TECHNICAL REPORT

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Guidance on standards available for preparation and testing of monolithic, unshaped refractory products

Lignes directrices relatives aux normes disponibles pour la préparation et l'essai des produits réfractaires monolithiques non façonnés

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 21828 was prepared by Technical Committee ISO/TC 33, *Refractories*.

Introduction

This Technical Report is the first step to providing a set of International Standards and regional and national standards relating to the testing of unshaped refractory materials in a convenient framework for easy access and use.

The intention is to draw on the best practice used worldwide considering the standards available in Asia, the Americas and Europe.

These test methods can be used for quality control purposes at point of manufacture or reception by the user, including testing to confirm published data or installed material from site.

It is intended that quality control at reception and final control of the lining be considered as two different issues.

The control at reception, sampling and test piece preparation are generally done with greater accuracy with clean equipment in carefully controlled conditions.

Properties are unavoidably influenced in site installations as a result of the equipment type, climatic conditions and, often, by specific site factors (target date for completion, job site access).

Sampling and test pieces prepared in industrial site conditions are, therefore, subject to a greater degree of variance due to the previously mentioned factors.

Unshaped refractory products used in industrial linings are not fired in kilns before installation, such that the subsequent sample appraisal can be more complex due to the induced temperature gradients in returned samples after placement or commissioning.

Differences in results can be seen for the same material tested in two different laboratories due simply to the efficiency of the mixing process, mixer type, power or degree of filling, independently of the test method chosen.

The single most determining step in unshaped testing is test piece preparation.

This can be true even when the instructions given by the manufacturer are used in conjunction with the selected standard.

The comments given in each section are to provide objective information to compare standards or methods from different origins. Because of the extreme importance of test piece preparation, it is intended that unity of source be maintained when selecting standards in these preparation sections in order to minimize differences.

If not carried out with agreement between the parties, it is intended that testing at reception use the same methods as those used by the manufacturer, if known, or allowances be made in the appraisal using the guidelines given in the comments sections of this Technical Report.

Guidance on standards available for preparation and testing of monolithic, unshaped refractory products

1 Scope

This Technical Report gives guidance on the International Standards and regional and national standards which apply to the testing of unshaped refractory materials, including, but not limited to, sampling, forming, obtaining test specimens or pieces and physical testing.

The parties involved in selecting the standard to be used should agree in advance on the standard or standards to be used and their applicability to the information to be generated by the standard.

The listing of standards by their title and scope in this Technical Report does not imply the correctness of those standards or their fitness of purpose. The listing was determined based on the title and scope as provided by the originating standards body.

2 Terms and definitions

Terms and definitions for the preparation and testing of unshaped refractory products should be used in accordance with those given in the standards listed in Table 1.

Table 1 — Standards giving terms and definitions

Publisher	International Standard, regional or national standard	Comment
ISO International Organization for Standardization	ISO 836:2001, *Terminology for refractories* Scope: This International Standard describes terms used in International Standards dealing with refractory materials and products and assists in the understanding of the terms and the standards themselves. The descriptions are those generally understood with the refractories industry and should not be taken as absolute definitions.	
CEN European Committee for Standardization	EN 1402-1:2003, *Unshaped refractory products — Part 1: Introduction and classification* Scope: This part of this European Standard defines terms relating to unshaped refractory products and establishes the classification for the various types of products. Raw materials and crushed or granulated refractory materials which do not contain any binder are excluded.	

Table 1 (*continued*)

Publisher	International Standard, regional or national standard	Comment
ASTM International	C71, *Standard Terminology Relating to Refractories* Scope: This terminology covers terms particularly related to refractories and encompasses raw materials, manufacture, finished products, applications, and testing procedures.	When any of the definitions in this terminology are quoted or published out of context, editorially insert the limiting phrase “in refractories” after the dash following the term to properly limit the field of application of the term and definition.
	C401, *Standard Classification of Alumina and Alumina-Silicate Castable Refractories* Scope: This classification covers alumina and alumina-silicate castable refractories that, when tempered with water, will develop structural strength by chemical action.	The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.
Standards Australia	AS 2780-2003, *Refractories and refractory materials — Glossary of terms*	

3 Classification

Unshaped refractory products should be classified in accordance with the standards listed in Table 2.

Table 2 — Classification standards

Publisher	International Standard, regional or national standard	Comment
ISO International Organization for Standardization	ISO 1927-1, *Unshaped refractory materials — Part 1: Introduction and classification* Scope: This part of ISO 1927 defines terms relating to unshaped refractory products and establishes the classification for the various types of products. It does not apply to raw materials and crushed or granulated refractory materials which do not contain any binder.	
CEN European Committee for Standardization	EN 1402-1:2003, *Unshaped refractory products — Part 1: Introduction and classification* Scope: This part of this European Standard defines terms relating to unshaped refractory products and establishes the classification for the various types of products. Raw materials and crushed or granulated refractory materials which do not contain any binder are excluded.	

