Donaldson's Ultra-Web nanofiber technology has been a fundamental development for Donaldson Co. While it was originally developed for industrial applications, later iterations have become the lynchpin behind some of the company's most important engine air filtration products, including the PowerCore filter family.

MARKING A MEDIA MILESTONE

With a heritage spanning nearly three decades, Donaldson's Ultra-Web nanofiber media remains bedrock technology for engine air filtration

BY MIKE BREZONICK

In today's world of ever-present technological advancement and constant innovation, the idea of a product lasting more than a few years without undergoing a near-total remake strains credulity. That's especially true in a market like diesel engines, which have undergone significant changes and enhancements since the late 1980s.

So it's somewhat startling to realize that more than 15 years after its introduction into the mobile and stationary engine markets, Donaldson's Ultra-Web nanofiber media technology has remained the backbone of the filtration specialist's engine air filter product line.

"Ultra-Web was ahead of its time," said Doug Crofoot, director, Process Science & Technology for Corporate Technology at Donaldson Co. "While competition in nanofiber technology is emerging, Donaldson Ultra-Web continues to provide superior durability in humidity control and operating temperature ranges. We have been constantly improving the chemistry and processes."

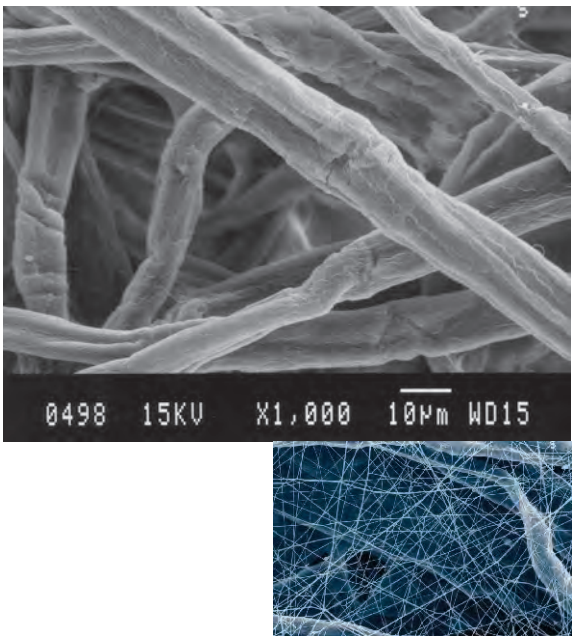
Donaldson first began investigating the properties and possibilities of submicron-diameter fibers in the early 1970s, and later in that decade the Corporate Technology team began experimentation involving electro-spinning nanofibers from polyamide polymers. Not long after, that research yielded the first commercial product, a media launched in 1981 for industrial dust collection applications.

"The original target market for Ultra-Web was industrial filtration applications that typically operate at a much lower flow rate per unit area of filter media," noted Crofoot. "At these low flows, a small increase in restriction can have a significant effect on operational performance such as energy costs, dust removal efficiency or protection of an occupied breathing space.

"An engine intake system is designed for much higher air flows. This means that a nanofiber, typically more than 100 times smaller than a human hair, must withstand much higher shear force due to the air flowing past in an engine intake application. While Ultra-Web surface filtration had proven itself effective for industrial applications, another decade of research was required to develop the superior industrial and engine-grade Ultra-Web nanofibers we have today."

Other critical issues that faced the Corporate Technology team included the nature of the contaminants being captured and the operating environment. "Ultra-Web nanofibers used in industrial applications were primarily intended to capture particulates on the surface of the filter material to facilitate pulse cleaning," Crofoot said. "These are predominantly indoor installations as opposed to the moisture, temperature and vibration extremes in on- and off-road engine applications. It was not known how nanofibers, 0.25 microns in diameter, would react, particularly in combination with the dynamics of high air throughput.

"In engine applications, nanofibers used or applied improperly could result in reduced filter life. It was necessary to understand and characterize the nature of the contaminants an



An enlarged view of filter media shows how cellulose fibers (top) are larger than Ultra-Web nanofibers and have larger spaces between the fibers. This can cause contaminant loading in the depth of the media and lead to higher restriction and less capacity. Ultra-Web nanofibers (bottom) have smaller interfiber spacing, allowing more contaminant to be captured on the surface of the media.

engine filter would be expected to see on a worldwide basis and design the filter structure accordingly.

"A great deal of effort also went into characterizing the environmental conditions an engine filter is expected to experience coupled with the anticipated life expectancy or replacement schedule. These conditions include maximum underhood temperature during operation, heat soak upon shutdown, moisture — in the form of rain, snow or fog — as well as exposure to contaminants such as spray and/or fumes from fuel, lube oil, windshield washer fluid and exhaust soot."

