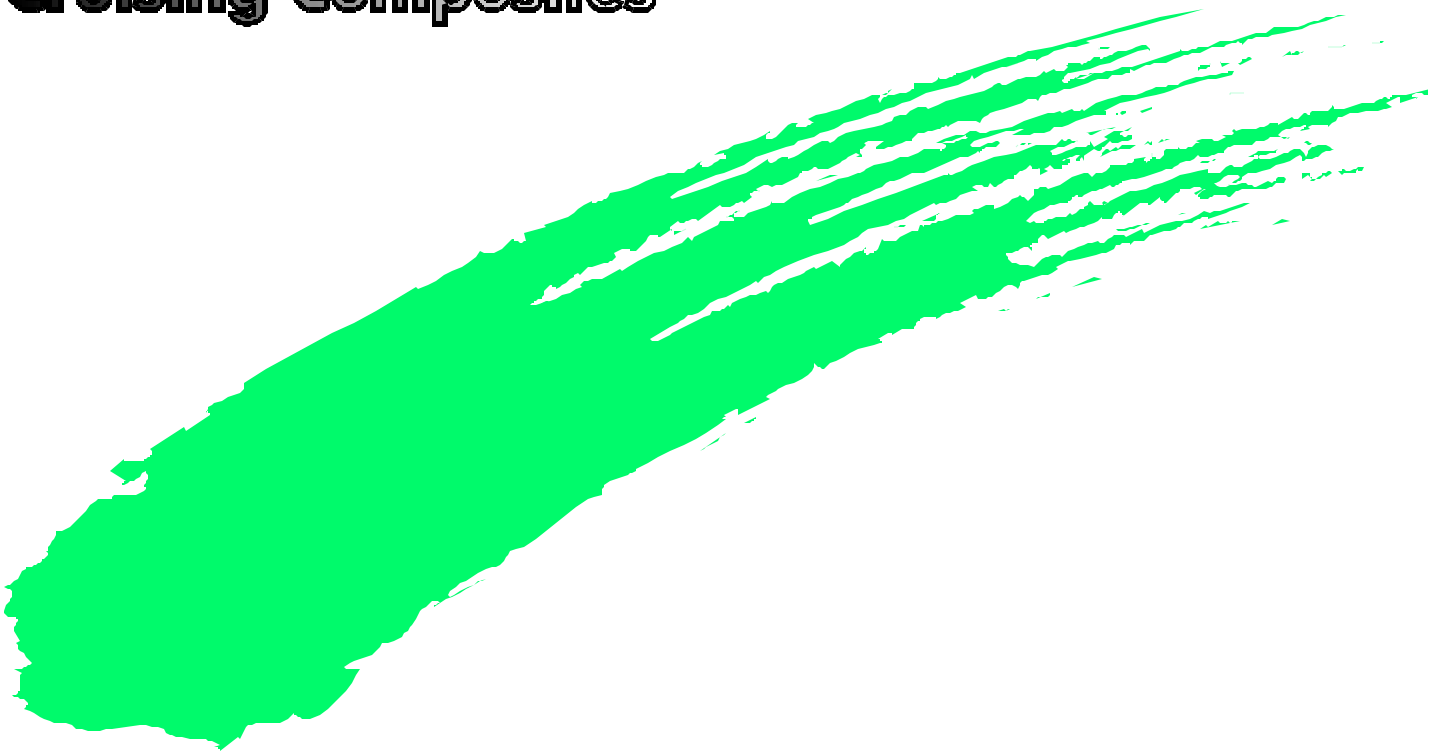
The Quantum Guide to Sail Materials

Cruising Composites

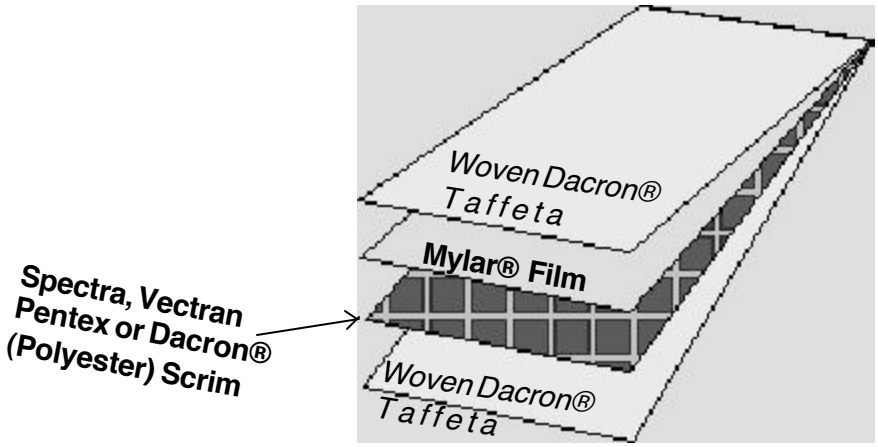


QUANTUM
SAIL DESIGN GROUP

QUANTUM'S GUIDE TO COMPOSITES FOR TRI RADIAL CRUISING SAILS POLYESTER / PENTEX® / SPECTRA® / VECTRAN®

Tri Radial construction means composite materials. Woven material, with it's strength oriented across the short axis of the panel, (fill), is inappropriate. Why align loads with the weaker axis of the cloth? At best, woven materials can be produced in nearly balanced configurations. If the boat is small, and the load is low, a high quality balanced like Contender's "Radial Wide Warp Oriented," (which is actually balanced), could be used. But for the most part, since a high quality warp oriented woven polyester cannot be made without large amounts of crimp and very poor bias stretch characteristics, wovens just don't work. A tri radial using woven materials is a "cosmetic" tri radial. It's like putting a hood scoop and a spoiler on a Pinto.