Table 2 (*continued*)

Publisher	International Standard, regional or national standard	Comment
ASTM International	C401, *Standard Classification of Alumina and Alumina-Silicate Castable Refractories* Scope: This classification covers alumina and alumina-silicate castable refractories that, when tempered with water, will develop structural strength by chemical action.	The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.
	C673-97, *Standard Classification of Fireclay and High-Alumina Plastic Refractories and Ramming Mixes* Scope: This classification covers fireclay and high-alumina plastic refractories and ramming mixes that can be pounded or rammed into place to form a monolithic structure. The terms “plastic” and “ramming mix” are generally intended to describe the workability of the material. In this regard, plastics are considered to be materials having a workability index of more than 15 % in accordance with Test Method C181, while ramming mixes generally have less than 15 % workability by the same procedure.	

4 Sampling

Sampling and sample preparation of unshaped refractory products should be carried out in accordance with the standards listed in Table 3.

Table 3 — Standards giving procedures and sampling and sample preparation

Publisher	International Standard, regional or national standard	Comment
ISO International Organization for Standardization	ISO 8656-1:1988, *Refractory products — Sampling of raw materials and unshaped products — Part 1: Sampling scheme* Scope: This part of ISO 8656 specifies methods and conditions of sampling for raw materials and prepared unshaped refractory products, in order to indicate the mean values of a consignment and the interval of sampling. It does not apply to products in the form of large static quantities or cargoes from which reliable samples cannot be taken. The type of sampling equipment, and the preparation and reduction of the samples, which should not alter the properties to be tested, are to be agreed between the interested parties.	Difficulties can be encountered when sampling certain types of unshaped products, for example mouldables.
CEN European Committee for Standardization	EN 1402-2:2003, *Unshaped refractory products — Part 2: Sampling for testing* Scope: This part of this European Standard gives guidance on the sampling of unshaped refractory materials for the purpose of inspection and testing for quality and general information on the reduction and treatment of samples prior to testing. It covers all materials formulated as unshaped refractory materials.	

Table 3 (*continued*)

Publisher	International Standard, regional or national standard	Comment
ASTM International	C862, *Standard Practice for Preparing Refractory Concrete Specimens by Casting* Scope: This practice covers the mixing, casting and curing of monolithic refractory concrete specimens for use in further testing. It does not apply to monolithic castable refractories intended primarily for gunning applications.	The values given in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. Various specimen sizes are required for specific test methods. Refer to these test methods to determine the size and number of specimens which will be required from the sample.
Standardization Administration of China	GB/T 17617-2004, *Refractory products — Sampling of raw materials and unshaped products* Scope: This standard specifies definition, method and conditions of sampling for raw materials and unshaped refractory products.	
Standards Australia	AS 2497, *Sampling procedures for acceptance testing of shaped refractory products*	
	AS 4433.2, *Guide to the sampling of particulate materials — Part 2: Preparation of samples*	

5 Formation of test specimens/pieces

5.1 Casting

Formation of test specimens/pieces by casting should be carried out in accordance with the standards listed in Table 4.

Table 4 — Standards giving procedures for formation of test specimens/pieces by casting

Publisher	International Standard, regional or national standard	Comment
CEN European Committee for Standardization	EN 1402-5:2003, *Unshaped refractory products — Part 5: Preparation and treatment of test pieces* Scope: This part of this European Standard specifies methods for the preparation and treatment (curing, drying and firing) of test pieces from unshaped refractory materials. The dimensions of the test pieces are specified. The methods are applicable to dense and insulating castables and to ramming materials with the four types of chemical compositions defined in EN 1402-1. The dimensions of the test pieces are stated and the preparation of the mixture, compaction methods, storage and post-treatment of the test pieces are described.	

Table 4 (*continued*)

Publisher	International Standard, regional or national standard	Comment
ASTM International	C860, *Standard Practice for Determining the Consistency of Refractory Castable Using the Ball-In-Hand Test* Scope: The amount of water used in a castable has a significant influence on its performance. This practice covers the procedures for determining the consistency of a castable using the ball-in-hand test. This practice applies to regular weight castable refractories and insulating castable refractories which are described in Classification C401. It also applies to such castables containing metal fibres.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. (See 6.2.3 for a specific safety warning.)
	C862, *Standard Practice for Preparing Refractory Concrete Specimens by Casting* Scope: This practice covers the mixing, casting and curing of monolithic refractory concrete specimens for use in further testing. It does not apply to monolithic castable refractories intended primarily for gunning applications. The values given in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. Various specimen sizes are required for specific test methods. Refer to these test methods to determine the size and number of specimens which will be required from the sample.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C974, *Standard Practice for Preparing Test Specimens from Basic Refractory Castable Products by Casting* Scope: This practice covers a procedure for preparing test specimens from a basic refractory castable by casting prepared material in a mold. Specimens prepared in accordance with this procedure are intended for use in ASTM test methods.	This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C1445, *Standard Test Method for Measuring Consistency of Castable Refractory Using a Flow Table* Scope: This test method covers the procedure for determining the consistency of castable refractory mixes by the flow table method. This test method applies to regular weight castable refractories, insulating castable refractories, and castable refractories that require heavy vibration for forming, which are described in Classification C401. They also apply to such castables containing metal fibres. The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C1446, *Standard Test Method for Measuring Consistency of Self-Flowing Castable Refractories* Scope: This test method covers the determination of the consistency (degree of self-flow) and working time of self-flowing castable refractories. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use.

