

THE KEYWORDS FOR BLOWOUT PREVENTERS ARE
Trust but Verify

— Stephen Rassenfoss, *JPT* Emerging Technology Editor —

GE Oil & Gas displayed its new blind-shear ram, which is capable of cutting components older blowout preventers could not, at the 2012 Offshore Technology Conference. *Brett Coomer / Houston Chronicle*

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Blowout preventers (BOPs) have become a constant concern. Periodic certifications of the equipment and maintenance used to be enough to ensure that this last line of defense would perform if needed. Now, users are constantly “wanting to know, is it ready?” said Chuck Chauviere, the general manager for drilling systems for GE Oil & Gas.

The question can be asked many ways. Is the BOP capable of cutting the pipe or connectors and sealing a blowout? Are the electrical and hydraulics systems working properly? Is the crew trained to quickly make the right decisions in an emergency? Will backup power and communications systems perform under extreme circumstances?

Much has changed in the 2 years since the Macondo disaster in which 11 people died; but, the process is far from over. A rewrite of the American Petroleum Institute (API) guidelines for BOP operations and maintenance, *API 53: Recommended Practices for Blowout Prevention Equipment Systems for Drilling Wells*, was going through another round of revisions in mid-summer and could be published late in the year, said Roland Goodman, manager of upstream standards at API. The guidelines provide details needed to make changes in the sections of API 16 that cover BOP construction, testing, and recertification.

In May, the Bureau of Safety and Environmental Enforcement (BSEE) kicked off a push to write the first US BOP regulation with a hearing in Washington. Industry representatives got a taste of what is ahead when David Hayes, deputy secretary of the US Department of the Interior, said, “There are at least four things we are looking for in a new proposed rule:

- ▶ “One, BOPs need to be able to cut whatever is in their way and completely seal off the well.
- ▶ “No. 2, better maintenance for BOPs, like what you would expect of a jet engine or any other very sophisticated mechanical device upon which lives depend.
- ▶ “No. 3, BOPs need better sensors to tell us what is happening at the bottom of the sea.
- ▶ “No. 4, everyone working with BOPs should be fully and properly trained to handle any contingency.”

One thing that stood out was the regulator’s focus on shearing whatever was in the BOP. Tom Hunter, chairman of the US Interior Department’s Ocean Energy Safety Advisory Committee, summed it up by saying BOPs need to be “shear certain.” For someone who has spent many months crafting measurable BOP performance guidelines for engineers, the catch phrase was both ambitious and ambiguous.

“What is ‘shear certain?’ How do we arrive at it, and what are the criteria?” said Frank Gallander, chairman of the API subcommittee that rewrote API 53, who spoke on one of the panels at the all-day BSEE meeting.

Based on comments made that day, “shear certain” sounded like the ability of a BOP to cut any part of a drillstring. If that is the ideal, it is missing the reality that

many BOPs in service are unable to cut certain drilling components, such as connectors, drill bits, and stabilizers.

Gallander, a subsea well intervention specialist for Chevron, pointed out that the industry is seeking new methods to reach that goal, including research into shearing with lasers or explosives. There have been promising results, but developing and testing a new technology is time consuming with no guarantee of success.

“They have put it to us as an industry. We look at that as a challenge and will do what we can do” to meet it, Gallander said.

The industry is also responding in other ways, including moving to two shear rams per deepwater well and building an industry database of BOP and tubular test information to better gauge the capabilities of shearing rams.

The regulatory agenda echoed themes in the report from the National Academy of Engineering *Macondo Well-Deepwater Horizon Blowout* on the causes of and lessons learned from Macondo. One of its authors, Roger McCarthy, a consulting engineer with a long career investigating high-profile disasters, said government standards are needed to drive spending on things that do not add reserves or increase production. “If you look at energy spending on new technology that aids production, it is dramatic,” McCarthy said. “But there has not been a parallel investment there on reliability.”

Given all the criticism and calls for change, McCarthy said he would not have been surprised to see some resistance; but, “they took it rather well, all things considered, and said, ‘Tell us what we need to do,’” he said.

New and Improved

BOP makers have begun rolling out new products with the added muscle required to meet Goal 1 for shearing rams—exert enough force to cut whatever is inside it based on the maximum strength of the drillstring components. The latest shearing technology from Cameron, GE Oil & Gas, and National Oilwell Varco (NOV) were on display at the 2012 Offshore Technology Conference (OTC).

