Vectran™

Enhance • Transform • Discover

LIQUID CRYSTAL POLYMER FIBER TECHNOLOGY

kuraray

ABOUT KURARAY

Kuraray is a world leader in the manufacture of specialty fibers, chemicals and functional materials. We are committed to our customers and driven to develop products that ensure quality and value while differentiating our customers from competition.

Vectran™

ABOUT Vectran™

Pound for pound Vectran™ is five times stronger than steel and ten times stronger than aluminum.

CHARACTERISTICS OF Vectran™

- High strength and modulus
- Excellent creep resistance
- Abrasion resistance
- Excellent flex/fold characteristics
- Minimal moisture absorption
- Chemical resistance
- Low coefficient of thermal expansion (CTE)
- High dielectric strength
- Outstanding cut resistance
- Vibration damping characteristics
- High impact strength

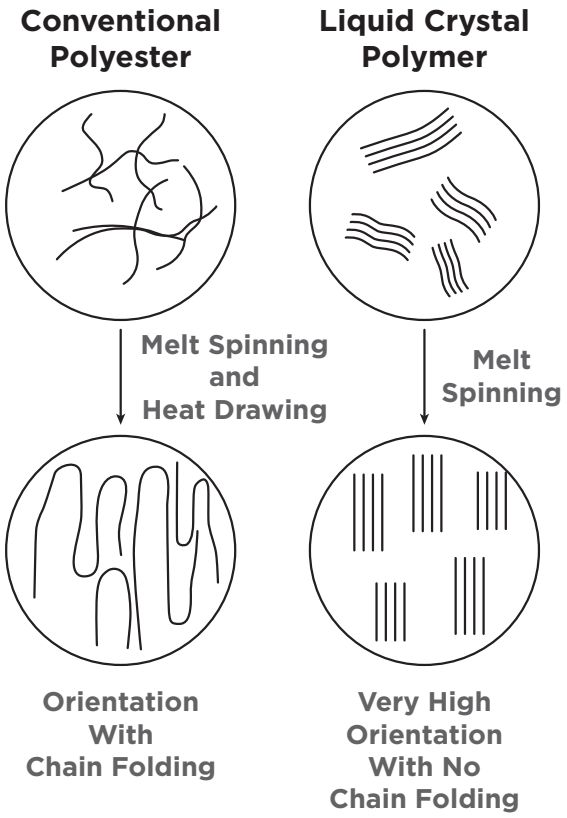
APPLICATIONS

- Ropes and cables
- Recreation and leisure
- Aerospace
- Industrial
- Electronics

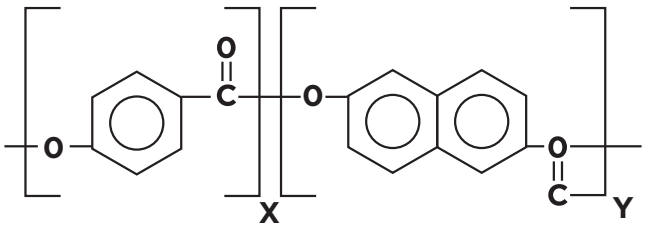
FIBER CHEMISTRY

Vectran™ offers a balance of properties unmatched by other high performance fibers. LCP polymer molecules are stiff, rod-like structures organized in ordered domains in both solid and melt states. These oriented domains lead to anisotropic behavior in the melt state, thus the term “liquid crystal polymer.”

Vectran™ HAS EXCELLENT FIBER TENSILE PROPERTIES:

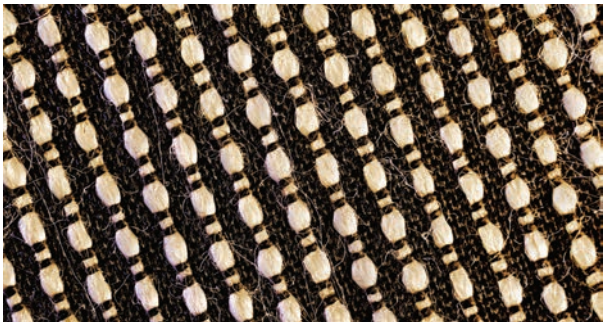


Vectran™ is different from other high performance fibers such as aramid and ultra-high molecular weight polyethylene (HMPE). Vectran™ is thermotropic, it is melt-spun and it melts at high temperatures.



TENSILE PROPERTIES

Vectran™ offers unique properties as compared to traditional metals in terms of strength-to-weight ratios.



Vectran™ VS. TRADITIONAL MATERIALS

Material	Density (g/cm^3)	Tensile Strength (GPa)	Specific Strength (km*)	Tensile Modulus (GPa)	Specific Modulus (km**)
Vectran™ NT	1.4	1.1	79	52	3,700
Vectran™ HT	1.4	3.2	229	75	5,300
Vectran™ UM	1.4	3.0	215	103	7,400
Titanium	4.5	1.3	29	110	2,500
Stainless Steel	7.9	2.0	26	210	2,700
Aluminum	2.8	0.6	22	70	2,600

* Specific strength = Strength/Density (also divided by force of gravity for SI units). Also known as breaking length, the length of fiber that could be held in a vertical direction without breaking.
** Specific modulus = Modulus/Density (also divided by force of gravity for SI units). This measure increases with increasing stiffness and decreasing density.

MECHANICAL PROPERTIES OF Vectran™ FILAMENT YARN (AVERAGE)

	HT			UM		
	GPa	g/ denier	ksi	GPa	g/ denier	ksi
Break Strength	3.2	25.9	465	3	24.4	440
Initial Modulus	75	600	10,760	103	838	15,020
Elongation at Break, %	3.8			2.8		

FINISHING

Vectran™ fiber is available in a variety of sizing options. Please contact your Vectran™ sales representative to right-size your finish for your unique application.

THERMAL PROPERTIES

Vectran™ HT has excellent thermal properties especially in regard to thermal loading.