Table 4 (*continued*)

Publisher	International Standard, regional or national standard	Comment
Standardization Administration of China	YB/T 5202-1:2003, *Preparation of specimen for unshaped refractories — Part 1: Refractory castables*	
Standards Australia	AS 1774.4.1, *Refractories and refractory materials — Preparation of test pieces — By casting* Applies to dense, medium weight and lightweight castables containing either hydraulic cements or other binders. It applies to conventional and low-cement castables and any other type of refractory castable that can be installed by a casting process. A method for measuring the consistency of unshaped castable refractories is given in Appendix A. Castable refractory samples are mixed with water or other specified liquids until a specified consistency is achieved. They are then consolidated in a mould and allowed to cure and dry under defined conditions prior to testing.	
	AS 1774.4.1-Appendix A, *Methods for measuring consistency of unshaped castable refractories* Describes procedures for measuring the consistency of castable mixes by determining a tap flow, vibration-flow or self-flow value. Tap flow method: a castable sample, mixed with a measured amount of liquid (usually water) and moulded to shape, is placed on a metal surface which is then raised and dropped through a known height a given number of times. The resulting average increase in the diameter of the base of the sample is then measured and the value (i.e. tap flow value) used as a measure of consistency. Vibration-flow method: a castable sample, mixed with a measured amount of liquid (usually water) and moulded to shape, is placed on a vibration table which is then vibrated for a prescribed period of time. The resulting average increase in the diameter of the base of the sample is then measured and the value (i.e. vibration-flow value) used as a measure of consistency. Self-flow method: a castable sample, mixed with a measured amount of liquid (usually water) and moulded to shape, is placed on a metal surface and allowed to flow undisturbed for a prescribed period of time. The resulting average increase in the diameter of the base of the sample is then measured and the value (i.e. self-flow value) used as a measure of consistency.	

5.2 Gunning

Formation of test specimens/pieces by gunning should be carried out in accordance with the standards listed in Table 5.

Table 5 — Standards giving procedures for formation of test specimens/pieces by gunning

Publisher	International Standard, regional or national standard	Comment
ISO International Organization for Standardization	ISO 20182, *Refractory test-piece preparation — Gunning refractory panels by the pneumatic-nozzle mixing type guns* Scope: This International Standard describes the procedure for the preparation of test panels from refractory materials by gunning through pneumatic-nozzle mixing type guns at ambient temperatures.	The values obtained from test pieces cut from the panel prepared using this method might not correspond with those obtained from test pieces of the same material prepared at a gunning installation site. It does not apply to plastic gunning mixes, and might not apply to those mixes that contain aggregates that are susceptible to hydration. It also does not apply to shotcrete-type mixes.
CEN European Committee for Standardization	EN ISO 20182, *Refractory test-piece preparation — Gunning refractory panels by the pneumatic-nozzle mixing type guns* Scope: This International Standard describes the procedure for the preparation of test panels from refractory materials by gunning through pneumatic-nozzle mixing-type guns at ambient temperatures.	
ASTM International	C903, *Standard Practice for Preparing Refractory Castable Specimens by Cold Gunning* Scope: This practice covers a procedure for preparing refractory castable specimens usually containing calcium aluminate cement with or without metal fibers by cold nozzle-mix gunning. Specimens prepared in accordance with this practice are intended for use in standard ASTM test methods required for evaluating gunned materials. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C973, *Standard Practice for Preparing Test Specimens from Basic Refractory Gunning Products by Pressing* Scope: This practice covers a procedure for preparing test specimens from basic refractory gunning products by pressing prepared material in a mold. After pressing, test specimens prepared from dolomitic mixes are subjected to a prescribed heat treatment. Specimens prepared in accordance with this procedure are intended for use in ASTM test methods. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.	This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
Standards Australia	AS 1771.4.5, *Preparation of test pieces — Gunning refractories* Describes the procedures for the preparation of test pieces from refractory materials by dry and wet gunning at ambient temperatures.	The values obtained from test pieces prepared using this method might not correspond with those obtained from test pieces of the same material prepared at a gunning installation site. This standard does not apply to plastic gunning mixes.

