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A Case Study in R&D in Precision Cleaning: The Development of a New Fiber Optic Connector Cleaner

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On March 18, 2003 MicroCare modestly introduced a new cleaner for the fiber optics industry. By itself, the introduction was not a huge event: MicroCare introduces six to ten new products each year. But behind the press releases and advertising lurks a fascinating story of the research and development process. It's a good example of the manner in which precision cleaning is evolving at a furious pace. It also shows the difficulty of creating even a simple product in today's complex world: there were more surprises and dead ends than anyone expected. It also cost more and took longer, which is another lesson learned. Here's the story of how a simple R&D project took almost three years.

Mouse Clicks Open a New Door

Like so many important events, this project started inauspiciously. MicroCare's Vice President of technology, Jay Tourigny, was checking his email when one missive caught his eye. It was from a company he'd never heard of, asking if MicroCare could make high-purity wipes to clean connectors and ferrules on the ends of fiber optic jumper cables. Thinking this sounded promising, he clicked "reply." And with that simple mouse-click an entire product development cycle began.

[Photo, right. Jay Tourigny, Vice President, MicroCare and inventor of the new fiber optic connector cleaning system..]

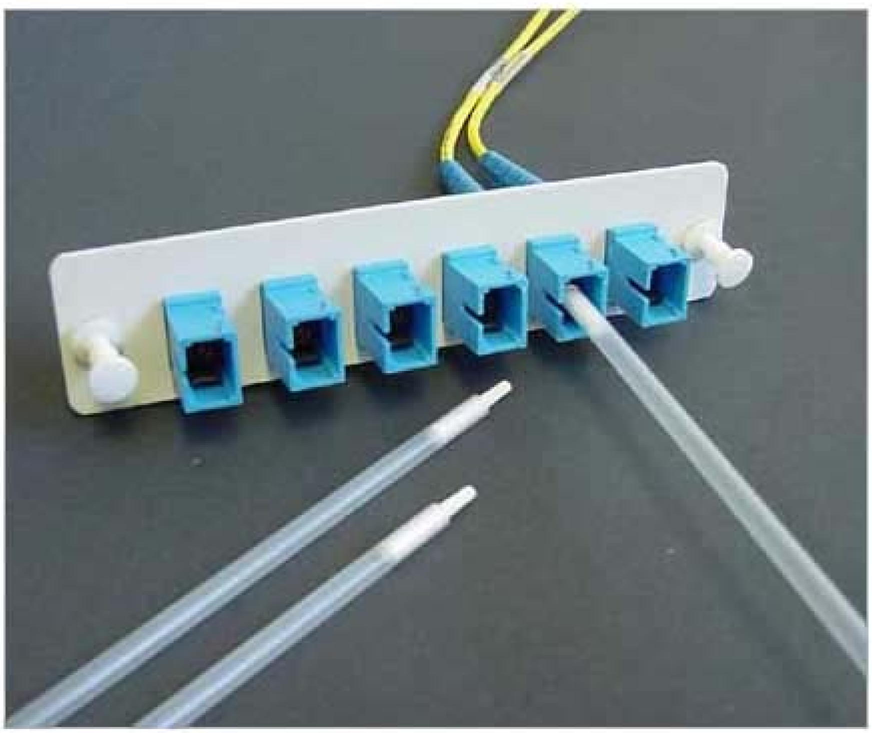
The email was from Harvey Stone at AFL Telecommunications which manufactures the Noyes brand of fiber optic inspection systems. Stone is tall, lean and pony-tailed, casual in demeanor but brimming with energy and ideas. He was trying to assemble a cleaning package to go with the rest of their product line. Since AFL Telecom had little emphasis on fiber optic cleaning at that time, he needed technical help to turn a concept into a product, hence the inquiry to MicroCare.

