Sandia National Laboratories
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date: April 13, 2005

to: Frank Wyant, 6861 (MS-0748)

from: Bruce L. Levin, 6113 (MS-0706)

subject: Documents Supporting Hemyc Tests and Insulation Fabrication

The following is a list and brief explanation of the documents that support the Hemyc test results and the silica fabric encasing material used in the fabrication of the Hemyc insulation system.

Materials Characterization of Siltemp® and Refrasil®:

Heat Transfer Impact of Siltemp® and Substitute Insulation Encasing Material memo dated April 12, 2005 from Bruce L. Levin to Frank Wyant—Explains and quantifies the thermal resistance contribution of Siltemp® and Refrasil® fabric as part of the Hemyc insulation system.

Shrinkage of Refrasil® Insulation Cover Material memo dated April 12, 2005 from Bruce L. Levin and Chuck Girard to Frank Wyant—Evaluates the shrinkage of the Refrasil® fabric witnessed in the first and second Hemyc furnace tests by comparing dimensions of standard and pre-shrunk cloths listed on the manufacturer's specification sheets. Similar information was provided by the Siltemp® manufacturer showing shrinkage equivalency of the fabrics.

Adherence of Siltemp® and Refrasil® to Military Specification memo dated April 13, 2005 from Bruce L. Levin to Frank Wyant—Briefly describes MIL-C-24576A(SH), that the end user can require the fabric vendor to adhere to the mil specs, and stated the materials tests completed at Sandia National Laboratories.

Material Assessment Summary for Hemyc Raceway Fire Barrier System Outer Silica Fabrics by S. P. Nowlen and F. J. Wyant at Sandia National Laboratories—Discusses the implications of the results of the material characterization tests performed on Siltemp® and Refrasil® samples at SNL.

Analysis Narrative and Results (of the Siltemp® and Refrasil® fabrics) conducted by the Materials Science Department at Sandia National Laboratories and compiled by Ted Borek—Describes and shows results of the physical tests that were completed on the fabric samples. Dimensional, weight, chemical, mechanical (tensile), and thermal shrinkage tests were performed.

Description of Yarn Tensile Tests of the Two Fabric Samples conducted by Robert Bernstein and Michelle M. Shedd of the Material Science Department at SNL—Explains the tensile tests and results of yard threads taken in two axes for the fabric samples.

Force and Percent Elongation Graphs of the Yard Fabric Samples—Graphs show results of multi-sample tests for the two fabrics referred to in the description above.

Heat Treatment of Ceramic Fabrics report by Markus Reiterer and Denise Bencoe of the Materials Science Department at SNL—Graphically and visually explained and showed the dimensional shrinkage that took place as a function of temperature for the Siltemp® and Refrasil® fabric samples.

Quick Look Report on Material Shrinkage Test by Steven P. Nowlen of the Risk and Reliability Analysis Department at SNL—Describes a comparative material shrinkage test on samples of Siltemp® and Refrasil® fabric.

Manufacturer's Data for Thermal Materials—Provides published data for the Siltemp® and Refrasil® high temperature fabrics and an inspection sheet, supplied by PCI Promatec, giving the fabric acceptance criteria. Also included is a page from the B&B Promatec Procedure IP-002 that identifies both Siltemp® and Refrasil® as approved silica dioxide cloth materials for use in the fabrication of Promatec protective wrap components. Finally, a manufacturer's specification sheet on Thermal Ceramics Blanket Products has been added.

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date: April 12, 2005

to: Frank Wyant, 6861 (MS-0748)

from: Bruce L. Levin, 6113 (MS-0706)

subject: Heat Transfer Impact of Siltemp® and Substitute Insulation Encasing Materials

Overview:

Samples of Siltemp® and Refrasil® insulation cover fabrics were provided by the insulation manufacturer per Sandia's request to determine the equivalency of the materials as requested by the NRC. Siltemp® is no longer manufactured and a substitute material was required in the fabrication of the Hemyc and MT systems used to insulate raceways, conduit, and junction boxes. The insulated samples have undergone two 1 hour thermal tests for the Hemyc and will undergo a 3 hour thermal test for the MT system with furnace temperatures having reached 1700^{o}F and reaching 1925^{o}F respectively for the two systems per the ASTM E 119 – 00a standard temperature-time curve. Figure 1 shows the internal insulation surface pass/fail boundary temperature curves of the Hemyc and MT insulation systems compared to the furnace temperature curve based on a starting room temperature of 70^{o}F. The purpose of the study, described in the following analysis, is to determine the overall effect of the insulation encasing with respect to the Kaowool S® insulation in the Hemyc systems. 1½ inch and 2 inch Hemyc insulation systems have been tested as specified in the test plan. The Hemyc insulation systems have been analyzed in this study for evaluation.

Siltemp® and Refrasil® samples were sent to Sandia's materials science lab to be tested for similarity of nominal thickness, nominal weight, silica content (% SiO_2) and other components, tensile strength, thermal conductivity, and surface emissivity. Results from the materials lab showed that the physical aspects of materials were similar enough to be essentially the same. The thermal conductance and emittance tests have yet to be performed. The materials department uses an outside lab to determine surface emittance of materials at a substantial cost and added time for this project. The following thermal analysis was performed to determine the necessity of outsourcing conductance and emissivity tests of the fabric materials.

The function of the fabric material is to cover and encase the insulation and to serve as a refractory surface on the flame exposed side of the system. Results of the thermal analysis show that the cover fabrics have a minimal resistive heat transfer impact as part of the insulation system. Both fabrics are similar in material composition, fabric weave, weight, and thickness to be considered equal. The Siltemp® tensile strength is greater by 34 to 74 percent compared to the Refrasil®. This is most likely due to water repellent sizing added to the Siltemp® and causing more stiffness in the material. The tensile strength of both fabrics is more than enough to encase the Kaowool S® insulation and withstand the hose-stream test. Ametek states that its Siltemp® product is good up to 1800°F for short-term continuous operating temperature. Hitco Carbon Composites, Inc. publishes continuous protection, strength, and flexibility up to 1800°F for its Welding Grade Cloth, WGC-18 (Tan) Refrasil® Cloth, and the fabric will not melt or vaporize until temperatures exceed 3100°F. Thermal tests on these samples would have to be performed to verify these specifications.

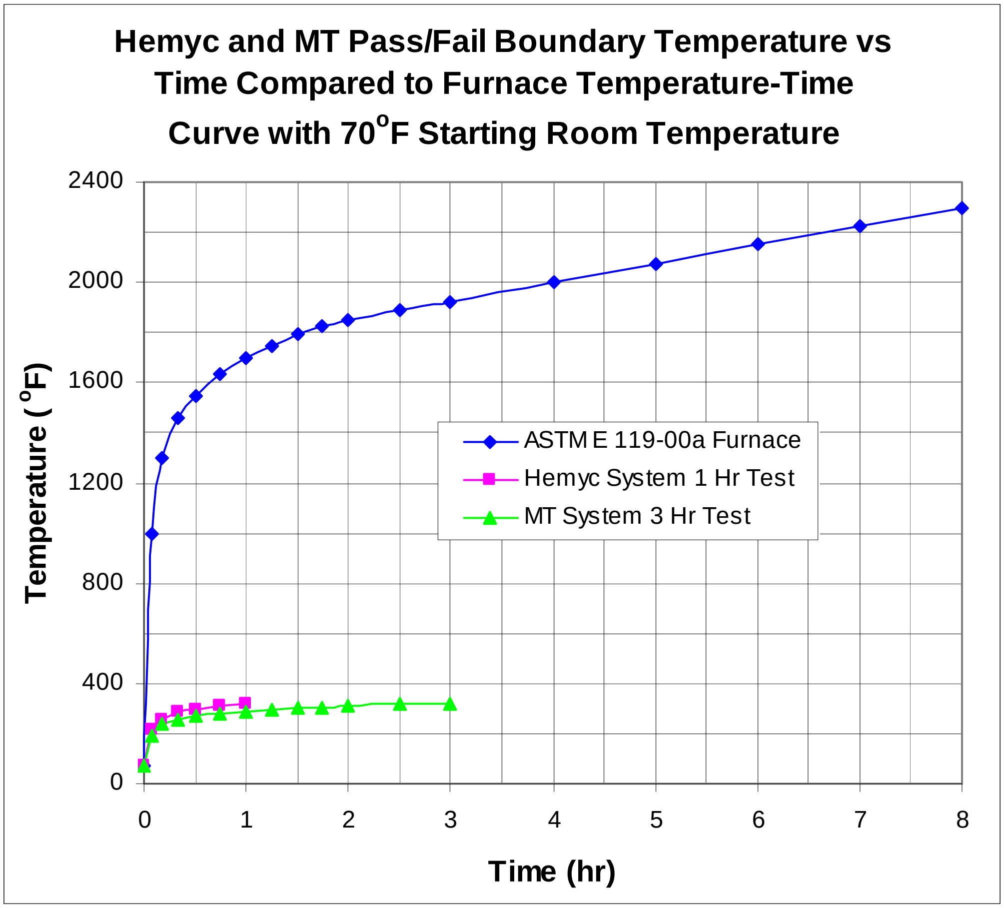

Figure 1. ASTM E 119-00a furnace and Hemyc and MT inside insulation surface pass/fail boundary temperature-time curves

Analysis:

A standard heat transfer balance equation was used to determine outside surface and interface temperatures with and without the fabric encasing at various internal insulation system surface temperatures for a furnace temperature of 1700°F. The heat transfer path was convective and radiant from the furnace air to the insulation system outside surface, and then conductive through the insulation system to the inside insulation system surface. The insulation systems consisted of the 1½ and 2 inch Kaowool S® insulations for the insulation only cases, and the silica fabric encasing and 1½ or 2 inch Kaowool S® for the insulation with encasing cases. The respective values were estimated and assumed to be the same for the unknown thermal conductivity and surface emittance for the Siltemp® and Refrasil® fabrics.

The heat radiation rate from the furnace air to the insulation surface, based on an estimated emittance of 0.2, of 13.2 Btu/hr-ft^2-^{o}F was used. The convection heat transfer rate of still furnace air to the insulation system surface was estimated to be 0.37 Btu/hr-ft^2-^{o}F. This value was based on a peak heat production rate of 28,000 Btu/min for the 18 ft L x 12 ft W x 7 ft H furnace as provided by Omega Point Laboratories. Natural gas flow rate is approximately 25 ft^3/min at 60^{o}F and 30 in Hg at this heat production rate. Air flow rate for complete combustion is approximately 10 times the gas flow rate at the above temperature and pressure or slightly more than 1040 cfm at 1700^{o}F and 30 in Hg. Even with 25% excess air flow, the air velocity around the insulated test specimens is close to that of still air. Radiant heat transfer between the 6 inch insulation lined furnace steel plate wall, insulated flooring, and insulated ceiling and the insulation system surface was estimated to be negligible since it was assumed that the surface temperatures of the wall, floor, and ceiling and insulation system surfaces will be at or near the same temperatures throughout the test. Also the net radiative heat-transfer rate between the combustion flame and the insulation system surface was assumed to be zero since the surface of the fabric material is refractory.

The conductive heat transfer rate through the encasing material was estimated based on the mass fraction, density, and conductivity of silica and other elements in the cover fabric. The heat transfer coefficient due to the conductivity through the fabric was calculated to be 120

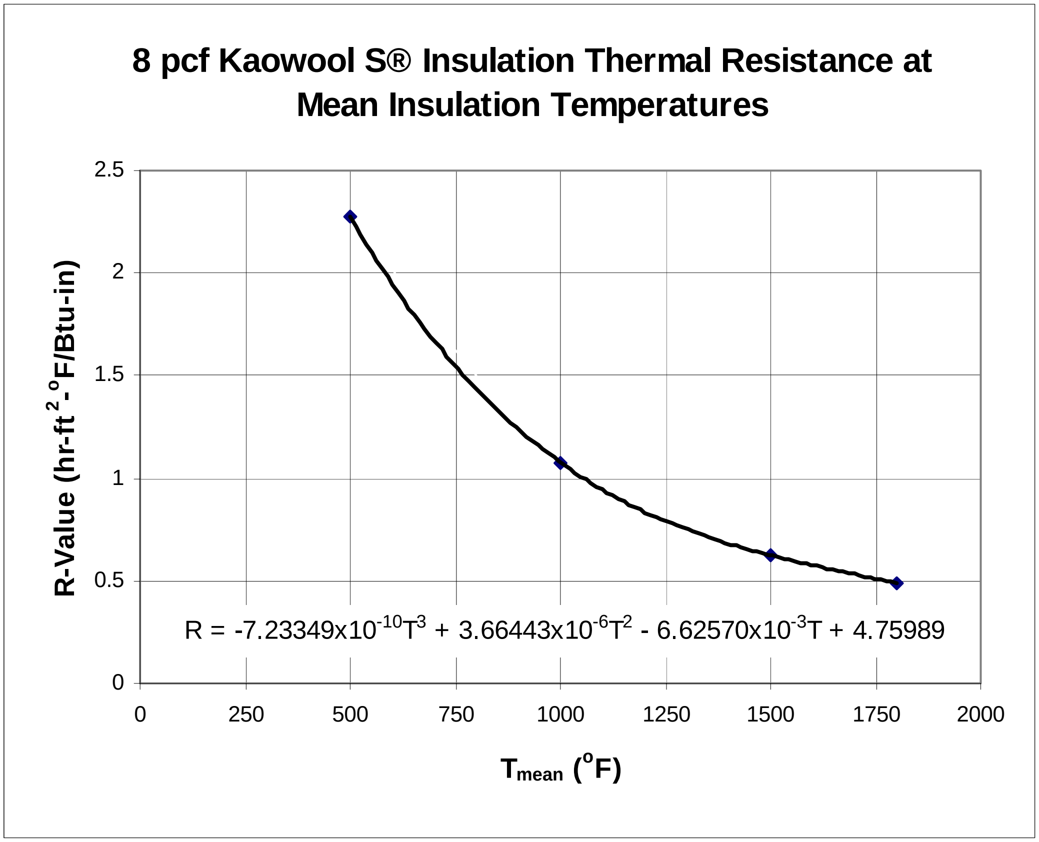

Figure 2. Thermal resistance at mean temperatures for 8 pcf Kaowool S®

Btu/hr-ft^2-^{o}F per surface for 0.03 inch thick 18 oz/yd of 36 inch wide material. The encasing fabric was used on both inside and outside surfaces of the insulation. Conductivity rates were provided by Blanket Products division of Thermal Ceramics for the Kaowool® insulation product line. Conductivity values were plotted for different mean insulation temperatures for the 8 pcf (lbm/ft^3) insulation being used in the furnace tests. Figure 2 shows an R-value per inch of insulation vs. mean temperature curve and an equation to calculate insulation R-values.