5.3 Ramming

Formation of test specimens/pieces by ramming should be carried out in accordance with the standards listed in Table 6.

Table 6 — Standards giving procedures for formation of test specimens/pieces by ramming

Publisher	International Standard, regional or national standard	Comment
CEN European Committee for Standardization	EN 1402-5:2003, *Unshaped refractory products — Part 5: Preparation and treatment of test pieces* Scope: This part of this European Standard specifies methods for the preparation and treatment (curing, drying and firing) of test pieces from unshaped refractory materials. The dimensions of the test pieces are specified. The methods are applicable to dense and insulating castables and to ramming materials with the four types of chemical compositions defined in EN 1402-1. The dimensions of the test pieces are stated and the preparation of the mixture, compaction methods, storage and post-treatment of the test pieces are described.	6.2.2.2 deals with forming test pieces from plastic refractories using a power press.
ASTM International	C975, *Standard Practice for Preparing Test Specimens from Basic Refractory Ramming Products by Pressing* Scope: This practice covers a procedure for preparing test specimens from basic refractory ramming products by pressing prepared material in a mould. Specimens prepared in accordance with this procedure are intended for use in ASTM test methods. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C1054, *Standard Practice for Pressing and Drying Refractory Plastic and Ramming Mix Specimens* Scope: This practice covers the pressing and drying of chemically and nonchemically bonded aluminium-silicate and high-alumina plastic and ramming mix refractory specimens classified in accordance with Classification C673. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C181, *Standard Test Method for Workability Index of Fireclay and High-Alumina Plastic Refractories* Scope: This test method covers the determination of the workability index of fireclay and high-alumina plastic refractories by measuring the plastic deformation of a moulded test specimen when subjected to impacts.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 6 (*continued*)

Publisher	International Standard, regional or national standard	Comment
Standards Australia	AS 1774.4.3, *Refractories and refractory materials — Physical test methods — Preparation of test pieces — Unshaped refractories on site* It describes the procedure for the preparation of test blocks on site from all types of unshaped refractory materials.	NOTE The values obtained from test pieces prepared using this method might not correspond with those obtained from test pieces of the same material prepared using test laboratory methods. Where the physical dimensions of entry to the gunning site will not permit samples to be prepared adjacent to this site, the sample size can be adjusted. There is a growing practice of taking cored samples from the cured installed lining. In such cases, the curing and drying requirements of this standard are applicable.
	AS 1774.4.4, *Refractories and refractory materials — Physical test methods — Preparation of test pieces — Mouldable refractories* It describes procedures for laboratory preparation of test pieces from mouldable refractories. The standard does not apply to mouldable refractories that are supplied dry.	

5.4 Other forming methods, such as pressing

Formation of test specimens/pieces by other forming methods should be carried out according to the standards listed in Table 7.

Table 7 — Standards giving procedures for formation of test specimens/pieces by other methods

Publisher	International Standard, regional or national standard	Comment
ISO International Organization for Standardization	ISO 1893:2007, *Refractory products — Determination of refractoriness under load — Differential method with rising temperature*	
	ISO 3187:1989, *Refractory products — Determination of creep in compression*	
	ISO 5018:1983, *Refractory materials — Determination of true density*	
	ISO 8840:1987, *Refractory materials — Determination of bulk density of granular materials (grain density)*	
	ISO 8894-1, *Refractory materials — Determination of thermal conductivity — Part 1: Hot-wire methods (cross-array and resistance thermometer)*	
	ISO 8894-2:1990, *Refractory materials — Determination of thermal conductivity — Part 2: Hot-wire method (parallel)*	
	ISO 12676:2000, *Refractory products — Determination of resistance to carbon monoxide*	
	ISO 12680-1:2005, *Methods of test for refractory products — Part 1: Determination of dynamic Young's modulus (MOE) by impulse excitation of vibration*	

Table 7 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	ISO 16282, *Methods of test for dense shaped refractory products — Determination of resistance to abrasion at ambient temperature*	
	EN 1402-5:2003, *Unshaped refractory products — Part 5: Preparation and treatment of test pieces* Scope: This part of this European Standard specifies methods for the preparation and treatment (curing, drying and firing) of test pieces from unshaped refractory materials. The dimensions of the test pieces are specified. The methods are applicable to dense and insulating castables and to ramming materials with the four types of chemical compositions defined in EN 1402-1. The dimensions of the test pieces are stated and the preparation of the mixture, compaction methods, storage and post-treatment of the test pieces are described.	
Standards Australia	AS 1774.4.3, *Refractories and refractory materials — Physical test methods — Preparation of test pieces — Unshaped refractories on site* Describes the procedure for the preparation of test blocks on site from all types of unshaped refractory materials.	NOTE The values obtained from test pieces prepared using this method might not correspond with those obtained from test pieces of the same material prepared using test laboratory methods. Where the physical dimensions of entry to the gunning site will not permit samples to be prepared adjacent to this site, the sample size can be adjusted. There is a growing practice of taking cored samples from the cured installed lining. In such cases, the curing and drying requirements of this standard are applicable.
	AS 1774.4.4, *Refractories and refractory materials — Physical test methods — Preparation of test pieces — Mouldable refractories* Describes procedures for laboratory preparation of test pieces from mouldable refractories. The standard does not apply to mouldable refractories that are supplied dry.	