FIBER THERMAL PROPERTIES

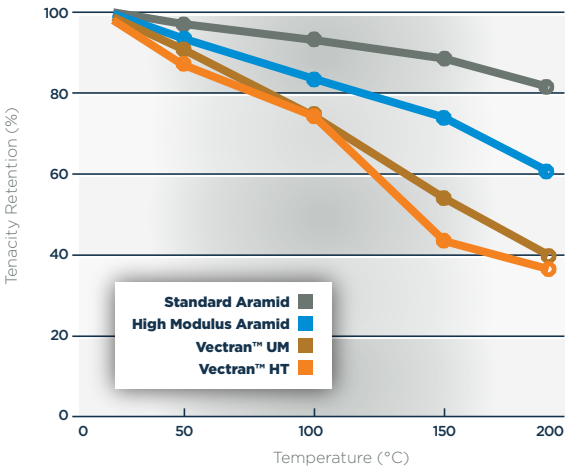
	Vectran™		Aramid	
	HT	UM	Standard	High Modulus
LOI	28	30	30	30
M.P., °C	None	350	None	None
HAS (Hot air shrink, 180 °C, 30 minutes), %	<0.2	<0.1	<0.2	<0.1
BWS (Boiling water shrinkage, 100 °C, 30 minutes), %	<0.2	<0.1	<0.2	<0.1
50% Strength Retention Temperature, °C	145	150	400	230
TGA (20% weight loss), °C	>450	>450	>450	>450

EQUILIBRIUM MOISTURE REGAIN

Tempe-rature (°C)	Relative Humidity (%)	Vectran™		Aramid (PPT)	
		HT	UM	Standard	High Modulus
20	65	<0.1	<0.1	4.2	4.1
20	80	<0.1	<0.1	4.8	4.8
20	90	<0.1	<0.1	5.4	5.5

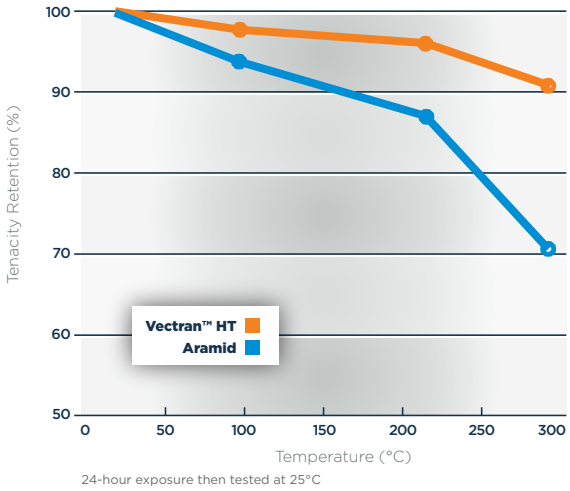
Vectran™ AT HIGH TEMPERATURE

Mechanical property retention during or after thermal exposure is a key concern in many applications. The tensile strength of Vectran™ at temperature should be used as a reference in selecting process conditions.



Vectran™ AFTER THERMAL EXPOSURE

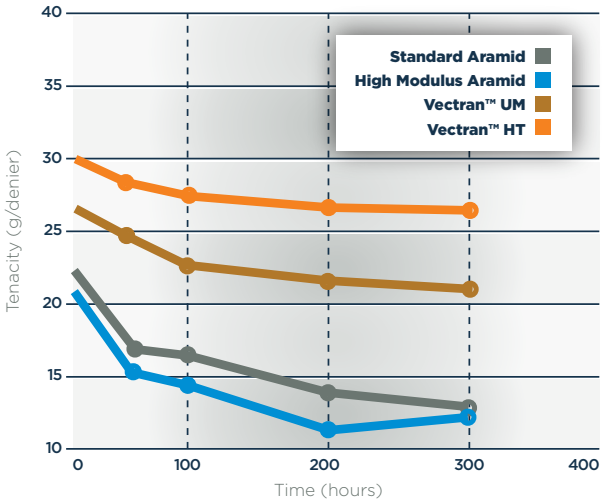
For high temperature processing at low mechanical load, Vectran™ will have excellent strength after processing, superior to aramids.



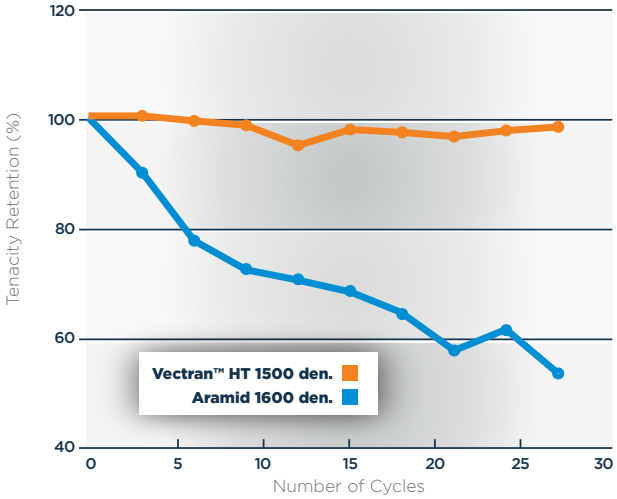
24-hour exposure then tested at 25°C

Vectran™ RESISTANCE TO CYCLIC THERMAL LOADS

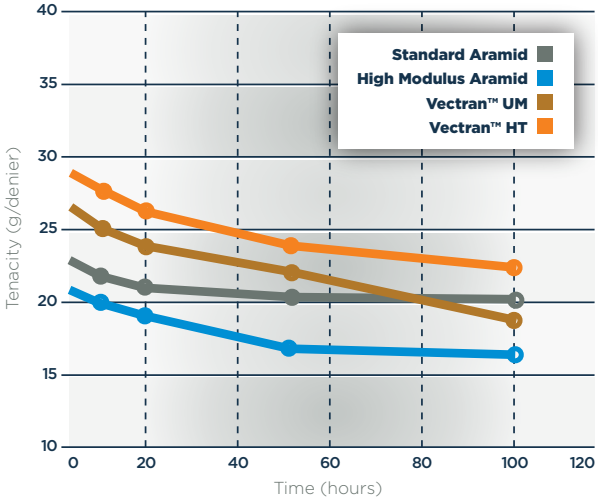
The resistance of Vectran™ to cyclic thermal loads at higher temperatures is superior to aramids and increases product lifetimes.



