# 2020 PRICE LIST

## MATERIALS TESTING & RESEARCH CENTER

## DESCRIPTION OF SERVICES OFFERED

The Materials Testing & Research Center is an independent research and referee testing laboratory, specializing in the evaluation of refractory, glass, whiteware, carbon, insulation, and advanced ceramic materials. It is operated by The Edward Orton Jr. Ceramic Foundation, a non-profit organization providing products and services to the ceramic materials community since 1896.

For an overview of the center operations and for details on submitting samples, see pages 2 and 3. For additional information contact Mr. Brian Rayner, Testing Services Manager.

**ORTON**
**Materials Testing & Research Center**
6991 Old 3C Highway
Westerville, Ohio 43082
Phone: 614-818-1321
Fax: 614-895-5610
E-mail: rayner@ortonceramic.com
Or Check our Website at:
www.ortonceramic.com

# THE ORTON MATERIALS TESTING & RESEARCH CENTER (MTRC)

## Background

The Orton Materials Testing and Research Center is a full service independent, non-profit research and testing laboratory that specializes in measuring the behavior of ceramic materials, performing thermal analysis measurements, and providing consulting services on ceramics and other related materials.

Initially, MTRC was known as The Refractories Fellowship Laboratory, which was established in 1917 at the Mellon Institute in Pittsburgh, Pennsylvania. It was relocated at The Ohio State University in Columbus, Ohio in 1965 and renamed the Refractory Research Center. Since 1990, the Center has been operated by the Edward Orton Jr. Ceramic Foundation, which is located in Westerville, Ohio, a suburb of Columbus, Ohio.

In addition to offering testing services, the Edward Orton Jr. Ceramic Foundation manufactures and sells both test instrumentation and products used in firing ceramics.

## Center Operation

Testing projects are reviewed for requirements and assigned to one of the MTRC engineers, who consults with the customer as needed. Results of tests are emailed to the customer as soon as they are available.

## Placing Orders

Please provide a purchase order and description of the materials to be tested along with identification of test work desired. Note that each test has an identifying T number (e.g. T9320), which can be used when placing an order. A request for testing services form is located on the last page of this price list.

Completion time for a project varies, depending upon the type of test desired and the availability of equipment and personnel. Testing is conducted on a first-come, first-serve basis with a typical turnaround time of 1 to 3 weeks for most tests. Every effort is made to be responsive to the client. If additional expenses are incurred to meet the special needs of the customer, then these will be quoted separately.

## Samples And Correspondence

Orton Materials Testing & Research Center
Attn: Mr. Brian Rayner (Testing Services Manager)
6991 Old 3C Highway
Westerville, OH 43082

Phone: 614-818-1321
Fax: 614-895-5610
E-Mail: rayner@ortonceramic.com

## Additional Correspondence

Beau Billet (Lab Manager)

Phone: 614-818-1355
E-Mail: billet@ortonceramic.com

Joseph Homeny (Technical Director)

Phone: 614-818-1323
E-Mail: homeny@ortonceramic.com

**Freight**
Freight must be prepaid. A service charge will be assessed if sent collect.

**Sample Identification**
The identification of each sample is essential. Whenever possible, include the chemical or generic name(s) for the material(s). Please provide appropriate Material Safety Data Sheets.

**Sample Sizing And Preparation**
Most tests do not include any time for special cutting or preparation that may be necessary if the samples are not provided in standard size or form. Sample preparation is billed as technician time at $145 per hour.

**Hazardous Or Destructive Materials**
To protect the health and safety of personnel, any toxic or hazardous materials present in the samples submitted for testing must be disclosed. Also, please advise if any possible toxic or hazardous reactions may occur as a result of preparing the samples for testing or during testing. When hazardous conditions or reactions that may be destructive to test instrument parts are known or anticipated please advise, so provisions can be made during testing to eliminate injury and minimize damage to testing equipment. If any damages occur as a result of negligence by the customer to inform Orton of possible hazardous or destructive materials, all costs of repair or replacement of instrument parts will be included in the invoice.

**Return Of Materials**
All test requests should include instructions for return of samples if desired. Samples, which are not returned, will be held for six months, then discarded. When samples are returned, they will be shipped prepaid and the cost added to the invoice.

**Pricing**
Pricing is effective January 1, 2020. Discounts may be available where the same test is conducted on multiple samples. Inquire with requirements to determine if a discount is available.

All quotations and agreements are contingent upon strikes, accidents, fires, availability of materials, and all other causes beyond control of the Edward Orton Jr. Ceramic Foundation.

**Billing**
Invoices for test work completed are sent following shipment of the test results. Terms are net 30 days, FOB Westerville, OH. No minimum order is required. Arrangements for payment in U.S. funds need to be made for orders originating outside the United States before work begins.

**Test Results**
Results should be considered advisory and/or experimental in nature. Neither the Edward Orton Jr. Ceramic Foundation, nor its employees, assumes any obligation or liability for damages, including, but not limited to, consequential damages arising out of or in conjunction with the use, or inability to use, the resulting information.

# ADVANCED CERAMIC TEST METHODS

**ASTM C-1161 FLEXURAL STRENGTH OF ADVANCED CERAMICS AT AMBIENT TEMPERATURE-T9763**

Flexural strength is determined in three-point or four-point bending on bars of rectangular cross-section. Testing of ten specimens per type/brand is recommended by ASTM.

$50 per specimen

**ASTM C-1211 FLEXURAL STRENGTH OF ADVANCED CERAMICS AT ELEVATED TEMPERATURE-T9772**

Flexural strength is determined in three-point or four-point bending on bars of rectangular cross-section. Testing of ten specimens per type/brand is recommended by ASTM.

Quote

**ASTM C-1259 DYNAMIC YOUNG'S MODULUS, SHEAR MODULUS, AND POISSON'S RATIO FOR ADVANCED CERAMICS BY IMPULSE EXCITATION OF VIBRATION-T9767**

A non-destructive sonic method is used to determine the modulus of elasticity and modulus of rigidity for calculation of Poisson's Ratio. Bars of rectangular cross-section are used for the measurements.

$280 per test of 5 specimens (Young’s modulus only)
$320 per test of 5 specimens (Young’s modulus, shear modulus, and Poisson’s ratio)

**ASTM C-1341 FLEXURAL PROPERTIES OF CONTINUOUS FIBER-REINFORCED ADVANCED CERAMIC COMPOSITES-T9764**

Flexural strength is determined in three-point or four-point bending on bars of rectangular cross-section. Testing of ten specimens per type/brand is recommended by ASTM.

$50 per specimens

**ASTM C-1421 FRACTURE TOUGHNESS OF ADVANCED CERAMICS AT AMBIENT TEMPERATURE-T9762**

Fracture toughness is determined in three-point or four-point bending on chevron-notched bars of rectangular cross-section. Testing of five specimens per type/brand is recommended by ASTM.

$75 per specimen

**ASTM C-1424 MONOTONIC COMPRESSIVE STRENGTH OF ADVANCED CERAMICS AT AMBIENT TEMPERATURE-T9907**

The compressive strength is determined on a right cylinder. Testing of at least five specimens per type/brand is recommended by ASTM.

$50 per specimen

**ASTM C-1499 EQUIBIAXIAL STRENGTH AT AMBIENT TEMPERATURE-T9771**

Equibiaxial strength is determined by concentric ring configurations under monotonic uniaxial loading.

$70 per specimen

**ASTM E-112 AVERAGE GRAIN SIZE-T9769**

Average grain size is determined by the linear intercept method on a polished section by optical microscopy.

$850 per specimen

**ASTM E-494 ULTRASONIC VELOCITY IN MATERIALS-T9908**

A non-destructive sonic method is used to determine the longitudinal and transverse velocities for the calculation of the modulus of elasticity, modulus of rigidity, and Poisson's Ratio. Specimens with parallel sides are used for the measurements.

