Mineral Fiber in High Temperature Applications
Using ASTM Testing Procedures to Validate Performance of Fibrous Thermal Insulations (550°F - 850°F)
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. The system design operating temperature is 750°F. Various insulation material manufacturer’s data sheets state their material’s maximum operating temperature as 850°F, 1000°F, 1200°F, or 1400°F. Some important considerations 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 life cycle cost
9. **Installation:** Ease of installation and availability of material

A manufacturer of fibrous high temperature material claims their product is rated to 1200°F. ASTM C447 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 chemical means to bind the fiber.
Understanding and Utilizing ASTM Test and Test Methods and Applications

ASTM standards are developed to define the conditions and methods used to evaluate product performance. These evaluations are performed under carefully controlled laboratory conditions (temperature, humidity, vibration, etc.) and may not reflect actual field performance. ASTM standards are most useful as a reference to compare performance of different materials.

Performance testing should be conducted on material in the form that it will be used on the job. For fibrous insulation, the orientation or the fiber is important to many of its physical properties. Materials made and tested in sheet or block form may not have the same properties after they have been fabricated into other shapes such as pipe insulation. It is important to know in what form the insulation product was tested.

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. 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 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 C335 Apparatus**

![High Temperature Pipe](image1)

![Digital Read-Out](image2)


- 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-hot-plate apparatus and is a primary (or absolute) method.
- This test method does not specify all details necessary for the operation of the apparatus. Decisions on sampling, specimen selection, preconditioning, specimen mounting and positioning, the choice of test conditions, and the evaluation of test data shall follow applicable ASTM Test Methods, Guides, Practices or Product Specifications or governmental regulations. If no applicable standard exists, sound engineering judgment that reflects accepted heat transfer principles must be used and documented.

**ASTM C177 Apparatus**

![High Temperature Board](image3)
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 fusing 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 cool for 24 hours, removed from the test pipe, photographed and cut into 3” post heat samples.

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

- Knauf Insulation Earthwool 1000°F Pipe Insulation does not lose its shape when exposed to temperatures in excess of 350°F as called out in ASTM C447 section 5.7.2.
- Even when exposed to 850°F, Earthwool 1000°F Pipe Insulation maintains its shape and form due to the length and interwoven nature of the glass fibers.

Top row: Knauf Insulation Earthwool ASTM C411 After 850°F Both Layers, 750°F Bottom row: 650°F, 550°F

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

Top row: Knauf Insulation Earthwool ASTM C411 After 550°F Inner Layer, 650°F Bottom row: 750°F, 850°F
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 lead to increased reduction of binder content adjacent to the hot pipe; however, shape and form remain intact due to the length and interwoven nature of the glass fibers.

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.

Composite GMW/RMW Inner Layer Pipe Insulation Sections - Post C411 Test
The composite GMW/RMW pipe insulation did not hold its shape and form as well at elevated temperatures when compared to performance of Knauf Insulation Earthwool® 1000°F Pipe Insulation.

The 1200°F Rock Mineral Wool Product actually shows greater deterioration than the composite product. The short fiber, which is typical 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.
The 1200°F Rock Mineral Wool Product with the typical 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.

Although there is not an ASTM Standard for an oven soak heat test, some 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 how the binder was affected by the 550°F, 650°F, 750°F 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.