Nextel™
Ceramic Textiles Technical Notebook

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3M™ Nextel™ Continuous Filament Ceramic Oxide Fibers 312, 440, 550, 610, and 720

Introduction

3M™ Nextel™ Continuous Filament Ceramic Oxide Fibers 312, 440, 550, 610, and 720 represent a major advancement in refractory fiber technology. These metal oxide fibers can be readily converted into textiles which meet demanding performance requirements in high temperature operating environments. Fabrics, paper, tapes, sleevings and yarn are typical products.

Additionally, the fibers have low elongation and shrinkage at operating temperatures, which allow for a dimensionally stable product to be made. These novel fibers also offer good chemical resistance, low thermal conductivity, thermal shock resistance, low porosity and unique electrical properties.

Because the filaments are continuous and strong, ceramic oxide textiles can be produced without the aid of other fibers or wire inserts.

Industrial Fibers

Nextel Ceramic Fibers 312 and 440, when converted to fabrics, tapes, sleevings, and paper are used in the aerospace, industrial, automotive, electrical and petrochemical markets as heat shields, curtains, linings, insulation, blankets and seals. Nextel Flame Stopping Dot Paper, engineered with Nextel Fiber 312, is ideal in applications where both flame barrier properties and light weight are critical.

Nextel Ceramic Fiber 550 is used in the electronic market for both insulation and seals.

Composite Fibers

Nextel Ceramic Fibers 610 and 720 are used in ceramic and metal matrix composites. Nextel Ceramic Fiber 610 is noted for it's outstanding single filament tensile properties. Nextel Ceramic Fiber 720 finds applications in ceramic matrix composites because of it's high creep resistance.

Special Note: Throughout this notebook we have used data based on typical properties of the products. If you need to develop a specification, please consult a 3M Representative. Application data has been collected from a variety of sources and may be of use for special applications.

Health & Safety Bulletin
3M™ Nextel™ 312, 440, 550, 610 & 720

Introduction
3M™ Nextel™ Ceramic Fibers are refractory aluminoborosilicate (312 & 440), aluminosilica (550 & 720), and alumina (610) fibers with diameters ranging from 7-13 microns. They are produced in continuous lengths. During manufacture, Nextel 312, 440, 550, 610, and 720 Ceramic Fibers are coated with organic sizings or finishes which serve as aids in textile processing. Nextel 312, 440, 550, 610, and 720 Ceramic Fibers pose no significant health risks under most conditions of use. Under certain conditions, however, Nextel 312, 440, 550, 610, and 720 Ceramic Fibers may cause health effects if not handled properly. The following information describes the nature of these potential hazards and gives recommended safe handling practices for minimizing the risks. Additional information is available in Material Safety Data Sheets (MSDS) and Product Toxicity Summary Sheets.

Fiber and Dust Inhalation
Although Nextel fibers are classified as ceramic fibers, they are manufactured in continuous lengths and have diameters (approximately 7 to 13 microns) which are not considered to be respirable by humans. Since they are not considered to be respirable, inhalation exposure to Nextel 312, 440, 550, 610, or 720 fibers is not expected to pose a carcinogenic risk to humans. They may, however, cause mechanical irritation of the nose and throat.

In certain operations, Nextel 312, 440, 550, 610, and 720 Ceramic Fibers may break to form a dust, particularly if the sizing has been removed or the fibers have been exposed to high temperatures. The potential for Nextel 312 Ceramic Fiber dust to cause biological effects was evaluated in an intratracheal instillation study in rats. Intratracheal instillation delivers test materials directly to the lower respiratory tract and thus bypasses the processes by which fibers and dust are normally filtered out in the upper airways when they are inhaled. In this study, Nextel 312 Ceramic Fiber dust caused lung inflammation with no evidence of more serious effects such as granulomas or fibrosis. A control group similarly exposed to quartz dust developed lung granulomas and fibrosis. From this study it was concluded that thepotential for Nextel 312 Ceramic Fiber dust to cause pulmonary fibrosis or other significant lung injury is minimal.

There is currently no specific OSHA Permissible Exposure Limit (PEL) or ACGIH Threshold Limit Value (TLV) for refractory ceramic fibers. The Refractory Ceramic Fiber Coalition (RCFC) has suggested an exposure limit of 0.5 fibers/cc for those fibers <3 microns in diameter. The RCFC suggested exposure limit is an organizational number rather than a regulatory number. However, since Nextel 312, 440, 550, 610, and 720 Ceramic Fibers are nonrespirable (fiber diameter of >3 microns), they are not covered by this suggested limit. Instead, Nextel 312, 440, 550, 610, and 720 Ceramic Fibers are covered by the OSHA PELs for "particulates not otherwise regulated" of 15 mg/m^3 as total particulate and 5 mg/m^3 as respirable particulate. In addition, these fibers are covered by the ACGIH TLVs for "particulates not otherwise classified" of 10 mg/m^3 as inhalable (total) particulate and 3 mg/m^3 as respirable particulate. Both values are 8-hour time-weighted averages. 3M recommends the ACGIH TLVs.

The EU directive 97/69/EC of December 5, 1997 is the European legal base for classification, packaging and labeling of certain man-made vitreous fibers. Laboratory studies have shown that certain man-made vitreous fibers have carcinogenic effects. Due to the fact that Nextel ceramic fibers do not meet the critical geometric dimensions for respirable fibers (note R in 97/96/EC) Nextel fibers do not have to be classified as dangerous substances according this directive.

Furthermore, the Nextel ceramic fiber diameter of 7-13 microns puts them outside the World Health Organization (WHO) definition of respirable. Fibers are defined as respirable by WHO convention if the length is greater than 5 microns and the diameter is less than 3 microns with a length to diameter ratio greater than 3:1.

Local exhaust ventilation and/or use of NIOSH approved dust mist respirators is recommended for operations where fibers or dust may become airborne. If nose or throat irritation occurs, move to fresh air.

Eye and Skin Contact
3M Nextel 312, 440, 550, 610, and 720 Ceramic Fibers can cause mechanical irritation of the eyes and skin similar to that caused by fiberglass. Safety glasses or

goggles, gloves and long sleeved clothing with tight fitting cuffs are recommended to minimize eye and skin contact. Contaminated clothing should be laundered each day. If eye irritation occurs, flush eyes with water. If skin irritation occurs, wash the affected area with soap and water and change to fresh clothing.

Heat Cleaning/Treatment

Heat cleaning Nextel 312, 440, 550, 610, & 720 Ceramic Fibers to remove the polymeric sizings and finishes or heat treatment of Nextel 312 Ceramic Fibers generates thermal decomposition products which can be hazardous if inhaled at concentrations exceeding their recommended exposure limits. Carbon monoxide and formic acid are the predominant decomposition products. By controlling carbon monoxide concentrations to the ACGIH Threshold Limit Value of 25 ppm (8 hr TWA), other decomposition products should also be adequately controlled. Control of carbon monoxide levels may be most effectively achieved through the use of exhaust ventilation, for example an exhaust enclosure or hood. The ventilation system should provide a minimum capture velocity of 150 ft /min (45,72 m/min) and should not be subject to disturbances produced by cross drafts. See the Nextel 312, 440, 550, 610, and 720 Ceramic Fiber Heat Cleaning/Heat Treating Procedure Bulletins for detailed instructions.

After Service Considerations

Analyses of Nextel 312 Ceramic Fibers, either as manufactured or after use, has shown that neither free silica nor the cristobalite form of silica is present. The silica in the fibers is present in the form of mullite, which is a stable mixture of alumina and silica. This differentiates Nextel 312 Ceramic Fibers from some other refractory ceramic fibers which when repeatedly heated to very high temperatures, >2012°F (>1100°C), may be partially converted to a form of crystalline silica.

Refer to “Fiber & Dust Inhalation” Section of this bulletin for precautions and respirator recommendations when using Nextel Ceramic Fibers.

3M™ Nextel™ Fiber Terminology

Chopped Fiber – Short lengths of fiber made by cutting continuous fiber roving. Chopped fibers are uniform in length and diameter unlike melt blown fibers.

Continuous Strand – A strand in which individual filament lengths approach the strand length.

Denier – Number of grams per 9000 meters.

End – A single strand, roving or yarn, incorporated in a product.

Fiber – Thread-like structure having a length at least 100 times its diameter, can be either definite short lengths or continuous.

Filament – A single fiber having extreme length.

Fill – Ends that run at right angles to the warp.

Finish – Material applied to fiber products to improve fiber-resin bonding, improve lubricity and high temperature abrasion, or stabilize a weave. Can contain a coupling agent.

Greige Goods – Loom state fabric; fabric that may contain sizing but no finish.

Heat Cleaning – Batch or continuous process to remove sizing.

Heat Treating – Batch or continuous process to remove sizing and change the crystal structure of the fiber improving its resistance to moisture and chemical attack.

Nonwoven Mat – An assembly of several layers of discontinuous fibers held together by mechanical interlocking in a random web.

Paper – A nonwoven made from an aqueous suspension of discontinuous fibers and binder(s).

Pick – A single strand, roving, or yarn incorporated in a product.

Plied Yarn – An assembly of two or more previously twisted yarns.

Roving – A loose assemblage of fibers in single strand, without twists.

Serving – Wrapping a yarn such as rayon around a roving or yarn for protection.

Singles – A yarn made from one or more strands twisted together but not plied. Examples: 1/0, 2/0, 4/0. Single strand construction is singles yarn made from one strand (1/0).

Sizing – Starch, oil, wax, or other suitable organic ingredient applied to a fiber strand to protect and aid handling. A sizing contains ingredients to provide lubricity and binding action. Unlike a finish, a sizing is usually removed before final product use.

Strand – An untwisted primary filament bundle, can be either continuous filament or staple fiber (sliver).

Tex – Number of grams per 1000 meters.

Twist – Twisting and/or plying strands or singles.

Warp – Ends that run lengthwise in a fabric.

Yarn – An assembly of one or more strands twisted together. Examples: 1/0, 4/0, 1/2, 2/2, 4/5.

Yield – Length of yarn per unit weight.

Nomenclature

Fiber Type	Textile Type
A=312	F=Fabric
B=440	P=Tape
C=550	T=Thread
D=610	S=Sleeving
F=720	C=Chopped
	N=Nonwoven Paper
	M=Mat

Example:

AF-30

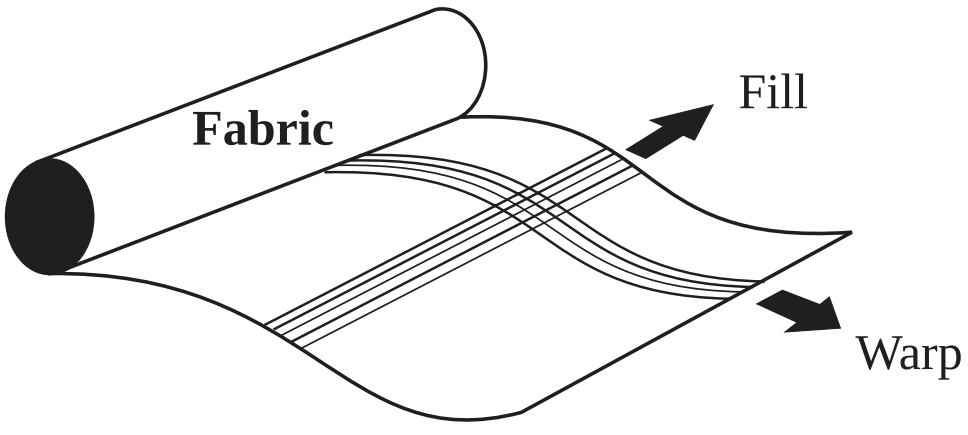
Fiber Type Textile Type Nominal Dimension

Example:

BP-18

3M™ Nextel™ Fiber 440 Tape 0.018 inch thick

Fill – Ends that run crosswise in a fabric.
Warp – Ends that run lengthwise in a fabric.



Fiber Selection Guide

3M™ Nextel™ Industrial Fibers & 3M™ Nextel™ Composite Fibers

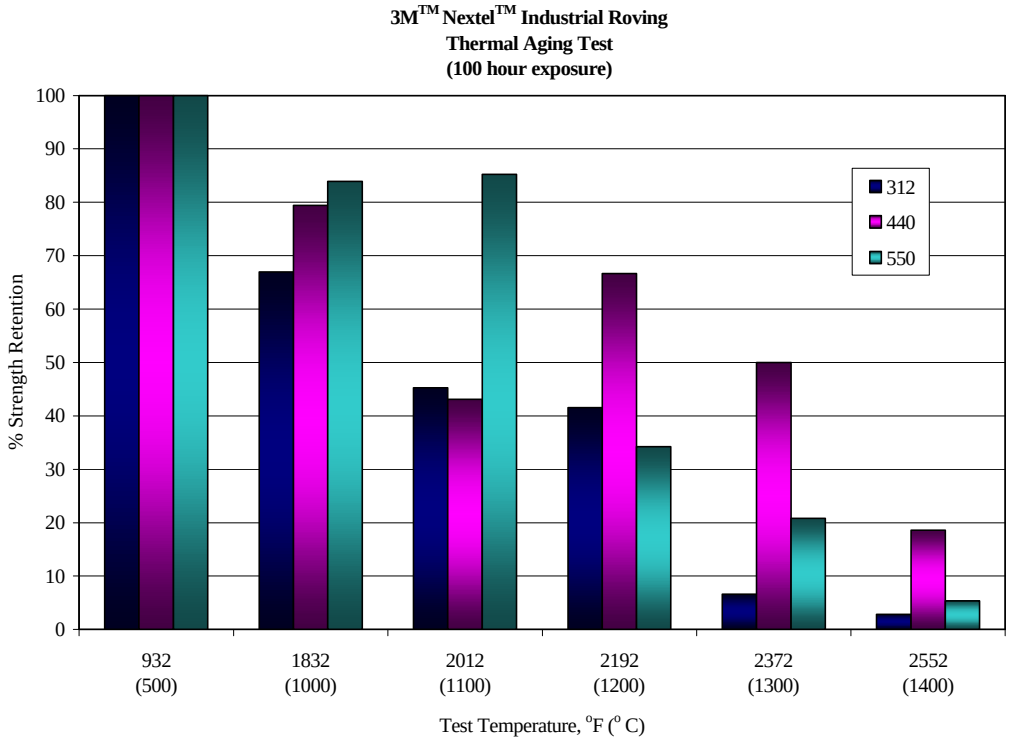
The family of 3M Nextel Fibers was developed to serve a variety of needs. 3M Nextel Fibers 312, 440, and 550 are designed for non-structural applications where their primary purpose is to insulate or to act as a flame barrier. 3M Nextel Fibers 610 and 720 are composite grade fibers designed for load bearing applications in metal, ceramic, and polymer matrices. To aid in the selection of the proper fiber for each of these different applications, the fibers are tested in a manner appropriate to their end use. The graphs that follow show the results of two different methods of testing fiber strength. In the thermal aging test, fiber break load is measured at room temperature after exposure at an elevated temperature for 100 hours. In the strength at temperature test, fiber break load and single filament tensile strength is determined while the fiber is held at temperature.

Two of the industrial fibers, 3M Nextel Ceramic Fibers 312 and 440, are made from Al_2O_3, SiO_2, and B_2O_3 at varying percentages. Because B_2O_3 is present, these compositions have both crystalline and glassy phases. The glassy phase helps the fiber retain strength after exposure to high temperature because it slows the growth of the crystalline phases that weaken the fiber. However, when the fiber is stressed at high temperature, the glassy phase weakens the fiber due to viscous flow much like a glass fiber. 3M Nextel Ceramic Fiber 550 does not contain B_2O_3 and therefore does not have a glassy phase. At exposure temperatures higher than 2192°F (1200°C), the strength of 3M Nextel Ceramic Fiber 550 is lower strength than 3M Nextel Ceramic Fiber 440 due to the formation of larger grained mullite. On the other hand, because 3M Nextel Ceramic Fiber 550 has no glassy phase it retains its strength better at temperature as is shown in the graph below where the roving is tested at temperature.

The composite grade fibers, 3M Nextel Ceramic Fibers 610 and 720, have more refined crystal structures based on α-Al_2O_3 and do not contain any glassy phases. This allows the fibers to retain their strength at higher temperatures. The at temperature strength testing (3M Nextel Composite Fibers, % Strength Retention at Temperature, Single Filament) shows the effect of adding additional components to the fiber. 3M Nextel Ceramic Fiber 610 is a fine grained single-phase composition of α-Al_2O_3. It has the highest strength at room temperature, thus making it well-suited for metal matrix composites. However, because it is essentially single phased, the strength rapidly decreases at higher temperatures due to grain growth (3M Nextel Ceramic Fiber 610 and 720 graphs of Strength Retention and Grain Size after 1000 hours Exposure). 3M Nextel Ceramic Fiber 720, which is α-Al_2O_3 with SiO_2 added (forming α-Al_2O_3 / mullite), has better strength retention at temperature due to reduced grain boundary sliding. This addition also helps to "pin" the grains and reduce grain growth when exposed to thermal aging as shown (3M Nextel Ceramic Fiber 610 and 720 graphs of Strength Retention and Grain Size after 1000 hours Exposure). Further confirmation of the effect of additional phases and removal of the glassy phase is shown in creep testing (3M Nextel Ceramic Fiber Creep Limit).

