



National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material[®] 1888b

Portland Cement

This Standard Reference Material (SRM) is intended primarily for the evaluation or calibration of methods for analysis of cements and materials of similar matrix. A unit of SRM 1888b consists of four sealed vials, each containing approximately 5 g of portland cement ground to pass through a 75 μm (No. 200) sieve.

Certified Mass Fraction Values: Certified values for 13 constituents of SRM 1888b are reported in Table 1 as mass fractions on an as-received basis [1]. A NIST certified value is a value for which NIST has the highest confidence in its accuracy in that all known or suspected sources of bias have been investigated or taken into account [2]. A certified value is the present best estimate of the true value based on the results of analyses performed at NIST and collaborating laboratories using the instrumental and classical test methods listed in Appendix A.

Reference Mass Fraction Values: Reference values for nine constituents are reported in Table 2. A reference value is a noncertified value that is the best estimate of the true value based on available data. These values do not meet NIST criteria for certification and are provided with associated uncertainties that may reflect only measurement reproducibility, may not include all sources of uncertainty, or may reflect a lack of sufficient statistical agreement among multiple analytical methods [2].

Information Values: Two information values are reported in Table 3. An information value is considered to be a value that will be of interest to the SRM user, but insufficient information is available to assess the uncertainty associated with the value [2].

Expiration of Certification: The certification of **SRM 1888b** is valid, within the measurement uncertainty specified, until **01 June 2025**, provided the SRM is handled in accordance with instructions given in this certificate (see "Instructions for Use"). The certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification before expiration, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

The coordination of technical measurements for certification was performed by J.R. Sieber of the NIST Analytical Chemistry Division.

Analyses leading to the certification of this SRM were performed at NIST by A.F. Marlow and J.R. Sieber of the NIST Analytical Chemistry Division and M. Stair of the Cement and Concrete Reference Laboratory. Analytical determinations were also performed by D. Broton, M. Bharucha, S. Markovic, R. Naamane, and C. Wedzicha of Construction Technology Laboratories, Inc., Skokie, IL.

Statistical consultation for this SRM was provided by S.D. Leigh of the NIST Statistical Engineering Division.

Support aspects involved with the certification and issuance of this SRM were coordinated through the NIST Measurement Services Division.

Stephen A. Wise, Chief
Analytical Chemistry Division

Robert L. Watters, Jr., Chief
Measurement Services Division

Gaithersburg, MD 20899
Certificate Issue Date: 27 July 2010

INSTRUCTIONS FOR USE

Cement powder is hygroscopic and the following procedure is recommended. Samples should be used immediately after opening. To relate analytical determinations to the certified values in this Certificate of Analysis, a minimum test portion of 500 mg should be used. The vial should be recapped immediately and stored in a desiccator. When a sample is used after storage in a previously opened vial, the total loss on ignition (LOI) at 950 °C for that sample should be determined in accordance with ASTM C 114 [3] and the mass of the sample corrected for any additional moisture, combined water, or carbonate above the value reported in this certificate for total LOI at 950 °C (i.e., the sum of the individual LOI values reported in the tables). See Appendix B for more information about loss on ignition of portland cement.

Preparation and Analysis¹: The material for SRM 1888b was obtained in the form of powder prepared using a typical industrial process. The material was blended and bottled at NIST under the direction of M.P. Cronise of the NIST Measurement Services Division. Homogeneity testing was performed at NIST using X-ray fluorescence spectrometry (XRF). For most constituents, material heterogeneity was low and fit for the purpose of value assignment. Quantitative determinations done at NIST included X-ray fluorescence spectrometry [4] and thermogravimetric analysis. Methods employed by collaborating laboratories included X-ray fluorescence spectrometry, inductively coupled plasma optical emission spectrometry (ICP-OES), and reference methods given in ASTM C 114-09 Standard Test Methods for Chemical Analysis of Hydraulic Cement [3]. See Appendix A for a complete list.

Reporting: The constituents listed in this Certificate of Analysis are expressed as the chemical forms and in the order given in ASTM C 114-09, Section 3, Table 1.