One of the key improvements Donaldson's research efforts yielded was the development of a protective coating for the fibers that would allow them to resist the effects of moisture. Even that wasn't as straightforward as it appeared. "Most known coating methods, such as dip or spray application, to a nanofiber network would film over the space between the nanofibers," explained Crofoot. "Our polymer chemists incorporated a patented coating into the nanofiber formulation, and through a proprietary operation the coating forms on the surface of the nanofiber — thus providing a protective shield.

"A further improvement was the development of polymer cross-linking technology that extended the temperature and moisture resistance and provided added chemical resistance to survive the rigors of the engine environment. Both of these improvements required changes in the Ultra-Web process and additional capital investment."

What ultimately resulted was an optimized nanofiber web with extremely fine inter-fiber spacing that causes submicron contaminants such as dust and soot to load on the surface rather than disperse throughout the depth of the filter media where pores can quickly become clogged. Donaldson said its extensive testing has shown that Ultra-Web Technology can enhance efficiency of high-quality filter media to greater than 99.97 to 99.99% while at the same time offering as much as five times as much contaminant (soot and dust)-holding capacity, which extends filter service intervals without significantly increasing restriction.

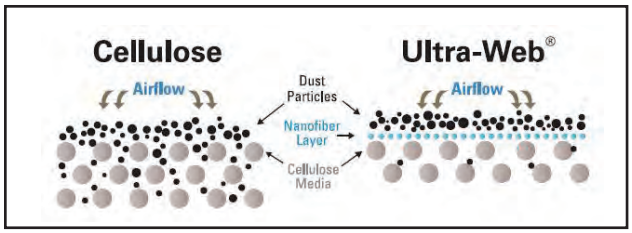
In 1993, the company introduced Donaldson Endurance, its first extended service air filter using Ultra-Web technology, for the trucking industry aftermarket. In a real-world application with a large trucking fleet in Michigan, the use of Donaldson Endurance filter elements extended air filter change intervals from 150,000 to more than 300,000 miles with no impact on truck operation or unscheduled downtime.

Ultra-Web products have also been used in off-road applications. Shortly after the release of the Donaldson Endurance air filter, two coal mines in Gillette, Wyo., tested Ultra-Web technology on engines used in rock drills. In one case, the filters incorporating Ultra-Web technology extended typical filter service intervals from five days to 20 — a fourfold improvement over competitive replacement filters. In the other above-ground coal mine trial, Donaldson Endurance filters with Ultra Web technology extended typical service life from two to three weeks to three months. These types of results demonstrated significant cost savings, Donaldson said, for customers operating in high-dust environments.

Ultra-Web was also a key component in the development of one of Donaldson's most significant products of the last decade, the PowerCore filter line. Used in a wide range of on- and off-road medium- and heavy-duty vehicles and equipment, as well as high-performance light vehicles, the PowerCore filters incorporate filter media that is formed into parallel tubes versus conventional pleated designs.

While PowerCore filters are available with several media options, Donaldson said the advantages provided by the combination of PowerCore and Ultra-Web technology include a more space-efficient design (up to 50% less space than conventional systems) and the ability to engineer unique configurations to fit tight underhood environments. Most recently, Donaldson unveiled PowerCore G2, a second-generation filtration technology that also offers Ultra-Web options (see November 2008, *Diesel Progress North American*).

Ultra-Web was also the foundation



This illustration shows how Ultra-Web nanofibers allow more contaminant to be trapped on the surface of the filter media. This allows them to hold as much as five times more contaminant than conventional cellulose media, Donaldson said.

for mission-critical air filter products dedicated to military applications, including the self-cleaning Pulse Jet Air Cleaner (PJAC) for the M-1 Abrams tank. The company said that the M-1 PJAC has been demonstrated to increase service intervals by more than 10 times in severe desert dust conditions while also providing an efficiency level more than 10 times the military specifications (see December 2008, *Diesel Progress North American*).

"Ultra-Web was critical to achieving our performance targets," said Gary Gillingham, director for the Aerospace and Defense Group at Donaldson. "The goal was to provide a filter that would not clog up while ingesting 600 lb. of dust an hour.

"We were unable to clog our PJAC using Ultra-Web in the lab or during rigorous U.S. Army desert testing, whereas, our PJAC using filters without Ultra-Web clogged in less than 30 miles of operation."

Donaldson has continued to research and refine its nanofiber filtration developments and, to date, the Ultra-Web technology has more than 80 issued and pending patents. It has not been, Crofoot noted, a "Point A to Point B" refinement process. "A lot of iterations by a lot of talented people took place to get it where it is today.

"The engine market represents diverse needs based on specific OEM platforms and end user requirements. Donaldson has developed many grades of Ultra-Web. These might include differences in the amount or thickness of nanofiber used in the composite to achieve a certain performance level.

"Looking ahead, we will continue to layer Ultra-Web with other Donaldson filtration technologies to create robust products that will improve filtration performance for our customers in both engine and industrial applications." dp

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