

NAT'L INST. OF STAND & TECH
3

NBS
PUBLICATIONS

A11107 258670



NBS SPECIAL PUBLICATION 260-78

U.S. DEPARTMENT OF COMMERCE/National Bureau of Standards

Standard Reference Materials:

A Standard Reference Material Containing Nominally Thirty Percent Austenite (SRM 487)

QC
100
.U57
No. 260-73
1982
c. 2

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards¹ was established by an act of Congress on March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau's technical work is performed by the National Measurement Laboratory, the National Engineering Laboratory, and the Institute for Computer Sciences and Technology.

THE NATIONAL MEASUREMENT LABORATORY provides the national system of physical and chemical and materials measurement; coordinates the system with measurement systems of other nations and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce; conducts materials research leading to improved methods of measurement, standards, and data on the properties of materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; develops, produces, and distributes Standard Reference Materials; and provides calibration services. The Laboratory consists of the following centers:

Absolute Physical Quantities² — Radiation Research — Chemical Physics — Analytical Chemistry — Materials Science

THE NATIONAL ENGINEERING LABORATORY provides technology and technical services to the public and private sectors to address national needs and to solve national problems; conducts research in engineering and applied science in support of these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; develops engineering data and measurement capabilities; provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user. The Laboratory consists of the following centers:

Applied Mathematics — Electronics and Electrical Engineering² — Manufacturing Engineering — Building Technology — Fire Research — Chemical Engineering²

THE INSTITUTE FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides scientific and technical services to aid Federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in Government operations in accordance with Public Law 89-306 (40 U.S.C. 759), relevant Executive Orders, and other directives; carries out this mission by managing the Federal Information Processing Standards Program, developing Federal ADP standards guidelines, and managing Federal participation in ADP voluntary standardization activities; provides scientific and technological advisory services and assistance to Federal agencies; and provides the technical foundation for computer-related policies of the Federal Government. The Institute consists of the following centers:

Programming Science and Technology — Computer Systems Engineering.

¹Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Washington, DC 20234.

²Some divisions within the center are located at Boulder, CO 80303.

Standard Reference Materials:

A Standard Reference Material Containing Nominally Thirty Percent Austenite (SRM 487)

NBS Special publication 487

G. E. Hicho and E. E. Eaton

National Bureau of Standards
Library, E-01 Admin. Bldg.

OCT 25 1982

Fracture and Deformation Division
Center for Materials Science
National Measurement Laboratory
National Bureau of Standards
Washington, DC 20234



U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director

Issued September 1982

Library of Congress Catalog Card Number: 82-600587

National Bureau of Standards Special Publication 260-78
Natl. Bur. Stand. (U.S.), Spec. Publ. 260-78, 25 pages (Sept. 1982)
CODEN: XNBSAV

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1982

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Price \$3.50
(Add 25 percent for other than U.S. mailing)

PREFACE

Standard Reference Materials (SRM's) as defined by the National Bureau of Standards are well-characterized materials produced in quantity and certified for one or more physical or chemical properties. They are used to assure the accuracy and compatibility of measurements throughout the Nation. SRM's are widely used as primary standards in many diverse fields in science, industry, and technology, both within the United States and throughout the world. They are also used extensively in the fields of environmental and clinical analysis. In many applications, traceability of quality control and measurement processes to the national measurement system are carried out through the mechanism and use of SRM's. For many of the Nation's scientists and technologists it is therefore of more than passing interest to know the details of the measurements made at NBS in arriving at the certified values of the SRM's produced. An NBS series of papers, of which this publication is a member, called the NBS Special Publication - 260 Series, is reserved for this purpose.

This 260 Series is dedicated to the dissemination of information on different phases of the preparation, measurement, certification and use of NBS-SRM's. In general, much more detail will be found in these papers than is generally allowed, or desirable, in scientific journal articles. This enables the user to assess the validity and accuracy of the measurement processes employed, to judge the statistical analysis, and to learn details of techniques and methods utilized for work entailing the greatest care and accuracy. These papers also should provide sufficient additional information not found on the certificate so that new applications in diverse fields not foreseen at the time the SRM was originally issued will be sought and found.

Inquiries concerning the technical content of this paper should be directed to the authors. Other questions concerned with the availability, delivery, price, and so forth will receive prompt attention from:

Office of Standard Reference Materials
National Bureau of Standards
Washington, D.C. 20234

George A. Uriano, Chief
Office of Standard Reference Materials

OTHER NBS PUBLICATIONS IN THIS SERIES

Catalog of NBS Standard Reference Materials (1981-83 edition), R. W. Seward, ed., NBS Spec. Publ. 260 (November 1981).

Michaelis, R. E., and Wyman, L. L. Standard Reference Materials: Preparation of White Cast Iron Spectrochemical Standards. NBS Misc. Publ. 260-1 (June 1964). COM74-11061**

Michaelis, R. E., Wyman, L. L., and Flitsch, R. Standard Reference Materials: Preparation of NBS Copper-Base Spectrochemical Standards. NBS Misc. Publ. 260-2 (October 1964). COM74-11063**

Michaelis, R. E., Yakowitz, H., and Moore, G. A. Standard Reference Materials: Metallographic Characterization of an NBS Spectrometric Low-Alloy Steel Standard. NBS Misc. Publ. 260-3 (October 1964). COM74-11060**

Hague, J. L. Mears, T. W., and Michaelis, R. E., Standard Reference Materials: Sources of Information, NBS Misc. Publ. 260-4 (February 1965). COM74-11059

Alvarez, R., and Flitsch, R., Standard Reference Materials: Accuracy of Solution X-Ray Spectrometric Analysis of Copper-Base Alloys. NBS Misc. Publ. 260-5 (March 1965). PB168068**

Shultz, J. I., Standard Reference Materials: Methods for the Chemical Analysis of White Cast Iron Standards, NBS Misc. Publ. 260-6 (July 1975). COM74-11068**

Bell, R. K., Standard Reference Materials: Methods for the Chemical Analysis of NBS Copper-Base Spectrochemical Standards. NBS Misc. Publ. 260-7 (October 1965). COM74-11067**

Richmond, M.S., Standard Reference Materials: Analysis of Uranium Concentrates at the National Bureau of Standards. NBS Misc. Publ. 260-8 (December 1965). COM74-11066**

Anspaeh, S. C., Cavallo, L. M., Garfinkel, S. B., Hutchinson, J. M. R., and Smith, C. N., Standard Reference Materials: Half Lives of Materials Used in the Preparation of Standard Reference Materials of Nineteen Radioactive Nuclides Issued by the National Bureau of Standards. NBS Misc. Publ. 260-9 (November 1965). COM74-11065**

Yakowitz, H., Vieth, D. L., Heinrich, K. F. J., and Michaelis, R. E., Standard Reference Materials: Homogeneity Characterization on NBS Spectrometric Standards II: Cartridge Brass and Low-Alloy Steel, NBS Misc. Publ. 260-10 (December 1965). COM74-11064**

Napolitano, A., and Hawkins, E. G., Standard Reference Materials: Viscosity of Standard Lead-Silica Glass, NBS Misc. Publ. 260-11 (November 1966). NBS Misc. Publ. 260-11**

Yakowitz, H., Vieth, D. L., and Michaelis, R. E., Standard Reference Materials: Homogeneity Characterization of NBS Spectrometric Standards III: White Cast Iron and Stainless Steel Powder Compact, NBS Misc. Publ. 260-12 (September 1966). NBS Misc. Publ. 260-12**

Spijkerman, J. L., Snediker, D. K., Ruegg, F. C., and DeVoe, J. R., Standard Reference Materials: Mossbauer Spectroscopy Standard for the Chemical Shift of Iron Compounds, NBS Misc. Publ. 260-13 (July 1967). NBS Misc. Publ. 260-13**

Menis, O., and Sterling, J. T., Standard Reference Materials: Determination of Oxygen in Ferrous Materials - SRM 1090, 1091, and 1092, NBS Misc. Publ. 260-14 (September 1966). NBS Misc. Publ. 260-14**

Passaglia, E., and Shouse, P. J. Standard Reference Materials: Recommended Method of Use of Standard Light-Sensitive Paper for Calibrating Carbon Ares Used in Testing Textiles for Colorfastness to Light, NBS Misc. Publ. 260-15 (June 1967). (Replaced by NBS Spec. Publ. 260-41.)