Table 1. Certified Mass Fraction Values for SRM 1888b

Constituent	Mass Fraction ^(a) (%)		
SiO ₂	20.42	±	0.23
Al ₂ O ₃	4.277	±	0.036
Fe ₂ O ₃	3.062	±	0.053
CaO	63.13	±	0.29
MgO	3.562	±	0.057
SO ₃	2.634	±	0.017
Na ₂ O	0.1364	±	0.0044
K ₂ O	0.658	±	0.017
TiO ₂	0.2316	±	0.0076
P ₂ O ₅	0.07307	±	0.00081
Mn ₂ O ₃	0.0652	±	0.0022
Cl	0.0143	±	0.0015
SrO	0.1009	±	0.0030

^(a) Each certified value is a weighted mean of the results from two to four methods [5]. The uncertainty listed with each certified value is an expanded uncertainty about the mean [6] with coverage factor 2 (approximately 95 % confidence) calculated by combining a between-method variance incorporating inter-method bias with a pooled, within-method variance following the ISO Guide [7].

¹ Certain commercial organizations, services, equipment, or materials are identified in this certificate in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the organizations, services, materials, or equipment identified are necessarily the best available for the purpose.

Table 2. Reference Mass Fraction Values for SRM 1888b

Constituent	Mass Fraction (%)		
Cr ₂ O ₃ ^(a)	0.01021	±	0.00077
ZnO ^(a)	0.01253	±	0.00012
Sulfide Sulfur ^(b)	0.015	±	0.001
Insoluble Residue ^(b)	0.32	±	0.02
Free CaO ^(b)	1.42	±	0.02
Fluoride (F ⁻) ^(b)	0.048	±	0.005
Measurand	Mass Fraction (%)		
LOI between 45 °C and 220 °C ^(a)	0.573	±	0.014
LOI between 220 °C and 550 °C ^(a)	0.616	±	0.021
LOI between 550 °C and 950 °C ^(a)	0.850	±	0.069

^(a) Each reference value is a weighted mean of the results from two to four methods [5]. The uncertainty listed with each reference value is an expanded uncertainty about the mean [6] with coverage factor 2 (approximately 95 % confidence) calculated by combining a between-method variance incorporating inter-method bias with a pooled, within-method variance following the ISO Guide [7].

^(b) Each reference value is the mean of results obtained by a single laboratory using one analytical technique. The associated uncertainty is calculated as $U = ts / \sqrt{n}$ where s is the standard deviation and the coverage factor, t , was determined from the Student's t -distribution corresponding to the associated degrees of freedom for $n = 12$ determinations and to the 95 % confidence level.

Table 3. Information Values for SRM 1888b

Measurand	Mass Fraction (%)
LOI between ambient temperature and 45 °C ^(a)	< 0.04
Total analyzed constituents ^(b)	100.42

^(a) The value reported is the estimated limit of detection of the test method, which was performed at two laboratories. The mean values obtained by each analyst at the times of analysis were less than this value.

^(b) Three corrections have been made to the calculated total of analyzed constituents: (1) the amount of fluorine present, (2) the amount of chlorine present, and (3) the overestimation of oxygen by expressing total S as SO₃ when a quantifiable amount of sulfide sulfur is present. All three corrections were subtracted from the gross total. The correction for F was determined by multiplying the mass fraction of fluorine by the ratio of the atomic mass of oxygen to two times the atomic mass of fluorine (0.421). The correction for chlorine was determined by multiplying the mass fraction of chlorine by the ratio of the atomic mass of oxygen to two times the atomic mass of chlorine (0.226). The correction for sulfide sulfur was determined by multiplying the mass fraction of sulfide sulfur by the ratio of three times the atomic mass of oxygen to the atomic mass of sulfur (1.50).

