

## **2022 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**

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# 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  
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## Additional Correspondence

Beau Billet (Lab Manager)

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**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 \$160 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, 2022. 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. A 3.5% fee is charged for orders paid with credit cards.

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.

\$550 per test of 10 specimens

### **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.

\$305 per test of 5 specimens (Young's modulus only)

\$350 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.

\$550 per test of 10 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.

\$410 per test of 5 specimens

### **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.

\$290 per test of 5 specimens

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

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

\$80 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.

Quote

**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.

\$350 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.

\$1120 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.

\$140 per test of 5 specimens

### **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.

\$455 per test (of 2 specimens)

\$295 per test of each additional type/brand (up to 12 specimens total)

### **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. Sixteen measurements per specimen are recommended by ASTM.

\$210 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.

\$275 per test of 5 specimens

### **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.

\$275 per test of 5 specimens

### **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.

\$350 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.

\$275 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.

\$275 per test of 5 specimens

**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.

\$370 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.

\$220 per test of 5 specimens

### **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.

\$220 per test of 5 specimens

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

The compressive strength is determined on 2" cubes.

\$220 per test of 5 specimens

### **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.

\$305 per test of 5 specimens (Young's modulus only)

\$350 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.

\$220 per test of 5 specimens

### **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.

\$330 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.

\$265 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.

\$325 per test of 6 specimens (strength)

\$750 per test of 6 specimens (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.

\$350 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.

\$750 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.

\$275 per test of 5 specimens

### **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.

\$220 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.

\$135 per test of 5 specimens

### **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.

<b>TEMPERATURE</b>	<b>PER TEST OF 4</b>
1600°F or Less	\$890
1600°F to 2600°F	\$1040
2600°F to 3000°F	\$1325

### **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.

\$540 per test of 10 specimens (5 specimens machine direction / 5 specimens opposite machine direction)

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

A 10 gram 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.

\$585 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.

\$550 per test of 10 specimens

### **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.

\$365 per glass to 800°C

\$365 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.

\$310 per glass to 1000°C

\$365 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.

\$400 per glass to 1000°C

\$305 per glass for beam preparation

### **ASTM C-657 DC VOLUME RESISTIVITY OF GLASS-T9577 Same as D-257.**

### **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.

\$1060 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.

\$1010 first temperature specified

\$305 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.

\$400 per glass to 1000°C

\$305 per glass for beam 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.

		<b>PER TEST OF 2</b>	<b>PER TEST OF 4</b>	<b>EA ADD'L 24 HR HOLD</b>
Misc. Products	Less than 2000°F	\$840	\$1135	\$480
Medium Duty Fireclay	Schedule 1 2370°F	\$910	\$1210	\$480
High Duty Fireclay	Schedule 2 2460°F	\$970	\$1260	\$480
Misc. Products	2550°F	\$1030	\$1325	\$525
Super Duty Products	Schedule 3 2640°F	\$1070	\$1365	\$525
Misc. Products	2750°F	\$1135	\$1440	\$525
Mullite, High Alumina	Schedule 6 2900°F	\$1200	\$1500	\$570
Mullite, High Alumina	Schedule 7 3000°F	\$1230	\$1535	\$570
Silica Brick to Failure	Schedule 4	\$1500	\$1815	
Mag-Chrome Brick to Failure	Schedule 5	\$1500	\$1815	
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<sup>3</sup> piece) per type/brand is suggested by ASTM.

\$250 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.

	<b>PER TEST</b>
One specimen up to cone 36	\$475
Two specimens in one firing, within 3 Cone numbers, up to cone 36	\$595

### 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.

\$155 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	\$160
Each Additional Sieve	\$10
Full Analysis: 3, 4, 6, 8, 10, 14, 20, 28, 35, 48, 65, 100, 150, 200, 270, 325, 400 mesh	\$290

**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.

		<b>PER TEST OF 3</b>	<b>EA ADD'L SPECIMEN</b>
Misc. Products	2000°F or Less	\$645	\$30
Low Duty Fireclay	Schedule A, 2190°F	\$680	\$30
Ladle Brick	Schedule E, 2350°F	\$715	\$35
Fireclay Nozzles	Schedule D, 2460°F	\$790	\$35
High Duty Fireclay	Schedule B, 2550°F	\$820	\$35
Misc. Products	Schedule F, 2730°F	\$860	\$35
Super Duty Fireclay	Schedule C, 2910°F	\$1010	\$40
High Alumina	Schedule G, 3000°F	\$1250	\$40
Misc. Products	Schedule H, 3090°F	\$1460	\$40
Misc. Products	Up to 3140°F	\$1680	\$40

**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.

\$235 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.

