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3M™ Nextel™ Ceramic Fibers and Textiles

Technical Reference Guide

3M™ Nextel™ Ceramic Fibers and Textiles:

Technical Reference Guide

Table of Contents

Note: The purpose of this guide is to provide basic information to product users for use in evaluating, processing, and troubleshooting their use of certain 3M products. The information provided is general or summary in nature and is offered to assist the user. The information is not intended to replace the user's careful consideration of the unique circumstances and conditions involved in its use and processing of 3M products. The user is responsible for determining whether this information is suitable and appropriate for the user's particular use and intended application. The user is solely responsible for evaluating third party intellectual property rights and for ensuring that user's use and intended application of 3M product does not violate any third party intellectual property rights.

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

Introduction

3M™ Nextel™ Continuous Filament Ceramic Oxide Fibers 312, 440, 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, 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.

High Temperature Fibers

Nextel ceramic fibers 312 and 440, when converted to fabrics, tapes, and sleevings, are used in the aerospace, industrial, automotive, electrical and petrochemical markets as heat shields, curtains, linings, insulation, blankets and seals.

Structural Fibers

Nextel ceramic fibers 610 and 720 are used in ceramic, polymer and metal matrix composites. Nextel ceramic fiber 610 is noted for its outstanding single filament tensile properties. Nextel ceramic fiber 720 is used in ceramic matrix composites because of its high creep resistance.

Health and Safety Bulletin

3M™ Nextel™ 312, 440, 610 and 720

Introduction

3M™ Nextel™ Ceramic Fibers are refractory aluminoborosilicate (312 and 440), aluminosilica (720), and alumina (610) fibers with diameters ranging from 8-14 microns. They are produced in continuous lengths. During manufacture, Nextel ceramic fibers 312, 440, 610, and 720 may be coated with organic sizings or finishes which serve as aids in textile processing. Nextel ceramic fibers 312, 440, 610, and 720 pose no significant health risks under most conditions of use. Under certain conditions, however, Nextel ceramic fibers 312, 440, 610, and 720 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. Safety Data Sheets (SDS) and Product Toxicity Summary Sheets should also be consulted for additional information

Fiber and Dust Inhalation

Nextel ceramic fibers are classified as ceramic fibers and are manufactured in continuous lengths and have diameters (approximately 8 to 14 microns) which are not considered to be respirable by humans. Accordingly, inhalation exposure to Nextel ceramic fibers 312, 440, 610, or 720 is not expected to pose a carcinogenic risk to humans, but may cause mechanical irritation of the nose and throat.

In certain operations, Nextel ceramic fibers 312, 440, 610, and 720 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 ceramic fiber 312 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 ceramic fiber 312 dust caused lung inflammation, but there was no evidence of more serious effects such as granulomas or fibrosis. A control group similarly exposed to quartz dust developed lung granulomas and fibrosis. It was concluded from this study that the potential for Nextel ceramic fiber 312 dust to cause pulmonary fibrosis or other significant lung injury is minimal.

Nextel ceramic fibers products are designed, manufactured, and sold for industrial use. They are not designed, manufactured, or recommended for use in medical devices, food, drug, electronic cigarette, personal inhalation devices, or cosmetic applications. As a general policy, 3M Advanced Materials Division does not knowingly sample, support, or sell Nextel ceramic fiber products for use in medical devices, drugs, food, electronic cigarettes, personal inhalation devices, cosmetics, or other applications where the product fibers, or the organic coating on the fiber, have the potential to enter a human body through ingestion or inhalation.

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. This RCFC limit is a recommendation from an industry organization rather than a regulatory requirement. Nextel ceramic fibers 312, 440, 610, and 720 are nonrespirable fibers (diameter of >3 microns); therefore, they are not covered by this suggested limit. Instead, the current ACGIH® TLV® of 1 mg/m³ 8-hour time weighted average (TWA) for particulate matter of aluminum metal and insoluble compounds is recommended for Nextel ceramic fibers 312, 440, 610, and 720 since they are alumina-based materials.

Because Nextel ceramic fibers have diameters of 8 to 14 microns, they fall outside the World Health Organization (WHO) definition of respirable. Fibers are defined as respirable by WHO convention if the diameter is less than 3 microns, the length is greater than 5 microns and the aspect ratio (length/diameter) is at least 3:1.

The European Chemical Agency (ECHA) added aluminosilicate refractory ceramic fibers (RCFs) to the Candidate List for substances of very high concern (SVHC) under REACH. While many 3M™ Nextel™ Ceramic Fibers and Fabrics are aluminosilicate ceramics, no current 3M™ Nextel™ Ceramic Fiber products are subject to the RCF categories that ECHA has designated for the SVHC Candidate List.

Only fibers that meet both of the following conditions are classified under the new SVHC category:

(i) Al_2O_3 and SiO_2 are present within either of the following ranges: (Al_2O_3 : 43.5–47.0% w/w and SiO_2 : 49.5–53.5% w/w) and (Al_2O_3 : 45.5–50.5% w/w and SiO_2 : 48.5–54.0% w/w)

(ii) Fibers have a length weighted geometric mean diameter of less than two standard geometric errors of 6 or fewer micrometers (µm).

3M™ Nextel™ Ceramic Fibers are not considered to be SVHCs, and are not subject to future authorization actions under REACH. Please refer to Nextel Regulatory Data Sheets, available on 3m.com/sds, for up to date SVHC information.

Regulation (EC) No 1272/2008 on classification, labeling, and packaging of substances and mixtures (CLP) is the European legal base for classification, packaging and labeling of certain man-made vitreous fibers. Laboratory

Health and Safety Bulletin (continued)

3M™ Nextel™ 312, 440, 610 and 720

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 are not classified as dangerous substances according this directive.

Eye and Skin Contact

3M™ Nextel™ Ceramic Fibers 312, 440, 610, and 720 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 irritation occurs, flush eyes with water. If skin irritation occurs, wash the affected area with soap and water and change to fresh clothing.

For more information refer to Safety Data Sheet (SDS).

Heat Cleaning/Treatment

Nextel ceramic fibers 610 and 720 are used in ceramic, polymer and metal matrix composites. Heat cleaning Nextel ceramic fibers 312, 440, 610, and 720 to remove the polymeric sizings and finishes or heat treatment of Nextel ceramic fibers 312 generates thermal decomposition products which can be hazardous if inhaled at concentrations exceeding their recommended exposure limits. Carbon monoxide may be a 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, i.e., 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. For detailed instructions, refer to the Heat Cleaning/Heat Treating Procedure Bulletins for Nextel ceramic fibers 312, 440, 610 and 720.

