National Institute of Standards & Technology

Certificate

Standard Reference Material® 772a

Magnetic Moment Standard - Nickel Sphere

This Standard Reference Material (SRM) is intended for use in the calibration of magnetometers (such as vibrating sample magnetometers) used in the measurement of the magnetic properties of materials. SRM 772a consists of a nickel sphere 2.383 mm in diameter with a mass of 63.16 mg. The SRM 772a lot was produced from annealed nickel wire with a purity of 99.999 %. The wire was ground into spheres. The spheres were then ultrasonically cleaned in acetone and methyl alcohol and annealed at 1220 K in a dry hydrogen atmosphere for 2 h. The microstructure is equiaxed with an average grain size of about 100 μm.

Certified Value and Uncertainty: The certified value for magnetic moment, m, at 298 K and in an applied field of 398 kA/m (5000 Oe) is:

$$m = 3.47\ \text{mAm}^2 \pm 0.01\ \text{mAm}^2\ (3.47\ \text{emu} \pm 0.01\ \text{emu}) \quad (1)$$

The uncertainty in the certified value is calculated as $U = ku_c$, where $k = 2$ is the coverage factor for a 95 % level of confidence and u_c is the combined standard uncertainty calculated according to the ISO Guide [1-3].

Corrections for temperature and field can be made using the equation:

$$m = 3.47\ [1 + 0.0026\ \ln\left(\frac{H}{398}\right)]\ [1 - 0.00047(T - 298)] \quad (2)$$

where m is the magnetic moment in mAm^2, H is the applied magnetic field strength in kA/m and T is the temperature in kelvins. These corrections have no significant effect on the uncertainties for temperatures between 293 K and 303 K and for fields between 318 kA/m and 478 kA/m (4000 Oe and 6000 Oe). For an extended range, H between 280 kA/m and 4000 kA/m (3500 Oe and 50 000 Oe) and T between 280 K and 310 K, the uncertainties are approximately doubled. To modify Equation 2 for m in emu and H in oersteds, replace the value 398 by 5000.

Expiration of Certification: The certification of this SRM is valid indefinitely within the measurement uncertainties specified, provided the SRM is used in accordance with the instructions in this certificate. If deformation or discoloration of the nickel sphere are visible, discard the unit.

Certification of this SRM was performed by R.D. Shull, R.D. McMichael, and L.J. Swartzendruber of the NIST Metallurgy Division.

Statistical analysis and measurement advice were provided by S.D. Leigh of the NIST Statistical Engineering Division.

The support aspects involved in the preparation, certification, and issuance of this SRM were coordinated through the NIST Standard Reference Materials Program by R.J. Gettings.

Carol A. Handwerker, Chief
Metallurgy Division

Gaithersburg, MD 20899
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Thomas E. Gills, Director
Office of Measurement Services

Technical assistance was given by L.H. Bennett, D.E. Mathews, L.C. Smith, G.E. Hicho, F.S. Biancaniello, R.L. Park, J.G. Hodos, and R.V. Drew of the NIST Metallurgy Division, H.E. Metger of the NIST Fabrication Technology Division, and G.A. Candela, retired.

The spheres were ground under the supervision of G. Gleason of the Ball Tech Division of Microsurface Engineering, Inc.

Measurement Technique: The magnetic moment was determined by a sampling technique using an absolute magnetometer developed at NIST based on the Faraday method. The magnetometer was calibrated by using three different methods to determine the value of the field gradient. The value of the specific magnetization, σ, was determined to be 54.94 Am^2/kg (54.94 emu/g) at 298 K in a field of 398 kA/m (5000 Oe), with the same relative uncertainty as for the *m* value of Equation 1. The value obtained for the σ of this set of nickel spheres differs slightly from that obtained from samples of SRM 772 nickel spheres. The small difference in σ for 772 and 772a can be attributed to slight differences in their thermo-mechanical treatment. To be in best agreement with the values specified here for 772a, the value of 54.95 given in the SRM 772 certificate should be replaced by 55.12.

Storage and Handling: To avoid accidental loss of the nickel sphere, the SRM box should be held on a level surface while opening. When not in use, store SRM 772a in the box provided or in a manner that provides equivalent or better protection against damage. The nickel sphere should be carefully handled to avoid scratching, deformation, or the attachment of magnetic dust or particles from the environment. The use of plastic or other non-magnetic tweezers with smooth surfaces and a gentle grip is recommended. Do not expose the SRM to corrosive chemicals or heat in an oxidizing atmosphere.

NOTE ON UNITS: One Oe corresponds to $(1000/4\pi)$A/m. For additional discussion on units of measure, refer to References 4 and 5.

REFERENCES

[1] *Guide to the Expression of Uncertainty in Measurement,* ISBN 92-67-10188-9, 1st Ed., ISO, Geneva, Switzerland, (1993); see also Taylor, B.N. and Kuyatt, C.E., "Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results," NIST Technical Note 1297, U.S. Government Printing Office, Washington DC, (1994); (available at http://physics.nist.gov/Pubs/).

[2] "U.S. Guide to the Expression of Uncertainty in Measurement," ANSI/NCSL Z 540-2-1997, National Conference of Standards Laboratories, Boulder, CO, (1997/1998).

[3] Rukhin, A.L. and Vangel, M.G., "Estimation of a Common Mean and Weighted Means Statistics," Journal of the American Statistical Association, **Vol 93 #441**, pp. 303-308, (1998).

[4] Bennett, L.H., Page, C.H., and Swartzendruber, L.J., "Comments on Units of Magnetism," J. Res. Nat. Bur. Std., **83(1)**, p. 9, (1978).

[5] Taylor, B.N., "Guide for the Use of the International System of Units (SI)," NIST Special Publication 811.

Users of this SRM should ensure that the report in their possession is current. This can be accomplished by contacting the SRM Program at: Telephone (301) 975-6776 (select "Certificates"), Fax (301) 926-4751, e-mail srminfo@nist.gov, or via the Internet http://ts.nist.gov/srm.