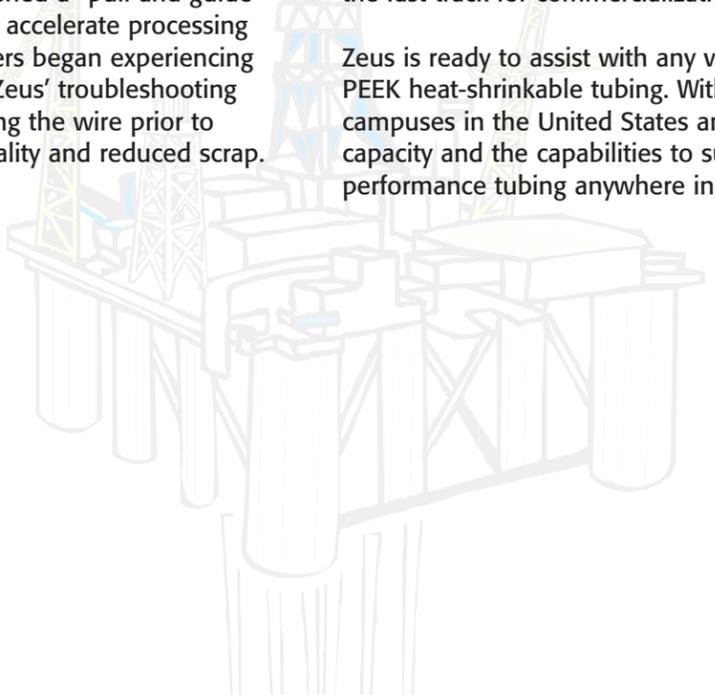


with the set-up of the processing operation. Initially, Novatek project engineers used a heat gun to shrink the tubing over the cable. Even at temperatures up to 860° F, the process was unacceptably slow (2.5 inches per minute).

To speed throughput, Zeus provided a Quartz oven, set up the processing line, and established a "pull and guide" processing system to ultimately accelerate processing rates. When the project engineers began experiencing unacceptably high scrap rates, Zeus' troubleshooting uncovered the problem. Cleaning the wire prior to processing reined improved quality and reduced scrap.

In its first commercial test, about 6,400 feet of IntelliPipe was used in an Oklahoma well for 500 drilling hours. A high-speed data link was established with above-ground receivers, allowing testing modules to operate with higher temperature ratings in the lowest portion of the string in a second well. The results of this test have put IntelliPipe on the fast track for commercialization.

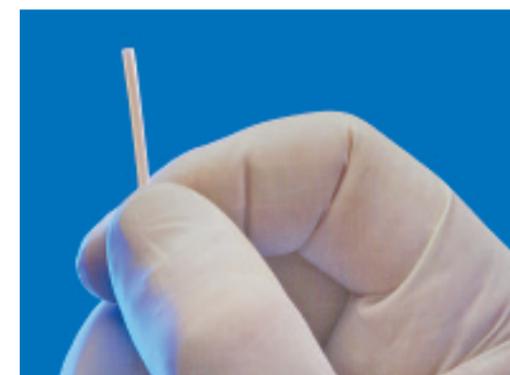
Zeus is ready to assist with any volume requirements of PEEK heat-shrinkable tubing. With nine facilities on six campuses in the United States and Europe, it has the capacity and the capabilities to supply this high performance tubing anywhere in the world.



A ZEUS CASE STUDY

Zeus PEEK heat-shrinkable tubing enables smart drilling technology for natural gas and oil exploration

(NOTE: IntelliPipe® is now marketed through IntelliServe™, a joint venture between Novatek and Grant Prideco, Inc., a leader in drill pipe technology.)



"We thrive on difficult applications. It's not the polymer that solves the problem; it's what Zeus does to enhance the innate performance attributes of a polymer so it aligns with a specific application that leads to scientific, commercially viable breakthroughs."

- Bob Ballard, R&D Director
Zeus, Inc.

"During testing it became very clear that we would be hard-pressed to find another polymer or material construction to compete with Zeus' PEEK heat-shrinkable tubing in this application. Testing has gone so well, in fact, that we have patented the use of PEEK heat-shrinkable tubing for the IntelliPipe application."