Yakowitz, H., Michaelis, R. E., and Vieth, D. L., Standard Reference Materials: Homogeneity Characterization of NBS Spectrometric Standards IV: Preparation and Microprobe Characterization of W-20% Mo Alloy Fabricated by Powder Metallurgical Methods, NBS Spec. Publ. 260-16 (January 1969). COM74-11062**

Catanzaro, E. J., Champion, C. E., Garner, E. L., Marinenko, G., Sappenfield, K. M., and Shields, W. R. Standard Reference Materials: Boric Acid: Isotopic and Assay Standard Reference Materials, NBS Spec. Publ. 260-17 (February 1970). Out of Print

Geller, S. B., Mantek, P.A., and Cleveland, N. G., Standard Reference Materials: Calibration of NBS Secondary Standard Magnetic Tape (Computer Amplitude Reference) Using the Reference Tape Amplitude Measurement "Process A," NBS Spec. Publ. 260-18 (November 1969). (See NBS Spec. Publ. 260-29.)

Paule, R. C., and Mandel, J., Standard Reference Materials: Analysis of Interlaboratory Measurements on the Vapor Pressure of Gold (Certification of Standard Reference Material 745). NBS Spec. Publ. 260-19 (January 1970). PB190071**

Paule, R. C., and Mandel, J., Standard Reference Materials: Analysis of Interlaboratory Measurements on the Vapor Pressures of Cadmium and Silver, NBS Spec. Publ. 260-21 (January 1971). COM74-11359**

Yakowitz, H., Fiori, C. E., and Michaelis, R. E., Standard Reference Materials: Homogeneity Characterization of Fe-3 Si Alloy, NBS Spec. Publ. 260-22 (February 1971). COM74-11357**

Napolitano, A., and Hawkins, E. G., Standard Reference Materials: Viscosity of a Standard Borosilicate Glass, NBS Spec. Publ. 260-23 (December 1970). COM71-00157**

Sappenfield, K. M., Marineko, G., and Hague, J. L., Standard Reference Materials: Comparison of Redox Standards, NBS Spec. Publ. 260-24 (January 1972). COM72-50058**

Hicho, G. E., Yakowitz, H., Rasberry, S. D., and Michaelis, R. E., Standard Reference Materials: A Standard Reference Material Containing Nominally Four Percent Austenite, NBS Spec. Publ. 260-25 (February 1971). COM74-11356**

Martin, J. F., Standard Reference Materials: National Bureau of Standards-US Steel Corporation Joint Program for Determining Oxygen and Nitrogen in Steel, NBS Spec. Publ. 260-26 (February 1971). 85 cents* PB81176620

Garner, E. L., Machlan, L. A., and Shields, W. R., Standard Reference Materials: Uranium Isotopic Standard Reference Materials, NBS Spec. Publ. 260-27 (April 1971). COM74-11358**

Heinrich, K. F. J., Myklebust, R. L., Rasberry, S. D., and Michaelis, R. E., Standard Reference Materials: Preparation and Evaluation of SRM's 481 and 482 Gold-Silver and Gold-Copper Alloys for Microanalysis, NBS Spec. Publ. 260-28 (August 1971). COM71-50365**

Geller, S. B., Standard Reference Materials: Calibration of NBS Secondary Standard Magnetic Tape (Computer Amplitude Reference) Using the Reference Tape Amplitude Measurement "Process A-Model 2," NBS Spec. Publ. 260-29 (June 1971). COM71-50282

Gorozhanina, R. S., Freedman, A. Y., and Shaievitch, A. B. (translated by M. C. Selby), Standard Reference Materials: Standard Samples Issued in the USSR (A Translation from the Russian). NBS Spec. Publ. 260-30 (June 1971). COM71-50283**

Hust, J. G., and Sparks, L. L., Standard Reference Materials: Thermal Conductivity of Electrolytic Iron SRM 734 from 4 to 300 K, NBS Spec. Publ. 260-31 (November 1971). COM71-50563**

Mavrodineanu, R., and Lazar, J. W., Standard Reference Materials: Standard Quartz Cuvettes, for High Accuracy Spectrophotometry, NBS Spec. Publ. 260-32 (December 1973). 55 cents* SN003-003-01213-1

Wagner, H. L., Standard Reference Materials: Comparison of Original and Supplemental SRM 705, Narrow Molecular Weight Distribution Polystyrene, NBS Spec. Publ. 260-33 (May 1972). COM72-50526**

Sparks, L. L., and Hust, J. G., Standard Reference Materials: Thermoelectric Voltage, NBS Spec. Publ. 260-34, (April 1972). COM72-50371**

Sparks, L. L., and Hust, J. G., Standard Reference Materials: Thermal Conductivity of Austenitic Stainless Steel, SRM 735 from 5 to 280 K, NBS Spec. Publ. 260-35 (April 1972). 35 cents* COM72-50368**

Cal, J. P., Mandel, J., Moore, L. J., and Young, D. S., Standard Reference Materials: A Referee Method for the Determination of Calcium in Serum, NBS SRM 915, NBS Spec. Publ. 260-36 (May 1972). COM72-50527**

Shultz, J. I., Bell, R. K., Rains, T. C., and Menis, O., Standard Reference Materials: Methods of Analysis of NBS Clay Standards, NBS Spec. Publ. 260-37 (June 1972). COM72-50692**

Richmond, J. C., and Hsia, J. J., Standard Reference Materials: Preparation and Calibration of Standards of Spectral Specular Reflectance, NBS Spec. Publ. 260-38 (May 1972). COM72-50528**

Clark, A. F., Denson, V.A., Hust, J. G., and Powell, R. L., Standard Reference Materials The Eddy Current Decay Method for Resistivity Characterization of High-Purity Metals, NBS Spec. Publ. 260-39 (May 1972). COM72-50529**

McAdie, H. G., Garn, P.D., and Menis, O., Standard Reference Materials: Selection of Thermal Analysis Temperature Standards Through a Cooperative Study (SRM 758, 759, 760), NBS Spec. Publ. 260-40 (August 1972.) COM72-50776**

Wood, L. A., and Shouse, P. J., Standard Reference Materials: Use of Standard Light-Sensitive Paper for Calibrating Carbon Arcs Used in Testing Textiles for Colorfastness to Light, NBS Spec. Publ. 260-41 (August 1972) COM72-50775**

Wagner, H. L. and Verdier, P. H., eds., Standard Reference Materials: The Characterization of Linear Polyethylene, SRM 1475, NBS Spec. Publ. 260-42 (September 1972). COM72-50944**

Yakowitz, H., Ruff, A. W., and Michaelis, R. E., Standard Reference Materials: Preparation and Homogeneity Characterization of an Austenitic Iron-Chromium-Nickel Alloy, NBS Spec. Publ. 260-43 (November 1972). COM73-50760**

Schooley, J. F., Soulen, R. J., Jr., and Evans, G. A., Jr., Standard Reference Materials: Preparation and Use of Superconductive Fixed Point Devices, SRM 767, NBS Spec. Publ. 260-44 (December 1972). COM73-50037**

Greiser, B., Maienthal, E. J. Rains, T. C., and Rasberry, S. D., Standard Reference Materials: Powdered Lead-Based Paint, SRM 1579, NBS Spec. Publ. 260-45 (March 1973). COM73-50226**

Hust, J. G., and Giarratano, P. J., Standard Reference Materials: Thermal Conductivity and Electrical Resistivity Standard Reference Materials: Austenitic Stainless Steel, SRM's 735 and 798, from 4 to 1200 k, NBS Spec. Publ. 260-46 (March 1975). SN003-003-01278-5