$320 per test of 5 specimens

# CARBON TEST METHODS

**ASTM C-454 DISINTEGRATION OF CARBON REFRACTORIES BY ALKALI-T9540**

Ten 2" cube specimens are required by ASTM. A 1" hole is drilled into the face of each specimen and filled with 8 gm of Potassium Carbonate. The effects of being fired at 1750°F for 5 hours are determined visually.

$990 per test of 10 specimens

**ASTM C-559 BULK DENSITY BY PHYSICAL MEASUREMENTS OF MANUFACTURED CARBON AND GRAPHITE ARTICLES-T9556**

The bulk density is determined using the specimen weight and dimensions.

$25 per specimen

**ASTM C-561 ASH IN A GRAPHITE SAMPLE-T9558**

Ash content of graphite materials is determined by oxidation at 950°C. The ash content for two representative specimens per type/brand is determined.

$420 per test of 2 specimens

**ASTM C-611 ELECTRICAL RESISTIVITY OF MANUFACTURED CARBON AND GRAPHITE ARTICLES AT ROOM TEMPERATURE-T9585**

Electrical resistivity of carbon and graphite materials is determined by a DC method. Specimens may be in the form of plates, rods, bars, or tubes.

$145 per specimen

**ASTM C-651 FLEXURAL STRENGTH OF MANUFACTURED CARBON AND GRAPHITE ARTICLES USING FOUR-POINT LOADING AT ROOM TEMPERATURE-T9587**

Flexural strength is determined in four-point bending on specimens of rectangular cross-section.

$50 per specimen

**ASTM C-695 COMPRESSIVE STRENGTH OF CARBON AND GRAPHITE-T9588**

The compressive strength is determined on a right cylinder. The diameter of the specimen must be ten times the maximum particle size and the ratio of height to diameter must be between 1.9 and 2.1.

$50 per specimen

**ASTM C-767 THERMAL CONDUCTIVITY OF CARBON REFRACTORIES-T9610**
**Same as ASTM C-182**

**ASTM C-769 SONIC VELOCITY IN MANUFACTURED CARBON AND GRAPHITE MATERIALS FOR USE IN OBTAINING AN APPROXIMATE YOUNG'S MODULUS-T9620**

Approximation of Young's Modulus is calculated through sonic velocity measurements in 3 directions. The velocity of sound waves is measured using a James V-meter.

$320 per test of 5 specimens

**ASTM C-838** **BULK DENSITY OF AS-MANUFACTURED CARBON AND GRAPHITE SHAPES-T9660**

Bulk density is calculated from weight and volume measurements.

$250 per test of 10 specimens

**ASTM C-1025** **MODULUS OF RUPTURE IN BENDING OF ELECTRODE GRAPHITE-T9747**

Flexural strength is determined in four-point bending on 6" x 1 1/2" x 1 1/2" specimens.

$50 per specimen

**ASTM C-1039** **APPARENT POROSITY, APPARENT SPECIFIC GRAVITY, AND BULK DENSITY OF GRAPHITE ELECTRODES-T9748**

A vacuum is used to determine the apparent porosity, bulk density, liquid absorption, and apparent specific gravity. Testing of five specimens (2" diameter x 7 1/2" high) per type/brand is suggested by ASTM.

$340 per test of 5 specimens

# CONCRETE TEST METHODS

## ASTM C-39 COMPRESSIVE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS-T9901

The compressive strength is determined on a right cylinder. The ratio of height to diameter must be between 1.8 and 2.2.

$40 per specimen

## ASTM C-78 FLEXURAL STRENGTH OF CONCRETE (THIRD-POINT LOADING)-T9902

Flexural strength is determined in four-point bending on bars of rectangular cross-section.

$40 per specimen

## ASTM C-109 COMPRESSIVE STRENGTH OF HYDRAULIC CEMENT MORTARS-T9903

The compressive strength is determined on 2" cubes.

$40 per specimen

## ASTM C-215 FUNDAMENTAL TRANSVERSE, LONGITUDINAL, AND TORSIONAL RESONANT FREQUENCIES OF CONCRETE SPECIMENS-T9904

A non-destructive sonic method is used to determine the modulus of elasticity and modulus of rigidity for calculation of Poisson's Ratio. Bars of rectangular cross-section are used for the measurements.

$280 per test of 5 specimens (Young's modulus only)
$320 per test of 5 specimens (Young's modulus, shear modulus, and Poisson's ratio)

## ASTM C-293 FLEXURAL STRENGTH OF CONCRETE (CENTER-POINT LOADING)-T9905

Flexural strength is determined in three-point bending on bars of rectangular cross-section.

$40 per specimen

## ASTM C-403 TIME OF SETTING OF CONCRETE MIXTURES BY PENETRATION RESISTANCE-T9511

The resistance of the concrete mixture to penetration by standard needles is measured. The initial and final setting times are determined from a plot of penetration resistance versus time. A sample of at least 25 lbs. should be submitted

$280 per specimen

## ASTM C-496 SPLITTING TENSILE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS-T9551

A diametral compressive load is applied along the length of a cylindrical specimen (2" diameter x 4" high) until tensile failure occurs.

$215 per test of 5 specimens

**ASTM C-580** **FLEXURAL STRENGTH AND MODULUS OF ELASTICITY OF CHEMICAL RESISTANT MORTARS, GROUTS, MONOLITHIC SURFACINGS, AND POLYMER CONCRETES-T9910**

Flexural strength is determined in three-point bending on bars of rectangular cross-section. Testing of six specimens per type/brand is recommended by ASTM.

$50 per specimen (strength)
$115 per specimen (strength and elastic modulus)

**ASTM C-597** **PULSE VELOCITY THROUGH CONCRETE-T9906**

The pulse velocity is calculated through longitudinal wave measurements in 3 directions. The velocity of sound waves is measured using a James V-meter.

$320 per test of 5 specimens

# FIBROUS INSULATION TEST METHODS

**ASTM C-165 COMPRESSIVE PROPERTIES OF THERMAL INSULATIONS-T9404**

The compressive resistance is determined on either rigid board or blanket insulation. Specimens can be square or circular with a preferred width or diameter of 6". Testing of four specimens per type/brand is recommended by ASTM.

$285 per test of 4 specimens

**ASTM C-167 THICKNESS AND DENSITY OF BLANKET OR BATT THERMAL INSULATIONS-T9405**

One representative roll of insulation is required. Density is calculated from weight and dimensional measurements.

$250 per specimen

**ASTM C-203 BREAKING LOAD AND FLEXURAL PROPERTIES OF BLOCK-TYPE THERMAL INSULATIONS-T9403**

Flexural strength is determined on 1" x 4" x 12" specimens. Testing of four specimens per type/brand is recommended by ASTM.

$200 per test of 4 specimens

**ASTM C-303 DENSITY OF PREFORMED BLOCK-TYPE THERMAL INSULATION-T9406**

Minimum specimen size is 4" x 8" in cross-section. Density is calculated from weight and dimensional measurements.

$25 per specimen

**ASTM C-356 LINEAR SHRINKAGE OF PREFORMED HIGH-TEMPERATURE THERMAL INSULATION SUBJECTED TO SOAKING HEAT-T9505**

Linear shrinkage is determined after a thermal insulating material is exposed to soaking heat for 24 hours. Four 6" x 2 1/2" x 1" or 2" specimens are required by ASTM.

| TEMPERATURE | PER TEST OF 4 |
|---|---|
| 1600°F or Less | $825 |
| 1600°F to 2600°F | $960 |
| 2600°F to 3000°F | $1220 |

**ASTM C-686 PARTING STRENGTH OF FIBROUS INSULATING MATERIAL-T9407**

Tensile strength is measured on O-ring specimens. A 5 sq. ft. representative section of insulation should be submitted.