REFERENCES

- [1] Thompson, A.; Taylor, B.N.; *Guide for the Use of the International System of Units (SI)*; NIST Special Publication 811; U.S. Government Printing Office: Washington, DC (2008); available at: http://ts.nist.gov/WeightsAndMeasures/Metric/mpo_pubs.cfm (accessed Jun 2010).
- [2] May, W.; Parris, R.; Beck II, C.; Fassett, J.; Greenberg, R.; Guenther, F.; Kramer, G.; Wise, S.; Gills, T.; Colbert, J.; Gettings, R.; MacDonald, B.; *Definition of Terms and Modes Used at NIST for Value-Assignment of Reference Materials for Chemical Measurements*; NIST Special Publication 260-136 (2000); available at <http://ts.nist.gov/MeasurementServices/ReferenceMaterials/upload/SP260-136.PDF> (accessed Jun 2010).
- [3] Sieber, J.; Broton, D.; Fales, C.; Leigh, S.; MacDonald, B.; Marlow, A.; Nettles, S.; Yen, J.; *Standard Reference Materials for Cement*; Cement and Concrete Res., Vol. 32 (12), pp 1899–1906 (2002).
- [4] DerSimonian, R.; Laird, N.; *Meta-analysis in Clinical Trials*; Control. Clin. Trials, Vol. 7, pp 177-188 (1986).
- [5] Horn, R.A., Horn, S.A.; Duncan, D.B.; *Estimating Heteroscedastic Variance in Linear Models*; J. Am. Stat. Assoc., Vol. 70, pp 380-385 (1975).
- [6] JCGM 100:2008; *Evaluation of Measurement Data — Guide to the Expression of Uncertainty in Measurement (ISO GUM 1995 with Minor Corrections)*; Joint Committee for Guides in Metrology (2008); available at http://www.bipm.org/utis/common/documents/jcgm/JCGM_100_2008_E.pdf (accessed Jun 2009); see also Taylor, B.N.; 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/cuu/Uncertainty/index.html> (accessed Jun 2009).
- [7] ASTM C 471M-01 (2006); *Standard Test Methods for Chemical Analysis of Gypsum and Gypsum Products (Metric)*, Annu. Book ASTM Stand., Vol. 04.01, West Conshohocken, PA.
- [8] ASTM C 25-06; *Standard Test Methods for Chemical Analysis of Limestone, Quicklime, and Hydrated Lime*; Annu. Book ASTM Stand., Vol. 04.01, West Conshohocken, PA.

Users of this SRM should ensure that the Certificate of Analysis in their possession is current. This can be accomplished by contacting the SRM Program: telephone (301) 975-2200; fax (301) 926-4751; e-mail srminfo@nist.gov; or via the Internet at <http://www.nist.gov/srm>.

Appendix A

Analytical Methods

Constituent	Methods
SiO ₂	Total Si determined using XRF and gravimetry
Al ₂ O ₃	Total Al determined using XRF and ICP-OES
Fe ₂ O ₃	Total Fe determined using XRF and ICP-OES
CaO	Total Ca determined using XRF and Gravimetry
MgO	Total Mg determined using XRF and ICP-OES
SO ₃	Total S determined using XRF, ICP-OES, and gravimetry
Na ₂ O	Total Na determined using XRF and ICP-OES
K ₂ O	Total K determined using XRF and ICP-OES
TiO ₂	Total Ti determined using XRF and ICP-OES
P ₂ O ₅	Total P determined using XRF and ICP-OES
Mn ₂ O ₃	Total Mn determined using XRF and ICP-OES
Cl	Total Cl determined using XRF ^(a) with standard additions at NIST and ion-selective electrode at collaborating laboratory
Cr ₂ O ₃	Total Cr determined using XRF and ICP-OES
SrO	Total Sr determined using XRF and ICP-OES
ZnO	Total Zn determined using XRF and ICP-OES
Sulfide S	KIO ₃ titration after reaction with HCl
Insoluble Residue	Gravimetry
Free CaO	ASTM C 114-09 method performed by collaborating laboratory
F	Ion-selective electrode at collaborating laboratory
Loss on Ignition (LOI)	Thermogravimetric analysis performed at NIST and by collaborating laboratory. See Appendix B for a discussion of test methods and relevance of values [2,7,8].

^(a) Borate fusion was not used for Cl.

