NIST SPECIAL PUBLICATION 260-118

U.S. DEPARTMENT OF COMMERCE/Technology Administration/National Institute of Standards and Technology

Standard Reference Materials:

Calibration of NIST Standard Reference Material 3202 for 18-Track, Parallel, and 36-Track, Parallel Serpentine, 12.65 mm (0.5 in), 1491 cpmm (37871 cpi), Magnetic Tape Cartridge

Mark P. Williamson

The National Institute of Standards and Technology was established in 1988 by Congress to "assist industry in the development of technology . . . needed to improve product quality, to modernize manufacturing processes, to ensure product reliability . . . and to facilitate rapid commercialization . . . of products based on new scientific discoveries."

NIST, originally founded as the National Bureau of Standards in 1901, works to strengthen U.S. industry's competitiveness; advance science and engineering; and improve public health, safety, and the environment. One of the agency's basic functions is to develop, maintain, and retain custody of the national standards of measurement, and provide the means and methods for comparing standards used in science, engineering, manufacturing, commerce, industry, and education with the standards adopted or recognized by the Federal Government.

As an agency of the U.S. Commerce Department's Technology Administration, NIST conducts basic and applied research in the physical sciences and engineering and performs related services. The Institute does generic and precompetitive work on new and advanced technologies. NIST's research facilities are located at Gaithersburg, MD 20899, and at Boulder, CO 80303. Major technical operating units and their principal activities are listed below. For more information contact the Public Inquiries Desk, 301-975-3058.

Technology Services
- Manufacturing Technology Centers Program
- Standards Services
- Technology Commercialization
- Measurement Services
- Technology Evaluation and Assessment
- Information Services

Electronics and Electrical Engineering Laboratory
- Microelectronics
- Law Enforcement Standards
- Electricity
- Semiconductor Electronics
- Electromagnetic Fields[1]
- Electromagnetic Technology[1]

Chemical Science and Technology Laboratory
- Biotechnology
- Chemical Engineering[1]
- Chemical Kinetics and Thermodynamics
- Inorganic Analytical Research
- Organic Analytical Research
- Process Measurements
- Surface and Microanalysis Science
- Thermophysics[2]

Physics Laboratory
- Electron and Optical Physics
- Atomic Physics
- Molecular Physics
- Radiometric Physics
- Quantum Metrology
- Ionizing Radiation
- Time and Frequency[1]
- Quantum Physics[1]

Manufacturing Engineering Laboratory
- Precision Engineering
- Automated Production Technology
- Robot Systems
- Factory Automation
- Fabrication Technology

Materials Science and Engineering Laboratory
- Intelligent Processing of Materials
- Ceramics
- Materials Reliability[1]
- Polymers
- Metallurgy
- Reactor Radiation

Building and Fire Research Laboratory
- Structures
- Building Materials
- Building Environment
- Fire Science and Engineering
- Fire Measurement and Research

Computer Systems Laboratory
- Information Systems Engineering
- Systems and Software Technology
- Computer Security
- Systems and Network Architecture
- Advanced Systems

Computing and Applied Mathematics Laboratory
- Applied and Computational Mathematics[2]
- Statistical Engineering[2]
- Scientific Computing Environments[2]
- Computer Services[2]
- Computer Systems and Communications[2]
- Information Systems

---

[1] At Boulder, CO 80303.
[2] Some elements at Boulder, CO 80303.

NIST Special Publication 260-118

Standard Reference Materials:

Calibration of NIST Standard Reference Material 3202 for 18-Track, Parallel, and 36-Track, Parallel Serpentine, 12.65 mm (0.5 in), 1491 cpmm (37871 cpi), Magnetic Tape Cartridge

Mark P. Williamson

Advanced Systems Division
National Computer Systems Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899

U.S. DEPARTMENT OF COMMERCE, Barbara Hackman Franklin, Secretary
TECHNOLOGY ADMINISTRATION, Robert M. White, Under Secretary for Technology
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY, John W. Lyons, Director

Issued July 1992

National Institute of Standards and Technology Special Publication 260-118
Natl. Inst. Stand. Technol. Spec. Publ. 260-118, 52 pages (July 1992)
CODEN: NSPUE2

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1992

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402–9325

Preface

Standard Reference Materials (SRM's) as defined by the National Institute of Standards and Technology (NIST) 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 is 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 NIST in arriving at the certified values of the SRM's produced. The NIST Special Publication 260 Series is a series of papers reserved for this purpose.

The 260 Series is dedicated to the dissemination of information on different phases of the preparation, measurement, certification, and use of NIST 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 greatest care and accuracy. These papers also should provide sufficient additional information so SRM's can be utilized in new applications in diverse fields not foreseen at the time the SRM was originally issued.

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

Standard Reference Materials Program
Bldg. 202, Rm. 204
National Institute of Standards and Technology
Gaithersburg, MD 20899

William P. Reed, Chief
Standard Reference Materials Program

OTHER NIST PUBLICATIONS IN THIS SERIES

McKenzie, R. L., ed., NIST Standard Reference Materials Catalog 1990-91, NIST Spec. Publ. 260 (January 1990)

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**

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 1965). 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**

Anspach, 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 of 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).

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).

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).

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**

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., Marinenko, 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). PB 81176620**

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). COM74-50018**

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: Thermal Conductivity of Austenitic Stainless Steel, SRM 735 from 5 to 280 K, NBS Spec. Publ. 260-35 (April 1972.) COM72-50368**

Cali, 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**

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**

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**

Greifer, 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). COM75-10339**

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). Superseded by NIST Spec. Publ. 260-113.

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). COM75-10698**

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). COM75-10339**

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). COM75-11193**

Durst, R. A., Standard Reference Materials: Standardization of pH Measurements, NBS Spec. Publ. 260-53 (February 1988, Revision of December 1975 version).

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). PB272168**

Ditmars, 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). PB272127**

Powell, R. L., Sparks, L. L., and Hust, J. G., Standard Reference Materials: Standard Thermocouple Material, Pt-67: SRM 1967, NBS Spec. Publ. 260-56 (February 1978). PB277172**

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). PB297098**

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). PB286944**

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). PB289899**

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). PB294245**

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). PB297207**

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). PB80-132046**

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). PB300461**

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, and 2014, NBS Spec. Publ. 260-66 (October 1979). PB80-104961**

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). PB80-110117**

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). PB80-197486**

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). PB80-209117**

Marinenko, R. B., Biancaniello, F., Boyer, P. A., Ruff, A. W., and DeRobertis, L., Standard Reference Materials: Preparation and Characterization of an Iron-Chromium-Nickel Alloy for Microanalysis, NBS Spec. Publ. 260-70 (May 1981). PB84-165349**

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). PB82-135161**

Reeder, D. J., Coxon, B., Enagonio, D., Christensen, R. G., Schaffer, R., Howell, B. F., Paule, R. C., and Mandel, J., Standard Reference Materials: SRM 900, Antiepilepsy Drug Level Assay Standard, NBS Spec. Publ. 260-72 (June 1981). PB81-220758

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). PB82-215559**

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 (April 1982). PB82-221300**

Weidner, V. R., and Hsia, J. J., Standard Reference Materials: Preparation and Calibration of First Surface Aluminum Mirror Specular Reflectance Standards (SRM 2003a), NBS Spec. Publ. 260-75 (May 1982). PB82-221367**

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 (August 1982). PB83-115568**

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 (August 1982). PB83-117325**

Hicho, G. E., and Eaton, E. E., Standard Reference Materials: Standard Reference Material Containing Nominally Thirty Percent Austenite (SRM 487), NBS Spec. Publ. 260-78 (September 1982). PB83-115576**

Richmond, J. C., Hsia, J. J., Weidner, V. R., and Wilmering, D. B., Standard Reference Materials: Second Surface Mirror Standards of Specular Spectral Reflectance (SRM's 2023, 2024, 2025), NBS Spec. Publ. 260-79 (October 1982). PB84-203447**

Schaffer, R., Mandel, J., Sun, T., Cohen, A., and Hertz, H. S., Standard Reference Materials: Evaluation by an ID/MS Method of the AACC Reference Method for Serum Glucose, NBS Spec. Publ. 260-80 (October 1982). PB84-216894**

Burke, R. W., and Mavrodineanu, R., Standard Reference Materials: Accuracy in Analytical Spectrophotometry, NBS Spec. Publ. 260-81 (April 1983). PB83-214536**

Weidner, V. R., Standard Reference Materials: White Opal Glass Diffuse Spectral Reflectance Standards for the Visible Spectrum (SRM's 2015 and 2016), NBS Spec. Publ. 260-82 (April 1983). PB83-220723**

Bowers, G. N., Jr., Alvarez, R., Cali, J. P., Eberhardt, K. R., Reeder, D. J., Schaffer, R., and Uriano, G. A., Standard Reference Materials: The Measurement of the Catalytic (Activity) Concentration of Seven Enzymes in NBS Human Serum SRM 909, NBS Spec. Publ. 260-83 (June 1983). PB83-239509**

Gills, T. E., Seward, R. W., Collins, R. J., and Webster, W. C., Standard Reference Materials: Sampling, Materials Handling, Processing, and Packaging of NBS Sulfur in Coal Standard Reference Materials 2682, 2683, 2684, and 2685, NBS Spec. Publ. 260-84 (August 1983). PB84-109552**

Swyt, D. A., Standard Reference Materials: A Look at Techniques for the Dimensional Calibration of Standard Microscopic Particles, NBS Spec. Publ. 260-85 (September 1983). PB84-112648**

Hicho, G. E., and Eaton, E. E., Standard Reference Materials: A Standard Reference Material Containing Two and One-Half Percent Austenite, SRM 488, NBS Spec. Publ. 260-86 (December 1983). PB84-143296**

Mangum, B. W., Standard Reference Materials: SRM 1969: Rubidium Triple-Point - A Temperature Reference Standard Near 39.30 °C, NBS Spec. Publ. 260-87 (December 1983). PB84-149996**

Gladney, E. S., Burns, C. E., Perrin, D. R., Roelandts, I., and Gills, T. E., Standard Reference Materials: 1982 Compilation of Elemental Concentration Data for NBS Biological, Geological, and Environmental Standard Reference Materials, NBS Spec. Publ. 260-88 (March 1984). PB84-218338**

Hust, J. G., Standard Reference Materials: A Fine-Grained, Isotropic Graphite for Use as NBS Thermophysical Property RM's from 5 to 2500 K, NBS Spec. Publ. 260-89 (September 1984). PB85-112886**

Hust, J. G., and Lankford, A. B., Standard Reference Materials: Update of Thermal Conductivity and Electrical Resistivity of Eleetrolytic Iron, Tungsten, and Stainless Steel, NBS Spec. Publ. 260-90 (September 1984). PB85-115814**

Goodrich, L. F., Vecchia, D. F., Pittman, E. S., Ekin, J. W., and Clark, A. F., Standard Reference Materials: Critical Current Measurements on an NbTi Superconducting Wire Standard Reference Material, NBS Spec. Publ. 260-91 (September 1984). PB85-118594**

Carpenter, B. S., Standard Reference Materials: Calibrated Glass Standards for Fission Track Use (Supplement to NBS Spec. Publ. 260-49), NBS Spec. Publ. 260-92 (September 1984). PB85-113025**

Ehrstein, J.R., Standard Reference Materials: Preparation and Certification of Standard Reference Materials for Calibration of Spreading Resistance Probes, NBS Spec. Publ. 260-93 (January 1985). PB85-177921**

Gills, T. E., Koch, W. F., Stolz, J. W., Kelly, W. R., Paulsen, P. J., Colbert, J. C., Kirklin, D. R., Pei, P.T.S., Weeks, S., Lindstrom, R. M., Fleming, R. F., Greenberg, R. R., and Paule, R. C., Standard Reference Materials: Methods and Procedures Used at the National Bureau of Standards to Certify Sulfur in Coal SRM's for Sulfur Content, Calorific Value, Ash Content, NBS Spec. Publ. 260-94 (December 1984). PB85-165900**

Mulholland, G. W., Hartman, A. W., Hembree, G. G., Marx, E., and Lettieri, T. R., Standard Reference Materials: Development of a 1 μm Diameter Particle Size Standard, SRM 1690, NBS Spec. Publ. 260-95 (May 1985). SN003-003-02665-4*

Carpenter, B. S., Gramlich, J. W., Greenberg, R. R., Machlan, L. A., DeBievre, P., Eschbach, H. L., Meyer, H., Van Audenhove, J., Connolly, V. E., Trahey, N. M., and Zook, A. C., Standard Reference Materials: Uranium-235 Isotopic Abundance Standard Reference Materials for Gamma Spectrometry Measurements, NBS Spec. Publ. 260-96 (September 1986). PB87-108544**