- Scott Dahlgren, Sr. Development
Engineer, Novatek Engineering

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THE APPLICATION

Novatek engineers needed a material to protect sensitive wiring from extreme temperatures, pressure and dielectric interference during deep well oil drilling. After testing other materials, Zeus PEEK heat-shrinkable tubing was selected to form a "second skin" around the wires, thus ensuring data transmission in harsh environments.

THE CHALLENGE

Oil companies are under tremendous pressure to find new sources of oil—even if that oil comes from wells previously thought to be "tapped out." Yet exploration is extremely costly. Time and money is a commodity to be preserved even as the pursuit for oil heats up.

Since 1997, Novatek researchers have been working to develop an intelligent drill string system for the high-speed, bi-directional transmission of real-time data to assist in identifying previously undiscovered pockets of oil in existing wells. Funded in part by the U.S. Department of Energy, the new technology—called the IntelliPipe® system—is a replacement for mud pulse telemetry, a slow, unreliable technology currently used in down-hole exploration. In early 2000, Novatek researchers found themselves in a quandary. The materials they had been using to protect the wiring in a data transmission antenna were failing under the harsh drilling conditions. For the IntelliPipe system to work, they needed an alternative material to protect sensitive wiring at the drill end of the pipe.

THE SOLUTION

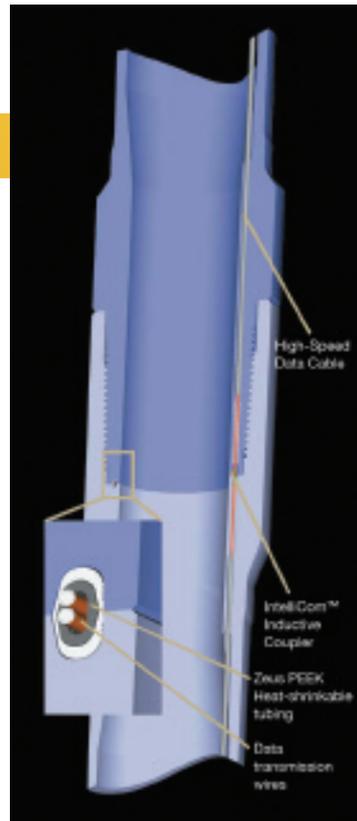
Zeus, Inc., a world leader in the design and production of high performance fluoropolymer extrusions, provided the solution: PEEK heat-shrinkable tubing. Since the 1980s, Zeus has been extruding PEEK polymers supplied by Victrex in a range of commercially successful formats for medical, electrical, fluid handling and mechanical applications. Zeus' PEEK extrusions are prized for their precise, tenacious performance in extreme applications, delivering tensile, mechanical and dielectric strength; hydrolytic stability in hot water, steam, solvents and chemicals; and resistance to stress cracking and bursting. Zeus' heat-shrinkable PEEK tubing delivered these properties to the IntelliPipe application. The Zeus team delivered a total solution that has enabled Novatek to make dramatic progress toward commercial success.

THE STORY

It is called "smart drilling" and it is the modern approach to oil exploration that allows oil explorers to drill safer, more productive wells by using high-speed, down-hole communications systems. These systems, which employ various types of sensors and telemetry units, transmit data from the drill to the surface as the well is bored. This includes information like temperature, geology, pressure and rate of penetration. Those on the surface use this data to make decisions on where to drill, when to stop, and when to proceed.

Oil companies have relied on mud pulse telemetry as the industry standard for data transmission from the drill site to the surface. The technology is slow—it typically functions at 3 to 6 bits per second—and has limited capability to receive commands from the surface. While serviceable, it does not deliver the speed and accuracy demanded by oil explorers.

With partial funding from the U.S. Department of Energy, Provo, Utah-based Novatek Engineering has spent the last eight years developing an intelligent drill string system for the high-speed, bi-directional transmission of real-time data. The technology is light years ahead of mud pulse telemetry, transmitting data to and from the surface to the drill head at a rate of one million bits per second. This technology, now called



IntelliPipe® and marketed through a joint venture between Novatek and Grant Prideco, a Houston-based drill pipe technology leader, enables drill operators to instantaneously and more precisely direct the drill bit towards pockets of oil and away from dead ends.