Tested at 25°C, after exposure at 250°C



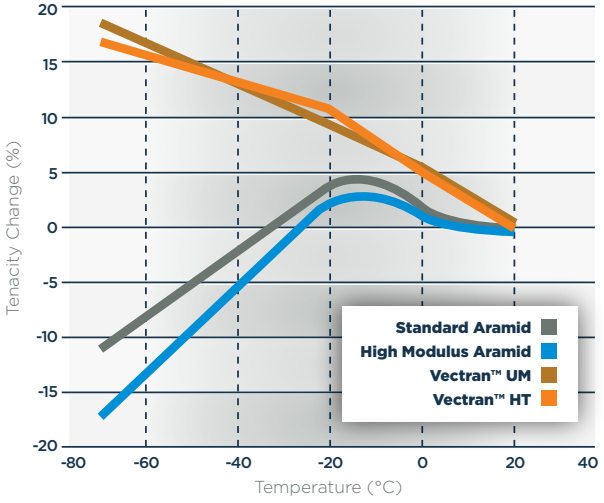
Each Cycle = 8 hours @ 195°C; testing at ambient temperature



Tested at 25°C, after exposure to 120°C steam

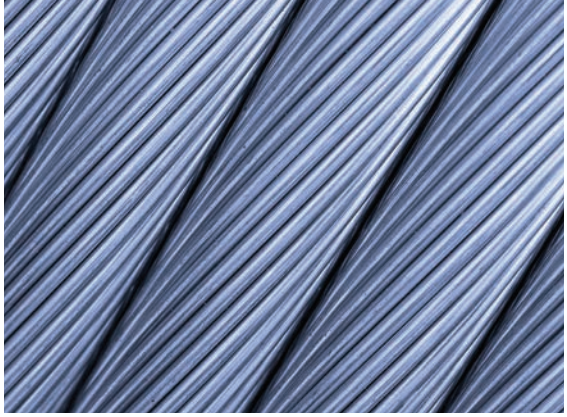
Vectran™ AT LOW TEMPERATURE

Evaulated by ILC Dover during the design of the airbag system for the 1997 Mars Pathfinder mission, ILC reported Vectran™ increased in strength in tests at -62°C, leading to its selection for the airbag fabric and external assembly tendons.



Vectran™ HT CTE AT VARIOUS TEMPERATURES

Temperature Range	Fiber Longitudinal Direction CTE (m/m- °C x 10^{-06})	
	Vectran™ HT	Standard Aramid
-150 to 100°C	-4.8	-4.9
100 to 200°C	-11.6	-5.8



THERMAL CONDUCTIVITY OF Vectran™ HT

	Direction	Temperature °C	Density g/cm³	Specific Heat J/kg-°K	Thermal Conductivity	
					W/m-°K	10^{-3}cal/cm-sec-°C
Vectran™ HT	Longitudinal	23	1.4	1,100	1.5	3.5
		100	1.4	1,420	2.0	4.7
Standard Aramid	Longitudinal	23	1.44	1,230	2.5	5.9

OUTGASSING AND OFFGASSING

For aerospace applications, materials are screened for outgassing and offgassing properties. Outgassing, the release of chemicals from non-metallic substances in vaccum conditions, and offgassing, the release of chemicals from materials at ambient or high pressure, are important in assessing the use of materials in these unique environments. Vectran™ has excellent out- and offgassing characteristics.

OFFGASSING AND OUTGASSING TEST RESULTS FOR Vectran™ HT FIBER

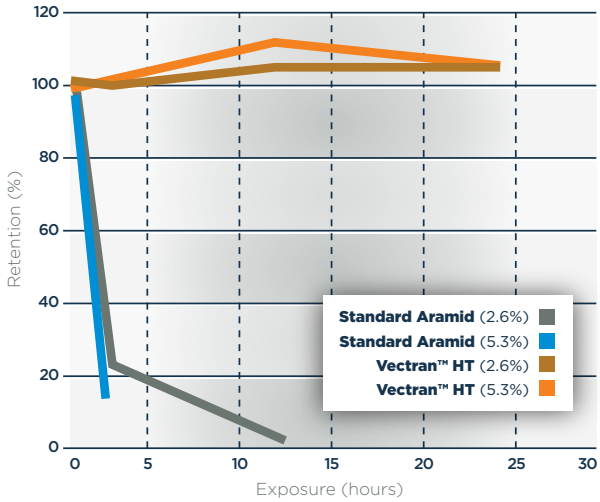
Vectran™ Fiber with:	TML%	CVCM%	WVR%	Toxic Hazard Index
No finish	*	0.00	0.00	2.226**
T97 finish	*	0.00	0.00	0.009
T150 finish	0.30	0.00	0.00	0.015