Mavrodineanu, R., and Gills, T. E., Standard Reference Materials: Summary of the Coal, Ore, Mineral, Rock, and Refactory Standards Issued by the National Bureau of Standards, NBS Spec. Publ. 260-97 (September 1985). SN003-003-02688-3*

Hust, J. G., Standard Reference Materials: Glass Fiberboard SRM for Thermal Resistance, NBS Spec. Publ. 260-98 (August 1985). SN003-003-02674-3*

Callanan, J. E., Sullivan, S. A., and Vecchia, D. F., Standard Reference Materials: Feasibility Study for the Development of Standards Using Differential Scanning Calorimetry, NBS Spec. Publ. 260-99 (August 1985). SN003-003-02675-1*

Taylor, J. K., Standard Reference Materials: Handbook for SRM Users, NBS Spec. Publ. 260-100 (September 1985). PB86-110897**

Mangum, B. W., Standard Reference Materials: SRM 1970, Succinonitrile Triple-Point Standard: A Temperature Reference Standard Near 58.08 °C, NBS Spec. Publ. 260-101 (March 1986). SN003-003-02722-7*

Weidner, V. R., Mavrodineanu, R., Mielenz, K. D., Velapoldi, R. A., Eckerle, K. L., and Adams, B., Standard Reference Materials: Holmium Oxide Solution Wavelength Standard from 240 to 640 nm - SRM 2034, NBS Spec. Publ. 260-102 (July 1986). PB86-245727**

Hust, J. G., Standard Reference Materials: Glass Fiberblanket SRM for Thermal Resistance, NBS Spec. Publ. 260-103 (September 1985). SN003-003-02687-5*

Mavrodineanu, R., and Alvarez, R., Standard Reference Materials: Summary of the Biological and Botanical Standards Issued by the National Bureau of Standards, NBS Spec. Publ. 260-104 (November 1985). SN003-003-02704-9*

Mavrodineanu, R., and Rasberry, S. D., Standard Reference Materials: Summary of the Environmental Research, Analysis, and Control Standards Issued by the National Bureau of Standards, NBS Spec. Publ. 260-105 (March 1986). SN003-003-02725-1*

Koch, W. F., ed., Standard Reference Materials: Methods and Procedures Used at the National Bureau of Standards to Prepare, Analyze, and Certify SRM 2694, Simulated Rainwater, and Recommendations for Use, NBS Spec. Publ. 260-106 (July 1986). PB86-247483**

Hartman, A. W., and McKenzie, R. L., Standard Reference Materials: SRM 1965, Microsphere Slide (10 μm Polystyrene Spheres), NBS Spec. Publ. 260-107 (November 1988).

Mavrodineanu, R., and Gills, T. E., Standard Reference Materials: Summary of Gas Cylinder and Permeation Tube Standard Reference Materials Issued by the National Bureau of Standards, NBS Spec. Publ. 260-108 (May 1987).

Candela, G. A., Chandler-Horowitz, D., Novotny, D. B., Marchiando, J. F., and Belzer, B. J., Standard Reference Materials: Preparation and Certification of an Ellipsometrically Derived Thickness and Refractive Index Standard of a Silicon Dioxide Film (SRM 2530), NIST Spec. Publ. 260-109 (October 1988).

Kirby, R. K., and Kanare, H. M., Standard Reference Materials: Portland Cement Chemical Composition Standards (Blending, Packaging, and Testing), NBS Spec. Publ. 260-110 (February 1988).

Gladney, E. S., O'Malley, B. T., Roelandts, I., and Gills, T. E., Standard Reference Materials: Compilation of Elemental Concentration Data for NBS Clinical, Biological, Geological, and Environmental Standard Reference Materials, NBS Spec. Publ. 260-111 (November 1987).

Marinenko, R. B., Blackburn, D. H., and Bodkin, J. B., Standard Reference Materials: Glasses for Microanalysis: SRM's 1871-1875, NIST Spec. Publ. 260-112 (February 1990).

Mangum, B. W., and Wise, J. A., Standard Reference Materials: Description and Use of a Precision Thermometer for the Clinical Laboratory, SRM934, NIST Spec. Publ. 260-113 (June 1990).

Vezzetti, C. F., Varner, R. N. and Potzick, J. E., Standard Reference Materials: Bright-Chromium Linewidth Standard, SRM 476, for Calibration of Optical Microscope Linewidth Measuring Systems, NIST Spec. Publ. 260-114 (January 1991).

Williamson, M. P., Willman, N. E., and Grubb, D. S., Standard Reference Materials: Calibration of NIST Standard Reference Material 3201 for 0.5 Inch (12.65 mm) Serial Serpentine Magnetic Tape Cartridge, NIST Spec. Publ. 260-115 (February 1991).

Mavrodineanu, R. , Burke, R. W., Baldwin, J. R., Smith, M. V., and Messman, J. D., Standard Reference Materials: Glass Filters as a Standard Reference Material for Spectrophotometry and Selection, Preparation, Certification and use of SRM 930 and SRM 1930, NIST Spec. Publ. 260-116 (in prep).

Vezzetti, C. F., Varner, R. N., and Potzick, J. E., Standard Reference Materials: Antireflecting-Chromium Linewidth Standard, SRM 475, for Calibration of Optical Microscope Linewidth Measuring Systems, NIST Spec. Publ. 260-117 (January 1992).

*Send order with remittance to Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20102. Remittance from foreign countries should include an additional one fourth of the purchase price for postage.

**May be ordered from: National Technical Information Services (NTIS), Springfield, VA 22161.

Conformance

The NIST SRM 3202 is specified in the testing requirements of the following standards.:

ANSI X3.180 - 1990
ISO/IEC 9661:1988
ECMA 120 - 1987

Disclaimer

Manufacturer's names and model numbers are cited solely to identify the hardware and software used and do not imply a recommendation and are not necessarily the best available for the purpose.

Acknowledgments

Special thanks are due to StorageTek for their assistance in modifying the Honeywell 96 tape drive, extensive technical support, and donation of read/write heads; to Honeywell for their donation of the Honeywell 96 tape drive; to Hewlett Packard for their donation of an HP3586C selective level meter and an HP3456A digital voltmeter; to Tektronics for their donation of the AM502 differential amplifier; and to IBM for their technical support.

The author greatly appreciates the time, support, and guidance provided by Mr. Gerald Taylor and Dr. Richard Thornely of StorageTek.

Appreciation is also due to Mrs. Natalie Willman of NIST for her assistance with the C programming language, Dr. James Filliben of NIST for his guidance in statistical analysis, and Dr. Ronald Boisvert of NIST for his contribution of the curve fitting program.

The SRM 3202 system was developed by the author and the calibration of the SRM 3202 tapes were performed by Mr. Lloyd D. Gilmore. The project was supervised by Mr. Dana S. Grubb, manager, Data Storage Group.

Funding for the development of SRM 3202 was provided by NIST and by several of the members of Technical Committee X3B5, Digital Magnetic Tape.

Table of Contents

List of Figures

List of Table

1. Introduction

1.1 Need for Standard Reference Tapes

Reliable interchange of magnetic computer storage media is an essential requirement of modern data processing systems. Interchange is the ability of the system to extract information stored on magnetic media, such as computer magnetic tape, cassette, cartridge, or disk, that was written by another compatible media-handling system either within or external to the originating installation.

When the magnetically encoded data on the tape or disk are converted into electrical signals by the reproducing system, it is necessary for the media parameters to be compatible with the design of other reproducing or recording systems. It is inefficient and unreliable for an electronic system to need continuous readjustment in order to handle nonuniform magnetic media.

Interchange standards define a wide variety of mechanical, electrical, and magnetic parameters, such as length, width, thickness, longitudinal curvature, electrical resistance, signal-to-noise ratio, etc. However, several magnetic properties, such as typical field, average signal amplitude, overwrite, and resolution, cannot be meaningfully measured directly. Therefore, it is necessary that each type of magnetic computer storage medium intended for interchange be produced with media properties within given relative tolerances. In other words, there must be a "reference" against which the media parameters can be compared and for which the data processing systems can be calibrated.

Signal amplitude is an important parameter because different amplitudes require different read amplifier gain settings to provide the signal level necessary for the detection circuitry. While modern tape drives use automatic gain control, wide variations in recorded amplitude can cause read errors. For older magnetic media with relatively low physical recording densities (e.g., 126 flux transitions per millimeter (ftpmm), 3200 flux transitions per inch (ftpi)), signal amplitude is the only properties for which an Standard Reference Material (SRM) is needed.

With modern tape systems, the physical recording density has increased significantly so that several other magnetic properties have become critical for dependable media interchange. For example, the ability of the write head adequately to overwrite previously recorded data is important on these media with higher physical recording density which have lower signal amplitudes and poorer signal to noise ratios than their low density predecessors. Other properties include typical current (a specific point on the magnetic saturation curve), and frequency resolution (frequency rolloff).

1.2 Background of the NIST Secondary Standard Reference Tape Program

Earlier SRMs developed by NIST include SRM 3200 and SRM 6250, 12.65 mm (0.5 in), open-reel tape, SRM 1600, 3.8 mm (0.15 in), cassette, and SRM 3216, 6.3 mm (0.25 in), cartridge (see table 1). SRM 3200, 6250, 1600, and 3216 are produced on a system which is entirely manual in operation. The system uses a ramp generator for the write current and direct plotting on analog recorders.

The SRM 3217, 6.3 mm (0.25 in), cartridge is produced on a second system that is partially computer controlled and has a digital plotter.

The SRM 3201, 12.65 mm (0.5 in) cartridge was the first SRM produced on a new generation of computer-controlled systems developed at NIST. All instruments in the SRM 3201 and SRM 3202 test system are commercially available. The software, the peak-to-peak detector, and other specialized digital and analog circuits were developed by NIST.

The SRM 3202 system, the subject of this Special Publication, uses a computer-controlled arbitrary function generator to provide the write current. A computer-controlled selective level meter is used to measure the signal output amplitude on a read-after-write pass. Tape drive motion is controlled via an IEEE-488 interface. In addition, files for each tape tested are stored by the computer on magnetic media. The 12.65 mm (0.5 in) magnetic tape cartridge has 18-tracks recorded in parallel, or 36 tracks employing parallel serpentine recording and a physical recording density of 972 ftpmm (24689 ftpi). The SRM consists of a digital magnetic tape in its cartridge and documentation of the tape's performance relative to the Master Standard Reference Tape's performance, on the following properties: typical field, average signal amplitude, overwrite, and resolution. Section 6 contains definitions of these properties and other special terms used in magnetic tape testing.

SRM	Description
3200/6250	12.65 mm (0.5 in), 32/126/356 ftpmm (800/3200/9042 ftpi), open-reel tape
1600	3.8 mm (0.15 in), 63 ftpmm (1600 ftpi), cassette tape
3216	6.3 mm (0.25 in), 126 ftpmm (3200 ftpi), cartridge tape
3217	6.3 mm (0.25 in), 252/394 ftpmm (6400/10000 ftpi), cartridge tape
3201	12.65 mm (0.5 in), 262/394 ftpmm (6667/10000 ftpi), cartridge tape
3202	12.65 mm (0.5 in), 972 ftpmm (24689 ftpi), cartridge tape

Table 1. NIST Standard Reference Tapes

The following sections explain the testing methodology, the measurement system, the selection of the Master Standard Reference, and the usage of the SRM 3202.

2. Testing Methodology

This section describes the methodology used for testing saturation, overwrite, and resolution of SRM 3202 tapes. All measurements are made on a read-after-write pass over the middle-third of the tape under test. Also, measurements are only made on track 9 of an 18-track parallel read/write head. The measurements described in this paper are performed using the NIST Master Standard Read/Write Head # 6 (StorageTek SN C024173). Measurements are performed on SRM 3202 tapes at the ambient condition of 23 $^{o}C \pm 2$ ^{o}C (74 $^{o}F \pm 4$ ^{o}F), and 40 to 60 percent relative humidity after 24 hours of acclimatization.

2.1 Self-Correcting Calibration System

The SRM 3202 Secondary Standard Reference Tapes are calibrated using a self-correcting calibration system. This scheme is fully documented in an article cited in reference 4.

In this self-correcting scheme, there is a Master Standard Reference Tape, and several working tapes that are calibrated against it. The data are stored in table form on magnetic disk and a magnetic disk backup medium.