The radiant and convective heat transfer coefficients were used to calculate the overall thermal resistance from the furnace air to the outside insulation system surface. This resistance was combined with the insulation system resistance to determine overall resistances and overall heat transfer coefficients for both insulation systems, with and without the silica fabric, calculated at various inside insulation surface temperatures with a furnace air temperature of 1700^{o}F.

Results:

The resultant overall heat transfer coefficients of the insulations and insulations with fabric

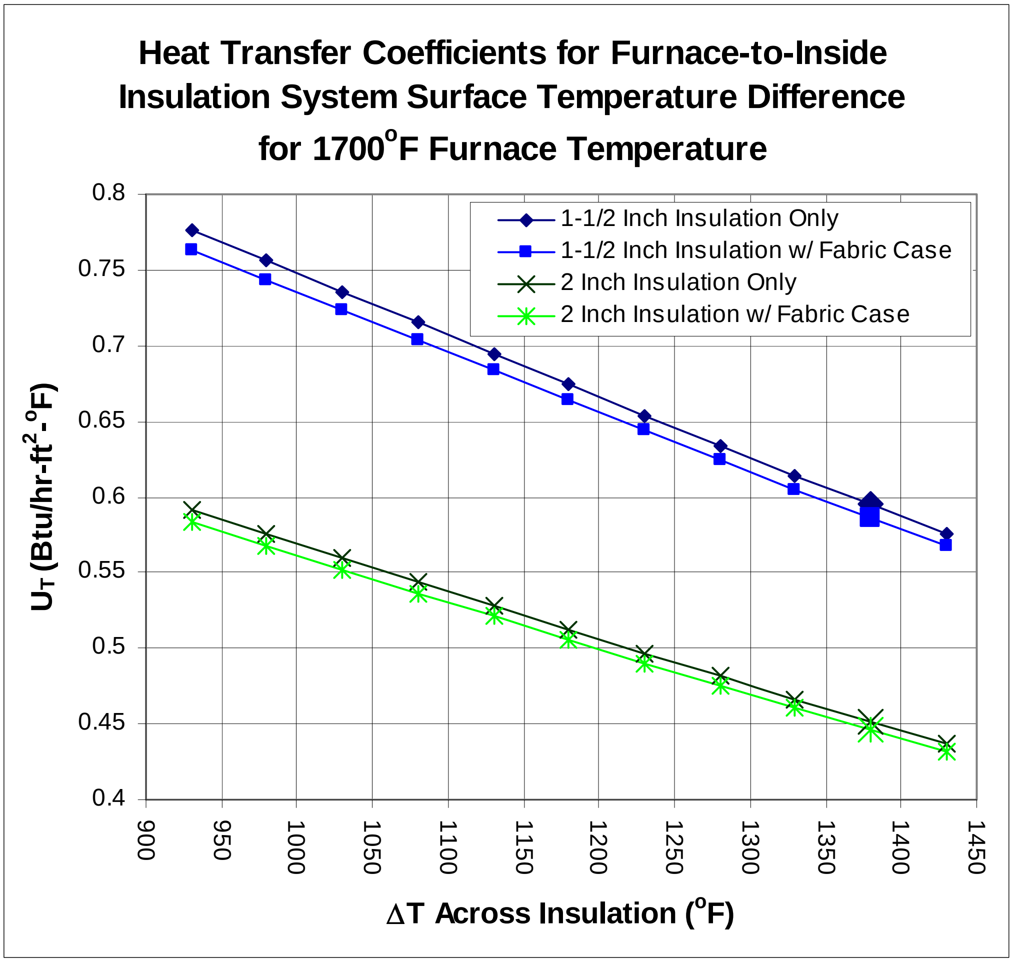

Figure 3. Overall Heat Transfer Coefficients for Hemyc insulation systems with and without fabric encasings for 1½ and 2 inch Kaowool S®

encasings were plotted and compared to determine the heat transfer effect of the fabric encasings with respect to the insulation systems. Figure 3 shows a plot of the overall heat transfer coefficient with respect to temperature difference across the insulation systems for the insulations with and without the fabric encasings. Note that the fabric encasings decrease the heat transfer rates slightly. Figure 4 quantifies the percent contribution of the fabric encasing in reducing heat transfer vs. temperature difference across the insulation systems. In both of these graphs, the insulation systems pass the furnace tests at a temperature difference at or greater than 1380°F as noted by the bold point on each curve for a furnace temperature of 1700°F. At the pass/fail point, the silica fabric thermally benefits the insulation system by less than 1.49 and 1.26 percent for the 1½ and 2 inch Hemyc systems respectively. These two graphs also show that the thermal heat transfer contribution to failure or success of the insulation system by the fabric encasings is also very low.

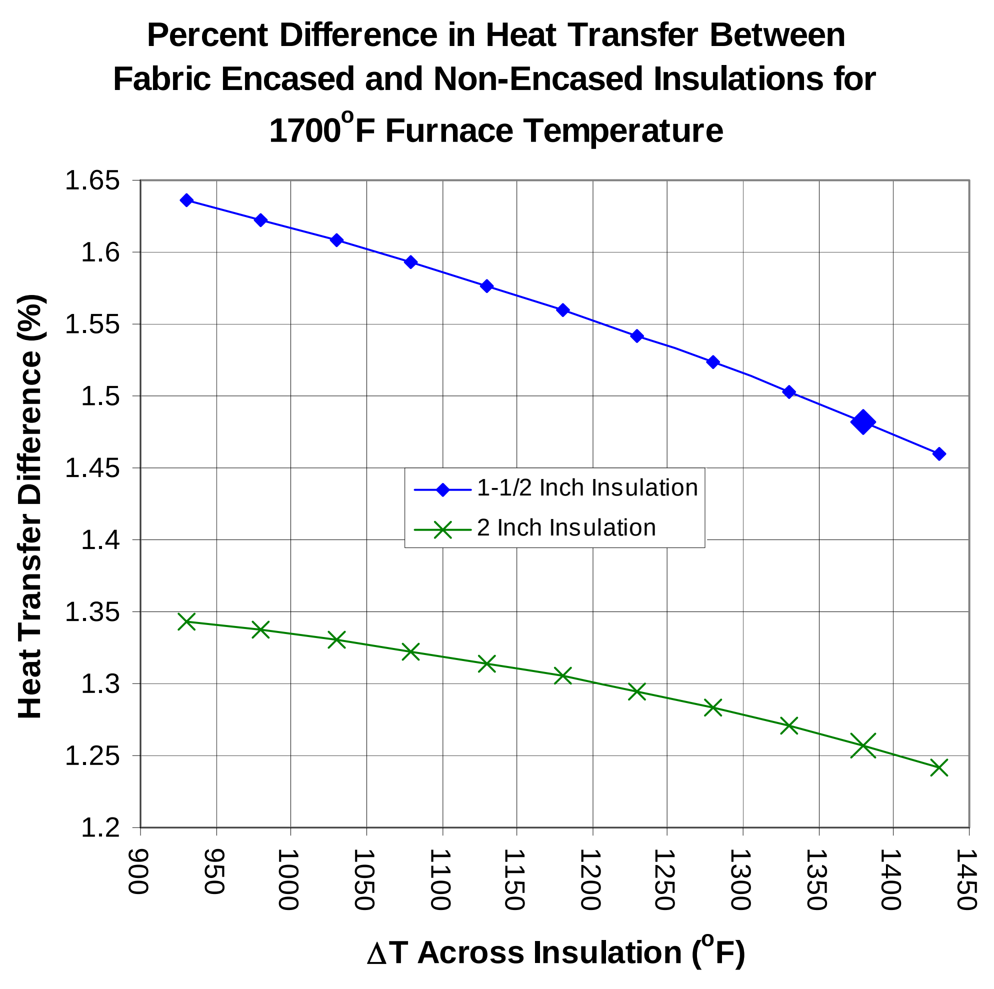

Figure 4. Percent contribution to heat transfer reduction by the fabric encasing

Conclusion:

Based on the material lab tests and product descriptions, the Siltemp® and Refrasil® refractory cloth cover fabrics are very similar in composition, weave, and other physical characteristics. The manufacturer’s thermal specifications are also similar. The likelihood of significant differences in surface emittance and thermal conductivity are also very low. Any emittance and thermal conductivity differences of these two fabrics would not result in significant contribution to heat transfer reduction in the insulation systems being tested. Knowledge of the actual thermal conductivity and surface emittance of the two cloth fabrics would be academic because they do not have a significant effect on the system heat transfer. Both fabrics should serve equally for the intended purpose as part of the insulation system.

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URS Corp		Charles Girard
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date: April 12, 2005

to: Frank Wyant, 6861 (MS-0748)

from: Bruce L. Levin, 6113 (MS-0706)
Chuck Girard, (URS Corporation)

subject: Shrinkage of Refrasil® Insulation Cover Material

Per our discussion and inspection of the furnace photographs, it was noted that the Refrasil® cover fabric shrank pulling apart at seams and separating the underlying Kaowool S® insulation providing an unobstructed heat path to the metal conduits. This first test was conducted on Friday, March 11, 2005.

Standard Welding Grade Cloth, WGC-18 (Tan) or Standard UC100-48 (Tan) light cloth was used as the cover material for the Hemyc insulation system. Both these materials have a nominal thickness of 0.030 inches and a nominal width of 36 inches. The weight per square yard is 18 oz. Review of the manufacture's product sheet showed that a Pre-shrunk light cloth C100-48 (White) is also available with a nominal thickness and width of 0.028 and 33 inches respectively and weighs 18 oz/sq yd. The C series cloth is a pre-shrunk version of the UC series cloth and is used in applications where shrinkage cannot be tolerated. A representative from Hitco Carbon Composites, Inc. indicated that UC standard cloth will begin to shrink at temperatures of 400^{o}F. If the pre-shrunk material is made from the same roll of cloth as the UC cloth, then the material shrinks 3 inches linearly in the width direction with a likely hood of the same shrinkage in the length direction. This is a linear change of 8.3 percent. The fabric would also shrink 0.002 inches in thickness or a thickness change of 6.7 percent. This temperature dependence could account for the shrinkage witnessed in the first furnace test of the test samples.

Further investigation revealed that Siltemp®, manufactured by AMETEK Chemical Products has similar product lines—Standard 84CH (Tan), Water Repellent WR84CSR (Tan), and Pre-Shrunk 84S (White) cloths. The first two products have the same thickness and width dimensions and weight per square yard as the first two Refrasil® cloths. The pre-shrunk Siltemp® version at 0.026 inches and 18.5 oz. has a similar thickness and weight per square yard as the pre-shrunk Refrasil® fabric. The nominal width of the pre-shrunk Siltemp® fabric is the same as the pre-shrunk Refrasil® fabric. This information along with the memo titled *Heat Transfer Inpact of Siltemp® and Substitute Insulation Encasing Materials*, dated April 12, 2005 indicates the similarity of these product lines from the two manufacturers.

Actual thermal tests have been done to quantify the shrinkage of the Siltemp® and Refrasil® fabrics to determine how equal they are to each other.

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date: April 13, 2005

to: Frank Wyant, 6861 (MS-0748)

from: Bruce L. Levin, 6113 (MS-0706)

subject: Adherence of Siltemp® and Refrasil® to Military Specifications

Chuck Girard and I discussed the military specifications that pertain to woven silica glass cloth that relate to the Siltemp® and Refrasil® fabrics used to encase Kaowool S® insulation in the Hemyc system. The related mil specs are MIL-C-24576A(SH), 27 July 1987 and MIL-C-24576A(SH) Amendment 1, 13 January 1988. The mil specs cover material, weight class, associated federal and military specifications and standards, other government and ASTM publications for testing and measurement, physical properties, quality assurance provisions which include examination, acceptance criteria, and material tests, packaging, intended use, ordering data, inspection, and material safety data sheet (MSDS) submittals

Chuck's communications with the Refrasil® manufacturer was that they do not perform the Mil Spec tests on their material unless requested by the end user. In general, these tests are done to assure 96% silica content, non-combustibility, and abrasion resistance to verify compliance with the Mil Spec material composition and construction for the purposes of protecting equipment and personnel from spatter from metal welding and cutting operations. In fact, the manufacturer of Refrasil® provided Chuck with the Mil Spec reference numbers. In turn, I attained the Mil Specs from our research librarians. Basically lot samples are taken, tested, and evaluated to ascertain that the material meets the requirements in the Mil Specs. When specified, the end user can require a Certificate of Compliance from the vendor that measurements and tests have been completed to show adherence to the Mil Specs.

A different set of tests from that outlined in the Mil Specs were completed on the fabrics from the two manufacturers at Sandia National Laboratories. Results of these tests show that the Siltemp® and Refrasil® fabrics are essentially the same materially, structurally, and for functional purposes used in the Hemyc insulation system.

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Material Assessment Summary for Hemyc Raceway Fire Barrier System Outer Silica Fabrics

April 14, 2005

S.P. Nowlen and F. J. Wyant
Sandia National Laboratories

1 Introduction and Summary

1.1 Introduction

During testing of the Hemyc fire barrier wraps, one of the two behaviors that led to premature failure was shrinkage of the outer cover material. This shrinkage opened gaps in the protective wrap leading to raceway temperature rises well in excess of the acceptance criteria. The purpose of this report is to provide perspectives relevant to the material shrinkage behavior.

1.2 Background - Material Selection

The Hemyc fire barrier system is comprised of “pads” or “pillows” which are formed using an inner cover, a 2” layer of mineral fiber insulation, and an outer cover. The original material specifications allowed for the use of either of two materials as the out cover material. One was manufactured by Amatek Corporation and sold under the trade name Siltemp®. The second was manufactured by Hitco Carbon Composites Inc. and is sold under the trade name Refrasil®. Both materials are nominally identical silica-based woven textile fabrics.

The Siltemp material is no longer manufactured and can no longer be purchased on the open market. Hence, all of the SNL/RES tests were conducted using the Refrasil material to form the fire barrier wraps. Given that one of the two predominant modes of failure was shrinkage of the outer cover, it is appropriate to consider whether a barrier system constructed using the Siltemp material would experience the same behavior.

1.3 Summary of Material Evaluation and Conclusions

Based on the various analyses, material literature reviews, and tests conducted by SNL, it appears that the Refrasil and Siltemp materials are for all intents identical with respect to the question of material properties, and in particular, material shrinkage behavior. The only substantive difference observed was a slightly higher carbon content for the Siltemp material as compared to the Refrasil. Based on discussions with knowledgeable individuals, this difference is likely associated with a “scratch coat” surface treatment that was applied to the Siltemp but not to Refrasil. The “scratch coat” was apparently provided as a cosmetic treatment, and appears to have no impact at all on the material shrinkage behavior.