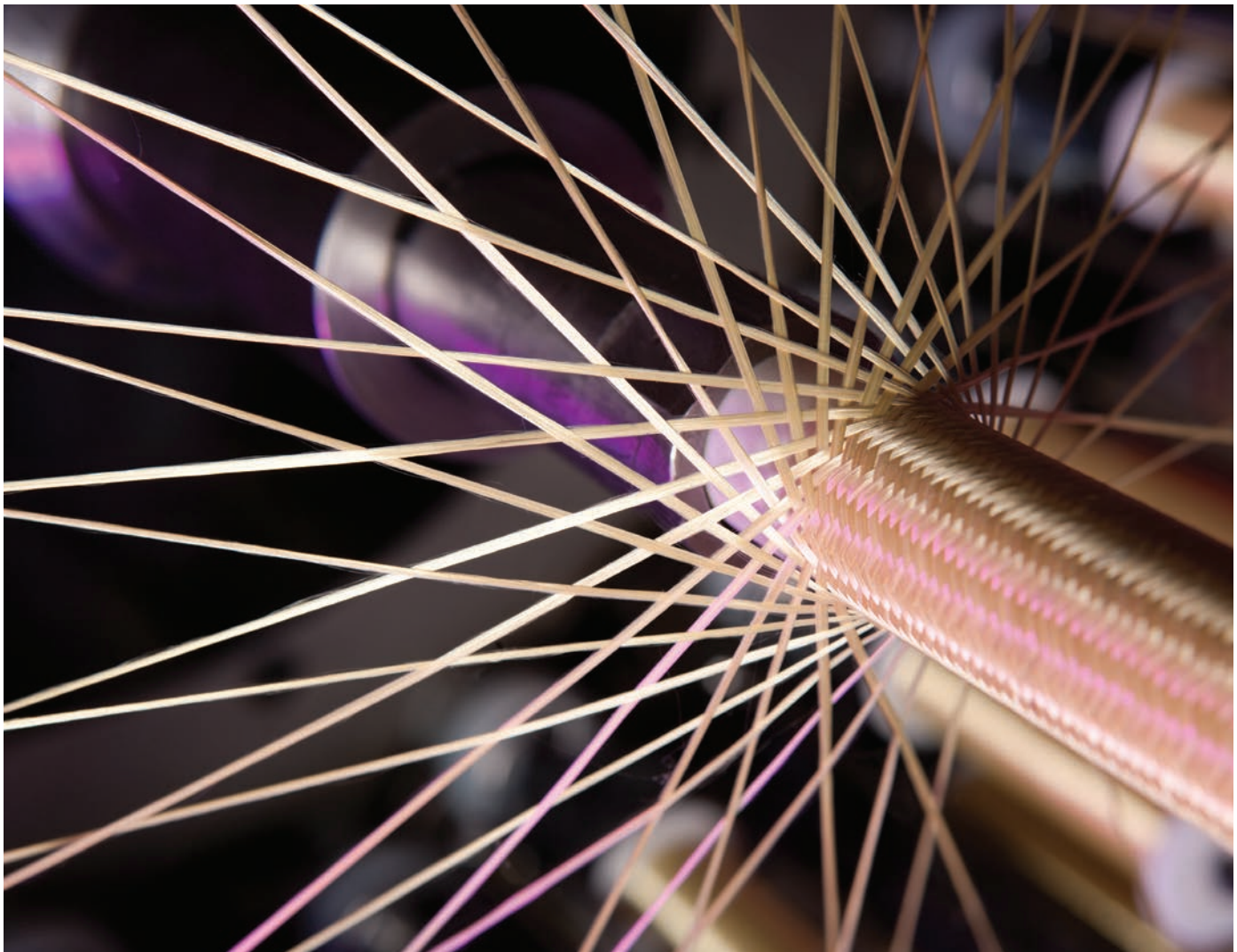
* Test results exceeded precision limits required to produce a statistically meaningful average. individual samples measurements: fiber without finish, 0.21 and 0.07%; fiber with T97 finish, 0.13 and 0.19%.
** The contribution of benzyl alchohol to this T-value is 2.214. the concentration in the sample was 0.31µg/g; no measured SMAC value was available, therefore a conservatively low value of 0.14µg/g was assumed.

CHEMICAL RESISTANCE

Vectran™ fiber is resistant to organic solvents, some acids of >90% concentration, and bases of <30% concentration. Chemical resistance is important in protective apparel use, garment care and upkeep. The superior bleach resistance of Vectran™, shown below at two concentrations, and dimensional and chemical stability simplify garment care.