New information changed the project quickly. After some preliminary discussions with Tourigny, Stone attended a technical conference sponsored by SAE which focused on the problems of cleaning fiber optic connectors. One other major problem was the solvent-of-choice, isopropyl alcohol, which seemed to be source of an endless array of problems. Stone realized that the industry didn't need a better wipe, it needed a better solvent. He brought that finding back to Tourigny to see if a better mousetrap could be found.

The Fiber Optic Challenge

A slender fiber optic cable is the industry's favorite method for long-distance communication. The first modern systems were installed in the 1970s and in the 1980s major telecom companies began deploying fiber on a large scale. Today thousands of kilometers are laid every year, even for temporary installations like political rallies, golf tournaments and parades.

The number of installations means the economic magnitude of the cleaning problem is huge. One global producer of routers determined that 30% of their defective boards returned to the factory actually are simply failures due to dirty optical connectors. Another source estimates that 50% of all the network failures are due to contamination on connectors.



[Photo, right. A typical office-style commercial quality connector for six fibers. The fiber optic cables are the two yellow cables in the rear.]

The problem stems from the nature of light itself. As the light pulse moves along the cable, the signal gradually attenuates. While the makers of the actual glass fiber have perfected their product to a degree unimaginable twenty years ago – if the ocean was a clear as a fiber optic cable, a boater could see the bottom of the deepest ocean – their ability to conduct light is not perfect. Today's systems lose only 1.5 to 3 dB of signal per kilometer, but the loss is multiplied over the vast distances fiber optic cables span.

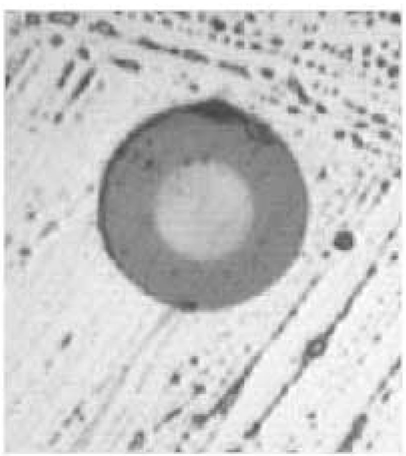
Every fiber must be connected to a termination block where the optical signal is converted into an electrical signal to be processed and routed. A signal 'loss budget' is designed into each system and each component.

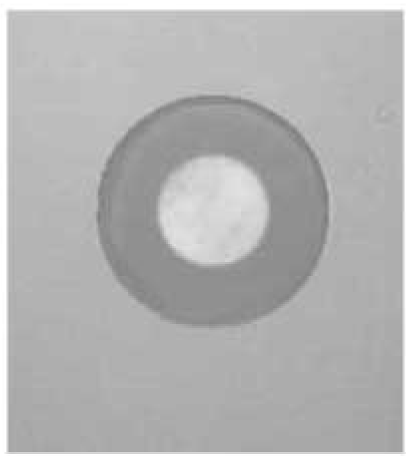
Fiber Systems International designs and builds ruggedized multi-channel fiber optic connectors for military, oil field, broadcast, and other tough applications. Jon Woodruff, Fiber Systems Product Manager, reports a typical total system budget is 11 dB and for each connector between.75 dB to .5 dB. "But since some systems have three, four or even six connections on each fiber, the losses add up," Woodruff sighs. "A single dirty connector can be a real problem." Experience has shown that a 4 mm spec of dust located on the core of a single-mode fiber can cause as much as 6 dB of loss. Similarly, a 1-micron blot on each of five sequential connectors can push an entire system over the loss budget, bringing the network down.

The Contamination

Contaminated connectors are unexpectedly difficult to clean because of the variety of the contamination and the awkward shapes of the connectors themselves.

As he started his research, Tourigny discovered on the connectors three different problems: organic contamination, ionic contamination and insoluble particulate. "One of the most common problems is sheetrock dust from construction or drilling holes in walls," Tourigny notes. "But the worst of all are fingerprints because they have organic, inorganic and particulate components." This made finding a "one size fits all" cleaner more difficult.