The Secondary Standard Reference Tapes will be calibrated at some later date, and subsequent batches calibrated over a period of years. At the time of the calibration of a batch of secondary tapes, the working tapes are run again and a correction factor table is determined, which is defined as the differences in signal amplitude and write current between the working tapes data when they were first run, and the current working tapes data. If significant differences are found, this "correction" table may then be added to the data obtained when the Secondary Standard Reference Tape is run. This will correct the system's gain adjustments which may have drifted since the Master Standard Reference Tape was selected. See section 6 for definitions of the Master Standard Reference Tape, Secondary Standard Reference Tape, and working tapes.

2.2 Saturation Test

The result of the saturation test is a plot of the read signal amplitude as a function of the write current. The tape is written with a 1f signal (972 ftpmm (24689 ftpi)), see appendix A, and an increasing current. Then the tape is rewound and the average of multiple samples of signal amplitude produced by each current setting is read from the tape and stored in a table. These values are then fitted to a third order polynomial curve and plotted with average signal amplitude along the y axis and write current along the x axis. Curve fitting is needed since the read signal is subject to various sources of noise, such as thermal and magnetoresistive bias noise.

For all tapes, the following values are calculated:

Peak amplitude (Ap) the peak average signal amplitude.

Peak current (Ip) the write current corresponding to the peak amplitude.

Typical amplitude (At) 85 percent of the peak amplitude (Ap).

Typical field the minimum recording field which will produced the typical amplitude (At).

Typical Current (It) the write current which will produce the typical field.

When a Master Standard Reference Tape is chosen and a saturation test is performed on it, the following data are calculated:

Standard Reference Current (Ir) the typical current of the Master Standard Reference Tape.

Standard Measurement Current (Im) 1.5 times the standard reference current (Ir)

Standard Reference Amplitude (SRA) the average signal amplitude from the Master Standard Reference Tape when it is recorded with the Standard Measurement Current (Im).

When a Secondary Standard Reference Tape is calibrated, the following data are compared:

- Standard Reference Current (Master Standard Reference Tape)
- Standard Measurement Current (Master Standard Reference Tape)
- Typical Current (Test Tape)
- Ratio of It to Ir
- Ratio of the test tape's average signal amplitude at the Standard Measurement Current (Im) to the Standard Reference Amplitude (SRA).

Figure 1 shows a SRM 3202 saturation curve produced by this system. The x axis is the base-to-peak write current in milliamperes and the y axis is the base-to-peak average signal amplitude in amplitude units. The amplitude units are normalized to 40 units for the peak amplitude of the Master Standard Reference Tape. Figure 2 shows the Master Standard Reference Tape saturation curve.

Each point on an SRM 3202 saturation curve consist of the medians of at least 10 selective level meter samples at each of the 50 discrete current values. The data is then fitted to a third-order polynomial.

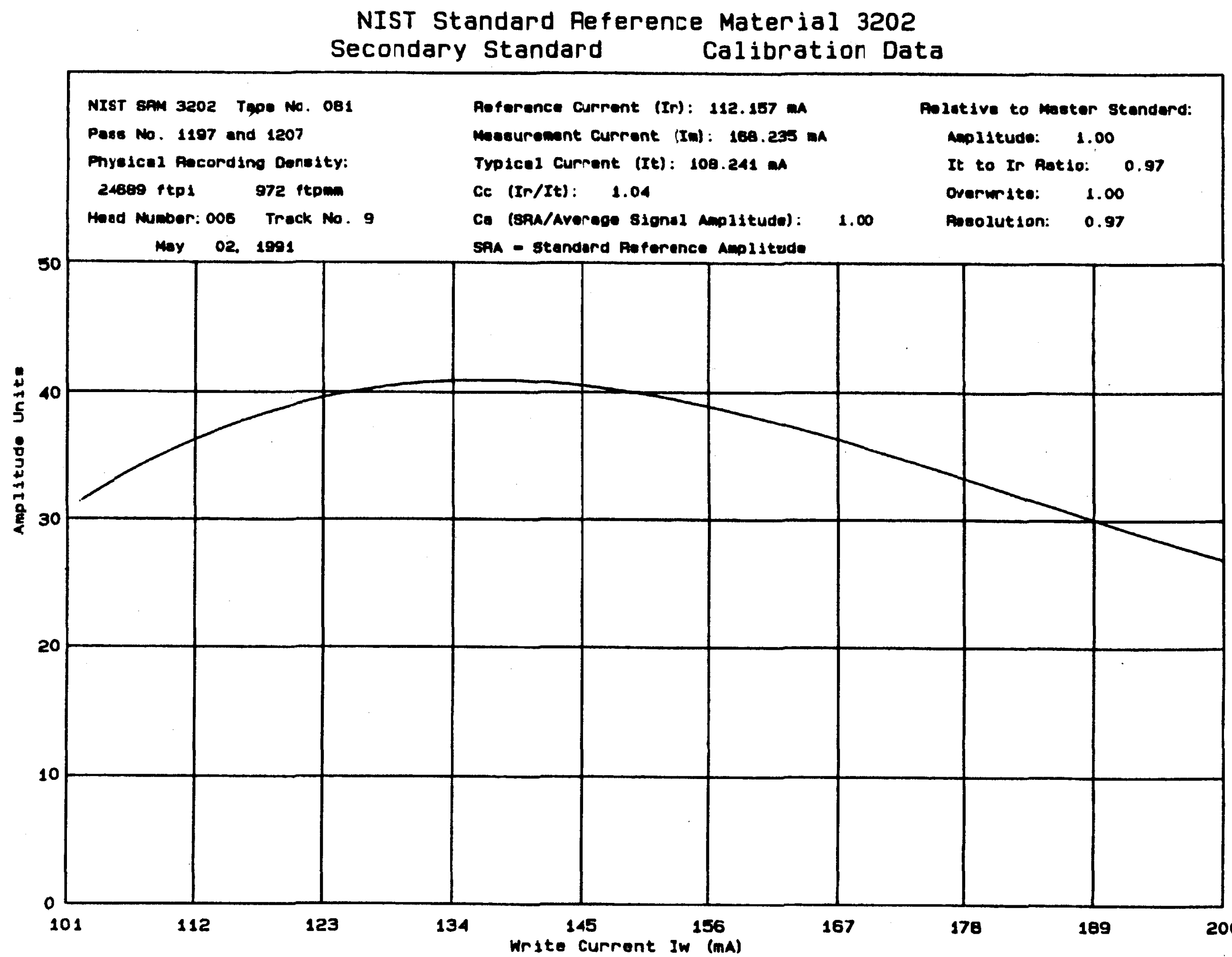


Figure 1. Secondary Standard Calibration Data

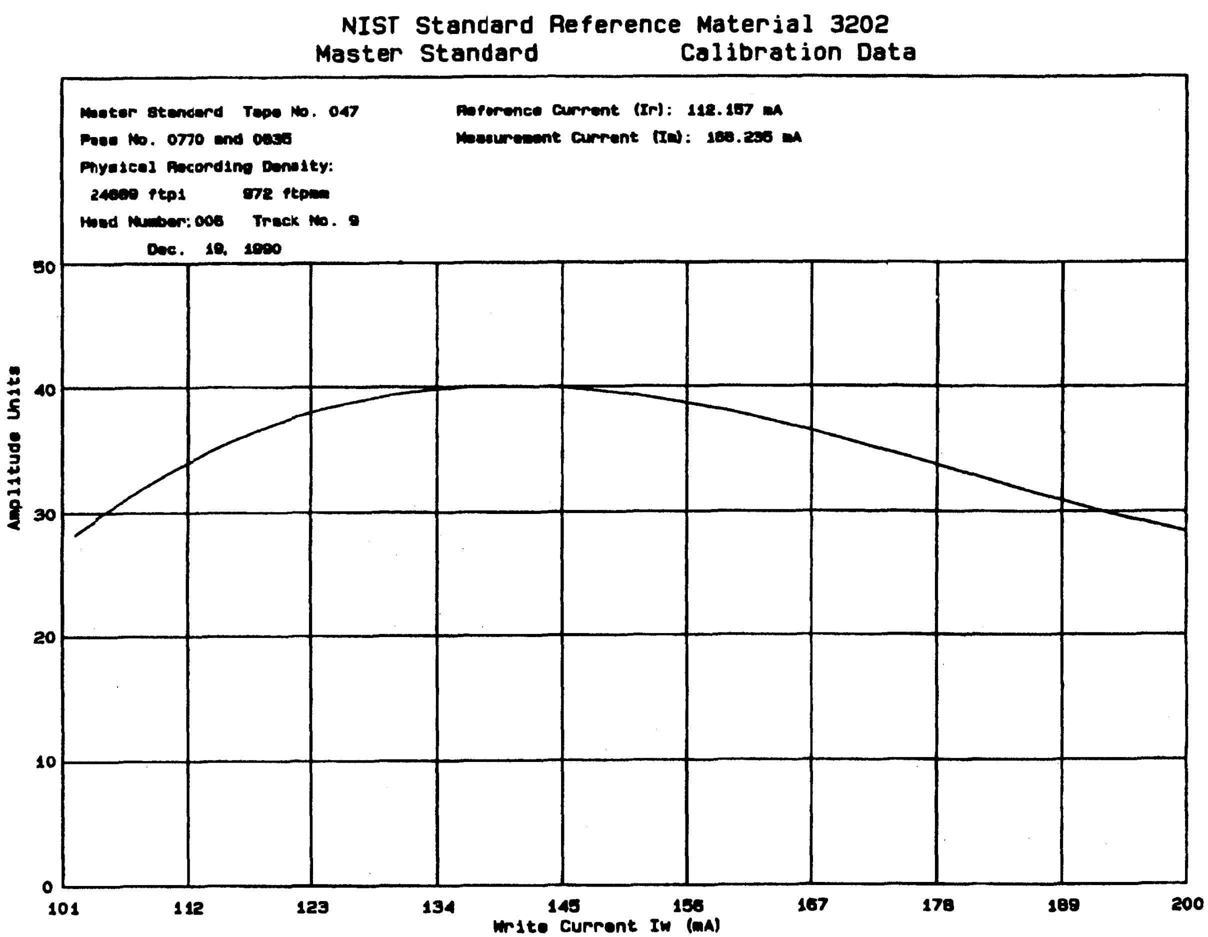


Figure 2. Master Standard Calibration Data

2.3 Overwrite Test

"Overwrite" is defined as the ratio of the average signal amplitude of the residual of the tone pattern after being overwritten by the 1f pattern, to the average signal amplitude of the original tone pattern (see Figs. 3 and 4).

A tape is recorded with the tone pattern (6-bit pattern 100000) at the Standard Measurement Current (Im). The average signal amplitude of the tone pattern is read from the tape. The tape is then recorded with the 1f pattern at the standard measurement current (Im). The average signal amplitude of the 1f pattern is read from the tape. The residual average signal amplitude of the tone pattern is then measured.

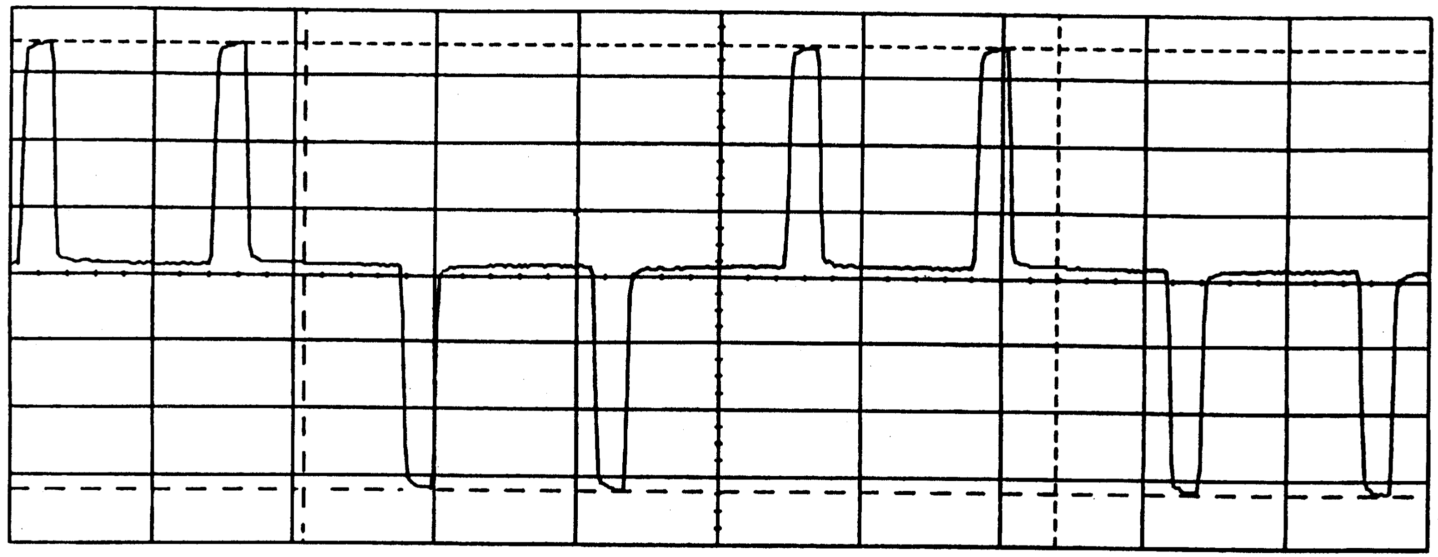
2.4 Resolution Test

Resolution is defined as the ratio of the average signal amplitude at the 1.5f physical recording density to that at the 1f physical recording density. See Section 6 for definitions the 1.5f physical recording density.