SNL concludes that Hemyc fire barriers formed using Siltemp would experience the same shrinkage behavior and resulting premature failure as was observed for the tested barrier systems constructed using Refrasil.

2 Material and Manufacturer Specifications and Analysis

2.1 Overview

Samples of both the Refrasil and Siltemp material were secured for comparative evaluation. The Refrasil material evaluated was taken from the actual bolt of material procured for construction of the SNL/RES test fixtures. The Siltemp sample was provided for reference by a licensee (Entergy) from on-hand new-old-stock materials.

2.1 General Specification

The material specifications sheets for both the Siltemp and Refrasil materials cite virtually identical material properties. In particular, both materials are available in both a nominal and “pre-shrunk” conditions. Clearly, the shrinkage properties of the two materials are well known and clearly advertised. In both cases, the material width specifications for the nominal versus pre-shrunk material indicate approximately 8% total linear shrinkage. The nominal material is available in 36” widths, and the pre-shrunk material is available in 33” widths.

2.2 Surface Treatment

The Refrasil material is also available in an “abrasion resistant” version which includes a surface treatment as well. The manufacturer makes the following statements with regard to the surface treatment:

The AR series Refrasil is coated with a specially formulated coating, making it more abrasion resistant than standard UC series cloth. The AR series Refrasil is recommended for use in high traffic areas and for fabrication because the coating resists minor damage from dragging, scraping, tearing and snagging. The coating also provides greater seam strength than standard UC series Refrasil cloth making it an excellent choice as a high temperature fabrication cloth. The AR series Refrasil is identified by its orange coating. Although there will be a loss of coating from exposure to high temperatures, only the abrasion resistance of the fabric will be affected, not its overall thermal performance.

2.3 Visual Inspection and Observations

Visually, the two sample materials are virtually identical. Each material is comprised of a relatively loose square-weave fiber mat with a nominal weave density of approximately 33 threads per inch. The weave density and structure appears identical in both materials, and for each material is the same along both the width and length of the sample. Both materials have essentially the same heft and texture.

The two materials have very similar color under similar lighting conditions. Depending on the lighting intensity and angle, the color of each material varies from a light golden-tan to a medium tan. The Siltemp material displays a slightly less reflective surface than the Refrasil giving the Refrasil a slight appearance of a lighter coloring. However, under flat lighting conditions, the differences are difficult to discern.

Each material frays readily at any cut edges. The very loose weave allow threads to fall away from the cut edge of a piece making it difficult to obtain and retain a clean and straight edge cut. There appears to be no binding effect between the individual threads making up the weave other than the mechanical interleaving of the threads.

2.4 SNL Analysis of Physical Properties

Physical tests conducted on two Siltemp and one Refrasil samples indicate the average fabric thicknesses to be nearly identical (0.029 - 0.030 inch). The area density results show that the Siltemp sample deviates from the published nominal value (18 oz/sq yd) by between -6% and +8.4%. The Refrasil sample measurement resulted in a -8.3% from nominal. These deviations are likely within the measurement uncertainties involved with actual sample size measurements and in collecting the samples from larger material pieces (e.g., possibly from thread fraying, thread loss and changes in weave density during cutting of the fabric samples).

The initial tensile tests performed on the fabric samples were tainted by the fact that one sample was tested in an orientation different from the other two. Additional tensile tests were performed by another group indicate that the tensile strengths of Siltemp and Refrasil are not significantly different.

2.5 SNL Analysis of Chemical Composition

EDS spectrum analysis of Siltemp and Refrasil samples show that the materials are both primarily silica (SiO_2) with a small amount of carbon present. The carbon content was slightly higher in the Siltemp samples than was found in the Refrasil. ICP/MS elemental analysis indicates that each material contains a variety of trace elements. The major difference being that Refrasil had only ~1/3 the amount of trace elements than the Siltemp sample.

Analysis by gas chromatography with mass spectrometry of the volatilized material identified ethanol as the principal constituent of the organics derived from the Siltemp samples. The same analysis method showed propylene as the principal volatile organic from the Refrasil sample. This difference probably reflects differences in fabric manufacturing methods.

2.6 Thermal Tests

Thermal characterizations of Siltemp and Refrasil samples indicated virtually identical temperature response and mass loss over the full range of test temperatures.

3 Conclusions

The materials testing performed at SNL strongly indicate that the Refrasil fabric is very similar in terms of physical characteristics, chemical composition and thermal behavior as the Siltemp fabric.

Analysis Narrative and Results

Statement of the Problem: Is a proposed inorganic insulation cloth, ‘Siltemp substitute,’ the same or equivalent to Siltemp cloth for the application under consideration. Several physical, chemical, mechanical, and thermal tests were requested.

Introduction: Three samples were submitted, and are summarized in Table 1. Siltemp1 and Siltemp2 are nominally the same material.

Table 1. Siltemp Samples

Sample
Siltemp1 (darker material)
Siltemp 2 (darker material, has ‘To Mark Salley, Siltemp, From B. Collyer’ written on it
Siltemp substitute (lighter material)

The analyses requested are summarized in Table 2.

Table 2. Tests Requested

Category	Test
Physical Test	Thickness
	Nominal weight (oz/sq. yd)
Chemical Test	Silica Content
	‘Pyrolysis’ Gas Chromatography
Mechanical Test	Tensile Strength
Thermal Test	Thermal Conductivity
	Surface emissivity

Physical Test Results

The cloth thickness was determined by using an electronic micrometer on several locations of the cloth samples submitted. The results are summarized in Table 3.

Table 3. Physical Test, Thickness, Inches

Sample	Average thickness, inches
Siltemp 1	0.030
Siltemp 2	0.029
Siltemp replacement	0.030

The nominal cloth weight was determined by cutting a square section of sample, measuring and determining the area, then weighing the cut specimen on an analytical balance. The results are summarized in Table 4.

Table 4. Physical Test, Area Density, oz/sq. yd.

Sample	Area density, oz/sq. yd
Siltemp 1	16.92
Siltemp 2	19.33
Siltemp replacement	16.51
Siltemp 2, 2nd test	19.69

The ‘second’ Siltemp sample was tested twice.

Chemical Test Results

A section of each cloth was placed on an aluminum stub and analyzed by energy dispersive spectroscopy (EDS) in a scanning electron microscope. The EDS spectrum for Siltemp1 is shown in Figure 1. Present are silicon, oxygen, carbon, and aluminum. It is not known if the aluminum in this sample is due to the aluminum mounting stub used in the analysis. The carbon may be part of the cloth coating.

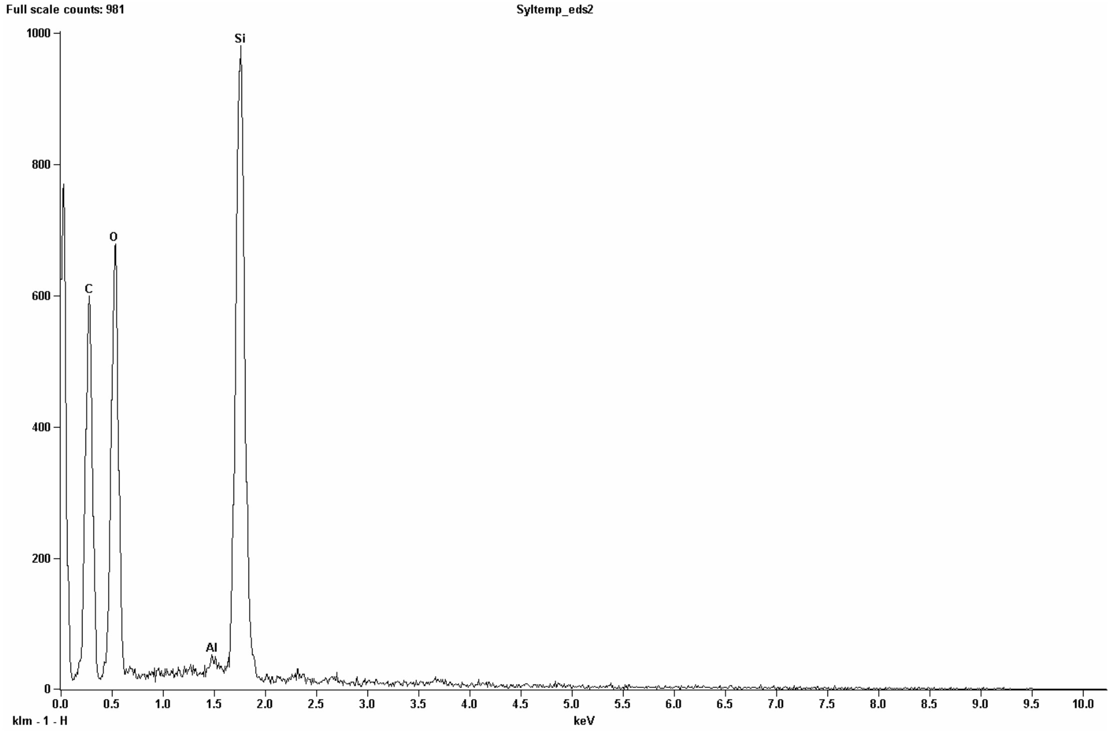


Figure 1. Siltemp1 EDS Spectrum

The EDS spectrum for Siltemp2 is shown in Figure 2. Present are silicon, oxygen, and carbon.

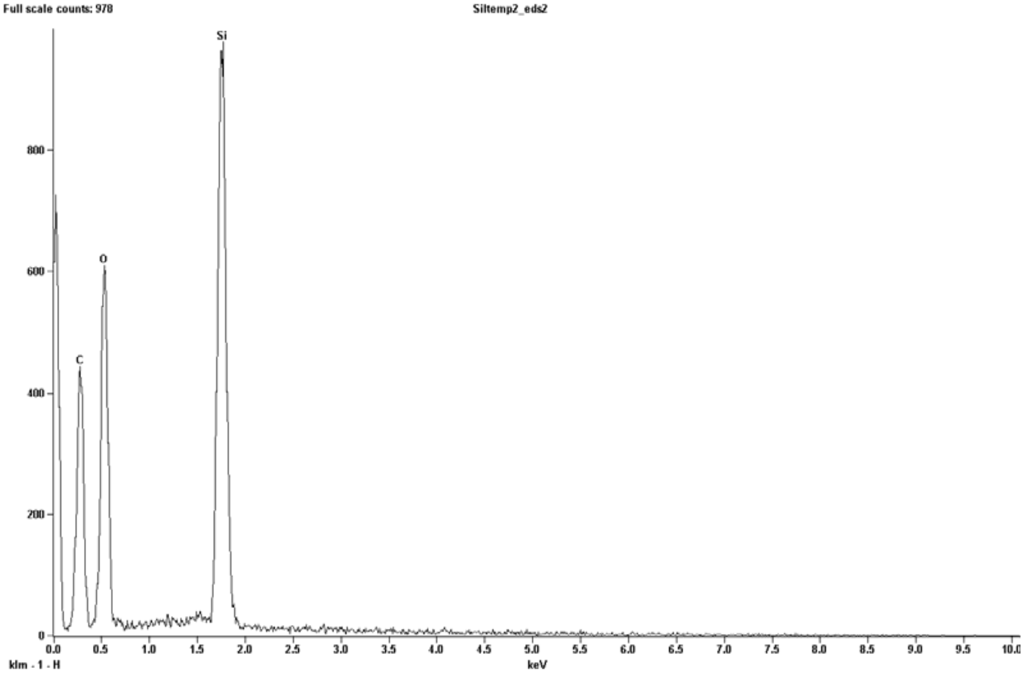


Figure 2. Siltemp2 EDS Spectrum

The EDS spectrum for the Siltemp substitute is shown in Figure 3. Present are silicon, oxygen, and carbon.

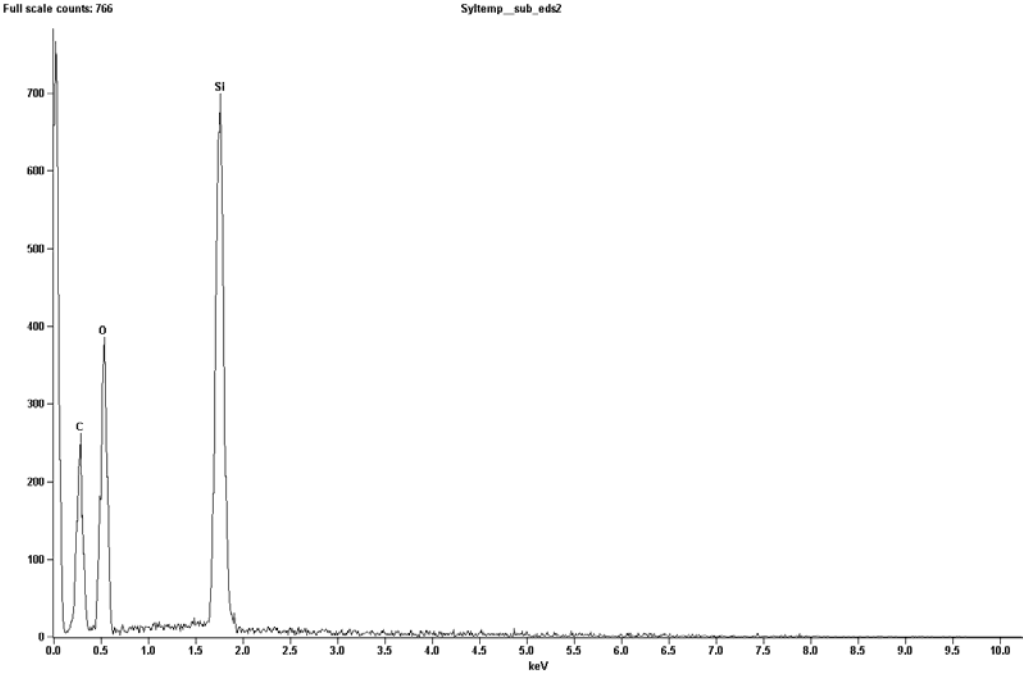


Figure 3. Siltemp Substitute EDS Spectrum

The bulk of the material has been shown to be silica by the SEM/EDS analysis. A portion of each cloth was acid-digested and analyzed by inductively coupled plasma-mass spectrometry (ICP/MS) for trace elemental analysis. The results are shown in Table 5.

Table 5. Siltemp Samples, trace inorganic analysis, ppm

	Siltemp 1	Siltemp 2	Siltemp Replacement
Aluminum	3370	5920	850
Titanium	3250	2190	1310
Magnesium	223	211	*nd*
Zirconium	98	207	349
Antimony	4	44	*nd*
Zinc	*nd*	*nd*	25
Niobium	*nd*	*nd*	11

The trace elemental analysis is shown graphically in Figure 4.