\$235 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     \$265 per test of 10 specimens  
Warpage                     \$265 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.

\$250 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                      \$315 per test of 3 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.

\$315 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.

		<b>EA ADD'L TEST TEMP</b>
First Hot Face Temperature Specified	\$1625	\$400
First Mean Temperature Specified	\$1890	\$415

**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.

\$575 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.

	<b>FIRING TEMPERATURE</b>	<b>PER TEST</b>
Medium Duty	2550°F	\$880
High Duty	2730°F	\$980
Super Duty	2910°F	\$1190
High Alumina	3100°F	\$1290

**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	\$830	\$30
Group 20	1950°F	\$880	\$30
Group 23	2250°F	\$940	\$30
Group 26	2550°F	\$1000	\$35
Group 28	2750°F	\$1060	\$35
Group 30	2950°F	\$1235	\$40
Group 32	3150°F	\$1920	\$40

**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	\$300 per specimen (call for feasibility)
up to 800°C	\$890 per specimen plus \$165 per temperature point
up to 1600°C	\$1115 per specimen plus \$175 per 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	\$1195
Hourly Charge for Test Duration	\$6 per hour
Sample Inspection During Test	\$315

**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.

\$210 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.

\$330 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	\$525 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.

\$265 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.

\$300 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	\$475	\$45 each
1001°F to 1500°F	\$565	\$45 each
1501°F to 2000°F	\$630	\$45 each
2001°F to 2500°F	\$690	\$50 each
2501°F to 2750°F	\$870	\$50 each
2751°F to 2912°F	\$1095	\$55 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.

\$225 per specimen

**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.

\$550 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<sup>3</sup> piece) per type/brand is suggested by ASTM.

\$370 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)	\$505
2200°F Ignition Firing (12 hour hold)	\$595
Residual Carbon, Loss on Ignition, And Carbon Yield Determinations	\$35 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	\$945	\$1510	\$505
1401°C to 1500°C (2732°F)	\$1080	\$1730	\$650
1501°C to 1600°C (2912°F)	\$1220	\$1950	\$750
1601°C to 1650°C (3002°F)	\$1420	\$2270	\$850
1651°C to 1700°C (3092°F)	\$1670	\$2670	\$995
Alcoa Modified (2600°F)	\$3360		
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).

\$315 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.

\$320 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.

	<b>PER TEST OF 1 MATERIAL</b>	<b>PER TEST OF 3 MATERIALS</b>	<b>PER TEST OF 6 MATERIALS</b>
Measurements	\$245	\$740	\$1480
Basic Test Cost	<u>\$1985</u>	<u>\$1985</u>	<u>\$1985</u>
	\$2230	\$2725	\$3465

**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.

<b>REGULAR TYPE</b>	<b>INSULATING TYPE</b>	<b>PER TEST OF 5</b>
	Class N, 1700°F	\$605
	Class O, 1900°F	\$630
Class A, 2000°F		\$650
	Class P, 2100°F	\$790
Class B, 2300°F	Class Q, 2300°F	\$810
Class C, 2500°F	Class R, 2500°F	\$855
Class D, 2700°F	Class S, 2700°F	\$1020
Class E, 2900°F	Class T, 2900°F	\$1060
	Class U, 3000°F	\$1215
Class F, 3100°F		\$1260

**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.

\$380 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.

\$525 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.

\$320 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.

\$525 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.

\$525 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.

\$870 per test of 5 specimens (\$50 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)	\$910
Room Temperature, 400, 800, and 1200°C	\$1675
Room Temperature, 400, 800, 1200, and 1600°C	\$1975
Extra Temperature Points (1200°C or less)	\$255
Extra Temperature Points (greater than 1200°C)	\$300

**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.

\$1375 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.

\$350 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.

\$305 per test of 5 specimens (Young's modulus only)

\$350 per test of 5 specimens (Young's modulus, shear modulus, and Poisson's ratio)

**DIN 51053**  
**ISO 3187**

**DETERMINATION OF CREEP OR REFRACTORINESS UNDER LOAD-T9900**

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<sup>2</sup> (29 psi) load and 50 hour hold.