Cameron showed a large unit created for an ultrahigh-pressure shallow-water gas development rated for 25,000 psi, far beyond the 15,000-psi limit for most such equipment.

GE Oil & Gas introduced an improved blind-shear ram design that applies the force more effectively, allowing it to sever thick connectors that could not be severed by past models.

NOV has been selling its low-shear ram designed to reduce the force needed for shearing by first puncturing the pipe. The blade has a hump in the middle able to punch a hole in a pipe, setting up the massive structural failure required for shearing.

Both the GE and NOV designs have improved mechanisms to push the pipe toward the center of the cavity for a cleaner cut. That feature became a concern after the post-disaster analysis of the *Deepwater Horizon*’s BOP—

Speaking of Blowout Preventers

The following are comments made during the hearing on blowout preventer (BOP) regulation held by the Bureau of Safety and Environmental Enforcement (BSEE) in May.

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“One, it would be 100% available at all times. Two, it would be totally controllable at any time. Three, it would be completely diagnosable. Four would be what I would call ‘shear certain’—if you need to clear the way, you can clear the way. Next, no matter what has happened, there needs to be a mechanism where you can provide a sheared closure. Last—maybe most important for industry colleagues—these blowout preventers need to be obtainable. They cannot just be complex drawings and lines. They need to be built.”

—Tom Hunter,

chairman of the Ocean Energy Safety Advisory Committee, on suggested BOP design principles

Forensic Examination of Deepwater Horizon Blowout Preventer by Det Norsk Veritas [DNV]—concluded that the BOP failed to cut because the pipe had buckled, moving it out of the zone where the blades were able to shear it.

BOP makers were also showing ways to track the machine’s status, showing if the rams in a BOP are open, closed, or somewhere in between.

Two programs now allow quick monitoring of key BOP components using displays with green, yellow, and red lights. The programs were designed to make decision makers aware of the health of the well-control system and help them decide if any problems justify action.

Measuring Up to the Task

The introduction of new, more capable equipment is not a cure-all in an industry with a large, long-lasting fleet of BOPs that have their limits. New shearing-ram designs from GE and NOV are said to be able to cut connectors that could not be severed by older models.

To compensate for those limits, the revised API 53 calls for an estimate of the force that shearing rams are capable of exerting and the pressure needed to cut a drilling component. It advises that shearing should require “not more than 90% of the BOP’s maximum operating pressure.”

The section on shearing pressure evaluation said, “Any identified risks shall be mitigated and/or managed through the development of specific guidelines, operational procedures, and a thorough risk assessment.”

The goal of the process is to ensure thorough consideration of whether the BOP is suited for the well to be drilled and that procedures are in place to ensure a blowout can be stopped.

“We are saying understand the limits and capabilities of the system,” said Gallander, chairman of the API 53 subcommittee. “Everyone involved needs to understand the risk

and be prepared. That is the most important thing.”

Drillers will also be required to deploy two blind-shear rams to increase the reliability of the system by doubling the chances for successfully shearing and sealing a well. After Macondo, Shell and BP required two blind-shear rams on each well, which has become increasingly common.

The result is taller stacks of BOPs. While the API rule is likely to push the common practice from four BOPs to five, stacks seven units tall or more are not uncommon.

All these factors, plus the many new drilling rigs on order worldwide, are increasing demand for new BOPs, said Dan Church, president of the Axon Pressure Products manufacturing division of Axon Energy Products. Another driver for demand is that some older BOPs are being forced out of service because they lack the documentation required for recertification.

For BOP makers, though, the forces driving up demand also have a down side. The Macondo disaster highlighted the legal hazards that come with making a critical piece of safety equipment. While regulators are asking for improved BOPs, the uncertainty created by the prospect of a new regulation complicates new product introductions.

GE’s new shear ram was tested using the API 16A qualification process for shear rams with the input of a user group. The API is revising that standard, while regulators are drafting rules with input from advisors such as McCarthy, who is an advocate for a new generation of testing equipment capable of realistically simulating a high-pressure deepwater blowout.

When asked about whether it is developing new testing methods, the company responded, “GE continues to monitor and respond to the directions provided by the regulators around the design and verification of this equipment.”

The fluid state of the rules weighs on the marketplace. No one wants to place an order with a long lead time for a major piece of equipment that could be made obsolete by new regulations before it is delivered or be the first customer for a new generation of untried equipment.

"We are waiting for the rules to manifest themselves," said Moe Plaisance, vice president for governmental and industry affairs at Diamond Offshore Drilling. "What are the international jurisdictions going to do, and what are the operators going to want, and what are our customers going to want?"