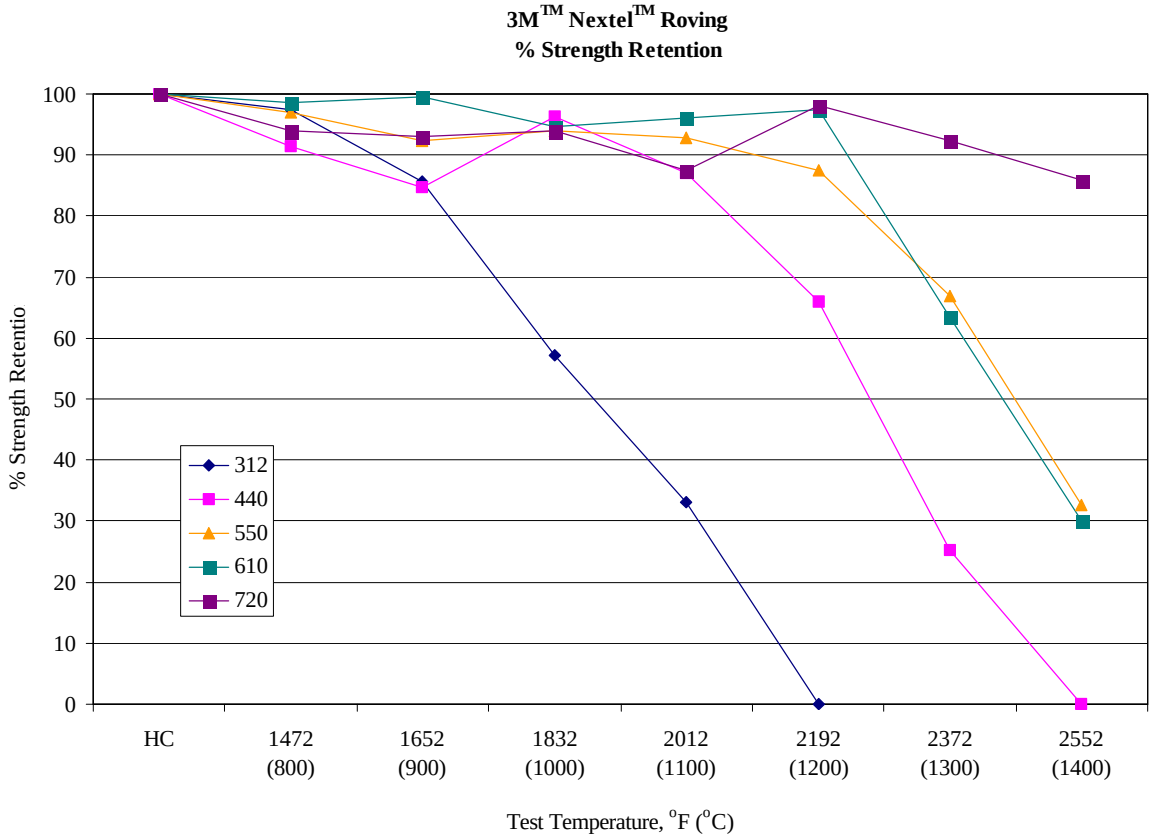
When selecting the fiber type for a particular application, it is important to consider all these factors. If the fiber/fabric will not have to support a load at temperature, the lower-cost industrial grade fibers may be appropriate. However, if the fiber will be load bearing at temperature, as in ceramic matrix composites, then one of the composite grade fibers would be a better choice. Other factors, such as corrosion,

chemical resistance, or atmospheric conditions
may influence the final selection.

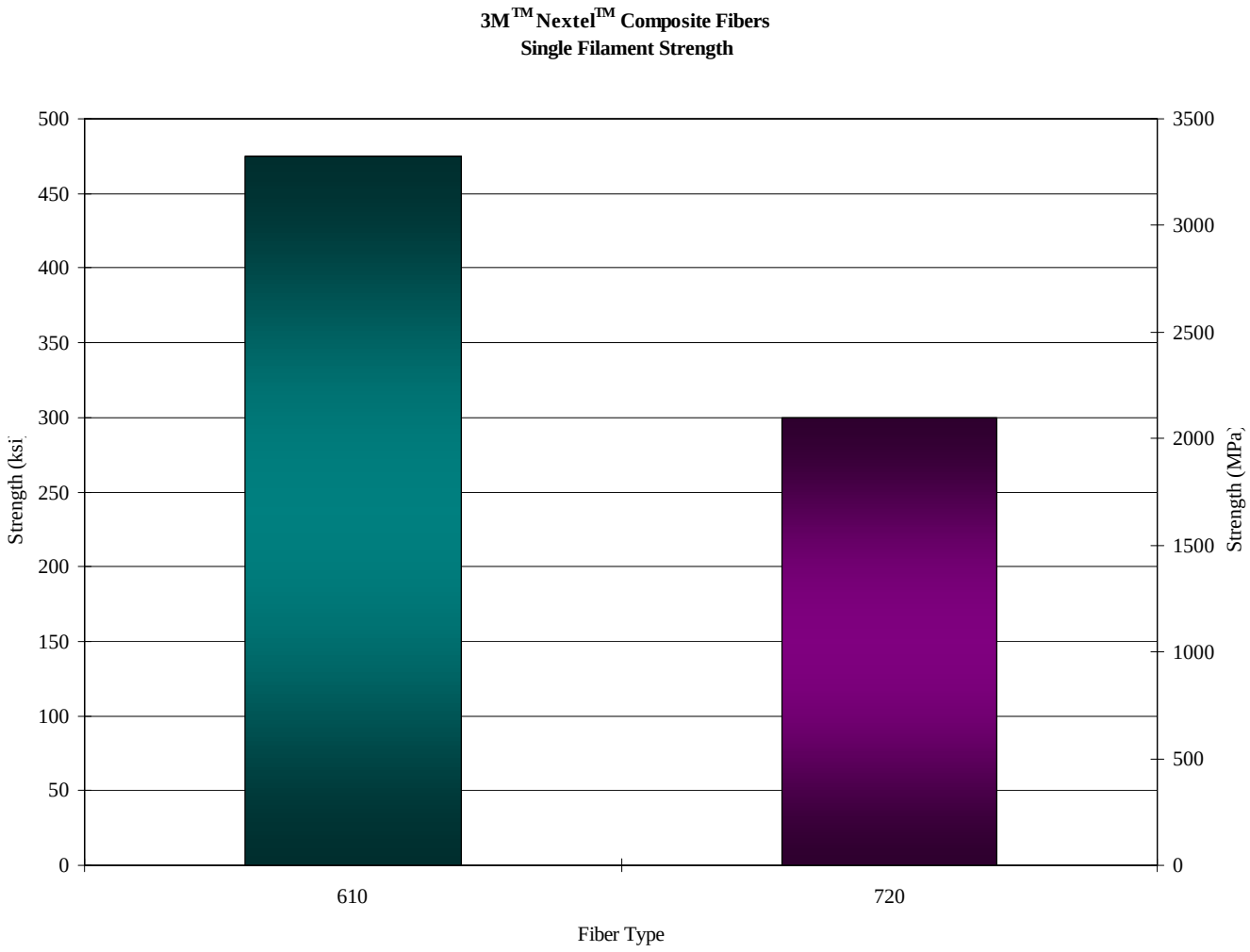


Outline of Test:
Sample Number: 5
Samples: Nextel Roving 312, 1800 denier & Nextel Roving 440 & 550, 2000 denier
Gage Length: 2 inches (5.1 cm)
Extension Rate: 0.5"/min (1.3 cm/min)

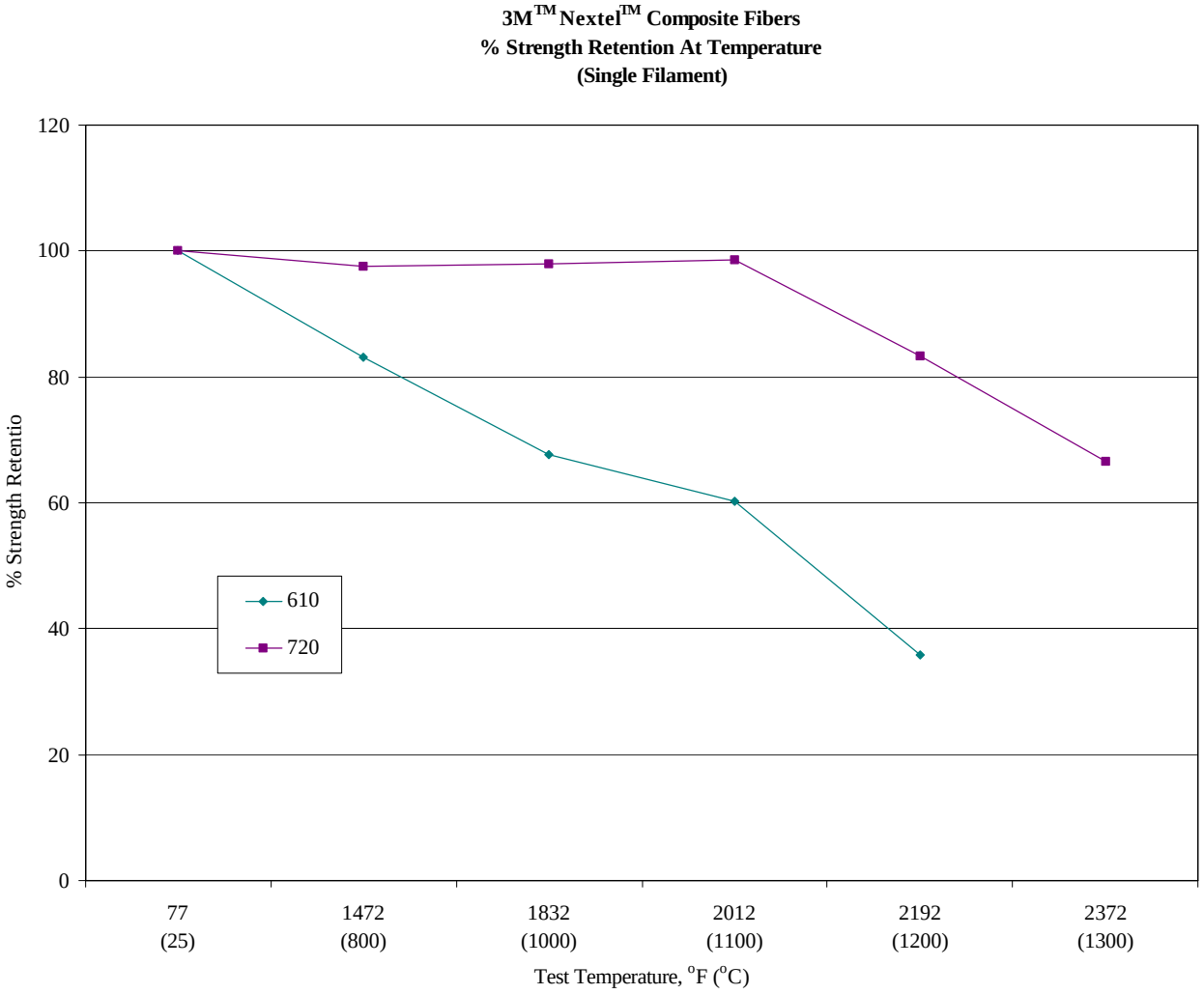
Note: All samples were heat cleaned (sizing removed) at 932°F (500°C) which represents the 100% strength bar. All the samples were wetted with DI water before testing to aid in handling.



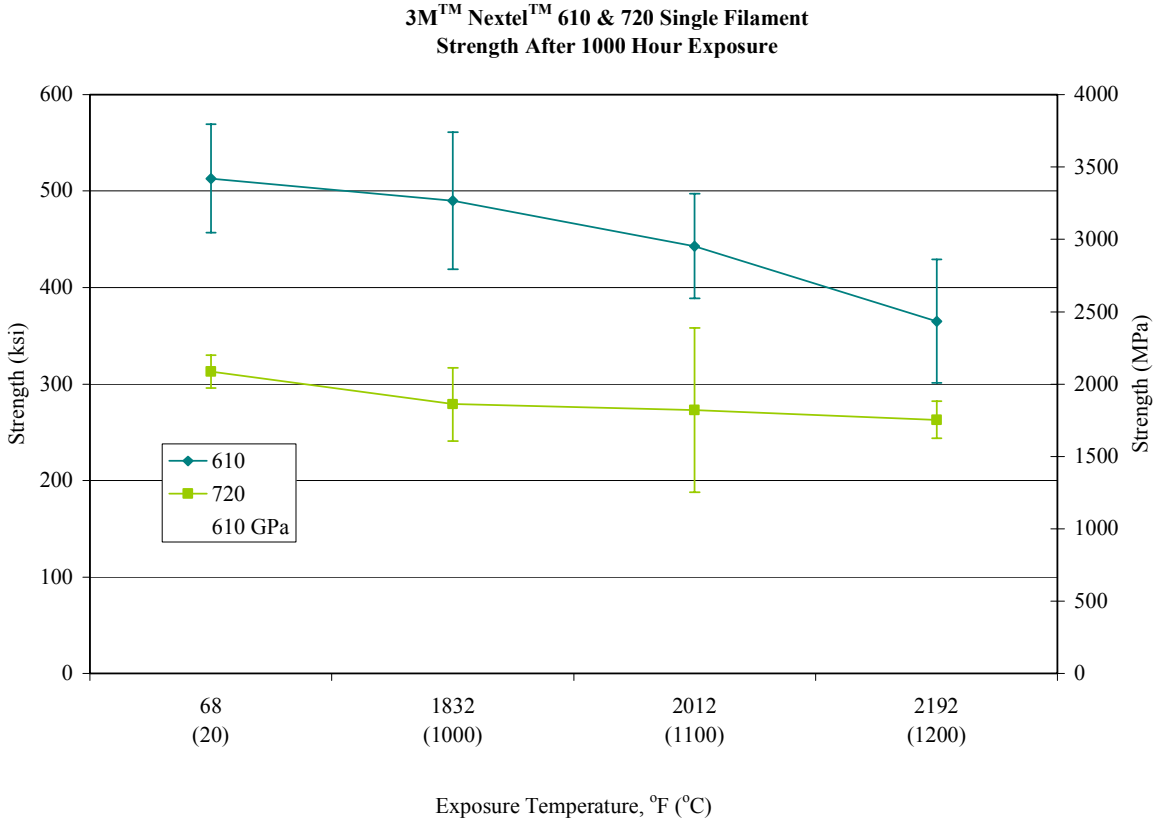
Outline of Test:
Sample Number: 10
Samples: Nextel Roving, 1500 denier (400 filaments / bundle)
Total Gage Length: 10 inches (254 mm)
Hot Zone Length: 1 inch (25,4 mm)
Extension Rate: 0.5inch/min (12.7 mm/min)
Note: Samples were held at temperature for approximately 1.5 minutes before testing.



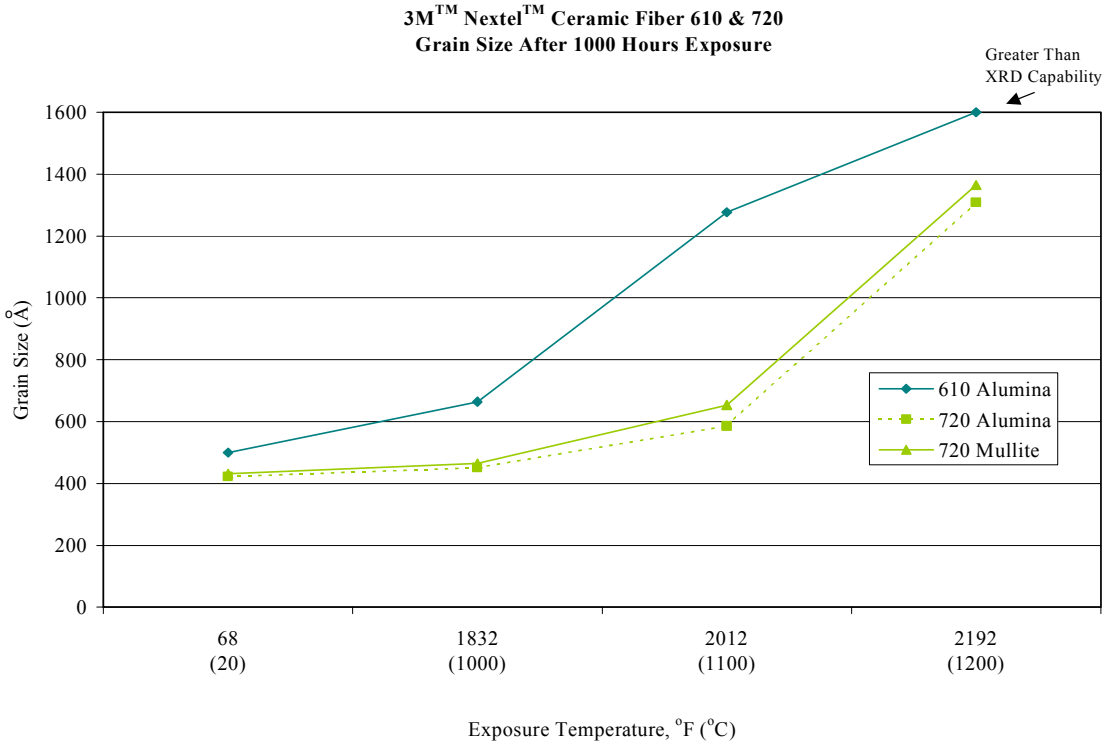
Outline of Test:
Sample Number: 10
Gage Length: 1 inch (25,4 mm)
Extension Rate: 0.2 inch/min (5.1 mm/min)



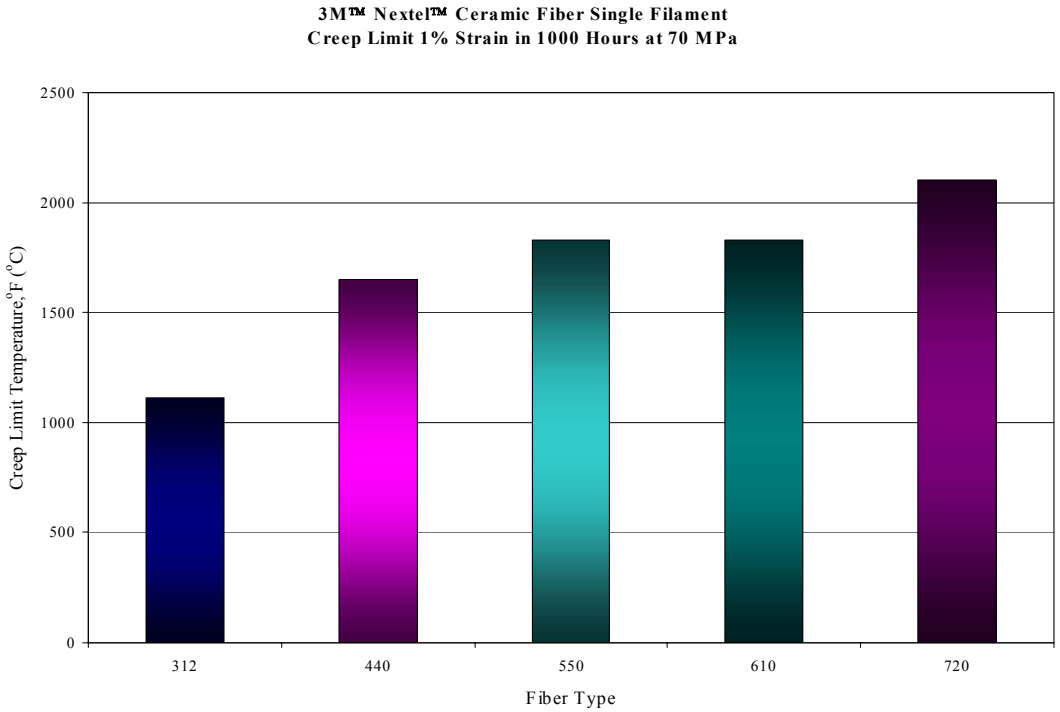
Outline of Test:
Sample Number: 10
Total Gage Length: 10 inches (254 mm)
Crosshead Speed: 0.3 inches/min (0.76 mm/min)
Hot Zone Length: 1 inch (25,4 mm)
Note: Samples were held at temperature for approximately 1.5 minutes before testing.