<b>TEMPERATURE</b>	<b>PER TEST OF 1 (50 hr hold)</b>	<b>PER TEST OF 1 (100 hr hold)</b>	<b>PER TEST OF 1 (RUL only)</b>
1400°C or Less	\$945	\$1510	\$505
1401°C to 1500°C	\$1080	\$1730	\$650
1501°C to 1600°C	\$1220	\$1950	\$750
1601°C to 1650°C	\$1420	\$2270	\$850
1651°C to 1700°C	\$1670	\$2670	\$995
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 \$180 per analysis.

\$980 per test of 1 specimen  
\$1295 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.

\$1460 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.

\$1400 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  
Specimen Firing

Same as ASTM C-198  
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.

**PRICE PER SPECIMEN**

Standard Analysis (Al <sub>2</sub> O <sub>3</sub> , SiO <sub>2</sub> , CaO, MgO, K <sub>2</sub> O, Na <sub>2</sub> O, Fe <sub>2</sub> O <sub>3</sub> , TiO <sub>2</sub> , P <sub>2</sub> O <sub>5</sub> , Cr <sub>2</sub> O <sub>3</sub> , MnO, NiO, ZrO <sub>2</sub> )	\$495
Special Analyses	Quote

Note: Add \$65 for detection of each non-oxide (carbon, silicon carbide, or silicon nitride).  
Add \$105 for detection of boron.

**DYNAMIC 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°C). Test duration is typically 24 or 48 hours. Visual or quantitative analysis can be conducted on the corroded specimens.

Quote

**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 \$85 to \$385 per additional 24 hours and are quoted depending on firing conditions.

<b>TEMPERATURE RANGE</b>	<b>FIRING CONDITIONS</b>	<b>PRICES</b>
25°C-1000°C	Electric firing with normal air atmosphere	\$295 per firing
25°C-1500°C	Electric firing with normal air atmosphere	\$605 per firing
25°C-1700°C	Electric firing with normal air atmosphere	\$890 per firing
25°C-1500°C	Gas firing with normal combustion gas	\$895 per firing
25°C-1700°C	Gas firing with normal combustion gas	\$1030 per firing
Thermal Gradient		Quote
Other Test Conditions		Quote

### **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.

Quantitative Determination            \$510 per specimen (amorphous phase content)

### **ELEVATED TEMPERATURE ABRASION RESISTANCE OF REFRACTORY MATERIALS-T9590**

A specimen is heated to elevated temperature and 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.

Quote



## **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.

<b>TEMPERATURE RANGE</b>	<b>RUN IN AIR ATMOSPHERE</b>	<b>RUN IN SPECIAL ATMOSPHERE (Ar, O<sub>2</sub>, N<sub>2</sub>, CO<sub>2</sub>)</b>
25-1550°C	\$305	\$370

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.

<b>TEMPERATURE RANGE</b>	<b>RUN IN AIR ATMOSPHERE</b>	<b>RUN IN SPECIAL ATMOSPHERE (Ar, O<sub>2</sub>, N<sub>2</sub>, CO<sub>2</sub>)</b>
25-1550°C	\$365	\$495

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.

<b>TEMPERATURE RANGE</b>	<b>RUN IN AIR ATMOSPHERE</b>	<b>RUN IN SPECIAL ATMOSPHERE (Ar, O<sub>2</sub>, N<sub>2</sub>, CO<sub>2</sub>)</b>
25-1550°C	\$440	\$505

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).

<b>TEST DESCRIPTION</b>	<b>CRYOGENIC -180 to 300°C</b>	<b>25 to 1000°C</b>	<b>25 to 1600°C</b>
Heating Only Air Atmosphere	N/A	\$200	\$310
Heating and Cooling Air Atmosphere	N/A	\$250	\$410
Heating Only Special Atmosphere (Ar, O <sub>2</sub> , N <sub>2</sub> , CO <sub>2</sub> )	\$300	\$290	\$450
Heating and Cooling Special Atmosphere (Ar, O <sub>2</sub> , N <sub>2</sub> , CO <sub>2</sub> )	N/A	\$340	\$510

Sample Sizing-T9100 \$160 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.