After Service Considerations

Analysis of Nextel ceramic fibers 312, 440, 610 and 720, either as manufactured or after use, has shown that neither free crystalline 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 ceramic fibers 312, 440, 610 and 720 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 and Dust Inhalation” section of this document for precautions and respirator recommendations when using Nextel ceramic fibers.

3M™ Nextel™ Ceramic Fiber Terminology

Chopped Fiber – Short lengths of fiber made by cutting continuous fiber roving. Chopped fibers are relatively 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.

Heat Cleaning – Batch or continuous process to thermally remove sizing.

Heat Treating – Batch or continuous process to thermally remove sizing and change the crystal structure of the Nextel 312 fiber, improving its resistance to moisture and chemical attack.

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 filaments in single strand, with very little twist. Also known as strand or tow.

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

Splice – A union of two fibers or yarns joined together at the end.

Sizing – Starch, oil, wax, or other suitable 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 – A loose assemblage of filaments in a single strand with very little twist. Also known as roving or tow.

Tex – Grams per 1000 meters.

Tow – A loose, essentially untwisted, strand of fibers.

Twist – Twisting and/or plying strands.

Warp – Ends that run lengthwise in a fabric.

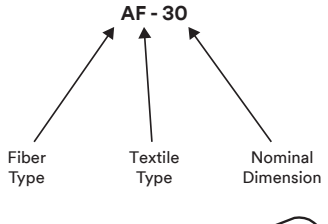
Yarn – An assembly of one or more strands twisted together. Examples: 1/2, 2/2, 4/5.

Yield – Length of yarn per unit weight.

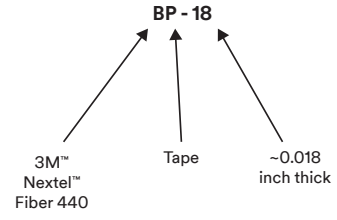
Nomenclature

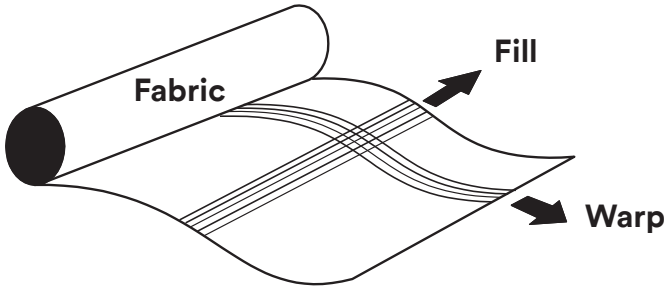
Fiber Type	Textile Type
A=312	F=Fabric
B=440	P=Tape
D=610	T=Thread
E=720	S=Sleeving
	C=Chopped

Example:



Example:





Fill – Ends that run crosswise in a fabric.

Warp – Ends that run lengthwise in a fabric.

Fiber Selection Guide

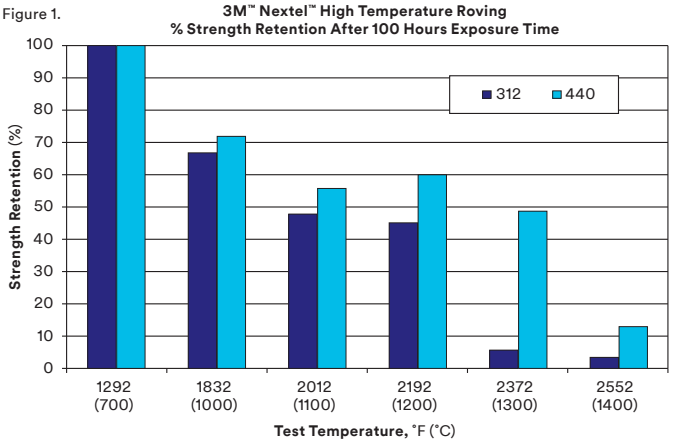
3M™ Nextel™ High Temperature Industrial Fibers and 3M™ Nextel™ Structural Fibers

The family of 3M™ Nextel™ Ceramic Fibers was developed to serve a variety of needs. 3M™ Nextel™ Ceramic Fibers 312 and 440 are designed for non-structural applications where their primary purpose is to insulate or to act as a flame barrier. 3M™ Nextel™ Ceramic Fibers 610 and 720 are structural 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, roving break load is measured at room temperature after exposure at an elevated temperature for 100 hours (Figure 1). In the strength at temperature test, roving break load is determined while the fiber is held at temperature (Figure 2).

Two of the high temperature industrial fibers, 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.

The structural grade fibers, 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 (Figure 2).

Figure 1.

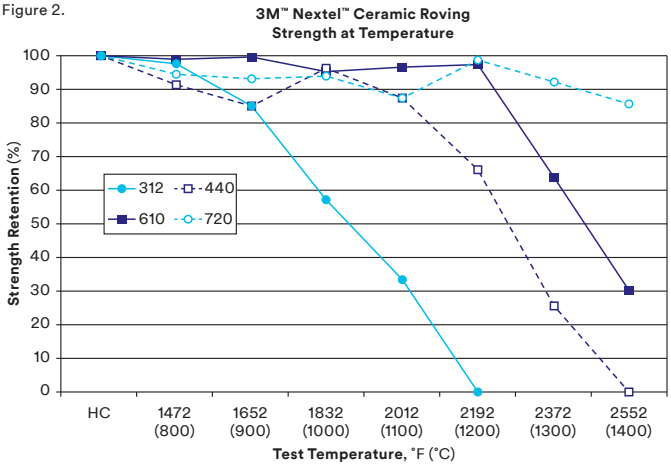


Outline of Test:
Sample Number: 10 pulls from 3 different lots (30 test samples)
Samples: Nextel Roving 312: 1800 denier
Nextel Roving 440: 2000 denier
Gage Length: 2 inches
Extension Rate: 0.5 inch/min
Note: All samples were heat cleaned (sizing removed) at 1292°F (700°C) which represents the 100% strength bar. All the samples were wetted with DI water before testing to aid in handling.

Nextel ceramic fiber 610 is a fine grained single-phase composition of α-Al_2O_3. Nextel ceramic fiber 610 has the highest strength (Figure 3) and modulus, which can be used for polymer, metal and ceramic matrix composites. However, because it is essentially single phased, the strength rapidly decreases at higher temperatures due to grain growth (Figures 4 and 5). 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 in Figures 4 and 5. Further confirmation of the effect of additional phases and removal of the glassy phase is shown in creep testing (Figure 6).

