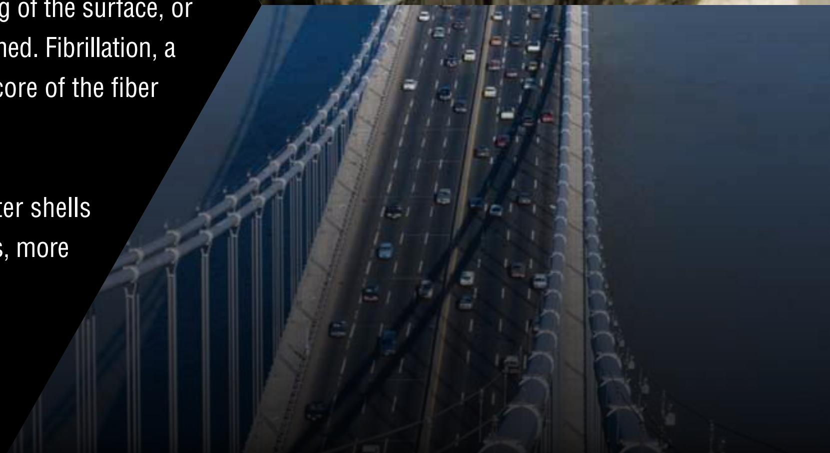
# ASK THE EXPERTS

## CHANGES OCCUR DURING FIBRILLATION AND OXIDATION. EXPECT IT. UNDERSTAND IT.



Ballistic vests. Bridge reinforcements. Lightweight composites. Turnout gear outer shells and thermal liners. High performance materials that share one common thread: DuPont™ Kevlar®. Developed by DuPont in 1965, DuPont Kevlar is a para-aramid fiber known to be one of the strongest fibers in the world. Offering strength noted at 5 times stronger than steel, para-aramid fibers are the backbone in applications ranging from ballistic vests to large structures like buildings and bridges.

In addition to strength, para-aramid fibers also maintain integrity when facing high thermal exposures (temperatures in excess of 1000° F). High strength and high thermal resistance make para-aramids the fiber of choice when making high performance outer shells and thermal liners for structural turnout gear. Over 80% of the flame resistant outer shell fabrics in North America are blended with para-aramid fibers.

While Dupont Kevlar (USA) is the most well known, additional para-aramid fiber brands include Teijin Twaron® (Netherlands) and Teijin Technora® (Japan).

### Engineered to Last

***Where do the strength and toughness of para-aramid fibers come from?***

The answer lies in the orientation of the polymer chains. High strength fibers possess high levels of crystallization, which reduces elongation and increases fiber strength. Like DuPont Kevlar, most high strength fibers experience a splintering of the surface, or "fibrillation" of individual fibers after being crimped, washed, or strained. Fibrillation, a self-screening process typical of high strength fibers, protects the core of the fiber while allowing gradual strength loss over time.

With normal field use and laundering all para-aramid reinforced outer shells undergo some level of fibrillation; less apparent in light colored fabrics, more apparent in dark or black fabrics.

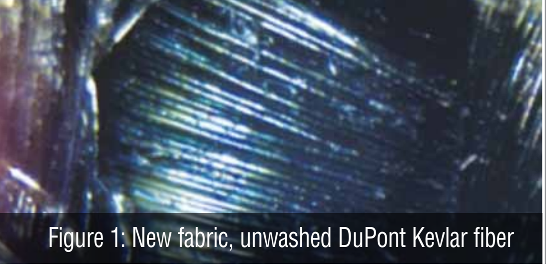


Figure 1: New fabric, unwashed DuPont Kevlar fiber

A closer look at an outer shell under a microscope shows non-fibrillated DuPont Kevlar fiber (Figure 1) and fibrillated DuPont Kevlar fiber (Figure 2). After fibrillation the fiber reflects light in a different cast. Darker fabrics like black shift from a rich dark color to charcoal; lighter fabrics such as gold may develop a hairy appearance.

Figure 2: New fabric, washed DuPont Kevlar fiber

## Engineered for Performance

*How does fibrillation affect the performance of outer shell fabrics?*

Outer shell fabric performance is divided into 4 key areas:

- **Thermal Stability**
- **Durability**
- **Comfort**
- **Appearance**

## Thermal Stability

Fibrillation does not negatively impact protection or flame resistance. In fact, TPP usually increases after wash (when fibrillation/lofting occur), because the fabrics become thicker and more insulating (Chart A).

## Durability

The use of high strength DuPont™ Kevlar® fibers increases the tear, cut, abrasion, and flame resistance of fabrics in the fire service. Fibrillation will occur as the fabric is subjected to normal wear, flexing, and repeated washing. However, fibrillation alone is not a sign that a fabric has lost significant strength properties. When cared for in accordance to NFPA 1851, outer shell fabrics experience only minor and gradual strength loss over time (Chart B).

## Comfort

Fiber fibrillation does not negatively impact comfort. After repeated use or washing, the fabric will become softer and more flexible.

## Appearance

Once they are put into service, all para-aramid rich fabrics undergo some level of appearance change, typically caused by fibrillation or oxidation.

## Change In Appearance: From Fibrillation

Dupont Kevlar starts out with a smooth consistent appearance (Figure 1). The process of fibrillation causes small/hairy fibrils to form on top of the fiber core (Figure 2). The result is a fiber with greater surface area, reflecting light differently than the original fiber. This "frosting" of the surface is similar to what happens with a brown glass bottle: if you grind down the glass bottle small enough the remaining powder will appear white because the surface particles dominate the reflected color. The substance of the glass remains brown but it appears white, just as black para-aramid fibers remain black yet they appear charcoal.

## From Oxidation

After DuPont Kevlar rich fabrics are exposed to light the fiber's surface begins a process called oxidation. As a para-aramid oxidizes it changes color: fabrics appear to get darker. This change in color is similar to the way a copper penny appears green after oxidation. Like a copper penny, the change in color from oxidation is normal and not indicative of degradation.

The rate at which a DuPont Kevlar rich fabric darkens through oxidation depends on many factors. These include the fabric blend, fabric design, and most importantly the way in which the fabric or garment is stored (protected from light). Sometimes turnout gear will fully oxidize in a day, other times it takes weeks, and other times different panels of the garment will oxidize (darken) at different rates. One thing is certain: the entire garment will eventually oxidize and darken over time.

## Conclusion

Fibrillation and oxidation are common to all outer shells and thermal liners rich with para-aramid fiber. It is important to understand the affects of fibrillation and oxidation to gain realistic expectations on fabric appearance, durability, and performance.

**Chart A: Thermal Protective Performance (TPP)**

| COMPOSITE | NEW | POST 5 WASH |
|---|---|---|
| PBI Max™ 7.0/CROSSTECH® Black, 2F/Glide 2-Layer | 41.9 | 48.3 |
| Armor 7.0®/CROSSTECH Black, 2F/Glide 2-Layer | 40.6 | 52.1 |
| Fusion™/CROSSTECH Black, 2F/Glide 2-Layer | 40.2 | 51.5 |

TPP increases after wash and fibrillation occur

**Chart B: Breaking Strength (lbs. of force)**

| OUTER SHELL | NEW | POST 5 WASH |
|---|---|---|
| PBI Max 7.0 | 485 | 469 |
| Armor 7.0 | 554 | 488 |
| Fusion | 295 | 230 |

NFPA minimum breaking strength is 140 lbs.

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