The best modern composites for cruising sails typically consist of three components: woven (taffeta) exterior layers for overall strength, durability, and as a protection for the interior parts, a load bearing fiber grid (scrim), and a film (Mylar®) for bias stability.



Typical Composite
Laminate Cruising Fabric

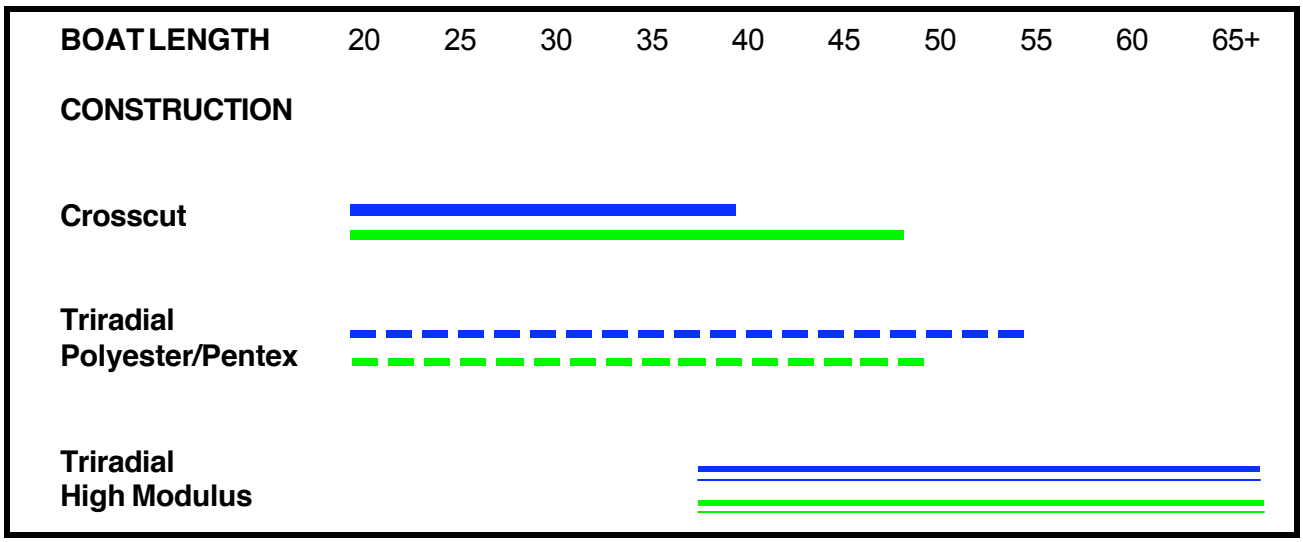
This type of composite material is designed specifically for cruising sails. It is not racing material. With woven exteriors and modern lamination techniques, they are every bit as durable as woven polyester in terms of ability to remain intact as a triangle, (they actually have better tear strength). Scrim construction makes them stronger, (how much depends on fiber type), than woven material in their primary load bearing direction, and the Mylar® film helps make them more stretch resistant on the bias.

