST BY SUBJECTS

PAGE

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|-------------|--|-----|
| E-2 SM 6-42 | 99.99 Grade Fine Silver by the Point-to-Point D-C Arc Technique | |
| E-2 SM 6-49 | Spectrographic Analysis of Gold, Silver, and Platinum by the Copper Fluoride-Carrier Technique | 107 |

Tantalum

Suggested Method for Spectrochemical Analysis of:

- | | |
|-------------|--|
| E-2 SM 8-15 | Tantalum by the Silver Chloride-Graphite Carrier-D-C Arc Technique |
|-------------|--|

Tin and Tin Alloys

Method for Spectrochemical Analysis of:

- *E 51 - 67 (1972) Tin Alloys by the Powder D-C Arc Technique

Suggested Methods for Spectrochemical Analysis of:

- | | |
|-------------|---|
| E-2 SM 6-4 | Tin-Base Alloys by the Powder D-C Arc Technique |
| E-2 SM 6-9 | Tin by the Cast Pin-Spark Technique |
| E-2 SM 6-47 | Tin and Lead Alloys by the Point-to-Plane Spark Technique |

Titanium and Titanium Alloys

Method for Spectrochemical Analysis of:

- | | | |
|-------------|---|----|
| *E 539 - 75 | X-Ray Emission Spectrometric Analysis of 6Al-4V Titanium Alloy (formerly SM 8-20) | 77 |
|-------------|---|----|

Suggested Methods for Spectrochemical Analysis of:

- | | |
|-------------|---|
| E-2 SM 8-7 | Titanium Metal by the Powder D-C Arc Technique |
| E-2 SM 8-8 | Titanium and Titanium Alloys by the Solution-Porous Cup-Spark Technique |
| E-2 SM 8-9 | Aluminum-Chromium-Titanium Alloy by the Point-to-Plane Spark Technique |
| E-2 SM 8-10 | Titanium Sponge and Metal by the Solution-Rotating Disk-Spark Technique |
| E-2 SM 8-11 | Titanium Alloys by the Solution-Rotating Disk-Spark Technique |
| E-2 SM 8-14 | Titanium Alloys by the Point-to-Plane Spark Technique |

Tungsten and Tungsten Alloys

Method for Spectrochemical Analysis of:

- *E 383 - 69 (1974) Nickel-Tungsten Alloys for Tungsten Using an X-Ray Spectrometer

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|--------------|---|-----|
| †E-2 SM 8-18 | Tungsten by the Powder A-C and D-C Arc Techniques | |
| E-2 SM 8-22 | Optical Emission Spectrometric and Spectrographic Analysis of Tungsten .. | 140 |

Zinc and Zinc Alloys

Method for Spectrochemical Analysis of:

- *E 27 - 64 (1976) Zinc-Base Alloys and High Grade Zinc by the Solution Residue D-C Arc Technique

Suggested Methods for Spectrochemical Analysis of:

- | | |
|-------------|---|
| E-2 SM 6-12 | Zinc-Base Alloys by the Powder D-C Arc Technique |
| E-2 SM 6-15 | Zinc Die-Casting Metal and High-Purity Zinc by the Cast-Pin and Point-to-Plane Techniques |
| E-2 SM 6-18 | Zinc and Its Alloys by the Point-to-Plane Spark and Condensed Arc Techniques Using a Recording Photoelectric Spectrometer |
| E-2 SM 6-30 | Zinc by the Solution-Rotating Disk-Spark Technique |
| E-2 SM 6-34 | Zinc and Its Alloys by the Solution-Rotating Disk-Spark Technique |
| E-2 SM 6-41 | Prime Western Zinc Using an X-Ray Spectrometer |

Zirconium and Zirconium Alloys

Proposed Method for Spectrochemical Analysis of:

- | | |
|--------|---|
| E-2 P6 | Zirconium and Its Alloys by the Point-to-Plane Technique Using an Optical Emission Spectrograph or Spectrometer |
|--------|---|

Suggested Methods for Spectrochemical Analysis of:

- | | |
|-------------|---|
| E-2 SM 8-12 | Zirconium by the Barium Fluoride-Graphite Carrier-D-C Arc Technique |
| E-2 SM 8-13 | Zirconium by the Silver Chloride Carrier-D-C Arc Technique |

LIST BY SUBJECTS

PAGE

SPECTROCHEMICAL ANALYSIS OF NONMETALLIC MATERIALS

General

Suggested Methods for Spectrochemical Analysis of:

E-2 SM 10-9	Ceramics and Other Nonmetallic Materials by the Powder D-C Arc Technique	
E-2 SM 10-28	Flame Emission Determination of Sodium and Potassium in Raw Materials and By-Products of Portland Cement Plants	160
E-2 SM 10-32	Atomic Absorption Determination of Sodium and Potassium in Portland Cement Raw Materials and Kiln Dust	187
E-2 SM 10-33	X-Ray Emission Spectrometric Analysis of Aluminosilicate Raw Materials and Refractories by the Lithium Tetraborate-Lanthanum Oxide-Fusion Technique	193
E-2 SM 11-2	Unknown Materials by the Powder D-C Arc Semiquantitative Technique	
E-2 SM 11-16	Semi-Quantitative Spectrochemical Analysis of Miscellaneous Materials	
E-2 SM 11-19	Miscellaneous Materials by the Powder A-C Arc and Pellet Spark Techniques	
E-2 SM 11-22	Semiquantitative Spectrographic Analysis of Miscellaneous Materials by the Graphite Dilution Technique	202
E-2 SM 11-23	Semiquantitative Spectrographic Analysis of Miscellaneous Materials by the Lithium Fluoride-Graphite Dilution Technique	210

Alkalies

Suggested Method for Spectrochemical Analysis of:

E-2 SM 10-27	Spectrographic Analysis of Sodium Chloride and Other Sodium Compounds by the Solution Residue Technique (replaces SM 10-15 and SM 10-23)	153
--------------	--	-----

Carbonates

Method for Spectrochemical Analysis of:

*F 102-71	Emissive Carbonates by the Powder D-C Arc Technique	
-----------	---	--

Cement

Suggested Methods for Spectrochemical Analysis of:

E-2 SM 10-16	Cement for Manganic, Sodium and Potassium Oxides by the Flame Photometer Technique	
E-2 SM 10-20	Cement Raw Mix by the Lithium Tetraborate Fusion Technique Using an X-Ray Spectrometer	
E-2 SM 10-26	Portland Cement by Fusion with Lithium Tetraborate Using an X-Ray Spectrometer	
E-2 SM 10-28	Flame Emission Determination of Sodium and Potassium in Raw Materials and By-Products of Portland Cement Plants	160
E-2 SM 10-30	Neutron Activation Analysis of Dry-Process Portland Cement Raw Mix	175
E-2 SM 10-32	Atomic Absorption Determination of Sodium and Potassium in Portland Cement Raw Materials and Kiln Dust	187
E-2 SM 10-34	X-Ray Emission Spectrometric Analysis of Portland Cement by the Energy-Dispersive Technique	197

Glass, Ceramics, and Refractory Materials

Suggested Methods for Spectrochemical Analysis of:

E-2 SM 10-1	Silica Refractories by the Powder-Intermittent Arc Technique	
E-2 SM 10-10	Silica Brick and Glass Sand by the Powder D-C Arc Technique	
E-2 SM 10-13	Glass for Alkali Elements by Flame Photometry	
E-2 SM 10-14	Alumina Ceramic Materials by the Powder D-C Arc Technique	
E-2 SM 10-18	Alumina by the Powder D-C Arc Technique Using an Optical Emission Spectrometer	
E-2 SM 10-19	Titanium Oxide, Aluminum Oxide, and Zirconium Oxide for Alkali Oxides by the Recording Flame Photometer Technique	
E-2 SM 10-22	Calcined Alumina by the Powder D-C Arc Technique Using an Optical Emission Spectrometer	
E-2 SM 10-24	Glasses and Ceramics for Magnesium and Zinc Using an Atomic Absorption Spectrometer	
E-2 SM 10-29	X-Ray Emission Spectrometric Analysis of Calcite Soda-Lime Glass	168
E-2 SM 10-31	Atomic Absorption Analysis of Glass	181
E-2 SM 10-33	X-Ray Emission Spectrometric Analysis of Aluminosilicate Raw Materials and Refractories by the Lithium Tetraborate-Lanthanum Oxide-Fusion Technique	193
E-2 SM 11-15	Silicates by the Rotating Disk Technique Using an Optical Emission Spectrometer	

LIST BY SUBJECTS

PAGE

Ores, Rocks, and Minerals

Method for Spectrochemical Analysis of:

- *E 400 - 71 *Ores, Minerals, and Rocks by the Fire Assay Preconcentration-Spark Technique*