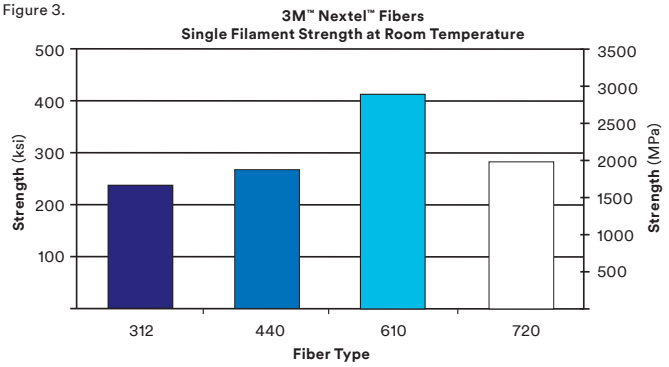
When selecting the fiber type for a particular application, it is important to consider all these factors. If the fiber/fabric will not have to support a load at temperature, the lower-cost high temperature industrial grade fibers may be appropriate. However, if the fiber will be used as load bearing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

Figure 2.



Outline of Test:
Sample Number: 10
Samples: Nextel Roving 312: 900 denier
Nextel Roving 440: 1000 denier
Nextel Roving 610: 1500 denier
Nextel Roving 720: 1500 denier
Total Gage Length: 10 inches (254 mm)
Hot Zone Length: 1 inch (25.4 mm)
Extension Rate: 0.5 inch/min (12.7 mm/min)
Note: Samples were held at temperature for approximately 1.5 minutes before testing.

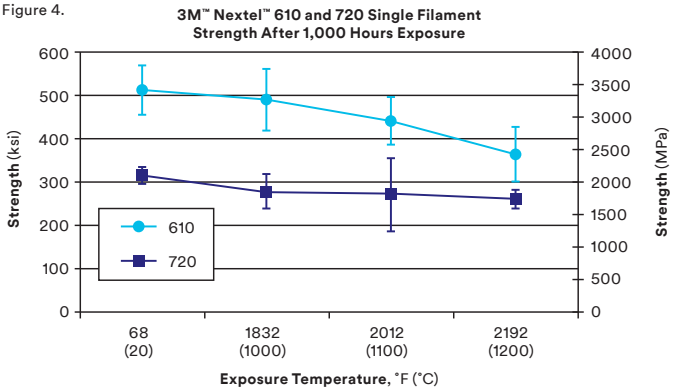
Figure 3.



Test Description:
Gage Length: 1 inch (25.4 mm)

Extension Rate: 0.2 inch/min (5.1 mm/min)
Sample Number: 10

Figure 4.



Outline of Test:
Sample Number: 10

Crosshead Speed: 0.02 inch/min (0.5 mm/min)
Gage Length: 1 inch (25.4 mm)

Figure 5.

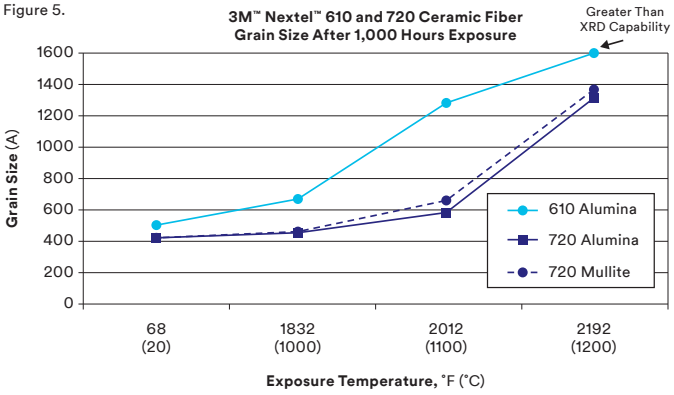
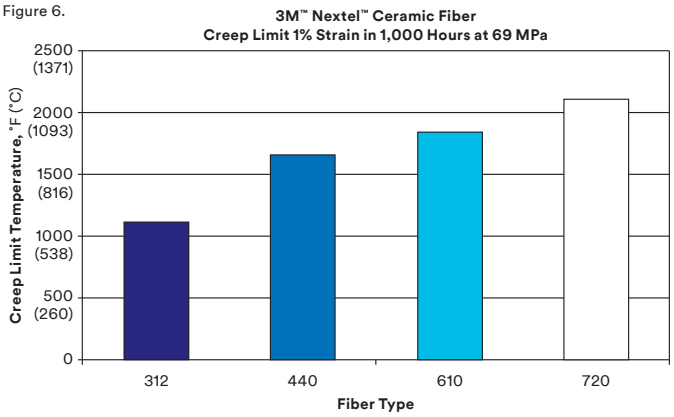


Figure 6.



Fiber Weight Loss

3M™ Nextel™ Ceramic Fiber Roving Typical Properties (Not for specification purposes)

Heat cleaned roving samples (with sizing removed) 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 3M™ Nextel™ Ceramic Fiber 312.

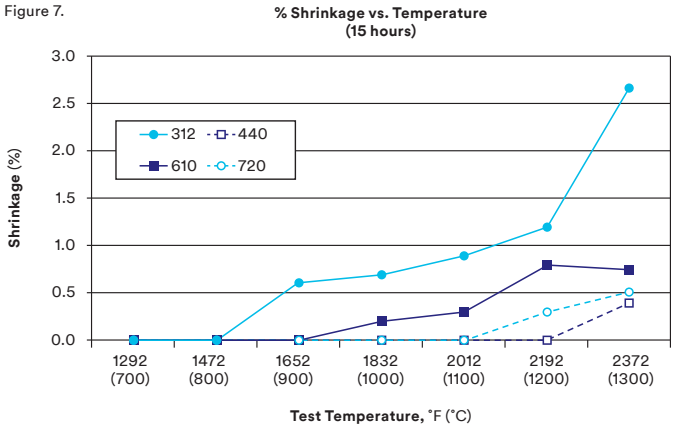
Fiber	Nextel 312	Nextel 440	Nextel 610	Nextel 720
Wt loss (%)	2.6	<0.1	<0.1	<0.1

Fiber Shrinkage

3M™ Nextel™ Ceramic Fiber Roving Typical Properties (Not for specification purposes)

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 3M™ Nextel™ Ceramic Roving 312 showed shrinkage of less than 1.0 % at these conditions.

Figure 7.