$50 per specimen

**ASTM C-892 UNFIBERIZED SHOT CONTENT OF INORGANIC FIBROUS BLANKETS-T9715**

A 10 gm specimen is fired to 2300°F and forced consecutively through No. 30, 50, and 70 screens. Shot content is determined by percent retained on each screen.

$540 per specimen

**ASTM C-892 THERMAL CONDUCTIVITY OF FIBROUS INSULATING MATERIAL-T9716**
**Same as ASTM C-182**

# GLASS TEST METHODS

## ASTM C-158 STRENGTH OF GLASS BY FLEXURE-T9501

Flexural strength is determined in three-point or four-point bending on bars of rectangular or circular cross-section. Between ten to thirty specimens per type/brand is recommended by ASTM.

$50 per specimen

## ASTM C-336 ANNEALING POINT AND STRAIN POINT OF GLASS BY FIBER ELONGATION-T9502

The annealing point of a glass is defined as the temperature at which a round fiber, nominally 0.65 mm in diameter, elongates under a load of 1.0 kg at a rate of 0.14 mm/min when it is cooled at a rate of 4°C/min. The strain point is determined by extrapolation of the annealing point data as the temperature at which the elongation rate is 0.0316 times that at the annealing temperature. A representative sample of 50 gm or more of flame workable glass in pieces a minimum of 5 mm in diameter is required. Fritted or ground samples must be remelted to obtain a piece large enough from which fibers can be drawn.

$320 per glass to 800°C
$320 per glass for fiber preparation

## ASTM C-338 SOFTENING POINT OF GLASS BY FIBER ELONGATION-T9503

The softening point of a glass is defined as the temperature at which a round fiber, nominally 0.65 mm in diameter and 235 mm long, elongates under its own weight at a rate of 1 mm/min when the upper 100 mm of its length is heated at a rate of 5°C/min. A representative sample of 50 gm or more of flame workable glass in pieces a minimum of 5 mm in diameter is required. Fritted or ground samples must be remelted to obtain a piece large enough from which fibers can be drawn.

$270 per glass to 1000°C
$320 per glass for fiber preparation

## ASTM C-598 ANNEALING POINT AND STRAIN POINT OF GLASS BY BEAM BENDING-T9575

The annealing point of a glass is defined as the temperature at which a 3-point loaded beam, nominally 3 to 4 mm in cross section on a 50 mm span, elongates under a load of between 0.2 kg and 1.0 kg at a rate determined by the span, load, and moment of inertia when it is cooled at a rate of 4°C/min. The strain point is determined by extrapolation of the annealing point data as the temperature at which the elongation rate is 0.0316 times that at the annealing temperature. Representative specimens, nominally 3 to 4 mm in cross section and 75 mm in length, are required.

$350 per glass to 1000°C
$280 per glass for beam preparation

## ASTM C-657 DC VOLUME RESISTIVITY OF GLASS-T9577

**Same as D-257.**

## SOFTENING POINT OF GLASS BY PENETROMETER (LABINO METHOD)-T9160

A 3/16” cube specimen is supported on a horizontal platform inside a furnace. A probe rod is lowered to contact the glass specimen. As the furnace is heated at a rate of 25°C/min, the probe penetrates the glass specimen. The temperature at which the probe penetrates a certain distance is correlated to the softening point. Three representative specimens, approximately 3/16” by 3/16” by 3/16”, are required.

$280 per glass to 1000°C
$280 per glass for cube preparation

## ASTM C-829 LIQUIDUS TEMPERATURE OF GLASS BY THE GRADIENT FURNACE METHOD-T9576

The liquidus temperature is the maximum temperature where equilibrium exists between the amorphous glass and its primary crystalline phase. A sample of about 30 gm is crushed to -20 mesh and placed in a platinum boat with dimensions of 0.5" x 0.5" x 6.0". The glass specimen is held at a specified temperature gradient over its entire length for a period of time necessary to obtain thermal equilibrium between the crystalline and glassy phases. The specimen is quenched and viewed with a microscope to determine the glass/crystalline interface location and corresponding temperature.

$930 per glass

## ASTM C-965 VISCOSITY OF GLASS ABOVE THE SOFTENING POINT-T9578

The viscosity of glass above the softening point is determined using a platinum alloy spindle immersed in a platinum crucible of molten glass. The crucible is placed in a vertical tube furnace capable of 1600°C. The viscometer is mounted above the tube furnace and is capable of measuring from 1.5 to 5.0 Poise ($\log_{10}$). About 400 gm of glass is necessary for the test. After the data is collected, it is fit to a Fulcher equation to describe the viscosity/temperature relationship.

$930 first temperature specified
$280 each additional temperature specified

## ASTM C-1350 VISCOSITY OF GLASS BETWEEN SOFTENING POINT AND ANNEALING RANGE BY BEAM BENDING-T9579

The viscosity of glass from 10 to 15 Poise ($\log_{10}$) is determined by measuring the rate of viscous bending of a loaded glass beam. Representative specimens, nominally 3 to 4 mm in cross section and 75 mm in length, are required.

$350 per glass to 1000°C
$280 per glass for beam preparation

## ASTM C-1351 VISCOSITY OF GLASS NEAR THE SOFTENING POINT BY VISCOUS COMPRESSION OF A RIGHT CYLINDER-T9583

The viscosity of glass from 5 to 9 Poise ($\log_{10}$) is determined by measuring the rate of viscous compression of a loaded glass cylinder. Representative specimens, nominally 6 to 12 mm in diameter and 3 to 6 mm in height, are required.

$350 per glass to 1000°C
$280 per glass for cylinder preparation

# REFRACTORY TEST METHODS

## ASTM C-16 LOAD TESTING REFRACTORY BRICK AT HIGH TEMPERATURES-T9300

A 25 psi load is applied to 9" x 4 1/2" x 2 1/2" or 3" bricks during a specified heating schedule. A minimum of two specimens per type/brand is suggested by ASTM. The percent deformation is measured on each brick after testing simultaneously in a gas-fired kiln up to 3150°F.

| | | PER TEST OF 2 | PER TEST OF 4 | EA ADD'L 24 HR HOLD |
|---|---|---|---|---|
| Misc. Products | Less than 2000°F | $775 | $1050 | $310 |
| Medium Duty Fireclay | Schedule 1 2370°F | $840 | $1115 | $310 |
| High Duty Fireclay | Schedule 2 2460°F | $895 | $1170 | $310 |
| Misc. Products | 2550°F | $950 | $1225 | $340 |
| Super Duty Products | Schedule 3 2640°F | $990 | $1265 | $340 |
| Misc. Products | 2750°F | $1050 | $1325 | $340 |
| Mullite, High Alumina | Schedule 6 2900°F | $1110 | $1385 | $370 |
| Mullite, High Alumina | Schedule 7 3000°F | $1140 | $1415 | $370 |
| Silica Brick to Failure | Schedule 4 | $1320 | $1595 | $370 |
| Mag-Chrome Brick to Failure | Schedule 5 | $1320 | $1595 | $370 |
| Other Temperatures and Conditions | | Quote | Quote | Quote |

## ASTM C-20 APPARENT POROSITY, WATER ABSORPTION, APPARENT SPECIFIC GRAVITY, AND BULK DENSITY OF BURNED REFRACTORY BRICK AND SHAPES BY BOILING WATER-T9310

The apparent porosity, bulk density, apparent specific gravity, and water absorption are determined by the boiling method. Testing of five specimens (1/4 brick or a 25 to 30 $in^3$ piece) per type/brand is suggested by ASTM.