Outline of Test:
Sample Number: 10
Crosshead Speed: 0.02 inch/min (0.5 mm/min)
Gage Length: 1 inch (25,4 mm)



Grain size determined by X-ray diffraction.



Fiber Weight Loss

Nextel™ Ceramic Fiber Roving

Roving samples were subjected to 2192°F (1200°C) for fifteen hours. Fibers were weighed before and after the fifteen hour exposure in order to determine weight loss. The only fiber having any appreciable weight loss was Nextel Ceramic Fiber 312. The fiber evolves B_2O_3 at temperatures greater than 2012°F (1100°C).

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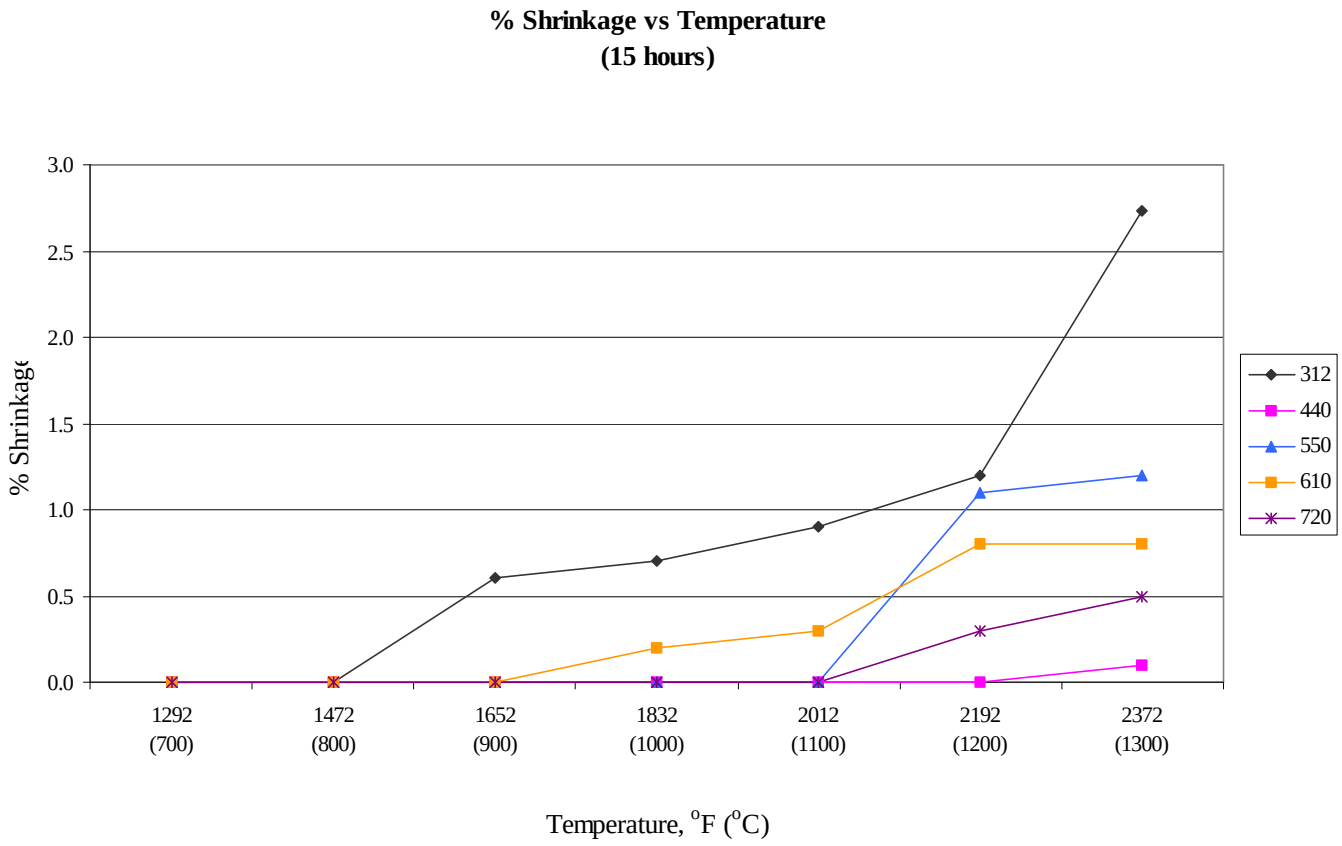
Fiber	Weight Loss %
312	2.5
440	0
550	0
610	0
720	0

Shrinkage

Roving samples were held at each temperature for fifteen hours. After that time they were measured for shrinkage. All fiber compositions showed less than three percent shrinkage after fifteen hours at 2372°F (1300°C). Fiber compositions other than Nextel™ Roving 312 showed shrinkage of less than 1.5% at these conditions.



3M™ Nextel™ Ceramic Fiber Typical Properties

3M™ Nextel™ Ceramic Fiber 312, 440, and 550

Property	Units	Nextel™ 312	Nextel™ 440	Nextel™ 550
Sizing Color	color	white	coral	blue
Chemical Composition	wt. %	62.5 Al_2O_3 24.5 SiO_2 13 B_2O_3	70 Al_2O_3 28 SiO_2 2 B_2O_3	73 Al_2O_3 27 SiO_2
Melting Point	°F (°C)	3272 (1800)	3272 (1800)	3272 (1800)
Filament Diameter	µm	10 – 12	10 - 12	10 – 12
Denier / Nominal Filament Count Tex / Nominal Filament Count	g/9000 m g/1000 m	600 / 400 900 / 400 1800 / 750 67 / 400 100 / 400 200 / 750	700 / 400 1000 / 400 2000 / 750 78 / 400 111 / 400 222 / 750	1000 / 400 2000 / 750 111 / 400 222 / 750
Crystal Size	nm	<500	<500	<500
Crystal Phase		Mullite + amorphous (or 100% amorphous)	γ-Al_2O_3 + Mullite + amorphous Si02	γ-Al_2O_3 + amorphous $Si0_2$
Density	g/cc	2.70	3.05	3.03
Refractive Index		1.568	1.614	1.602
Surface Area	m^2/g	<0.2	<0.2	<0.2
Filament Tensile Strength (25.4 mm gauge)	MPa ksi	1700 250	2000 290	2000 300
Filament Tensile Modulus	GPa msi	150 22	190 27	193 28
Thermal Expansion (100-1100°C)	ppm/°C	3 (25-500°C)	5.3	5.3
Dielectric Constant	(@ 9.375 GHz)	5.2	5.7	~5.8
Loss Tangent	(@ 9.375 GHz)	0.018	0.015	NA
Specific Heat @500°C (932°F)	cal/g/°C or BTU/lb/°F	0.25	0.27	NA

3M™ Nextel™ Ceramic Fiber Typical Properties

3M™ Nextel™ Ceramic Fiber 610 and 720

Property	Units	Nextel™ 610	Nextel™ 720
Sizing Color	color	off-white	green
Chemical Composition	wt. %	>99 Al_2O_3	85 Al_2O_3 15 SiO_2
Melting Point	°F (°C)	3632 (2000)	3272 (1800)
Filament Diameter	µm	10 - 12	10 - 12
Denier / Nominal Filament Count	g/9000 m	1500/400 3000/750 10000/2550	1500/400 3000/750
Tex / Nominal Filament Count	g/1000 m	167/400 333/750 1111/2550	167/400 333/750
Crystal Size	nm	<500	<500
Crystal Phase		α-Al_2O_3	α-Al_2O_3 + Mullite
Density	g/cc	3.9	3.40
Refractive Index		1.74	1.67
Surface Area	m^2/g	<0.2	<0.2
Filament Tensile Strength (25.4 mm gauge)	MPa ksi	3100 450	2100 300
Filament Tensile Modulus	GPa msi	380 55	260 36
Thermal Expansion (100-1100°C)	ppm/°C	8.0	6.0
Dielectric Constant	(@ 9.375 GHz)	~9.0	~5.8
Loss Tangent	(@ 9.375 GHz)	NA	NA
Specific Heat @500°C (932°F)	cal/g/°C or BTU/lb/°F	TBD	TBD

Sizing

Sizing is a processing aid applied to rovings and yarns to provide lubricity and binding action to protect the fibers and assist in handling.

299 and 399 Sizing
This 100% organic sizing, composed of polyvinyl alcohol (PVA) and additives (plasticizers, lubricants, etc.), is designed for easy removal by heat cleaning.

A pigment has been added to some of the sizing chemistry of some products to aid in identification. Both the pigment and the sizing will decompose upon heat cleaning. Standard product colors are:

Product	Color
312	White
440	Coral
550	Blue
610	Off-White
720	Green

Heat cleaning is used to remove all of the organic coatings from the surface of the 3M™ Nextel™ Fibers. This is important in applications where fabrics are going to be impregnated with resin for polymer composite applications. Heat cleaning is also used when Nextel Materials are coated with silicone rubber since sizing will inhibit the cure of the silicone. Heat cleaning is recommended when Nextel™ Ceramic Fabric is to be used as electrical insulation, (thermocouples, heaters, etc.), under reducing atmosphere or vacuum conditions. Under these conditions the 299/399 sizing decomposes to a conductive carbon layer and may cause electrical shorts.

See Electrical Insulation Resistance (p. 43) for further details.

222 Sizing
This sizing consists of a proprietary inorganic coating, which lubricates and protects the fiber during twisting and braiding. This produces a fiber that is tan in color. The 222 sizing has been found to be useful in electrical applications where it is undesirable to heat clean the product to remove organic coatings. Organic coatings decompose to conductive carbon in neutral or reducing atmospheres when heated above 932°F (500°C).

See Electrical Insulation Resistance (p. 43) for further details.

3M™ Nextel™ Roving and Yarn 312

3M™ Nextel™ Roving 312 – Typical Properties *Color: White*

Roving	Nominal Filament Count	Yield ± 10% yds/lb	Yield ± 10% m/kg	Breaking Load* lbs	Breaking Load* kg
600 denier (67 tex)	400	7420	14950	6	2,7
900 denier (100 tex)	400	4950	9970	7	3,2
1200 denier (133 tex)	750	3720	7490	12	5,4
1800 denier (200 tex)	750	2480	4990	14	6,4
3600 denier (400 tex)	1375	1240	2500	24	10,9

3M™ Nextel™ Served Roving 312 – Typical Properties *Color: White*

Roving	Nominal Filament Count	Yield ± 10% yds/lb	Yield ± 10% m/kg	Breaking Load* lbs	Breaking Load* kg
600 denier (67 tex)	400	6300	12700	7	3,2
900 denier (100 tex)	400	4300	8670	9	4,1

3M™ Nextel™ Plied Yarn 312 – Typical Properties *Color: White*

Yarn	Ends	Diameter in	Diameter mm	Yield ± 10% yds/lb	Yield ± 10% m/kg	Breaking Load* lbs	Breaking Load* kg
600 denier (67 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.007	0,18	3590	7240	14	6,4
900 denier (100 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.010	0,25	2390	4820	19	8,6
1/3	3	0.014	0,36	1580	3190	29	13,2
2/2	4	0.016	0,41	1180	2380	35	15,9
1/5	5	0.019	0,48	950	1920	43	19,5
2/3	6	0.024	0,61	780	1570	53	24,0
3/4	12	0.034	0,86	390	790	99	44,9
4/5	20	0.052	1,32	230	460	150	68,0
3/8	24	0.054	1,37	195	390	160	72,6
1800 denier (200 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.016	0,41	1190	2400	32	14,5
1/3	3	0.021	0,53	790	1590	45	20,4
1/4	4	0.026	0,66	590	1190	63	28,6
2/2	4	0.028	0,71	590	1190	57	25,9
2/3	6	0.034	0,86	390	790	89	40,4
2/5	10	0.050	1,27	230	460	150	68,0
2/6	12	0.054	1,37	195	390	145	65,8

Note: Yields and breaking loads are based upon sized rovings and yarns. The allowable range in add-ons for sizing is 1.1 to 3.0% by weight. An inorganic sizing is available on any 900 denier or 1800 denier Nextel Plied Yarn 312.

* Tested at room temperature.

** The allowable tolerance on final twist is ± 30%. Other twist levels available.

3M™ Nextel™ Plied Yarn 312 with 222 Sizing – Typical Properties *Color: Tan*

Yarn	Ends	Diameter		Yield ± 10%		Breaking Load*	
		in	mm	yds/lb	m/kg	lbs	kg
900 denier (100 tex) 2.7 Twists/inch (106 Twists/m)**							
1/4	4	0.015	0,38	1190	2400	27	12,2
1800 denier (200 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.016	0,41	1190	2400	21	9,5
3600 denier (400 tex) 2.7 Twists/inch (106 Twists/m)**							
2/5	10	0.073	1,85	120	240	165	74,8

3M™ Nextel™ Roving and Yarn 440

3M™ Nextel™ Roving 440 – Typical Properties *Color: Coral*

Roving	Nominal Filament Count	Yield ± 10%		Breaking Load*	
		yds/lb	m/kg	lbs	kg
700 denier (78 tex)	400	6350	12800	7	3,2
1000 denier (111 tex)	400	4460	8990	9	4,1
2000 denier (222 tex)	750	2230	4490	14	6,4

3M™ Nextel™ Plied Yarn 440 – Typical Properties *Color: Coral*

Yarn	Ends	Diameter		Yield ± 10%		Breaking Load*	
		in	mm	yds/lb	m/kg	lbs	kg
700 denier (78 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.007	0,18	3000	6050	15	6,9
1/4	4	0.013	0,33	1530	3080	27	12,2
1000 denier (111 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.010	0,25	2150	4330	20	9,1
2/2	4	0.017	0,43	1070	2160	35	15,9
3/4	12	0.036	0,91	350	710	95	43,1
2000 denier (222 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.016	0,41	1065	2150	34	15,4
2/5	10	*0.047*	1,19	210	420	140	63,5

Note: All yields are based upon sized rovings and yarns. The allowable range in add-ons for sizing is 1.1 to 3.0% by weight. An inorganic sizing is available on any 900 denier or 18000 denier Nextel Plied Yarn 312.

* Tested at room temperature.

** The allowable tolerance on final twist is ± 30%. Other twist levels available.

3M™ Nextel™ Roving and Yarn 550

Nextel Roving 550 – Typical Properties ***Color: Blue***

Roving	Nominal Filament Count	Yield ± 10%		Breaking Load*	
		yds/lb	m/kg	lbs	kg
1000 denier (111 tex)	400	4460	8990	9	4,1
2000 denier (222 tex)	750	2230	4490	14	6,4

3M™ Nextel™ Plied Yarn 550 – Typical Properties ***Color: Blue***

Yarn	Ends	Diameter		Yield ± 10%		Breaking Load*	
		in	mm	yds/lb	m/kg	lbs	kg
1000 denier (111 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.010	0,25	2150	4330	21	9,5
2000 denier (222 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.017	0,43	1070	2160	36	16,3

3M™ Nextel™ Roving and Yarn 610

3M™ Nextel™ Roving 610 – Typical Properties ***Color: Off-White***

Roving	Nominal Filament Count	Yield ± 10%		Breaking Load*	
		yds/lb	m/kg	lbs	kg
1500 denier (167 tex)	400	2930	5910	11	5,0
3000 denier (333 tex)	750	1490	3000	25	11,3
10000 denier (1111 tex)***	2550	450	910	TBD****	TBD****

3M™ Nextel™ Plied Yarn 610 – Typical Properties ***Color: Off-White***

Yarn	Ends	Diameter		Yield ± 10%		Breaking Load*	
		in	mm	yds/lb	m/kg	lbs	kg
1500 denier (167 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.010	0,25	1420	2860	20	9,1
2/2	2	0.017	0,43	710	1430	38	17,2

Note: All yields are based upon sized rovings and yarns. The allowable range in add-ons for sizing is 1.1 to 3.0% by weight. The allowable tolerance on final twist is ± 30%.