Hust, J. G., Standard Reference Materials: Electrical Resistivity of Electrolytic Iron, SRM 797, and Austenitic Stainless Steel, SRM 798, from 5 to 280 K, NBS Spec. Publ. 260-47 (February 1974). COM74-50176**

Mangum, B. W., and Wise, J. A., Standard Reference Materials: Description and Use of Precision Thermometers for the Clinical Laboratory, SRM 933 and SRM 934, NBS Spec. Publ. 260-48 (May 1974). 60 cents* SN003-003-01278-5

Carpenter, B. S., and Reimer, G. M., Standard Reference Materials Calibrated Glass Standards for Fission Track Use, NBS Spec. Publ. 260-49 (November 1974). COM74-51185

Hust, J. G., and Giarratano, P. J., Standard Reference Materials: Thermal Conductivity and Electrical Resistivity Standard Reference Materials: Electrolytic Iron, SRM's 734 and 797 from 4 to 1000 K, NBS Spec. Publ. 260-50 (June 1975). \$1.00* SN003-003-01425-7

Mavrodineanu, R., and Baldwin, J. R., Standard Reference Materials: Glass Filters As a Standard Reference Material for Spectrophotometry; Selection; Preparation; Certification; Use-SRM 930, NBS Spec. Publ. 260-51 (November 1975). \$1.90* SN003-003-01481-8

Hust, J. G., and Giarratano, P. J., Standard Reference Materials: Thermal Conductivity and Electrical Resistivity Standard Reference Materials 730 and 799, from 4 to 3000 K, NBS Spec. Publ. 260-52 (September 1975). \$1.05* SN003-003-01464-8

Durst, R. A., Standard Reference Materials: Standardization of pH Measurements, NBS Spec. Publ. 260-53 (December 1975, Revised). \$1.05 SN003-003-01551-2

Burke, R. W., and Mavrodineanu, R. Standard Reference Materials: Certification and Use of Acidic Potassium Dichromate Solutions as an Ultraviolet Absorbance Standard, NBS Spec. Publ. 260-54 (August 1977). \$3.00* SN003-003-01828-7

Dimars, D. A., Cezairliyan, A., Ishihara, S., and Douglas, T. B., Standard Reference Materials: Enthalpy and Heat Capacity; Molybdenum SRM 781, from 273 to 2800 K, NBS Spec. Publ. 260-55 (September 1977). \$2.20* SN003-003-01836-8

Powell, R. L., Sparks, L. L., and Hust, J. G., Standard Reference Materials: Standard Thermocouple Materials, Pt.67: SRM 1967, NBS Spec. Publ. 260-56 (February 1978). \$2.20* SN003-003-018864

Cali, J. P. and Plebanski, T., Guide to United States Reference Materials, NBS Spec. Publ. 260-57 (February 1978). \$2.20* PB 277173

Barnes, J. D., and Martin, G. M., Standard Reference Materials: Polyester Film for Oxygen Gas Transmission Measurements SRM 1470, NBS Spec. Publ. 260-58 (June 1979) \$2.00* SN003-003-02077

Chang, T., and Kahn, A. H. Standard Reference Materials: Electron Paramagnetic Resonance Intensity Standard; SRM 2601, NBS Spec. Publ. 260-59 (August 1978) \$2.30* SN003-003-01975-5

Velapoldi, R. A., Paule, R. C., Schaffer, R., Mandel, J., and Moody, J. R., Standard Reference Materials: A Reference Method for the Determination of Sodium in Serum, NBS Spec. Publ. 260-60 (August 1978). \$3.00* SN003-003-01978-0

Verdier, P. H., and Wagner, H. L., Standard Reference Materials: The Characterization of Linear Polyethylene (SRM 1482, 1483, 1484), NBS Spec. Publ. 260-61 (December 1978). \$1.70* SN003-003-02006-1

Soulen, R. J., and Dove, R. B., Standard Reference Materials: Temperature Reference Standard for Use Below 0.5 K (SRM 768). NBS Spec. Publ. 260-62 (April 1979). \$2.30* SN003-003-02047-8

Velapoldi, R. A., Paule, R. C., Schaffer, R., Mandel, J., Machlan, L. A., and Gramlich, J. W., Standard Reference Materials: A Reference Method for the Determination of Potassium in Serum. NBS Spec. Publ. 260-63 (May 1979). \$3.75* SN003-003-02068

Velapoldi, R. A., and Mielenz, K. D., Standard Reference Materials: A Fluorescence Standard Reference Material Quinine Sulfate Dihydrate (SRM 936), NBS Spec. Publ. 260-64 (January 1980). \$4.25* SN003-003-02148-2

Marinenko, R. B., Heinrich, K. F. J., and Ruegg, F. C., Standard Reference Materials: Micro-Homogeneity Studies of NBS Standard Reference Materials, NBS Research Materials, and Other Related Samples. NBS Spec. Publ. 260-65 (September 1979). \$3.50* SN003-003-02114-1

Venable, W. H., Jr., and Eckerle, K. L., Standard Reference Materials: Didymium Glass Filters for Calibrating the Wavelength Scale of Spectrophotometers (SRM 2009, 2010, 2013). NBS Spec. Publ. 260-66 (October 1979). \$3.50* SN003-003-02127-0

Velapoldi, R. A., Paule, R. C., Schaffer, R., Mandel, J., Murphy, T. J., and Gramlich, J. W., Standard Reference Materials: A Reference Method for the Determination of Chloride in Serum, NBS Spec. Publ. 260-67 (November 1979). \$3.75* SN003-003-02136-9

Mavrodineanu, R. and Baldwin, J.R., Standard Reference Materials: Metal-On-Quartz Filters as a Standard Reference Material for Spectrophotometry-SRM 2031, NBS Spec. Publ. 260-68 (April 1980). \$4.25* SN003-003-02167-9

Velapoldi, R. A., Paule, R. C., Schaffer, R., Mandel, J., Machlan, L. A., Garner, E. L., and Rains, T. C., Standard Reference Materials: A Reference Method for the Determination of Lithium in Serum, NBS Spec. Publ. 260-69 (July 1980). \$4.25* SN003-003-02214-4

Marinenko, R. B., Biancaniello, F., Boyer, P. A., Ruff, A. W., DeRobertis, L., Standard Reference Materials: Preparation and Characterization of an Iron-Chromium-Nickel Alloy for Microanalysis, NBS Spec. Publ. 260-70 (May 1981). \$2.50* SN003-003-02328-1

Seward, R. W., and Mavrodineanu, R., Standard Reference Materials: Summary of the Clinical Laboratory Standards Issued by the National Bureau of Standards, NBS Spec. Publ. 260-71 (November 1981). \$6.50* SN003-003-02381-7

Reeder, D.J., Coxon, B., Enagonio, D., Christensen, R. G., Schaffer, R., Howell, B. F., Paule, R. C., Mandel, J., Standard Reference Materials: SRM 900, Antiepilepsy Drug Level Assay Standard, NBS Spec. Publ. 260-72 (June 1981). \$4.25* SN003-003-02329-9

Interrante, C. G., and Hicho, G. E., Standard Reference Materials: A Standard Reference Material Containing Nominally Fifteen Percent Austenite (SRM 486), NBS Spec. Publ. 260-73 (January 1982). \$2.75* SN003-003-02386-8

Marinenko, R. B., Standard Reference Materials: Preparation and Characterization of K-411 and K-414 Mineral Glasses for Microanalysis: SRM 470. NBS Spec. Publ. 260-74 (in press).

Weidner, V. R., Hsia, J. J., Standard Reference Materials: Preparation and Calibration of First Surface Aluminum Mirror Specular Reflectance Standards (SRM 2003a). NBS Spec. Publ. 260-75 (in press).

Hicho, G. E. and Eaton, E. E., Standard Reference Materials: A Standard Reference Material Containing Nominally Five Percent Austenite (SRM 485a), NBS Spec. Publ. 260-76 (in press).

Furukawa, G. T., Riddle, J. L., Bigge, W. G., and Pfieffer, E. R., Standard Reference Materials: Application of Some Metal SRM's as Thermometric Fixed Points. NBS Spec. Publ. 260-77 (in press).