6 Drying and/or treatment of prepared specimens/pieces

Drying and/or treatment of prepared specimens/pieces should be carried out in accordance with the standards listed in Table 8.

Table 8 — Standards giving procedures for drying and/or treatment of prepared specimens/pieces

Publisher	International Standard, regional or national standard	Comment
CEN European Committee for Standardization	EN 1402-5:2003, *Unshaped refractory products — Part 5: Preparation and treatment of test pieces* Scope: This part of this European Standard specifies methods for the preparation and treatment (curing, drying and firing) of test pieces from unshaped refractory materials. The dimensions of the test pieces are specified. The methods are applicable to dense and insulating castables and to ramming materials with the four types of chemical compositions defined in EN 1402-1. The dimensions of the test pieces are stated and the preparation of the mixture, compaction methods, storage and post-treatment of the test pieces are described.	
ASTM International	C179, *Standard Test Method for Drying and Firing Linear Change of Refractory Plastic and Ramming Mix Specimens* Scope: This test method covers the determination of the drying shrinkage and of the combined drying and linear change of ramming and plastic refractories. The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are provided for information only.	This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C865, *Standard Practice for Firing Refractory Concrete Specimens* Scope: This practice covers the firing of specimens made from refractory concretes (castable refractories) in accordance with Practice C862 for cast specimens. The procedure is also recommended for heating rates to be used for high-temperature test methods such as Methods C16, C583, etc., when these methods are used to test refractory concretes. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C607, *Standard Practice for Coking Large Shapes of Carbon-Bearing Materials* Scope: This practice covers the preparation of coking of carbon-bearing material for subsequent testing such as modulus of rupture, slag testing, thermal conductivity, and thermal expansion. Test Method C831 is the specified method for testing residual carbon.	The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
Standards Australia	AS 1774.30, *Refractories and refractory materials — Physical test methods — Drying and firing schedules* It sets out the drying and firing schedules to be used for test samples of different refractory materials.	

7 Testing of prepared specimens/pieces

Testing of prepared specimens/pieces should be carried out in accordance with the standards listed in Table 9.