The Key Element is the Scrim

Just as in racing composites, Quantum uses pre-tensioned formed scrims as the guts of the material. Less expensive alternatives in the cruising composite marketplace (like much of the Norlam line) do not use scrim at all. They rely on the woven taffeta component or an insert for primary strength. A taffeta/film/taffeta construction can have good ultimate strength (1% numbers), but will stretch more initially. Pre-tensioned scrims have no crimp or twist to pull out, just large, flat, straight yarns which resist stretch immediately when loaded. Also, as is the case with all materials, it not just the strength in the primary (warp in composites) that counts, but the secondary (fill) and bias directions. The best scrims use plenty of fiber in the fill direction as well as the warp, and weaker fiber is not substituted. For example, many PENTEX® or SPECTRA® scrims only utilize the high strength fiber in the warp, substituting polyester yarns in the fill to keep the cost down. Quantum only recommends scrims with high counts of the same fiber that is used in the warp. One of the primary reasons why Quantum uses Dimension to produce most of our composite materials is that they use the best scrims, and allow us to modify them, adding more and better fiber to the fill for better multiaxial stability.

Scrims can utilize one of four fiber types. The type of fiber used determines the ultimate strength and stretch characteristics. For lighter and medium load applications Polyester scrims are appropriate. For medium and slightly higher load applications PENTEX® scrims are the choice. For the highest load applications, or for cases where a strong emphasis is placed on performance, high modulus fibers like SPECTRA® or VECTRAN® make the most sense. Of course, with additional strength and stretch resistance comes cost.

Quantum's Guide to Application of Construction Types



All constructions are single ply. Crosscut constructions and triradial with polyester composites can be built of multiple layers or "plys" to extend the size and loading range they can be used in. Cost and weight of plied construction often begins to outweigh the advantages.

*Blue lines are headsails, green lines are mainsails.

What Are the Downsides to Tri Radials and Composites?

Cost and potential mildew problems. The cost issue is straightforward. More pieces and less efficient use (a lot more material ends up on the cutting room floor than with a cross cut sail), of more expensive material translates into higher prices. You pay for the bigger engine. Mildew is a problem with all composites because the layered nature of the construction traps moisture as is wicks in via the holes the sewing punches through. The taffetas of modern composites are treated with an anti-fungicide which helps, particularly on the exterior, but you cannot guarantee that the sail will not develop mildew. If the sail is used more and dried as a result, the problem is reduced. Mildew treated in early stages can be stopped. Mildew will not harm the performance of the fabric, it is strictly a cosmetic problem.

Why Bother With Composites and Tri Radial Construction?

In a word, shape. The ability of a sail structure to resist stretch, and maintain an airfoil shape is directly proportional to the strength and stretch resistance of the materials used. The actual construction details (how many panels and sections, and the method of building the corner reinforcements) are also factors. Tri Radial sails built with composite materials hold their shape better initially, and over time. Shape is important if you want a boat to sail well upwind. It also is meaningful in controlling heel and weather helm. Weight of the sail itself is another consideration. The bigger the sail, the more the weight savings. On small to medium size boats, most of the gain is in strength, not in lighter weight. Composites and tri radial construction make particularly good sense for roller furling headsails where the sail is being asked to “do it all,” but has no battens to help the structural strength. A stronger, lower stretch sail will certainly perform better when partially furled.

