How To Know If A High Temperature Material Will Perform As Advertised
Using ASTM High Temperature Testing Procedures to Validate Fibrous Thermal Insulations vs. Maximum Temperature Limitations
Which Insulation Material Should I Specify?

When beginning an insulation design, the material selection should include consideration of the process to be insulated, particular process conditions, personnel and environmental considerations.

**Application Criteria**

1. **Process**
   - A. Design Life
   - B. Maximum / Minimum Operating Temperature
   - C. Life Cycle Cost Including installation, Operation and Maintenance
   - D. High Maintenance Area
   - E. Prone to Foot Traffic
   - F. Vibration From High Pressure Steam
   - G. Vibration From Proximity to Turbines or Motors

2. **Process Condition Requirements**
   - A. Steel Alloy (Stainless, Carbon, etc.)
   - B. Constant or Cyclic Temperatures
   - C. Freeze Protection
   - D. Below Grade
   - E. Corrosion Prevention

3. **Personnel and Environment**
   - A. Surface Burn Protection (140°F, 60°C)
   - B. Fire Safety

Once project requirements have been defined, material selection can begin. Let’s begin our material selection. The system design operating temperature is 750°F. Various insulation material manufacturer’s data sheets state their material’s maximum operating temperature could be 850°F, 1000°F, 1200°F, or maybe 1400°F. Before making that decision, some important considerations should be considered are:

**Material Selection Criteria**

1. **Health and Safety:** GHS compliant Safety Data Sheets
2. **Standards:** Meets ASTM or Applicable Government Specifications
3. **Temperature:** Meets Minimum / Maximum Temperature Performance
4. **Fire Resistance:** Meets Fire Requirements – ASTM/UL
5. **Surface Compatibility:** Applicable for Use Over Stainless and Carbon Steel
6. **Thermal:** Thermal Performance – Initial and lifetime
7. **Abuse Resistance:** Withstand Foot Traffic Where Necessary
8. **Cost:** Material initial cost and lifecycle cost
9. **Installation:** Ease of installation and availability of material

Consider this scenario: one manufacturer of fibrous, high temperature materials has for several years made the claim that even though the product is classified as a 1200°F material they agree with ASTM C447 which states “Thermosetting organic materials or binders will start to deteriorate above 350°F (177°C).” Once the binder material starts to deteriorate, the product will have no mechanical means to bind the fiber.

If a manufacturer states the material complies with a certain ASTM material standard, what does this really mean? This document is intended as an aid in understanding these claims.
Understanding and Utilizing ASTM Test and Test Methods and Applications

The first and most important thing that should be understood about ASTM standards is the fact that they were not been developed for and have nothing to do with installed/in place performance. Although ASTM standards may be used as a reference, they were developed solely for the repeatability of inter-laboratory testing. This means tested materials are new and a test will be performed in an environmentally conditioned laboratory with controlled temperature, humidity, vibration, etc. Ask yourself, are my project materials going to be subjected to controlled conditions?

Next, let’s suppose the material requires fabrication. Does the fabricated material meet the standards of the base material? The simple answer is no. Unless the fabricator has submitted the finished product for testing, you have absolutely no certification. Thermal, fire, etc. cannot be attached to the base manufacturers material unless the fabricator has documentation to show tests were performed on the fabricated item and the manufacturer has monitored the fabricator to assure that all fabricated items have been produced in accordance with the material manufacturers fabrication standards.

What is ASTM and how do I use the ASTM standards?

ASTM International, formerly known as the American Society for Testing and Materials (ASTM), is a globally recognized leader in the development and delivery of international voluntary consensus standards. ASTM International standards are the tools of customer satisfaction and competitiveness for companies across a wide range of markets. Through 141 technical standards-writing committees, ASTM serves diverse industries ranging from metals to construction, petroleum to consumer products, and many more. When new industries look to advance the growth of cutting-edge technologies, many of them come together under the ASTM International umbrella to achieve their standardization goals.