Hieho, G. E. and Eaton, E. E., Standard Reference Materials: Standard Reference Material Containing Nominally Thirty Percent Austenite (SRM 487), NBS Spec. Publ. 260-78 (in press).

- * Send order with remittance to Superintendent of Documents, US Government Printing Office Washington, DC 20402. Remittance from foreign countries should include an additional one-fourth of the purchase price for postage.
- ** May be ordered from: National Technical Information Service (NTIS), Springfield, Virginia 22151.

TABLE OF CONTENTS

	PAGE
Abstract.....	1
Introduction.....	2
General Description of the SRM	3
Preparation of the Compacts.....	3
Characterization of SRM 487.....	5
Conclusions.....	13
Acknowledgements.....	13
References.....	15

LIST OF TABLES

1. Chemical Analysis of Stainless Steel Powder.....	5
---	---

LIST OF FIGURES

1. Scanning electron micrographs of the powders used to produce SRM 487.....	4
2. Fabrication procedure for SRM 487.....	6
3. General microstructure of a compact.....	7
4. Characterization steps for SRM 487.....	11
5. Calibration curve showing the volume percent austenite as a function of weight percent nickel...	12
6. Histogram showing frequency of occurrence versus the volume percent austenite.....	14

A Standard Reference Material Containing
Nominally Thirty Percent Austenite (SRM 487)

G. E. Hicho and E. E. Eaton ⁽¹⁾

Fracture and Deformation Division
Center for Materials Science
National Measurement Laboratory
National Bureau of Standards
Washington, D C 20234

Abstract

This Standard Reference Material, SRM 487, is intended for the calibration of x-ray diffraction equipment used in determining the amount of retained austenite in hardened steels. The SRM was produced using powder metallurgical techniques and involved blending 30 percent by weight AISI type 310 stainless steel powder (austenitic) with AISI type 430 stainless steel powder (ferritic). From this blend, 233 compacts were produced and subsequently examined for nickel content by x-ray fluorescence spectrometry. A calibration curve was established using 19 compacts randomly selected from the population of 233. The curve relates the weight percent nickel from x-ray fluorescence measurements to the volume percentage austenite as determined by quantitative microscopy measurements of area percent. The curve was then used to assign the certified values to the remaining compacts. This SRM may be used as an x-ray diffraction standard for retained austenite or in very special cases as an x-ray fluorescence standard for nickel content.

Key Words: austenite in ferrite; powder metallurgy; quantitative microscopy; retained austenite standard; Standard Reference Material; x-ray fluorescence.

(1) Student, Mechanical Engineering Department, University of Maryland.

Introduction

This Standard Reference Material was produced in order to calibrate x-ray diffraction (XRD) equipment used to determine the amount of retained austenite in hardened steels.

In various heat treating processes, steel is heated to a temperature where a face-centered-cubic solid phase called austenite is formed. After a sufficient stabilization time, the steel is quenched into a medium where the austenite may be entirely transformed to a metastable, body-centered-tetragonal solid phase called martensite. However, sometimes the austenite is not completely transformed to martensite. The untransformed (retained) austenite could be detrimental to the properties of the finished product. Often there are requirements as to the maximum amount of retained austenite permitted in hardened steels. Therefore, it is necessary to quantitatively determine the amount of the retained austenite in the finished product.

The amount of retained austenite in steel is usually determined by XRD procedures using a direct comparison of the integrated intensities of a series of both austenite and ferrite diffraction lines. It is highly recommended that the user of SRM 487 read National Bureau of Standards (NBS) Technical Note 709, [1], describing the x-ray method used at the National Bureau of Standards (NBS) to determine the amount of austenite in an austenite-ferrite mixture, prior to using this SRM.

An XRD reference material for retained austenite, should be reasonably free of certain metallurgical confoundments which severely affect the intensities of both the austenite and ferrite lines - preferred granular orientation, large grain size, and residual stress. The previous SRM [2], was found to be reasonably free of these confoundments. Therefore, the present SRM, (487), since it was prepared in a similar manner, should be free of these confoundments, and be very useful in determining the amount of retained austenite in hardened steels.

The National Bureau of Standards is in the process of producing a series of SRM's containing various percentages of austenite in ferrite. The first of these was issued in 1970 and contained nominally four percent austenite [3]. A renewal of that SRM is available and in addition a 15% austenite in ferrite SRM.

A separate characterization of the austenite content for each compact is required because a homogenous blend of austenite in ferrite can not be guaranteed to the degree required. Therefore, each unit of the SRM is individually certified.

The purpose of this paper is to present a detailed description of the preparation and characterization of the 233 compacts, and their subsequent certification as SRM 487.

General Description of the SRM

This SRM is composed of two constituents whose structures are metallurgically different. The components are AISI type 310 stainless steel (austentic) and AISI type 430 stainless steel (ferritic) powders. The 310 is a highly stable austenitic stainless steel (24.99 weight percent Cr and 20.41 weight percent Ni) requiring a substantial change in composition to produce a transformation to a structure other than austenite. The 430 contains 16.82 weight percent Cr, and effectively no nickel - .08 weight percent.

Following the blending of the powders, the powders were pressed into compacts and subsequently sintered, repressed, and vacuum annealed. The finished compacts were approximately 21 mm (.83 in) in diameter and 2.4 mm (.094 in) thick. Only one surface of the SRM was polished, and it is that surface which is certified as to the austenite content. No surface preparation of the SRM is necessary, in fact damage to the surface renders the certification void.

The main concept of the SRM lies in the fact that the nickel content for each compact is related directly to the austenite content.

Because of the significant differences between the nickel content of the austenitic component (20.41 weight percent) and that of the ferritic component (.08 weight percent), it was possible to use XRF analysis to obtain a very precise measurement of total nickel counts on the surface of the compact. The total nickel counts were then corrected to weight percent nickel.

Using a calibration curve (described later) and the values obtained by XRF analyses, it was then possible to assign a volume percent austenite to each compact.

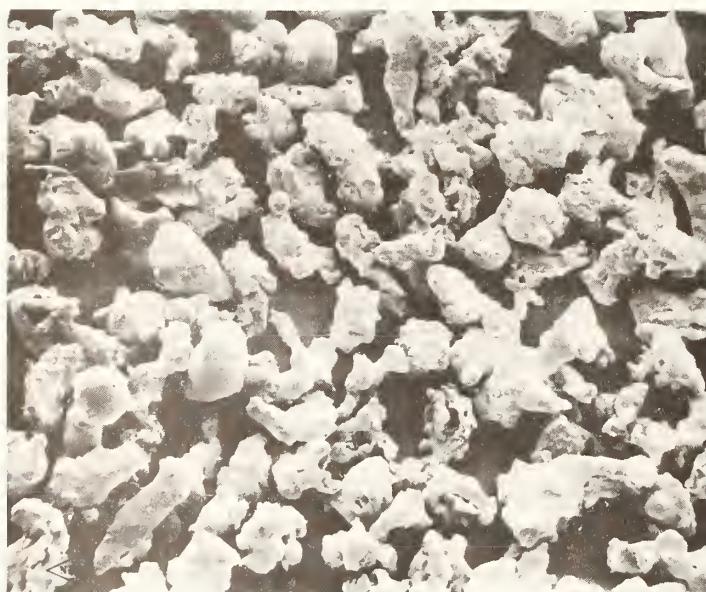
Preparation of the Compacts

The austenitic and ferritic powders used to make this SRM were produced by water atomization techniques. The preliminary sizing of the powders was done by the manufacturer, however, final sizing was done at the National Bureau of Standards.