$230 per test of 5 specimens

## ASTM C-24 PYROMETRIC CONE EQUIVALENT OF FIRECLAY AND HIGH ALUMINA REFRACTORY MATERIALS-T9320

Compares the deformation of prepared cone specimens with Orton PCE test cones. Indicate approximate cone value anticipated or describe material. A representative sample of 150 gm or more of granular material to pass a No. 70 ASTM Sieve (No. 65 Tyler) should be submitted.

| | PER TEST |
|---|---|
| One specimen up to cone 36 | $420 |
| Two specimens in one firing, within 3 Cone numbers, up to cone 36 | $550 |
| One specimen up to cone 38 | $520 |
| Two specimens in one firing, within 3 Cone numbers, up to cone 38 | $635 |

## ASTM C-92 SIEVE ANALYSIS AND WATER CONTENT OF REFRACTORY MATERIALS-T9350

Water Content: A 2 to 5 lb. representative sample of material should be submitted.

$140 per specimen

Sieve Analysis: Tyler Standard series sieves are used. A 2 to 5 lb. representative sample of material should be submitted.

| | |
|---|---|
| 1 to 4 Sieves | $145 |
| Each Additional Sieve | $5 |
| Full Analysis: 3, 4, 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270, 325, 400 mesh | $210 |

**ASTM C-93** **COLD CRUSHING STRENGTH AND MODULUS OF RUPTURE OF INSULATING FIREBRICK-T9360**

Crushing Strength: The crushing load is applied to the 4 1/2" x 4 1/2" face of half bricks. Testing of 10 specimens per type/brand is suggested by ASTM.

$400 per test of 10 specimens

MOR: Flexural strength is determined in three-point bending on 9" x 4 1/2" x 2 1/2" or 3" bricks. Testing of ten specimens per type/brand is suggested by ASTM.

$400 per test of 10 specimens

**ASTM C-113** **REHEAT CHANGE OF REFRACTORY BRICK-T9370**

Three 9" x 4 1/2" x 2 1/2" or 3" bricks are heated on a specified heating schedule and the percent linear change is reported. At least three 9" bricks per brand/type are suggested by ASTM.

| | | **PER TEST OF 3** | **EA ADD'L SPECIMEN** |
|---|---|---|---|
| Misc. Products | 2000°F or Less | $595 | $25 |
| Low Duty Fireclay | Schedule A, 2190°F | $635 | $25 |
| Ladle Brick | Schedule E, 2350°F | $665 | $30 |
| Fireclay Nozzles | Schedule D, 2460°F | $725 | $30 |
| High Duty Fireclay | Schedule B, 2550°F | $755 | $30 |
| Misc. Products | Schedule F, 2730°F | $800 | $30 |
| Super Duty Fireclay | Schedule C, 2910°F | $930 | $35 |
| High Alumina | Schedule G, 3000°F | $1150 | $35 |
| Misc. Products | Schedule H, 3090°F | $1350 | $35 |
| Misc. Products | Up to 3140°F | $1560 | $35 |

**ASTM C-133** **COLD CRUSHING STRENGTH AND MODULUS OF RUPTURE OF REFRACTORIES-T9380**

Crushing Strength: The crushing load is applied to the 2" x 2" face of a 2" cube or the 2" diameter face of a 2" diameter x 2" high cylinder. Testing of five specimens per type/brand is recommended by ASTM.

$200 per test of 5 specimens

MOR: Flexural strength is determined in three-point bending on 9" x 4 1/2" x 2 1/2" or 3" bricks. Other sizes can be used depending on the material. Testing of five specimens per type/brand is recommended by ASTM.

$200 per test of 5 specimens

**ASTM C-134** **SIZE AND BULK DENSITY OF REFRACTORY BRICK AND INSULATING FIREBRICK-T9390**

The weight per volume is determined using the specimen weight and dimensions. Warpage is measured with the use of warpage wedges. Testing of ten specimens of each type/brand is suggested by ASTM.

| | |
|---|---|
| Size and Bulk Density | $250 per test of 10 specimens |
| Warpage | $250 per test of 10 specimens |

**ASTM C-135 TRUE SPECIFIC GRAVITY OF REFRACTORY MATERIALS BY WATER IMMERSION-T9400**

A water immersion technique is used to determine the true specific gravity of a ground specimen. A completely representative sample is required for the analysis.

$205 per specimen

**ASTM C-179 DRYING AND LINEAR CHANGE OF REFRACTORY PLASTIC AND RAMMING MIX SPECIMENS-T9410**

Three 9" bricks are molded in a press at 1000 psi and the linear drying and firing shrinkage is determined. A 50 lb. representative sample should be submitted, including a specification of the type/class of the material.

| | |
|---|---|
| Specimen Preparation and Drying Shrinkage | $290 per test of 5 specimens |
| Firing Shrinkage | Same as ASTM C-113 |

**ASTM C-181 WORKABILITY INDEX OF FIRECLAY AND HIGH-ALUMINA PLASTIC REFRACTORIES-T9420**

The workability/consistency of as-received material is determined. Cylindrical specimens are impacted under a 14-lb. load and the percent deformation is reported. The testing of five specimens is recommended by ASTM. A 10 lb. representative sample should be submitted, including the production date for the material.

$290 per test of 5 specimens

**ASTM C-182 THERMAL CONDUCTIVITY OF INSULATING FIREBRICK-T9430**

The heat flow through a refractory is determined with a water-cooled copper calorimeter. The temperature limit of refractory must be specified, as well as the hot face or mean test temperatures desired. The maximum hot face temperature for testing is 2700°F. The specimens required are six 9" bricks or an 18" x 13.5" x 2.5" slab.

| | | **EA ADD'L TEST TEMP** |
|---|---|---|
| First Hot Face Temperature Specified | $1500 | $370 |
| First Mean Temperature Specified | $1750 | $370 |

**ASTM C-198 COLD BONDING STRENGTH OF REFRACTORY MORTAR-T9440**

Fireclay brick halves are bonded with a 1/16" thick joint. After air and oven drying, the MOR is determined for the brick/joint assembly. Testing of 5 specimens is suggested by ASTM. At least 10 lbs. of mortar should be submitted for analysis.

$530 per test of 5 specimens

**ASTM C-199 PIER TEST OF REFRACTORY MORTARS-T9450**

A multiple brick pier is made with 1/8" thick vertical and horizontal joints. The assembly is air and oven dried, and then fired for 5 hours at the specified temperature. If the mortar flows from the joints during firing, it fails the test. At least 10 lbs. of mortar should be submitted of analysis.

| | **FIRING TEMPERATURE** | **PER TEST** |
|---|---|---|
| Medium Duty | 2550°F | $780 |
| High Duty | 2730°F | $860 |
| Super Duty | 2910°F | $1050 |
| High Alumina | 3100°F | $1140 |

**ASTM C-201 THERMAL CONDUCTIVITY OF REFRACTORIES-T9460**
**Same as ASTM C-182**

**ASTM C-202 THERMAL CONDUCTIVITY OF REFRACTORY BRICK-T9470**
**Same as ASTM C-182**

**ASTM C-210 REHEAT CHANGE OF INSULATING FIREBRICK-T9480**

Three 9" x 4 1/2" x 2 1/2" or 3" bricks are fired for 24 hours after which the percent linear and volume changes are measured.

| IFB CLASS | TEMPERATURE | PER TEST OF 3 | EA ADD'L SPECIMEN |
|---|---|---|---|
| Group 16 | 1550°F | $765 | $25 |
| Group 20 | 1950°F | $810 | $25 |
| Group 23 | 2250°F | $865 | $25 |
| Group 26 | 2550°F | $920 | $30 |
| Group 28 | 2750°F | $980 | $30 |
| Group 30 | 2950°F | $1140 | $35 |
| Group 32 | 3150°F | $1360 | $35 |
| Group 33 | 3250°F | $1510 | $35 |