Open, Closed, or What?

After the destruction of the *Deepwater Horizon*, a top priority was stopping the oil flow by closing the BOP. But the team of experts from inside and outside BP had little to go on.

"I cannot tell you how difficult, if not impossible, that was to figure out," said Tom Hunter, former head of the Sandia National Laboratories, who was among the many technical experts called in to offer advice.

"We spent countless hours trying to understand what was happening with this system and never had more than anything but a guess. It was not a self-revealing system," said Hunter, now chairman of the Ocean Energy Safety Advisory Committee.

He recounted that experience during the May BSEE hearing while making the case that BOPs need to be equipped with better real-time monitoring of such things as pressure, temperature, and what is flowing through them and be able to continue reporting even in extreme circumstances. Pressure and temperature monitors are common enough inside oil wells. Building ones rugged enough to withstand a blowout and still deliver good data, however, is a tall order.

BOP makers are working with industry groups and regulators to

figure out what added data would prove useful, said Chauviere of GE, who added that the company has some ideas on how to best do that.

One example is a device offered by GE that reports on the location of the piston and the force that can be exerted by it. The standard BOP uses the volume of fluid inside the piston to tell if it is open or closed.

In the past year, GE has been selling a sensor that can show an operator on a drilling rig the current location of each ram. The company went beyond simply observing if the BOP piston was open or closed because, Chauviere said, there is increased interest in knowing its exact position.

Cameron displayed models at OTC with dial indicators that allow video cameras on remotely operated vehicles to record piston positions.

Adding sensors to BOPs comes with engineering challenges. For example, sensors capable of checking the condition of critical metal components using ultrasound have been around since the 1970s. They are commonly used on structures, such as pressure vessels, that do not have the background noise experienced at a wellhead during drilling.

This type of sensor "probably works better on structures like a bridge than on a component that is moving and shaking and going through thermal cycling," said Michael Creech, chief operating officer in the industry division at Bureau Veritas. Creech, who has a background in nondestructive testing, said advances in signal processing technology able to filter out more of the ambient sound offer the hope this approach could be used near a wellhead.

Doubling Up

Taller BOP stacks and stepped-up maintenance standards are changing how offshore rigs are equipped and how drilling is managed.

Some rigs are now equipped with a spare BOP stack to allow them to move from well to well without delays

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"I can stand up here and say, from a personal and from the company point of view at Diamond Offshore, you want to be part of a solution and do what is best for our country, our people, and for the world. We are active all over the world. Whatever comes about here will influence what happens there."

—Moe Plaisance,
vice president at
Diamond Offshore

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"We had a lot of questions. First of all, do the data and the drawings we have match the system undersea? Secondly, what are the positions of the rams? Are they closed or open? Are the locks set? What, if anything, is inside the bore? Are there any flow restrictions? Is it stable? Is it going to tip over? Lastly, what is the flow going through the bore and closed rams. I cannot tell you how difficult, if not impossible, that was to figure that out."

—David Hayes,
deputy secretary for the US
Department of the Interior,
on trying to analyze the
Deepwater Horizon BOP

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"At the end of the day, engineers designing BOPs have to be given specific performance metrics. We can only talk in generalities for so long."

—Jose Gutierrez,
director of technology and
innovation at Transocean,
on regulation

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"If these things are going to be expected to work under conditions where all hell is breaking loose, they have to be tested in conditions that simulate all hell breaking loose. I recognize, and we recognize, that's neither cheap nor easy. The consequences of not doing this testing have to be weighed against failing to operate under very difficult conditions."

—Roger McCarthy,
an independent consulting
engineer and a member
of the National Academy
of Engineering panel that
reported on lessons
learned from Macondo,
on BOP regulation

that could cost upward of USD 1 million a day.

"We feel we need the flexibility" to avoid costly breaks in drilling, said Plaisance of Diamond Offshore. "When a BOP comes up after it has been on the bottom for 200 to 300 days, it requires quite a bit of time to inspect and rehab it and make sure it is ready to go again."

The demand for doubles has grown to the point where GE created an interchangeable connection allowing quick change outs of BOP stacks. But many older rigs industrywide are not high enough to move the tallest stack, much less transport two of them. And offshore repairs can be impossible on the crowded deck of a drilling rig. Another option tried is keeping a spare on shore, but delivering something so large on short notice has problems of its own.