The austenitic stainless steel powder, passed a 250 mesh screen, but was retained on a 325 mesh screen. This sieving yielded the 310 stainless steel powder in the particle size range of 53 to 44 micrometers. The ferritic stainless steel powder passed a 325 mesh screen, but was retained on a 400 mesh screen. This yielded 430 stainless steel particles in the size range of 44 to 37 micrometers. Micrographs of the powders are shown in figure 1. Each powder was then sampled and chemically analyzed. The results of the chemical analyses are shown in Table 1.



a



b

Figure 1. Scanning electron micrographs of the powders used to produce SRM 487. Mag. X160

- a. as sized 310 stainless steel powder
- b. as sized 430 stainless steel powder

Table I. Chemical Analysis of Stainless Steel Powder.
(Content in Weight Percent)

<u>Elements</u>	<u>310 Stainless Steel</u>	<u>430 Stainless Steel</u>
Chromium	24.99	16.82
Nickel	20.41	0.08
Iron	bal	bal
Carbon	0.05	0.02
Manganese	0.20	0.15
Phosphorus	0.01	0.005
Sulfur	0.007	0.008
Silicon	0.75	0.83

The steps in the preparation of SRM 487 are shown in figure 2. A total of 223 units were produced.

After three cycles of pressing and heat treatment (843°C, 30 minutes) in a vacuum, each compact was hand ground on silicon carbide papers, and then polished on felt cloths using 6 μ , and 1 μ , diamond paste with mineral spirits as the lubricant. The temperature of 843°C was chosen as the sintering temperature since it was found [2] that at this temperature, diffusion of the nickel into the ferrite material was minimal. A micrograph of a compact, at low and high magnifications, is shown in figure 3.

As the final step in the procedure, each compact was polished on microcloth using β -alumina as the abrasive and distilled water as the lubricant. Upon completion of this step, the weight percent nickel of each compact's surface was determined using x-ray fluorescence spectrometry.

Characterization of SRM 487

Certain basic XRF concepts were used in the determination of the weight percent nickel in SRM 487. These concepts will now be discussed.

Although an alloy steel, each compact consists primarily of high purity Fe, Ni, and Cr powders and in the XRF analysis were treated as ternary unknowns. Because of this, it was possible to analyze for all three elements in each compact using the combined procedure of Rasberry-Heinrich [4] and the Naval Research Laboratory [5] programs for the correction of interelement effects.

An AXS, automated wavelength x-ray spectrometer, employing a Cr target with an Al filter, operating at 50 and 10 ma was used. To reduce the effect of surface inhomogeneity of the austenite, each

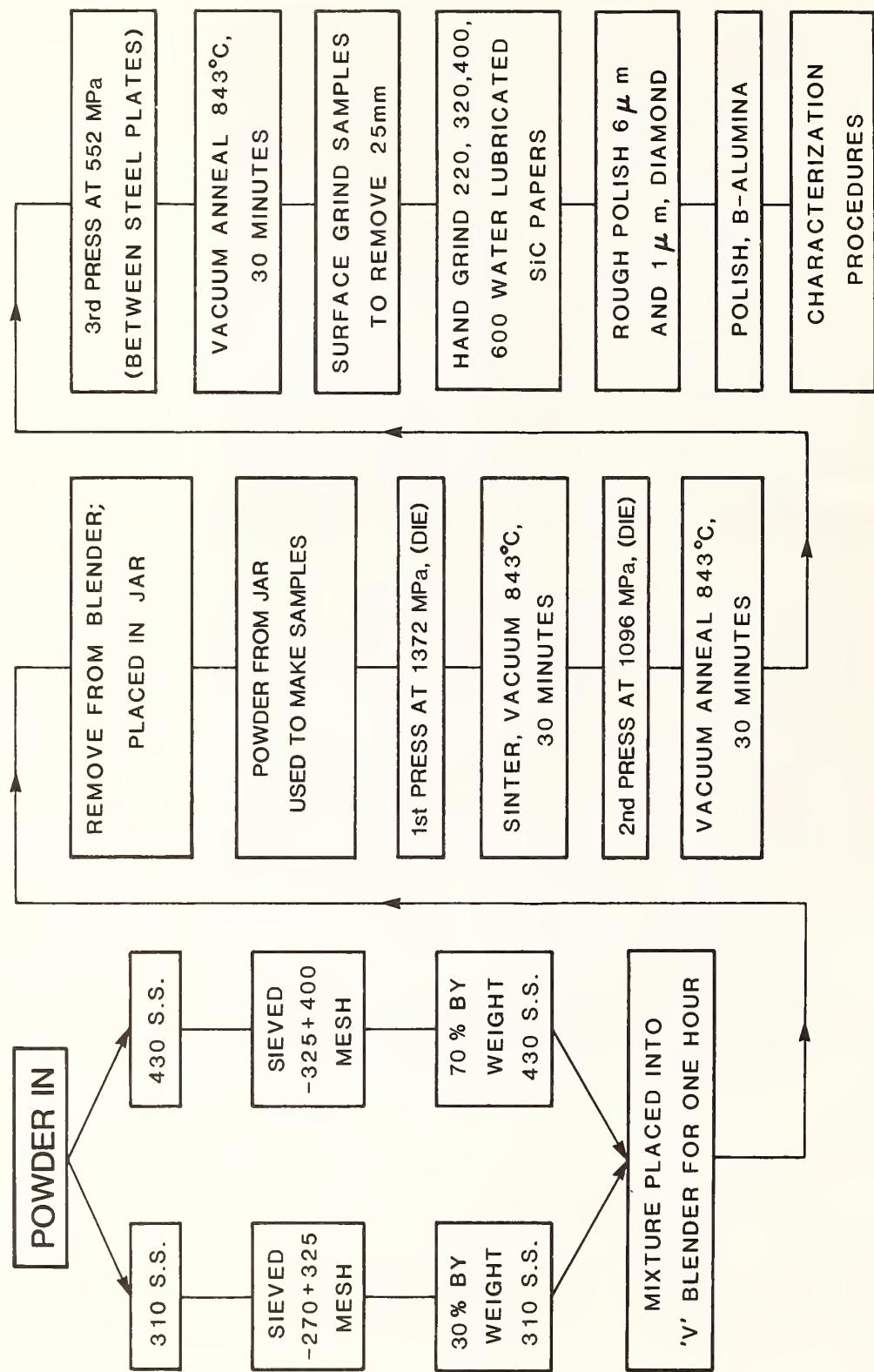
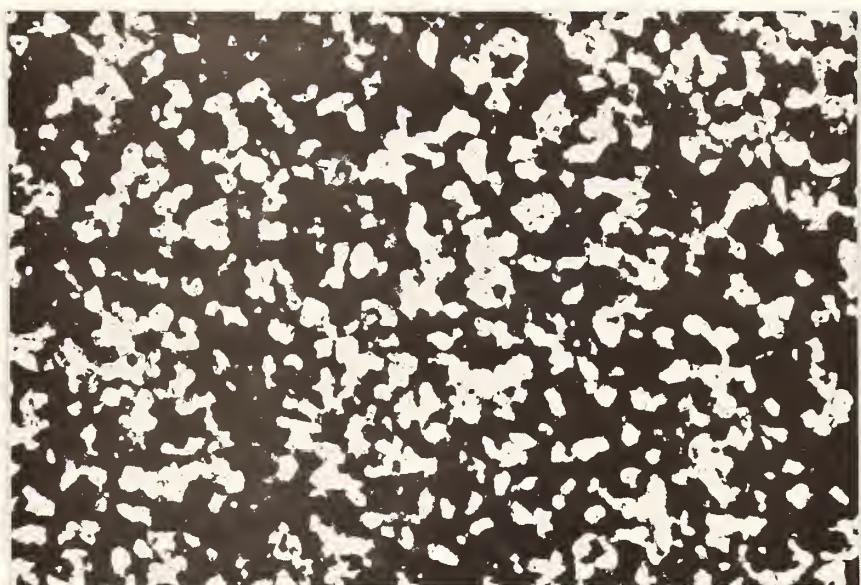


Figure 2. Fabrication procedure for SRM 487.



a



b

Figure 3. General Microstructure of a compact.

- a. Optical micrograph showing the white austenite particles in the ferrite mixture. Mag. X40.
- b. Optical micrograph of an enlarged austenite particle. Mag. X800.

compact was rotated with its axis tilted approximately 60° to the beam, and examined for approximately 30 seconds.

