Coiled tubing technical advances cut operational costs sharply

COILED TUBING'S FIRST practical application was in 1944 during World War II when it served as a fuel pipeline for Allied troops during the European invasion. The oil and gas industry did not consider coiled tubing use until the mid 60s but oil and gas applications did not really gain popularity until the early 1990s.

Since then, its use as a drilling and intervention tool has gained acceptance in the industry, mainly as the equipment's reliability improved, primarily the coiled tubing itself and downhole motors.

The industry reached a certain point with coiled tubing and then the market flattened, relegated to niche players. One niche market was Alaska, where operators decided that re-entry drilling was going to be the next step after fracturing to improve production.

"Production dropped and fracturing was their Godsend for a while," said **Ken Newman**, President of **CTES** and one of the founders of ICoTA (International Coiled Tubing Association).

coiled tubing units that can drill, case and complete wells in 1-2 days with rigs that are capable of running jointed drill pipe as well as coiled tubing equipment.

Additionally, since natural gas prices have risen so dramatically in recent years, coalbed methane drilling with coiled tubing equipment has become very popular, particularly in southern Alberta and parts of the US.

As a result of this "boom" in shallow gas wells and coalbed methane drilling, a large percentage of coiled tubing is being utilized in Canada.

"There are approximately 1,100 coiled tubing units in the world," Mr Newman explained, "but only 200 or so in Canada.

"However, 25% of the coiled tubing is going to Canada," he continued. "It's an incredible movement there due to coalbed methane."

OVERCOMING DISADVANTAGES

While use of coiled tubing holds some unique advantages over drilling with jointed drill pipe in certain operations such as underbalanced drilling and fracturing operations, there are a few drawbacks to the technology. However, these disadvantages can be overcome when drilling in the right environment. First, coiled tubing cannot rotate so it is not a good option if there is a risk of differential sticking. Second, the tubing is prone to fatigue. As a result, according to Mr Newman, a coiled tubing operator will have to replace tubing more often than replacing jointed pipe. Third, because the coiled tubing string cannot rotate, a drilling motor must be used. Motors were highly unreliable in the early 90s, however, one thing that has helped the industry is that motor technology has improved dramatically during the past 10 years.

Ensign Resource Service Group's ADR-1000-CT rigs can drill with both jointed drill pipe and coiled tubing. The rigs can drill and case the surface hole with jointed pipe and then drill to TD with coiled tubing. The company ordered ten such units that will be delivered this summer, all of which are earmarked for the Canadian shallow well drilling market.

"In the mid-to-late 90s," Mr Newman continued, "operators began drilling new wellbores, opening new pay by re-entry drilling into existing wells and putting in 2,000-3,000 ft long open hole completions typically with coiled tubing."

In southern Alberta, Canada, operators are drilling 2,000 ft deep gas wells with

CT DRILLING RIG

Drilling with coiled tubing has been an available option for contractors and operators for many years. In 2004, **Ensign Resource Service Group** announced the construction of 10 state-of-the-art automated drilling rigs, ADR-1000-CT coiled tubing drilling rigs, utilizing the company's patented coil over table design coupled with the company's ADR technology. The rigs are targeted toward drilling shallow natural gas and coalbed methane wells. The rig design is unique in that it has the ability to drill with larger 3 ½-in. coiled tubing as well as with conventional jointed drill pipe. Utilizing cross-trained crews able to drive tractor units, the rigs are efficient and safe self-moving units.

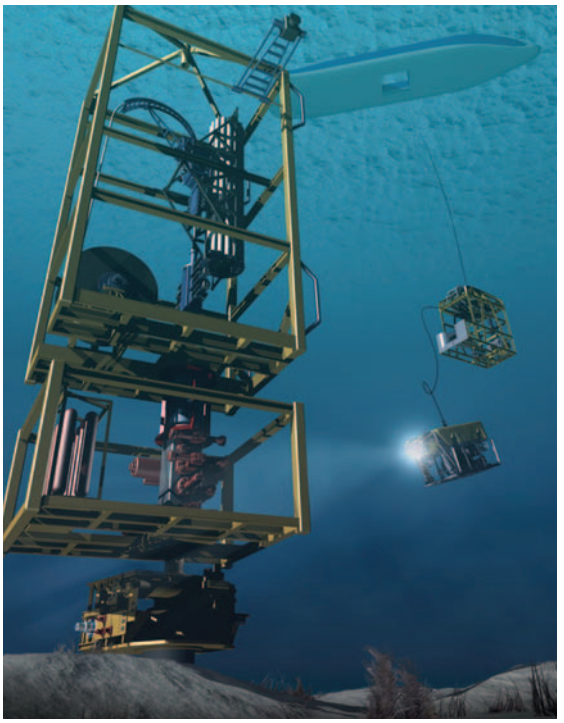
By installing the coiled tubing unit over the table, Ensign bends the tubing only once on and once off the table, or twice per cycle. This compares with conventional coiled tubing operations where the tubing reel is at the end of the catwalk with a gooseneck into the mast.