Table 9 — Standards giving procedures for testing of prepared specimens/pieces

Publisher	International Standard, regional or national standard	Comment
CEN European Committee for Standardization	EN 1402-6:2003, *Unshaped refractory products — Part 6: Measurement of physical properties* Scope: This part of this European Standard specifies methods for the determination of properties of unshaped materials from test pieces prepared and stored according to EN 1402-5.	The methods are applicable to dense and insulating castables and to ramming materials (including plastics), as defined in EN 1402-1, before and after firing.
	EN 1402-8:2003, *Unshaped refractory products — Part 8: Determination of complementary properties* Scope: This part of this European Standard specifies methods for determination of the properties of unshaped refractory materials from test pieces prepared and stored in accordance with EN 1402-5. The methods complement those described in EN 1402-6.	The methods have been adapted from standards for shaped refractory products to make them applicable to dense and insulating castables, and ramming materials, as defined in EN 1402-1, before and after firing.
ASTM International	C16, *Standard Test Method for Load Testing Refractory Shapes at High Temperatures* Scope: This test method covers the determination of the resistance to deformation or shear of refractory shapes when subjected to a specified compressive load at a specified temperature for a specified time.	The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C20, *Standard Test Methods for Apparent Porosity, Water Absorption, Apparent Specific Gravity, and Bulk Density of Burned Refractory Brick and Shapes by Boiling Water* Scope: These test methods cover the determination of the following properties of burned refractory brick: a) apparent porosity; b) water absorption; c) apparent specific gravity; d) bulk density. These test methods are not applicable to refractories attacked by water.	The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	C24, *Standard Test Method for Pyrometric Cone Equivalent (PCE) of Fireclay and High Alumina Refractory Materials* Scope: This test method covers the determination of the Pyrometric Cone Equivalent (PCE) of fire clay, fire clay brick, high alumina brick, and silica fire clay refractory mortar by comparison of test cones with standard pyrometric cones under the conditions prescribed in this test method.	The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C133, *Standard Test Methods for Cold Crushing Strength and Modulus of Rupture of Refractories* Scope: These test methods cover the determination of the cold crushing strength and the modulus of rupture (MOR) of dried or fired refractory shapes of all types. The test methods appear in the following sections: Test method — Sections Cold crushing strength — 4 to 9 Modulus of rupture — 10 to 15	The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C135, *Standard Test Method for True Specific Gravity of Refractory Materials by Water Immersion* Scope: This test method covers the determination of true specific gravity of refractory materials under prescribed conditions. It is not applicable to materials attacked by water.	The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C198, *Standard Test Method for Cold Bonding Strength of Refractory Mortar* Scope: This test method covers the determination of the bonding strength of air-setting refractory mortar by determining the flexural strength (modulus of rupture) at room temperature of oven-dried brick-mortar joints.	The values stated in inch-pound units are to be regarded as the standard. The values stated in SI units are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	C199, *Standard Test Method for Pier Test for Refractory Mortars* Scope: This test method covers the determination of refractoriness of all types of refractory mortar by heating a pier of brick laid up with the test mortar to learn whether the prescribed heat treatment causes the mortar to flow out of the joints.	The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C201, *Standard Test Method for Thermal Conductivity of Refractories* Scope: This test method covers the determination of the comparative thermal conductivity of refractories under standardized conditions of testing. This test method is designed for refractories having a conductivity factor of not more than 200 Btu·in./h·ft^{2}·°F (2 818 W/m·K), for a thickness of 1 in. (25 mm).	Detailed ASTM test methods to be used in conjunction with this procedure in testing specific types of refractory materials are as follows: Test Method C182, Test Method C202, Test Method C417 and Test Method C767. The values stated in inch-pound units are to be regarded as the standard. The values in parentheses are provided for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C357, *Standard Test Method for Bulk Density of Granular Refractory Materials* Scope: This test method covers a procedure for determining the bulk density of granular refractory materials, commercial products which usually have particles that are retained on a 0.265 in. (6,7 mm) or coarser sieve.	This test method is not suitable for materials that hydrate in boiling water. Such materials can be tested in accordance with Test Method C493. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C577, *Standard Test Method for Permeability of Refractories* Scope: This test method covers determination of the permeability of refractory brick and monoliths, from which suitable specimens can be cut, at room temperature.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	E177, *Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods* Scope: The purpose of this practice is to present concepts necessary to the understanding of the terms "precision" and "bias" as used in quantitative test methods. This practice also describes methods of expressing precision and bias and, in a final section, gives examples of how statements on precision and bias may be written for ASTM test methods. E691, *Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method* Scope: This practice describes the techniques for planning, conducting, analysing, and treating the results of an interlaboratory study (ILS) of a test method. The statistical techniques described in this practice provide adequate information for formulating the precision statement of a test method.	
	C583, *Standard Test Method for Modulus of Rupture of Refractory Materials at Elevated Temperatures* Scope: This test method covers determination of the high-temperature modulus of rupture of refractory brick or monolithic refractories in an oxidizing atmosphere and under action of a force or stress that is increased at a constant rate.	This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C604, *Standard Test Method for True Specific Gravity of Refractory Materials by Gas-Comparison Pycnometer* Scope: This test method covers the determination of the true specific gravity of solid materials, and is particularly useful for materials that easily hydrate which are not suitable for test with Test Method C135. This test method can be used as an alternative to Test Method C135, Test Method C128 and Test Method C188 for determining true specific gravity.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C704, *Standard Test Method for Abrasion Resistance of Refractory Materials at Room Temperature* Scope: This test method covers the determination of relative abrasion resistance of refractory brick at room temperature. This test method can also be applied to castable refractories (see Metric Dimensions C861 and Practice C865) and plastic refractories (see Practice C1054).	The values stated in SI units are to be regarded as the standard. The values given in parentheses are provided for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	C830, *Standard Test Methods for Apparent Porosity, Liquid Absorption, Apparent Specific Gravity, and Bulk Density of Refractory Shapes by Vacuum Pressure* Scope: These test methods cover the determination of the following properties of refractory shapes: a) apparent porosity; b) liquid absorption; c) apparent specific gravity; d) bulk density.	These test methods are applicable to all refractory shapes, except those that chemically react with both water and mineral spirits. When testing a material capable of hydration or other chemical reaction with water but which does not chemically react with mineral spirits, mineral spirits are substituted for water and appropriate corrections for the density differences are applied when making calculations. The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. Test Methods C20 cover procedures for testing properties of refractories that are not attacked by water.
	C832, *Standard Test Method of Measuring Thermal Expansion and Creep of Refractories Under Load* Scope: This test method covers the procedure for measuring the linear change of refractory specimens that are subjected to compressive stress while being heated and while being held at elevated temperatures. This test method does not apply to materials whose strength depends on pitch or carbonaceous bonds unless appropriate atmospheric control is used (see 7.3).	The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	C1099, *Standard Test Method for Modulus of Rupture of Carbon-Containing Refractory Materials at Elevated Temperatures* Scope: This test method covers the determination of the modulus of rupture of carbon-containing refractories at elevated temperatures in air.	The values stated in inch-pound units and degrees Fahrenheit are to be regarded as standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For specific hazard statements, see Section 5.
	C1113, *Standard Test Method for Thermal Conductivity of Refractories by Hot Wire (Platinum Resistance Thermometer Technique)* Scope: This test method covers the determination of thermal conductivity of non-carbonacious, dielectric refractories. Applicable refractories include refractory brick, refractory castables, plastic refractories, ramming mixes, powdered materials, granular materials, and refractory fibres. Thermal conductivity k-values can be determined from room temperature to 1 500°C (2 732°F), or the maximum service limit of the refractory, or to the temperature at which the refractory is no longer dielectric.	This test method is applicable to refractories with k-values less than 15 W/m·K (100 Btu·in./h·ft^2·°F). In general, it is difficult to make accurate measurements of anisotropic materials, particularly those containing fibers, and the use of this test method for such materials should be agreed between the parties concerned. The values stated in SI units are to be regarded as standard. This standard does not purport to address the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulator limitations prior to use.
	C1171, *Standard Test Method for Quantitatively Measuring the Effect of Thermal Shock and Thermal Cycling on Refractories* Scope: This test method is used for determining the strength loss or reduction in continuity, or both, of prism-shaped specimens which are cut from refractory brick or shapes and subjected to thermal cycling.	The strength loss is measured by the difference in modulus of rupture (MOR) between uncycled specimens and the specimens subjected to thermal cycling. The reduction in structural continuity is estimated by the difference in sonic velocity before and after thermal cycling. The values stated in inch-pound units are to be regarded as the standard. The values stated in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	C1419, *Standard Test Method for Sonic Velocity in Refractory Materials at Room Temperature and its Use in Obtaining an Approximate Young's Modulus* Scope: This test method describes a procedure for measuring the sonic velocity in refractory materials at room temperature. The sonic velocity can be used to obtain an approximate value for Young's modulus.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C1548, *Standard Test Method for Dynamic Young's Modulus, Shear Modulus, and Poisson's Ratio of Refractory Materials by Impulse Excitation of Vibration* Scope: This test method covers the measurement of the fundamental resonant frequencies for the purpose of calculating the dynamic Young's modulus, the dynamic shear modulus (also known as the modulus of rigidity), and the dynamic Poisson's ratio of refractory materials at ambient temperatures. Specimens of these materials possess specific mechanical resonant frequencies, which are determined by the elastic modulus, mass, and geometry of the test specimen. Therefore, the dynamic elastic properties can be computed if the geometry, mass, and mechanical resonant frequencies of a suitable specimen can be measured. The dynamic Young's modulus is determined using the resonant frequency in the flexural mode of vibration and the dynamic shear modulus is determined using the resonant frequency in the torsional mode of vibration. Poisson's ratio is computed from the dynamic Young's modulus and the dynamic shear modulus.	Although not specifically described herein, this method can also be performed at high temperatures with suitable equipment modifications and appropriate modifications to the calculations to compensate for thermal expansion. The values are stated in SI units and are to be regarded as the standard. This standard can involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C914, *Standard Test Method for Bulk Density and Volume of Solid Refractories by Wax Immersion* Scope: This test method covers the basic procedure for determining bulk density and volume of refractory shapes. This test is applicable to all refractory shapes or monoliths, burned or unburned, independent of composition or forming method, including materials that slake and hydrate. It is particularly suitable for determining bulk density and volume of complex shapes after forming, since results can be obtained in a matter of minutes.	This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C1407, *Standard Practice for Calculating Areas, Volume, and Linear Change of Refractory Shapes* Scope: This practice covers the methods of calculating areas, volumes and linear changes of irregularly shaped refractory specimens. Areas of irregular (both conventional and shaped) specimens are required for determining the creep of certain refractory products. Linear and volume changes of irregularly shaped refractories are required for determining reheat change.	The values stated in SI units are to be regarded as the standard. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	C288, *Standard Test Method for Disintegration of Refractories in an Atmosphere of Carbon Monoxide* Scope: This test method covers the comparative behaviour of refractories under the disintegrating action of carbon monoxide (CO). The test method is an accelerated exposure to CO to determine potential material behaviour in a relatively short time.	The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
	C874, *Standard Practice for Rotary Slag Testing of Refractory Materials* Scope: This practice describes a procedure for comparing the behaviour of refractories to the action of molten slag in a rotating test furnace. A reference material should be included in each test and run for comparison. No numerical results are obtained from this practice. Numerical evaluation of test results is the responsibility of the test operator. The test and equipment are patterned according to a method developed by Valley Dolomite Corporation.	The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.
Japanese Industrial Standards Committee	R2553, *Testing method for crushing strength and modulus of rupture of castable refractories* Scope: This standard specifies the testing method for crushing strength and modulus of rupture of castable refractories and lightweight castable refractories after curing, drying and firing.	
	R2554, *Method of test for permanent linear change on castable refractories* Scope: This standard specifies the method of test for permanent linear change on castable refractories.	
	R2555, *Testing method for the rate of linear change of castable refractories* Scope: This standard specifies the testing method for the rate of linear change of castable refractories.	
	R2576, *Method of test for permanent linear change on high alumina and fireclay plastic refractories* Scope: This standard specifies the method of test for permanent linear change on high alumina and fireclay plastic refractories after drying and firing.	
	R2577, *Testing method for the rate of linear change of high alumina and fire clay plastic refractories* Scope: This standard specifies the testing method for the rate of linear change of high alumina and fire clay plastic refractories.	
	R2654, *Method of test for permanent linear change on light weight castable refractories* Scope: This standard specifies the method of test for permanent linear change on light weight castable refractories.	