For check purposes during XRF examination, three specimens, each containing a different weight percent nickel, were prepared. Specimen A, containing 1.439 weight percent nickel, was prepared in the same manner as described previously; i.e., press, sinter, press, etc. An extensive number of measurements using a quantitative microscope (QM) were performed upon this compact and its area percent austenite value was known with high accuracy. Specimens B and C (corresponding to the 5 and 30 area percent austenite compacts) were made from pure chromium, nickel, and iron powders. But unlike A they were vacuum melted into buttons and subsequently machined to fit a holder. Filings from these compacts were individually examined for nickel content using atomic absorption spectrometry. The mean for six determinations of weight percent nickel in B, was 1.511 with a standard deviation of 0.009. Likewise, the mean for four determinations of nickel in C, was 6.478 with a standard deviation of 0.015 weight percent nickel.

Specimens A, B, and C were then measured for nickel content by XRF along with each set of compacts whose weight percent nickel was to be determined. These same samples were then used to monitor the output of the unknown samples and were checks on the x-ray spectrometer in that any deviation from the predetermined values of A, B, and C indicated an abnormality in the analyses of the unknowns.

A summary of the XRF precision data on samples A, B, and C is as follows. The mean weight percent nickel for 20 XRF determinations of specimen A was 1.439 with a standard deviation of 0.012 and relative standard deviation of 0.8 percent. The mean weight percent nickel for 14 XRF determinations of specimen B was 1.518 with a standard deviation of 0.014 and relative standard deviation of 0.92 percent. The mean for 14 determinations of specimen C was 6.481 weight percent nickel with a standard deviation of 0.028 and a relative standard deviation of 0.43 percent.

Following the XRF determination of the weight percent nickel for each compact, the total population was ranked from lowest to highest weight percent nickel in order to select compacts to be used in the establishment of the calibration curve. The selection was done in the following manner.

Arbitrarily, selection was started at the sixth lowest weight percent nickel value. That compact and every 24th compact was selected until the total population was exhausted. In addition eight more samples were selected to fill in the curve. From the population of 233 compacts, 19 compacts were chosen for the calibration curve.

The calibration curve is a plot of the volume percent, which is equivalent to the area percent [6] austenite value as determined from QM procedures, along the ordinate and the weight percent nickel value as determined by XRF along the abscissa. It is this calibration curve which permits the assignment of a volume percent austenite from a corresponding weight percent nickel (XRF). The development of the calibration curve follows.

In order to obtain a more accurate value of the area percent austenite when using the QM method, it was necessary to examine each calibration compact for surface porosity prior to the austenite determination. In the QM determination for porosity, the surface was considered as being divided into individual quadrants, each 0.625 mm square. There are 34 of these quadrants in a row, and 34 rows. The area percent porosity for each quadrant was obtained and entered into the computer's memory. An area equal to about 90% of the sample's total area was subsequently used to establish a mathematical relationship which yielded a mean porosity, and a standard deviation for each compact's surface. If a compact had excessive porosity it was discarded. Once the porosity was determined for each compact, the compacts were stained.

In order to determine the area percent of austenite on the compact's surface using QM methods, the austenite (the 310 stainless steel component) had to "stand out" from the ferrite background. An extensive amount of research was conducted in order to find a stain that permitted this. One reagent, Murakami's satisfied our needs. This reagent, 10 grams sodium hydroxide (NaOH), 10 grams potassium ferricyanide ($K_3 Fe (CN)_6$), and 100 mL distilled water, when heated to about 100°C, stained the compact to the extent that under the microscope the austenite (310) was unattacked and the ferrite was stained dark red. Hence it was now possible to use the QM to determine the percentage of white particles (i.e. austenite) on the component's surface.

Following the same QM procedure described previously for the porosity determination, each of the 19 calibration compacts were stained with Murakami's reagent and the area percent austenite and standard deviation determined.

In order to ascertain the extent of inhomogeneity of the austenite over the compacts surface, a normalization of the data using the standard deviation was performed.

The equation used in the normalization procedure was $(A-B)/S$, where A is the area percent austenite value for that quadrant, and B and S were the mean and standard deviation obtained for the compact's surface. The value obtained for each quadrant was subsequently plotted and a pattern was obtained which revealed the extent of inhomogeneity that existed on the compact's surface. If the normalization revealed a surface with excessive inhomogeneity of

the austenite, the compact was discarded. None of the calibration compacts showed any severe inhomogeneity to the extent that it would be discarded.

Since a total of three hours was needed for each set of observations only two orientations of the compact were used. The characterization steps used for this SRM are shown in figure 4.

The calibration curve was fitted using least-square regression methods. The variance representing the fit of the calibration curve's experimental data points was .57 area percent austenite. The correlation coefficient, a measure of the fit of the curve to the data points was found to be 0.94. The equation for the curve using the 19 calibration points is as follows:

$$\text{Volume percent austenite} = 4.737W + 2.056$$

where W represents the weight percent nickel as determined by XRF spectrometry. The calibration curve, along with the data points used to develop this curve, is shown in figure 5.

A question arose as to what uncertainty (i.e. standard deviation) should be assigned to each SRM compact. It was noted that two prime factors in this analysis were the QM determination for area percent austenite itself and the associated porosity correction.

A statistical analysis of the data revealed that the variance of fit of the porosity correction contributed less than 2% of the total variance of a single austenite determination. In addition, an analysis of the austenite values for replicate determination of the calibration samples revealed that the variance associated with short term replication errors was found to be less than 10% of the variance of fit for the calibration curve. These results raised the question whether the lack of fit of this calibration curve was due to sample problems, long term errors (i.e., measurement variability), or sample idiosyncrasies. Analysis of the data proved the latter true, therefore a smaller uncertainty should be assigned to the certified value since we are only dealing with the imprecision of the calibration curve.

This conclusion was corroborated in an QM experiment performed on a single sample over a period of 14 days. An analysis of the QM measurements for a single 5% austenite sample showed a variance of 0.06 which is comparable to the variance of fit listed previously.

The equation to be used for the standard deviation (i.e. uncertainty) of a single compact based on errors of the calibration curve, is:

$$SD = (.755) [1/19 + 0.2797 (X+6.594)^2]^{1/2} \quad [7]$$

Considering that this uncertainty encompasses the errors associated with both the QM determinations of the porosity and the