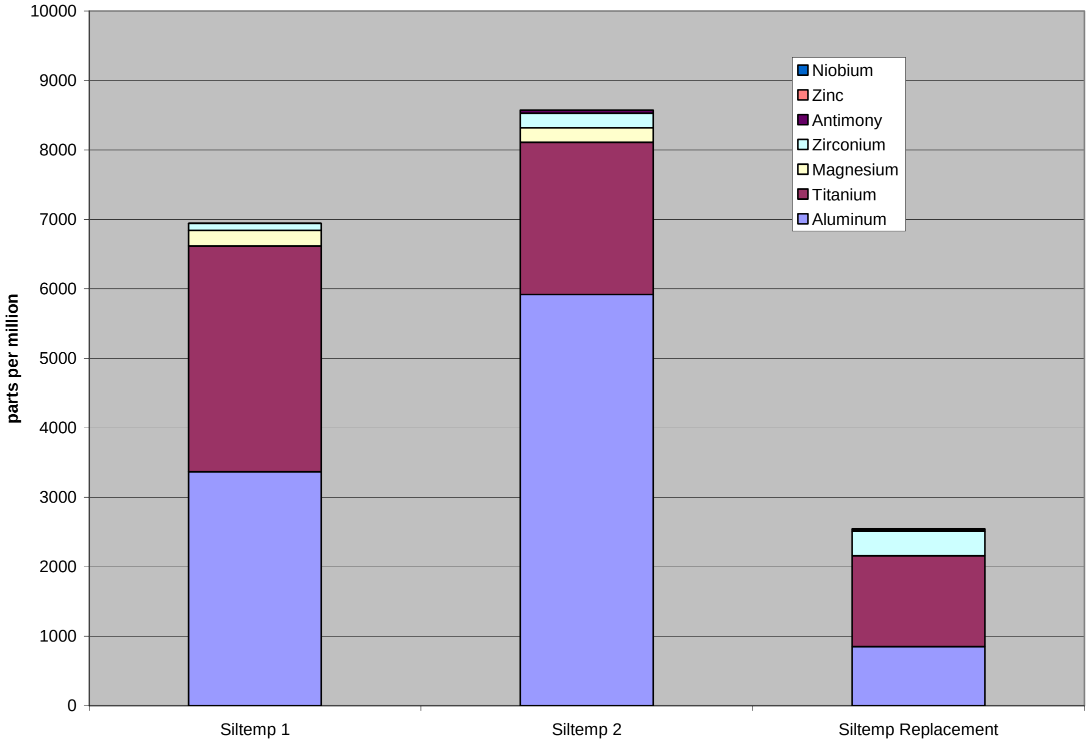


Figure 4. Siltemp Samples, trace inorganic analysis, ppm

A portion of cloth was placed in a clean glass desorption tube, the tube heated to 380°C under a stream of helium, and the species volatilized under these conditions were analyzed by gas chromatography with mass spectrometry detection. Where there is sufficient signal, the mass spectrum was computer-compared with a NIST mass spectral library in an attempt to tentatively identify the organics observed. The result for Siltemp1 is shown in Figure 5 and Figure 6. In Figure 5, the initial portion of the total ion chromatogram has been expanded, the peaks identified. The principal species observed is ethanol. The remaining species are identified on Figure 6.

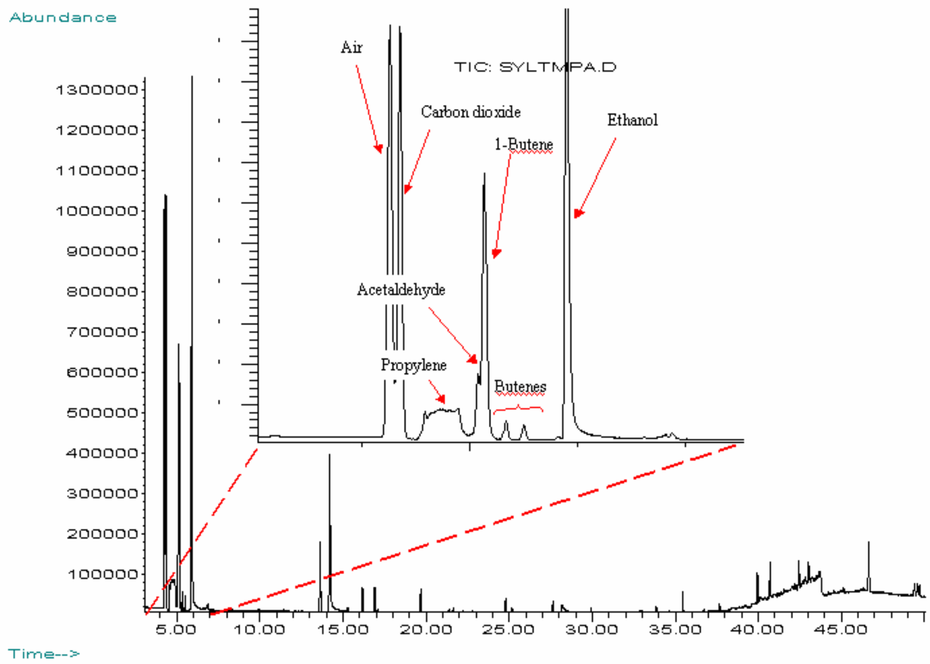


Figure 5. 380°C Thermal Desorption GC/MS of Siltemp1, Part 1

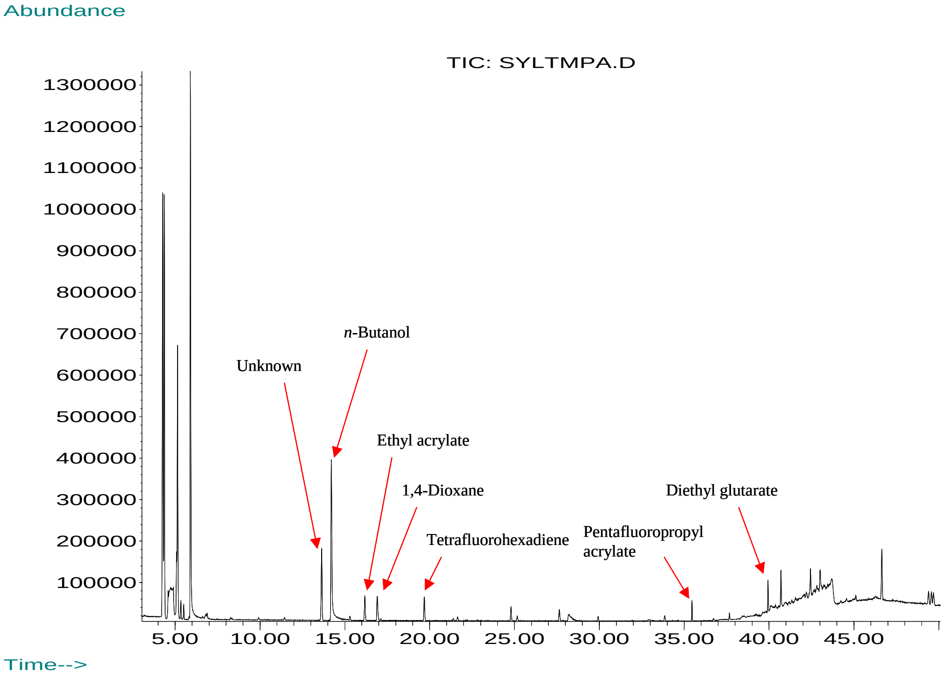


Figure 6. 380°C Thermal Desorption GC/MS of Siltemp1, Part 2

The result for Siltemp2 is shown in Figure 7 and Figure 8. In Figure 7, the initial portion of the total ion chromatogram has been expanded, the peaks identified. The principal species observed is ethanol. The remaining species are identified on Figure 8.

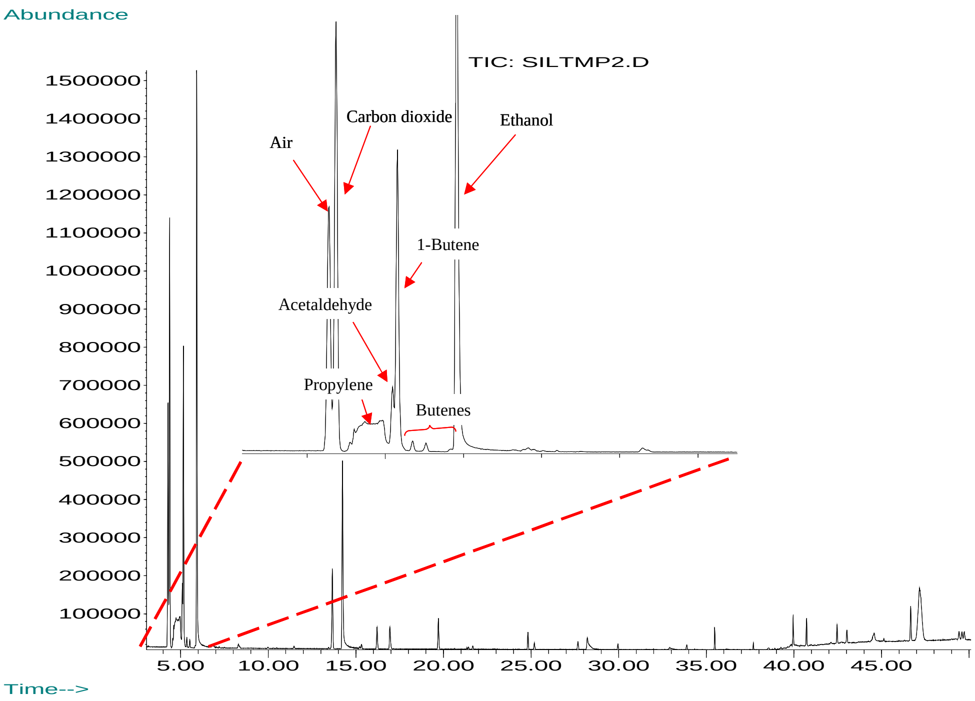


Figure 7. 380°C Thermal Desorption GC/MS of Siltemp2, Part 1

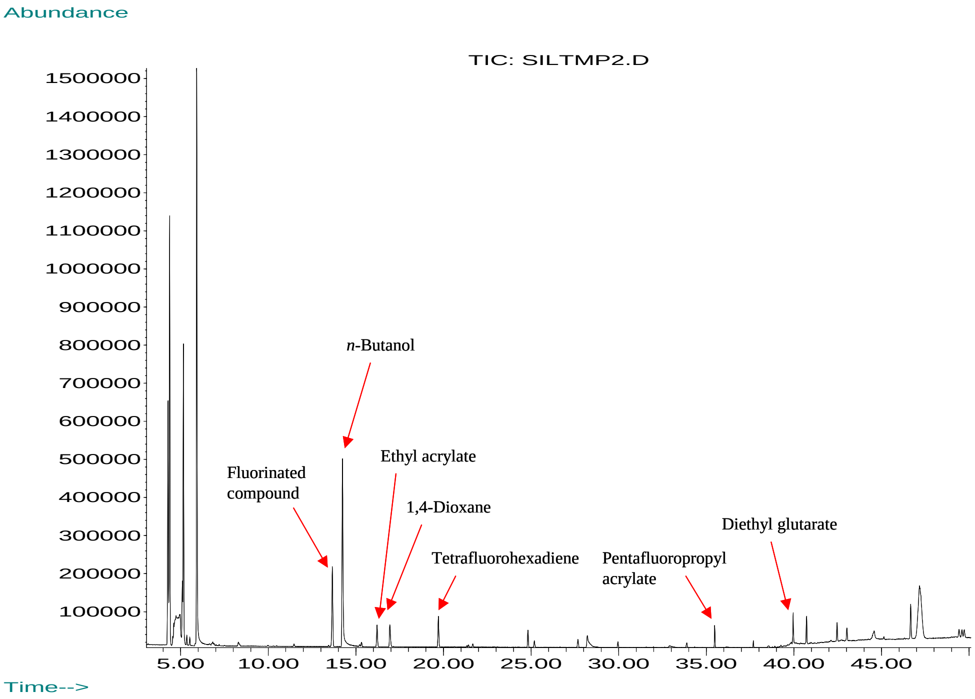


Figure 8. 380°C Thermal Desorption GC/MS of Siltemp2, Part 2

The result for Siltemp substitute is shown in Figure 9. In F4, the initial portion of the total ion chromatogram has been expanded, the peaks identified. The principal species observed is propylene. Some of the remaining species are identified on Figure 10.