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
Standardization Administration of China	GB/T 3001:2007, *Refractory products — Determination of modulus of rupture at ambient temperature* Scope: This test method covers the determination of the modulus of rupture of the refractories at ambient temperature under conditions of a constant rate of increase of stress. This method can be applied to shaped and unshaped refractories. If it is to be applied to chemically bonded or tar-bonded bricks, they will require some form of pre-heat treatment.	
	GB/T 5072:2008, *Refractories — Determination of cold compressive strength* Scope: This test method covers the determination of cold compressive strength of refractories. This test method applied to dense and insulating refractories including unshaped refractories.	
	GB/T 5988:2007, *Refractory products — Determination of permanent change in dimension on heating* Scope: This test method covers the determination of permanent change in dimension on heating of refractories. It can be applied to shaped and unshaped refractories.	
	GB/T 7322:2007, *Refractory products — Determination of pyrometric cone equivalent (refractoriness)* Scope: This test method covers the determination of pyrometric cone equivalent (refractoriness) of refractories. It can be applied to refractory raw materials and shaped and unshaped refractory products.	
	GB/T 7320:2008, *Refractories — Determination of thermal expansion* Scope: This standard covers the determination of thermal expansion (push rod method and differencial method) for refractories. It can be applied to the determination of linear expansion rate or average linear expansion coefficient of shaped and unshaped refractories.	
	GB/T 5990:2006, *Refractory materials — Determination of thermal conductivity — Hot-wire method* Scope: This standard specifies a hot-wire method for the determination of thermal conductivity of refractory products and materials. The test method (cross-array) is applicable at temperatures not higher than 1 250°C and to refractory materials whose thermal conductivity is less than 1,5 W/(m·K) and whose thermal diffusivity is less than $10^{-6}m^2/s$. The test method (parallel) is applicable at temperatures up to and including 1 250°C and to refractory materials whose thermal conductivity is less than 25 W/(m·K). This standard is also applicable to powdered or granular materials.	