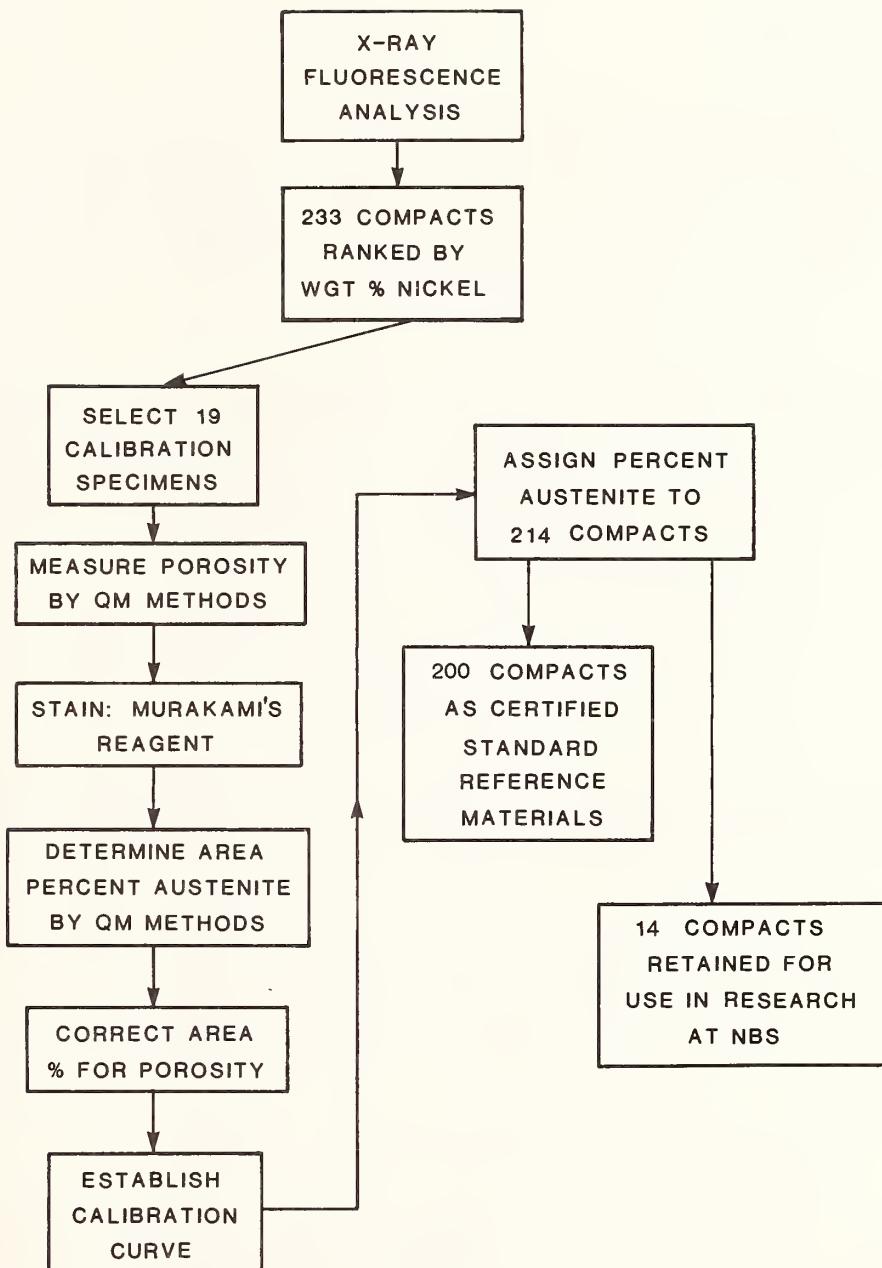


Figure 4. Characterization steps for SRM 487.

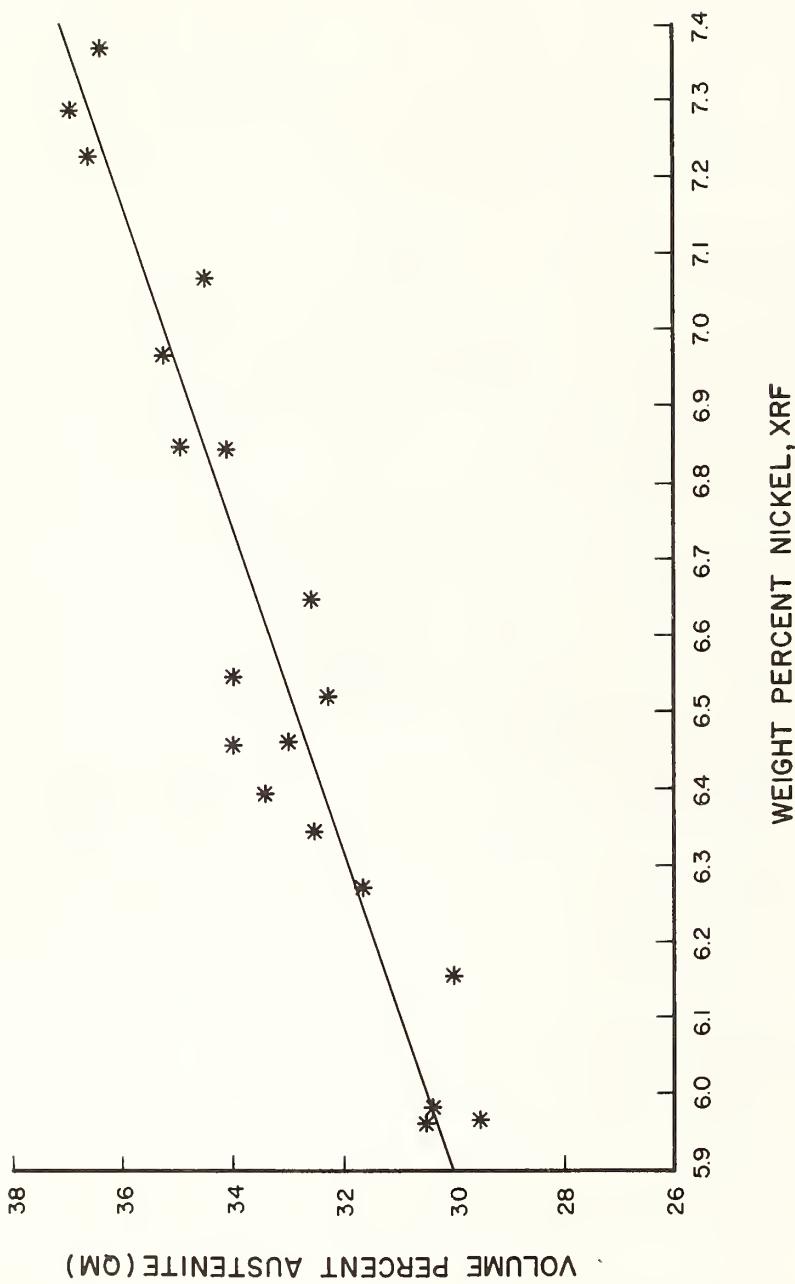


Figure 5. Calibration curve showing the volume percent austenite as a function of weight percent nickel.

austenite, and the errors associated with the XRF measurements, we believe the certified value assigned to each compact is within \pm 0.50 of the assigned volume percent austenite. The distribution of the percent austenite for the 200 compacts is shown in figure 6. The values for the population ranged from 29.75 to 34.78 volume percent austenite.

Conclusions

SRM 487 is satisfactory for issuance as a standard for x-ray determination of retained austenite in hardened steels. The range for the 195 certified compacts was found to be 29.75 to 34.78 volume percent austenite. The mean for this population was approximately 32.56 volume percent austenite. In using SRM 487, care must be taken not to alter the certified face. During x-ray diffraction examination of the compact, it is highly recommended that the compact be rotated in order to minimize the effect of possible inhomogeneity of the certified surface. In addition, the user should read NBS Technical Note 709 prior to using the SRM.

Acknowledgements

The authors thank J. Early and C. Interrante for their guidance during the preparation of this SRM. In particular, Dr. Early's aid in helping us solve our powder metallurgical problems was greatly appreciated.

We would also like to thank P. Pella of the X-Ray Fluorescence Group for his effort in determining the nickel content of the compacts. In addition, we thank S. Low for his assistance during the computer programming of the calibration curve and F. Biancaniello who prepared the XRF check samples and heat treated all of the compacts.

Special thanks are due also to the statisticians who aided us in the analysis of the data generated during all stages of the preparations of this SRM. They are J. Filliben, H. Ku, and S. Leigh. Thanks also are given to J. Mandel and R. Paule who helped corroborate some of the results we obtained during the final stages of our research on this SRM.

And finally to our secretaries P. Salpino and C. Gallupe, both of whom worked so diligently on this manuscript.