TENACITY RETENTION
Vectran™ HT VS. ARAMID





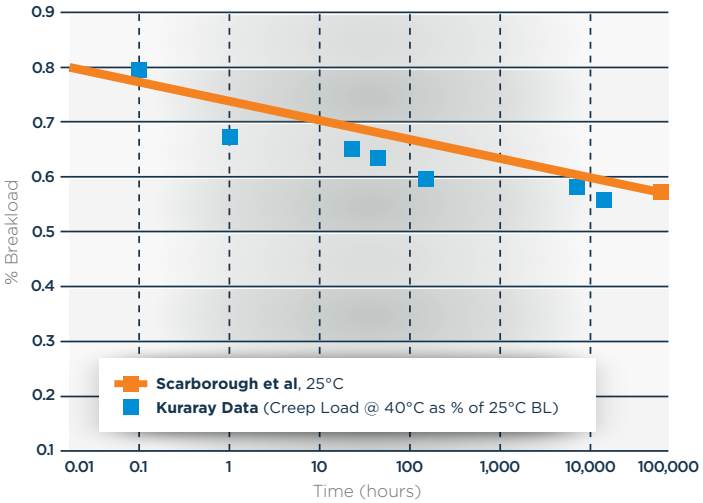
CHEMICAL RESISTANCE OF Vectran™ FIBER

	Reagent	Formula	Concentration (%)	Temperature (°C)	Time (hours)	Fiber Strength Retention (%)		
						Vectran™ HT	Vectran™ UM	Aramid (reg.)
ACIDS	Hydrochloric Acid	HCl	1 1	50 50	100 10,000	100 84	96 -	93 16
			10 10	70 70	1 10	96 93	- -	73 26
	Sulfuric Acid	H_2SO_4	1 1 1	50 50 50	100 1,000 10,000	99 93 85	99 - -	98 88 28
			10 10	20 20	100 10,00	100 90	- -	94 69
			10 10	50 50	100 10,00	98 82	- -	86 12
			10 10	70 70	10 100	94 93	- -	79 19
			10	100	10	96	-	40
	Nitric Acid	NHO_3	1 1 1	50 50 50	100 1,000 10,000	99 97 86	100 - -	83 29 14
			10 10	70 70	1 100	95 92	- -	60 5
	Phosphoric Acid		10 10	70 100	100 100	93 91	- -	46 20
	Formic Acid		90 90	20 70	100 100	96 93	- -	93 42
	Acetic Acid		40 40	70 100	100 100	94 90	- -	37 22
ALKALIS	Sodium Hydroxide (Caustic Soda)	NaOH	10 10	20 70	100 20	97 66	- -	68 21
	Calcium Hydroxide	$Ca(OH)_2$	saturated saturated saturated	50 50 50	100 1,000 10,000	96 85 9	86 - -	93 60 20
	Cement Extract		- -	20 20	10 10,000	99 90	- -	98 69
			- - -	50 50 50	10 100 10,000	99 97 6	- - -	94 90 20
ORGANIC SOLVENTS	Acetone	CH_3COCH_3	100 100	20 20	100 10,000	100 99	100 -	99 99
	Benzene	C_6H_6	100	70	100	95	-	93
	Carbon Tetrachloride	H_2SO_4	100	20	100	96	-	95
	Ether		100	20	100	98	-	95
	Ethyl Acetate		100	20	100	98	-	96
	Toluene	$C_6H_6CH_3$	100 100	20 20	100 10,000	100 98	100 -	96 99
	Methanol	CH_3CH_2OH	100	20	100	96	-	94
	Perchloro Ethylene		100	20	100	95	-	96
	Formal Dehyde		37	20	100	96	-	98
	Ethylene Glycol	$HCOCH_2CH_2OH$	50 50	100 100	10 100	92 79	- -	90 74
	Ammonia Solution	NH_3	10	70	24	35	-	95
SALTS	Sodium Carbonate	Na_2CO_3	1 1	50 50	100 10,000	96 80	100 -	100 67
	Sodium Chloride	NaCl	1 1	50 50	100 10,000	100 95	99 99	100 97
	Copper Sulfate	$CuSO_4$	1 1	50 50	100 10,000	101 90	100 100	100 68
	Zinc Chloride	$ZnCl_2$	1 1	50 50	100 10,000	98 85	99 99	99 97
OILS	Mineral Oil		100 100	20 20	100 10,000	100 100	100 -	100 100

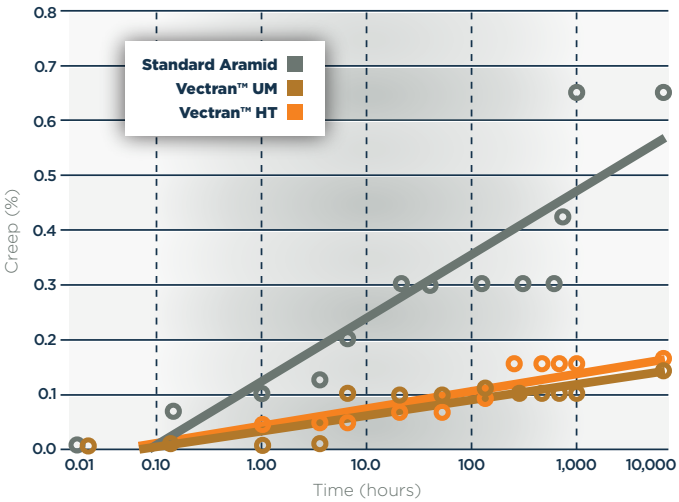
CREEP AND STRESS RELAXATION

As a critical design component in material applications that need long-term dimensional stability, Vectran™ performance is superior to competitive materials. These characteristics are important in applications like sailcloth, halyards, bowstring, marine cables and robotic tendons.

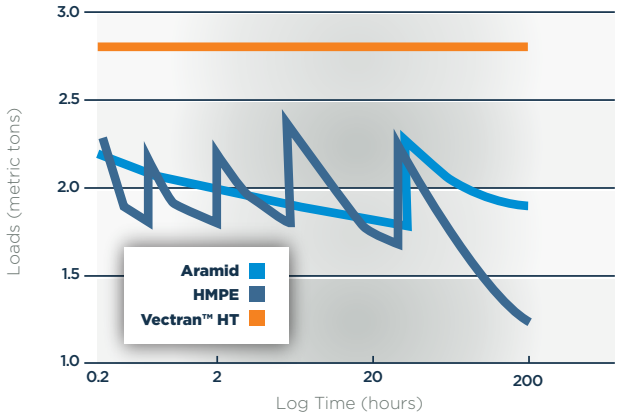
CREEP RUPTURE



CREEP BEHAVIOR AT AMBIENT TEMPERATURE (30% OF BREAK LOAD)



STRESS RELAXATION (13 MM DIA WIRELAY ROPE)

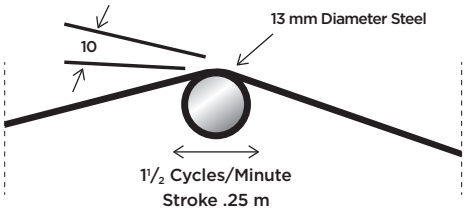


Whitehill Manufacturing Corporation
WMCJETS/JETSTRAN I-A VEC $^{1}/_{2}$" Rope

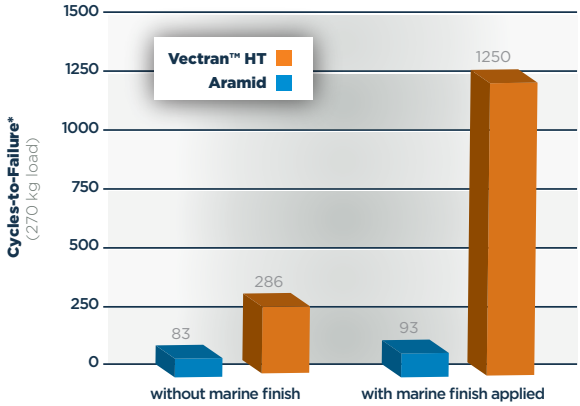
EXTERNAL ABRASION RESISTANCE

Abrasion test comparisons of Vectran™ and aramid braids were conducted by a high-performance rope and cable company using the test shown.

With or without marine finish on the braid, Vectran™ outperforms aramid materials.



Note: Samson Ocean Systems Abrasion test



* Eight-strand plain braid, 64x1500 denier threadlines. All tests dry

YARN-ON-YARN ABRASION RESISTANCE

Fatigue resistance can be measured using the rope and cordage industry standard known as the yarn-on-yarn abrasion test (ie. The Cordage Institute test method CI-1503). This test simulates abrasion of adjacent yarns inside a rope or rope-splice during flexure. Using this test, the combination of wet and dry abrasion resistance by Vectran™ outperforms competitive materias like aramids and HMPEs.