"That typical arrangement is quite old style," said **Robert H Geddes**, President of Canadian Operations for Ensign Energy Services. "When you do that you bend the pipe six times every cycle."

With coil over table technology, Ensign can utilize 3 ½-in. coiled tubing versus 2 ⅞-in. tubing, enabling the company to put more drill collars on bottom due to higher strength larger diameter tubing, which allows drilling a straighter hole.

"We typically drill ½-1° variation on our holes," Mr Geddes noted.

The company has several patents on the coil over table method. When drilling with coiled tubing, the contractor backs in a trailer with the reel that has a built-in injector and it cantilevers above the table. The mast is laid down, the coiled tubing is connected and controlled by the driller. When he reaches TD, the automatic slips are set, the reel structure cantilevers back down via hydraulics and



The Subsea Intervention Module (SIM) sits atop the wellhead on the seafloor. SIM is anticipated to reduce intervention costs by up to 50%, perhaps more, and is expected to lead to improved production rates and accelerated reserve recovery.

the mast is raised. The entire process takes about 15 minutes, according to the company.

The rig design does not use drawworks, which made the design easily adaptable to a coiled tubing operation. The ADR drill string is worked utilizing a floating crown top drive assembly coupled to two hydraulic ram cylinders.

The built-in top drive is capable of 20,000 ft/lbs of torque, and provides the usual advantages of a top drive unit such as back reaming, well control, finite rotational control for directional drilling and running casing. No power tongs are required.

COST SAVINGS

Typically before Ensign's rigs were developed an operator would batch drill wells, set surface casing and then follow that up with a coiled tubing unit. With the ADR-1000-CT rig, Ensign can drill a 700 m well in a day, and sometimes drill two wells per day. Time-wise, that is about the same as if surface casing was set and then a coiled tubing unit moved in. Where some of the savings is gained is that Ensign's unit can drill the surface hole, set casing and then drill the well with coiled tubing from the same rig rather than using two separate rigs.

Additional savings results from the rigs being 2-3 times safer than conventional rigs, according to Mr Geddes, because the pipe is untouched by the crew whether drilling with jointed pipe or with coiled tubing. Drillers are housed in climate-controlled cabins and operate automated pipe handling arms, make up and break out machines and auto slips without touching the pipe and without being exposed to typical drill floor hazards.

Savings also result because Ensign is able to move on and off location quicker than conventional rigs, resulting in about a 10% savings compared to a conventional rig. The ADR-1000-CT is self-moving and is completely wheel-mounted with dedicated tractor units.

Time is also saved due to the self-leveling capability of the rig. Additionally, the unit's small footprint enables the unit to fit into locations half the size of a typical double rig.

NEW UNITS DELIVERED

The 10 ADR-1000-CT units announced late last year are scheduled for delivery by mid-summer 2005. All are earmarked for Canadian drilling operations although there has been some interest from operators internationally. "A couple of major operators in the US are quite excited about the flexibility of the unit," Mr Geddes said.

Ensign is in negotiations with several major operators that may result in additional units being built. The company has already built an ADR unit to work for Shell in Gabon, although that particular rig does not utilize a coiled tubing unit.

However, part of the flexibility is that any of the ADR units built by Ensign can accept a coiled tubing unit, meaning a purpose-built coiled tubing rig is not necessary.

SUBSEA INTERVENTION

ExxonMobil introduced a subsea well intervention method that utilizes a coiled tubing rig that sits atop the wellhead on the seafloor and is latched onto the subsea well via a remotely operated vehicle (ROV). The Subsea Intervention Module (SIM) is expected to reduce operation costs by up to 50% and possibly more. The anticipated lower operational cost is expected to lead to improved production rates and accelerated reserve recovery.

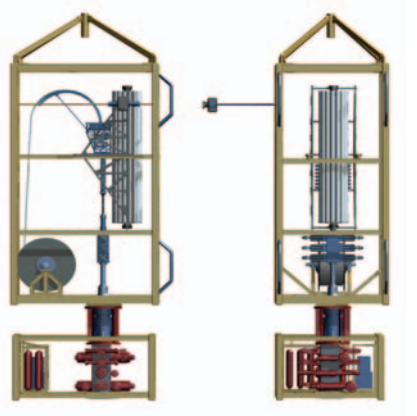
While the SIM could potentially be used for drilling operations, that aspect of the method is not the primary aim. "If it was to be used for drilling," said **Alex Crabtree, BJ Services'** Product Line Technology Manager for Coiled Tubing, "it would more likely be used for drilling a new sidetrack."

ExxonMobil holds the patent to the SIM, which has been under development for several years. The SIM support vessel is a 372 ft long monohull vessel with double skin and features a large working moonpool and dynamic positioning. The vessel carries supplies and equipment for a 30-day period for multiple well interventions. Workshops are fitted for servicing the SIM coiled tubing unit as well as the BOP and bottom hole assembly tools.

The SIM tool comprises a remotely operated subsea coiled tubing unit and an accompanying BOP module. The system can operate in water depths to around 6,500 ft.