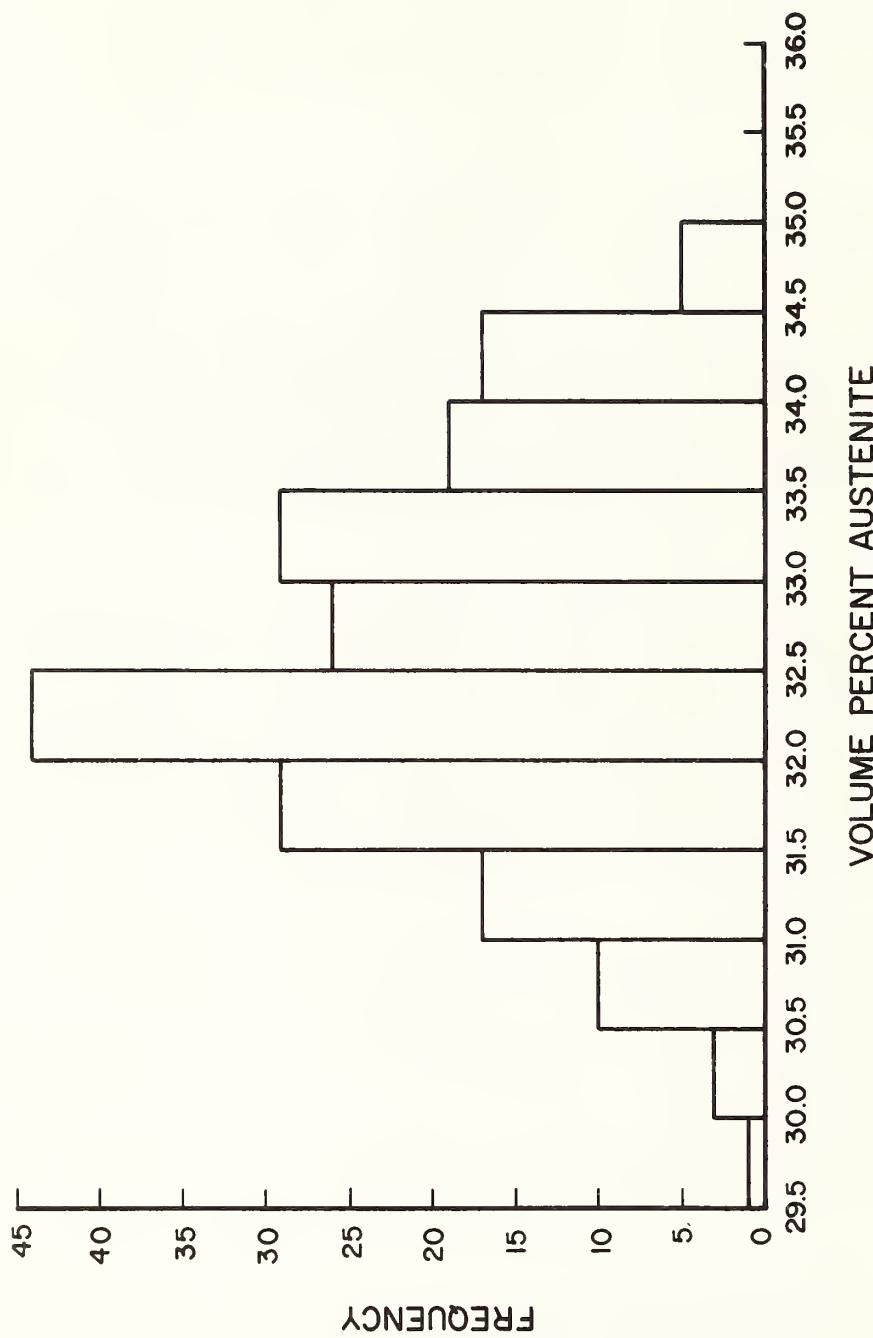


Figure 6. Histogram showing frequency of occurrence versus the volume percent austenite.

References

- [1] Bechtold, C. J. An X-Ray Diffraction Method for Determining the amount of Austenite in an Austenite-Ferrite Mixture. Natl. Bur. Stand. (U.S.) Tech. Note 709; 1972 February. 14p.
- [2] Interrante, C. G. and Hicho, G. E., A Standard Reference Material Containing Nominally Fifteen Percent Austenite. Natl. Bur. Stand. (U.S.) Spec. Publ. 260-73; 1982 January. 25p.
- [3] Hicho, G. E. et al., A Standard Reference Material Containing Nominally Four Percent Austenite. Natl. Bur. Stand. (U.S.) Spec. Publ. 260-25; 1971 February. 14p.
- [4] Rasberry, S. D., and Heinrich, K. F. J., Calibration of Interelement Effects in X-Ray Fluorescence Analysis, Analytical Chemistry, Vol. 46, Page 81, 1974 January.
- [5] Birks, L. S., Gilfrich, J. V., and Criss, J. W., NRLXRF, A Fortran Program for X-Ray Fluorescence Analysis, X-Ray Optics Branch, Materials Science Division, NRL, Washington, D.C. 1977 (COSMIC) Suite 112, Barrow Harrow, Athens, GA. 30602. Project Number DOD-00065 (July 1977 revision).
- [6] Delesse, A., "Pourdeterminer la composition des roches," Ann. des Mines B (1848), fourth series, pp. 378-388.
- [7] Walpole, R.E., Myers, R.H., Probability and Statistics for Engineers and Scientists, 2nd editions, pp. 289-295.

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET (See instructions)		1. PUBLICATION OR REPORT NO. NBS SP 260-78	2. Performing Organ. Report No.	3. Publication Date September 1982
4. TITLE AND SUBTITLE Standard Reference Materials: A Standard Reference Material Containing Nominally Thirty Percent Austenite (SRM 487)				
5. AUTHOR(S) G. E. Hicho and E. E. Eaton				
6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions) NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			7. Contract/Grant No.	8. Type of Report & Period Covered Final
9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP) Same as item 6.				
10. SUPPLEMENTARY NOTES Library of Congress Catalog Card Number: 82-600587 <input type="checkbox"/> Document describes a computer program; SF-185, FIPS Software Summary, is attached.				
11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here) This Standard Reference Material, SRM 487, is intended for the calibration of x-ray diffraction equipment used in determining the amount of retained austenite in hardened steels. The SRM was produced using powder metallurgical techniques and involved blending 30 percent by weight AISI type 310 stainless steel powder (austenitic) with AISI type 430 stainless steel powder (ferritic). From this blend, 233 compacts were produced and subsequently examined for nickel content by x-ray fluorescence spectrometry. A calibration curve was established using 19 compacts randomly selected from the population of 233. The curve relates the weight percent nickel from x-ray fluorescence measurements to the volume percentage austenite as determined by quantitative microscopy measurements of area percent. The curve was then used to assign the certified values to the remaining compacts. This SRM may be used as an x-ray diffraction standard for retained austenite or in very special cases as an x-ray fluorescence standard for nickel content.				
12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons) austenite in ferrite; powder metallurgy; quantitative microscopy; retained austenite standard; Standard Reference Material; x-ray fluorescence				
13. AVAILABILITY <input checked="" type="checkbox"/> Unlimited <input type="checkbox"/> For Official Distribution, Do Not Release to NTIS <input checked="" type="checkbox"/> Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. <input type="checkbox"/> Order From National Technical Information Service (NTIS), Springfield, VA. 22161			14. NO. OF PRINTED PAGES 25	15. Price \$3.50

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH—The Journal of Research of the National Bureau of Standards reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active. These include physics, chemistry, engineering, mathematics, and computer sciences. Papers cover a broad range of subjects, with major emphasis on measurement methodology and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Bureau's technical and scientific programs. As a special service to subscribers each issue contains complete citations to all recent Bureau publications in both NBS and non-NBS media. Issued six times a year. Annual subscription: domestic \$18; foreign \$22.50. Single copy, \$4.25 domestic; \$5.35 foreign.

NONPERIODICALS

Monographs—Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NBS under the authority of the National Standard Data Act (Public Law 90-396).

NOTE: The principal publication outlet for the foregoing data is the *Journal of Physical and Chemical Reference Data* (JPCRD) published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements available from ACS, 1155 Sixteenth St., NW, Washington, DC 20056.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The standards establish nationally recognized requirements for products, and provide all concerned interests with a basis for common understanding of the characteristics of the products. NBS administers this program as a supplement to the activities of the private sector standardizing organizations.

Consumer Information Series—Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

Order the above NBS publications from: Superintendent of Documents, Government Printing Office, Washington, DC 20402.

Order the following NBS publications—FIPS and NBSIR's—from the National Technical Information Services, Springfield, VA 22161.

Federal Information Processing Standards Publications (FIPS PUB)—Publications in this series collectively constitute the Federal Information Processing Standards Register. The Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

NBS Interagency Reports (NBSIR)—A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Services, Springfield, VA 22161, in paper copy or microfiche form.

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, DC 20234

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-215



OFFICIAL BUSINESS

Penalty for Private Use, \$300

FIRST CLASS
