Tech Article

Circuit Board Design & Cleaning Evolves to Support Down-Hole Logging Technologies

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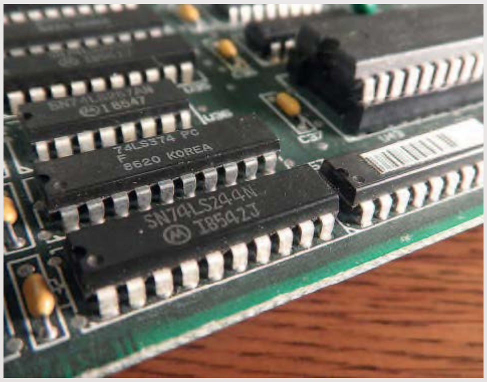

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The future of the oil and gas industry won't be found in giant unexplored reservoirs in remote parts of the world. The real future of the industry will be found in using smarter electronics in down-hole tools. For years, oil-field engineers have demanded ever-smarter down-hole tools, but many are unaware of the underlying technologies that enable those devices. This article examines the evolution of the electronics used in down-hole logging tools over the past forty years and the cost-saving cleaning chemistries that are crucial to their success.

Smarter Drilling

From the very first directional well in Morgan County, Ohio in the 1930s to the sophisticated, computer-controlled wells developed today, the financial attraction of directional and horizontal drilling has proved to be irresistible. Modern horizontal and multilateral wells enable developers to reach more oil in large, thin reservoirs that would be prohibitively expensive to develop using simpler technology. Directional drilling also can revitalize older wells that have been depleted or damaged by traditional vertical recovery techniques.

At the core of the drilling revolution has been the development of better down-hole logging-while-drilling tools (LWD) using increasingly smart sensors and systems to process sensor data. LWD technology has evolved fairly rapidly in the past thirty plus years. Solid-state accelerometers have replaced spinning mechanical gyroscopes; mud pulse telemetry has given away to high-speed digital data transmission. The LWD tools themselves have evolved from simple sensors into miniature science labs, detecting, organizing, storing, processing and transmitting down-hole gelogical data. When combined with near-real-time analysis, these tools act like a sub-surface GPS, navigating their way through the rock to the richest reserves. They are the eyes and ears of the geologists on the surface.

But the tools haven't evolved in isolation; they are the product of an even more vigorous revolution in electronics design that has its fundamental roots in the Russian-US space race of the Cold War.

The Electronics Evolution

Until the 1970s, almost all electronics were built from individual components, using labor-intensive assembly of hundreds and thousands of separate diodes and transistors. The miniaturization demanded by the space race led to the first computer chips called "through-hole" circuit board designs. The first through-hole components made their introduction in the commercial applications in the late 1960s – the integrated circuits were embedded in the black plastic housings of the "chips" and the circuits were connected with the long metal legs of the chips, which commonly have 16 to 20 legs. The defining physical features of a through-hole PCB (printed circuit board) are these "legs" that protrude from the sides of the components and go through the actual circuit board. During assembly, a technician solders the legs into place, creating the hundreds of electrical connections that make the device "smart". The chips have a high "stand-off" from the board allowing heat to escape easily. Unfortunately, these long, spindly spider legs are prone to harmonic failure from prolonged vibration – exactly the environment found in down-hole tools.

The late 1980s saw the evolution to the first “surface mount” components. These designs retained the spider legs along the perimeter of the earlier generation chips, but made them smaller, more numerous and eliminated the space-wasting holes going through the actual PCB. Surface mount technology stayed with the same basic design as through-hole chips, but miniaturized all the pieces – by miniaturizing the legs and using all four sides of the chips, the number of electrical connections could be increased to 100 to 200 on the densest designs.

Shorter legs and tighter stand-offs were more vibration resistant and enabled more chips per-square centimeter, making the resulting tools “smarter”. Many chip designs, such as the popular QFP format, had 200+ electrical connections which made the chips extremely powerful.

But the component designers weren’t finished. By the end of the 1990s, ball grid array (BGA) components were becoming commonplace. BGA components evolved away from space-wasting legs, and all electrical connections are under the chip, using micron-sized dots of solder to complete the circuits – BGA designs also increase exponentially the number of connections that can be made, since the number of possible connections is limited by the area of the chip, not the perimeter.

Initially seen as microprocessors in computers, BGA components packed still more transistors into the smallest possible package. Each chip supported thousands of tiny solder connections (hidden underneath the chip) which make them extremely rugged, even in harsh environments. BGA designs have stand-offs measured in microns, but they make for smarter electronics. In fact, a single component can serve as the central brain to process data and also drive peripheral systems on the LWD tools, such as the data link to the surface and the interfaces.

The Cleaning Conundrum

Unfortunately, these dense designs are very difficult to clean, and cleaning the circuitry in down-hole tools is absolutely critical to their success. During soldering, chemicals called fluxes enhance the flow of the molten solder and improve the quality of the solder joint. Fluxes use activators which form salts when heated and activated. Just as salt in sea water corrodes oil rigs, microscopic flux residues can corrode the solder joints that make modern electronics work. These residual salts on the tiny electrical connections can cause the PCB to fail.

Another problem is that heat speeds the corrosive activity. Specifically, heat accelerates the reactions forming salt complexes which then become more difficult to clean off the PCBs. Dense PCB designs run hot, so corrosion that might occur over years in a benign office environment can happen in just days. A down-hole tool that will have a long, profitable work-life must be clean, dry, salt-free and corrosion-free.

Since any given LWD tool might be repaired and then cleaned hundreds of times during its operational life, cleaning quickly, thoroughly and safely is a paramount objective for the technicians.