A tape is recorded at the 1f physical recording density at the Standard Measurement Current (Im), and the average signal amplitude is recorded.

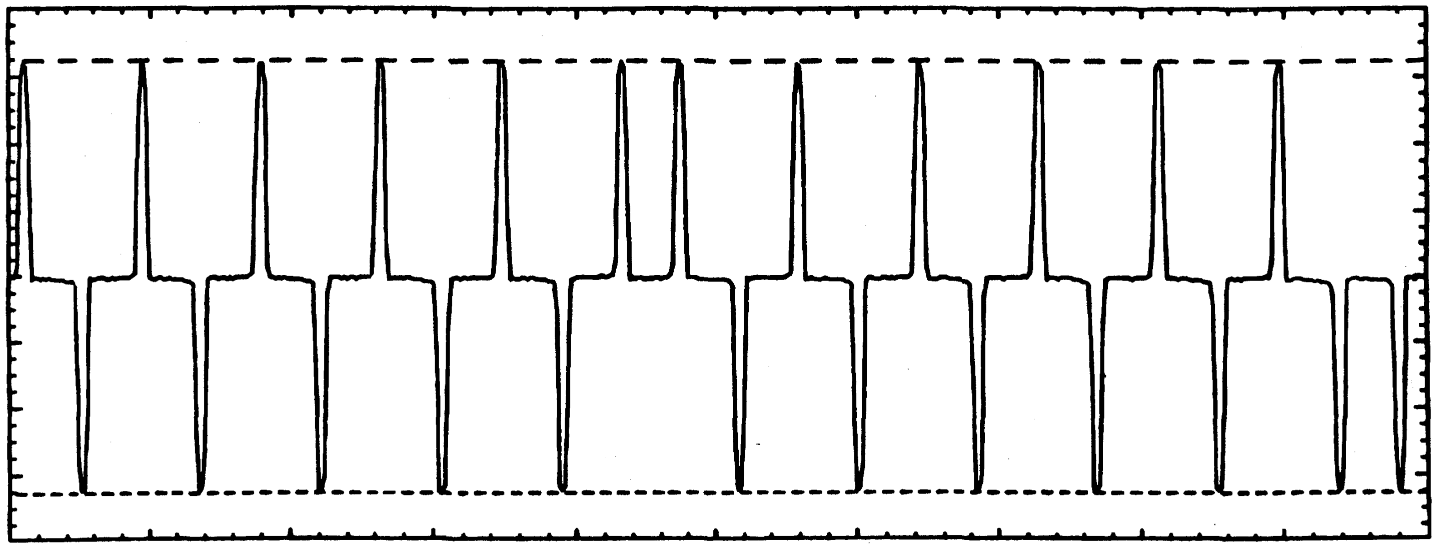
The tape is ac bulk erased and recorded at the 1.5f physical recording density at the Standard Measurement Current (Im). The average signal amplitude is recorded.

The ratio of the average signal amplitude at the 1.5f physical recording density to the average signal amplitude at the 1f physical recording density is then calculated.



Double Density NRZI Recording Pattern ("all 1's") at 0.762 m/s (30 in/s)
972 ftpmm (24689 ftpi), 1/6 duty cycle
Channel 1: 600 mV/div
Timebase: 500 ns/div
Frequency: Approximately 370 kHz

Figure 3. SRM 3202 1f Recording Pattern



Bipolar Tone Pattern ("100000") written at 0.762 m/s (30 in/s)
Channel 1: 600 mV/div
Timebase: 1.6 μs/div

Figure 4. SRM 3202 Tone Recording Pattern

3. Description of the Measurement System

Manufacturer's names and model numbers are cited solely to identify the equipment used and do not imply a recommendation. Such identification is essential, since the system software must be written using the control/status codes and data formats specified for the particular equipment. Alternative equipment may be used, but some modification of the NIST system software will be necessary. As the instruments are set up by the software, those interested in the instruments' settings should consult the software listings for the instrument drivers. (Source code is available on magnetic media from NIST.)

Figure 5 shows the measurement system interconnection. It is essential that the 50 ohm terminator be used as shown.

3.1 Tape Transport

A Honeywell 96 instrumentation tape drive was selected for the SRM 3202 test system, since it offered the necessary stable transport velocities and provided relative ease for modifications. The drive was modified for use with a cartridge tape feeder and 18-track parallel recording read/write heads. Although a Honeywell standard transport speed of 0.762 m/s (30 in/s) is used for writing, a nonstandard speed of 0.3048 m/s (12 in/s) is used for reading. In order to accomplish this, the HP3325A frequency synthesizer is connected to the Honeywell 96 external reference input (J7 on the A4 control logic card. J16 must also be jumpered to indicate external reference). The 0.3048 m/s (12 in/s) is obtained by selecting 0.381 m/s (15 in/s) and then reducing the reference frequency from the standard 3.2 to 2.56 MHz. This frequency of 2.56 MHz was derived by dividing the desired speed by the next highest standard transport speed and multiplying that quantity by the standard reference frequency. For example:

$$\text{Desired frequency} = (0.3048\ ms^{-1} / 0.381\ ms^{-1}) * 3.2\ MHz = 2.56\ MHz$$

The Honeywell 96 vacuum column system is set to maintain a tape tension of 2.2 N ± 0.3 N (7.9 ozf ± 1.1 ozf). In addition, the measurement system includes a tape lifter, which injects a jet of air between the head and tape whenever the tape is stopped or measurements are not being performed. This effectively reduces problems with machine drag and the possibility of head-to-tape adhesion. As shown in Figure 6, the tape lifter is controlled using the Honeywell 96 track select lines. This provides IEEE-488 control of the tape lifter.

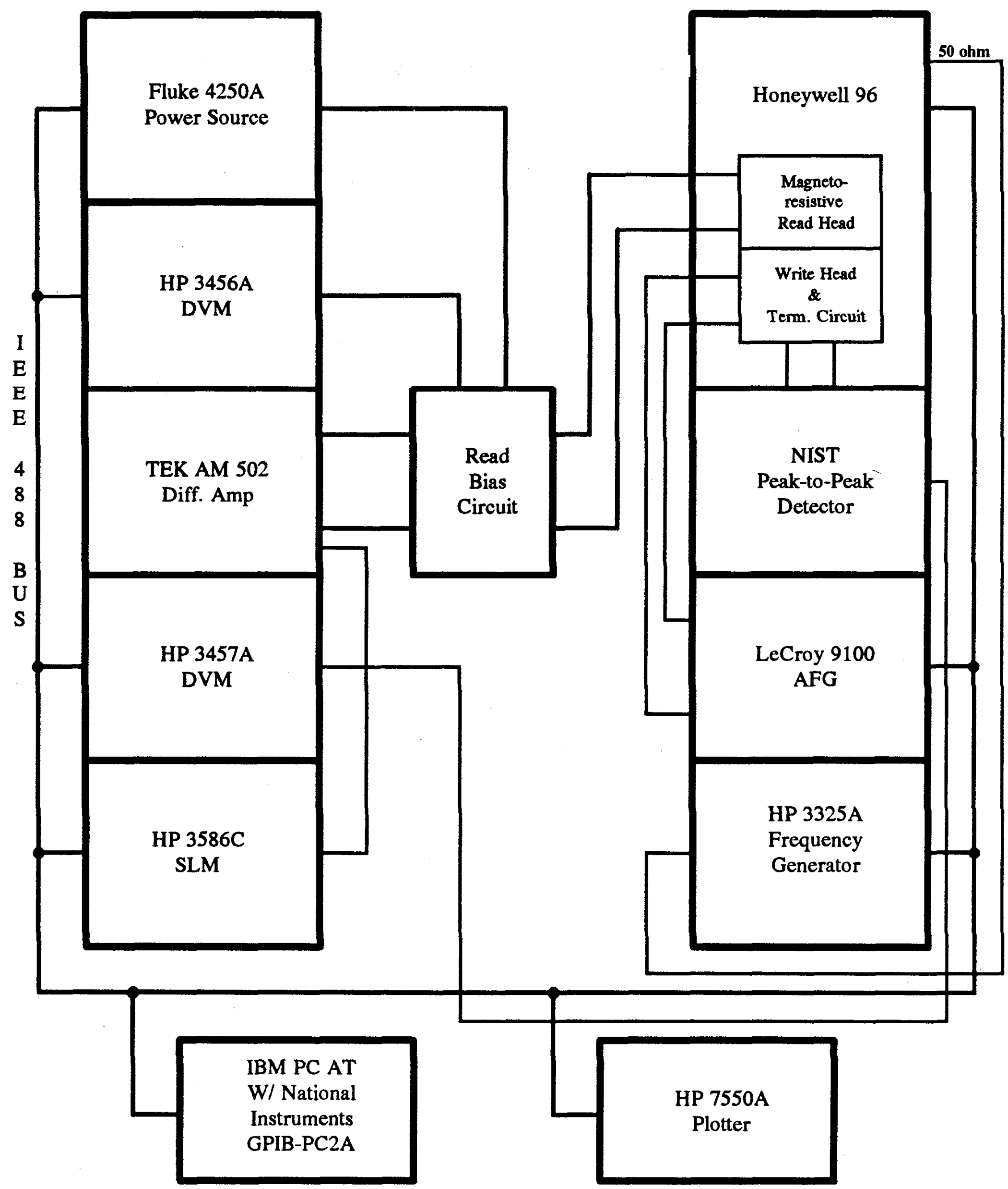


Figure 5. Measurement System Interconnections

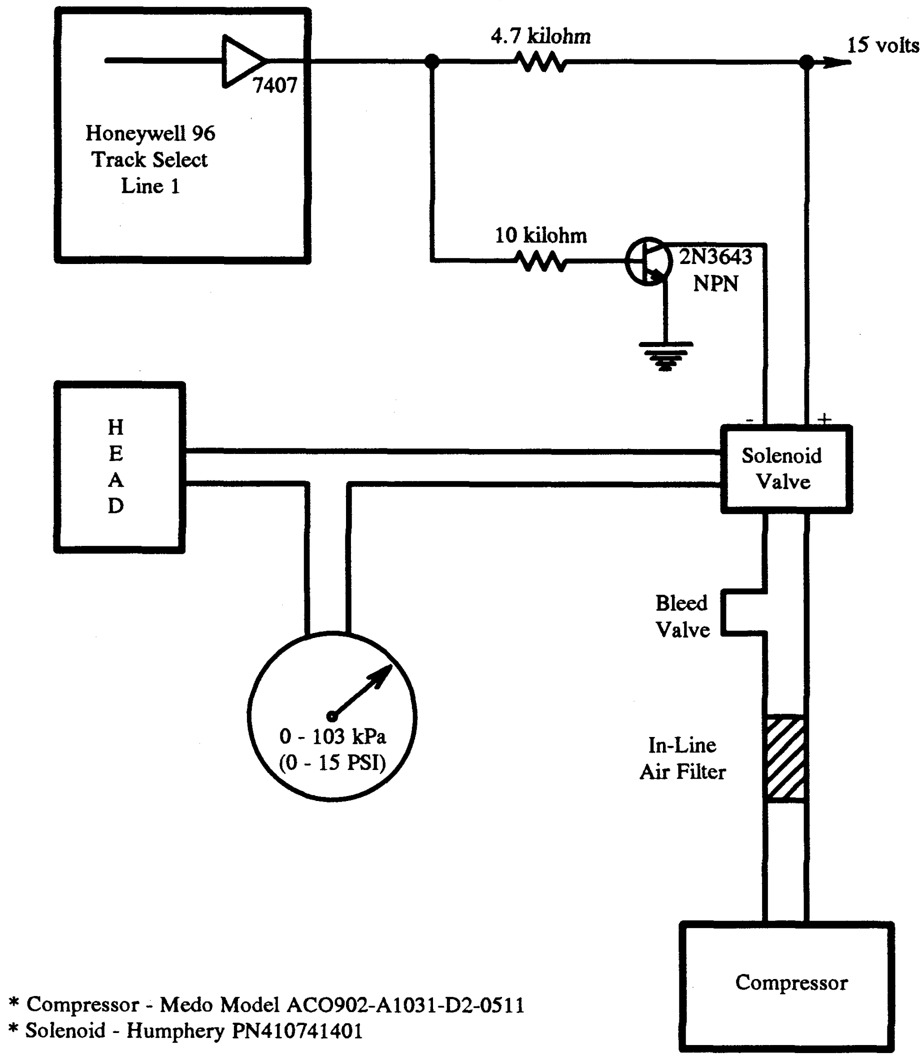


Figure 6. SRM 3202 Tape Lifter

3.2 Write Instrumentation and Circuitry

As shown in Figure 7, a LeCroy 9100 Arbitrary Function Generator (AFG) is used to produce the double density nonreturn to zero 1f, 1.5f, and tone pattern. The AFG is only capable of providing a maximum of 100 mA base-to-peak current from a single waveform output channel. Therefore, the two waveform output channels were summed, resulting in a maximum 200 mA base-to-peak waveform.