COMPARATIVE TESTING OF YARN-ON-YARN ABRASION RESISTANCE

Yarn	Average Cycles-to-Failure	
	Dry	Wet
Vectran™ T97, 1500D	16,672	21,924
Aramid 1, 1500D	1,178	705
Aramid 2, 1500D	1,773	759
Aramid 3, 1500D	974	486
PBO, 1500D	2,153	–
HMPE, 1500D	8,518	23,619

Test Method CI-1503: 1.5 wraps, 500g load, 66 cycles/min, no twist.

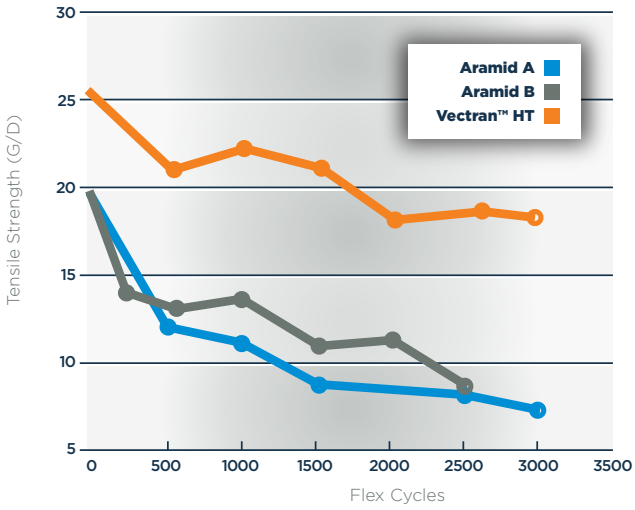
YARN-ON-YARN ABRASION OF Vectran™ HT

	Cycles-to-Failure*			
	Dry Test	Wet Test	Dry Test	Wet Test
Test Load	500 g	500 g	800 g	800 g
Vectran™ HT	12,987	30,519	3,581	16,524
Aramid	939	3,029	422	1,719

* 1500 denier yarns, no twist, 1 wrap.

FLEX FATIGUE

Flexural fatigue is a critical concern in many applications where yarns or fabrics are subject to repeated bending or creasing. Examples include ropes, sailcloth, inflatable and/or temporary structures, etc. Improving the service life of products by increasing flex fatigue resistance is an important driver for the use of Vectran™ fibers.



FATIGUE TESTING OF COATED FABRICS

Base Material	Tenacity Loss at Failure Location 100 Cycles, %	Failure Location
Vectran™	0.8	Away from Fatigued Crease
Aramid	22.9	At Crease

FLEX FATIGUE RESULTS ON 1500D YARN

Material	Cycles-to-Failure
Vectran™ T97	115,113
Aramid 1	5,114
Aramid 2	40,666
Aramid 3	1,383
PBO	23,821

Test Conditions: Tinius Olsen tester, ASTM D2176-97a, modified for yarn, 2 kg weight

FLEX FATIGUE RESULTS ON 2 MM CORDS

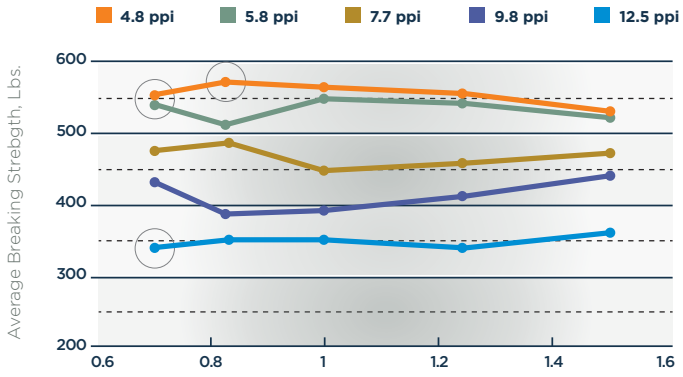
Material	Cycles-to-Failure
Vectran™ T117	41,909
Aramid 1	2,115
Aramid 2	14,963
Aramid 3	8,143
PBO	25,158

Construction: Parallel core/extruded jacket.
Test Conditions: 45 mm dia pulley, 45 kg test load, 58 cycles/min, 5 tests/sample on cyclic test machine

BEND TOLERANCE

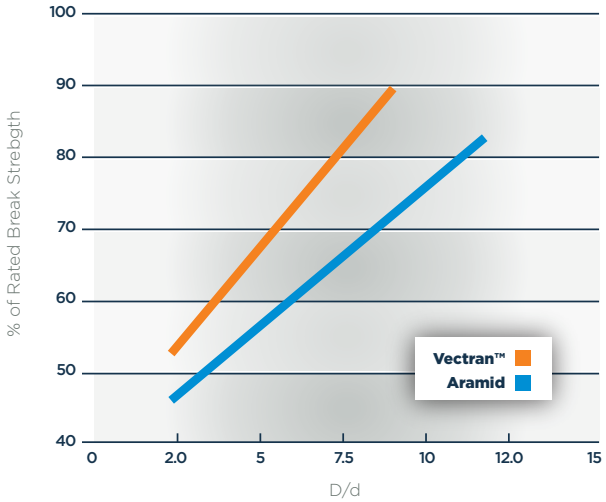
Tolerance to bending around small radii is important in ropes and cables, as it allows the use of smaller running gears or termination hardware. Aerospace and rope manufacturers conducted pin diameter tests on Vectran™ braid and wire rope, respectively.