ASTM Committee C16 on Thermal Insulation was formed in 1938. C16 meets twice a year, in April and October, with about 120 members attending over three days of technical meetings capped by a discussion on relevant topics in the Thermal Insulation industry. The Committee, with a membership of approximately 350, currently has jurisdiction of over 145 standards, published in the Annual Book of ASTM Standards, Volume 04.06. C16 has 8 technical subcommittees that maintain jurisdiction over these standards. Information on this subcommittee structure and C16’s portfolio of approved standards and Work Items under construction are available from the List of Subcommittees, Standards and Work Items below. These standards have played and continue to play a preeminent role in all aspects important to the industry of thermal insulation, including products, systems, and associated coatings and coverings, excluding refractories.

ASTM C1696 - Standard Guide for Industrial Insulation Systems

- This guide covers information on selection of insulation materials, systems design, application methods, protective coverings, guarantees, inspection, testing, and maintenance of thermal insulation primarily for industrial applications in a temperature range of -320 to 1200°F (-195.5 to 648.8°C).
- This guide is intended to provide practical guidelines by applying acceptable current practice while indicating the basic principles by which new materials can be assessed and adapted for use under widely differing conditions. Designers, fabricators and installers will find this guide helpful.

ASTM C411- Standard Test Method for Hot-Surface Performance of High Temperature Insulation

- This test method covers the deterioration of the performance of commercial sizes of both block and pipe forms of thermal insulating materials when exposed to simulated hot-surface application conditions. The term “hot-surface performance” references a simulated use-temperature test in which the heated testing surface is in a horizontal position.
- This test method refers primarily to high-temperature insulations that are applicable to hot-side temperatures in excess of 200°F (93°C). It is used for materials such as preformed insulations, insulating cements, blankets and includes proper laboratory preparation of the samples.

ASTM C447 - Standard Practice for Estimating the Maximum Use Temperature of Thermal Insulations

- This practice covers estimation of the maximum use temperature of thermal insulation including loose fill, blanket, block, board and preformed pipe insulation. It is based upon selected performance criteria and characterization of product properties during and after use conditions.

- This test method establishes the criteria for the laboratory measurement of the steady-state heat flux through flat, homogeneous specimen(s) when their surfaces are in contact with solid, parallel boundaries held at constant temperatures using the guarded-hot-plate apparatus.
- The test apparatus designed for this purpose is a guarded-end or calibrated-end pipe apparatus. The guarded-end apparatus is a primary (or absolute) method.
- This test method allows for operation over a wide range of temperatures. The upper and lower limit of the pipe surface temperature is determined by the maximum and minimum service temperature of the specimen or of the materials used in constructing the apparatus.

**ASTM C335 Apparatus**

High Temperature Pipe  
Digital Read-Out


- This test method covers the measurement of the steady-state heat transfer properties of pipe insulations. Specimen types include rigid, flexible and loose fill; homogeneous and nonhomogeneous and mass insulations with metal jackets.
- The test apparatus for this purpose is a guarded-end or calibrated-end pipe apparatus. The guarded-end apparatus is a primary (or absolute) method.
- This test method allows for operation over a wide range of temperatures. The upper and lower limit of the pipe surface temperature is determined by the maximum and minimum service temperature of the specimen or of the materials used in constructing the apparatus.

**ASTM C177 Apparatus**

High Temperature Board
Comparison of High Temperature Insulation Materials Utilizing the ASTM C411 Test Methods

- Random materials such as Glass Mineral Wool, Rock Mineral Wool and Composite Rock/Glass Mineral Wool were purchased from distribution and submitted to an independent laboratory for testing.
- Each test consisted of a 3 x 2 Inner Layer and a 7 x 2 Outer Layer.

- Samples, prior to testing, were documented, measured and installed on a pre-heated ASTM C335 test pipe.
- Inner layer was installed with seams at 8 and 2 o’clock positions
- Outer layer was installed with seams at 10 and 4 o’clock positions to insure staggered joints. This positioning insured no joints at the 12 o’clock position and no direct heat path.
- Temperature inside the specimen was measured at 25 mm intervals through the thickness of the assembly beginning at 25 mm from the pipe surface and proceeding out toward the exposed surface.
- The temperatures were recorded every 15 seconds for the first 10 hours then every 60 seconds until the test was completed.
- Time/temperature curves were carefully monitored to detect signs of exothermic reaction, or chemical temperature heat rise exceeding the hot surface temperature, within the insulation. Exotherm can cause possible melting and degradation of the fiber and diminished thermal properties.
- Each material was tested at four temperatures: 550°F, 650°F, 750°F and 850°F.
- After 96 hours of continuous heat, the materials were cooled for 24 hours, removed from the test pipe, photographed and cut into 3” post heat samples.