Key to Methods:

XRF	X-ray fluorescence spectrometry after borate fusion at NIST [6] and the collaborating laboratory
ICP-OES	Inductively coupled plasma optical emission spectrometry at the collaborating laboratory
Gravimetry	Indicates the specific gravimetric method found in ASTM C 114-09 performed by the collaborating laboratory.

Appendix B

Loss on Ignition of Portland Cement

In conjunction with other analyses, thermal analysis of cement is helpful in investigation of performance issues and in resolution of disputes. Mass losses listed in the certificate of analysis are presented for information purposes only and can be used as a guide for analyzing cement. The actual results obtained from a specimen of SRM 1888b will depend on the age and storage history of the vial from which the specimen was obtained. The optimum situation involves the use of a vial taken from a freshly opened pouch (see "Instructions for Use").

The values reported in the Certificate of Analysis for SRM 1888b came from a four-step thermogravimetric analysis program used for ordinary portland cement. Commercial, programmable thermogravimetric analyzers were employed for the measurements at the laboratories of NIST and Construction Technologies Laboratories. After constant mass was attained at the specified temperature, the temperature was increased to the next programmed step. The mass losses at these temperatures may be indicative of the following:

- Ambient to 45 °C: Free moisture in the specimen,
- 45 °C to 220 °C: Combined H₂O from gypsum [CaSO₄·2H₂O], plaster [CaSO₄·½H₂O], and syngenite [K₂Ca(SO₄)₂·H₂O],
- 220 °C to 550 °C: Ca(OH)₂ and Mg(OH)₂ converted to CaO and MgO,
- 550 °C to 950 °C: Carbonate compounds converted to oxide compounds.

The compounds listed above may be present in portland cement. Additional compounds may be present in pre-hydrated cement. The hydrate compounds may include ettringite [3CaO·Al₂O₃·2CaSO₄·32H₂O], calcium monosulfate aluminate [3CaO·Al₂O₃·CaSO₄·12H₂O], and hydrated forms of calcium silicates [Ca₃SiO₅ and Ca₂SiO₄], calcium aluminate [4CaO·Al₂O₃·nH₂O], and calcium aluminoferrite [Ca₂(Al_xFe_{1-x})₂O₅]. Crystal phase identification using X-ray diffraction was not performed to identify specific hydrates in SRM 1888b.

ASTM International standard methods of test include the compounds listed above and the analytical conditions of the test. These industry standards contain assignments of compounds and processes associated with mass loss as a function of temperature from hydraulic cement and its chemical constituents.

ASTM C 471M Standard Test Methods for Chemical Analysis of Gypsum and Gypsum Products [8] identifies mass loss between ambient temperature and 45 °C as free moisture. Higher temperatures may decompose calcium sulfate forms and other hydrates. In addition, C 471M utilizes the mass loss between 45 °C and 220 °C in the determination of the mass fraction of chemically combined H₂O and in the calculation of the amount of gypsum or gypsum and plaster in gypsum-containing products. Although gypsum and plaster decompose at specific temperatures, the chemically bound H₂O is completely removed by 220 °C.

ASTM C 25 Standard Test Methods for Chemical Analysis of Limestone, Quicklime and Hydrated Lime [9] assigns the mass loss between 110 °C and 550 °C as chemically combined water in Ca(OH)₂ and Mg(OH)₂ in the calculation of the total mass fraction of Ca and Mg hydroxides. As stated in ASTM C471M, chemically bound water from gypsum and plaster is completely removed by the time the temperature reaches 220 °C. Therefore, mass loss between 220 °C and 550 °C is indicative of hydroxide compounds.

ASTM C114 Standard Test Methods for Chemical Analysis of Hydraulic Cement, Appendix X2 [3] assigns the mass loss between 550 °C and 950 °C as loss of CO₂ from hydraulic cement, which is primarily the result of decomposition of carbonate compounds.

Decomposition of compounds at lower temperatures may influence the amounts of compounds that decompose at higher temperatures. For example, Ca(OH)₂ may form as a result of removal of water bound to gypsum.