3M™ Nextel™ Ceramic Fiber 312, 440, 610 and 720 Typical Properties

(Not for specification purposes)

Property	Units	Nextel 312	Nextel 440	Nextel 610	Nextel 720
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	>99 Al_2O_3	85 Al_2O_3 15 SiO_2
Melting Point	°C	1800	1800	2000	1800
Continuous Use Temperature (40% fiber strength retention)[1]	°C	1200	1300	—	—
Continuous Use Temperature (Single Filament ≤1 % strain)[2]	°C	—	—	1000	1150
Filament Diameter	µm	8 – 12	10 – 12	11 – 13	12 – 14
Denier / Nominal Filament Count	g/9000 m	600 / 400 900 / 400 1200/750 1800 / 750 3600 / 1375	1000 / 400 2000 / 750	1500 / 400 3000 / 750 4500 / 1125 10000 / 2550 20000 / 5100	1500 / 400 3000 / 750 10000 / 2550
Tex / Nominal Filament Count	g/1000 m	67 / 400 100 / 400 133 / 750 200 / 750 400 / 1375	111 / 400 222 / 750	167 / 400 333 / 750 500 / 1125 1111 / 2550 2222 / 5100	167 / 400 333 / 750 1111 / 2550
Crystal Size	nm	<500	<500	<500	<500
Crystal Phase		Distorted Mullite+ amorphous	γ-Al_2O_3 + amorphous	α-Al_2O_3	α-Al_2O_3 + Mullite
Density	g/cc	2.8	3.0	3.9	3.4
Refractive Index		1.57	1.61	1.74	1.67
Filament Tensile Strength (25,4 mm gauge)	MPa ksi	1630 236	1840 267	2800 406	1940 281
Filament Tensile Modulus	GPa msi	150 22	190 27	370 54	250 36
Thermal Expansion (100-1100°C)	ppm/°C	3.0 (25-500°C)	5.3	8.0	6.0
Dielectric Constant @ 9.5 GHz	3a 3b	2.7 4.8	2.8 5.0	4.7 6.9	3.8 6.2
Loss Tangent @ 9.5 GHz	3a 3b	0.003 0.004	0.001 0.001	0.002 0.002	0.001 0.001
Specific Heat @395°C[4]	cal/g/°C	0.46	0.51	0.38	0.58

[1]Tested at room temperature after 100 hours soak.
[2]Tested under 69 MPa after 1000 hours.
[3a]As per standard IEC 61189-2-721: AF-20 (312), BF-20 (440), DF-19 (610) and EF-19 (720) heat clean fabrics were used to run dielectric data using cavity method.
[3b]Test data after Air part subtracted.
[4]Test ran on fibers heat treated at 950°C for 1 hour.

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. Starch, oil, wax or other suitable organic ingredients can be applied to a fiber strand to protect and aid handling.

299, 300 and 324 sizings are composed of polyvinyl alcohol (PVA) and additives (plasticizers, lubricants, etc.), that are 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.

Typical Colors of Standard Products (Not for specification purposes)

Product	Sizing	Typical Color (Sized)	Typical Color (Heat Cleaned)
312	299	White	White
440	300C	Coral	White
610	324	White to Off-White/Yellowish	White to Off-White/Yellowish
720	299G	Green	White to Off-White/Yellowish
	299	White to Off-White/Yellowish	

Nextel ceramic rovings 610 and 720 may also be treated with an epoxy resin or water sizing upon request.

500 sizing: Organic sizing designed for adhesion to epoxy resin systems

Water sizing: water only – no organic sizing

Heat cleaning is used to remove 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 3M™ Nextel™ Ceramic Fabric is to be used as electrical insulation, (thermocouples, heaters, etc.), under reducing atmosphere or vacuum conditions.

3M™ Nextel™ Ceramic Rovings, Yarns, and Chopped Fibers 312 and 440

Typical Properties (Not for specification purposes)

3M™ Nextel™ Ceramic Roving 312

Roving	Nominal Filament Count	Yield		Breaking Load*	
		yds/lb	m/kg	lbs	kg
600 denier (67 tex)	400	7400	15000	6	2.7
900 denier (100 tex)	400	4900	9800	8	3.6
1200 denier (133 tex)	750	3600	7300	14	6.4
1800 denier (200 tex)	750	2400	4900	16	7.3
3600 denier (400 tex)	1375	1200	2400	30	14

3M™ Nextel™ Ceramic Served Roving 312

Roving	Nominal Filament Count	Yield		Breaking Load*	
		yds/lb	m/kg	lbs	kg
600 denier (67 tex)	400	6300	13000	7	3.2
900 denier (100 tex)	400	4300	8700	10	4.5

3M™ Nextel™ Ceramic Roving 440

Roving	Nominal Filament Count	Yield		Breaking Load*	
		yds/lb	m/kg	lbs	kg
1000 denier (111 tex)	400	4400	8800	10	4.5
2000 denier (222 tex)	750	2200	4400	18	8.2

3M™ Nextel™ Ceramic Yarn 312

Yarn	Ends	Diameter		Yield		Breaking Load*	
		in	mm	yds/lb	m/kg	lbs	kg
600 denier (67 tex) 1.5 Twists/inch (59 Twists/m)**							
1/2	2	0.007	0.18	3590	7240	13	5.9
900 denier (100 tex) 1.5 Twists/inch (59 Twists/m)**							
1/2	2	0.008	0.20	2370	4780	19	8.6
900 denier (100 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.009	0.23	2370	4780	19	8.6
1/3	3	0.013	0.33	1580	3190	28	13
1/5	5	0.018	0.46	950	1920	44	20
2/3	6	0.022	0.56	780	1570	50	23
3/4	12	0.034	0.86	390	790	100	45
4/5	20	0.048	1.22	230	460	150	68
3/8	24	0.052	1.32	195	390	130	59
900 denier (100 tex) 4.0 Twists/inch (157 Twists/m)**							
1/2	2	0.010	0.25	2370	4780	20	9.1
4/5	20	0.052	1.32	230	460	130	59
1800 denier (200 tex) 0.5 Twists/inch (20 Twists/m)**							
1/2	2	0.009	0.23	1180	2380	32	15
1800 denier (200 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.016	0.41	1180	2380	33	15
1/3	3	0.020	0.51	780	1570	43	20
1/4	4	0.025	0.64	590	1190	64	29
2/3	6	0.033	0.84	390	790	91	41
2/5	10	0.047	1.19	230	460	150	68
2/6	12	0.054	1.37	195	390	150	68
1800 denier (200 tex) 4.0 Twists/inch (157 Twists/m)**							
1/2	2	0.018	0.46	1180	2380	33	15

Note: Yields and breaking loads are based upon sized rovings and yarns.
* Tested at room temperature.
** Other twist levels available.