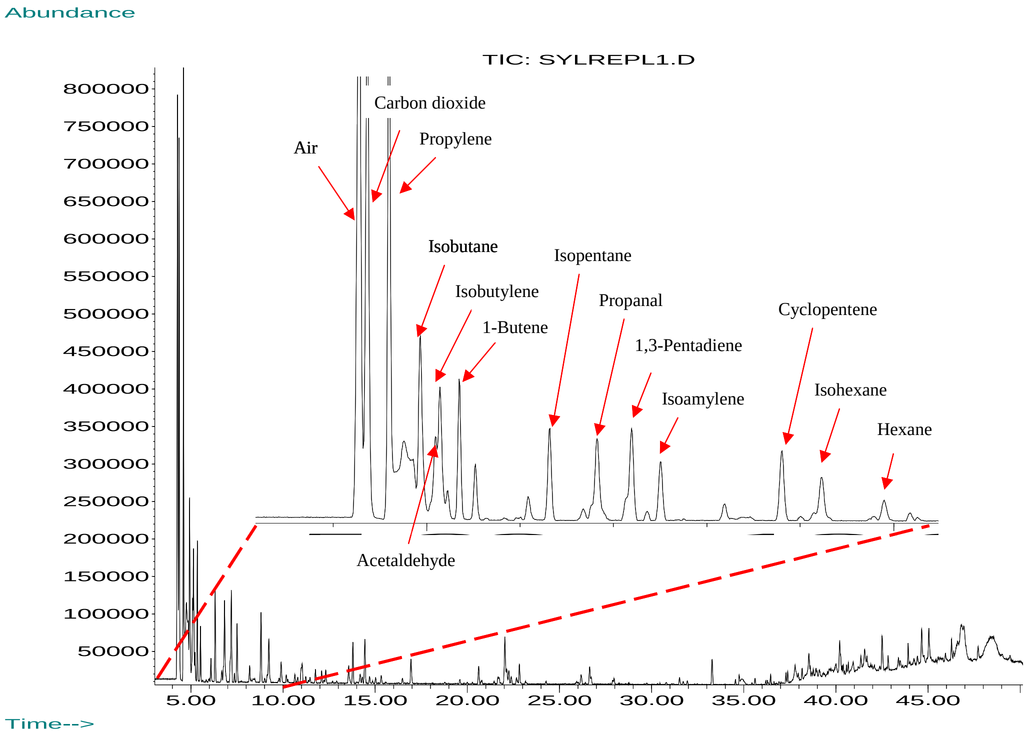


Figure 9. 380°C Thermal Desorption GC/MS of Siltemp Substitute, Part 1

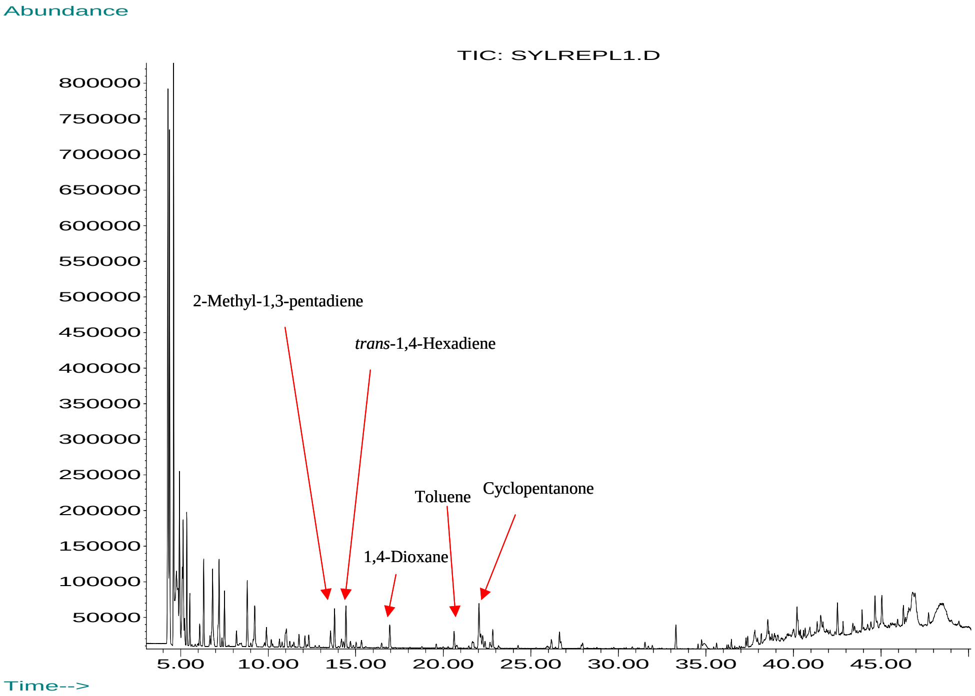


Figure 10. 380°C Thermal Desorption GC/MS of Siltemp Substitute, Part 2

Mechanical Test Results

Some tensile tests were performed on these materials. One set of tests were run by Larry Whinnery from the parachute group, using his Instron load frame. He tested ½" wide samples cut from the materials supplied. The tests were run at a CHS of 10"/minute. Siltemp 1 was run in a different direction than the other two.

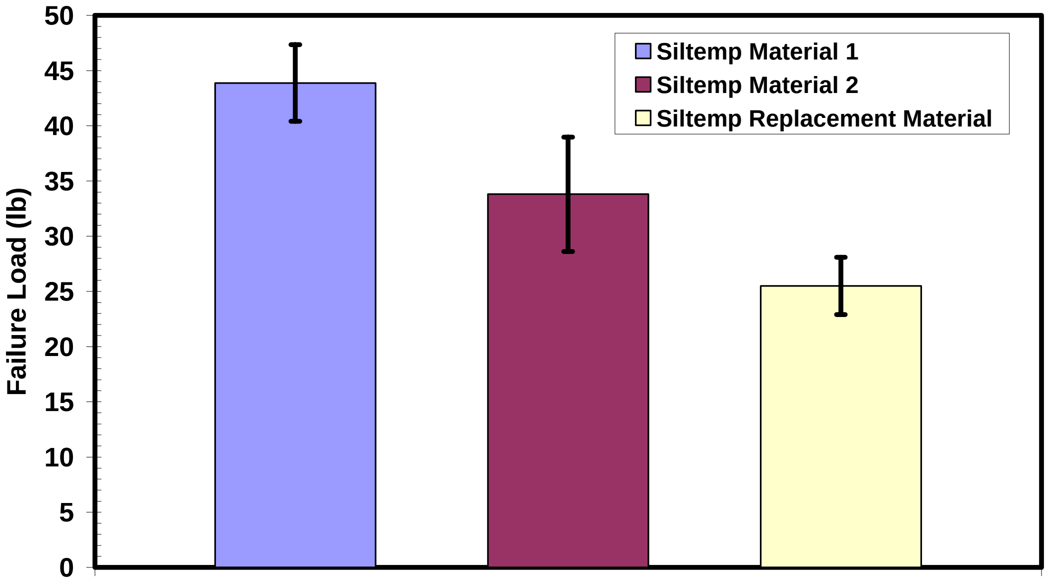
Tensile Test Results of Siltemp Materials

SILTEMP 1	
THICKNESS	0.031-0.032
WARP YARNS	20
FILL YARNS	15
TEST #1	42.09
TEST #2	41.66
TEST #3	47.87
AVERAGE	**43.87**
Stdev	**3.47**

SILTEMP 2	
THICKNESS	0.028-0.029
WARP YARNS	14
FILL YARNS	8
TEST #1	30.93
TEST #2	39.79
TEST #3	30.69
AVERAGE	**33.80**
Stdev	**5.19**

SILTEMP 3	
THICKNESS	0.030-0.031
WARP YARNS	14
FILL YARNS	8
TEST #1	27.86
TEST #2	22.73
TEST #3	25.89
AVERAGE	**25.49**
Stdev	**2.59**

Siltemp MaterialsTension Tests



These tests do not conclusively demonstrate that the materials are equivalent.

Further tensile testing on these materials was performed by Robert Bernstein; those results were submitted as a separate report.

Thermal Test Results

Samples were submitted for some thermal characterization. The TGA/DTA of the Siltemp and Siltemp replacement are shown in Figure 11.

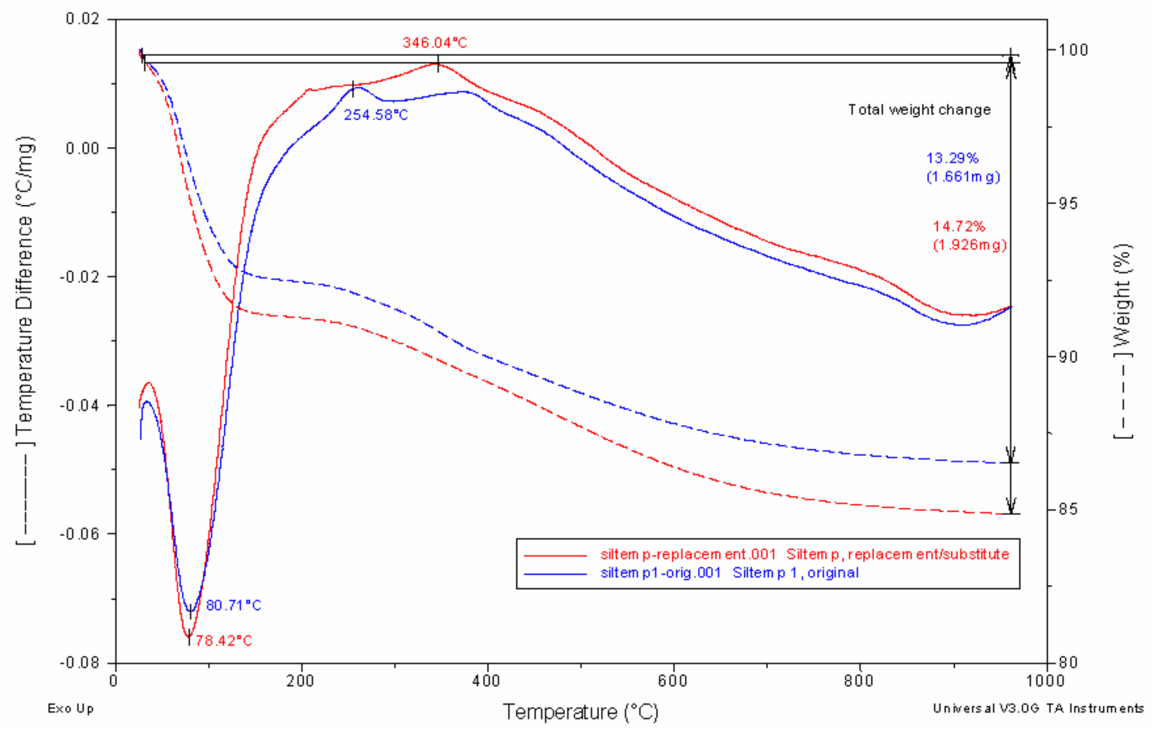


Figure 11. Siltemp and Siltemp Replacement TGA/DTA

A more complete thermal analysis by this group was forwarded separately.

No further testing was performed by us on this material.

Ted Borek 505-844-7758
Sandia National Laboratories Organization 1822

--END OF REPORT---

Description of Yarn Tensile Tests of Two Fabric Samples
Robert Bernstein, Michelle M. Shedd, Dept. 1821

Tensile studies were performed on two materials designated Siltemp 2 and Siltemp 4. The Siltemp 4 sample was unintentionally mislabeled, as it is not Siltemp, but a product from another manufacturer.
Due to practical reasons, the sample sheets were not tested. Instead, individual yarns were removed and tested. The yarns were taken from both the 'x' and the 'y' axis as defined in Figure 1.

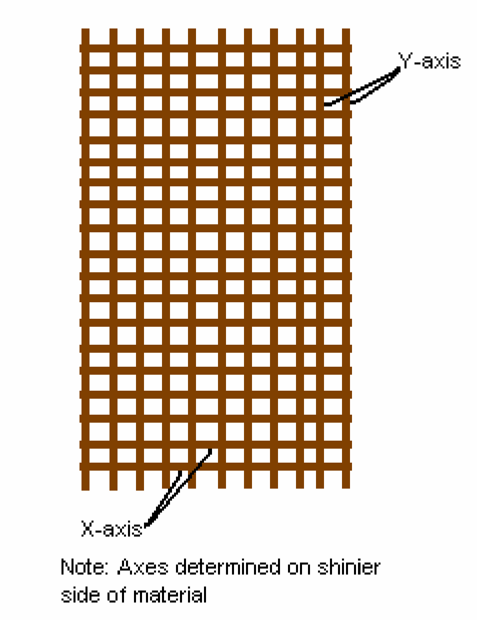


Figure 1: Yarn axis definition

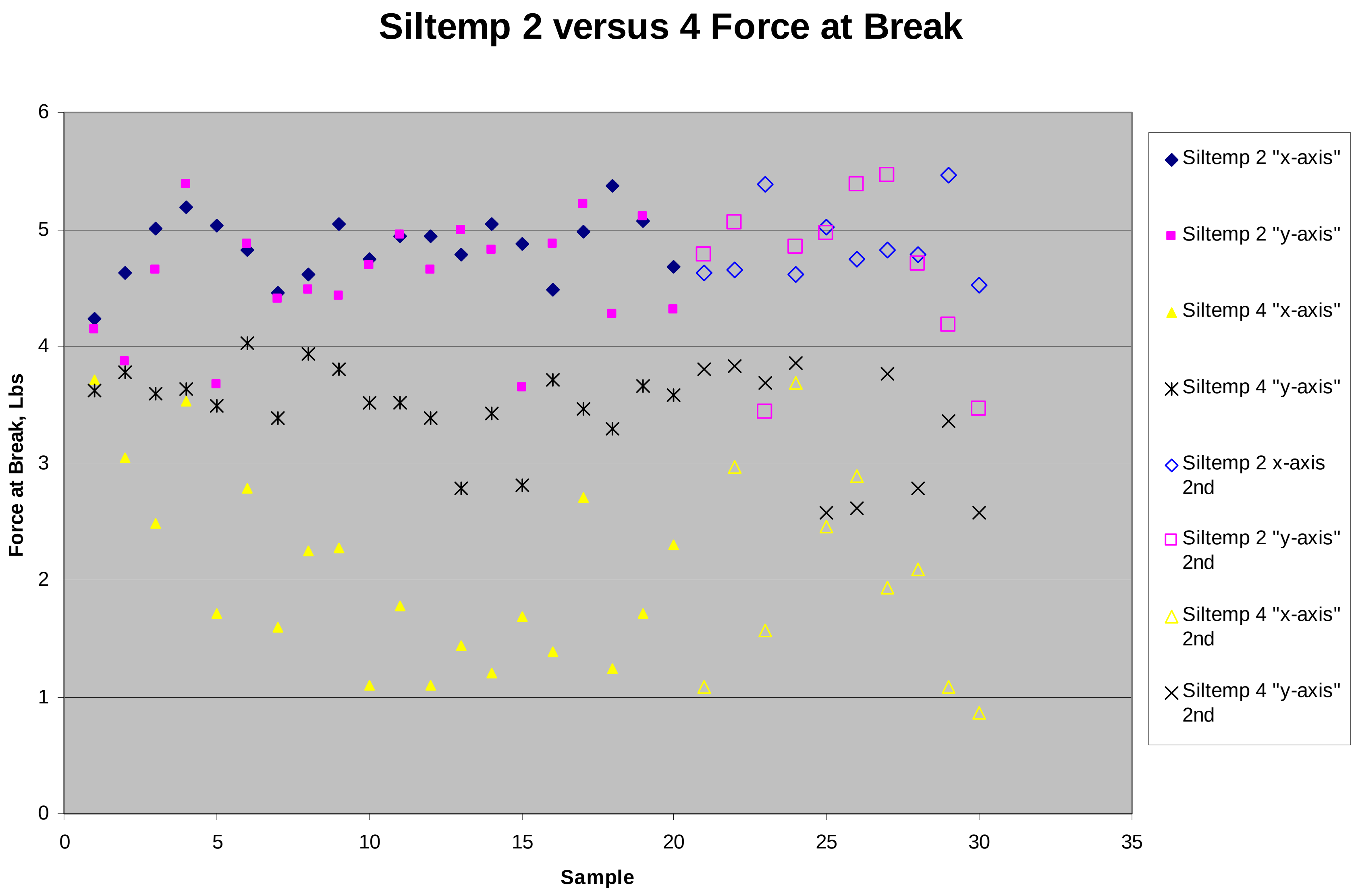
Tensile testing was performed on an Instron model 5564, using capstans (2.54 cm diameter). The gauge length was 7.62 cm, and the pull rate was 5.08 cm/min. The force at break (maximum force observed; absolute value not corrected for yarn thickness) was recorded, along with percent elongation. Percent elongation was defined by the cross head movement because an extensometer could not be placed on the yarns due to their small size. It was noted that the Siltemp 4 sample was lighter in color compared to Siltemp 2. In both materials, the yarns were composed of two smaller threads. During tensile testing, Siltemp 4 yarns snapped twice –once for each smaller thread. This was not seen for Siltemp 2 yarns. It is unknown if this affected tensile results.