**ASTM D-257 D-C RESISTANCE OR CONDUCTANCE OF INSULATING MATERIALS-T9485**

Surface and volume electrical resistivity of insulating materials are determined by DC, as well as by AC methods. Specimen dimensions and electrode configuration are determined on an individual basis.

| | |
|---|---|
| Room Temperature | $280 per specimen (call for feasibility) |
| 200°C to 1200°C | $830 per specimen plus $160 per high temperature point |
| 800°C to 1600°C | $1030 per specimen plus $160 per high temperature point |

**ASTM C-288 DISINTEGRATION OF REFRACTORIES IN AN ATMOSPHERE OF CARBON MONOXIDE-T9500**

Shows the comparative behavior of refractory products with accelerated exposure to nearly pure CO at 940°F. The sample performance is rated based on the ASTM visual criteria. Specimens shall be 9" x 2 1/2" or 3" square in cross section. Maximum capacity of the test furnace is 50 specimens.

| | |
|---|---|
| Basic Test Cost | $1100 |
| Hourly Charge for Test Duration | $5 per hour |
| Sample Inspection During Test | $290 |

**ASTM C-357 BULK DENSITY OF GRANULAR REFRACTORY MATERIALS-T9510**

A 3 mesh by 8 mesh specimen of about 70 gm is weighed, boiled in water, and its volume measured using a buret. A sample of at least 5.5 lbs. should be submitted as recommended by ASTM.

$185 per specimen

**ASTM C-403 TIME OF SETTING OF CONCRETE MIXTURES BY PENETRATION RESISTANCE-T9511**

The resistance of the concrete mixture to penetration by standard needles is measured. The initial and final setting times are determined from a plot of penetration resistance versus time. A sample of at least 25 lbs. should be submitted

$290 per specimen

**ASTM C-417** **THERMAL CONDUCTIVITY OF UNFIRED MONOLITHIC REFRACTORIES-T9520**
**Same as ASTM C-182**

**ASTM C-491** **MODULUS OF RUPTURE OF AIR-SETTING PLASTIC REFRACTORIES-T9550**

Five 9" x 4 1/2" x 2 1/2" or 3" bricks are prepared in a hydraulic press at 1000 psi. MOR is determined after drying and firing the specimens.

| | |
|---|---|
| Specimen Preparation and Drying Shrinkage | $290 per test of 5 specimens |
| Firing Shrinkage | Same as ASTM C-113 |
| MOR | Same as ASTM C-133 |

**ASTM C-496** **SPLITTING TENSILE STRENGTH OF CYLINDRICAL CONCRETE SPECIMENS-T9551**

A diametral compressive load is applied along the length of a cylindrical specimen (2" diameter x 4" high) until tensile failure occurs.

$200 per test of 5 specimens

**ASTM C-577** **PERMEABILITY OF REFRACTORIES-T9560**

Air or nitrogen is used to determine permeability. The direction of flow should be indicated by arrows on the specimens. Testing of four 2" cube specimens of each type/brand is recommended by ASTM.

$280 per test of 4 specimens

**ASTM C-583** **MODULUS OF RUPTURE OF REFRACTORY MATERIALS AT ELEVATED TEMPERATURES-T9570**

Flexural strength is determined for 1" x 1" x 6" bars at temperature in three-point bending. Price includes a 12 hour hold at the test temperature. Testing of five specimens per type/brand is recommended by ASTM.

| TEMPERATURE | 1-5 SPECIMENS | 6-30 SPECIMENS |
|---|---|---|
| 1000°F or Less | $440 | $40 each |
| 1000°F to 1500°F | $520 | $40 each |
| 1500°F to 2000°F | $580 | $40 each |
| 2000°F to 2500°F | $635 | $40 each |
| 2500°F to 2750°F | $825 | $40 each |
| 2750°F to 2912°F | $1000 | $40 each |
| Additional Hold Time at Temperature | Quote | Quote |

**ASTM C-604** **TRUE SPECIFIC GRAVITY BY GAS COMPARISON PYCNOMETER-T9571**

A volume displacement technique is used to determine the true specific gravity of a ground specimen. A completely representative sample is required for the analysis.

$200 per specimen

**ASTM C-605** **REHEAT CHANGE OF FIRECLAY NOZZLES AND SLEEVES-T9580**

Specimens (25 to 26 $in^3$) are taken from four different sleeves or nozzles and fired per Schedule D of ASTM C-113 (2460°F reheat). The percent linear and volume changes are measured.

$755 per test of 4 specimens

**ASTM C-621** **ISOTHERMAL CORROSION RESISTANCE OF REFRACTORIES TO MOLTEN GLASS-T9581**

The corrosion resistance of a specimen (0.39" x 0.39" x 2.0") in contact with molten glass under static, isothermal conditions is determined.

Quote

**ASTM C-704** **ABRASION RESISTANCE OF REFRACTORY MATERIALS AT ROOM TEMPERATURE-T9590**

The volume of materials abraded by a specified exposure to SiC grit blast is measured. Specimens are typically 4 1/2" square and 3" thick.

$510 per test of 5 specimens

**ASTM C-830** **APPARENT POROSITY, LIQUID ABSORPTION, APPARENT SPECIFIC GRAVITY, AND BULK DENSITY OF REFRACTORY SHAPES BY VACUUM PRESSURE-T9630**

A vacuum is used to determine the apparent porosity, bulk density, liquid absorption, and apparent specific gravity. Testing of five specimens (1/4 brick or 25 to 30 $in^3$ piece) per type/brand is suggested by ASTM.

$340 per test of 5 specimens

**ASTM C-831** **RESIDUAL CARBON, APPARENT RESIDUAL CARBON, AND APPARENT CARBON YIELD IN COKED CARBON CONTAINING BRICKS AND SHAPES-T9640**

Used for characterization and comparison of carbon containing brick and shapes. A 1" x 3" x 6" specimen is suggested by ASTM.

| | |
|---|---|
| 1800°F Coking (up to 12 specimens) | $470 |
| 2200°F Ignition Firing (12 hour hold) | $550 |
| Residual Carbon, Loss on Ignition, And Carbon Yield Determinations | $25 per specimen |

**ASTM C-832** **MEASURING THE THERMAL EXPANSION AND CREEP OF REFRACTORIES UNDER LOAD-T9650**

This method determines thermal expansion and creep under a 25 psi compressive stress for 50 hours. Other compressive stresses, up to 100 psi can be specified. The percent linear change is recorded continuously during the heat up and creep period under load. Specimen size is 1 1/2" square by 4 1/2" long. Two specimens are suggested by ASTM.

| **TEMPERATURE** | **PER TEST OF 1 (50 hr hold)** | **PER TEST OF 1 (100 hr hold)** | **PER TEST OF 1 (EUL only)** |
|---|---|---|---|
| 1400°C (2552°F) or less | $870 | $1110 | $470 |
| 1400°C to 1500°C (2732°F) | $1000 | $1230 | $600 |
| 1500°C to 1600°C (2912°F) | $1125 | $1365 | $690 |
| 1600°C to 1650°C (3002°F) | $1270 | $1510 | $785 |
| 1650°C to 1700°C (3092°F) | $1340 | $1590 | $825 |
| Alcoa Modified (2600°F) | $3100 | | |
| Flexural Test Configuration | Quote | Quote | Quote |
| Other Test Conditions | Quote | Quote | Quote |

**ASTM C-860 DETERMINING AND MEASURING CONSISTENCY OF REFRACTORY CONCRETE-ASTM C-1445 T9670**

These methods determine the optimum water content and consistency of castable products. Consistency is judged with the Ball-in-Hand method (C-860) or measured with the Flow Table method (C-1445).