3M™ Nextel™ Ceramic Rovings, Yarns, and Chopped Fibers 312 and 440

3M™ Nextel™ Ceramic Yarn 440

Yarn	Ends	Diameter		Yield		Breaking Load*	
		in	mm	yds/lb	m/kg	lbs	kg
1000 denier (111 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.009	0.23	2150	4330	20	9.1
2/2	4	0.015	0.38	1070	2160	33	15
3/4	12	0.034	0.86	350	710	82	37
2000 denier (222 tex) 1.5 Twists/inch (59 Twists/m)**							
1/2	2	0.012	0.30	1065	2150	36	16
2000 denier (222 tex) 2.7 Twists/inch (106 Twists/m)**							
1/2	2	0.015	0.38	1065	2150	33	15
2/5	10	0.046	1.2	210	420	110	50

Note: All yields are based upon sized rovings and yarns.
* Tested at room temperature.
** Other twist levels available.

3M™ Nextel™ Ceramic Chopped Fibers 312

Nextel ceramic rovings may be chopped to nominal lengths. The following table lists standard lengths.

Fiber	Cut Length	AC-8 (1300 denier)*	AC-11 (3600 denier)
Nextel 312	1/8" (3.2mm)	x	x
	1/4" (6.4mm)	x	x
	1/2" (12.7mm)		x

*HEAT TREATING IS AVAILABLE AS AN OPTION

3M™ Nextel™ Ceramic Structural Rovings, Yarns, and Chopped Fibers 610 and 720

Typical Properties (Not for specification purposes)

3M™ Nextel™ Ceramic Roving 610

Roving	Nominal Filament Count	Yield		Breaking Load*	
		yds/lb	m/kg	lbs	kg
1500 denier (167 tex)	400	2900	5900	12	5.5
3000 denier (333 tex)	750	1400	2900	20	9.1
4500 denier (500 tex)	1125	990	2000	24	11
10000 denier (1111 tex)	2550	440	880	31	14
20000 denier (2222 tex)	5100	220	440	45	20

Note: All yields are based upon sized rovings.
* Tested at room temperature.

3M™ Nextel™ Ceramic Roving 720

Roving	Nominal Filament Count	Yield		Breaking Load*	
		yds/lb	m/kg	lbs	kg
1500 denier (167 tex)	400	2900	5900	7	3.2
3000 denier (333 tex)	750	1400	2900	10	4.5
10000 denier (1111 tex)	2550	440	880	24	11

Note: All yields are based upon sized rovings and yarns.
* Tested at room temperature.

3M™ Nextel™ Ceramic Structural Chopped Fibers 610 and 720

Nextel ceramic rovings may be chopped to nominal lengths. The following table lists standard lengths.
Other lengths may be chopped by special request.

Cut Length		Fiber	
in	mm	Nextel 610	Nextel 720
1/8	3.2	✓	✓
1/4	6.4	✓	✓
1/2	12.7	✓	
1	25.4		✓

3M™ Nextel™ Ceramic Sewing Threads 312 and 440 and 3M™ Sewing Thread

Typical Properties (Not for specification purposes)

Style	Thread Diameter		Approximate Yield		Breaking Load lbs (kg)		Knot Strength with sizing	
	in	mm	yds/lb	m/kg	with sizing	heat cleaned	lb	kg
3M™ Nextel™ Ceramic Sewing Threads 312								
AT-21*	0.020	0.51	1590	3200	33 (15)	19 (8.6)	9	4.1
AT-30	0.028	0.71	820	1650	50 (23)	28 (13)	15	6.8
3M™ Nextel™ Ceramic Sewing Threads 440								
BT-30	0.028	0.71	720	1450	49 (22)	34 (15)	14	6.4
3M™ Sewing Threads**								
GT-15*	0.015	0.38	2030	4090	29 (13)	N/A	11	5.0
GT-23	0.022	0.56	1210	2440	40 (18)	N/A	17	7.7

*Non-standard item; available by special order.
** 3M Sewing Threads are manufactured from high temperature continuous glass fiber coated with PTFE.

3M™ Nextel™ Woven Ceramic Fabrics

Woven ceramic fabrics from 3M allow engineers and designers to create new, imaginative solutions for previously impossible problems.

3M™ Nextel™ Woven Ceramic Fabrics 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 perform at continuous temperatures up to 2372°F (1300°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 for Nextel woven ceramic fabrics are as follows:

Typical Applications (Not for specification purposes)

Applications	Nextel 312	Nextel 440	Nextel 610	Nextel 720
Aerospace: Flame barrier, thermal shields, gaskets, seals, micrometeorite debris shields	×	×		
Industrial: Furnace curtains and linings, door seals, tube seals, gaskets, expansion joints, flexible couplings	×	×		
Ceramic Matrix Composites	×	×	×	×
Metal Matrix Composites			×	×
Polymer Matrix Composites	×	×	×	×

3M™ Nextel™ Woven Ceramic Fabrics 312, 440, 610 and 720

Typical Properties (Not for specification purposes)