Ever larger BOP systems add options for drillers, but that is only a positive if the person at the controls makes the right decisions in situations that are life-threatening and complicated. The DNV examination of the *Deepwater Horizon's* BOP offered the theory, which was challenged by attorneys for BP and Cameron, that the pipe buckled because it was locked in place by rams sealing the annular space above and was pushed upward by the high-pressure flow from the well.

In the API's revised BOP operations standard, an example showed the force required to shear a pipe is higher if the annular BOP above has been closed, increasing the pressure. It also covers in what order shearing rams should be fired when two are available.

Following the lead of aviation, where pilots are assisted by automated systems programmed to avert potentially disastrous conditions, the industry is talking about computer-aided BOP controls.

"We are considering increased automation," said Ken Dupal, well delivery manager for process safety implementation on deepwater wells at Shell. The company wants to make



The blades of GE Oil & Gas' new blind-shear ram are designed to apply force and shear more effectively.

when "most every scenario has unique characteristics that require interpreting data and making decisions based on that interpretation."

The focus on regular, well-documented pressure tests on ever more complicated BOP systems has aided the rapid growth of the BOP pressure testing system created by IPT Global. In about a year, Suretec software, which promises faster more accurate tests with easier scheduling, has replaced older testing methods on 25 offshore rigs drilling for Chevron, Shell, ExxonMobil, Statoil, and Petrobras, and it had orders for 10 more, said Mark Franklin, president of IPT. It is installing servers on rigs that can archive tests and move data to users over the Internet, and it plans to open a central monitoring center in August.

Adding Artificial Intelligence

BOP designs reflect the enormous cost of shutting down drilling for repairs. Multiple systems back up critical

functions. Workstations used to control and diagnose what goes on inside BOPs offer pages of data on the health of a BOP. Still, it can be difficult to determine if a warning light represents something that could compromise performance or vibrations nearby that are not a problem. Even when one component goes out, there are multiple backup systems to consider and some components are far more critical than others.

For software makers, this looks like an opportunity. Lloyds Register Group has adapted software widely used to make maintenance decisions at nuclear power plants to help make decisions on whether a BOP requires work.

A late summer test is planned of the RiskSpectrum software, said Inge Alme, technical director for ScandPower, the subsidiary of Lloyds Register that created the program. When monitoring a BOP, the program requires a detailed description of the components in that unit and how they interact so it has the information needed to advise if an issue is pressing or not.

The systems analysis software, which is used in about half of all nuclear power plants worldwide, has allowed the plants to reduce accidents and downtime, Alme said. But, in the nuclear industry, as with oil and gas, major events define its public image more than long-term operational improvements do.

"My view of oil and gas is there is pretty good risk analysis during the design phase. They are not as good in the operations phase," said Alme, who hopes this software will someday become an industry standard for modeling risk in a wide range of offshore exploration and production applications.

To make it easy to interpret the results, the RiskSpectrum program

uses a display with red, yellow, and green lights to indicate the status of each key component. The three-light display is also part of the BOP monitoring program rolled out this summer by NOV with an assist from BP.

A major goal is creating more awareness of the condition of the BOP and interaction. The system is one of NOV's eHawk diagnostic services, which monitor critical rig hardware such as top drives and mud pumps. It also records and analyzes the data-seeking patterns that suggest problems are likely.

The system can be accessed by decision makers with a secure Internet connection. The goal is to make "everything available to everyone," said Ashe Menon, director of equipment optimization in NOV's Rig Solutions unit.

Both programs are designed to seek out patterns in the data in search of ways to reduce time lost to unplanned maintenance and to improve performance.

Menon said that, if an indicator light turns red—which he likened to a warning light on a car dashboard—the subsea engineer responsible for the BOP would need to figure out what, if anything, is wrong using the BOP workstation. The goal of the dashboard is to create a constant awareness of the BOP's readiness

"It is a communication tool, not a diagnostic tool," said Jim McKay, a BP drilling engineer who was involved in developing and testing the NOV system. For subsea engineers, one side effect of this sort of monitoring is the feeling there is "someone looking over my shoulder," McKay said.

Given the importance of ensuring BOPs are ready, McKay predicted, "This kind of thing is coming in our industry." **JPT**

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"We all agreed that, when we came to an impasse, life and the environment will take precedence."

—Frank Gallander,
chairman of the
subcommittee that
revised API 53, on how
the committee resolved
disputed issues

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"There has to be a continuous learning process on this as well. We need to come up with a robust system by which we register not only the failures, which we typically see, but we need to register the near misses and we need to register the successes. When does this work when we ask it to work? Let's start a database on all of this so we can collect this information and understand. Just exactly how successful are we with the use of BOPs?"