BREAKING STRENGTH VS. PIN/CORD DIA. RATIO 8x1500/1 CONSTRUCTION



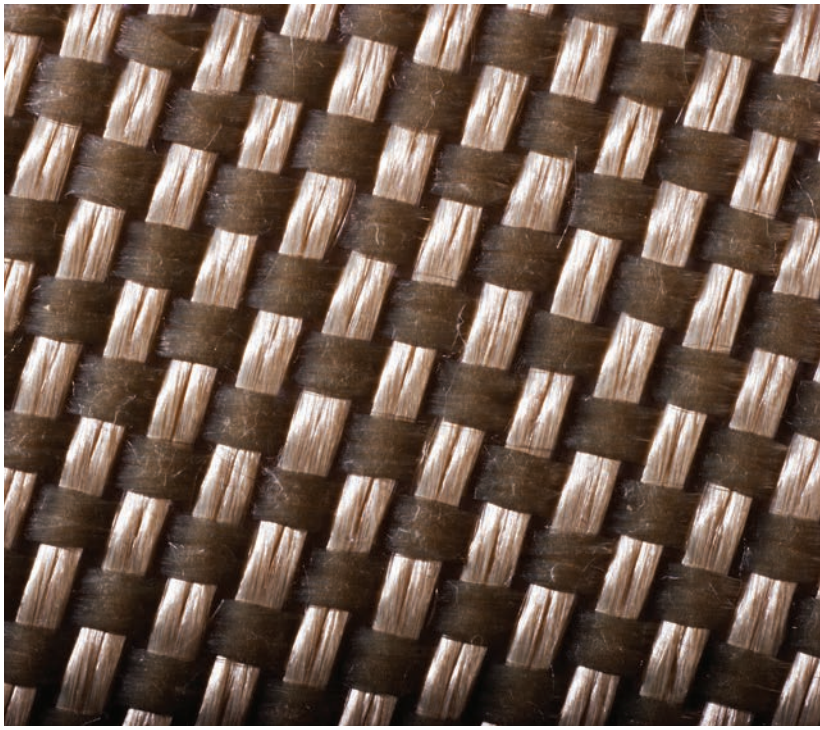
Large Circles – at least one failure over pin:
Remainder of Failures occurred at mid-open

BREAK STRENGTH VS. D/dWIRE ROPE CONSTRUCTION



IMPACT RESISTANCE

Vectran™ is unique in regards to other materials in that it provides a balance of properties rarely found in synthetic fibers: minimal moisture retention, thermal stability, and excellent impact resistance. Using the Dynatup Impact Test, Vectran™ performed far better than competitive materials.

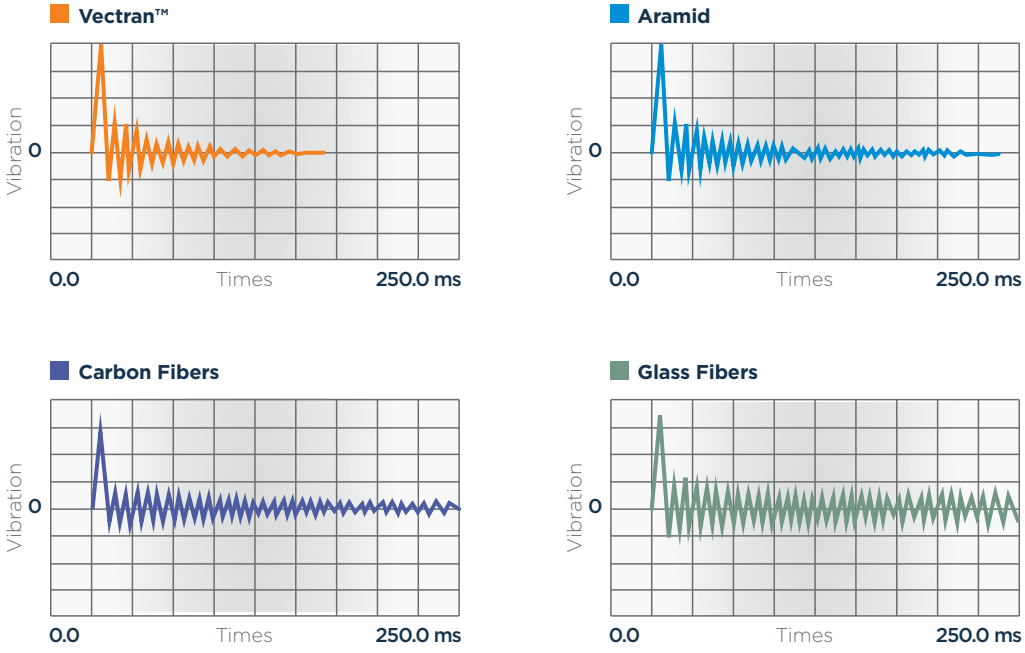


IMPACT RESISTANCE COMPARISON OF HIGH-PERFORMANCE FABRICS

Impact Energy (inch lbs.)	**Vectran™**	**Aramid**
25	No	No
30	No	No
50	No	Penetration
75	No	Penetration
100	No	Penetration
125	Penetration	Penetration

VIBRATION DAMPING

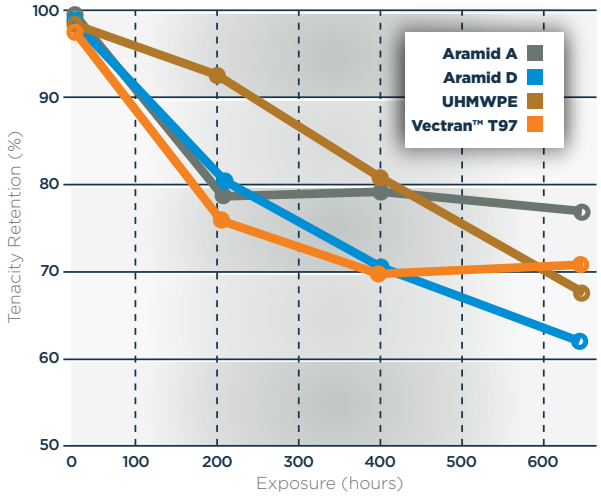
Vectran™ provides excellent damping properties making it ideal for sporting good and audio component applications.