Style	Target thread count per in. (cm)		Input fiber		Weave Type	Air Permeability* (Heat cleaned)	Width in. (cm)	Sized		Heat Cleaned			
								Weight oz/yd² (g/m²)	Thickness in. (mm)	Weight oz/yd² (g/m²)	Thickness in. (mm)	Breaking strength lbs/in. (kg/cm)	
	Warp	Fill	Yarn type	Denier (Tex)								Warp	Fill
Nextel Woven Fabric 312													
AF-8	20 (8)	10 (4)	Served Roving	600 (67)	10 Mesh Leno	N/A	38 (97)	3.3 (110)	0.015 (0.38)	2.4 (81)	0.009 (0.23)	30 (5)	20 (4)
AF-10	46 (18)	46 (18)	Served Roving	600 (67)	5 Harness Satin	Med	38 (97)	8.6 (290)	0.016 (0.41)	7.2 (240)	0.011 (0.28)	140 (25)	140 (25)
AF-10-900	31 (12)	31 (12)	Roving	900 (100)	4 Harness Satin	Med	38 (97)	7.3 (250)	0.013 (0.33)	7.2 (240)	0.011 (0.28)	150 (27)	150 (27)
AF-12	25 (10)	25 (10)	Roving	1200 (133)	5 Harness Satin	Med	42, 58 (107, 147)	8.0 (270)	0.014 (0.36)	7.9 (270)	0.011 (0.28)	120 (21)	130 (23)
AF-14	20 (8)	17 (7)	½ Yarn	900 (100)	Plain weave	High	38, 59 (97, 150)	9.0 (310)	0.015 (0.38)	8.8 (300)	0.014 (0.36)	120 (21)	120 (21)
AF-20	30 (12)	26 (10)	Roving	1800 (200)	5 Harness Satin	Low	36, 63 (91, 160)	13 (440)	0.021 (0.53)	13 (440)	0.020 (0.51)	140 (25)	140 (25)
AF-29	17.5 (7)	17.5 (7)	Roving	3600 (400)	4 Harness Satin	Med	50 (127)	16 (540)	0.030 (0.76)	16 (540)	0.028 (0.71)	170 (30)	160 (29)
AF-30	19 (7)	18 (7)	½ Yarn	1800 (200)	4 Harness Satin	High	36 (91)	18 (610)	0.032 (0.81)	18 (610)	0.030 (0.76)	160 (29)	170 (30)
AF-40	32 (13)	20 (8)	½ Yarn	1800 (200)	5 Harness Satin	Med	36 (91)	24 (810)	0.038 (1.0)	24 (810)	0.038 (0.97)	170 (30)	150 (27)
AF-62	40 (16)	20 (8)	½ Yarn	1800 (200)	Plain Double Layer	High	4, 12, 30 (10, 30, 76)	29 (980)	0.055 (1.4)	29 (980)	0.055 (1.4)	190 (34)	140 (25)
Nextel Woven Fabric 440													
BF-20	30 (12)	26 (10)	Roving	2000 (222)	5 Harness Satin	Low	36, 63 (91, 160)	15 (510)	0.021 (0.53)	15 (510)	0.020 (0.51)	230 (41)	230 (41)
BF-30	21 (8)	20 (8)	½ Yarn	2000 (222)	4 Harness Satin	Med	63 (160)	20 (680)	0.032 (0.81)	20 (680)	0.031 (0.79)	160 (29)	160 (29)
Nextel Woven Fabric 610													
DF-6	18.5 (7)	18.5 (7)	Roving	1500 (167)	4 Harness Satin	Med	36 (91)	7.5 (250)	0.008 (0.20)	7.3 (250)	0.006 (0.15)	180 (32)	180 (32)
DF-11	27.5 (11)	27.5 (11)	Roving	1500 (167)	8 Harness Satin	Med	36 (91)	11 (370)	0.012 (0.30)	11 (370)	0.010 (0.25)	–	–
DF-11-3000	14 (5.5)	14 (5.5)	Roving	3000 (333)	5 Harness Satin	–	36 (91)	11 (370)	0.013 (0.33)	11 (370)	0.010 (0.25)	–	–
DF-13-4500	12 (4.7)	12 (4.7)	Roving	4500 (500)	5 Harness Satin	–	36 (91)	14.1 (480)	0.019 [2] (0.48)	13.8 (470)	0.014 (0.36)	–	–
DF-19	23.5 (9)	23.5 (9)	Roving	3000 (333)	8 Harness Satin	Med	36 (91)	19 (640)	0.020 (0.51)	18 (610)	0.017 (0.43)	–	330 (59)
Nextel Woven Fabric 720													
EF-11	27.5 (11)	27.5 (11)	Roving	1500 (167)	8 Harness Satin	Med	36 (91)	11 (370)	0.013 (0.33)	11 (370)	0.012 (0.30)	180 (32)	170 (30)
EF-19	23.5 (9)	23.5 (9)	Roving	3000 (333)	8 Harness Satin	Med	36 (91)	19 (640)	0.023 (0.58)	18 (610)	0.021 (0.53)	240 (43)	230 (41)
EF-20	16 (6)	5 (2)	Roving	10,000 warp x 1500 fill (1111 × 167)	Plain - Semi Unidirection	Low	25 (64)	22 (750)	0.030 (0.76)	22 (750)	0.026 (0.66)	260 (46)	90 (16)

*Permeability (cfm/ft²): Low <20; Med 20-70; High > 70. A-Nextel 312 B-Nextel 440 D-Nextel 610 E-Nextel 720

[1] Heat cleaning is only available on fabric with widths 58" and less. This applies to AF-14, AF-20, BF-20 and BF-30.

[2] Thickness values shown for DF-13-4500 are based on ASTM D1777 Option 1 with an applied pressure of 0.60 psi. Thickness values shown for all other products are based on a 3M test method using a greater applied pressure of 0.625 psi.

Warp and Fill Breaking Load at Room Temperature

3M™ Nextel™ Woven Ceramic Fabrics 312, 440, 610 and 720

Typical Properties (Not for specification purposes)

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

Heat cleaned fabric samples were cut into approximately 1-1.5 inch × 6 inch (2.54-3.81 cm × 15.24 cm) strips in the warp and fill directions, respectively.

Edges were unraveled to a width of either 0.5 inch (1.27 cm) or 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 constant crosshead speed.

Fabric was placed into flat-face jaws. Air pressure was set at 60-80 psi ($4.14 \times 10^5 - 5.51 \times 10^5$ Pa).

Figure 8.

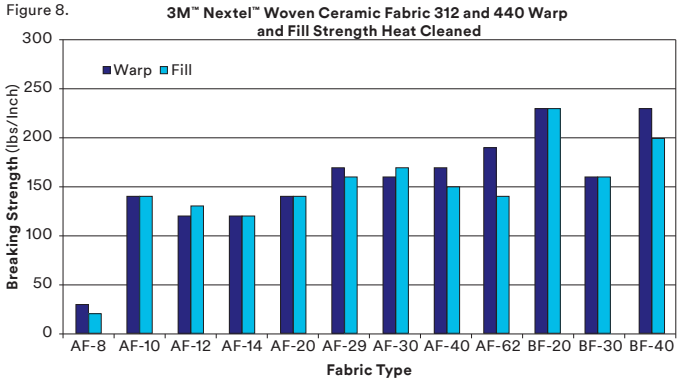
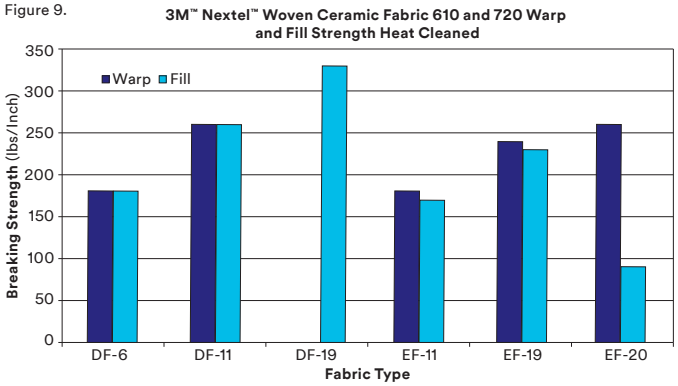


Figure 9.