Time/Temperature Curve Showing Exothermic Reaction

- ASTM C547 Standard Specification for Mineral Fiber Pipe Insulation states maximum internal temperature shall not exceed 200°F (111°C)
Knauf Insulation Earthwool® 1000° Nested 3 x 4 Pipe Insulation - Post C411 Test

- Unlike thermal insulation containing Phenol/Formaldehyde binder, Knauf Insulation Earthwool 1000° with ECOSE® Technology binder does not lose its structural integrity when exposed to temperatures in excess of the 350°F as called out in ASTM C447 section 5.7.2.
- Minimal binder degradation is seen when exposed to temperatures of 750°F.
- Even when exposed to 850°F the structural integrity remains due to the combination of the ECOSE Technology binder and long interwoven fibers.

Knauf Insulation Earthwool® 1000° Inner & Outer Pipe Insulation Sections - Post C411 Test

Top row: Knauf Earthwood ASTM C411 After 850° Both Layers, 750° Bottom row: 650°, 550°
Knauf Insulation Earthwool® 1000° 3' Pipe Insulation Samples - Post C411 Test

- Knauf Insulation Earthwool 1000° was removed from the test apparatus, separated, photographed and then cut into donut hand samples.
- Higher temperatures removed the binder adjacent to the hot pipe, but the long fiber remains intact.

Composite GMW/RMW Inner Layer Pipe Insulation Sections - Post C411 Test

Efforts have been made to produce a composite Glass Mineral Wool/Rock Mineral pipe insulation. The Glass Mineral Wool inner layer has a 1000°F temperature limit thereby eliminating the 1200°F maximum temperature claim.
Although the Glass Mineral Wool inner layer held up reasonably well, the Phenol/Formaldehyde binder began to deteriorate at a much lower temperature than the Knauf Insulation 1000° with ECOSE® Technology. The 1200°F Rock Mineral Wool Product actually shows greater deterioration than the composite product. The Phenol/Formaldehyde binder plus the extremely short fiber, which is normal in Rock Mineral Wool products, shows greater deterioration of not only the inner layer, but also the outer layer. Any elevated amount of heat/temperature will cause this product to shift and sag which can cause failure.
1200°F RMW 3" Pipe Insulation Samples - Post C411 Test

The 1200°F Rock Mineral Wool Product with the Phenol/Formaldehyde binder and extremely short fiber shows greater deterioration of not only the inner layer but deterioration continued to the outer layer. Elevated temperatures and any vibration will cause this product to shift and sag which can cause failure.

Knauf Insulation ET Board - Post 24 Hour Oven Soak

Although there is not an ASTM Standard for testing binder concentrations, most thermal testing laboratories utilize a laboratory grade oven, heat to 1000°F and hold the materials for 24 hours. For the purpose of this test our concern was not how much total binder was in the product, but rather how the binder was affected by the 550°, 650°, 750° and 850°F worst case soaking temperatures. We say worst case as there are no hot side/cold side conditions as would be found in an ASTM C411 test.
The Knauf ET Board with ECOSE® Technology binder was tested at 550°, 650°, 750° and 850°F (top to bottom, left to right). An aluminum foil backing was installed to represent the metal jacketing normally applied in the field. The white fiber shows the amount of binder that was removed by the C411 Hot Plate. Notice the fiber, although white, remains intact.

The ET Board samples were stacked on top of one another to show that the integrity of the material was maintained after heating on the C411 hot plate.
The post 96 hour soak of a popular 1000°F Glass Mineral Wool blanket shows that the Phenol/Formaldehyde binder was completely gone after only the 750°F exposure.

However, when this same 1000°F material exposed at various temperatures on the C411 hot plate, the material began to delaminate and degrade at much lower temperatures.

This 2" thick 8# density 1200°F Rock Mineral Wool material was only tested at 650°F. As evident, the short fiber combined with the Phenol/Formaldehyde binder showed significant degradation at this much lower temperature.