3.2.1 Peak-to-Peak Detector

Figures 8 and 9 show the NIST peak-to-peak detector circuit. The peak-to-peak detector is used only to monitor the current provided by the LeCroy 9100 AFG.

The peak-to-peak detector provides a low-noise dc output for measurement by the digital voltmeter. The detector's response is linear within 1 percent from 350 to 1350 mV and from 250 to 500 kHz. (The detector is also linear within 2 percent from 100 kHz to 2 MHz.) The circuit design relies on the use of a particular type of operational amplifier (Comlinear CLC-400), polypropylene or similar specification capacitors and other selected components. While the operational amplifiers are quite stable, the offsets should be adjusted prior to calibrating tapes.

3.2.2 Offset Adjustment of Peak-to-Peak Detector

The peak-to-peak detector is quite stable, but the offsets should be periodically readjusted. Following is a list of steps to adjust the detector:

1) Turn the power on and let the detector warm up for at least 1 hour.

2) Ground the two differential inputs to the detector.

3) Using an oscilloscope with a high gain preamplifier capable of at least 10 mV/div sensitivity, adjust the differential amplifier. Place the scope probe on the output of the amplifier (U1 pin 6) and adjust R7 for ground level on the oscilloscope.

4) Repeat step 3 for the linear halfwave rectifiers. Place the probe on U2 pin 6 and adjust R15, then place the probe on U3 pin 6 and adjust R21. As U2 and U3 are subject to noise, adjust the outputs for an average level of zero.

5) Use a high input impedance voltmeter capable of reading to 1 mV to adjust the offset of the inverting summing amplifier. Place the probe on U4 pin 6 and adjust R23 for an average reading of zero.

Each amplifier will drift approximately ±5 mV for output levels in the 500 mV and higher range. This means an error of less than 1 percent even when the detector has not been used for a period of time.

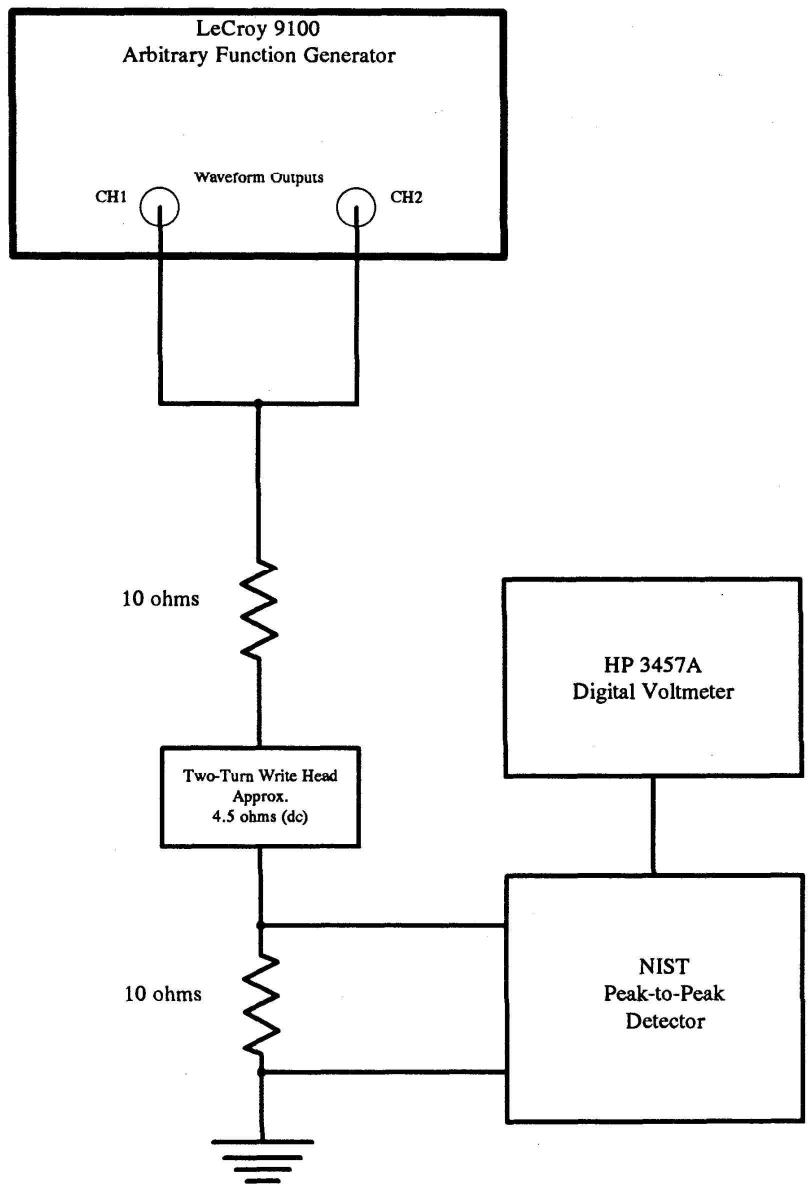


Figure 7. Write Circuitry and Instrumentation

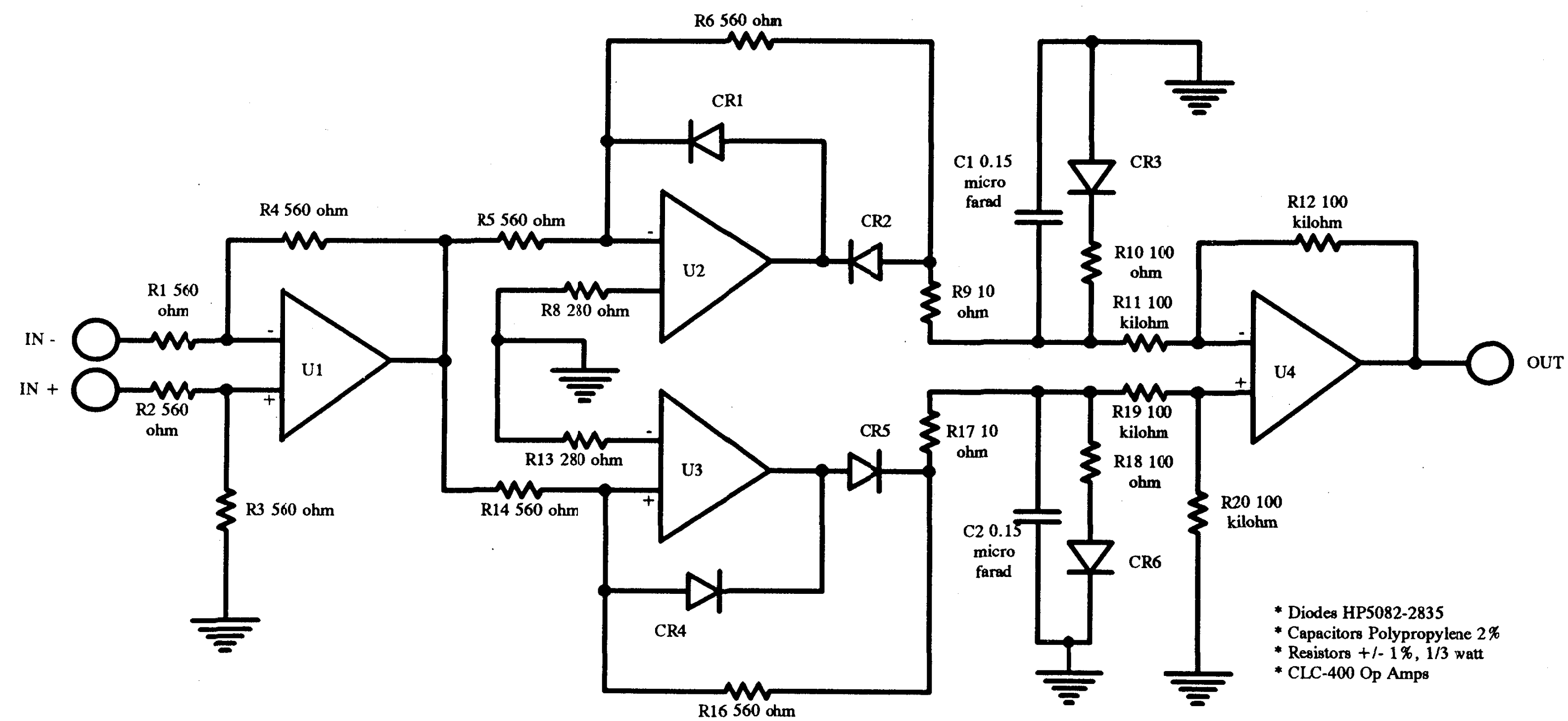


Figure 8. NIST Peak-to-Peak Detector Circuit

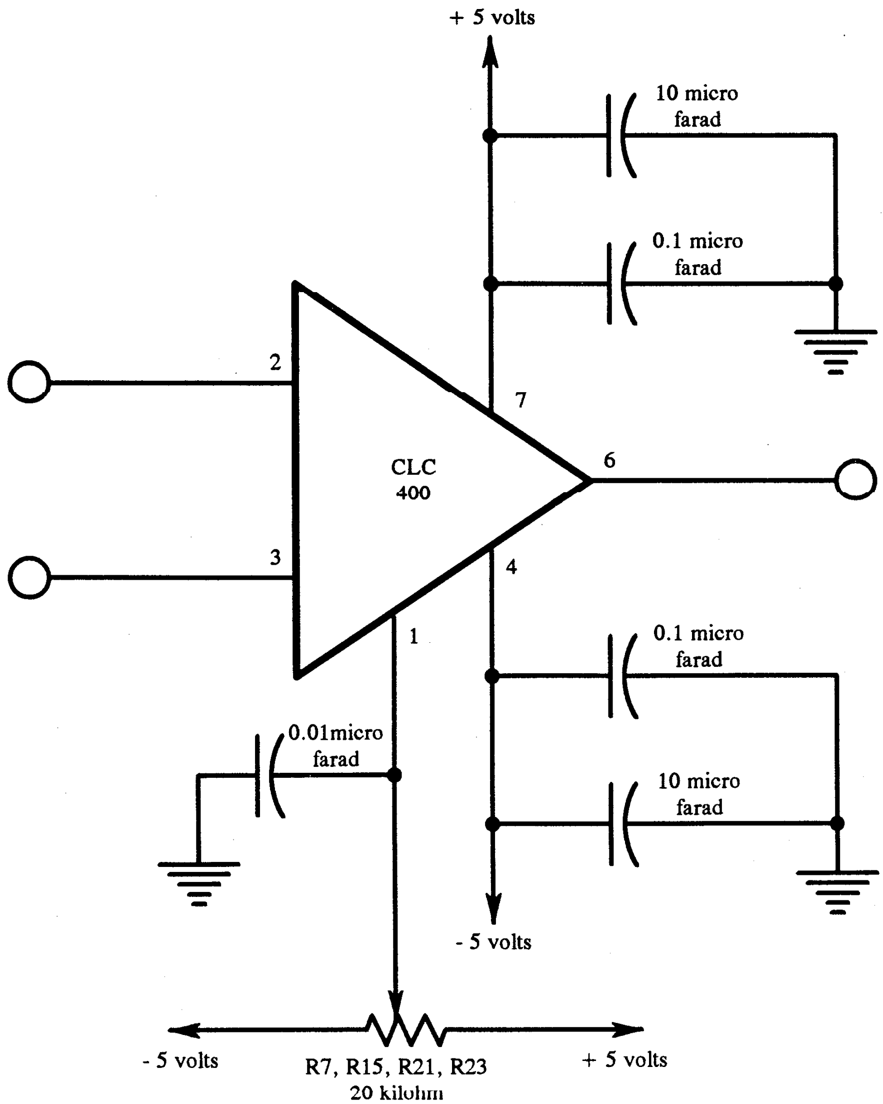


Figure 9. NIST Peak-to-Peak Detector Op Amp Connections

3.3 Read Instrumentation and Circuitry

As shown in Figure 10, the read instrumentation and circuitry is comprised of a Fluke 4250A bipolar voltage source, a Tektronics AM502 differential amplifier, a read-bias circuit, an 18-track, parallel magnetoresistive read head, an HP 3456A digital voltmeter (DVM), and an HP 3586C selective level meter (SLM).