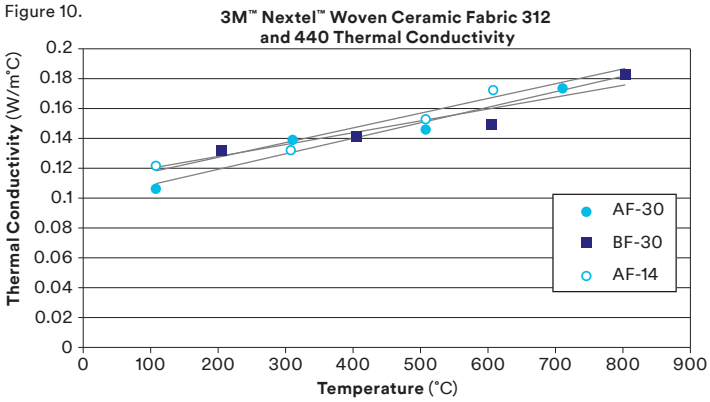
Thermal Conductivity

3M™ Nextel™ Woven Ceramic Fabrics 312 and 440

Typical Properties (Not for specification purposes)

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

Figure 10.



3M™ Nextel™ Ceramic Woven Tapes 312 and 440

Typical Properties (Not for specification purposes)

Style	Tape Width		Weight (sized)		Thickness (sized)		Breaking Strength Heat Cleaned	
	inch	cm	oz/yd	g/m	inch	mm	lbs/in	kg/cm
3M™ Nextel™ Ceramic Woven Tape 312, Style AP-18								
AP-18 1" Tape	1.0	2.5	0.31	9.6	0.020	0.51	130	23
AP-18 1½" Tape	1.5	3.8	0.45	14.0	0.019	0.48		
AP-18 2" Tape	2.0	5.1	0.60	18.6	0.019	0.48		
3M™ Nextel™ Ceramic Woven Tape 440, Style BP-18								
BP-18 2" Tape *	2.0	5.1	0.67	20.8	0.020	0.51	130	23

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.
* Available only by special order.

3M™ Nextel™ Ceramic Sleevings 312 and 440

Typical Properties (Not for specification purposes)

Sleeving Inside Diameter		Wall Thickness (sized)		Length per Unit Weight on Mandrel (sized)		Target Yield As Packaged, Roll Form (sized)		Picks per Unit Length	
inch	mm	inch	mm	yards/lb	m/kg	yards/lb	m/kg	picks/inch	picks/cm
3M™ Nextel™ Ceramic Sleeving 312, Style AS-40									
1/16	1.6	0.028	0.71	85	171	87	175	13	5
1/8	3.2	0.037	0.94	39	79	42	85	11	4
1/4	6.4	0.038	0.97	25	50	28	56	11	4
1/2	12.7	0.038	0.97	13	26	16	32	10	4
3/4	19.1	0.038	0.97	8.7	18	12	24	10	4
1	25.4	0.033	0.84	7.7	16	9.6	19	12	5
1 1/2**	38.1	0.033	0.84	5.4	11	7.2	15	12	5
2**	50.8	0.038	0.97	3.6	7.3	5.4	11	11	4
2 1/2**	63.5	0.037	0.94	3.1	6.2	4.4	8.9	8	3
3M™ Nextel™ Ceramic Sleeving 440, Style BS-40									
1/16**	1.6	0.027	0.69	76	153	76	153	13	5
1/8	3.2	0.038	0.97	35	71	38	77	12	5
1/4	6.4	0.035	0.89	23	46	25	50	11	4
1/2	12.7	0.039	0.99	12	24	15	30	10	4
3/4**	19.1	0.038	0.97	7.9	16	10	20	10	4
1**	25.4	0.033	0.84	7.0	14	8.6	17	12	5

AS-40 Input yarn is 900 denier 3M™ Nextel™ Ceramic Yarn 312, 1/2, 2.7z.
BS-40 Input yarn is 1000 denier 3M™ Nextel™ Ceramic Yarn 440, 1/2, 2.7z.
**Available only by special order.

Performance Test Results: Chemical Exposure Effects

Metal Compatibility

Issues of metal compatibility depend on several factors – temperature, atmosphere (oxidizing, reducing, neutral, and vacuum) and other materials (fluxes, etc.) that 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™ Ceramic 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™ Ceramic Fibers under oxidizing high temperature conditions.

Chemical Resistance

Short-term chemical exposure tests were performed on heat cleaned 3M™ Nextel™ Ceramic Woven Fabrics 312, 440, 610 and 720 and heat treated Nextel Ceramic Woven Fabric 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 fabrics 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 (Not for specification purposes)

Chemical	Concentration	3M™ Nextel™ Fabric 312		3M™ Nextel™ Fabric 440	3M™ Nextel™ Fabric 610	3M™ Nextel™ Fabric 720
		Heat Cleaned	Heat Treated	Heat Cleaned	Heat Cleaned	Heat Cleaned
Acids						
HNO_3 Nitric Acid	10%	Poor	Excellent	Excellent	Excellent	Excellent
HCL Hydrochloric Acid	10%	Excellent	Excellent	Excellent	Excellent	Excellent
H_2SO_4 Sulfuric Acid	10%	Good	Excellent	Excellent	Excellent	Excellent
H_3PO_4 Phosphoric Acid	10%	Poor	Poor	Poor	Poor	Poor
Bases						
KOH Potassium Hydroxide	10%	Poor	Poor	Poor	Poor	Poor
NaOH Sodium Hydroxide	10%	Poor	Poor	Poor	Poor	Poor
NH_4OH Ammonium Hydroxide	10%	Excellent	Excellent	Excellent	Excellent	Excellent

Excellent: >80% strength retention
Good: 40–80% strength retention
Poor: <40% strength retention

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 H2O (Not for specification purposes)

Chemical	Concentration	3M™ Nextel™ Fabric 312		3M™ Nextel™ Fabric 440	3M™ Nextel™ Fabric 610	3M™ Nextel™ Fabric 720
		Heat Cleaned	Heat Treated	Heat Cleaned	Heat Cleaned	Heat Cleaned
Acids						
H_2SO_4 Sulfuric Acid	10%	Good	Excellent	Excellent	Excellent	Excellent
H_3PO_4 Phosphoric Acid	10%	Good	Good	Good	Excellent	Good
Bases						
KOH Potassium Hydroxide	10%	Excellent	Excellent	Excellent	Excellent	Excellent
NaOH Sodium Hydroxide	10%	Excellent	Excellent	Excellent	Excellent	Good

Excellent: >80% strength retention
Good: 40–80% strength retention
Poor: <40% strength retention

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).