And size does matter. Fiber optic ferrules are tiny. The military favors ferrules in the 1.6 mm and 2.0 mm sizes. Civilian applications often use 2.5 mm ferrules, with a new 1.25 mm size gaining in popularity. It's worth noting that although small, these sizes are huge compared to the actual 125 micron fiber optic cable, nestled inside the ferrule.

[Photos, above. Microphotograph of a dirty fiber optic connection, left, and a clean one, right. Actual size of the light-carrying fiber is 125 microns.]

"The worst case are the MIL-C-28876 multi-channel connectors, like a 24 channel connector that's only 1.5 inches in diameter," notes Woodruff. "In order to clean the sockets you have to partially dissemble the connector by removing a captivator, and then remove all 24 alignment sleeves, which finally exposes the socket termini." Touringy agrees, having seen connectors on U.S. submarines. "After all of that disassembly and cleaning," he notes, "then you have to re-assemble the entire connector without touching or contaminating any surfaces. It's almost impossible to do."

How clean is clean enough? "Depends upon what you're measuring," says Woodruff. "If signal loss is the goal, you keep cleaning it to get down to the specification, but that can be time-consuming. If you don't have any test gear, like out in the middle of the desert, you test on a connectivity basis – if you connect it and get a green light, that's clean enough."

[Photo, left. A complex military-style high-endurance connector for 24 fibers produced by Fiber Systems International. Notice the "hermaphraditic" nature of the connector -- twelve male connectors and twelve female connectors. This adds strength to the junction.]

The "male" portion of the connector has a flat, exposed surface which makes it easy to clean. It is the female connector, the socket, nestled down inside a sturdy housing, that is the most difficult to clean. The diminutive size makes any horizontal wiping motion impossible. Solvent entrapment inside the female connector is common. Inspection is impossible without sophisticated tools, and the ultimate target of the cleaning process – the flat end of the 125 micron fiber – is so small that failures and rework are commonplace.

The Problem With Alcohol

Alcohol commonly is used to clean these connectors because alcohol is cheap, widely available and plastic-safe. However, it is not a particularly powerful solvent.

"The specification of alcohol always has been a problem," Woodruff reports. "Any time you say 'alcohol' people think of going to Ekert's, but drug store alcohol is just not clean enough." Other problems with alcohol as a cleaner include (a) an inability to dissolve some of the heavier organics found on the connectors, (b) an inability to remove particulates because IPA has a low density and is unable to “float” particles off surfaces, and (c) the infinitely hygroscopic nature of the alcohol, which dilutes its cleaning abilities. Any water absorbed by the solvent evaporates more slowly from the connector, often leaving a ring or water spot.

Shipping was also a problem. Alcohol is flammable and DOT regulated as a hazardous material. Stone was hopeful a new cleaner could be developed which would be easy to ship by air, without hazardous charges. This also would avoid the onerous and expensive training requirements the regulations inflict on companies which ship hazardous materials.

Packaging was another issue. The experts atAFL Telecom reported that bottles of alcohol often are contaminated during use. It would be very helpful for the technicians if the package was "contamination-proof" – that is, if there was a way to package the material so it could not be contaminated during use. The experts at AFL Telecom also hoped for a fast-drying new cleaner. AFL Telecom told of instances where connectors had been installed before completely drying. The laser light boiled the entrapped solvent, and in extreme instances exploding the connector apart. Fast-drying solvents also would boost productivity for techs in the field.

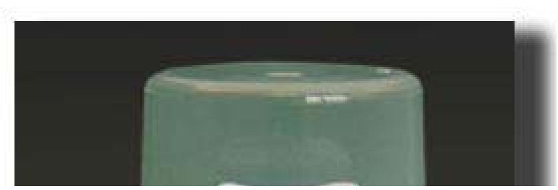
Lastly, the perfect cleaner would be available anywhere in the world, be environmentally safe and relatively affordable. Tourigny knew this would be a tough order to fill.