Data was obtained on two days, and data sets were graphed with slightly different symbols to distinguish the two sets. Before the samples in question were examined, a set of control samples were tested to assure the integrity of values acquired from the instrument. These samples were unaged Nylon yarns with tensile values well known.

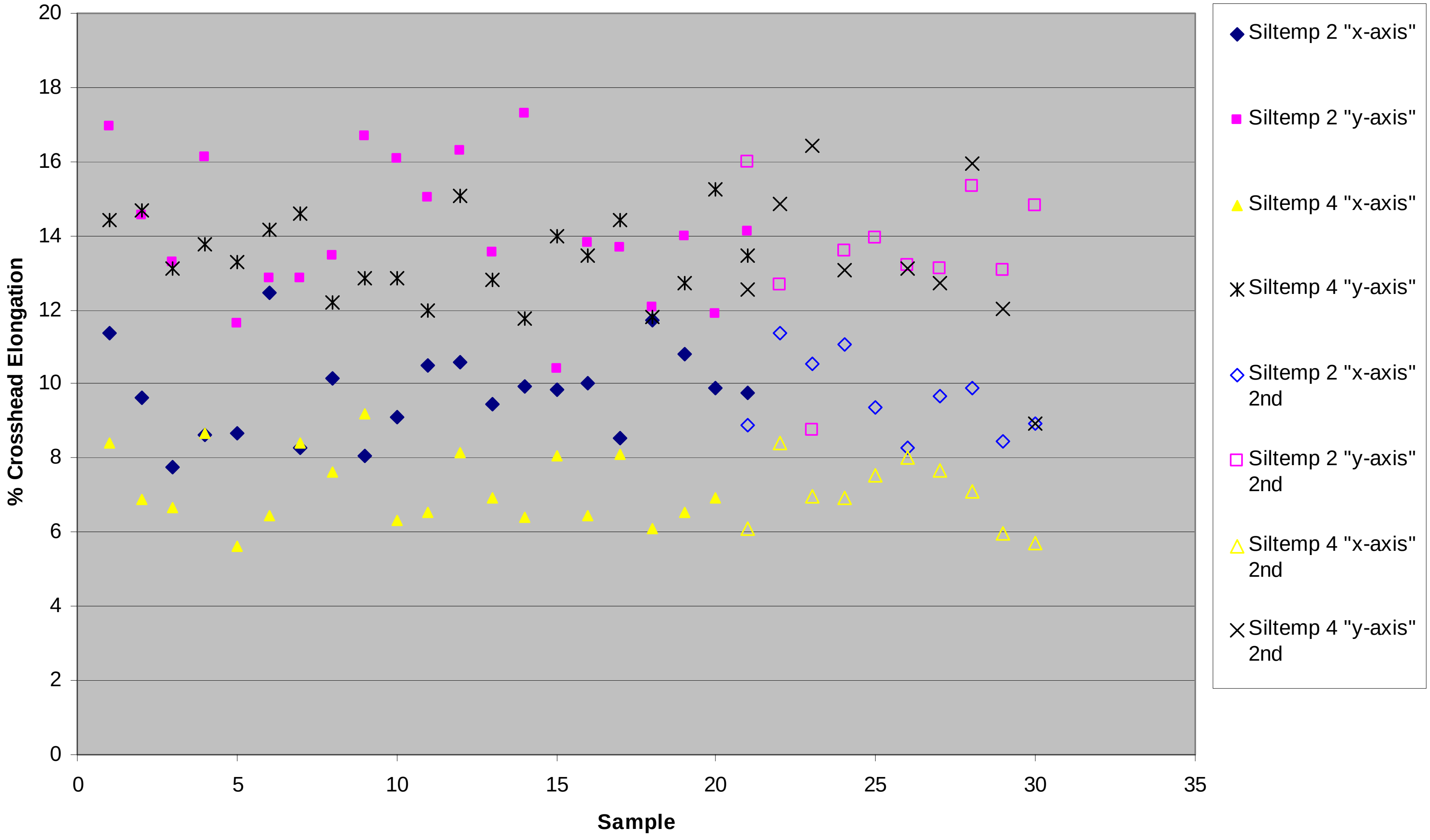
The data did not display overwhelming differences in the samples aside from a lower average force value for the Siltemp 4 yarns from the 'x' axis. The data was graphed a number of ways to try and highlight any variations between the materials. Interestingly, it appears that the percent elongation between the samples (Siltemp 2 and Siltemp 4) had greater similarity than that of the data set (‘x’ versus ‘y’) within each sample. The important concern is not necessarily if the two materials are significantly different, rather if the new material meets the necessary performance requirements.

Force and Percent Elongation Plots of Yarn Fabric Samples

Robert Bernstein, Michelle M. Shedd, Dept. 1821


Siltemp 2 versus 4 Force at Break
Force at Break, Lbs
Sample
0
1
2
3
4
5
6
0
5
10
15
20
25
30
35
◆ Siltemp 2 "x-axis"
■ Siltemp 2 "y-axis"
▲ Siltemp 4 "x-axis"
✳ Siltemp 4 "y-axis"
◇ Siltemp 2 x-axis 2nd
□ Siltemp 2 "y-axis" 2nd
△ Siltemp 4 "x-axis" 2nd
× Siltemp 4 "y-axis" 2nd

Siltemp 2 versus 4 Crosshead %Elongation



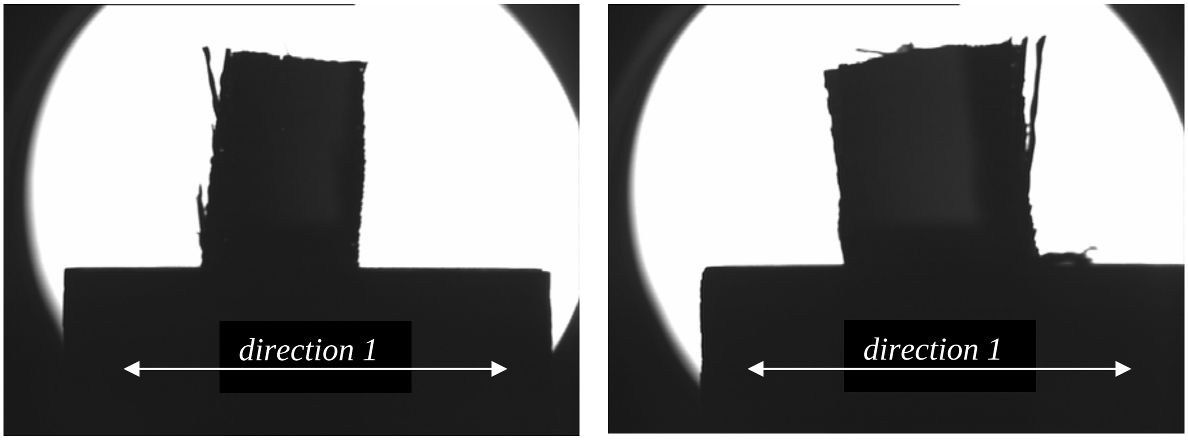
Heat Treatment of Ceramic Fabrics

Markus Reiterer, Denise Bencoe, Dep. 1815

With this kind of experiment, a slightly bigger stress-free thermal contraction has been determined for the new than for the reference material in a temperature range between 20 and 950°C.

The dimensional changes due to heat treatment of two types of ceramic fabric have been investigated in a high temperature furnace with an attached optical measurement system. As the optical system is not currently calibrated, a single crystal sapphire cylinder was placed beside the fabric during the 3rd and 4th experiment to obtain length calibration information (see **Fig. 4**).

To allow free shrinkage of the samples, the fabric was hanging freely in the oven, hooked on a platinum wire. **Fig. 1** shows the shadow of the cross section of the sample from the reference (a) and from the new (b) material after the heat treatment. The rough perimeter of the specimen leads to further inaccuracies in the measurement. As the whole set up is moving during the heat treatment, the height of the sample could not be measured. That is why, only the width of the samples (≈ 1 x 2 cm) was recorded. This measuring direction is indicated as *direction 1* and marked on the sample bags as well.



(a) (b)

Fig. 1: Cross-sectional view of the reference (a) and new (b) materials samples (*direction 1*).

Fig. 2 shows the uncorrected change of the sample width as a function of temperature (direction 1). The deviations of the individual lines might come from single fibers, which move a little during the heat treatment.

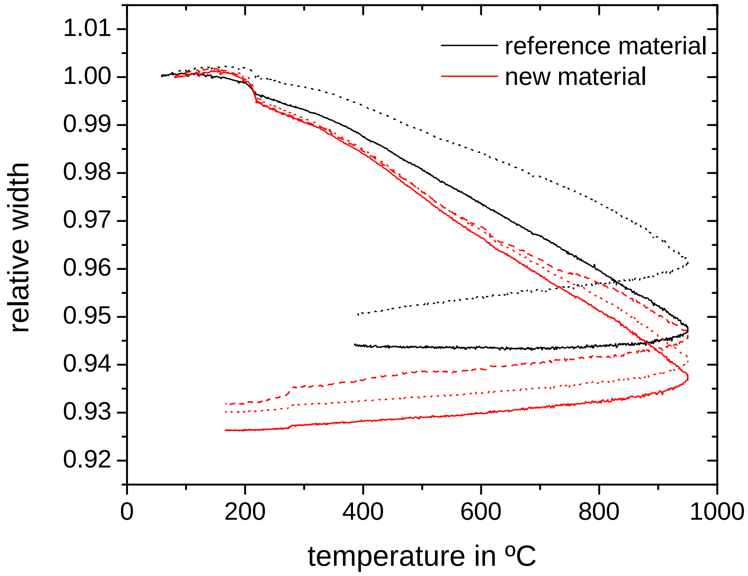


Fig. 2: Uncorrected evolution of the sample width in *direction 1*.

The thermal shrinkage of the samples had to be corrected for 2 parameters:

1. A temperature calibration was performed, as the actual temperature in the oven was higher than the displayed. The calibration was performed by melting point analysis of pure metals and an additional thermo-couple.
2. The thermal expansion was corrected by using a sapphire reference sample.

The corrected relative width for the reference and the new sample is shown as function of true temperature in **Fig. 3** (*direction 1*).

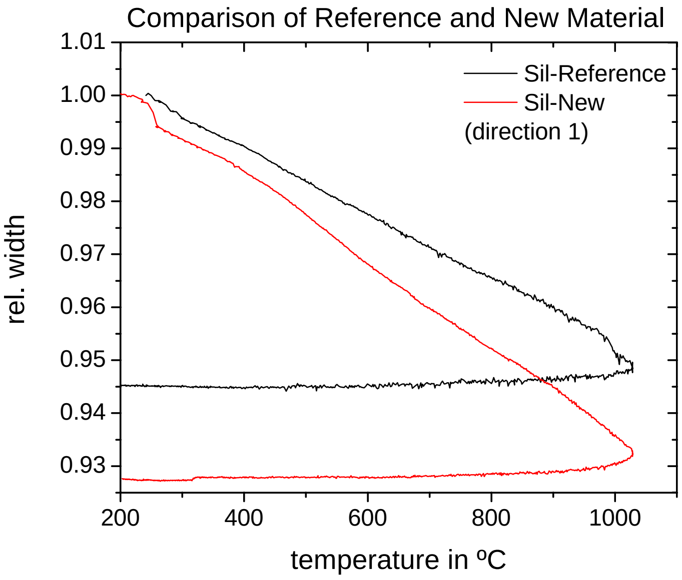
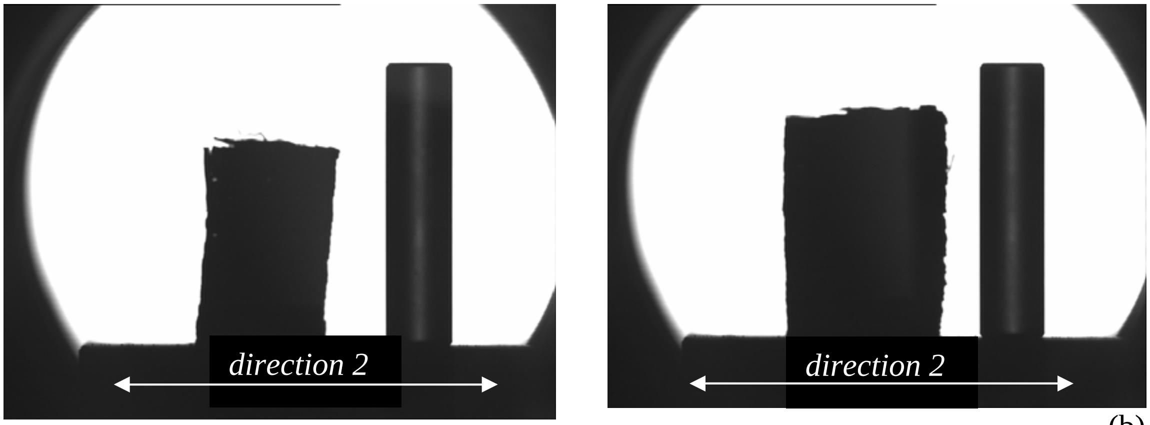


Fig. 3: Relative width plotted vs. true temperature, corrected for temperature and length measurement errors.

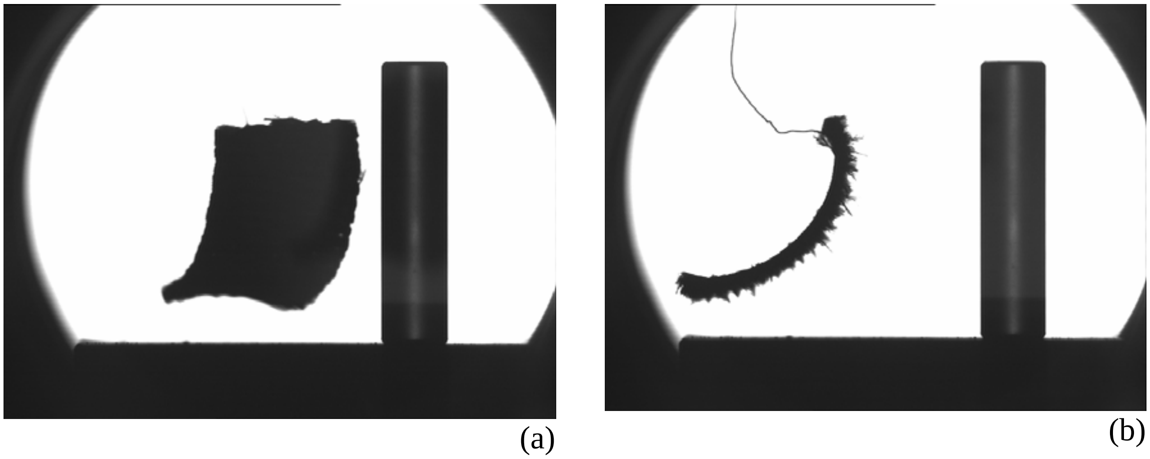
Subsequently, specimens were cut out of the fabric in the perpendicular direction, as indicated on the bags (*direction 2*) in order to investigate eventual anisotropic behavior. Pictures of the reference (a) and the new material (b), and the sapphire are given as **Fig. 4**.