$290 per specimen

**ASTM C-862 PREPARING REFRACTORY CONCRETE SPECIMENS BY CASTING-T9680**

Five brick specimens are prepared using the water content determined in ASTM C-860. This procedure assures the preparation of uniform samples for testing purposes. At least 50 lbs. of each material for testing should be submitted. Mixing is performed in a Hobart mixer and casting is performed either by spading or by vibration.

$290 per test of 5 specimens

**ASTM C-863 EVALUATING OXIDATION RESISTANCE OF SILICON CARBIDE REFRACTORIES AT ELEVATED TEMPERATURES-T9690**

Steam is used to accelerate the oxidation of SiC refractories at elevated temperatures. ASTM specifies a 500 hour test duration at a temperature between 800°C and 1200°C. The average volume and bulk density changes are measured on three specimens per material.

| | **PER TEST OF 1 MATERIAL** | **PER TEST OF 3 MATERIALS** | **PER TEST OF 6 MATERIALS** |
|---|---|---|---|
| Measurements | $230 | $690 | $1380 |
| Basic Test Cost | $1830 | $1830 | $1830 |
| | $2060 | $2520 | $3210 |

**ASTM C-865 FIRING REFRACTORY CONCRETE SPECIMEN-T9700**

Firing schedules are for five refractory concrete specimens made in accordance with ASTM C-862 and classified by ASTM C-401. Price includes linear change measurement.

| **REGULAR TYPE** | **INSULATING TYPE** | **PER TEST OF 5** |
|---|---|---|
| | Class N, 1700°F | $560 |
| | Class O, 1900°F | $580 |
| Class A, 2000°F | | $600 |
| Class B, 2300°F | | $650 |
| | Class P, 2100°F | $730 |
| Class C, 2500°F | Class Q, 2300°F | $745 |
| Class D, 2700°F | Class R, 2500°F | $790 |
| Class E, 2900°F | Class S, 2700°F | $940 |
| | Class T, 2900°F | $1010 |
| Class F, 3100°F | Class U, 3000°F | $1120 |
| Class G, 3200°F | Class V, 3200°F | $1170 |

**ASTM C-874 ROTARY SLAG TESTING OF REFRACTORY MATERIALS-T9721**

This method compares the behavior of refractories to the action of molten slag in a rotating furnace. Five specimens and a control constitute a lining. Specimens are machined from 9" straight bricks.

Quote

**ASTM C-914** **BULK DENSITY AND VOLUME OF SOLID REFRACTORIES BY WAX IMMERSION-T9720**

This method is used to determine volume and bulk density of a refractory of any shape providing it has sufficient structural integrity to permit handling. At least five representative specimens, as suggested by ASTM, should be supplied.

$345 per test of 5 specimens

**ASTM C-973** **PREPARING TEST SPECIMENS FROM BASIC REFRACTORY GUNNING PRODUCTS BY PRESSING-T9730**

Five brick specimens are prepared using the water content specified by the manufacturer. This procedure assures the preparation of uniform specimens for testing purposes. At least 50 lbs. of each material for testing should be submitted. Mixing is performed in a Hobart mixer and specimens are formed at 1800 psi.

$290 per test of 5 specimens

**ASTM C-974** **PREPARING TEST SPECIMENS FROM BASIC REFRACTORY CASTABLE PRODUCTS BY CASTING-T9740**

Five brick specimens are prepared using the water content specified by the manufacturer. This procedure assures the preparation of uniform specimens for testing purposes. At least 50 lbs. of each material for testing should be submitted. Mixing is performed in a Hobart mixer and casting is either performed by spading or by vibration.

$290 per test of 5 specimens

**ASTM C-975** **PREPARING TEST SPECIMENS FROM BASIC REFRACTORY RAMMING PRODUCTS BY PRESSING-T9745**

Five brick specimens are prepared using the water content specified by the manufacturer. This procedure assures the preparation of uniform specimens for testing purposes. At least 50 lbs. of each material for testing should be submitted. Mixing is performed in a Hobart mixer and specimens are pressed at 10,000 psi.

$290 per test of 5 specimens

**ASTM C-987** **VAPOR ATTACK ON REFRACTORIES FOR FURNACE SUPERSTRUCTURES-T9746**

The corrosion resistance of a specimen (2.2" x 2.2" x 0.8") in contact with vapors under static, isothermal conditions is determined. Three specimens are suggested by ASTM.

Quote

**ASTM C-1054** **PRESSING AND DRYING REFRACTORY PLASTIC AND RAMMING MIX SPECIMENS-T9750**

Five brick specimens are prepared at 1000 psi. This procedure assures the preparation of uniform specimens for testing purposes. At least 50 lbs. of each material for testing should be submitted.

$290 per test of 5 specimens

**ASTM C-1099 MODULUS OF RUPTURE OF CARBON-CONTAINING REFRACTORY MATERIALS AT ELEVATED TEMPERATURES-T9758**

Flexural strength is determined for 1" x 1" x 6" bars at 2550°F in three-point bending. Testing of five specimens per type/brand is recommended by ASTM.

$635 per test of 5 specimens ($40 for each additional specimen)

**ASTM C-1113 THERMAL CONDUCTIVITY OF REFRACTORIES BY HOT WIRE-T9855**

The hot wire technique is a transient, intermittent isothermal method for measuring thermal conductivity. A thin platinum wire is placed between two appropriately prepared 9" bricks of same density. Heat generated by current applied to the wire is conducted away from the wire at a rate dependent on the thermal conductivity of the material. Minimum of two bricks required.

| | |
|---|---|
| Room Temperature (1 data point) | $790 |
| Room Temperature, 400, 800, and 1200°C | $1625 |
| Room Temperature, 400, 800, 1200, and 1600°C | $1850 |
| Extra Temperature Points | $230 |

**ASTM C-1171 QUANTITATIVELY MEASURING THE EFFECT OF THERMAL CYCLING ON REFRACTORIES-T9765**

Determination of the relative thermal shock resistance of refractories by using 5 alternating 10 minute heating at 2190°F and cooling in air cycles. Ten specimens 1" x 1" x 6" per type/brand are required by ASTM and both the actual and percent change in strength and ultrasonic properties are reported.

$1270 per test of 10 specimens

**ASTM C-1223 GLASS EXUDATION FROM AZS FUSION-CAST REFRACTORIES-T9766**

Specimens (1" x 1" x 4.0") are subjected to temperatures that produce glass exudation. The quantity of exuded glass is calculated from the volume change.

Quote

**ASTM C-1419 SONIC VELOCITY IN REFRACTORY MATERIALS AT ROOM TEMPERATURE AND ITS USE IN OBTAINING AN APPROXIMATE YOUNG'S MODULUS-T9768**

Approximation of Young's Modulus is calculated through sonic velocity measurements in 3 directions. The velocity of sound waves is measured using a James V-meter.

$320 per test of 5 specimens

**ASTM C-1548 DYNAMIC YOUNG'S MODULUS, SHEAR MODULUS, AND POISSON'S RATIO FOR REFRACTORY MATERIALS BY IMPULSE EXCITATION OF VIBRATION-T9767**

A non-destructive sonic method is used to determine the modulus of elasticity and modulus of rigidity for calculation of Poisson's Ratio. Bars of rectangular cross-section are used for the measurements.