Formulating the Cleaner

MicroCare's first attempt with a cleaner was to use some of their current products in an aerosol can. The test contamination was simple but challenging: fingerprints.

The first choice was an HFC solvent from DuPont. It cleaned the connectors quite well and dried fast. But when AFL Telecom took the safety data sheet to their parent company there were some concerns about one of the ingredients. It seems that 1,2-trans dichloroethylene is not acceptable in Japan. To achieve the goal of a global cleaner, MicroCare would have to formulate a powerful cleaner without using trans.

Tourigny next tried "a whole bunch of stuff" that would not be acceptable in a final product but might serve as a starting point in a new formulation. They experimented with the ozone-deleting solvent HCFC-141b, PFCs and some high-boiling hydrocarbons. MicroCare also uses a wide array of flammable solvents. "We tried those," reports Tourigny, "but they all dried too slowly." In addition, flammable solvents would push the product back into the hazardous category.



The next wave of samples produced a new twist: extended materials compatibility. "We tested the connectors and fibers, and could tailor the solvent to be completely compatible with all of those materials," said Tourigny. "But then AFL Telecom came back and expressed concern that the solvent may damage their inspection scopes." Techs in the field have a habit of using the solvent cleaner on everything: test machines, inspection scopes and even benchtops. Because the usage was so uncontrolled "we wanted to make sure we had something that was safe for all the equipment associated with installation and inspection." The cleaner now had to be strong but plastic-safe – two requirements normally considered opposites.

Finding the right proportions was a problem, as well. "We started using blends, not azeotropes, with relatively high proportions of alcohol," Tourigny recalls. "But some components would preferentially evaporate, leaving the slow-drying alcohols, and actually extending the drying cycle. So we switched to formulating with azeotropes."

In the end, some DuPont research from Europe helped link all the parts together. They found that methanol optimized the cleaning process in the absence of trans. The mixture was not infinitely hygroscopic and dried in 2/3rd the time of alcohol. The cleaner dissipated static charges, had good toxicity ratings and meet the requirements for nonhazardous materials

More problems remained. It was becoming clear that on severely contaminated parts there was no chemical formulation that would reliably do the job without the addition of some degree of mechanical cleaning action.

The Projects Expands

"I was getting fairly discouraged at this point," Tourigny reports. "It was becoming pretty obvious that is was going to be difficult, if not impossible, to clean with just solvents alone." In addition, since aerosol packaging was not feasible a new package had to be found for the new solvent. So Tourigny now had two more R&D projects to develop simultaneously.

The aerosol option was unacceptable because it is DOT regulated for transportion. Nor would a traditional bottle or can meet AFL Telecom' requirements to avoid self-contamination. There could be no pouring or spilling, and no way for harried techs to dip dirty swabs into the clean solvent and contaminate it.

The evolving solvent formulation itself presented a new problem. The selected cleaner has a very high vapor pressure because it boils at very low temperatures. Normally this is highly desirable, because the solvent dries fast, but when trapped in a sealed container on a warm day, this same feature generates internal pressures that can cause leaks. This meant the packaging had to be metal and an air-tight.

John Basso, MicroCare's purchasing manager, searched internationally and domestically for any company making valves of any type. He phoned virtually every manufacturer of pump spray valves in the world. As the samples arrived, Tourigny would package samples for performance trials at elevated temperatures. "This effort covered literally hundreds, maybe even thousands, of configurations and designs," Tourigny recalls. Astoundingly, every one of them leaked.

In the end, a bit of serendipity helped. "We were in a meeting with one valve company, talking to their sales engineers, and we were all stumped," Tourigny said. "Then a senior production guy just stuck his head in to say hello. When he heard about our problem, he remembered they had made a high-pressure prototype years ago that they had never commercialized. We were able to take that prototype and, with relatively few modifications, found it would keep the hermetic seal."