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|--------------|---|-----|
| E-2 SM 10-28 | Flame Emission Determination of Sodium and Potassium in Raw Materials and By-Products of Portland Cement Plants | 160 |
| E-2 SM 11-9 | Lithium-Bearing Ores for Lithium, Sodium and Iron by the Solution Residue A-C Arc Technique | |
| E-2 SM 11-11 | Cerium Minerals for Rare Earths and Thorium by the Powder D-C Arc Technique | |
| E-2 SM 11-13 | Rocks and Minerals Using an X-Ray Spectrometer | |
| E-2 SM 11-14 | Iron Ore by the Fusion-Briquet Technique Using an Optical Emission Spectrometer | |
| E-2 SM 11-21 | Geologic Material by the Fire-Assay Preconcentration Intermittent D-C Arc Technique | |

Miscellaneous Metallic Oxides

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|--------------|--|-----|
| E-2 SM 6-50 | Spectrographic Analysis of Thorium Oxide by the Gallium Oxide-Carrier Technique | 113 |
| E-2 SM 6-52 | Optical Emission Spectrometric Analysis of Plutonium Dioxide by the Silver Chloride-Lithium Fluoride-Carrier Technique | 124 |
| E-2 SM 8-23 | Spectrographic Determination of Hafnium in Zirconium Dioxide | 145 |
| E-2 SM 10-18 | Alumina by the Powder D-C Arc Technique Using an Optical Emission Spectrometer | |
| E-2 SM 10-19 | Titanium Oxide, Aluminum Oxide, and Zirconium Oxide for Alkali Oxides by the Recording Flame Photometer Technique | |
| E-2 SM 10-22 | Calcined Alumina by the Powder D-C Arc Technique Using an Optical Emission Spectrometer | |
| E-2 SM 10-25 | Beryllia Oxide for Trace Elements by the D-C Arc Technique | |
| E-2 SM 11-1 | Cobaltic Oxide by the Powder D-C Arc Technique | |

Petroleum Products and Other Organic Materials

Methods for Spectrochemical Analysis of:

- *D 1318 - 64 (1973) *Sodium in Residual Fuel Oil (Flame Photometric Method)*
 *D 1638 - 74 *Sodium and Potassium in Polyols by Flame Photometry (Excerpt)*
 *D 2599 - 71 (1976) *Lead in Gasoline by X-Ray Spectrometer*
 *D 2622 - 67 (1972) *Sulfur in Petroleum Products (X-Ray Spectrometry)*
 *D 2929 - 69 (1975) *Sulfur Content of Cellulose Materials by X-Ray Fluorescence*

Proposed Methods for Spectrochemical Analysis of:

- | | |
|---------|--|
| †D-2 P1 | Wear and Contaminant Elements in Used Diesel Lubrication Oils Using a Rotating-Disk Electrode Technique |
| †D-2 P2 | Wear Metals in Used Diesel Lubricating Oils Using an Ashing Procedure |
| †D-2 P3 | Wear Metals in Used Diesel Lubricating Oils by a Rotating-Disk Electrode Technique Using Direct-Reading Spectrometer |

Suggested Method for Spectrochemical Analysis of:

- | | |
|--------------|---|
| †E-2 SM 12-1 | Polyethylene for Chromium Using an Atomic Absorption Spectrometer |
|--------------|---|

Steel-Making Slags and Sinter

Suggested Methods for Spectrochemical Analysis of:

- | | | |
|--------------|---|-----|
| E-2 SM 11-6 | Slags by the Powder D-C Arc Technique | |
| E-2 SM 11-10 | Blast-Furnace and Open-Hearth Sinter by the Pellet-Condensed Arc Technique | |
| E-2 SM 11-20 | Slags by the Fusion-Briquet Technique Using an Optical Emission Spectrometer | |
| E-2 SM 11-24 | Atomic Absorption Analysis of Slags and Sinters by the Lithium Tetraborate-Fusion Technique | 214 |

Uranium Oxide

Method for Spectrochemical Analysis of:

- *E 402 - 70 (1976) *Uranium Oxide by Gallium Oxide Carrier D-C Arc Technique*

LIST BY SUBJECTS

PAGE

Suggested Methods for Spectrochemical Analysis of:

- | | |
|-------------|--|
| E-2 SM 6-43 | <i>Impurities in Uranium Oxide by the Silver Chloride-Strontium Fluoride Carrier D-C Arc Technique</i> |
| E-2 SM 6-44 | <i>Semi-Quantitative Spectrochemical Analysis of Uranium Oxide by the D-C Arc Technique</i> |

Water, Water-Formed Deposits, Solutions

Methods for Spectrochemical Analysis of:

- *D 1428 - 64 (1971) *Sodium and Potassium in Industrial Water and Water-Formed Deposits by Flame Photometry*
- *D 2332 - 68 (1973) *Water-Formed Deposits by X-Ray Fluorescence*
- *D 2576 - 70 (1976) *Metals in Industrial Water and Industrial Waste Water by Atomic Absorption Spectrometry*