Table 9 (*continued*)

Publisher	International Standard, regional or national standard	Comment
	GB/T 8931:2007, *Refractories — Determination of slag resistance* Scope: This test method covers the determination of slag resistance of shaped and unshaped refractories.	
	GB/T 14983:2008, *Refractory products — Determination of alkali-resistance* Scope: This standard specifies a test method for the determination of alkali-resistance of shaped and unshaped refractories.	
	YB/T 2203:1998, *Test method for refractoriness under load of castable refractory — Non-differential with rising temperature*	
	YB/T 2206.1:1998, *Test method for thermal shock resistance of castable refractory — Compressed air flow quenching*	
	YB/T 2206.2:1998, *Test method for thermal shock resistance of castable refractory — Water quenching*	
	YB/T 2208:1998, *Test method for crushing strength of castables refractory at elevated temperature*	
	YB/T 4117:2003, *Test method for explosion resistance of dense refractory castables*	
	YB/T 5200:1993, *Dense refractory castables — Determination of bulk density and apparent porosity*	
	YB/T 5204:1993, *Dense refractory castables — Determination of sieve analysis*	
Standards Australia	AS 1774.1, *Refractories and refractory materials — Physical test methods — Determination of cold compressive strength* This standard sets out a method for determining the cold compressive strength of refractory bricks and monolithics.	
	AS 1774.3, *Refractories and refractory materials — Physical test methods — Determination of cold modulus of rupture* This standard sets out a method for determining the cold modulus of rupture, and a the-point load system, of refractory bricks and monolithics.	
	AS 1774.5, *Refractories and refractory materials — Physical test methods — The determination of density, porosity and water absorption* This standard sets out the evacuation method and the boiling water method for determining the following properties of a refractory: a) bulk density; b) apparent solid density; c) apparent porosity; d) water absorption.	The evacuation method is applicable to all refractories. The boiling water method is applicable only to refractories that are unaffected by boiling water and should not be used when the resistance to boiling water is in doubt. In addition, it sets out a method for determining bulk density by direct measurement of mass and volume and provides equations from which, after determining true density by ISO 5018, the following can be calculated: a) true porosity; b) sealed porosity.