The Fluke 4250A power source is required to provide 22 mA of current through each side of the magnetoresistive read head. The voltage drop across the magnetoresistive read head is monitored using two 50 kilohm resistors and a HP 3456A DVM. The Fluke 4250A power source is connected in a feedback loop with the DVM. The voltage output is then adjusted until a 0.88 V output is read by the DVM.

The voltage drop across the head is then fed to the AM502 differential amplifier. The AM502 converts the differential signal to a single signal. The amplifier has a bandwidth of dc to 1 MHz and 500 is the gain.

The read signal is then sampled by the HP 3586C selective level meter, which is setup with a bandwidth of 3100 Hz.

In order to protect the magnetoresistive read head from a surge in current, the output of the Fluke 4250A power source was fitted with a crowbar circuit (see Fig. 11) to limit the output current to a maximum of 75 mA.

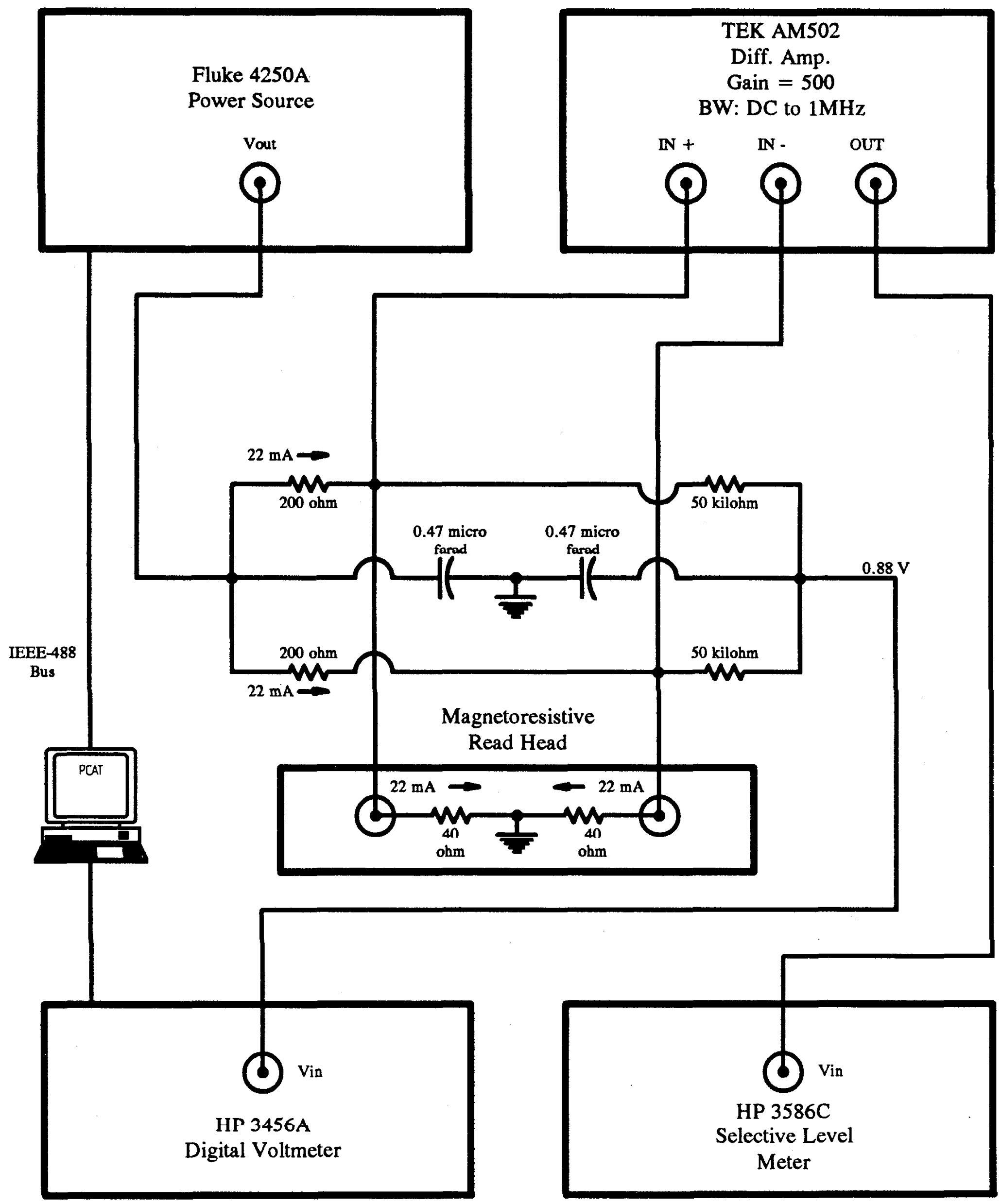
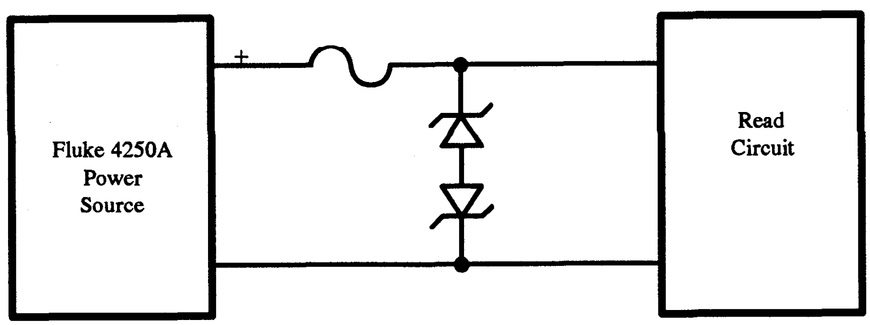


Figure 10. Read Instrumentation and Circuitry



* Fuse - 1/16 amp
* Zeners - Phillips ECG 5122A, 8.2 V, 5W

Figure 11. Read Head Current Limiting Circuit

3.4 Measurement System Software

The system software is menu-driven with computer control of all aspects of the tape testing. The operator is asked to key in answers to necessary questions, such as the type of tape to be tested and the type of test to be performed.

The program is written in C language, which allows a high degree of control of the hardware. In addition, C can be compiled to efficient object code, is portable with little modification between widely varying computers, and is designed for writing structured programs. The software was written using an IBM PC AT computer with DOS Version 3.2. Since the instruments needed for the system are all designed with very different commands, responses and formats, the source code is unique for each instrument. (Even very similar instruments from the same manufacturer, such as the HP3456A and HP3457A digital multimeters, are designed with different commands and responses.) Therefore, the substitution of other instruments will necessitate a re-write of the drivers.

The software should run properly on most IBM-compatible personal computers having a math coprocessor, a hard disk, and DOS Version 3.2 or later. The graphics functions used for displaying the saturation curves are specific to EGA monitors, and would require slight modification if another monitor is used. Computer speed should approximate that of an IBM PC AT or better.

The program is compiled using Borland Turbo C Version 1.5, although there are several other C compilers available that would probably be satisfactory. However, the IEEE-488 interface board used in the system must come with object code that works with the compiler. The compiler selected should make use of the math coprocessor and should produce relatively fast object code.

The system program should compile properly with most compilers, except for the graphics which use library functions specific to Turbo C. Also, the input byte and output byte functions are not specified in exactly the same way by all compilers, so modification of how these functions are specified would be needed. Segment addressing is not used, since both the program and the data use less than 64 kbytes.

The third-order polynomial curve fitting program was developed in Fortran by Dr. Ronald Boisvert of the NIST Computing and Applied Mathematics Laboratory.

4. Procedure for the Selection of a Master Standard Reference

Five centerline candidate tapes were received from each of 10 companies prior to the expiration of the ISO/IEC JTC 1/SC 11 and TC X3B5 extended centerline call deadline of November 30, 1990. Some companies were tape manufacturers, while others were drive manufacturers. Randomly assigned code letters were used to designate the companies in the data tabulated below. In alphabetical order, the companies are:

BASF
Carlisle
Dysan
Fuji
IBM
Memorex
StorageTeK
TDK
3M (U.S.)
3M (Italy)

Three saturation (sat) tests were performed on each of the five tapes from each of the 10 companies. Tests were run in random order by company. These tests were made using the Class 0 test option ("Test Tape") so that each tape was tested using its own Typical Current and Measurement Current rather than that of a master tape, since there was not, at this time, a master tape to use. (Since there is no common measurement current (Im), it is not possible to make a valid comparison of the output signal amplitudes using this particular data.)

The median Typical Current measurement for each tape was then selected.

Using the median Typical Current measurement for each tape, the five tapes were ranked for a given company, and the median of the medians was selected to represent that company. (For example, tape B21 pass 627 was selected to represent company B.)

The tapes were then ranked by Typical Current as shown below:

Tape	Pass	Median It	Rank It
B21	627	108.2	1
F43	619	111.1	2
J64	729	111.2	3
H53	641	111.3	4
G47	607	111.6	5
E35	742	112.3	6
K67	698	112.6	7
I58	751	113.0	8
D34	675	114.0	9
C29	632	119.3	10

Tape C29 was a clear outlier with its very high Typical Current. So C29 was deleted from the pool, which left an odd number of tapes. This made G47 the median tape, so it was selected as the PMSR (Proposed Master Standard Reference) Tape. Five more sat tests were run on G47 using the Class 3 test option (Master True):

Class	Pass	It	Am	Rank It	
3	768	111.7	3.166	1	
3	769	112.2	3.145	5	
3	770	112.1	3.111	3	<--- Median
3	771	112.1	3.106	2	
3	772	112.2	3.085	4	

Pass number 770 was selected, the sat test with the median Typical Current measurement, as the Master True file to use in subsequent tests. The following data is the Master True file.

Master True Header:
g0470770.f3s filename
g0470770.f3s mtfilename
121990 monthdayyear
ldg operator
006 headnumber
3.443 Ap_for_test_tape
138.0 Ip_for_test_tape
2.926 At_for_test_tape
112.1 It_for_test_tape
112.1 Ir_for_master_true
168.2 Im_for_master_true
3.111 Am_for_test_tape_at_master_true's_Im

Iwrite(mA)	Vmeasured (mV)	Amplitude Units
102.0000	2.4147	28.0575
104.0000	2.5317	29.4170
106.0000	2.6405	30.6812
108.0000	2.7414	31.8536
110.0000	2.8345	32.9354
112.0000	2.9200	33.9288
114.0000	2.9982	34.8375
116.0000	3.0693	35.6636
118.0000	3.1335	36.4096
120.0000	3.1911	37.0789
122.0000	3.2421	37.6715
124.0000	3.2868	38.1908
126.0000	3.3255	38.6405
128.0000	3.3584	39.0228
130.0000	3.3856	39.3389
132.0000	3.4075	39.5933
134.0000	3.4241	39.7862
136.0000	3.4357	39.9210
138.0000	3.4425	40.0000
140.0000	3.4448	40.0267
142.0000	3.4427	40.0023
144.0000	3.4364	39.9291
146.0000	3.4262	39.8106
148.0000	3.4123	39.6491
150.0000	3.3949	39.4469
152.0000	3.3742	39.2064
154.0000	3.3504	38.9298
156.0000	3.3238	38.6208
158.0000	3.2945	38.2803
160.0000	3.2627	37.9108
162.0000	3.2287	37.5158
164.0000	3.1927	37.0975
166.0000	3.1549	36.6582
168.0000	3.1154	36.1993
170.0000	3.0746	35.7252

(Data after 170 mA omitted as irrelevant.)