* Tested at room temperature.
** The allowable tolerance on final twist is ± 30%. Other twist levels available.
*** Experimental product.
**** TBD – To be determined.

3M™ Nextel™ Roving 720

3M™ Nextel™ Roving 720 – Typical Properties ***Color: Green***

Roving	Nominal Filament Count	Yield ± 10% yds/lb	Yield ± 10% m/kg	Breaking Load* lbs	Breaking Load* kg
1500 denier (167 tex)	400	2950	5950	6	2,7
3000 denier (333 tex)**	750	1490	3000	10	4,5

Note: All yields are based upon sized rovings and yarns. The allowable range in add-ons for sizing is 1.1 to 3.0% by weight. The allowable tolerance on final twist is ± 30%.

* Tested at room temperature.
** Experimental product.

3M™ Nextel™ Chopped Ceramic Fiber

Rovings may be chopped to specified length. The following table lists standard fibers and lengths. Other fibers and lengths may be chopped by special request.

Designation	***Cut Length***
AC-8 AC-11	1/8, 1/4 and 1/2 inch (3,2, 6,4, 12,7 mm)

3M™ Nextel™ Sewing Thread

3M™ Nextel™ Sewing Threads are a combination of Nextel Ceramic Fibers and rayon fibers. The rayon fibers impart resiliency and abrasion resistance to the threads to improve sewability.

The rayon is heat fugitive, i.e., the fibers decompose at temperatures above approximately 572°F (300°C). The amount of rayon in the thread is about 5% by weight.

3M™ Nextel™ Sewing Thread 312 – Typical Properties

		Style AT-21*		**Style AT-30**	
Diameter		0.019 inch	0,48 mm	0.028 inch	0,71 mm
Approximate Yield		1570 yd/lb	3160 m/kg	810 yd/lb	1630 m/kg
Breaking Strength	With Sizing	27 lb	12,2 kg	47 lb	21,3 kg
	Heat Cleaned	10 lb	4,5 kg	15 lb	6,8 kg
Knot Strength	With Sizing	5 lb	2,3 kg	14 lb	6,4 kg
	Heat Cleaned	3 lb	1,4 kg	8 lb	3,6 kg
Seam Strength	With Sizing	40 lb/in	7,1 kg/cm	*TBD*	*TBD*
	Heat Cleaned	18 lb/in	3,2 kg/cm		

3M™ Nextel™ Sewing Thread 440 – Typical Properties

		Style BT-30	
Diameter		0.029 inch	0,74 mm
Approximate Yield		710 yd/lb	1430 m/kg
Breaking Strength	With Sizing	44 lb	20,0 kg
	Heat Cleaned	25 lb	11,3 kg
Knot Strength	With Sizing	6 lb	2,7 kg
	Heat Cleaned	6 lb	2,7 kg
Seam Strength	With Sizing	TBD	TBD
	Heat Cleaned		

Test Methods:
1) Yield – ASTM D578
2) Thread Diameter – ASTM D578, Sec. 14 [except 3/8 inch diameter presser foot, 2 psi pressure].
3) Breaking Strength – ASTM D2256
4) Knot Strength – ASTM D2256
5) Seam Strength – 4 inch sample width, 4.5 stitches per inch, Type 301 lockstitch; 0.2 inch/minute crosshead rate; 2.5 inch jaw separation

*Non-standard item; available by special order.

3M™ Sewing Thread

3M Sewing Threads are manufactured from high temperature continuous glass fiber. Laboratory testing has shown the product to maintain strength at temperatures up to 1400°F (760°C). The sewing thread is coated with PTFE to improve sewability. This coating decomposes at elevated temperatures. 3M Sewing Threads, Style GT, can be used on most shuttle bobbin and rotary hook industrial sewing machines which have the capability of handling large threads of 0.023 inch (0,058 cm) diameter.

3M™ Sewing Thread – Typical Properties

		Style GT-15		Style GT-23	
Diameter		0.017 in	0,43 mm	0.022 in	0,56 mm
Approximate Yield		2080 yd/lb	4190 m/kg	1260 yd/lb	2540 m/kg
Breaking Strength	With Sizing	30 lb	14,0 kg	47 lb	21,3 kg
	Heat Cleaned	16 lb	7,3 kg	27 lb	12,2 kg
Knot Strength	With Sizing	12 lb	5,4 kg	19 lb	8,6 kg
	Heat Cleaned	8 lb	3,6 kg	14 lb	6,4 kg
Seam Strength	With Sizing	70 lb/in	12,5 kg/cm	117 lb/in	20,9 kg/cm
	Heat Cleaned	19 lb/in	3,4 kg/cm	26 lb/in	4,6 kg/cm

3M™ Nextel™ Sewing Thread and 3M™ Sewing Thread

Machine Sewing Instructions

3M™ Nextel™ Sewing Threads 312 and 440 are machine sewable threads used for fabricating high temperature sewn parts. The following should assist you in machine setup.

Recommended Sewing Machines
Singer, 7 Class 31, 33, 34, 97-10 Adler, 7 Class 104, 105, 204, 205 Consew, 733R.

The above are all shuttle bobbin machines capable of handling very large threads without machine modification. Large rotary hook machines have been used to sew Nextel Materials, but they are not recommended. They require modification, and the rotary hook action can cause damage to the thread and reduce seam strengths.

Thread Lubrication
These Nextel Sewing Threads are precoated with an organic lubricant and need no soaking or further lubrication on the machine. Adding lubricants such as silicone, PTFE, or soap may damage the high temperature properties of the thread.

Note: The coating on Nextel Sewing Thread 312 and 440 may decompose to hazardous by-products when heated. Heat Processing to remove coatings must be done with local exhaust ventilation, e.g., a hood which provides a minimum capture velocity of 150 feet (45,72 m) per minute. See our Heat Cleaning Instructions and our Health and Safety Bulletin for more information.

Machine Set up and Operation
Needle, Size 21-30
A size 26 is the preferred needle size for Style BT-30. This size allows the thread to pass through the needle eye and slot with a minimum of damage.

Thread Tension
Upper (needle side) tension should be measured after the tension device just before the take-up arm. For most fabric-to-fabric sewing this tension should be 0,4 to 0,7 kg. A setting of 0,6 kg is recommended as a starting point.

The lower (bobbin side) tension should be measured coming out of the thread plate. For most fabric-to-fabric sewing, this tension should be 0,4 to 0,7 kg. A setting of 0,4 kg is recommended as a starting point.

Preferred Stitch
Federal Standard Stitch Type 301 lock is recommended. Using this stitch type with an unbalanced bobbin tension, which allows the bobbin thread and stitch junction to remain on the bobbin side of the fabric surface, is suggested for fabric-to-fabric sewing. When quilting or sewing multiple layer parts, a buried stitch may be desired.

Stitch Length
3.7 to 7.0 stitches per inch (1.5 – 2.8 stiches per cm) is recommended. More stitches per inch may damage both thread and fabric and result in an excessive number of thread breaks.

Foot Pressure
The standard medium-range adjustment on the pressure foot assembly on 7-class machines for fabric-to-fabric sewing is usually sufficient. If the pressure is too low, slipping will occur and a short stitch length and abrasion to the fabric will be noticed. An overly high foot pressure will crush and break the fibers in the Nextel Fabric.

When sewing multiple layers or quilted parts, pressure on the foot may need adjusting depending on the part requirements.

Speed

If the above recommendations for machine, type, tensions, needle size and adjustments are followed, an operating speed of 550 stitches per minute should be attained. Slower speeds may be necessary if the thread is being sewn through many layers of fabric or thick blankets. Also, during initial machine setup, slower speeds will be required while adjusting tensions.

Deburring

All nicks, burrs, and sharp edges must be removed from the thread guides, tension devices, spring arm, take-up arm, needle guide, needle eye, throat plate, feed dog and hook. Any of these parts which show a worn groove must be replaced. Emery cord and emery paper may be used for this work.

3MÔ NextelÔ Woven Ceramic Fabrics

Woven ceramic fabrics and woven industrial fabrics from 3M allow engineers and designers with high temperature applications to create new, imaginative solutions for previously impossible problems.

3M™ Nextel™ Woven Ceramic Fabrics are designed to meet the toughest thermal, mechanical and electrical performance requirements. Nextel Woven Ceramic Fabrics outperform the useful limits of other high temperature textiles such as aramids, carbon, glass or quartz. Nextel Woven Ceramic Fabrics are engineered to perform at continuous temperatures up to 2200°F (1204°C).

When used in industrial furnaces, Nextel Woven Ceramic Fabrics can serve as thermal barriers to separate different temperature zones or the fabrics can serve to prevent particulate shedding.

Some typical applications of Nextel Woven Ceramic Fabrics are as follows:

Application	**Fabric**				
	3MÔ NextelÔ Woven Fabric				
	312	**440**	**550**	**610**	**720**
Aerospace					
Radomes	✓	✓			
Thermal shields	✓	✓			
Micrometeorite debris shields	✓				
Ceramic-matrix composites			✓	✓	✓
Metal-matrix composites				✓	
Polymer-matrix composites	✓			✓	✓
Automotive	✓				
Electronic					
Diffusion furnaces			✓		
Industrial					
Furnace linings Galvanized steel furnaces Porcelain furnaces	✓	✓			
Furnace zone dividers	✓	✓			
Door seals	✓	✓		✓	
Tube seals	✓	✓			
Gaskets	✓	✓			
Expansion joints	✓				

3M™ Nextel™ Woven Fabric 312 - Typical Properties

Style	Weight (Sized)	Available Width	Thickness (Sized)	Thread Count Warp	Thread Count Fill	Yarn Type	Air Permeability w/o Sizing	Weave	Breaking Strength without Sizing* Warp	Breaking Strength without Sizing* Fill
	oz/yd^2 (g/m^2)	inch (m)	inch (mm)	per inch (cm)	per inch (cm)		$ft^3/min/ft^2$ ($l/min/dm^2$)		lb/inch (kg/cm)	lb/inch (kg/cm)
Industrial										
AF-10	8.6 (292)	38 (0,97)	0.015 (0,38)	46 (18)	46 (18)	600d served roving	15 (46)	5 harness satin	115 (20)	140 (25)
AF-11	7.6 (258)	38 (0,97)	0.010 (0,25)	24 (9)	23 (9)	1200d roving	40 (122)	Plain	120 (21)	135 (24)
AF-12	8.1 (275)	58 (1,47)	0.013 (0,33)	25 (10)	25 (10)	1200d roving	15 (46)	5 harness satin	130 (23)	150 (27)
AF-14	9.0 (305)	38 (0,97)	0.014 (0,36)	20 (8)	17 (7)	900d 1/2	30 (91)	Plain	150 (27)	135 (24)
AF-20	13.4 (454)	36 (0,91)	0.020 (0,51)	30 (12)	26 (10)	1800d roving	15 (46)	5 harness satin	170 (30)	150 (27)
AF-30	17.6 (597)	36 (0,91)	0.030 (0,76)	19 (7)	18 (7)	1800d 1/2	50 (152)	Crowfoot satin	200 (36)	180 (32)
AF-40	24.0 (814)	36 (0,91)	0.037 (0,94)	32 (13)	20 (8)	1800d 1/2	35 (107)	5 harness satin	300 (54)	190 (34)
AF-62	29.5 (1000)	4, 12, 30 (0,10; 0,30; 0,76)	0.054 (1,37)	40 (16)	20 (8)	1800d 1/2	100 (305)	Plain double layer	260 (46)	190 (34)
Aerospace										
AF-10	8.6 (292)	38 (0,97)	0.015 (0,38)	46 (18)	46 (18)	600d served roving	75 (229)	5 harness satin	220 (39)	220 (39)
AF-10 w/o sizing	7.2 (244)	38 (0,97)	0.010 (0,25)	46 (18)	46 (18)	600d served roving	15 (46)	5 harness satin	115 (20)	140 (25)
AF-11	7.6 (258)	38 (0,97)	0.010 (0,25)	24 (9)	23 (9)	1200d roving	75 (229)	Plain	140 (25)	140 (25)
AF-11 w/o sizing	7.4 (251)	38 (0,97)	0.009 (0,23)	24 (9)	23 (9)	1200d roving	40 (122)	Plain	120 (21)	135 (24)
AF-12	8.1 (275)	58 (1,47)	0.013 (0,33)	25 (10)	25 (10)	1200d roving	100 (305)	5 harness satin	220 (39)	220 (39)
AF-12 w/o sizing	7.9 (268)	58 (1,47)	0.011 (0,28)	25 (10)	25 (10)	1200d roving	15 (46)	5 harness satin	130 (23)	150 (27)

* Tested at room temperature.

3MÔ NextelÔ Woven Fabrics 440 - Typical Properties

Style	Weight (Sized)	Available Width	Thickness (Sized)	Thread Count Warp	Thread Count Fill	Yarn Type	Air Permeability w/o Sizing	Weave	Breaking Strength without Sizing* Warp	Breaking Strength without Sizing* Fill
	oz/yd^2 (g/m^2)	inch (m)	inch (mm)	per inch (cm)	per inch (cm)		ft^3/min/ft^2 (l/min/dm^2)		lb/inch (kg/cm)	lb/inch (kg/cm)
BF-20	14.9 (505)	36 (0,91)	0.020 (0,51)	30 (12)	26 (10)	2000d roving	15 (46)	5 harness satin	250 (45)	220 (39)
BF-30	20.4 (692)	36 (0,91)	0.030 (0,76)	21 (8)	20 (8)	2000d 1/2	35 (107)	Crowfoot satin	290 (52)	260 (46)
BF-40	26.4 (895)	36 (0,91)	0.038 (0,97)	32 (13)	20 (8)	2000d 1/2	35 (107)	5 harness satin	340 (61)	260 (46)

3MÔ NextelÔ Woven Fabric 550 - Typical Properties

Style	Weight (Sized)	Available Width	Thickness (Sized)	Thread Count Warp	Thread Count Fill	Yarn Type	Air Permeability w/o Sizing	Weave	Breaking Strength without Sizing* Warp	Breaking Strength without Sizing* Fill
	oz/yd^2 (g/m^2)	inch (m)	inch (mm)	per inch (cm)	per inch (cm)		ft^3/min/ft^2 (l/min/dm^2)		lb/inch (kg/cm)	lb/inch (kg/cm)
CF-40	27.6 (936)	36 (0,91)	0.037 (0,94)	32 (13)	20 (8)	2000d 1/2	35 (107)	5 harness satin	340 (61)	260 (46)

3MÔ NextelÔ Woven Fabrics 610 and 720 - Typical Properties

Style	Weight (Sized)	Available Width	Thickness (Sized)	Thread Count Warp	Thread Count Fill	Yarn Type	Air Permeability w/o Sizing	Weave	Breaking Strength without Sizing* Warp	Breaking Strength without Sizing* Fill
	oz/yd^2 (g/m^2)	inch (m)	inch (mm)	per inch (cm)	per inch (cm)		ft^3/min/ft^2 (l/min/dm^2)		lb/inch (kg/cm)	lb/inch (kg/cm)
610 DF-11	11.0 (373)	36 (0,91)	0.011 (0,28)	27.5 (11)	27.5 (11)	1500d roving	20 (61)	8 harness satin	230 (41)	260 (46)
610 DF-19	19.3 (654)	36 (0,91)	.019 (0,48)	23.5 (9)	23.5 (9)	3000d roving	13 (40)	8 harness satin	300 (54)	260 (46)
720 XN-513	11.2 (380)	36 (0,91)	0.013 (0,33)	27.5 (11)	27.5 (11)	1500d roving	20 (61)	8 harness satin	160 (29)	160 (29)
720 XN-625	18.8 (637)	36 (0,91)	0.022 (0,56)	23.5 (9)	23.5 (9)	3000d roving	30 (91)	8 harness satin	180 (32)	180 (32)

* Tested at room temperature.