\$250 per calculation

**ASTM E-1461 THERMAL DIFFUSIVITY AND CONDUCTIVITY BY FLASH METHOD-T9111**

Thermal diffusivity and heat capacity is measured by light flash. The specimen sizes are a 12.7 mm diameter disk, 10.0 mm diameter disk, or 10.0 mm square. Specimen thickness may be 1-4 mm. Thermal conductivity is calculated from the thermal diffusivity, heat capacity, and density.

Room Temperature (1 data point)	\$780
Room Temperature to 100°C (4 data points)	\$900
Room Temperature to 500°C (4 data points)	\$1140
Room Temperature to 800°C (4 data points)	\$1380
Room Temperature to 1200°C (4 data points)	\$1920
Room Temperature to 1600°C	Quote
Extra Temperature Points (less than 500°C)	\$80
Extra Temperature Points (less than 800°C)	\$120
Extra Temperature Points (greater than 800°C)	\$290

## 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.

<b>TEST DESCRIPTION</b>	<b>PER TEST OF 5</b>
Modulus of Rupture	\$220
Compressive Strength (includes capping)	\$530
Absorption: 5 or 24 hour submersion test	\$160
Absorption: 1, 2, or 5 hour boil test	\$250
Saturation Coefficient	\$405
Efflorescence	\$160

### 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.

\$575 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.

\$250 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 does 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.

\$640 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.

\$550 per test of 10 specimens (strength)

\$1250 per test of 10 specimens (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. **Two contact cylinders per specimen are required.**

\$550 per test of 10 specimens

## LABOR AND CONSULTING CHARGES

### LABOR CHARGES

Technician Time and Sample Preparation-T8200	\$160 per hour
Engineer Time-T8100	\$250 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.

## SUBJECT INDEX

<u>Description</u>	<u>ASTM Reference</u>	<u>Page Number</u>
<b><u>Chemical and Microstructural</u></b>		
Chemical Analysis	--	23
Microscopic Analysis	--	23
X-Ray Diffraction	--	24
Grain Size	E-112	5
<b><u>Electrical Properties</u></b>		
Resistance of Insulating Materials	D-257	16
Resistivity of Carbon and Graphite	C-611	6
Resistivity of Glass	C-657	11
<b><u>Mechanical Properties</u></b>		
Bonding Strength of Fired Refractory Mortar	--	22
Bonding Strength of Refractory Mortars	C-198	15
Compressive Strength of Carbon and Graphite	C-695	6
Compressive Strength of Cement Mortars	C-109	8
Compressive Strength of Concrete	C-39	8
Compressive Strength of Thermal Insulation	C-165	10
Compressive Strength of Whitewares	C-773	28
Compressive Strength of Advanced Ceramics	C-1424	4
Creep or Refractoriness Under Load	DIN 51053 / ISO 3187	22
Crushing and Modulus of Rupture of Refractories	C-133	14
Equibiaxial Strength	C-1499	4
Flexural Properties of Thermal Insulation	C-203	10
Flexural Strength and Modulus of Mortars/Concretes	C-580	9
Flexural Strength of Advanced Ceramics	C-1161	4
Flexural Strength of Advanced Ceramics at Elevated Temperatures	C-1211	4
Flexural Strength of Carbon and Graphite	C-651	6
Flexural Strength of Ceramic Composites	C-1341	4
Flexural Strength of Concrete	C-78 / C-293	8
Flexural Strength of Glass	C158	11
Flexural Strength of Whitewares	C-674	28
Fracture Toughness of Advanced Ceramics	C-1421	4
Hot Load Testing of Refractories	C-16	13
Modulus of Rupture of Carbon Containing Refractories at Elevated Temperatures	C-1099	20
Modulus of Rupture of Graphite	C-1025	7
Modulus of Rupture of Plastic Refractories	C-491	17
Modulus of Rupture of Refractories at Elevated Temperatures	C-583	17
Parting Strength	C-686	10
Pulse Velocity Through Concrete	C-597	9
Sonic Velocity of Carbon and Graphite	C-769	6
Sonic Velocity of Refractories	C-1419	21
Splitting Tensile Strength	C496	8, 17
Strength of Clay Tile	C-67	28
Thermal Expansion and Creep of Refractories	C-832	18
Transverse, Longitudinal, and Torsional Frequencies	C-215	8
Ultrasonic Velocity in Materials	E-494	5
Young's Modulus of Advanced Ceramics	C-1259	4
Young's Modulus by Impulse Excitation	C-1548	21
<b><u>Physical Properties</u></b>		
Abrasion Resistance of Refractories	C-704	18
Elevated Temperature Abrasion Resistance of Refractories	--	24
Alkali Resistance of Refractories	--	22
Aluminum Cup Penetration	--	22
Annealing and Strain Point of Glass	C-336	11