$280 per test of 5 specimens (Young's modulus only)
$320 per test of 5 specimens (Young's modulus, shear modulus, and Poisson's ratio)

**DIN 51053** **DETERMINATION OF CREEP OR REFRACTORINESS UNDER LOAD-T9900**
**ISO 3187**

One cylindrical specimen (50 mm diameter x 50 mm high) is tested per firing. The percent linear change is recorded continuously during the heat-up and creep period under load. The minimum size required is a half brick. Standard conditions are 0.2 $N/mm^2$ (29 psi) load and 50 hour hold.

| TEMPERATURE | PER TEST OF 1 (50 hr hold) | PER TEST OF 1 (100 hr hold) | PER TEST OF 1 (RUL only) |
|---|---|---|---|
| 1400°C or Less | $870 | $1110 | $470 |
| 1400°C to 1500°C | $1000 | $1230 | $600 |
| 1500°C to 1600°C | $1125 | $1365 | $690 |
| 1600°C to 1650°C | $1270 | $1510 | $785 |
| 1650°C to 1700°C | $1340 | $1590 | $825 |
| Other Test Conditions | Quote | Quote | Quote |

**ALCOA MODIFIED ALUMINUM CUP PENETRATION-T9810**

The comparative resistance of refractory brick, mortars, or monolithics can be determined using this cup test, with 7075 aluminum alloy at 1500°F for 72 hours. Two 9" bricks are required. Before and after metal analysis is available at an additional cost of $175 per analysis.

$860 per test of 1 specimen
$1140 per test of 2 specimens

**ALCOA MODIFIED DISINTEGRATION OF REFRACTORIES BY ALKALI-T9540**

Nine 2" cube specimens are required. A 1" hole is drilled into the face of each specimen and filled with either 8 gm of Potassium Carbonate, 8 gm of Sodium Carbonate, or a mixture of 4 gm of Potassium Carbonate and 4 gm of Sodium Carbonate. The effects of firing three cubes each at 900°C, 1000°C, or 1100°C for 5 hours are determined visually.

$1220 per test of 9 specimens

**ALKALI RESISTANCE-T9800**

Test specimens are fired to 1700°F in two cycles in the presence of Potassium Carbonate. MOR, MOE, and visual observations are taken before and after exposure to alkali. Ten 1" x 1" x 6" bars are required.

$1170 per test of 10 specimens

**BONDING STRENGTH AFTER FIRING-T9820**

Fireclay brick halves are bonded with a 1/16" thick joint. After air and oven drying and a 5 hour hold at the specified firing temperature, the MOR is determined for the brick/joint assembly. Five 9" bricks are required. At least 10 lbs. of mortar should be submitted for analysis.

| | |
|---|---|
| Specimen Preparation and MOR | Same as ASTM C-198 |
| Specimen Firing | Same as Periodic Kiln Firing |

## CHEMICAL ANALYSIS-T9830

Full service analytical capabilities are offered. All analyses are performed by a subcontractor. MTRC prefers to prepare the needed representative powder from the bulk sample(s) submitted. Typical materials analyzed by MTRC are listed below.

| MATERIAL | PRICE PER SPECIMEN |
|---|---|
| Fireclay | $465 |
| Mullite | $465 |
| Bauxite | $465 |
| Feldspar | $465 |
| High Alumina | $465 |
| Chrome-Magnesite, Dolomite | $465 |
| Silica | $465 |
| Zircon | $465 |
| Alumina-Zirconia-Silica | $465 |
| Special Analyses | Quote |

Note: Add $50.00 for detection of each non-oxide (Carbon, Silicon Carbide, or Silicon Nitride).
Add $100.00 for detection of Boron.

## CORROSION RESISTANCE OF REFRACTORIES TO MOLTEN GLASS-T9582

The corrosion resistance of a specimen (0.75" x 0.75" x 8.0") in contact with molten glass under dynamic, isothermal conditions is determined. Known as the finger test, up to four specimens are attached to a rotating shaft that is lowered into molten glass (up to 1650$^{o}$C). Test duration is typically 24 or 48 hours. Visual or quantitative analysis can be conducted on the corroded specimens.

Quote

## CURING OR DRYING CHANGE-T9840

For refractory concretes the percent linear or volume change can be calculated after curing based on mold dimensions and after drying based on cured dimensions. At least 50 lbs. of each material for testing should be submitted.

$290 per test of 5 specimens

## MICROSCOPIC ANALYSIS-T9775

Optical Microscope: Reflected light techniques are used to characterize the microstructure of materials submitted. Photomicrographs can be provided, if requested. Quote.
Scanning Electron Microscope: Electron beam techniques are used to characterize the microstructure of materials submitted. Photomicrographs can be provided, if requested.

Quote

### PERIODIC KILN FIRINGS-T9200

Periodic kiln firing can be performed within all commercial ranges of temperatures and atmospheres, using almost any schedule used by commercial equipment. The prices apply to one firing with at least 1 cubic foot setting space up to a 24 hour cycle. Longer soak times are $75 to $350 per additional 24 hours and are quoted depending on firing conditions.

| TEMPERATURE RANGE | FIRING CONDITIONS | PRICES |
|---|---|---|
| 25°C-1000°C | Electric firing with normal air atmosphere | $275 per firing |
| 25°C-1500°C | Electric firing with normal air atmosphere | $560 per firing |
| 25°C-1700°C | Electric firing with normal air atmosphere | $820 per firing |
| 25°C-1500°C | Gas firing with normal combustion gas | $825 per firing |
| 25°C-1700°C | Gas firing with normal combustion gas | $950 per firing |
| Thermal Gradient | | Quote |
| Other Test Conditions | | Quote |

### ULTRASONIC VELOCITY-T9780

The speed of sound is measured non-destructively for brick through 3 dimensions. Testing of 5 specimens per type/brand is recommended.

$320 per test of 5 specimens

### WORKABILITY-T9785

A practical test used in industry to determine the approximate working time for placement of a castable in the field.

$145 per test

### X-RAY DIFFRACTION ANALYSIS-T9790

The major and minor crystalline phases present in a sample are determined on a qualitative basis. All analyses are performed by subcontractor. MTRC prefers to prepare the needed representative powder from the bulk sample(s) submitted.

| | |
|---|---|
| Qualitative Determination | $360 per specimen |
| Quantitative Determination | $485 per specimen (amorphous phase content) |

# THERMAL ANALYSIS METHODS

### DIFFERENTIAL THERMAL ANALYSIS (DTA)-T9140

Differential Thermal Analysis is a determination of the temperature difference between the sample and a known reference as a function of the reference temperature. It is a sensitive qualitative test for determining the temperature at which chemical and physical changes occur in the sample. DTA is especially useful in control and analysis and for indicating temperature regions for closer study or evaluation by other thermal analytical techniques.

| TEMPERATURE RANGE | RUN IN AIR ATMOSPHERE | RUN IN SPECIAL ATMOSPHERE (Ar, $O_2$, $N_2$, $CO_2$) |
|---|---|---|
| 25-1550°C | $285 | $340 |

Sample Required: 10 gm minimum, 60 mesh
Heating and Cooling Rate: 10°C/minute (standard)

### THERMAL GRAVIMETRIC ANALYSIS (TGA)-T9170

Thermogravimetric Analysis provides the change in weight of a sample as function of temperature. It is a precise quantitative method of determining combustibles, loss of volatiles, curing times, decomposition of hydrates and carbonates, and weight loss changes. Rates of weight loss or gain are easily determined from the curve. The use of controlled atmospheres allows for the study of solid-gas reactions.

| TEMPERATURE RANGE | RUN IN AIR ATMOSPHERE | RUN IN SPECIAL ATMOSPHERE (Ar, $O_2$, $N_2$, $CO_2$) |
|---|---|---|
| 25-1550°C | $285 | $340 |

Sample Required: 10 gm minimum, 60 mesh
Heating and Cooling Rate: 2°C/minute (standard)

### SIMULTANEOUS DIFFERENTIAL THERMAL ANALYSIS / THERMAL GRAVIMETRIC ANALYSIS (DTA / TGA)-T9150

Simultaneous DTA / TGA Analysis combines the two thermal analysis techniques, Differential Thermal Analysis and Thermogravimetric Analysis, in one measurement. The instrument is configured with the differential thermocouple assembly mounted on the balance, which allows monitoring the weight change and temperature differential simultaneously as a function of temperature.