Suggested Methods for Spectrochemical Analysis of:

- | | |
|--------------|--|
| E-2 SM 11-17 | <i>Water by the Residue Technique</i> |
| E-2 SM 11-18 | <i>Water by the Rotating Disk Technique Using an Optical Emission Spectrometer</i> |

APPENDIXES

- Appendix I—Selected References on Analysis of Metals Using Emission Spectroscopy
- Appendix II—Selected References on Analysis of Glass, Ceramics, Alkalies, and Cementitious Materials Using Atomic Emission And Absorption Analysis
- Appendix III—Selected References on Analysis of Organic Materials Using Atomic Emission and Absorption Spectroscopy
- Appendix IV—Related Publications
- Officers of Committee E-2 and Its Subcommittees
- Index
- ASTM Membership Blank

OTHER ASTM METHODS USING SPECTROCHEMICAL ANALYSIS

The boldface numbers in parentheses refer to the part of the *Annual Book of ASTM Standards* in which the methods appear.

Atomic Absorption Analysis

- C 169 Chemical Analysis of Soda-Lime and Borosilicate Glass (17)
- C 738 Test for Lead and Cadmium Extracted from Glazed Ceramic Surfaces (17)
- D 511 Test for Calcium Ion and Magnesium Ion in Water (31)
- D 1224 Test for Zinc and Cadmium in Paper (20)
- D 2331 Testing Water-Formed Deposits (31)
- D 2576 Test for Metals in Water and Waste Water by Atomic Absorption Spectrophotometers (31)
- D 2788 Test for Trace Metals in Gas Turbine Fuels (Atomic Absorption Method) (24)
- D 3223 Test for Total Mercury in Water (31)
- D 3237 Test for Lead in Gasoline by Atomic Absorption Spectrometry (25)
- D 3327 Analysis of Selected Elements in Waterborne Oils (31)
- D 3335 Test for Low Concentrations of Lead and Cadmium in Paint by Atomic Absorption Spectroscopy (27)
- D 3352 Test for Strontium Ion in Brackish Water, Sea Water, and Brines (31)
- D 3372 Test for Molybdenum in Water (31)
- D 3413 Test for Lead (Inorganic) in Workplace Atmospheres by Atomic Absorption Spectrometry (26)
- E 34 Chemical Analysis of Aluminum and Aluminum-Base Alloys (12)
- E 350 Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron (12)
- E 351 Chemical Analysis of Cast Iron—All Types (12)
- E 352 Chemical Analysis of Tool Steels and Other Similar Medium- and High-Alloy Steels (12)
- E 353 Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys (12)
- E 396 Chemical Analysis of Cadmium Metal (12)
- E 449 Analysis of Calcium Chloride Types I and II (30)
- E 506 Test for Mercury in Liquid Chlorine (30)
- E 507 Test for Aluminum in Iron Ores by Atomic Absorption Spectroscopy (12)
- E 508 Test for Calcium and Magnesium in Iron Ores by Atomic Absorption Spectroscopy (12)
- E 538 Test for Mercury in Caustic Soda (Sodium Hydroxide) (30)

Flame Emission Analysis

- C 114 Chemical Analysis of Hydraulic Cement (13)
- C 571 Chemical Analysis of Carbon and Carbon-Ceramic Refractories (17)
- C 573 Chemical Analysis of Fireclay and High-Alumina Refractories (17)
- C 575 Chemical Analysis of Silica Refractories (17)
- D 1318 Test for Sodium in Residual Fuel Oil (Flame Photometric Method) (23)
- D 1428 Test for Sodium and Potassium in Water and Water-Formed Deposits by Flame Photometry (31)
- D 2849 Testing Urethane Foam Polyol Raw Materials (36)
- D 3340 Test for Lithium and Sodium in Lubricating Greases by Flame Photometer (25)
- E 226 Spectrochemical Analysis of Magnesium Alloys for Calcium by Flame Photometry (12)

Spectrographic Analysis

- C 574 Chemical Analysis of Magnesite and Dolomite Refractories (17)
- C 696 Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Uranium Dioxide Powders and Pellets (45)
- C 697 Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Plutonium Dioxide Powders and Pellets (45)
- C 698 Chemical, Mass Spectrometric, and Spectrochemical Analysis of Nuclear-Grade Mixed Oxides ((U, Pu)O₂) (45)
- C 699 Chemical, Mass Spectrometric, and Spectrochemical Analysis of Beryllium Oxide Powders (45)
- C 758 Chemical, Mass Spectrometric, Spectrochemical, Nuclear, and Radiochemical Analysis of Nuclear-Grade Plutonium Metal (45)