Five sat tests on each of the remaining nine tapes were run. (See data below.) The Class 4 test option (Working True) was used so that the Standard Measurement Current (Im) of the Proposed Master Standard Reference Tape (PMSR) would be used. That is, tape G47 pass number 770 was used as the Master True (PMSR) file with Im = 168.2 mA.

Tape	Pass	Median	It	Am	
B21	812		108.9	3.002	
B21	813		108.8	2.976	
B21	814		109.7	2.930	
B21	815	Am	109.4	2.954	
B21	816	It	109.3	2.902	
C29	806		119.9	2.787	
C29	808		120.1	2.892	
C29	809	Am	119.9	2.839	
C29	810	It	120.0	2.838	
C29	811		120.2	2.882	
D34	796		114.2	3.068	
D34	797	It	114.6	3.090	
D34	799		113.9	2.999	
D34	800	Am	114.8	3.046	
D34	801		120.7	3.034	
E35	779		111.3	3.222	
E35	780		112.4	3.223	
E35	781	It	111.8	3.161	
E35	782	Am	111.7	3.179	
E35	783		112.1	3.138	
F43	817	Am	111.3	2.877	
F43	818		112.6	2.911	
F43	821		112.6	2.901	
F43	822		111.4	2.873	
F43	823	It	111.9	2.864	
G47	770		112.1	3.111	<--- PMSR
H53	802	It	111.9	3.167	
H53	803	Am	111.7	3.147	
H53	804		111.7	3.138	
H53	805		112.5	3.167	
H53	806		112.4	3.129	

I58	774	It	112.8	2.920
I58	775		113.2	2.933
I58	776		111.7	2.900
I58	777		111.8	2.794
I58	778	Am	113.6	2.916
J64	786		110.8	2.745
J64	787	It & Am	110.9	2.711
J64	788		110.9	2.708
J64	789		111.1	2.701
J64	790		111.4	2.714
K67	791		111.8	3.163
K67	792	Am	112.6	3.139
K67	793		113.1	3.109
K67	794		113.0	3.131
K67	795	It	112.9	3.169

The saturation curves for the median Typical Current passes were plotted. Note that the signal amplitude (Am) measurements were all made at the same Standard Measurement Current (Im) and, therefore, may be compared with each other. All of the curves looked smooth and satisfactory. In the data below, SRA is the Standard Reference Amplitude, the Am value of the PMSR Tape. For ease of comparison, the median data from the saturation curves above are shown in ascending order of Typical Current:

Tape	Pass	It	It/Ir	Am	Am/SRA	
B21	816	109.3	0.97	2.902	0.93	
J64	787	110.9	0.99	2.711	0.87	
E35	781	111.8	1.00	3.161	1.02	
H53	802	111.9	1.00	3.167	1.02	
F43	823	111.9	1.00	2.864	0.92	
G47	770	112.1	1.00	3.111	1.00	<--- PMSR
I58	774	112.8	1.01	2.920	0.94	
K67	795	112.9	1.01	3.169	1.02	
D34	797	114.6	1.02	3.090	0.99	
C29	810	120.0	1.07	2.838	0.91	

The signal amplitude data from the previous table is shown below in ascending order of signal amplitude:

Tape	Pass	Am	Am/SRA	
J64	787	2.711	0.87	
C29	810	2.838	0.91	
F43	823	2.864	0.92	
B21	816	2.902	0.93	
I58	774	2.920	0.94	
D34	797	3.090	0.99	
G47	770	3.111	1.00	<--- PMSR
E35	781	3.161	1.02	
H53	802	3.167	1.02	
K67	795	3.169	1.02	

For signal amplitude, Tape G47 pass 770 ranks seventh overall and sixth if the Typical Current outlier C29 is omitted. Its signal amplitude value is less than 1 percent away from that of the median, D34.

Five overwrite and five resolution tests were run on the PMSR Tape (G47):

Pass	Tone	1f	Overwrite	Ranking	
825	.2473	2.913	.0849	4	
826	.2444	2.889	.0846	3	<--- Median
827	.2453	2.870	.0855	5	
828	.2447	2.944	.0831	1	
829	.2402	2.874	.0835	2	

Pass	1.5f	1f	Resolution	Ranking	
830	.7191	2.875	.2501	3	<--- Median
831	.7149	2.907	.2459	1	
832	.7082	2.878	.2460	2	
833	.7383	2.898	.2547	5	
834	.7236	2.860	.2529	4	

The data from passes 826 and 830 were combined (using an editor) to artificially create the file 835 to use as the PMSR file for overwrite and resolution:

PMSR Header:
g0470835.f3o filename
g0470835.f3o mtfilename
g0470770.f3s satfilename
122890 monthdayyear
dsg operator
006 headnumber
168.2 Im_for_master_true
112.1 It_for_test_tape
0.000 Ir_for_master_true
1.000 It_to_Ir
0.084 overwrite_for_test_tape
0.084 overwrite_for_master_true
1.000 overwrite_test_to_master
0.250 resol_for_test_tape
0.250 resol_for_master_true
1.000 resol_test_to_master
0.244 tone_mV_overwrite
2.889 1f_mV_overwrite
2.875 1f_mV_resolution
0.719 1_5f_mV_resolution

Three overwrite tests were run on the previously selected tapes from each company (B21, C29, etc.):

Tape	Pass	Tone	1f	Overwrite	Ranking	
B21	836	.2539	2.698	.0941	2	<---
B21	837	.2557	2.694	.0949	3	
B21	838	.2523	2.700	.0934	1	
C29	874	.1883	2.618	.0719	1	
C29	875	.1916	2.594	.0738	3	
C29	876	.1915	2.614	.0733	2	<---
D34	880	.2360	2.821	.0836	2	<---
D34	881	.2390	2.831	.0844	3	
D34	882	.2326	2.807	.0829	1	
E35	867	.2559	2.915	.0878	1	
E35	868	.2597	2.901	.0895	3	
E35	869	.2575	2.901	.0887	2	<---

F43	886	.2429	2.681	.0906	1	
F43	887	.2425	2.637	.0919	3	
F43	888	.2424	2.653	.0913	2	<---
G47	826	.2444	2.889	.0846	PMSR	
H53	861	.2216	2.731	.0811	1	
H53	862	.2258	2.760	.0818	2	<---
H53	863	.2240	2.710	.0827	3	
I58	842	.2226	2.757	.0807	3	
I58	843	.2157	2.742	.0786	1	
I58	844	.2141	2.693	.0795	2	<---
J64	855	.2429	2.569	.0945	2	<---
J64	856	.2396	2.535	.0945	3	
J64	857	.2369	2.529	.0937	1	
K67	848	.2379	2.844	.0837	2	<---
K67	850	.2414	2.916	.0827	1	
K67	851	.2425	2.873	.0844	3	

The median overwrite measurements for each tape are shown below. For ease of comparison, the median data for the above overwrite tests are shown in ascending order of overwrite value:

Tape	Pass	Overwrite	Rank	
C29	876	.0733	1	
I58	844	.0795	2	
H53	862	.0818	3	
D34	880	.0836	4	
K67	848	.0837	5	
G47	826	.0846	6	PMSR
E35	869	.0887	7	
F43	888	.0913	8	
B21	836	.0941	9	
J64	855	.0945	10	

Tape G47 pass 835 ranks sixth overall and fifth (median) if the Typical current outlier C29 is omitted.

Three resolution tests were run on the previously selected tapes from each company (B21, C29, etc.).

Tape	Pass	1.5f	1f	Resolution	Ranking
B21	839	.6406	2.736	.2340	2 <--
B21	840	.6288	2.711	.2319	1
B21	841	.6542	2.773	.2359	3
C29	877	.7296	2.612	.2793	2 <--
C29	878	.7256	2.577	.2815	3
C29	879	.7195	2.604	.2763	1
D34	883	.7190	2.767	.2598	3
D34	884	.6857	2.727	.2514	1
D34	885	.6946	2.734	.2540	2 <--
E35	870	.7356	2.958	.2486	1
E35	871	.7512	2.912	.2579	3
E35	872	.7284	2.853	.2553	2 <--
F43	889	.6818	2.672	.2551	3
F43	890	.6682	2.632	.2539	2 <--
F43	891	.6541	2.636	.2481	1
G47	830	.7191	2.875	.2501	PMSR
H53	864	.7115	2.770	.2568	1
H53	865	.7187	2.745	.2618	2 <--
H53	866	.7278	2.759	.2638	3
I58	845	.7106	2.714	.2618	1
I58	846	.7371	2.698	.2731	3
I58	847	.7133	2.622	.2720	2 <--
J64	858	.6329	2.422	.2613	3
J64	859	.5976	2.382	.2508	2 <--
J64	860	.6067	2.424	.2502	1
K67	852	.7250	2.869	.2526	1
K67	853	.7627	2.890	.2639	2 <--
K67	854	.7629	2.836	.2690	3

The median resolution measurements for each tape are shown below. For ease of comparison, the data are shown in ascending order of resolution value:

Tape	Pass	Resolution	Rank	
B21	839	.2340	1	
G47	830	.2501	2	PMSR
J64	859	.2508	3	
F43	890	.2539	4	
D34	885	.2540	5	
E35	872	.2553	6	
H53	865	.2618	7	
K67	853	.2639	8	
I58	847	.2720	9	
C29	877	.2793	10	

Tape G47 pass 835 ranks second overall. While it would be possible to use a different tape, this is only 1.56 percent less than that for the median value of D34.

Conclusions for PMSR:

Tape G47 pass 770 is the clear choice for Typical Current and Signal Amplitude.

Tape G47 pass 835 is the clear choice for Overwrite.

Tape G47 pass 835 is within the accuracy of the system from the median value of D34 for Resolution. While a separate tape could be used for this parameter, we propose that G47 pass 835 be used for all parameters.

Figure 12 shows the rankings of the centerline candidate tapes. On August 13, 1991, TC X3B5, (Digital Magnetic Tape), approved the proposed Master Standard Reference. In addition, on November 1, 1991, ISO/IEC JTC 1 SC 11, (Flexible Magnetic Media for Digital Data Interchange) also approved this Master Standard Reference (see SC11 Resolution 4/91).

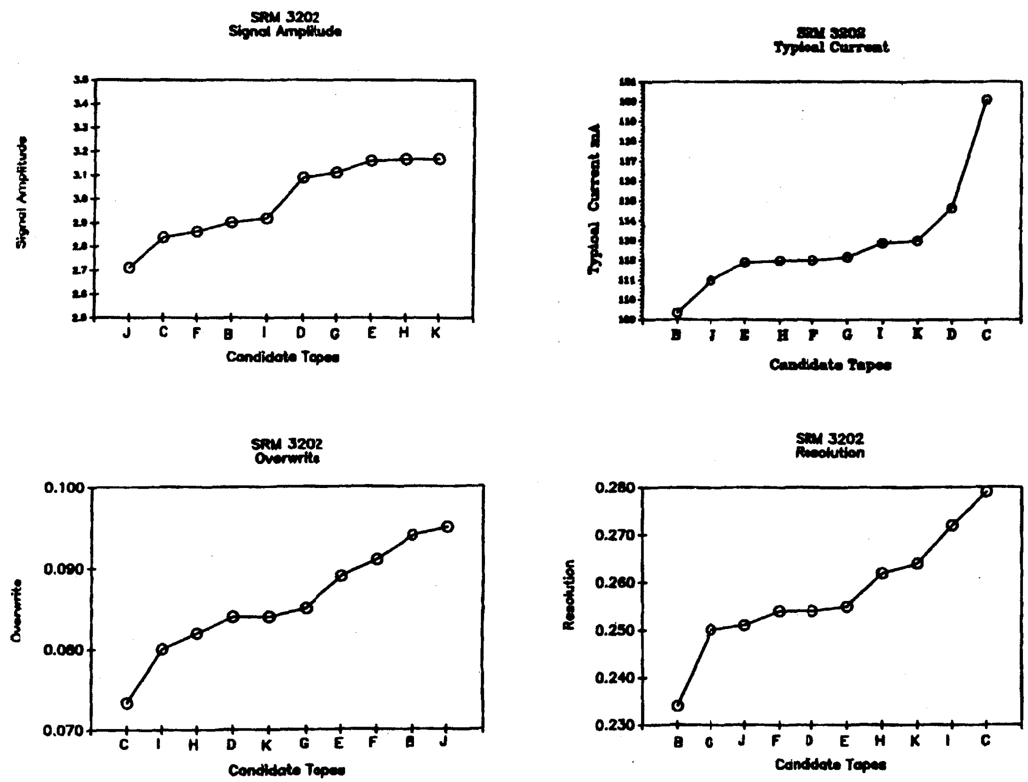


Figure 12. Centerline Candidate Tapes

5. Procedure for the Use of a SRM 3202 Tape

The Standard Reference Material (SRM) 3202 Tapes are to be used for calibrating tertiary tapes for daily use. The following procedure shall be followed when using an SRM 3202 tape.