(a) (b)

Fig. 4: Shadow of the reference (a) and the new (b) material before the experiment.

Unfortunately, the new material sample warped during the experiment and the base line was lost. Hence, no data was collected after that temperature. A frontal view (a) and a side view (b), which was arranged after the experiment manually, are shown in **Fig. 5**.



(a) (b)

Fig. 5: Picture of the new material sample after the experiment in frontal (a) and side (b) view.

The collected data from the experiment on the reference material in sintering *direction 1* and *2* could be used to see, if large anisotropic shrinkage occurs (**Fig. 6**). From the data we see that both directions shrink fairly similarly.

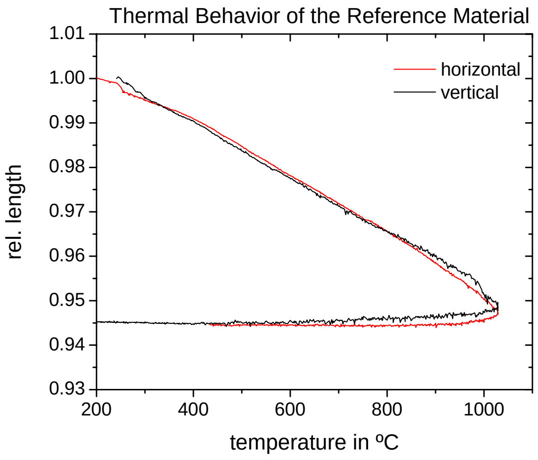


Fig. 6: Comparison of the shrinkage *in direction 1* and *2* for the reference material

It has to be emphasized, that this study is valid for the relative differences between the two materials, but the absolute numbers cannot be quantitatively guaranteed at this time. These are the first experiments performed on a new piece of equipment, which has been at Sandia less than 3 weeks.

Sandia National Laboratories
Operated for the U.S. Department of Energy by
Sandia Corporation

Mail Stop 0748; P.O. Box 5800
Albuquerque, New Mexico 87185-0748

March 25, 2005

Mark Salley
Fire Protection Team Lead
PRAB/RES/NRC
(original transmitted by e-mail)

Dear Mark,

Subject: Quick Look Report on Material Shrinkage Test

Attached is a quick look report for the Siltemp and REFRASIL comparative material shrinkage test we ran March 24, 2005. As you will note, we observed no substantive differences in the behavior of the two materials. We do recommend a confirmatory test be performed, but do not expect that a confirmatory test would change the overall assessment of material behavior.

Sincerely,

Steven P. Nowlen
Distinguished Member of the Technical Staff
Risk and Reliability Analysis Department 6861

Attachment: Quick Look Report on 3/24/2005 Material Shrinkage Testing (one page)

Quick Look Report on 3/24/2005 Material Shrinkage Testing

Overview

On March 24, 2005 SNL ran a preliminary test to assess the shrinkage behavior of the two materials, REFRASIL© and Siltemp©. The REFRASIL sample was taken from the actual bolt of material used to construct insulating pads for the SNL/NRC fire endurance test articles. The Siltemp material was “new old stock” material provided by a licensee from their own on-hand supplies (Siltemp is no longer manufactured and cannot be obtained on the open market today). Nominal 6"x6" samples of each material were cut. The cuts were made along the thread-lines of the material in order to minimize the fraying of the sample edges (both materials fray quite easily along any cut edge). Because there is a slight bias to the weave, this resulted in samples with a slight trapezoidal shape rather than true squares.

Summary of test procedure

The samples were placed on a thin insulating board, and an outline was drawn with a red marker pen around each sample. Two pieces of fine Nichrome wire were run across each of the samples to prevent the material from curling when heated (this proved to be an unnecessary precaution as neither material showed any tendency towards curling during the exposures). The board with the samples was then placed in PENLIGHT, a SNL radiant heating facility originally designed and operated for NRC component testing under the facility name SCETCh. The facility uses a cylindrical array of 24" quarts lamps to heat a thin cylindrical metal shroud to the desired set-point temperature. The metal shroud in turn delivers radiant heating to the samples. Given the geometry, and the nature of the material samples, the materials will quickly come into approximate thermal equilibrium with the metal shroud. The test was initiated by setting the shroud temperature to 300°C. The shroud temperature was increased in 50°C increments to a maximum temperature of 800°C. Total test duration was 90 minutes.

Summary of test results

The two materials behaved in a virtually identical manner. The first visible signs of shrinkage were noted at a shroud temperature of 450°C. After ten minutes at this exposure temperature both materials displayed a uniform shrinkage visually estimated at 1/16"-1/8" total (or about 2%) in each of the two primary directions (i.e., both along and across each sample). At this exposure, both materials retained their color, although some minor darkening was noted. The materials did not show additional signs of shrinkage until the shroud temperature was increased to 600°C. At this point a very slight increase in total shrinkage for both materials was noted (to about 1/8"-3/16" total or about 3%). Between 650°C and 700°C our marker reference lines faded, and no further direct visual observations of the relative shrink behavior in the furnace were possible. However, the materials continued to behave in a virtually identical manner throughout the test. At 750°C a substantial lightening of the color of both materials became apparent. At the peak exposure temperature of 800°C both materials completed a transition to a stark white color, and it was apparent that some additional shrinkage had occurred. Upon loss of all color for both samples, the test was terminated. Post exposure measurements revealed that the shrinkage in both materials was uniform across both material samples (no bias in shrinkage). There was no measurable difference in the total shrinkage for the two samples. Each had shrunk by slightly more than 1/4" for a total shrinkage of about 5%. These results indicate that no substantial differences in either the timing or extent of the material shrinkage behavior between REFRASIL and Siltemp should be expected.

Manufacturer’s Data for Thermal Materials

2/8/05
from Mike Jordan, PCI

HIGH TEMPERATURE TEXTILES

AMETEK high temperature fabrics are designed for use as an environmentally approved replacement for asbestos in a wide range of insulation and protection applications. AMETEK textile products provide high thermal resistance for applications in aerospace, marine, molten metal, and power industries.

SILTEMP® Silica Fabrics

When critical applications require safeguarding personnel and equipment against extreme temperatures, sparks, and molten metals – *Siltemp takes the heat, up to 1800°F for short-term continuous operating temperature.* **Siltemp silica textile fabrics can be used or configured as: welding drop cloths, protective screens, fire curtains, stress relief blankets, furnace insulation, cable wrap, and high temperature gaskets.** Siltemp is available in fabric, tape, rope, sleeving, mat, and yarn forms. Siltemp fabrics can be specified with aluminized, silicone, and other coatings for special application requirements. All Siltemp fabrics, excluding pre-shrunk, are hydrocarbon-coated to improve handling characteristics. The coating is designed to decompose at high temperatures, and generates virtually no smoke or fumes. Siltemp has a minimum silicone dioxide (SiO_2) content of 96%, and resists most corrosive fluids.

Standard Grade Siltemp fabrics – the most frequently specified products in our line – are suitable for most "hot" applications. *Abrasion Resistant Siltemp* is designed for durability and low temperature abrasion resistance. *Water-repellent Siltemp* should be used in applications involving water or oil. *Pre-shrunk Siltemp* fabrics can be supplied in *Commercial Grade* for applications requiring minimum shrinkage at high temperatures, and in *Aerospace Grade* for highly technical aerospace composite moldings. *Silicone Coated Siltemp* is designed for uses where surface abrasion and impermeability to fluids and gases are important. *Aluminized Siltemp* provides thermal reflectivity and is ideal for fabrication of covers.

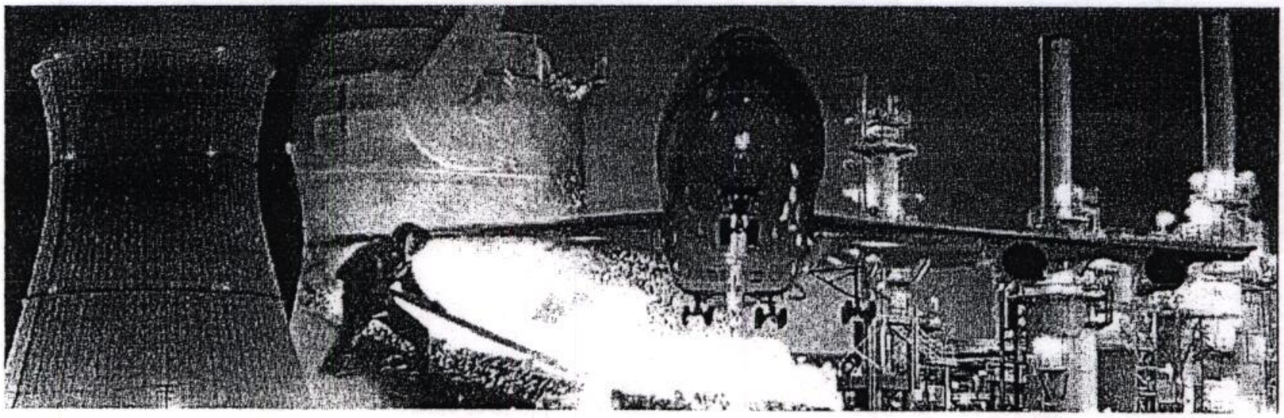
Product Type	Product Number	Color	Nominal Thickness, Inches	Nominal Weight, Oz./Yd.^{2}	Nominal Width, Inches
Standard	84CH	Tan	0.030	18	36
	188CH	Tan	0.054	36	36
Abrasion Resistant	84CSR	Tan	0.030	18	36
	188CSR	Tan	0.054	36	36
Water Repellent	WR84CSR	Tan	0.030	18	36
	WR188CSR	Tan	0.054	36	36
Pre-Shrunk	84S	White	0.026	18.5	33
	188S	White	0.052	38.0	33
Aluminized*	ALUM 84CH	Silver	0.033	21	34-1/2
	ALUM 188CH	Silver	0.057	39	34-1/2
Silicone*	SIL RUB84CH	Red	0.033	24	36
	SIL RUB188CH	Red	0.057	42	36

Standard roll length is 50 yards; shorter or longer rolls are available on request.
**Coated 1 side; 2 side coating is available on request. Coatings will lose properties as temperature increases. Silicone coating is also available in other colors.*

AMETEK Chemical Products - Haveg Division
900 Greenbank Road, Wilmington, DE 19808
Tel: 800-441-7777; 302-995-0400
Email: info.haveg@ametek.com
www.ametekhaveg.com

REFRASIL® Cloth

Refractory Silica Cloth Products



REFRASIL Cloth provides continuous protection up to 2300°F.

REFRASIL textiles are continuous filament, amorphous silica products with the thermal performance of a refractory material. The product is produced through the chemical leaching of specially formulated glass fibers. REFRASIL is >96% silica (SiO_2), resists oxidation and most corrosive solutions and presents no known health hazard. REFRASIL fiber diameters range from 8 to 10 microns.

REFRASIL textiles will not melt or vaporize until temperatures exceed 3100°F (1704°C). REFRASIL will insulate continuously and retain strength and flexibility up to 1800°F (982°C).

The most popular form of REFRASIL is woven cloth. REFRASIL cloths are available in a number of different weights and thickness'.

These cloths come in standard (UC series) as well as pre-shrunk (C series) form. The cloths can also be treated for abrasion resistance (AR series) and continuous temperatures to 2300°F (Irish series). A cost-effective cloth, Welding Grade Cloth (WGC), is also available.

FEATURES:

- Asbestos replacement
- Resilient
- Fireproof
- High temperature insulator resists molten metals and radiant heat
- Compatible with most chemicals
- Low halogen content
- High dielectric strength
- Minimal smoke emission
- Low thermal conductivity
- No known health hazards
- Amorphous structure
- Cost Effective

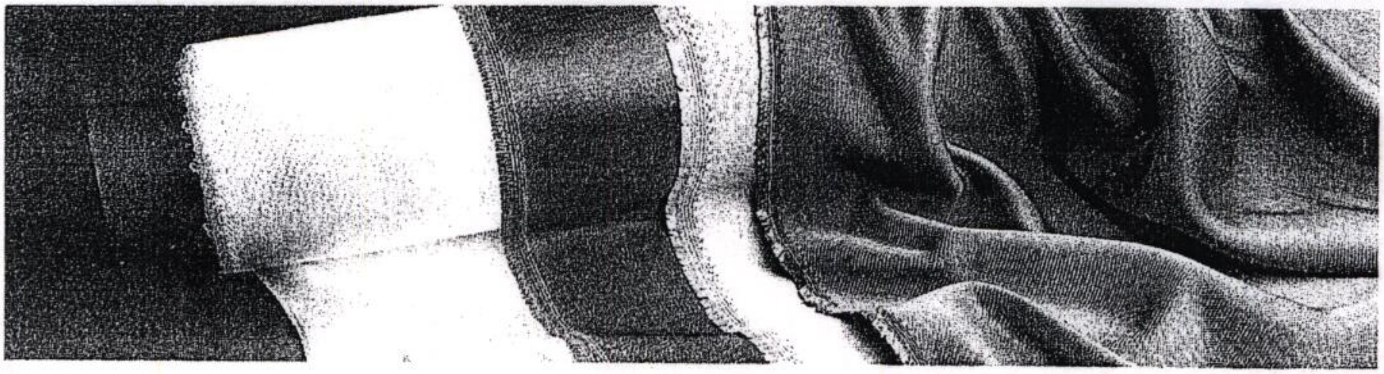
AVAILABILITY - Standard roll size for all REFRASIL cloth is 50 lineal yards ±10% maximum length. No roll contains more than two pieces of fabric and no piece within the roll is less than 10 lineal yards. REFRASIL's textiles are available in a variety of product forms to suit each customer's specific needs-cloth, tape, sleeving, rope, yarn, cordage, batt and bulk fiber. All textiles can be purchased through a nationwide network of stocking distributors.

HITCO CARBON COMPOSITES, INC.