How Much Stronger / How Much Less Stretch?

Material	Weight	Primary !%	Bias 1 %	Primary Stretch at 40lbs	Bias Stretch at 40 lbs
6.62 HA Woven Polyester	6.7 oz	86 lbs	21 lbs	7.5	45
CX 6 Polyester Composites	6.29 oz	105 lbs	28.5 lbs	6	24
CX P6 Pentex Composites	7.2	170 lbs	29 lbs	4	24.5
SX 10 Spectra Composites	6.99 oz	448 lbs	46 lbs	2.2	14.8
7.62 HA Woven Polyester	8.23 oz	108 lbs	23 lbs	5	34
CX 7 Polyester Composites	8.78 oz	122 lbs	27 lbs	5	25
CX P7 Pentex Composites	8.7 oz	194 lbs	29 lbs	3.5	22
SX 15 Spectra Composites	8.05	616 lbs	53 lbs	1.8	11.2
9.62 HA Woven Polyester	9.23 oz	131 lbs	16 lbs	4	45
CX 9 Polyester Composites	9.97 oz	172 lbs	28.5 lbs	3.8	25
CX P9 Pentex Composites	9.8 oz	266 lbs	27.4 lbs	2.3	24.8
SX 25 Spectra Composites	9.17 oz	680 lbs	42 lbs	0.8	14

The Fibers

Since the components are basically the same for most composites we use, the real difference is in the type of fiber used. The following table summarizes the performance of the four options, Polyester, PENTEX®, SPECTRA®, and VECTRAN®. Each has it's plus and minus characteristics. In brief, they can be summarized as follows:

POLYESTER

The most stretchy of the four, polyester composites show relatively modest (approx 20% on average) advantage over woven materials. It is the same fiber doing the work, (though a larger, uncrimped fiber). The bias is better (50%) since Mylar® film provides the stability, not weave or finish. Weight of finished sails will be about the same, maybe slightly (10-15% max) less. Combined with a much more efficient panel layout, the sails do hold their shape much better than cross cut. They have essentially the same durability in terms of ability to resist UV and flex damage. They are perfect for small to medium size boat applications.

PENTEX®

Best described as a “super modulus” polyester, PENTEX® is largely replacing polyester in composite applications. It has not been used successfully in woven applications. (Lack of shrinkage relative to polyester, and expense and difficulty using the fiber in both directions in a woven product have limited the success). PENTEX® is incrementally more expensive, but the raw fiber has 2.5x the modulus and slightly better tenacity. The finished composites have stretch and 1% numbers on the average of 20-30% better. Real world peformance differences may be less than tests would indicate, but should still be slightly better than polyester. Durability should be the same as polyester. (Same flex and UV degradation) It is the best choice for any composite application where polyester would have been the choice, especially as the boat size and loads get larger.

SPECTRA®

The standard in high-end, high-load applications where performance and durability are demanded with no concern for cost. SPECTRA® is Allied Signals version of the fiber, but Dyneema is an equally high performance fiber which is just as viable.The performance numbers are off the charts and so are the durability factors. It is very expensive, particularly when formed scrims are used. That is why several companies offer lower cost SPECTRA® products either by eliminating the scrim and using spectra only in the taffeta, or using an inserted technique. Both reduce the amount of spectra fiber and hence the performance. This is the approach taken in North’s SR line of SPECTRA® fabrics and Dimension’s TS (now being replaced by WS). We have not found this approach to be worth it. If you are going to go to the expense of SPECTRA® at all, do it right. The only downside (other than cost) is SPECTRA’s tendency to “creep,” or move gradually under high loads. This is why it is not used as a primary load bearing fiber in racing sails. The sails will “grow” slightly with usage, and though the shapes will be better than any other cruising material, they will not be as rock-solid as sails made with Aramids, Carbon, or Vectran. Sails will definitely change shape and need re-cutting with use. SPECTRA laminates are the most likely to develop mildew, a real downside.

