

Scaling up for ultra-high pressure

As the industry grapples to define requirements for operating in 20,000 psi and 350° Fahrenheit conditions, Cameron has already delivered what it calls ultra-HPHT technology, as **Jennifer Pallanich** reports.

A client using 15,000 psi equipment had a well off Louisiana that it thought might exceed 20,000 psi. It tasked Cameron with providing a 25,000 psi wellhead, production tree and blowout preventer, preferably in less than 18 months. That kind of engineering effort typically takes two or three years.

"We took a look at the existing 15,000 and 20,000 psi BOP equipment and beefed it up a bit to make it sufficiently strong to carry the loads we were looking at with 25,000 psi," says Cameron engineer Charles Gibbs. "From 15 to 20 is no big deal, and 20 to 25 is no big deal. But the increments add up."

Cameron started what it refers to as an ultra-high pressure, high-temperature (U-HPHT) initiative about a decade ago.

"We thought, if we develop a new wellhead and tree system, what are the other gaps?"

Kirk Guidry, vice president of engineering, says. "We did some homework up front, and then we jumped into designs."

The company began validating its U-HPHT equipment in its Houston testing facility as early as 2006. Some equipment is still undergoing testing.

One of the first HPHT areas Cameron considered was the production tree tubing hanger. A key challenge was ensuring the metal seal could maintain the preload so that it would seal at specified HPHT conditions of 30,000 psi and 400° Fahrenheit, Guidry says.

When Cameron started thinking about the U-HPHT tubing hanger, they based it on "something that we knew worked", Guidry says. "It worked at 15,000 psi and was tested at 350° Fahrenheit. But we didn't rule out 'let's get a blank sheet of paper and look at different seals.'"

The tubing hanger design



for HPHT conditions was "kind of engineering by committee. Engineers got together and looked at designs we thought would work."

Along the way, Cameron's engineers tweaked the seal material and worked to ensure the equipment could meet the necessary preload. The seal tested perfectly the first time out, a story duplicated with the gate valve.

"We had the designs. We just needed to look at the material selection, look at the stresses, and modify our design," Guidry says.

Next, Cameron turned its attention to the gate valve. Ultimately, the company changed its gate valve geometry to address concerns that the support mechanism within the stem packing would not bear up under pressure, thus risking a seal collapse.

"Even though the design passed on our gate valve, during our testing for the choke we had



Photos: Cameron

"After we designed and validated the equipment, the tools to install it were a huge challenge for us." *Kirk Guidry, Cameron*



HEAT TREATMENT: Cameron's 25,000 psi BOP inspection at the company's facility.



TOUGH KIT: Cameron says its 25,000 psi, fully cladded surface production tree is the first-to-market system for ultra-high pressure, high-temperature applications.



DESIGNED AND QUALIFIED: Cameron's 25,000 psi partially cladded drilling manifold was transported on a complete skid to the offshore platform.

some challenges and had to do some design changes there as well," Guidry says.

The new choke design uses the same bonnet connections as the gate valve, and the stem packing in it is big. Both the gate valve and choke use the same sealing technology.

"We have completed a 25,000 psi, 450° Fahrenheit completion for wellhead entry," he says.

There are changes in the works for even that technology, he says. "Where we lock in our hanger manually externally, we want to look at being able to lock it in internally."

Cameron is using its SRL metal-to-metal bore seal between the tree and tubing hanger and its MTBS in the tubing hanger body seal. Lock screw seals of graphite compression were qualified to hold down the tubing hanger and isolate annulus pressure.

"After we designed and validated

the equipment, the tools to install it were a huge challenge for us," Guidry observes. "Like a tubing hanger wouldn't have been able to deliver the preload and meet the safety requirements for our customer, so we had to completely redesign our installation tools for the tubing hanger, both sealing and being able to deliver the load in one trip."

Along the way, many hours of engineering and collaboration were devoted to the elastomeric and metal-to-metal seals, analysing the wall sections for operations in confined spaces with higher pressures and loads, and the use of the BOP as part of the installation tool.

To date, no standards for conditions exceeding 15,000 psi and 350° Fahrenheit exist, so suppliers must find other ways to prove their equipment can safely operate at those conditions.

"The industry is struggling

with the material properties for the design analysis and with new requirements for stress strain curves and fatigue testing of materials," Paul Bunch, engineering director, says.

"We're all trying to figure out how to do this without everybody going out and having to run their own tests. It hasn't been resolved. We're still in the process of figuring out how to do that."

API's technical report 17TR8, expected to be released in early 2015, addresses conditions exceeding 15,000 psi and 350° Fahrenheit.

"It was really written for subsea equipment, but it's already being referenced for surface equipment," says Bunch, who was involved in writing that code and helped Cameron develop its qualification procedures for HPHT equipment.



"Above 250° Fahrenheit, things start going downhill in a hurry."