During refurbishment, LWD tools are cleaned with a number of different chemicals due to the wide variety of contamination on them. Extensive hand-soldering is required on the circuit boards buried inside the tools, and removing the highly-

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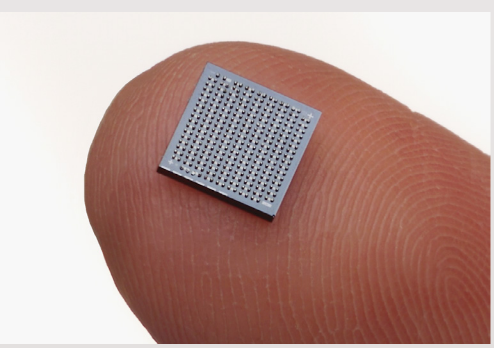

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Be it metallurgy, chemistry, software or hydraulics, every technology used on a modern oil or gas rig has evolved at a furious pace over the past three decades -few engineers or geologists are aware of the specific features that make modern DWL tools so smart, nor the chemistries required to keep them running profitably.

activated fluxes from the components can be difficult. A modern, powerful defluxing solvent is the best solution.

But the tools also are coated in dirt and hydrocarbon residues, so powerful degreasers are used on those types of contamination. Penetrating oils are used to detect cracks in the metals of the tools. Many LWD tools have their circuit boards protected with conformal coatings to keep water from the surfaces. Silicone coatings are a preferred choice because they are very durable and highly resistant to heat. Removing the grease, oils and rugged coatings during repair always is difficult, and fast, reliable cleaning could be an important time-saver.

Just as the electronics have evolved, cleaning chemistries have evolved as well. All through the space age and up to 1990s, ozone-depleting CFC fluids and simple alcohols were the cleaners of choice, often backed up with flammable solvents such as hexane and aggressive pollutants like paint strippers. These chemistries were normally packaged in aerosol cans although drums of fluids also were used.

In the 1990s and through the first part of the 21st century, many companies switched to HCFC-based cleaners. This innovation offered excellent cleaning with an affordable, nonflammable formulation. The larger oil field service companies used the fluid in vast quantities; tens of thousands of aerosol cans annually. But the fluid was only an interim step, as it was still an ozone-depleting material.

But all of those old-style cleaners are problematic in today's world. Ozone-depleting solvents have been banned in every modern country. Chemicals with toxicity problems are no longer acceptable. Nonflammable fluids offer an important safety boost, especially on off-shore rigs. Unwanted side-effects, like causing smog, global warming or waste disposal issues all must be considered in the solvent selection process. Of course, the cost always is an issue, as well.

It came as no surprise to the technical experts at MicroCare and other chemical companies that the oil field service teams would be looking for new cleaning answers on their LWD tools.

Case Study

The key objective with one particular oil services company was to replace the multiple cleaning solvents used for degreasing and defluxing the tools with a single, safe, nonflammable and less expensive cleaning product. If the cleaner of choice could also remove silicone coatings, that would be a significant improvement in productivity. All of the proposed cleaners would have to be safe for the environment, for people, and affordable for the company. All of the cleaners would have to be available globally. Simplifying shipping, storing and handling of hazardous chemicals was also a desired goal.

One client gradually implemented a particular "combination" solvent, a versatile nonflammable defluxer and a degreaser combined into one formulation, throughout their facilities. This formulation is now their degreaser/defluxer of choice for down-hole tools in the North Sea, off-shore in the Gulf of Mexico on oil rigs served from the Houston region, plus at facilities in Singapore and in the Alberta fields.

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The TriggerGrip™ Dispensing Tool reduces solvent waste and worker exposure.

This SuprClean™ cleaner is fast-drying, ozone-safe, features the right toxicity parameters and delivers excellent cleaning performance on fluxes, grease and penetrating oils.

A second product, VeriClean™, has been deployed for the silicone conformal coatings repairs; it turned out to be impossible to get the cleaning done with just one formulation.

The testing process took almost two years, and combined field tests with lab work. For example, the MicroCare Critical Cleaning Lab tested the new fluid on a variety of metals, wiring, and several sizes and types of O-rings, and found the new cleaner to be completely safe on those materials.

Input from the field techs was crucial, because if the cleaner wasn't fast, reliable and easy to use, it wouldn't be used. One technician who worked daily on the logging tools was part of the evaluation team. He sprayed the old cleaning fluid onto a tool and then sprayed the MicroCare cleaner onto another tool. He waited a few minutes then said "come see for yourself… the new cleaner [from MicroCare] works better and faster than current products." The combo-fluid did an excellent job on the highly activated fluxes used on the PCBs, plus the penetrating oils and general degreasing.

At the corporate level, the new development is a money-saver. The new cleaning fluid was approximately 20 percent less expensive than the legacy solvents when the conversion happened, and the price difference is even greater today. In addition, the new formulation is legal to use around the globe while the older products are restricted and, in most markets, are simply no longer available today. The product is completely ozone-safe, relatively low in Global Warming Potential, and easy to ship and store. It is often used with the TriggerGrip™ aerosol dispensing tools which reduces solvent waste and improves the quality of the cleaning.

Clever field service companies are incorporating these powerful cleaning technologies into their down-hole tool maintenance programs, enabling them to recover more hydrocarbons at lower costs.

About the Author:
Mike Jones, retired Vice President of International Sales for MicroCare, has over 30 years of experience in the critical cleaning industry. He is a prolific writer and educator focusing on critical cleaning in general and vapor degreasing and benchtop cleaning in particular. For more information, visit www.microcare.com.

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