Warp and Fill Breaking Load at Room Temperature

3M™ Nextel™ Woven Fabrics 312 and 440

Warp and fill breaking loads were measured at room temperature using the following procedure, based upon ASTM D-5035:

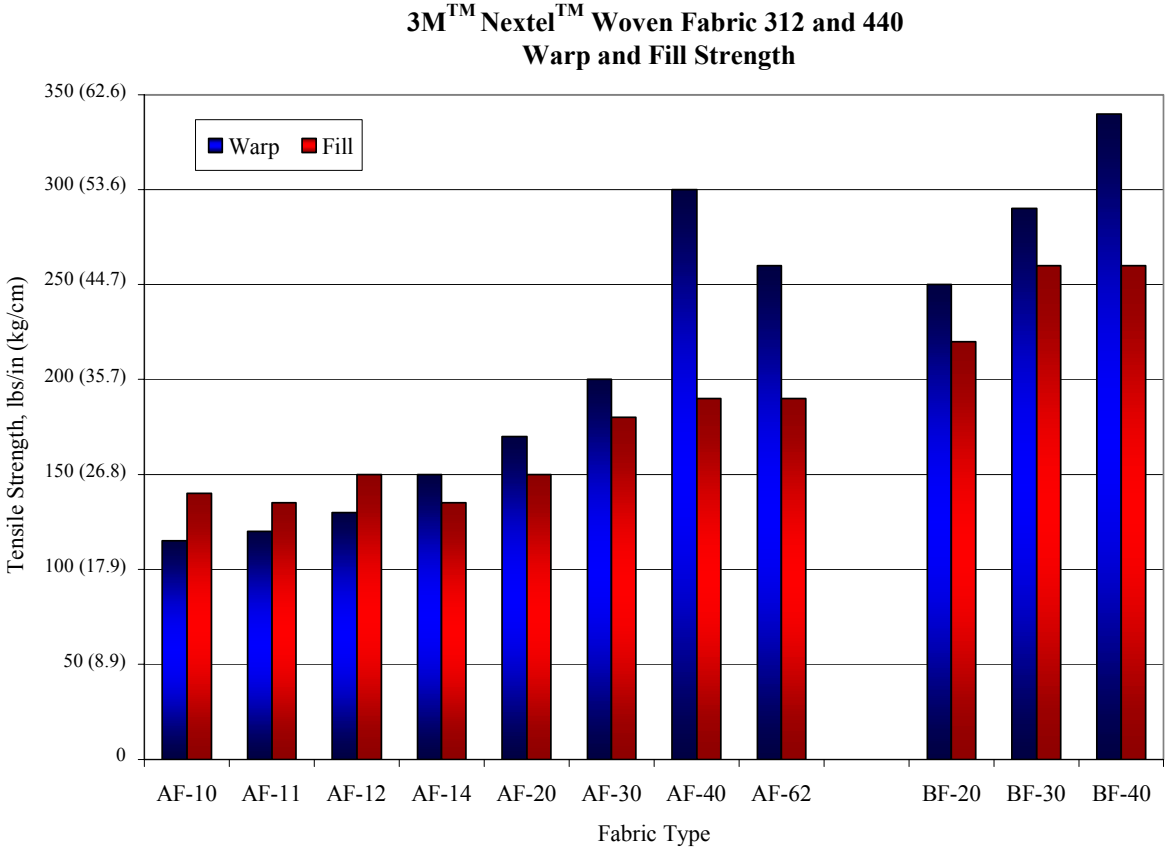
Fabric samples were cut into 1.5 inch x 6 inch (3.81 cm x 15.24 cm) strips in the warp and fill directions, respectively. Strips were placed in a 1472°F (800°C) oven for one hour to remove the sizing.

Edges were unraveled to 1 inch (2.54 cm). Masking tape was placed at each end with 3 inches (7,62 cm) test area exposed between taped areas.

The tensile tester was set up with a 3 inch (7.62 cm) gauge length and a crosshead speed of 0.5 inch (1.27 cm) per minute.

Fabric was placed into the jaws fitted with 1 inch (2.54 cm) pads. Air pressure was set at 60-80 psi ($4.14 \times 10^5 - 5.51 \times 10^5$ Pa).

Each sample was loaded until failure. Five samples of each fabric were tested at room temperature. The averages are shown below.



Hot Face vs. Cold Face Temperature

3M™ Nextel™ Woven Fabrics 312 & 440

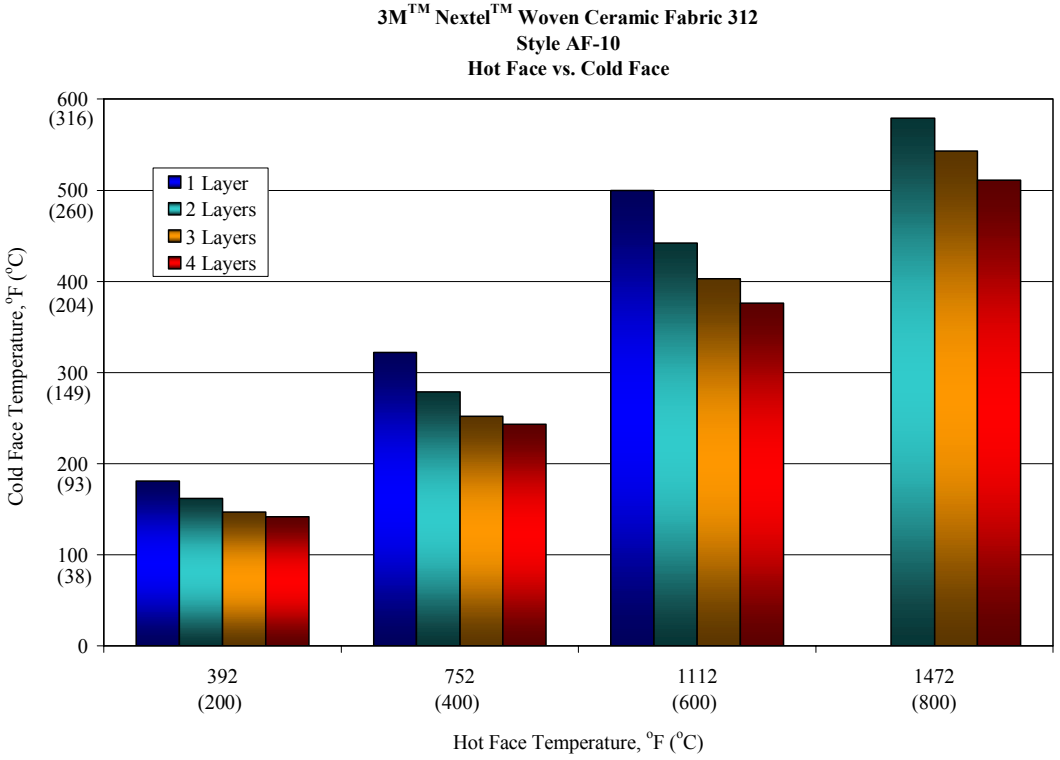
Hot face versus cold face temperature tests were conducted on samples of one through four layers of heat cleaned 3M Nextel Ceramic Fabrics 312 and 440.

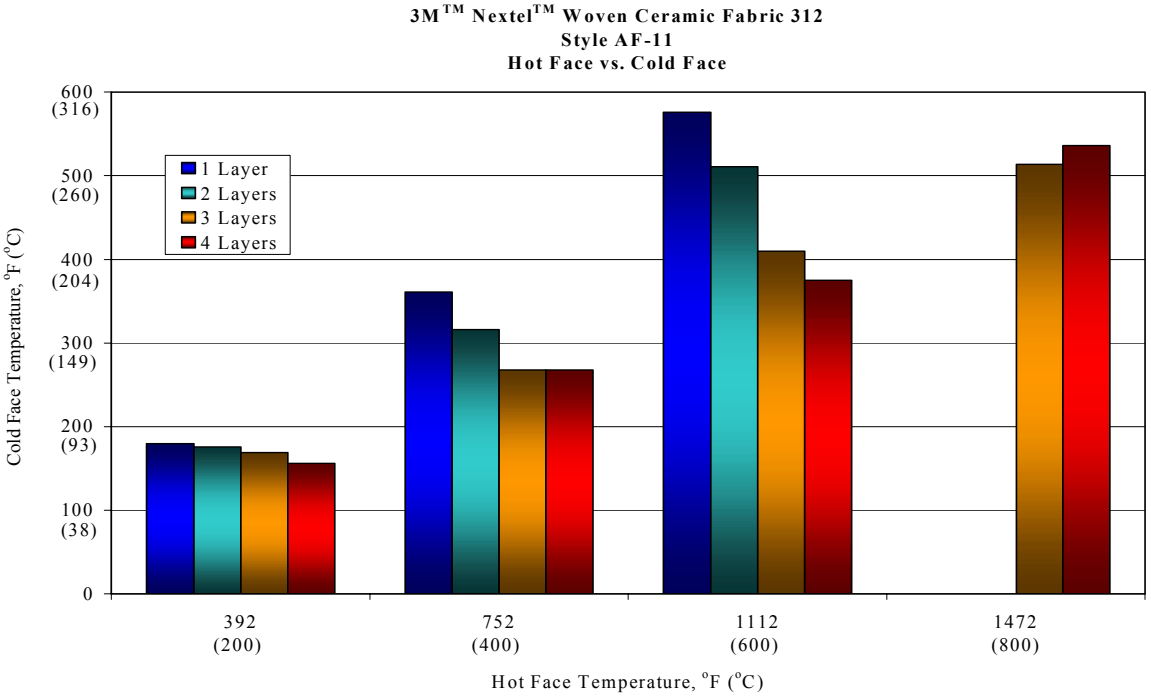
The heat source was a small lab furnace capable of reaching a temperature of 1832°F (1000°C).

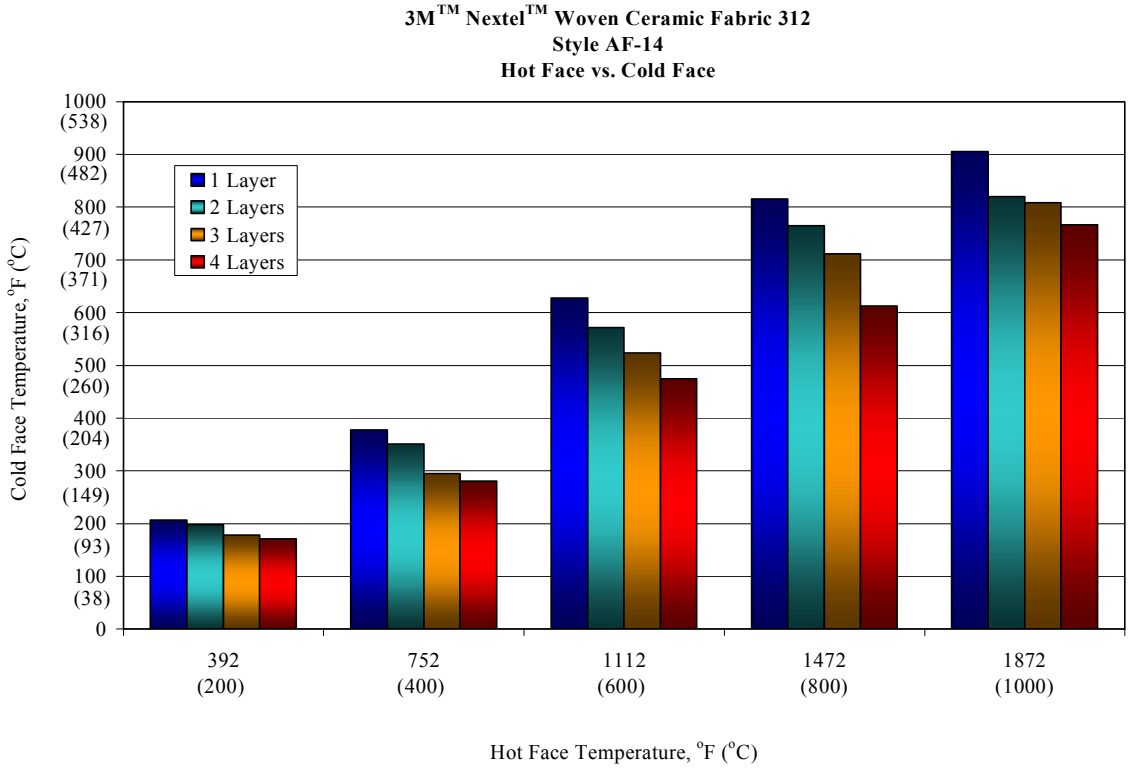
A 4 inch x 6 inch (10,16 cm x 15,24 cm) rectangular hole was cut in the top of the furnace. Fabric was cut so that the edges overlapped the opening. A thermocouple was placed in the furnace for the measurement of the hot face temperature. The cold face thermocouple was placed lightly on the top of the fabric.

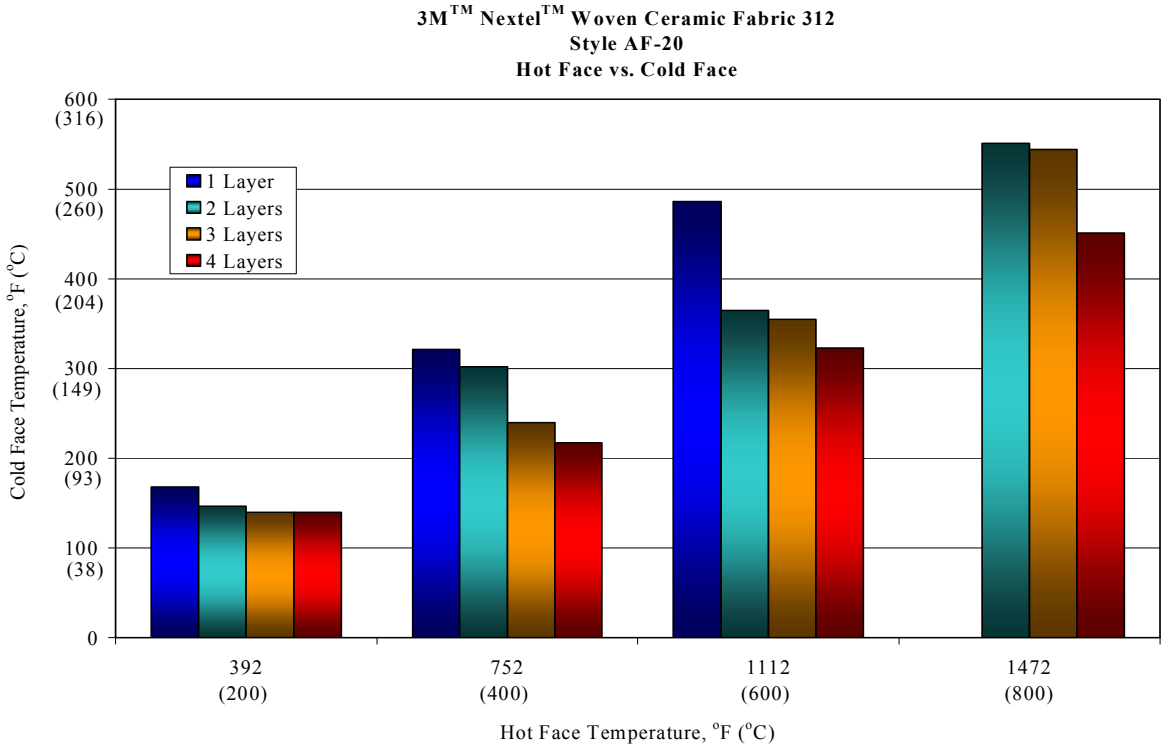
Temperature was recorded after the cold face temperature had reached a steady state.

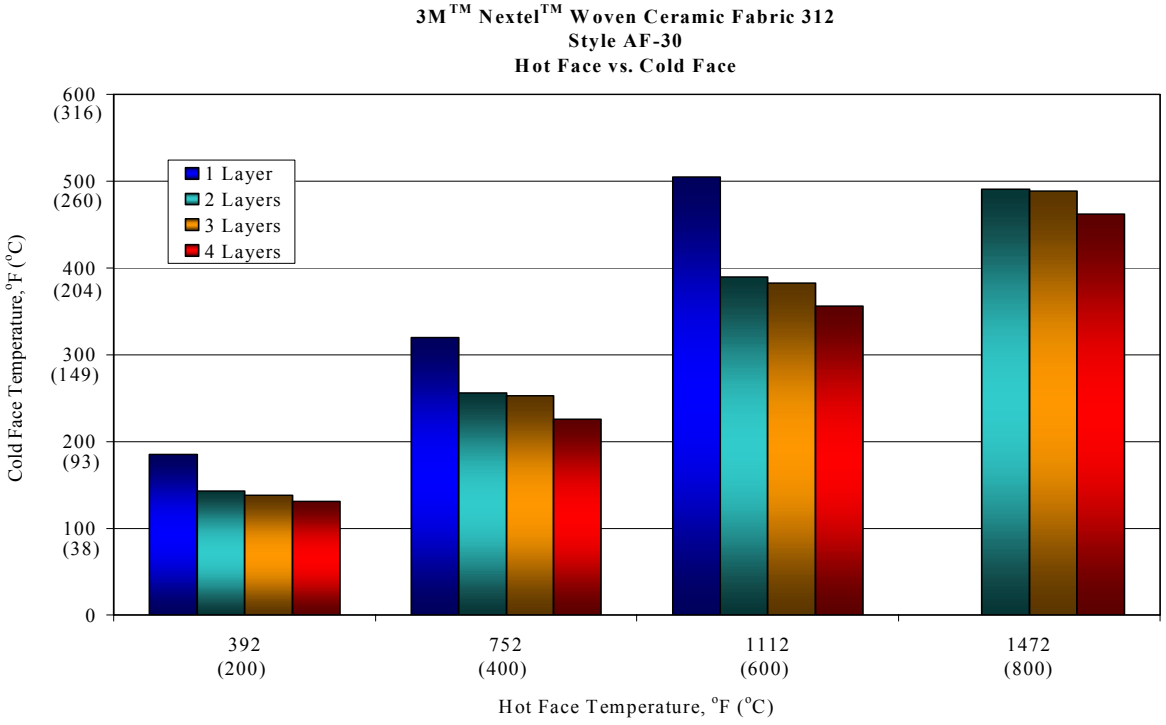
Results of the test are found in the following graphs:

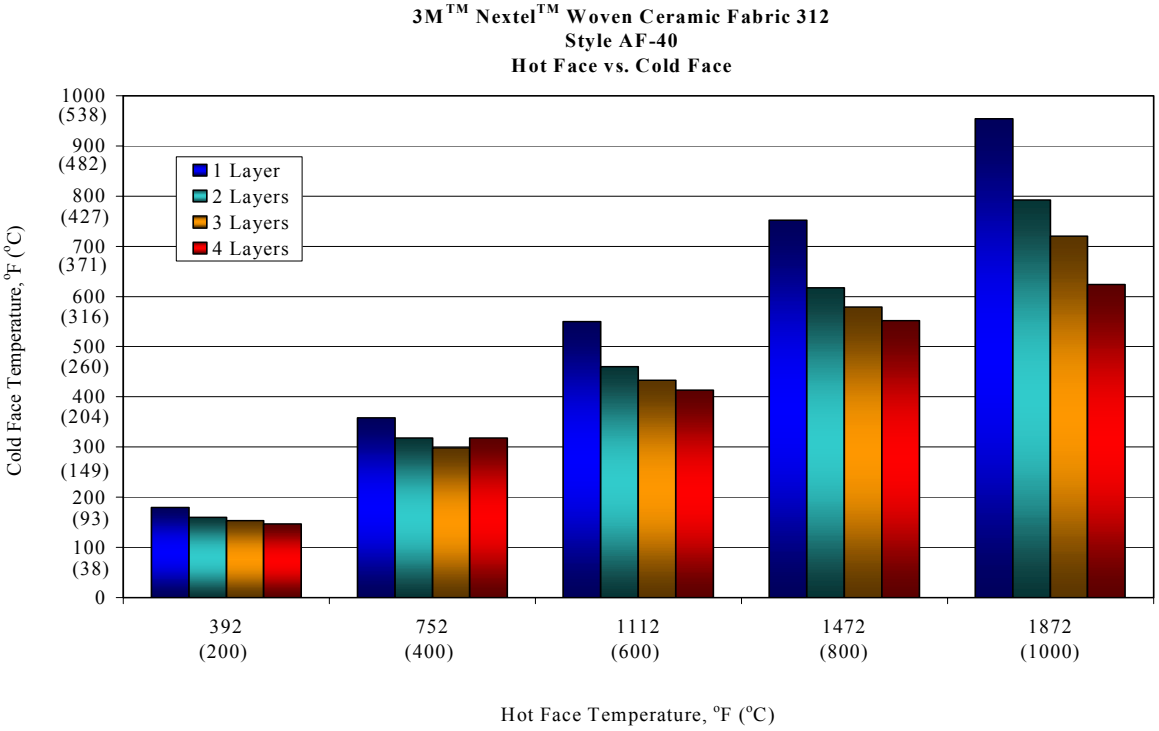


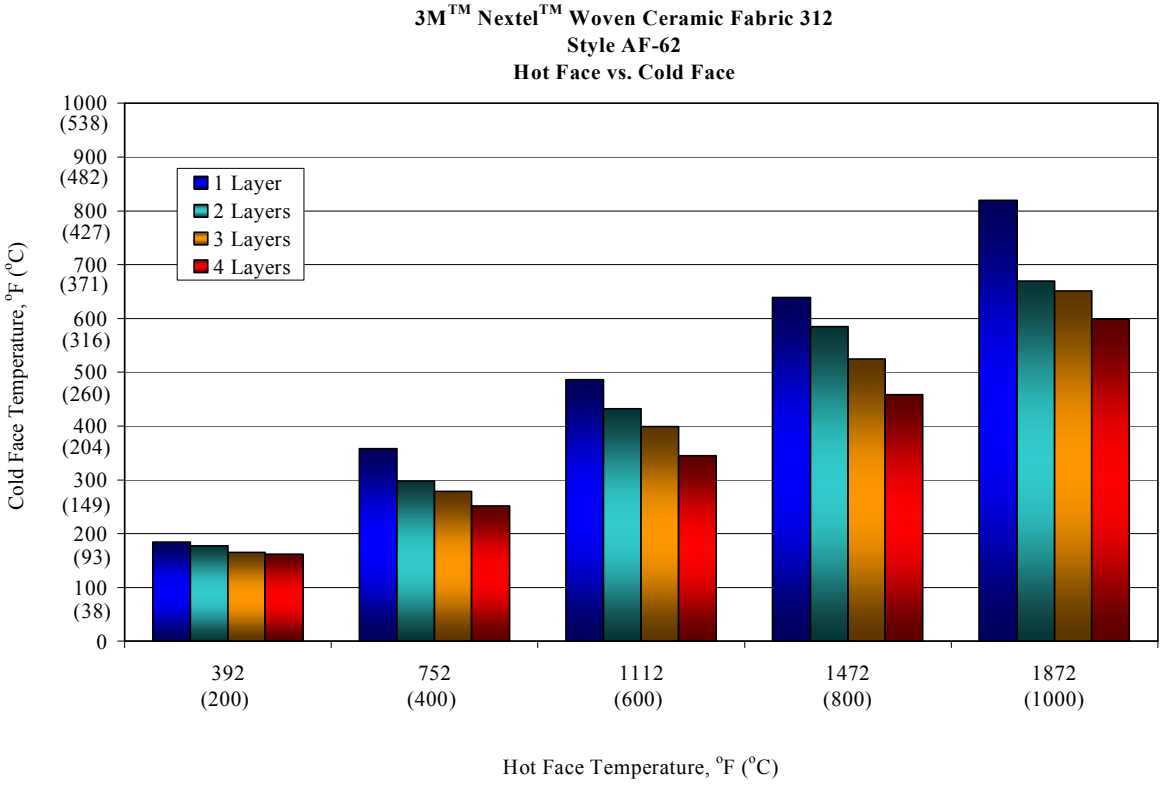

3M™ Nextel™ Woven Ceramic Fabric 312
Style AF-11
Hot Face vs. Cold Face
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
Hot Face Temperature, °F (°C)

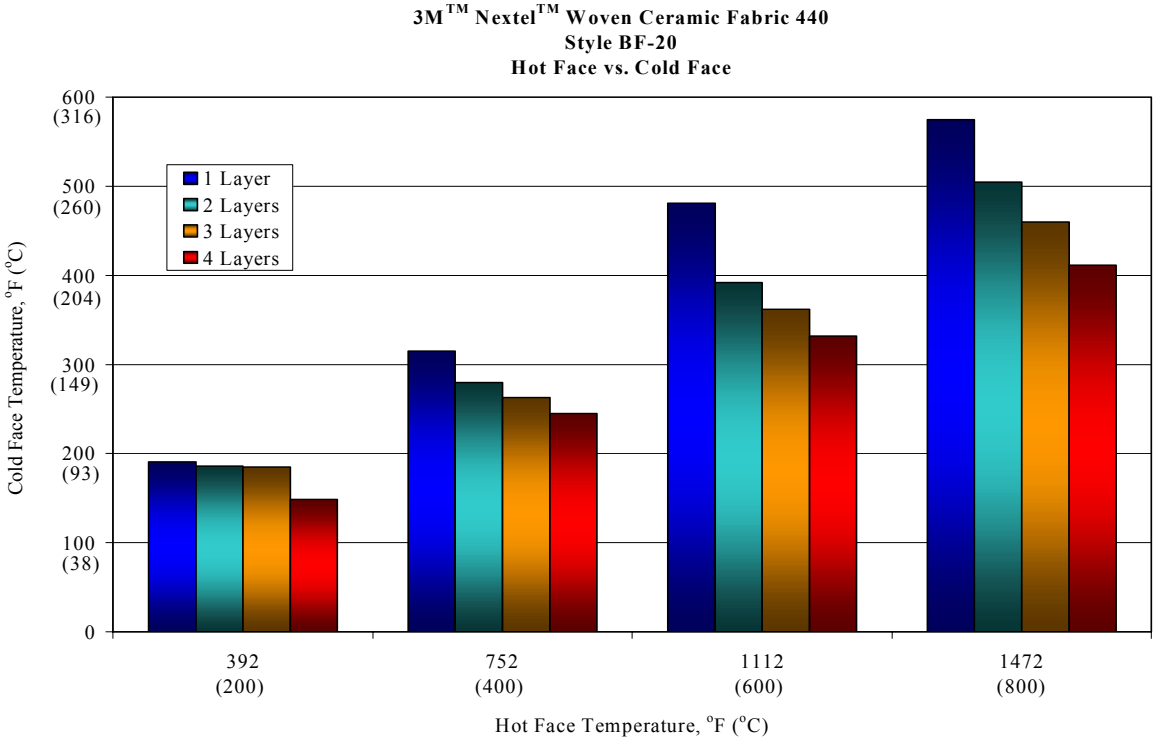

3M™ Nextel™ Woven Ceramic Fabric 312
Style AF-14
Hot Face vs. Cold Face
1000 (538)
900 (482)
800 (427)
700 (371)
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
1872 (1000)
Hot Face Temperature, °F (°C)

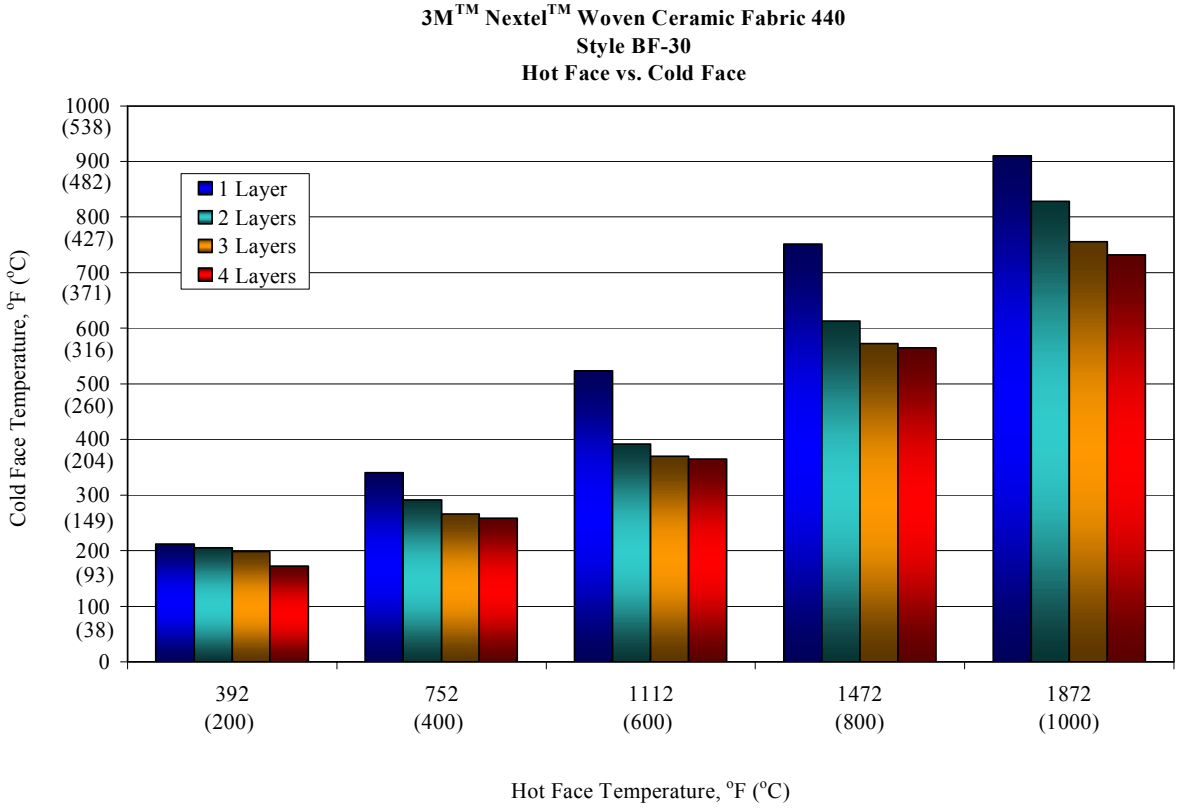

3M™ Nextel™ Woven Ceramic Fabric 312
Style AF-20
Hot Face vs. Cold Face
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
Hot Face Temperature, °F (°C)


3M™ Nextel™ Woven Ceramic Fabric 312
Style AF-30
Hot Face vs. Cold Face
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
Hot Face Temperature, °F (°C)


3M™ Nextel™ Woven Ceramic Fabric 312
Style AF-40
Hot Face vs. Cold Face
1000 (538)
900 (482)
800 (427)
700 (371)
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
1872 (1000)
Hot Face Temperature, °F (°C)


3M™ Nextel™ Woven Ceramic Fabric 312
Style AF-62
Hot Face vs. Cold Face
1000 (538)
900 (482)
800 (427)
700 (371)
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
1872 (1000)
Hot Face Temperature, °F (°C)

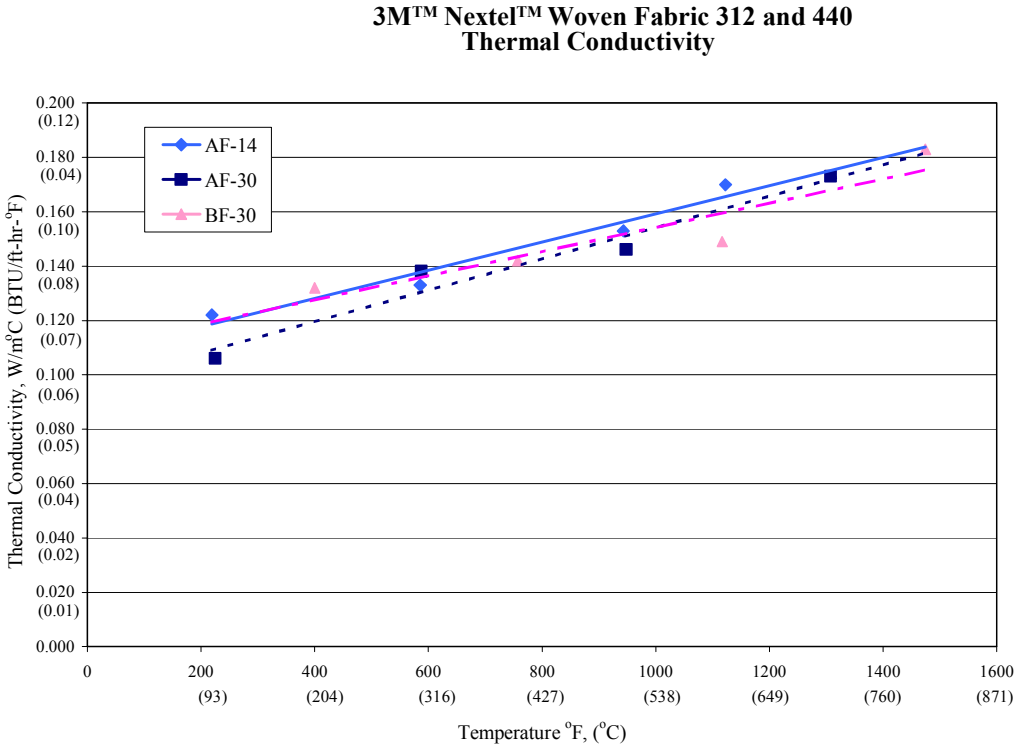

3M™ Nextel™ Woven Ceramic Fabric 440
Style BF-20
Hot Face vs. Cold Face
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
Hot Face Temperature, °F (°C)


3M™ Nextel™ Woven Ceramic Fabric 440
Style BF-30
Hot Face vs. Cold Face
1000 (538)
900 (482)
800 (427)
700 (371)
600 (316)
500 (260)
400 (204)
300 (149)
200 (93)
100 (38)
0
1 Layer
2 Layers
3 Layers
4 Layers
Cold Face Temperature, °F (°C)
392 (200)
752 (400)
1112 (600)
1472 (800)
1872 (1000)
Hot Face Temperature, °F (°C)

Thermal Conductivity

3M™ Nextel™ Woven Fabric 312 and 440

Fabrics made from both 3M Nextel Fiber 312 and 440 were tested for thermal conductivity. Results are reported graphically below. The tests were run in accordance with ASTM C-177-76, Steady State Heat Transmission Properties by means of the Guarded Hot Plate.



3M™ Nextel™ Flame Stopping Dot Paper 312

3M™ Nextel™ Flame Stopping Dot Paper 312 - Typical Properties**

Style	Weight	Available Width	Thickness	Tensile Strength	
				Machine Direction	Cross Machine Direction
	oz/yd^2 (g/m^2)	in (cm)	mils (mm)	lb/inch (kg/cm)	lb/inch (kg/cm)
FSDP	2.2 (75)	60 (152)	17 (0,4)	14 (2,5)	9 (1,6)

**This product is manufactured from 3M™ Nextel™ Ceramic Fiber 312. See typical property information on page 15 for other properties.