Once the package was found to be stable and offer a good shelf life, the valve company made a pre-production run and samples were shipped to AFL Telecom for evaluation. "We thought we were close, but it had to be tweaked even more to make it perfect," Tourigny recalls. The original package had an atomizer spray, but AFL Telecom felt it that was too messy. It also dispensed too much solvent, and the engineers didn't want to waste solvent. "So we had to go back and reconfigure it one more time," Tourigny remembers.

Two Down, One to Go

As he was developing the packaging, Tourigny also turned his attention to developing some device to boost the cleaning effectiveness of the solvent. Industry-wide, the standard is some sort of swab. But swabs are problematic, and Tourigny had a hunch the technology could be improved.

"Our goal was to develop a cleaning system that would clean 100% of the fiber optic face 100% of the time," he said. "Today, the industry averages maybe 20-40%. That leaves lots of room for improvement." Most fiber optic swabs use open-celled foam, or a micro-denier fabric, or both. Some appear to be hand-made, wrapped around a plastic core. Some use glues or binders to hold the swab together which might be dissolved by solvents. Some types of open-cell foam are relatively dirty and can deposit as much contamination as they take away.

Most swabs are designed to clean on the sides of the swab, but not the tip of the swab. "But with fiber optic connectors, you are most concerned with the very end of the stick, where it touches the fiber optic cable itself." Based on their experience with other MicroCare products, Tourigny felt the most promising alternative was sintered polymers.

MicroCare found sintered polymers to be an excellent choice. They are clean, they don't outgass or deposit lint, plus they offer excellent chemical stability and solvent resistance. Sintered polymers can be molded so glues or blowing agents are not required. Most importantly, they conform to the slightly curved, domed or beveled faces of the fiber optic termini, and recover back to their original dimensions. "This creates an mechanical gripping capability, just like a radial tire grips the road," says Tourigny. "It actually lifts particulate off the face of the fiber optic cable."

In the end, MicroCare's researchers went through hundreds of iterations to develop the final material, size, shape and assembly procedures for the cleaning sticks. At one point, MicroCare found certain tooling was not going to work on the next generation of cleaning sticks. "There were a lot of dead-ends," notes Tourigny with a grimmace. "It's a tough day when you have to tell your boss you're throwing away $40,000 of tooling, when only six months ago you were telling him it was essential."

The market feedback from AFL Telecom was crucial in the development of the cleaning sticks, Tourigny reports. "We couldn't have done it without them." Once MicroCare had prototypes ready, it was AFL Telecom who had the expertise to evaluate the products, to get samples out to customers for field trials. "They know the people to go to, they knew how to get them tested."

Stone agrees that getting market feedback is a fine art. Contractors are generally not good test sites, he adds, "because contractors just buy stuff and use it. It is the telco long haul market that need approvals, but those customers have the labs to do the tests." Of particular important were military customers. But every customer is different. In one field test, the technician broke the nib off the cleaning stick inside the connector just to annoy his supervisor. This meant a complete tear-down of the connector. "So we went back to MicroCare one more time to see if we could make the nibs more flexible without sacrificing cleaning performance," Stone recalls.

The Rollout

Today the fiber optic connector cleaner is available from AFL Telecom distributors around the world. The solvent is packaged in a miniature pump spray and is rated as "Not Hazardous/Not Regulated" for land, sea and air shipments. The container is leakproof, compact and fits easily into the hand, so technicians find it convenient to use. Each actuation dispenses a very precise flow of solvent. The cleaning sticks are packaged and shipping in brightly color-coded packages.

And what's Tourigny doing with all his new-found free time? "I'm working on the next big thing," he said. "I just hope it doesn't take another three years."

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Related Information:

- For additional information about the ozone-safe DuPont HFC solvents, check out the Vertrel® solvents web site.
- For other information about the Bromothane™ brand of nPB solvents, check out the Bromothane™ web site.
- For additional help, use the *Solvent Selection Guide* in this Site to help determine the optimal recommendation.
- A simplified PDF version of the same Selection Guide also is available.

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