| TEMPERATURE RANGE | RUN IN AIR ATMOSPHERE | RUN IN SPECIAL ATMOSPHERE (Ar, $O_2$, $N_2$, $CO_2$) |
|---|---|---|
| 25-1550°C | $410 | $460 |

Sample Required: 10 gm minimum, 60 mesh
Heating and Cooling Rate: 10°C/minute (standard)

## ASTM E-228 THERMAL LINEAR ANALYSIS (THERMAL EXPANSION/CONTRACTION)-T9110

Thermal Linear Analysis determines the expansion and/or contraction characteristic of a specimen as a function of temperature. Numerical and graphical results show the percent of linear thermal change (expansion or shrinkage) versus temperature using an Orton dilatometer. Tests on larger refractory specimens can also be made using a vertical thermal expansion furnace (see ASTM C-832).

| TEST DESCRIPTION | CRYOGENIC -180 to 300°C | 25 to 1000°C | 25 to 1500°C | 25 to 1600°C |
|---|---|---|---|---|
| Heating Only Air Atmosphere | N/A | $175 | $235 | $275 |
| Heating and Cooling Air Atmosphere | N/A | $225 | $295 | $360 |
| Heating Only Special Atmosphere ($Ar$, $O_2$, $N_2$, $CO_2$) | $285 | $260 | $335 | $360 |
| Heating and Cooling Special Atmosphere ($Ar$, $O_2$, $N_2$, $CO_2$) | N/A | $300 | $400 | $450 |

Sample Sizing-T9100 $145 per specimen

Sample Required: For specimens run to 1000°C, the maximum diameter is 1/2" and the standard lengths are 1/2", or 1", or 2". For specimens greater than 1000°C, the maximum diameter is 5/8" and the standard length is 1". Length can vary by 0.1". Specimen ends need to be flat and parallel and within ± 0.001". Tests can be made on specimens of non-standard length and unusual shapes (foils, wafers, or stacking small pieces).
Heating and Cooling Rates: 3°C/minute (standard)
ASTM Standard Conditions: Thermal linear analysis can be performed according to other standard conditions, such as outlined in C-372, C-824, and E-831.

## ASTM E-1269 HEAT CAPACITY BY DIFFERENTIAL SCANNING CALORIMETRY (DSC)-T9151

Specific heat capacity is measured by differential scanning calorimetry. For the Setaram DSC unit, the sample size for oxides is a 0.232” (plus 0.000”/minus 0.005”) diameter x 0.527” high cylinder and for non-oxides is a 0.192” (plus 0.000”/minus 0.005”) diameter x 0.456” high cylinder. For the Netzsch DSC unit, the sample size is a 0.236” (plus 0.000”/minus 0.005”) diameter x 0.040” thick disk. Since sample configuration may be dependent on sample composition, inquire before machining samples for submittal.

Quote

## HEAT CAPACITY CALCULATED FROM THERMODYNAMIC DATA-T9909

Specific heat capacity is calculated from thermodynamic data. The chemistry must be supplied for this calculation.

$145 per calculation

## ASTM E-1461 THERMAL DIFFUSIVITY AND CONDUCTIVITY BY LASER FLASH-T9111

Thermal diffusivity is measured by laser flash. The sample size for the Anter Laser Flash unit is a 0.500" (plus 0.000"/minus 0.005") diameter disk. Sample height is variable. Samples of 0.08", 0.12", and 0.16" should be provided. Since sample configuration may be dependent on sample composition, inquire before machining samples for submittal. Thermal conductivity is calculated from the thermal diffusivity, heat capacity, and density. See ASTM E-1269 for sample size requirements for determination of heat capacity. The diffusivity price includes the heat capacity determination.

Quote

# WHITEWARE TEST METHODS

## ASTM C-67 BRICK AND STRUCTURAL CLAY TILE TESTING-T9340

A minimum of five full size brick or tile units per type/brand is suggested by ASTM for determination of modulus of rupture, compressive strength, absorption, and saturation coefficient.

| TEST DESCRIPTION | PER TEST OF 5 |
|---|---|
| Modulus of Rupture | $200 |
| Compressive Strength (includes capping) | $495 |
| Absorption: 5 or 24 hour submersion test | $145 |
| Absorption: 1, 2, or 5 hour boil test | $230 |
| Saturation Coefficient | $375 |
| Efflorescence | $145 |

## ASTM C-279 CHEMICAL RESISTANT MASONRY UNITS-T9490

Granular specimens are boiled in a sulfuric acid solution for a specified time period. The percent weight loss for two representative specimens per type/brand is determined.

$470 per test of 2 specimens

## ASTM C-373 WATER ABSORPTION, BULK DENSITY, APPARENT POROSITY, AND APPARENT SPECIFIC GRAVITY OF FIRED WHITEWARE PRODUCTS-T9515

The water absorption, bulk density, apparent porosity, and apparent specific gravity are determined by the boiling method. Testing of five unglazed specimens (of at least 50 gm/piece) is suggested by ASTM.

$230 per test of 5 specimens

## ASTM C-554 CRAZING RESISTANCE OF FIRED GLAZED CERAMIC WHITEWARES BY A THERMAL SHOCK METHOD-T9516

The resistance to crazing of fired glazed whitewares is determined when subjected to thermal stresses. Specimens are initially heated at 250°F and water quenched. This cycle is repeated three times. If crazing dos not take place, then the three cycles are repeated in 25°F increments up to 450°F. Failure is defined as the temperature at which crazing is observed. Testing of five specimens is suggested by ASTM.

$560 per test of 5 specimens

## ASTM C-674 FLEXURAL PROPERTIES OF CERAMIC WHITEWARE MATERIALS-T9517

Flexural strength is determined in three-point bending on bars of circular or rectangular cross-section. Testing of ten specimens per type/brand is recommended by ASTM.

$50 per specimen (strength)
$115 per specimen (strength and elastic modulus)

## ASTM C-773 COMPRESSIVE (CRUSHING) STRENGTH OF FIRED WHITEWARE MATERIALS-T9518

The compressive strength is determined on a right cylinder. Testing of at least ten specimens per type/brand is recommended by ASTM. Additional costs may be incurred for machining of contact cylinders.

$50 per specimen

# LABOR AND CONSULTING CHARGES

## LABOR CHARGES

| | |
|---|---|
| Technician Time and Sample Preparation-T8200 | $145 per hour |
| Engineer Time-T8100 | $230 per hour |

## MACHINING SERVICES-T9881

Machining services for advanced ceramic test coupons include diamond cutting, coring, and surface grinding.

Quote

## ON-SITE INSPECTION OR SAMPLING-T9870

Arrangements can be made to offer needed services in-plant or on-site. Examples are quality control sampling, product inspection (including non-destructive sonic testing), failure analysis, and sampling of a failure.

Quote

## SPECIAL PROJECTS-T9880

For special projects, a proposal is submitted covering work to be done along with time and costs. Most projects are done on a cost-incurred basis. Orton makes every effort to provide high quality technical services on a responsive basis.

Quote

### RESEARCH & CONSULTANT SERVICES

**CENTER** staff is actively involved in the development of new test methods and the evaluation of existing tests. We can do comparative evaluations on specific materials. Capabilities exist to evaluate sensors, design or apply electronics, write specialized software, and design and build test equipment.

**THE CENTER** also undertakes proprietary research and testing projects for clients on a contract basis. These may include ceramic/refractory materials evaluation, development/characterization of new test procedures or evaluation of firing behavior. Following discussion of the project with a client, a proposal is prepared outlining the work to be performed, project schedule, and estimated cost. The Center utilizes the services of private consultants, University faculty, and others to complement its own professional staff and testing capabilities.

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**Notes:**

**Notes:**