—Bruce Levity,
director of risk
management solutions for
Det Norske Veritas North
America, on industry-
wide BOP performance
measurement

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"This is shearing an actual tool joint. This used to be considered unshearable; but, with this new device, we are able to cut and seal tool joints. We are improving the capabilities of the equipment."

—Chuck Chauviere,
general manager for drilling systems for GE Oil & Gas, narrating a video of a test of the company's new blind-shear ram

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"The fifth column raises sort of an interesting question: What is the expected life for some of these valves? There is not a lot of real good information out there. We have a placeholder. ... As this kind of information is gathered, the industry needs to correlate that with maintenance [records] and actually have a better idea as to what the expected life is of these components."

—Frank Chapman,
president of Ashford Technical Services, on observations by the company's monitoring system

Worries About Well Control Open the Way for New Ideas

The future of blowout preventer [BOP] technology is defined by obstacles, such as pipe connectors with steel walls 3 in. thick. While BOP makers are rolling out new models that apply more hydraulic force to shear pipes, others are seeking ways to blast through them using explosives and lasers.

Shell has created two devices it hopes to commercialize using carefully calibrated explosive charges—one to seal off a well deep in the ground and another to quickly cut through pipe above the BOP to allow a drillship to make a quick exit, said Curtis Wilie, technology delivery manager for deepwater wells for Shell.

The list of well-control technology developments offered in a speech by Paul Siegele, president of Chevron Energy Technology, ranged from the exotic—testing lasers for emergency pipe shearing—to the pragmatic—expanding the use of acoustic emergency communications to the Gulf of Mexico. Backup communications using sound waves sent through water have been used in the North Sea and offshore Brazil.

"They have had them in the Gulf of Mexico. They have just not been popular," said Neil Manning, president of CDL, a subsea engineering company that has a backlog of four orders for acoustic communications devices in the US Gulf of Mexico and expects more.

The search for reliable, quickly available solutions at a reasonable cost means much of what is new is based on something established. Mario Lugo, president and chief executive officer of Trendsetter Engineering, described this process as "solving an unconventional problem with conventional technology."

Wilie has developed two devices by adapting advanced pyrotechnics.

Shell's emergency separation tool [EST] employs a ring of charges to allow a floating platform to make an emergency disconnect. The charges are the same kind used to perforate casing during completions. The EST works like a circular firing squad and has been used to cut through a 9¾-in. drill collar. The controlled blast did not damage the polyurethane holder on the opposite side of the circle. Wilie said the number of charges employed is not exceptional, noting, "We utilize a much greater amount of explosive on a daily basis" for completions.

A second invention, the collapsible insert device [CID], uses charges imbedded inside a double-walled pipe to create a blockage to stop a blowout above the formation. The explosions push in the inner walls, filling the space inside the pipe like a closed heart valve. Wilie sees several CIDs installed just above a reservoir. They are triggered by coded signals sent using vibrations down the casing. Adding the insert adds about half an inch to the diameter of the pipe. The force needed to shut down the flow does not damage the outer casing, and the obstruction can be drilled out later to reopen the well without compromising the strength of the outer wall, Wilie said.

Triggering these devices requires a communications system that can survive a blast. Shell opted for an acoustic communication system from Metrol Technology that sends vibrations downhole along the pipe. Secure coding from another contractor is used to ensure the devices can only be triggered by an authorized person. No wires are required for acoustic communication, but battery-powered relays are needed along the way to sustain the signal.

"The key with these systems is they are intelligent. They can operate on multiple frequencies. They can tune

SEE VIDEO IN
THE JPT APP



These two devices developed by Shell use advanced explosives and acoustic communications to deal with emergencies. The emergency separation tool (EST) uses two rings of shaped charges for shearing if a drillship is rapidly moving off station. The collapsible insert device (CID) closes off the flow of oil using two charges inside the double-walled pipe to create a barrier. **A video showing how the CID works is available in the digital edition of JPT, available on the App Store and online at www.spe.org/jpt/print/.**

themselves to cope with a dynamic environment,” said Ben Taylor, general manager for Metrol.

Interest also has been rising in acoustic communication, which uses vibrations through water. One of CDL’s clients, Trendsetter Engineering, was installing an acoustic communication device to activate a backup hydraulic pressure source for a BOP. US regulators have been asked to approve the use of the acoustic systems as an alternative to requiring operators to keep a remotely operated vehicle (ROV) nearby to control them.