*Charles Gibbs,
Cameron*

» **BOP system**

The client ordered the 25,000 psi BOP system in late 2010. By the end of 2011, Cameron had completed testing, and the BOP was in the field by the first quarter of 2012.

Providing a BOP system for 25,000 psi did not mean just engineering to the expected 25,000 psi — it meant designing a system that could withstand the proof test, which requires withstanding 1.5 times the internal pressure, or 37,500 psi.

Gibbs says Cameron used existing material specifications for almost all of the BOP system.

“The rams are primarily the same rams as on the 15,000 psi system. We used them on the 20,000 psi system. Our first thought was to see if they’d work on a 25,000 psi system. So we used the 15,000 psi rams as our base point, and we started building out from that,” Gibbs says.

Gibbs gives the nod to the team that designed the ram for the 15,000 psi BOP, saying they made the piece strong enough to take extra loads.

“Our predecessors left a little in the bank,” Steve Shimonek, engineering supervisor, says. “Because they had the forethought to make it a little bit stronger than it really needed to be, we were able to take it further. But I don’t know how much further we’ll be able to take it from there. There will be another customer down the road who says, ‘Oh we’ve got to have more than 25. We need 30, at least.’ To start a clean-sheet-of-paper ram development [programme] would be several years, to do it right, the way this one was done, so it could go into the future.”

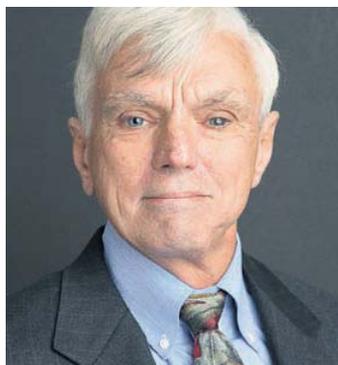
Cameron is examining how temperature affects the materials it uses in its equipment. Most of the materials in conventional use are limited to 250° Fahrenheit.

“Above 250° Fahrenheit, things start going downhill in a hurry,” Gibbs says.

API guidelines drop the allowable yield stress from 100% to 85% of the pressure rating



ON DUTY: Cameron's 25,000 psi BOP in the Gulf of Mexico.



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*Paul Bunch,
Cameron*

when the temperature reaches 350° Fahrenheit.

“We’re used to having everything we can work with in a certain dimension, and if everything fits in that, it fits on the rig,” Gibbs says. “When we increase the pressure rating, we increase the size. But when we increase the temperature, we have to go even further than that, to make up for the 85% requirement.

“There’s only so far that you can extend things. You can only make things so large before they start crumbling. A lot of these things have been the same



“We had to come up with different ways to get a lot more force than we were used to.”

*Steve Shimonek,
Cameron*



PRESSURE ON: A technician connects hydraulic hoses to Cameron's 25,000 psi DR-20 drilling chokes.

for 150 years. The connections are just larger, and larger bolts or studs hold them together. They’re getting so large that they’re not staying together. We’re at the point where we have to make major changes to how we do things,” he says. “Everything had to be beefed up. So we had to design our own end connection.”

The result for the 25,000 psi BOP was significantly larger flanges, which were 15 inches thick rather than the 8.06 inch-thick flanges Cameron uses on its 15,000 psi BOP.

“Any HPHT stuff, because of

the loads involved, you have to have so much metal in these things that it’s just massive,” Gibbs says.

The raw form for the main BOP body itself weighed in at 70,000 pounds, making it one of the largest pieces of equipment ever machined at the Cameron facility in Beziers, France.

“During manufacturing, the equipment they were making was very close to the limits of the machines they were making these things on,” Shimonek says.

Cameron is working to develop a method that avoids the use of flanges to connect the pieces of the BOP.

“We don’t have a solution, but we’ll get there,” Gibbs says.

Drill pipe for high-pressure reservoirs is thicker, with a larger diameter, and often made of higher-grade material. The BOP must be able to cut that pipe, and the force needed increases in response to both the pipe but also the reservoir pressure itself.

“That’s one of the biggest challenges,” Gibbs says.

One deep but small well required heavy wall pipe with higher yield strength “than any pipe we’d ever seen before”, Shimonek recalls. Typical yield strength is 105,000 psi yield, while the heavy wall pipe in question had 160,000 psi yield. The ram operators had to become very large.

Cameron increased the standard operating pressure from 3000 psi to 5000 psi. This change helped obtain the needed force. However, this higher force required some of the other components of the BOP to be redesigned to carry the higher loads. The trick then became balancing out the required shear force with the ultimate capacity of every component in the BOP.

Increasing the operating cylinder area, increasing the maximum operating pressure, and using higher strength materials enabled the company to accomplish the required increase in force.

“We had to come up with different ways to get a lot more force than we were used to,” Shimonek says. □