5.1 Testing and Storage Environment.

An SRM 3202 shall be used and stored within the environment specified for testing and storage in the media standards.

5.2 Environmental Conditioning of the Media.

An SRM 3202 shall be acclimated to the testing environment for a period of at least 24 hours prior to testing.

5.3 Stabilization of the Test System.

The test system shall be allowed a minimum of 1 hour for the system components to stabilize. Furthermore, the test system shall remain on until all testing operations are complete.

5.4 Procedure for the Calibration of the Test System.

a) To minimize the use of the SRM tape, and the risk of damage to it, test the system for correct operation using a tape other than the SRM tape.

b) The SRM tape shall be ac bulk erased prior to use.

c) Load the SRM tape and make one complete forward and one complete reverse pass at the read or write operating tape drive speed to retension the tape.

Note: **An SRM 3202 tape should never be wound at a speed significantly greater than that for reading or writing. Greater speeds may not evenly tension the tape.**

d) Make a forward write pass with the SRM 3202 tape.

e) Rewind the tape at the same tape drive speed used for reading or writing.

f) Make a complete forward read pass.

g) Plot the saturation curve; that is, the curve of average signal amplitude versus write current.

Note: Writing and reading shall only be done over the calibrated portion of the SRM tape, which is 46 m (150 ft) from the beginning of tape (BOT) to 91 m (300 ft) from BOT. In addition, partial passes shall never be made on an SRM tape.

h) Rewind the SRM 3202 tape at the same tape drive speed used for reading or writing.

i) Determine the maximum average signal amplitude from the saturation curve.

j) Determine I1, the minimum write current required to give an average signal amplitude equal to 85 percent (as specified in the Standards ANSI X3.180 - 1990, ISO/IEC 9661:1988, and ECMA 120 - 1987) of the maximum average signal amplitude. I1 is the current required to produce on the user's test system the typical field for the particular SRM tape (see Fig13).

k) Multiply I1 by the current calibration factor (Cc), provided with the SRM tape, to obtain I2.

Note: Cc is the ratio of the write current required on the NIST system to produce the reference field to the write current required on the NIST system to produce the SRM tape's typical field.

Note: I2 is the write current required to produce the reference field on the user's test system. The reference field is the typical field of the Master Standard Reference Tape.

l) Multiply I2 by 1.5 to obtain I3, the measurement current for the user's test system.

m) Determine the average signal amplitude A1 produced by the SRM 3202 tape at the write current I3.

n) Multiply A1 by the amplitude correction factor (Ca), provided with the SRM 3202 tape, to obtain A2.

Note: Ca is the ratio of the standard reference amplitude of the Master Standard Tape to the average signal amplitude of the SRM tape at the Standard Measurement Current on the NIST system. A2 is the Standard Reference Amplitude (SRA) on the user's test system.

o) The test system may now be used for the overwrite, and resolution using write current I3 and the relationships printed in the right hand column of the box at the top of the SRM 3202 tape's saturation curve chart.

Overwrite is calibrated as follows:

I. Run the SRM tape to obtain O1, the overwrite value produced by the SRM tape on the test system.

II. Obtain the value for O2, the overwrite value that the Master Standard Reference Tape would produce if run on the test system.

$$O2 = \frac{O1}{OA}$$

where OA is the SRM 3202 tape's overwrite value relative to the Master Standard as shown in the right hand column of the box at the top of the SRM 3202 tape's saturation curve chart. Repeat this procedure to calibrate resolution.

5.5 Procedure for Calibrating a Tertiary Tape

a) Some types of tapes give a significant rise in the output signal amplitude with usage. To stabilize the tertiary tapes, a minimum of 80 passes shall be made to minimize this effect.

Note: A pass is defined as beginning of tape (BOT) to the end of tape (EOT), or from EOT to BOT.

b) AC bulk erase and load the tertiary tape. Make one forward and one reverse pass at read or write operating tape drive speed to retension the tape.

c) Make a complete forward write pass with the tertiary tape.

Note: Writing and reading shall only be done over the same portion of the tertiary tape as the calibrated portion of the SRM tape, which is 46 m (150 ft) from the beginning of tape (BOT) to 91 m (300 ft) from BOT.

d) Rewind the tertiary tape at the same tape drive velocity used for reading or writing.

e) Make a complete forward read pass with the tertiary tape.

f) Rewind the tertiary tape at the same tape drive velocity used for reading or writing.

g) Determine the maximum average signal amplitude of the tertiary tape.

h) Determine the tertiary tape's typical field It1, the minimum write current required to give an average signal amplitude equal to 85 percent of the maximum average signal amplitude.

i) Determine At1, the average signal amplitude of the tertiary tape at the write current I3.

j) The relationship of the tertiary tape's average signal amplitude to the Master Standard Reference Tape shall be calculated from the ratio of At1 to A2

k) The overwrite and resolution relationships may now be measured for the tertiary tape using the write current I3.

Note: It may be desirable to re-run the SRM tape at the conclusion of the above operations to verify the stability of the test system. However, the SRM tape should not be run more than necessary.

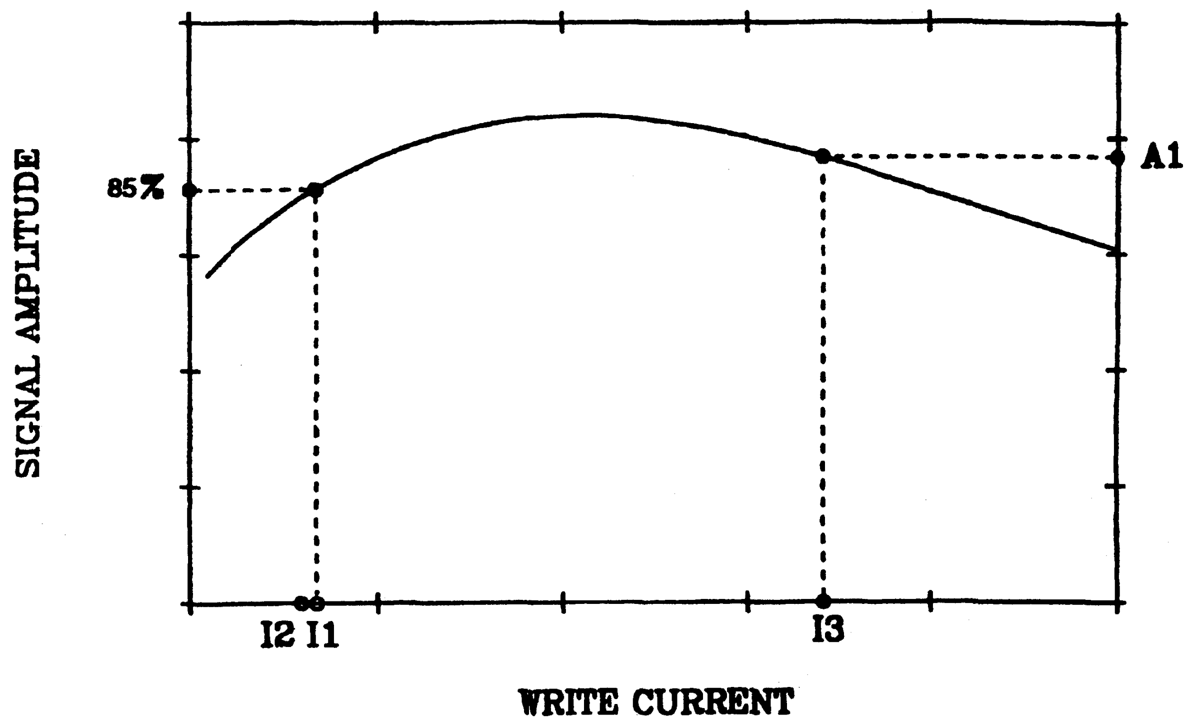


Figure 13. Saturation Curve on a User's System

6. Definitions

1f pattern - A repeated all ones pattern. The 1f pattern is recorded at a density of 972 ftpmm (24689 ftpi).

1.5f pattern - A repeated all ones pattern. The 1.5f pattern is recorded at a density of 972 ftpmm * 1.5 (24689 ftpi * 1.5).

average signal amplitude - The average peak-to-peak value of the signal output measured over a minimum of 25.4 mm (1.0 in), exclusive of dropouts.

ftpi - flux transitions per inch.

ftpmm - flux transitions per millimeter.

Master Standard Reference Tape - A tape selected as the standard reference field, signal amplitude, resolution, and overwrite ratio.

overwrite - The ratio of the average signal amplitude of the residual of the tone pattern recorded at the Standard Measurement Current, after being overwritten by the 1f pattern recorded at the Standard Measurement Current.

physical recording density - The number of recorded flux transitions per unit length of track, e.g., flux transitions per millimeter (ftpmm) or flux transitions per inch (ftpi).

Reference Field - The typical field of the Master Standard Reference Tape.

resolution - The ratio of the average signal amplitude at the 1.5f physical recording density, recorded at the Standard Measurement Current to the average signal amplitude at the 1f physical recording density, recorded at the Standard Measurement Current.

Secondary Reference Tape - A tape, the performance of which is known and stated in relation to that of the Master Standard Reference Tape.

Standard Measurement Current (Im) - A current whose value is 1.5 times the Standard Reference Current (Im = 1.5 * It).

Standard Reference Amplitude (SRA) - The average signal amplitude from the Master Standard Reference Tape when it is recorded with the Standard Measurement Current on the NIST Measurement System at 1f (972 ftpmm (24689 ftpi)). Traceability to the Standard Reference Amplitude is provided by the calibration factors supplied with each Secondary Standard Reference Tape.

Standard Reference Current (Ir) - The current that produces the Reference field.

tone pattern - The repeated 6-bit pattern 100000. The frequency of the tone pattern is one-sixth the frequency of the 1f signal.

typical current (It) - The write current which will produce the typical field.

typical field - The minimum recording field which, when applied to a magnetic tape, will cause an average signal amplitude equal to 85 percent of the maximum average signal amplitude at the 1f recording density.

working tapes - a tape whose signal amplitude characteristics is calibrated against the Master Standard Reference Tape.

7. References

1) ANSI X3.180-1990, "American National Standard for Information Systems, Magnetic Tape and Cartridge for Information Interchange, 18-Track, Parallel, 1/2 inch (12.65 mm), 37871 cpi (1491 cpmm), Group-Coded-Requirements for Recording," American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

2) ECMA-120, 2nd edition, December 1987, "Data Interchange on 12,7 mm 18-Track Magnetic Tape Cartridges," European Computer Manufacturers Association, 114 Rue du Rhône, 1204 Geneva (Switzerland).

3) ISO/IEC 9661:1988, "Information Processing, Data Interchange on 12,7 mm (0.5 in) Wide Magnetic Tape Cartridges, 18 Tracks, 1 491 Data Bytes per Millimetre (37 871 Data Bytes per inch)," International Organization for Standardization/International Electrotechnical Commission.

4) Podio, Fernando, "A New Computer-Based Self-Correcting Calibration System for Computer Storage Media Standard Reference Materials," Computers and Standards: The International Journal, Vol. 4, No. 4, 1985.

5) Williamson, Mark, P., "The 3480 Type Tape Cartridge: Potential Data Storage Risks, and Care and Handling Procedures to Minimize Risks," NIST Special Publication 500-199, November 1991.

6) Williamson, Mark, P., Willman, Natalie, E., and Grubb, Dana, S., "Calibration of NIST Standard Reference Material 3201 for 0.5 inch (12.65 mm) Serial Serpentine Magnetic Tape Cartridge," NIST Special Publication 260-115, February 1991.

NIST Measurement System Software, The software written for the SRM measurement system is public domain. Source code is available on floppy disks to interested parties. Please call or write to: National Institute of Standards and Technology, Data Storage Group, Building 225, Room A61, Gaithersburg, MD 20899, Attn: Magnetic Tape SRMs, (301) 975 -2908.