Hot Face vs. Cold Face Temperature

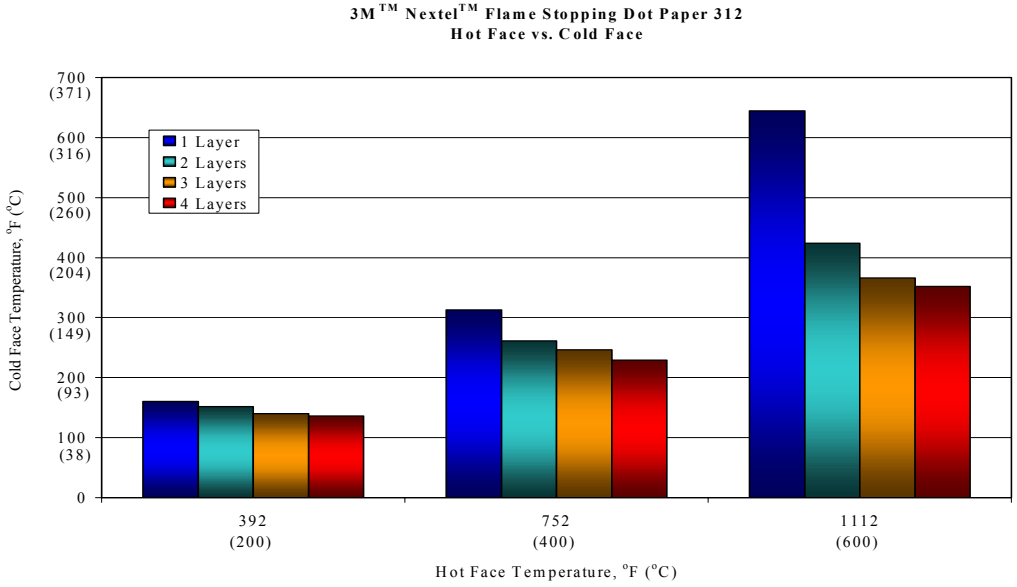
Hot face versus cold face temperature tests were conducted on samples of one through four layers of 3M Nextel Flame Stopping Dot Paper 312.

The heat source was a small lab furnace capable of reaching a temperature of 1832°F (1000°C).

A 4 inch x 6 inch (10,16 cm x 15,24 cm) rectangular hole was cut in the top of the furnace. Fabric was cut so that the edges overlapped the opening. A thermocouple was placed in the furnace for the measurement of the hot face temperature. The cold face thermocouple was placed lightly on the top of the fabric.

Temperature was recorded after the cold face temperature had reached a steady state.

Results of the test are found in the following graph:



3M™ Nextel™ Woven and Braided Tape

3M™ Nextel™ Woven and Braided Tape 312 and 440 – Typical Properties

Style	Tape Width		Weight (sized)		Thickness (sized)		Breaking Strength without Sizing*	
	inch	cm	oz/yd	g/m	inch	mm	lbs/in	kg/cm
3M Nextel Woven Tape 312, Style AP-18								
	1.0	2,5	0.30	9,3	0.018	0,46	160	29
	1.5	3,8	0.45	14,0	0.018	0,46		
	2.0	5,1	0.60	18,6	0.018	0,46		
3M Nextel Woven Tape 440, Style BP-18* **								
	1.0	2,5	0.33	10,2	0.019	0,48	180	32
	1.5	3,8	0.50	15,5	0.019	0,48		
	2.0	5,1	0.66	20,5	0.019	0,48		

Input yarn for Style AP-18 is 900 denier 3M Nextel Plied Yarn 312, 1/2, 1.5 z.

Input yarn for Style BP-18 is 1000 denier 3M Nextel Plied Yarn 440, 1/2, 1.5 z.

* Test method ASTM D5035; tests conducted at room temperature.
** Tape is manufactured with an adhesive backing.
*** Available only by special order.

Notes:
When installing tape, a 50% overwrap by width is recommended.

For typical hot face/cold face temperature properties for AP-18, refer to the hot face/cold face chart for AF-14 using two layers (page 22).

3M™ Nextel™ Braided Sleeving

3M™ Nextel™ Braided Sleeving – Typical Properties

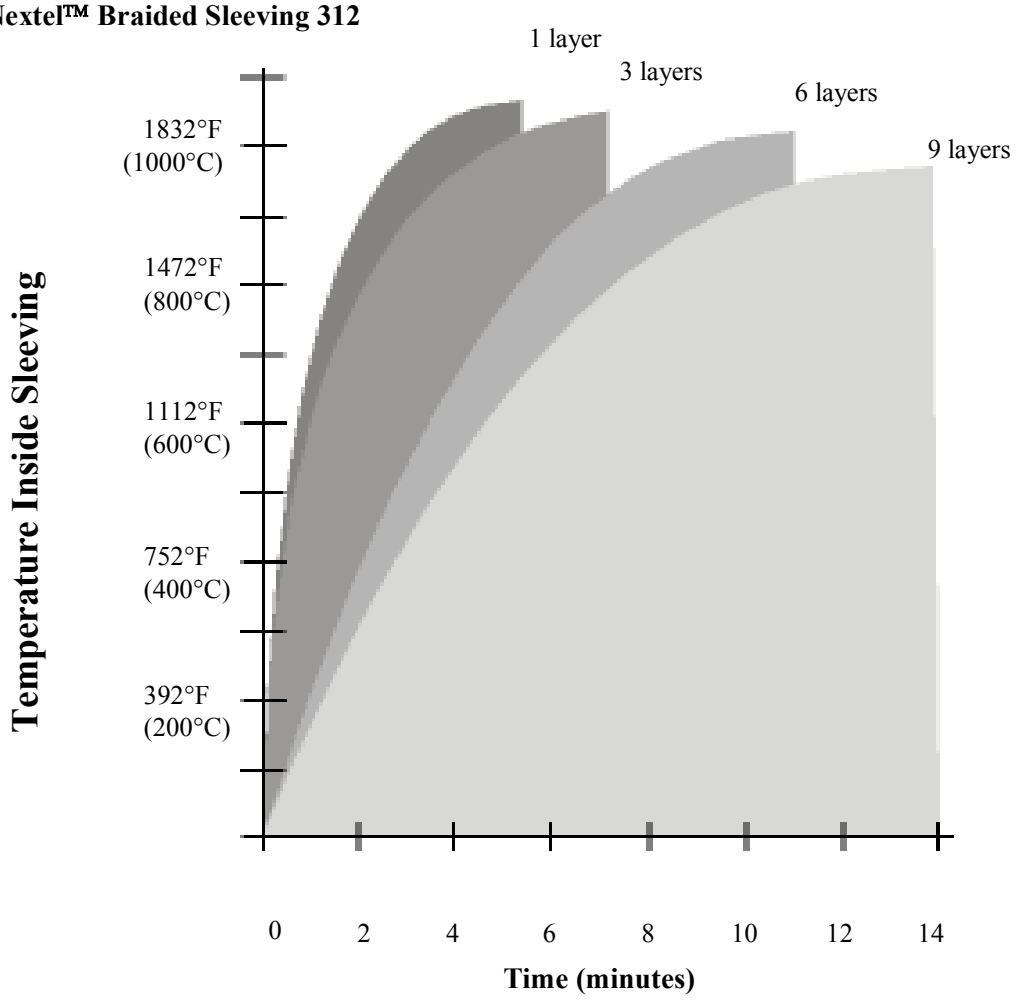
Sleeving Inside Diameter		Wall Thickness (sized)		Length per Unit Weight (sized)		Yield As Packaged, Roll Form (sized)		Picks per Unit Length		Length* Coverage Factor
inch	**mm**	**inch**	**mm**	**yards/lb**	**m/kg**	**lbs/100 ft**	**g/m**	**picks/inch**	**picks/cm**	
3M Nextel Braided Sleeving 312, Style AS-40										
1/16	1,6	0.027	0.69	83	167	0.38	5,7	12	5	0.95
1/8	3,2	0.038	0,97	37	75	0.79	12	12	5	0.88
1/4	6,4	0.036	0,91	24	48	1.2	18	11.5	4,5	0.86
1/2	12,7	0.041	1,04	12	24	2.1	31	10.5	4	0.75
3/4	19,1	0.039	0,99	8.7	18	2.8	42	10	4	0.72
1	25,4	0.035	0,89	7.4	15	3.5	52	12	5	0.77
1 1/2**	38,1	0.033	0,84	5.3	11	4.6	68	12	5	0.74
2**	50,8	0.034	0,86	3.4	6,9	6.2	92	11	4	0.63
2 1/2**	63,5	0.037	0,94	3.1	6,2	7.6	113	8	3	0.70
3M Nextel Braided Sleeving 312, Style AS-50										
2	50,8	0.027	0,69	5.7	11,5	5.4	80	5.5	2	0.92
3M Nextel Braided Sleeving 440, Style BS-40										
1/16**	1,6	0.026	0.66	77	155	0.44	6,5	12	5	0.97
1/8	3,2	0.038	0,97	33	66	0.88	13	12	5	0.87
1/4	6,4	0.038	0,97	22	44	1.3	19	12	5	0.88
1/2	12,7	0.042	1,07	11	22	2.2	33	10	4	0.73
3/4**	19,1	0.042	1,07	7.8	16	3.3	49	10	4	0.78
1**	25,4	0.036	0,91	6.7	14	3.9	58	12	5	0.78
1 1/2**	38,1	0.034	0,86	4.8	9,7	5.1	76	12	5	0.74
2**	50,8	0.036	0,91	3.2	6,5	6.9	103	10.5	4	0.67
2 1/2**	63,5	0.038	0.97	2.7	5,4	8.3	124	7.5	3	0.68

Input yarn is 900 denier 3M Nextel Plied Yarn 312, 1/2, 2.7z.
Input yarn is 1000 denier 3M Nextel Plied Yarn 440, 1/2, 2.7z.

*(Package Length x Factor = Approximate Length Covered at Specific ID)
Approximate Length Covered at Specific Inside Diameter per 100 foot of Braided Sleeving.
**Available only by special order.

Thermal Protection

3M™ Nextel™ Braided Sleeving 312



Temperature inside sleeving at various times after insertion into 2000°F (1093°C) furnace for increasing layers of 3M Nextel Sleeving. Braid was 1 in (2,54 cm) in diameter and was 0.039 in (0,097 cm) thick.

The chart above compares the effect of increasing layers of 3M Nextel Braided Sleeving 312 in a heat soak exposure. It demonstrates that for short periods of time there is a substantial reduction in internal temperature using multiple layers of sleeving. However, as the length of time increases the internal temperature approaches equilibrium with the furnace temperature and the effect of multiple layers of sleeving is diminished. Specifically, samples containing 1, 3, 6, and 9 layers of sleeving respectively were fabricated over a 0.75 inch (1,91 cm) metal tube. The samples were immersed in a furnace at 2000°F (1093°C) and the temperature inside the tube was measured. No cooling air was allowed to pass through the metal tube. The internal temperature with one layer of sleeving reaches equilibrium with the furnace temperature within 5-6 minutes while the internal temperature with nine layers reached only 1100 °F (593°C) in the same time period. As would be expected, constructions with 3 and 6 layers of sleeving had internal temperatures between those values.

Chemical Exposure Effects

Metal Compatibility
Issues of metal compatibility depend on several factors – temperature, atmosphere (oxidizing, reducing, neutral, and vacuum) and what other materials (fluxes, etc.) may be present. Therefore, we recommend that sample fabrics be tested under the actual use conditions before proceeding with any component fabrication.

In general, under oxidizing conditions any metals that form low melting oxides will degrade the performance of 3M™ Nextel™ Fabrics. These include alkali metals such as sodium, potassium and lithium. Also included are low melting glass formers such as lead, phosphorous, tin and antimony. The transition metals of titanium, vanadium, manganese, nickel and copper degrade 3M Nextel Fibers under oxidizing high temperature conditions.

At temperatures above 2192°F (1200°C) in a hydrogen containing atmosphere with a very low dew point, the SiO_2 component in our fibers can be reduced to SiO gas and degrade the fabric.

3M Nextel 440 Fibers are compatible with platinum metals at high temperatures and are used for flexible high temperature thermocouples.

Chemical Resistance
Short-term chemical exposure tests were performed on heat cleaned 3M Nextel Woven Tapes 312 and 440 and heat treated 3M Nextel Woven Tape 312 1 inch (2,54 cm) wide. Table 1 lists the strength retention results after chemical exposure and Table 2 lists the strength retention after rinsing the chemically exposed tapes with de-ionized water.

All samples were run on a tensile tester with cross-head speed of 0.5 inch/min (1,27 cm/min) using a 3 inch (7,61 cm) gauge length. All samples were loaded to failure (break).

Table 1. Percent Strength Retention After Exposure

Chemical	Concentration	3M™ Nextel™ Tape 312		3M™ Nextel™ Tape 440
		Heat Cleaned	Heat Treated	Heat Cleaned
Acids				
HNO_3 Nitric Acid	10%	50%	95%	88%
HCl Hydrochloric Acid	10%	85%	98%	98%
H_2SO_4 Sulfuric Acid	10%	38%	65%	72%
H_3PO_4 Phosphoric Acid	10%	<1%	<1%	<1%
Bases				
KOH Potassium Hydroxide	10%	<1%	<1%	<1%
NaOH Sodium Hydroxide	10%	<1%	<1%	<1%
NH_4OH Ammonium Hydroxide	10%	78%	77%	96%
CaO Calcium Oxide	Saturated	48%	99%	94%

Test Method:
1. Soak individual samples for one hour in a 10% (by weight) chemical bath.
2. Dry samples at room temperature for at least 20 hours.
3. Heat samples at 1472°F (800°C) for 15 minutes.
4. Return to room temperature, load samples to failure.
5. Determine strength retention (average of five samples).

Table 2. Percent Strength Retention After Rinsing in H_2O

Chemical	Concentration	3M™ Nextel™ Tape 312		3M™ Nextel™ Tape 440
		Heat Cleaned	Heat Treated	Heat Cleaned
Acids				
H_3PO_4 Phosphoric Acid	10%	82%	106%	100%
Bases				
KOH Potassium Hydroxide	10%	77%	86%	98%
NaOH Sodium Hydroxide	10%	61%	78%	84%

Test Method:
1. Soak samples for one hour in a 10% (by weight) chemical bath.
2. Dry samples at room temperature for at least 20 hours.
3. Soak samples in 150 ml of deionized water for 15 minutes.
4. Rinse sample in tap water.
5. Dry samples at 193°F (75°C) for 15 minutes.
6. Heat samples at 1472°F (800°C) for 15 minutes.
7. Return to room temperature, load samples to failure.
8. Determine strength retention (average of five samples).

Moisture Absorption

The 3M™ Nextel™ Ceramic Fibers 312, 440, 550, 610, and 720 absorb very little moisture due to their smooth, non-porous surface. Fibers exposed to 100% relative humidity for several hours at room temperature had 0.08% weight gain.

Jet Fuel and Hydraulic Fluid Compatibility

3M™ Nextel™ Woven Fabric 312 and 440
3M Nextel Woven Fabric 312 (AF-30) and 3M Nextel Woven Fabric 440 (BF-30) were heat cleaned, then immersed for thirty hours in JP-4 jet fuel or Chevron HyJet IV hydraulic fluid. After removal, the samples were dried at 230°F (110°C) for one hour and one inch tensile specimens were prepared.

Tensile Breaking Load (lb/in width)

Fabric	Heat Cleaned	JP-4	% Increase	HYJet IV	% Increase
AF-30	107	275	157%	287	168%
BF-30	235	334	42%	299	27%

The strength increases are due to residual organic material left on the surface of the fibers. If either fluid attacked the textiles one would expect a decrease in strength. 3M Nextel Woven Fabrics 312 and 440 show no degradation of the fiber strength after 30 hours in JP-4 jet fuel or HyJet IV hydraulic fluid.

Hydrazine and Ammonia Compatibility*

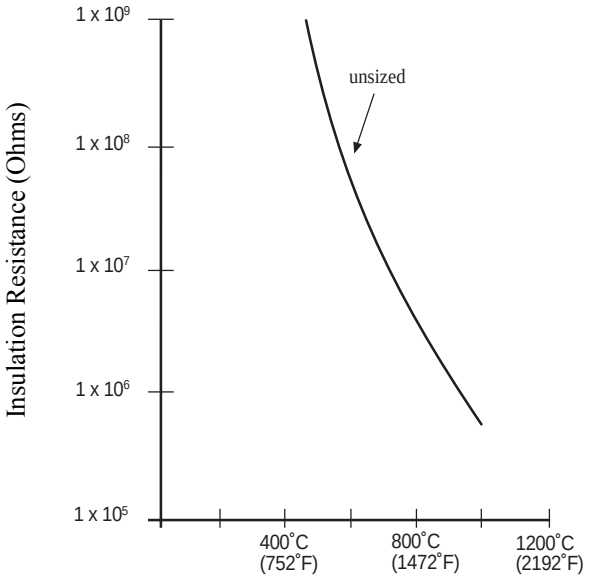
3M™ Nextel™ Woven Fabric 312 and 440
Compatibility with hydrazine and ammonia was also tested. 3M Nextel Woven Fabrics 312 and 440 were tested after exposure to both ammonia and hydrazine vapors for 48 hours per NHB 8606.1B. The 3M Nextel Fabrics did not exhibit any evidence of gross incompatibility with either fluid.

* Courtesy - NASA

Electrical Insulation Resistance

3M™ Nextel™ Braided Sleeving 312 (unsized)

Insulation resistance of 3M Nextel Braids on Type K thermocouple wire was measured as the temperature was increased from ambient to over 1832°F (1000°C). With 12 inch (30,5 cm) sections exposed to the test temperature, the remainder of the 18 inch (45,7 cm) thermocouple specimen extended through the oven wall and was connected to an ohmmeter. All wires were open-ended. A typical curve of insulation resistance as a function of temperature is shown in the figure below for thermocouple wires insulated with unsized yarn. The values of insulation resistance will change depending on thickness, length of thermocouple wire and braid construction.



Note: Sized sleeving will have lower insulation resistance and should be heat cleaned in air. Heating in a non-oxidizing environment will produce conductive carbon residue.

222 Sizing

This sizing consists of a proprietary inorganic coating which lubricates and protects the fiber during twisting and braiding. This produces a fiber that is tan in color. The 222 sizing has been found to be useful in electrical applications where it is undesirable to heat clean the product to remove organic coatings. Organic coatings decompose to conductive carbon in neutral or reducing atmospheres when heated above 932°F (500°C).