<u>Description</u>	<u>ASTM Reference</u>	<u>Page Number</u>
Annealing and Strain Point of Glass	C-598	11
Ash in Graphite	C-561	6
Bulk Density of Carbon and Graphite	C-559	6
Bulk Density of Carbon and Graphite	C-838	7
Bulk Density of Granular Refractory Materials	C-357	16
Bulk Density of Refractories	C-914	19
Bulk Density and Porosity of Whitewares	C-373	28
Chemical Resistant Masonry	C-279	28
Corrosion Resistance to Molten Glass	C-621	17
Corrosion Resistance to Molten Glass (Finger Test)	--	23
Density of Thermal Insulation	C-303	10
Disintegration of Carbon by Alkali	C-454	6
Disintegration of Refractories by Alkali	--	22
Disintegration of Refractories by Carbon Monoxide	C-288	16
Glass Exudation	C-1223	21
Liquidus Temperature	C-829	11
Oxidation Resistance of Silicon Carbide	C-863	19
Permeability of Refractories	C-577	17
Porosity and Density of Graphite	C-1039	7
Porosity and Density of Refractories	C-20	13
Porosity and Density of Refractories	C-830	18
Pyrometric Cone Equivalents	C-24	13
Residual Carbon and Carbon Yield	C-831	18
Rotary Slag Corrosion	C-874	19
Saturation Coefficient of Clay Tile	C-67	28
Sieve Analysis	C-92	13
Size and Bulk Density of Refractories	C-134	14
Softening Point of Glass	C-338	11
Thickness and Density of Thermal Insulation	C-167	10
True Specific Gravity	C-135	14
True Specific Gravity	C-604	17
Unfiberized Shot Content of Fibrous Blankets	C-892	10
Vapor Attack	C-987	20
Viscosity of Molten Glass	C-965	12
Viscosity by Beam Bending	C-1350	12
<b><u>Sample Preparation</u></b>		
Consistency of Refractory Concrete	C-860 / C1445	18
Labor Charges	--	29
Preparing Refractory Concrete Specimens by Casting	C-862	19
Preparing Specimens from Refractory Castables by Casting	C-974	20
Preparing Specimens from Refractory Gunning Products by Pressing	C-973	20
Preparing Specimens from Refractory Ramming Mixes by Pressing	C-975	20
Pressing and Drying of Refractory Plastics and Ramming Mixes	C-1054	20
Setting Time of Concrete	C-403	8, 16
Workability of Plastic Refractories	C-181	15
<b><u>Thermal Properties</u></b>		
Crazing Resistance of Whitewares	C-554	28
Differential Thermal Analysis (DTA)	--	25
Drying and Linear Change of Plastic Refractories	C-179	15
Firing Refractory Concrete	C-865	19
Heat Capacity (DSC)	E-1269	26
Heat Capacity (Calculated)	--	26
Linear Shrinkage of Thermal Insulation	C-356	10
Periodic Kiln Firing	--	23

<u>Description</u>	<u>ASTM Reference</u>	<u>Page Number</u>
Pier Test of Refractory Mortars	C-199	15
Quantitatively Measuring the Effect of Thermal Cycling	C-1171	21
Reheat Change of Insulating Refractories	C-210	16
Reheat Change of Refractories	C-113	14
Simultaneous Thermal Analysis (DTA/TGA)	--	25
Thermal Conductivity of Carbon by Calorimeter	C-767	6
Thermal Conductivity by Laser Flash	E-1461	27
Thermal Conductivity of Insulating Refractories by Calorimeter	C-182	15
Thermal Conductivity of Monolithic Refractories by Calorimeter	C-417	16
Thermal Conductivity of Refractories by Calorimeter	C-201	15
Thermal Conductivity of Refractories by Calorimeter	C-202	15
Thermal Conductivity of Refractories by Hot Wire	C-1113	21
Thermal Conductivity of Thermal Insulation by Calorimeter	C-892	10
Thermal Gravimetric Analysis (TGA)	--	25
Thermal Linear Expansion/Contraction	E-228	26



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