SPECTRA® / CARBON

In the last two years, to improve the shape holding characterisics of Spectra based composites, carbon has been added to the mix. Carbon’s excellent high modulus (low stretch) and lack of susceptibility to UV make it a good fit. Lower modulus carbon is used to address flex issues. The carbon is inserted between layers of either woven polyester or woven spectra taffetas to provide the stretch resistance. Various combinations of taffeta, spectra scrim, and carbon can be used to create fiber counts appropriate for different size applications. Spectra taffetas provide the ultimate breaking strength, chafe resistance, and overall durability component. Bainbridge’s CLC line and Dimension’s GXLD line are examples of this type of compostie. Spectra / Carbon composites are a good alternative when better performance is required in a ultra durable material that still has a relatively soft feel to it.

VECTRAN®

If shape is critical and there is no concern with overall sail weight, Vectran is the right choice.An alternative to Spectra®, this long-chain liquid crystal polymer has excellent initial modulus (stretch resistance). It is comparable to Kevlar 29®. Sail shape initially is very good. Unlike KEVLAR®, VECTRAN® has relatively good flex performance, (though it is still not as good as SPECTRA®, PENTEX®, or Polyester). VECTRAN’s Achilles heel is UV degradation and tenacity (ultimate strength). It breaks down quickly in sunlight, and must be protected by heavy taffettas coated with titanium oxide. This additional UV protection makes the materials heavy. Comparable fabric strengths are some 30-50% heavier than SPECTRA®. Quantum has had excellent results with VECTRAN® sails over the last nine years. It is slightly less expensive than SPECTRA, and seems less prone to mildew. We reccommend it more and more for high-end applications where performance and durability are equal priorities, and sail weight is not a concern.

VECTRAN® / CARBON

One of the latest composite combinations for super yacht loading requriements where the very best performance (lowest stretch) performance is a primary design criteria. As with vectran composites, these are not the lightest materials, but the addition of carbon provides very low stretch in big boat applications where high fiber counts are needed to handle the extreme loads. They are lighter than a pure vectran composite would be in these fiber densities. Vectran / Carbon composites provide superb shape holding and excellent durability in the highest load applications.

WOVEN HIGH MODULUS ALTERNATIVES (Hydra-Net)

Several manufacturers have experimented with weaving VECTRAN® or SPECTRA® into heavy weight woven polyester materials. Wovens using Vectran do not seem to offer much as far as increased ability to resist stretch. There is very little Vectran in the material, and it breaks down quickly with sunlight. It does not test significantly stronger than standard polyester wovens. Dimension's Hydra-Net uses SPECTRA® , and it's most appealing feature is that it does not have the mildew problems associated with composites that use the fiber. A "net" of SPECTRA® is woven into a relatively balanced tightly woven polyester. The stretch and 1% numbers are not impressive; no better than standard wovens. The SPECTRA® net will add strength and tear resistance over the long haul. It also has a soft hand so it appeals to traditionalists. It is not inexpensive. However, since it is a "fill oriented" material used in crosscut construction, it does keep the cost down somewhat by comparison to oriented (tri-radial) construction. It is a good choice for big-boat cruising applications looking for a more traditional look with better ultimate strength than woven polyester, who are concerned about mildew issues. In 2005, Dimension introduced a balanced version of Hydra-Net designed to be used in tri radial applications. The better alignment of threadline to loadline should improve shape holding, though there is an issue in any balanced material in getting enough strength in the warp (long) direction to bear the primary loads. At this point, the jury is still out on this approach, with only a limited number of sails built, and no long term track record.