Performance Test Results: Moisture Absorption

The 3M™ Nextel™ Ceramic Fibers 312, 440, 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 Ceramic Fabric 312 and 440

Nextel woven ceramic fabric 312 (AF-30) and Nextel woven ceramic fabric 440 (BF-30) were heat cleaned, then immersed for thirty hours in JP-4 jet fuel or 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.

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. Nextel woven ceramic fabrics 312 and 440 show no degradation of the fiber strength after 30 hours in JP-4 jet fuel or HyJet IV hydraulic fluid.

Tensile Breaking Load (lb/in width) (Not for specification purposes)

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

Performance Test Results: 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:

Thermal Optical Properties (Not for specification purposes)

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

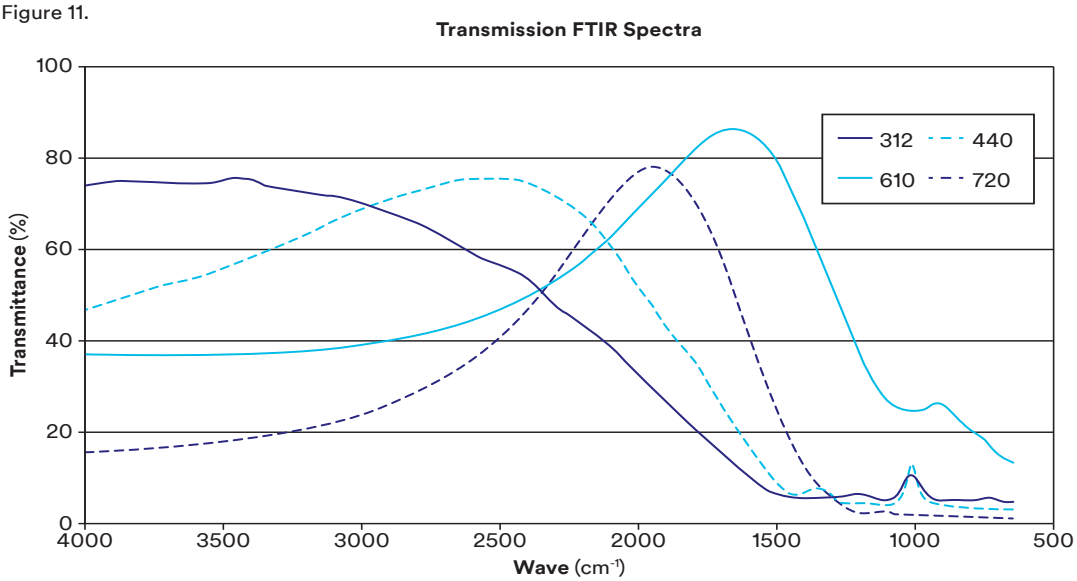
Performance Test Results: IR Absorbance and Transmittance

3M™ Nextel™ Ceramic Fiber 312, 440, 610 and 720

A small sample of chopped fiber (1/8 inch long) fired to 1742˚F (950˚C) was used to determine the transmittance and absorbance of 3M™ Nextel™ Ceramic Fibers in the infrared region.

The following graph shows IR transmission spectra. Absorbance can be calculated from the relationship $A=\log_{10}(100)/(\%T)$.

Figure 11.



For Nextel 312: Between 4000-3250 cm^{-1} the transmission loss is small and essentially due to reflection. Weak absorption shows between 3250 and 1500 cm^{-1}. Beyond 1500 cm^{-1} absorption becomes complete.

For Nextel 440: Weak absorption is observed shows between 4000 and 2750 cm^{-1}. Between 2750-2250 cm^{-1} the transmission loss is small and appears primarily due to reflection. The peak shaped transmission profile in this region reflects the unique optical properties of the material. Weak absorption is observed between 2250 and 1400 cm^{-1}. Beyond 1400 cm^{-1} absorption becomes complete except for a small area of weak absorption at 1000 cm^{-1}.

For Nextel 610: Weak absorption shows between 4000 and 2000 cm^{-1}. Between 2000-1400 cm^{-1} the transmission loss is small and appears primarily due to reflection. The peak shaped transmission profile in this region reflects the unique optical properties of the material. Weak absorption is observed between 1400 and 1100 cm^{-1}. Beyond 1100 cm^{-1} absorption becomes complete.

For Nextel 720: Weak absorption shows between 4000 and 2250 cm^{-1}. Between 2250-1600 cm^{-1} the transmission loss is small and appears essentially due to reflection. The peak shaped transmission profile in this region reflects the unique optical properties of the material. Weak absorption is observed between 1600 and 1250 cm^{-1}. Beyond 1250 cm^{-1} absorption becomes complete.

Heat Cleaning Instructions

3M™ Nextel™ Ceramic Textiles 312, 440, 610, and 720

Heat Cleaning

Heat cleaning is used to remove the organic coatings from the surface of 3M™ Nextel™ Ceramic Fibers. This is important in applications where fabrics are going to be used in prepreg 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 3M™ 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 material-based 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 3M™ Nextel™ Ceramic Fibers 312, 440 610 and 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 may be a predominant decomposition product. By controlling carbon monoxide concentrations to the ACGIH Threshold Limit Value of 25 ppm (8 hours 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 × 36 inches (9.2 m × 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 (4.25 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. Heat cleaning can be accomplished at a soak temperature of 700°C (1292°F). The time required will depend on the furnace design and the amount of material in the furnace. Large fabric rolls will require longer soak times than small samples (fast heating rates may result in undesirably high exothermic conditions due to rapid sizing decomposition).
4. Turn off furnace and let material and furnace cool to room temperature before handling.
5. Pigmented product will lose its color when sizing has been removed. Process should be repeated or extended until product is completely white (Nextel 312 and 440) or white/off-white/yellowish (Nextel 610 and 720).

Heat Treating Instructions

3M™ 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 may be a 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. Heat treating can be accomplished at a soak temperature of 900°C (1652°F). The time required will depend on the furnace design and the amount of material in the furnace. Large fabric rolls will require longer soak times than small samples (fast heating rates may result in undesirably high exothermic conditions due to rapid sizing decomposition).
4. Turn off furnace and let material and furnace cool to room temperature before handling

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