Example: Standard Type K thermocouple wire was prepared by over-braiding with 3M Nextel Roving sized with 222 Sizing. One end of the braided thermocouple was cut with a wire cutter and inserted into a quartz protection tube while the opposite end was connected to an ohmmeter. (Since the Chromel and Alumel wires are not welded, the ohmmeter is measuring the insulation resistance between the two wires.) The quartz tube was then inserted into an electric furnace maintained at 1472°F (800°C) and the resistance was recorded as a function of time. The test was also repeated for 170 Sizing.

Resistance (in ohms) of Thermocouple Constructions

Time (minutes)	222 Sizing	170 Sizing
0.5	20,000,000	120,000
1.0	10,000,000	20,000
1.5	5,000,000	5,000
2.0	4,000,000	300
3.0	3,000,000	60
10.0	2,500,000	9.5

After the testing the 222 sized thermocouple remained unchanged in appearance with a high

insulation resistance between the two wires. The thermocouple with the 170 sizing showed evidence of a carbon char which provided a conductive path through the insulation between the two wires and produced a short circuit (9.5 ohms).

Yarn strengths of 222 sized material are comparable to our standard organic sized yarn strength. Braids of 222 sized material tend to be somewhat fuzzier than braids sized with our standard organic material.

Radiation Resistance & Microwave Measurement

3M™ Nextel™ Ceramic Fibers 312 and 440

Radiation Resistance

Exposure to radiation from a Cobalt 60 source did no noticeable damage to the 3M Nextel Fibers 312 and 440. A total of 1×10^7 rads at an exposure rate of 2.1×10^5 rads/hour did not change the tensile strength of the fibers, yarns or fabrics made from the fibers.

Microwave Measurements

Power Transmission and Reflection for 3M Nextel Fabric panels 18 inch x 18 inch (45.7 cm x 45.7 cm) at 10 GHz.

Fabric Specimen	Transmission*		Reflection**	
	5 Layers	10 Layers	5 Layers	10 Layers
AF-30	96.5%	97.8%	7%	0.45%
BF-30	94.7%	96.7%	7%	0.14%

*Sample held with styrofoam panels, angles of incidence 0°.

**Sample uncompressed, angle of incidence 10°. Compared to copper plate with perpendicular polarization.

Cryogenic Testing

3M™ Nextel™ Woven Tape 312 and 440

Five samples of 3M Nextel Woven Tape 312 and 440 1 inch (2,54 cm) wide were cut to 6 inch (15,2 cm) lengths for testing in liquid nitrogen.

Samples were heat cleaned at 1472°F (800°C) for one hour to remove the sizing before testing.

Samples were placed in liquid nitrogen to soak for three minutes. Samples were then removed and tested for strength retention.

A second set of five samples was dipped into liquid nitrogen ten times and then tested for strength retention.

	Retained Strength	
Sample	Soaked 3 Minutes in N_2	Dipped 10 Times in N_2
3M Nextel Tape 312	127%	81%
3M Nextel Tape 440	98%	89%

Thermal Optical Properties*

The optical properties of fibers on the exterior of the space craft controls the amount of solar heating that will occur in orbit. For instance, a low absorptivity would be desired if one were designing components for a spacecraft mission. This would reflect most of the sun's energy and protect the craft and the instruments from high temperatures.

Optical measurements were made on 3M™ Nextel™ Woven Fabrics 312 and 440 using a Gler Dunkle DB-100 Emissometer and MS-251 Solar Reflectometer machines. The average absorptance (α) and emittance (ε) are as follows:

Material	Absorptivity (α)	Emissivity (ε)
312	0.14	0.88
440	0.15	0.87

NASA Nonmetallic Material Testing*

Flammability, Toxicity and Thermal Vacuum Stability testing on 3M Nextel Woven Fabrics was performed using procedures specified in NHB 8060.1B and SP-R-0022A.

Flammability: Passed test in 30% oxygen and 10 psia environment.

Toxicity: Passed Test.

Thermal Vacuum Stability: Heat cleaned fabric passed test. Sized 3M Nextel Fabric out-gassed volatile condensable materials of 0.15%, which exceeded the required limit of 0.1 weight %.

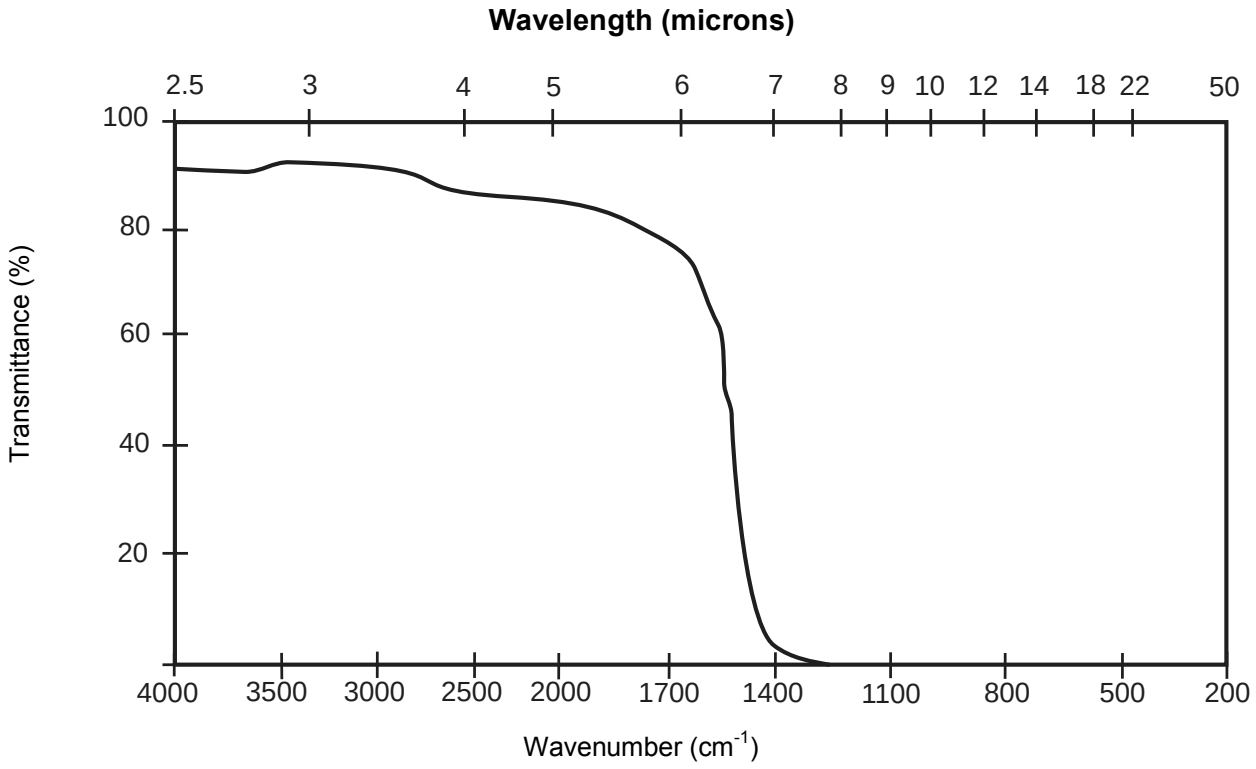
*Courtesy-NASA

IR Absorbance and Transmittance

3M™ Nextel™ Ceramic Fiber 312

A small flake of alumina-boria-silica (3:1:2) fired to 1742°F (950°C) was used to determine the transmittance and absorbance of 3M Nextel Ceramic Fiber 312 in the infrared region. The thickness of the flake was determined from the interference pattern to be 22.4 μm thick. The following graph shows that in the shortwave number region (4000-3000 cm^{-1}) the transmission loss is small and appears essentially due to reflection.

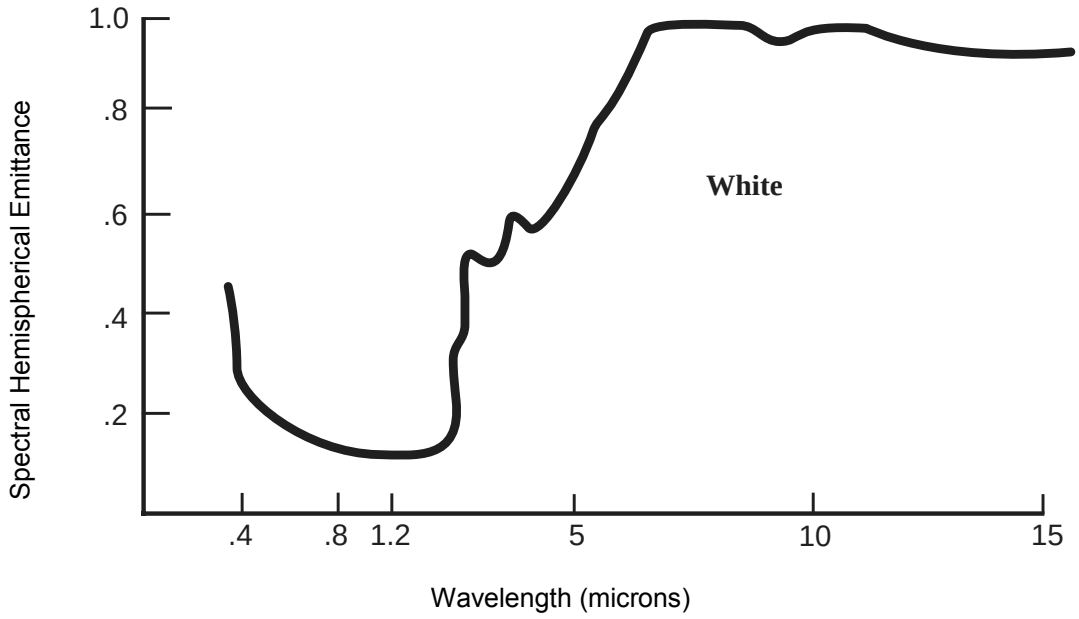
Weak absorption shows between 2700 and 1700 cm^{-1}. Beyond 1700 cm^{-1} absorption becomes strong and finally complete beyond 1400 cm^{-1}. Absorbance can be calculated from the relationship $A=\log_{10}(100)/(\%T)$.



Spectral Hemispherical Emittance

3M™ Nextel™ Woven Fabric 312

The emissivity of individual filaments of 3M Nextel Ceramic Fiber 312 could not be determined. However, the fibers in yarn form were woven into an eight ounce/square yard plain weave fabric. A fabric made from standard 3M Nextel Ceramic Fiber 312 was tested. The following data was obtained at room temperature using a Beckman DK1A and Willie Reflectometers covering wavelengths between 0.3 µ and 15 µ. The emittance of other fabrics made from 3M Nextel Ceramic Fibers 312 may vary due to differences in weave pattern and yarn construction.



Heat Cleaning Instructions

Nextel™ Ceramic Textiles 312, 440, 550, 610, and 720

Heat Cleaning

Heat cleaning is used to remove all of the organic coatings from the surface of the Nextel Fibers. This is important in applications where fabrics are going to be prepregged with resin for polymer composite applications. Heat cleaning is also used when Nextel materials are coated with silicone rubber since sizing will inhibit the cure of the silicone. Heat cleaning is recommended when Nextel Ceramic Fabric is to be used as electrical insulation, (thermocouples, heaters, etc.), under reducing atmosphere or vacuum conditions. Under these conditions the sizing decomposes to a conductive carbon and may cause electrical shorts. Fabricating cutting and sewing of Nextel parts is best done with the sizing left on the fabrics. The final parts can then be heat cleaned, if desired, with a simple heat cleaning cycle.

Heat cleaning Nextel Ceramic Fibers 312, 440, 550, 610 & 720 to remove the polymeric sizing and finishes generates thermal decomposition products which can be hazardous if inhaled at concentrations exceeding their recommended exposure limits. Carbon monoxide is the predominant decomposition product. By controlling carbon monoxide concentrations to the ACGIH Threshold Limit Value of 25 ppm (8 hr TWA), other decomposition products should also be adequately controlled. Control of carbon monoxide levels may be most effectively achieved through the use of exhaust ventilation such as an exhaust enclosure or hood.

Equipment Needed

1. Ventilated furnace or furnace equipped with an exhaust hood. For example, a quantity of fabric 10 yards x 36 inches (9,2 m x 0.92 m) could be heat cleaned in a ventilated furnace capable of maintaining 1292°F (700°C) and equipped with an exhaust hood operating at 150 cubic feet (4,17 cubic meters) per minute capture velocity and not subject to disturbances by cross drafts.
2. Temperature measuring device, fitted with Type K thermocouple.

Procedure

1. Remove combustible packaging materials.
2. Place monitoring thermocouple in an area likely to require the longest time for heat penetration. Place bulk textiles in room temperature furnace and apply heat.
3. Follow the time/temperature chart on this page. Exceeding the recommended heating rate may cause the heat cleaning temperature to increase above the recommended maximum due to exothermic decomposition of the organic sizing. The maximum recommended rate of temperature increase for heat cleaning bulk textiles is 540°F (300°C) per hour. The baking time starts once the thermocouple reaches temperature.
4. Pigmented product will lose its color and appear white when sizing has been removed. Process should be repeated or extended until product is completely white.
5. Turn off furnace and let material and furnace cool to room temperature before handling.

Nextel Textiles	Heat Cleaning	
	Thermocouple Temperature	Time
Large Roll Fabric	1292°F ±27 700°C ±15	12 hours
Small Samples	1292°F ±27 700°C ±15	5 minutes

Heat Treating Instructions

Nextel™ Ceramic Textiles 312

Heat Treating

Heat treating, which changes the crystal structure of the fiber, is a higher temperature process than heat cleaning. This treatment improves the chemical resistance, anneals the stress from the fiber, and increases the modulus or stiffness of the fiber. This is used when the product is going to be used in hot wet environments or in areas where other chemicals are present. It is also used to reduce the stress of the fiber and minimize the unraveling in the cut ends of braided sleeving or fabrics.

Carbon monoxide is the predominant decomposition product. By controlling carbon monoxide concentrations to the ACGIH Threshold Limit Value of 25 ppm (8 hr TWA), other decomposition products should also be adequately controlled. Control of carbon monoxide levels may be most effectively achieved through the use of exhaust ventilation such as an exhaust enclosure or hood.

Equipment Needed

1. Furnace capable of maintaining 1652°F (900°C). Furnace may be the same one used to heat clean the fabric or it may be a second furnace which would not require ventilation if the fabric had already been heat cleaned.
2. Temperature measuring device, fitted with Type K thermocouple.

Procedure

1. Remove combustible packaging materials.
2. Place monitoring thermocouple in an area likely to require the longest time for heat penetration. Place bulk textiles in room temperature furnace and apply heat.
3. Follow the time/temperature chart on this page. Exceeding the recommended heating rate may cause the heat treating temperature to increase above the recommended maximum due to exothermic decomposition of the organic sizing. The maximum recommended rate of temperature increase for heat treating bulk textiles is 540°F (300°C) per hour. The baking time starts once the thermocouple reaches temperature.
4. Pigmented product will lose its color and appear white when sizing has been removed. Process should be repeated or extended until product is completely white.
5. Turn off furnace and let material and furnace cool to room temperature before handling.

Nextel Ceramic Textiles 312	Heat Treating	
	Thermocouple Temperature	Time
Large Roll Fabric	1652°F ±27 900°C ±15	12 hours
Small Samples	1652°F ±27 900°C ±15	4 hours

Important Notice to Purchaser

3M MAKES NO WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILIYT OF FITNESS FOR A PARTICULAR PURPOSE. All statements, technical information and recommendations contained in this brochure are based upon tests conducted with 3M approved equipment and are believed to be reliable. However, many factors beyond the control of 3M can affect the use and performance of 3M Ceramic Fibers in a particular application, including the conditions under which the product is used. Since these factors are uniquely within the user's knowledge and control, it is essential the user evaluate the 3M Ceramic Fibers to determine whether this product is fit for the particular purpose and suitable for the user's application.

Throughout this notebook we have used data based on typical properties of the products. If you need to develop a specification, please consult a 3M Representative. Application data has been collected from a variety of sources and may be of use for special applications.

LIMITATION OF REMEDIES AND LIABILITY: If the 3M product is proven to be defective THE EXCLUSIVE REMEDY, AT 3M's OPTION, SHALL BE TO REFUND THE PURCHASE PRICE OF OR REPLACE THE DEFECTIVE 3M PRODUCT. 3M shall not otherwise be liable for any injury, losses or damages, whether direct, indirect, special, incidental, or consequential, regardless of the legal theory asserted, including tort, contract, negligence, warranty or strict liability.

For more information contact:

In the US:

3M Ceramic Textiles and Composites
3M Center, Building 0223-06-S-04
St. Paul, MN 55144-1000

Toll Free within the USA:
(877) 992-7749
From outside the USA:
(651) 737-5102

FAX: (888) 993-9185

www.3M.com/ceramics

In Canada:

3M Canada
300 Tartan Drive
London, Ontario, Canada
N5V 4M9

(800) 265-1840 Ext. 2803
FAX: (519) 452-6286

In Europe:

3M Deutschland GmbH
Ceramic Textiles &
Composites, Europe
Carl-Shurz-Str. 1
41453 Neuss, Germany

49-2131-142911
FAX: 49-2131-143898

In Japan:

H. Morimoto
Sumitomo 3M Ltd.
33-1, Tamagawadai 2-chome
Setagaya-ku, Tokyo
158-8583 Japan

03-3709-8436
FAX: 03-3709-8765

98-0400-5870-7
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