“It [an acoustic system] can kill a well in 45 seconds. It takes a long time to deploy an ROV,” Manning said.

Adding communications links, which can also be used to pick up early warning signs of trouble, are among the many incremental steps that can improve the industry’s odds offshore.

“It is not going to be the ‘be all and end all’ for the industry. We might be better off for having better monitoring capabilities and the ability to close the well you didn’t have,” Taylor said. “Comingling all of it together, you have a powerful set of options.” **JPT**

“In closing, I will note that we have seen how properly implemented safety systems can significantly influence the safety of a very dangerous industry. After the loss of the submarine Thresher almost 50 years ago, the Navy implemented what is now known as the Subsafe program. I will also note that implementation took less than 1 year after the loss of the Thresher. No US Navy Subsafe-certified submarine has been lost in the 50 years since then. In the 50 years prior to Thresher, ... we lost on average one submarine every 3 years due to noncombat-related causes. That change in safety is arguably the direct result of the implementation of the Subsafe program.”

—Donald Winter,
professor of engineering practice at the University of Michigan, former secretary of the US Navy, and chairman of the Academy of Engineering Macondo panel

For further reading:

ONLINE

API Standard 53: Blowout Prevention Equipment Systems for Drilling Wells <http://ballots.api.org/ecs/dpos/API-53-4th-Ed-Ballot1.pdf>

Macondo Well-Deepwater Horizon Blowout from The National Academy of Engineering. An electronic version is available for free at its website, www.nae.edu/53926.aspx

Forensic Examination of Deepwater Horizon Blowout Preventer by Det Norske Veritas. The main report is under appendix D at: www.boemre.gov/DeepwaterHorizonReportAppendices.htm

BSEE Transcript, May 22 hearing on BOPs: <http://recapd.com/widget?5748e8>

BOP risk and reliability model to give critical decision support for offshore drilling operations: www.scandpower.com/bop

PAPERS

SPE 151182 Blowout Preventer (BOP) Health Monitoring by Jim McKay, BP, et al.

SPE 140365 Low Force Shear Rams: the Future is More by Frank Springett, National Oilwell Varco

SPE 119762 Pull Your BOP Stack—Or Not? A Systematic Method to Making This Multi-Million Dollar Decision by Jeff Sattler, West Engineering Services

BOP Quality Control Tightened Globally

The Macondo disaster has had a significant effect on how blowout preventers (BOPs) are maintained. Before drilling could resume in the US Gulf of Mexico, every BOP had to be inspected and recertified, with all parts inspected for wear and compared to the original design specifications to ensure they are as good as new. What started in the US has spread globally.

"Every BOP was essentially re-evaluated, and that applied to all suppliers," said Michael Creech, chief operating officer in the industry division at Bureau Veritas, which has seen a significant rise in recertification work in the past 2 years. For example, rising equipment repairs and part sales had a significant effect on Cameron's drilling systems business, which includes BOPs. New equipment orders tripled in 2011 and aftermarket sales were up 70% in 2011, according to its annual report.

"This tragic incident has caused drilling contractors and operators, both on land and in deepwater environments, to turn to original equipment manufacturers (OEMs) for service, equipment repair, and related parts, in many cases to recertify BOP stacks back to OEM specifications or for new equipment to replace an aging fleet," Cameron wrote in the annual report.

Axon Energy Products also has seen a jump in recertification work, which has raised questions that can be difficult to answer. A problem faced by those doing this work is that some

older equipment lacks documentation to establish what had been done to it, said Dan Church, president of Axon's Pressure Products Equipment division. Some equipment is being retired because it lacks the paperwork to prove it has not been modified in a way that will affect its performance.

The high level of inspection work has pointed to the need for an American Petroleum Institute standard on recertification, said Church. Work has begun on an added section to API 16, which covers BOP construction and testing.

Soon after Macondo, BOP manufacturers also began changing their new equipment operations, Creech said. "A couple of manufacturers of BOPs have fundamentally changed the way they are certifying BOPs," he said. Those customers imposed more stringent and detailed testing protocols to measure BOP performance tests more consistently.

Bureau Veritas is also being called on to evaluate suppliers around the world—for example valve makers in China—to ensure that each factory is delivering components meeting the contract specifications covering materials, manufacturing, and testing.

And original equipment manufacturers are expanding their product reviews to downhole tools and connectors, seeking ways to reduce the risk of those components failing due to flaws in the design or specifications, said Creech, whose company is involved in these reviews. **JPT**