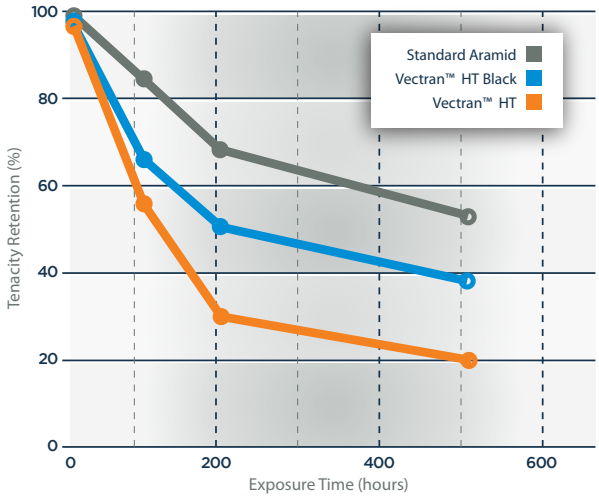
Periodic Damping of single fibers Reinforced Composite
(Matrix Resin: Epoxy)

UV RESISTANCE

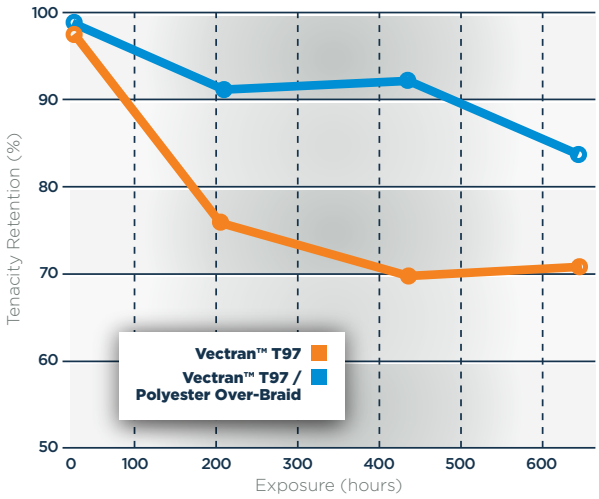
UV resistance of products made from high performance fibers is highly dependent upon a number of variables, including final product form. These ranges are dependent on rope vs fabric; filament and yarn size; finishes, coatings etc. Overall, Vectran™ is comparable to competitive materials in their tenacity retention after UV exposure.



Rope: 6mm Diameter, 12x1 Braid Test Method: AATCC #16E (Xenon-Arc Lamp)



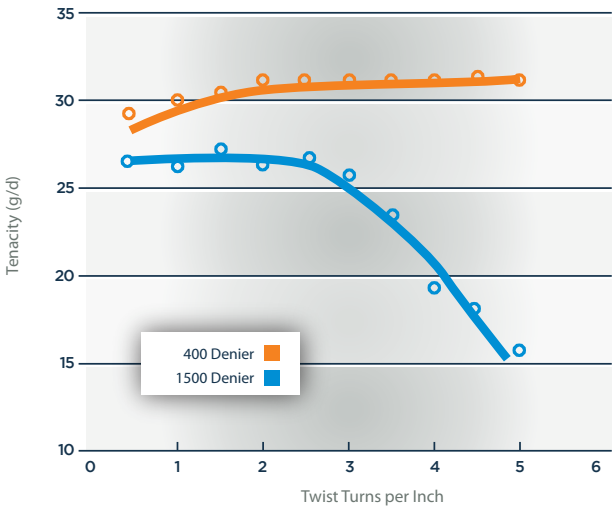
Light Source: Carbon-Arc Lamp Samples: 1500 Denier, 2tpi Twist



Rope: 6mm Diameter, 12x1 Braid Test Method: AATCC #16E (Xenon-Arc Lamp)

TWIST

Twisting is the process of combining filaments into yarn by twisting them together or combining two or more parallel singles yarns (spun or filament) into plied yarns or cords. Twisting improves uniformity and smoothness, and can be used to optimize strength and elongation.



RADIATION EXPOSURE

LCPs are transparent to microwave energy and are virtually unaffected by high levels of radiation. Vectran™ shares this characteristic and is stable in high X-ray exposure environments.

Vectran™ RADIATION EXPOSURE

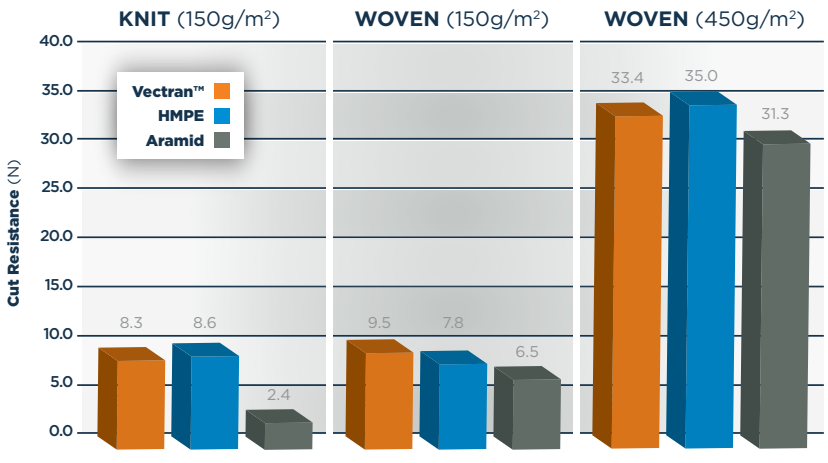
Sample	**Twist** (t/m)	**Denier** (dtex)	**Before Exposure Tenacity** (g/d)	**Elongation** (%)
Vectran™ HT	80	1,696	28.9	3.8
Vectran™ NT	30	1,589	23.9	2.6
Standard Aramid	30	1,748	22.7	4.5

Sample	**Twist** (t/m)	**Denier** (dtex)	**After Exposure Tenacity** (g/d)	**Elongation** (%)	**Strength Resistance** (%)
Vectran™ HT	80	1,691	28.4	4.3	98
Vectran™ NT	80	1,599	26.3	3.1	110
Standard Aramid	80	1,705	24.4	4.3	108

Source: Soft X-ray Amount of radiation exposure: 9.6xE+06 (mR/h at 1m) Exposure time: 30 minutes
This energy is equivalent to the 1800 times levels used in medical soft X-ray photography

CUT RESISTANCE

Vectran™ is an excellent choice in cut resistant applications due to its performance in launderability compared to competitive materials.



Cut Resistance by HOSDB

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Rev 5/2014

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