1600 West 135th St. • Gardena, CA 90249
www.hitco.com or www.refrasil.com
e-mail: refrasil@hitco.com
Tel: 800.421.5444 • 310.527.0700
Fax: 310.515.1779

REFRASIL® Cloth

Refractory Silica Cloth Products



REFRASIL Welding Grade Cloth (WGC) - is effective in applications such as welding blankets and screens, personnel protection shields, equipment protection, and stress relieving pads. WGC products have been specifically designed to provide the user with a cost-effective material for commercial and consumable welding applications. When used properly, WGC will protect personnel, equipment, and finishes from molten metal slatter and sparks. The high silica content makes WGC resistant to most chemicals and elements within the 1800°F temperature range. The products' low chloride content makes them suitable for welding stainless steels and ensures against chloride contamination.

WGC Series

Product Description	Product Code	Color	Nominal Thickness (in.)	Nominal Width (in.)	Weight oz/sq yd.
Standard	WGC-18	Tan	.030	36	18.0

Irish Series REFRASIL Cloth Extends Temperature Range to 2300° F. - Irish REFRASIL insulation cloth was developed to extend the temperature range and flexibility characteristics of REFRASIL textiles. The greenish color from which it derives the name Irish is the result of a special high-temperature treatment.

Irish REFRASIL insulation will withstand continuous temperatures to 2300°F with little or no change in properties.

Cloth is the standard form of Irish REFRASIL insulation, which is available in two versions, C1554 and 2221.

Irish REFRASIL 2221 has been treated with a coating for ease of handling and physical integrity during fabricating. Irish 2221 series REFRASIL cloth is also available as a 2 inch, or 4 inch, wide tape.

Irish Series

Product Description	Product Code	Color	Nominal Thickness (in.)	Nominal Width (in.)
Irish Cloth	C1554-48	Green	.026	33
	C1554-96	Green	.052	33
Treated Irish Cloth	2221-48	Green	.026	33
	2221-96	Green	.052	33

AR10048 - ORANGE

Standard UC100 and C100 Series Cloth Protect to 1800°F- REFRASIL standard woven fabric is known as the UC100 series cloth. UC cloths are identified by their tan color. The UC series cloths are available with the following coatings: Pressure sensitive adhesive, Silicone Rubber, Aluminum, Vermiculite, and Black Iron Oxide.*

UC Series - Standard Cloth

Product Description	Product Code	Color	Nominal Thickness (in.)	Nominal Width (in.)	Weight oz/sq yd
Super Light	UC100-28	Tan	.015	36	10
Light	UC100-48	Tan	.030	36	18
Heavy	UC100-96	Tan	.056	36	36
Super Heavy	UC100-192SS	Tan	.060	36	40

The C series cloths - are pre-shrunk versions of the popular UC series cloth and is identified by its white color. The "Pre-shrunk" C series cloth is used in applications where shrinkage cannot be tolerated.

C Series - PreShrunk Cloth

Product Description	Product Code	Color	Nominal Thickness (in.)	Nominal Width (in.)	Weight oz/sq yd
Light	C100-48	White	.028	33	18
Heavy	C100-96	White	.056	33	35

Abrasion-Resistant AR100 Series Provides Improved Abrasion Resistance and Strength - The AR series REFRASIL is coated with a specially formulated coating, making it more abrasion resistant than standard UC series cloth. The AR series REFRASIL is recommended for use in high traffic areas and for fabrication because the coating resists minor damage from dragging, scraping, tearing and snagging. The coating also provides greater seam strength than standard UC series REFRASIL cloth making it an excellent choice as a high temperature fabrication cloth. The AR series REFRASIL is identified by it's orange coating. Although there will be a loss of coating from exposure to high temperatures, only the abrasion resistance of the fabric will be affected, not its overall thermal performance.

AR Series - Abrasion Resistant Cloth

Product Description	Product Code	Color	Nominal Thickness (in.)	Nominal Width (in.)	Weight oz/sq yd
Light	AR100-48	Orange	.032	36	20
Heavy	AR100-96	Orange	.056	36	40

INSPECTION INSTRUCTIONS

MS-1024, REV. 3

SILTEMP FABRIC WR84CSR

1. Verify correct labeling of product.
2. Ensure that the material certification has been provided for the lot number(s) being supplied.
3. Compare the material certification with the acceptance criteria provided below.

Color	Tan
Weight OZ/YD$_2$	18 Minimum
Thickness IN.	.022 Minimum - .032 Maximum
Tensile Strength	
Warp LB/IN	90 Minimum
Fill LB/IN	70 Minimum
Silica Content %	96 Minimum

4. If the material fails to meet the Promatec specifications, place the material on hold and conttact the Product Assurance Manager.

I certify that the Siltemp Fabric WR84CSR, Lot No. ________________, has passed the inspection/test criteria provided above.

____

QC Inspector Date RR No./Date

PO. NO.____________________________

ATTACHMENT 7.2

Only approved materials as listed below shall be utilized in the fabrication of PROMATEC's protective wrap components.

1. Silica Dioxide Cloth
   - a. Siltemp S84 and/or 84 SRWR
   - b. Santex
   - c. Refrasil
2. Fiberglass cloth (Inner Blanket).
   - a. Alpha 76281-4634
   - b. J.P. Stevens 3582 3910
   - c. J.P. Stevens 2025
   - d. Havaglass
3. Coated fiberlass cloth
   - a. Alpha 76281-4634
   - ~~b. J.P. Stevens 3582 3910~~
4. Alumina Silica Fiber Blanket - 1" and 1-1/2" nom.
   - a. Johns Manville Cerablanket, 8# density 2400° F.
   - b. Babcock & Wilcox Kaowool Blanket, 8# density 2300° F. Carborundum Durablanket, 8# density 2300° F.
5. Trihydrate Alumina Grade 30
   - a. Alcoa-C30 and/or B. Solem-SB30
6. Hog Rings
   - a. Spenaz 16SS-110
   - b. Or approved equal
7. Lacing Hooks
   - a. Alpha-Maritex 2-1/2" AML-1201-SS
   - b. Erico Jones
   - c. Or approved equal.
8. Nylon Thread
   - a. Tex 90 Spun Kevlar
9. Quartz Thread
   - a. Astroquartz - Type Q-24 teflon coated
     and/or
   - b. Alphaquartz - Type Q-24 teflon coated

Thermal Ceramics

Blanket Products

Product Information

Kaowool Blanket, Kaowool S Blanket, Cerablanket, Cerachem Blanket and Cerachrome Blanket are air laid into a continuous mat and mechanically needled for added strength and surface integrity. Blanket products do not contain organic binders. Thermal Ceramic Blankets provide excellent resistance to chemical attack. Exceptions include hydrofluoric acid, phosphoric acid, and strong alkalies (ie. Na_2O, K_2O). Thermal Ceramic Blankets are unaffected by oil or water. Thermal and physical properties are restored after drying.

Kaowool Blanket

Kaowool blanket is produced from kaolin, a naturally occurring alumina-silica fire clay. Kaowool, the world's most recognizable name in ceramic fiber blanket, is available in a wide variety of densities and sizes. Kaowool blanket offers excellent handleability and high temperature stability. This allows it to meet a wide range of hot face and backup insulation applications in furnaces, kilns and other equipment requiring high temperature heat containment.

Kaowool S Blanket

Kaowool S Blanket is produced from high quality spun fibers. It is available in a wide variety of densities and sizes, and offers a highly cost effective alternative to Cerablanket with its 2300°F *(1260°C)* maximum temperature rating.

Cerablanket

Cerablanket is produced from exceptionally pure oxides of alumina and silica using the spinning process. The resultant quality spun fibers have been optimized for high handling strength, with on average the highest tensile strength of any Thermal Ceramics ceramic fiber blanket. Cerablanket is available in a wide variety of densities and sizes. Cerablanket offers excellent handleability and high temperature stability which allows it to meet a wide range of hot face and back up insulation applications in furnaces, kilns and other equipment requiring high temperature heat containment.

Cerachem Blanket

Cerachem Blanket is a 2600°F *(1427°C)* maximum temperature rated refractory blanket formed from a unique, patented, spun alumina-silica-zirconia fiber. It is specially designed for applications where high fiber tensile strength, low thermal conductivity and low shrinkage are required. Cerachem Blanket is used extensively in high temperature units in the ceramic, chemical processing, and ferrous metal industries. Thermal Ceramics Cerachem refractory blankets are ideal for a wide range of hot face lining and backup insulation applications in furnaces, kilns and other high temperature equipment.

Cerachrome Blanket

Made from spun alumina-silica-chromia fiber, Cerachrome Blanket is well suited for hot face lining applications where higher temperatures are encountered, such as soaking pit covers, reheat and forging furnaces. Cerachrome Blanket with its chromia-stabilized chemistry offers improved long term shrinkage characteristics over zirconia containing blankets such as Cerachem. Cerachrome Blanket effectively fills the gap between zirconia blankets and high alumina products.

Blanket Products

Product Information

Physical Properties	**Kaowool**	**Kaowool S**	**Cerablanket**	**Cerachem**	**Cerachrome**
Color	white	white	white	white	blue/green
Density, pcf	3, 4, 6, 8, 10, 12	4, 6, 8	3, 4, 6, 8	4, 6, 8	4, 6, 8
(kg/m^3)	*(48, 64, 96, 128, 192)*	*(64, 96, 128)*	*(48, 64, 96, 128)*	*(64, 96, 128)*	*(64, 96, 128)*
Thickness, in. *(mm)*	⅛ - 1 *(3.125-50)*	1 - 2 *(25-50)*	¼ - 2 *(6.25-50)*	½ - 2 *(12.5-50)*	½ - 2 *(12.5-50)*
Continuous use limit, °F *(°C)*	2000 *(1093)*	2000 *(1093)*	2150 *(1177)*	2400 *(1315)*	2500 (1371)
Classification temp. rating, °F *(°C)*	2300 *(1260)*	2300 *(1260)*	2400 *(1315)*	2600 *(1426)*	2600 *(1426)*
Melting point, °F*(°C)*	3200 *(1760)*	3200 *(1760)*	3200 *(1760)*	3200 *(1760)*	3200 *(1760)*
Chemical Analysis, Nominal %					
Alumina, Al_2O_3	45	35 - 45	46	35	43
Silica, SiO_2	50 - 55	50 - 54	54	50	54
Ferric oxide, Fe_2O_3	1.0	0.05	0.05	0.05	–
Titanium oxide, TiO_2	1.7	–	–	–	–
Calcium oxide , CaO	0.1	0.05	0.05	0.05	–
Magnesium oxide, MgO	trace	0.05	0.05	0.05	–
Alkalies as, Na_2O	0.2	0.2	0.2	0.2	–
Boron Oxide, B_2O_3	0.08	–	–	–	–
Chromium Oxide, Cr_2O_3	–	–	–	–	3
Zirconia	–	0 - 15	–	15	–
Other	–	0 - 3	trace	trace	trace
Thermal Conductivity, BTU•in./hr•ft^2•°F *(w/mK)* (ASTM C 201)					
Mean temperature, 8pcf					
@ 500°F *(260°C)*	0.44 *(0.06)*	0.44 *(0.06)*	0.44 *(0.06)*	0.44 *(0.06)*	0.44 *(0.06)*
@ 1000°F *(538°C)*	0.87 *(0.12)*	0.93 *(0.13)*	0.93 *(0.13)*	0.93 *(0.13)*	0.93 *(0.13)*
@ 1500°F *(816°C)*	1.45 *(0.21)*	1.60 *(0.23)*	1.60 *(0.23)*	1.60 *(0.23)*	1.60 *(0.23)*
@ 1800°F *(982°C)*	1.83 *(0.26)*	2.05 *(0.30)*	2.05 *(0.30)*	2.05 *(0.30)*	2.05 *(0.30)*
@ 2000°F *(1093°C)*	2.09 *(0.30)*	–	2.34 *(0.34)*	2.34 *(0.34)*	2.34 *(0.34*
Mean temperature, 6pcf					
@ 500°F *(260°C)*	0.47 *(0.07)*	0.47 *(0.07)*	0.47 *(0.07)*	0.47 *(0.07)*	0.47 *(0.07)*
@ 1000°F *(538°C)*	1.01 *(0.15)*	1.05 *(0.15)*	1.06 *(0.15)*	1.06 *(0.15)*	1.06 *(0.15)*
@ 1500°F *(816°C)*	1.73 *(0.25)*	1.90 *(0.27)*	1.90 *(0.27)*	1.90 *(0.27)*	1.90 *(0.27)*
@ 1800°F *(982°C)*	2.19 *(0.32)*	2.45 *(0.35)*	2.45 *(0.35)*	2.45 *(0.35)*	2.45 *(0.35)*
@ 2000°F *(1093°C)*	–	2.83 *(0.41)*	2.83 *(0.41)*	2.83 *(0.41)*	2.83 *(0.41)*
Mean temperature, 4 pcf					
@ 500°F *(260°C)*	0.54 *(0.08)*	0.54 *(0.08)*	0.54 *(0.08)*	0.54 *(0.08)*	0.54 *(0.08)*
@ 1000°F *(538°C)*	1.29 *(0.19)*	1.34 *(0.19)*	1.34 *(0.19)*	1.34 *(0.19)*	1.34 *(0.19)*
@ 1500°F *(816°C)*	2.30 *(0.33)*	2.48 *(0.36)*	2.48 *(0.36)*	2.48 *(0.36)*	2.48 *(0.36)*
@ 1800°F *(982°C)*	2.96 *(0.43)*	3.23 *(0.47)*	3.23 *(0.47)*	3.23 *(0.47)*	3.23 *(0.47)*
@ 2000°F *(1093°C)*	–	–	3.74 *(0.54)*	3.74 *(0.54)*	3.74 *(0.54)*

Military Specifications and Approvals

Mil-I-23128A	3, 6 pcf blanket
Mil-I-24244	All blankets
Mil-I-23128B	6, 8 pcf blanket

Water Leachable Elements on Surface of Fiber, typical quantities, PPM

Boron	40	Sulphur	10
Chlorine	<10	Sodium	40
Fluorine	<5	Silicate	125

Acoustical performance per ASTM C-423 A and E-795, Sound Absorption Coefficient

Kaowool Blanket	**250Hz**	**500 Hz**	**1000 Hz**	**2000 Hz**	**4000 Hz**	**NRC**
1”- 4 pcf	0.29	1.00	1.04	0.99	0.98	0.85
1”- 8 pcf	0.50	0.92	0.91	0.91	0.94	0.80
2”- 4 pcf	0.92	1.01	1.01	1.03	1.10	1.00
2”- 8 pcf	0.80	0.72	0.86	0.92	1.02	0.85

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