The key to IntelliPipe is the high-speed data cable inside of a high-pressure conduit. Ensuring the integrity of key wiring used in an antenna at the drill end of the pipe, and preserving its ability to transmit in a robust fashion under extreme conditions, posed a significant challenge for project engineers. The proprietary gold-plated wire had to be protected from extreme heat, pressure, friction, salt water and steam. Too, the wire had to be cosseted from electrical interference that might compromise its data transmission capability.

Project engineers knew the material selected to protect the wire had to provide lap shear bond strength, as any type of separation between the wire and the coating would result in a costly failure. The first material tested was a spray-coated Teflon®. Pressure from water and steam caused the coating to flake off.

Kapton® polyimide dispersion coating was tested next. Though proven to perform in electrical applications for more than 30

Zeus' PEEK heat-shrinkable tubing is used to seal wire put in an antenna-like fixture that is potted and installed at the drill end of the IntelliPipe. A connection is made with this wire at the head of the drill to assist in transmitting high resolution data to and from the surface in real time, thus facilitating safe and accurate drilling.

years and recognized for its stability at elevated temperatures, the Kapton coating also failed.

Representatives of Victrex, a leading producer of PEEK polymer suggested that the Novatek project engineers contact Zeus, a leading producer of high performance, precision PEEK tubing. Zeus' success with PEEK across a wide range of challenging applications was well known to Victrex and the project appeared well suited to Zeus' problem-solving culture.

Zeus R&D scientists and polymer engineers recommended PEEK heat-shrinkable tubing. PEEK is widely regarded as the highest performance thermoplastic material. What sets PEEK apart from other fluoropolymers is its ability to retain its mechanical properties at extremely high temperatures (continuous service temp of 482°F). Too, PEEK is exceptionally strong, yet flexible. It is highly resistant to organic and inorganic solvents.

With wire samples from Novatek, Zeus' R&D department set about testing PEEK heat-shrinkable tubing. Their objective was to create a homogenous bond between the wire and the PEEK tubing, recognizing that the tighter the bond, the less likelihood of failure. The scientists determined that by changing the morphology of PEEK by altering the structure of the polymer crystals, the heat-shrinkable tubing could deliver the required lap shear bond strength, forming an impenetrable shield around the wire. The IntelliPipe project engineers now had their coating.

Engineering the tubing was just one aspect of Zeus' total solution. A technical team traveled to Utah to assist

(continued on back)



Advantages of PEEK heat-shrinkable tubing:

- High continuous operating temperature
- Extends life of the protected item
- Assures reliable performance
- Shrink temperature 650° F – 725° F
- Consistent shrink ratios of up to 1.3:1
- 10-20% longitudinal shrinkage

AT A GLANCE

- Novatek required a material that would deliver superior lap shear bond strength, thus ensuring the IntelliPipe system's ability to transmit data from deep inside the earth's recesses. Zeus' PEEK heat-shrinkable tubing provided an impenetrable "second skin" around key wiring, locking out contaminants and securing the integrity of the cable. The PEEK tubing has performed so well, Novatek has patented its use in the IntelliPipe application.
- Novatek tried two materials prior to selecting Zeus' PEEK heat-shrinkable tubing: a spray-coated layer of Teflon, which flaked off due to the extreme pressure of water and steam, and a Kapton® polyimide dispersion coating that also succumbed to pressure under testing.
- PEEK is widely regarded as the highest performance thermoplastic material. Zeus' experience with PEEK in terms of material modification, extrusion, optimization, and applications enabled Zeus to provide a PEEK heat-shrinkable tubing that formed a homogenous bond around the IntelliPipe wiring, making it impervious to temperature extremes, steam, salt water and electrical interference.
- Zeus took a total solution approach to the IntelliPipe project. Not only did it provide a proven component in its PEEK heat-shrinkable tubing, Zeus provided R&D, manufacturing and troubleshooting support at critical junctures. When the IntelliPipe system is commercialized, Zeus is prepared to handle volume orders with nine facilities on six campuses in the United States and Europe.