Fluids are delivered through a concentric coiled tubing pump down line. Control signals are conveyed via an ROV umbilical and flying J-box. Pumps aboard the vessel provide pressure for well stimulation fluids and nitrogen. Additionally the SIM system will also be capable of electric-line logging.

To commercialize the SIM technology, ExxonMobil licensed the technology to a



The SIM module includes a bottom hole assembly carousel tool rack that contains different BHAs for a particular job. The BHAs are selected from the tool rack, latched to the end of the coiled tubing and then run into the wellbore.

joint venture (**SIM Ventures Ltd**) comprised of BJ Services and **Otto Candies**. The joint venture will operate the SIM following design and construction of the vessel and module, expected to occur in 2008.

While the first operation of the SIM will be offshore Angola in approximately 6,000-7,000 ft of water for ExxonMobil, the system will be available to the industry. The technology can be used for intervention on any subsea well constructed with 36-in. structural casing and completed with a horizontal tree.

SIM CONCEPT

The idea originated with **Mobil Oil**, which had the idea of taking the injector portion of a coiled tubing unit and running that down to the subsea wellhead and inside an atmospheric chamber. Then the coiled tubing would be run from the surface vessel through the subsea injector and into the well. ExxonMobil revisited the concept in 2002 and put together the idea of sending the complete coiled tubing package subsea. The original concept was to deal with subsea wellheads that were in a few hundred feet of water. With the current iteration of SIM technology, wellheads in around 6,500 ft of water can be targeted.

"There is no real practical limit to the concept in terms of going to 10,000 ft," Mr Crabtree said. "Beyond that there are other issues that begin creeping in.

"Technically, it is not a big issue in terms of the components but it becomes more difficult in terms of size (of equipment)."

The SIM module is run to the subsea wellhead on a large winch, and then is latched to the wellhead. A second smaller coiled tubing unit is on the vessel and it runs down a concentric coiled tubing string, resulting in two flow paths. The ROV plugs the second umbilical into the SIM module.

Two heavy duty ROV spreads will be contained on the vessel. They will be utilized primarily to help land and lock down the SIM module onto the wellhead and then to make the pump down line connection and other control circuit connections to the module.

The coiled tubing that is run downhole is from the coiled tubing unit on the SIM module latched to the wellhead. The power and fluid is pumped from the coiled tubing umbilical from the surface to the module via the pump down line.

BJ Services was approached by ExxonMobil, according to Mr Crabtree, because one aspect of the module includes a bottom hole assembly (BHA) carousel tool rack that contains different BHAs. For a particular job, perhaps 12 different tool strings may be necessary, so rather than bring the SIM back to the surface to change the BHA, it is changed remotely subsea. The particular tool, or BHA, is selected from the tool rack, latched to the end of the coiled tubing and then run into the wellbore.

The connection and latching methodology was developed by BJ Services as part of its coiled tubing BHA. "We had a hands free latching methodology and hold patents on that," Mr Crabtree explained.

All of the systems that command and control the ROVs, the SIM module, the pump down line, pumping equipment, vessel positioning, etc, will be fully integrated. For example, when landing the module, not only will the system operators control the module but also the ROV to latch and lock the module, and control the location of the vessel at the surface during these operations. Integrating those operations make it possible for only 1-2 people to perform those operations, Mr Crabtree explained.

TESTING, COMMERCIALIZATION

The concept was tested for several months in Canada inside a tank filled with artificial seawater. An injector head was submerged in the tank over a wellhead. The injector was running under load in the submerged environment as part of numerous studies regarding the marinization of standard coiled tubing equipment.

Another test investigated the reliability of the system and examined a couple of alternative ideas and designs that will be compared and assessed. The next phase of testing will move into the detailed aspect including additional field testing of the system's components.

The tests concluded that there wasn't a massive change required to the injector system, according to Mr Crabtree. There are some components within the injector system itself that may require some changes, for example, utilizing stainless steel or a high nickel or other type of alloy.

The SIM concept is moving toward detail design presently, as well as commercial assessment in terms of the potential market. In the future, there may be one or two additional vessels, depending upon the commercial success of the first unit. Plans call for the first unit to be deployed in 2008.

DEEPREACH CT SERVICE

Halliburton says its DeepReach coiled tubing service can extend downhole reach up to 30% compared with conventional tapered coiled tubing strings. The service utilizes multiple outside diameter coiled tubing sections in a single string with larger OD sections near the top and smaller OD sections near the bottom of the string.

This arrangement reduces tension along the string length while sufficient flow capacity is retained for performing well interventions.

The key component of DeepReach is the transition joint, which is designed for specific tubing sizes. Each end of the transition joint has a section of conventionally configured tubing with a transition section in the middle. The transition section is engineered and manufactured to minimize stress risers and the shape and length of the joints vary for different tubing sizes.

The service uses twin carriage coiled tubing injectors with the company's patented V-Block gripper blocks to enable handling the full weight and speed capacities through the changing OD of the tubing and transition joints. These injectors are available with maximum pull capacities up to 135,000 lbs.

With DeepReach, the weight of the coiled tubing is reduced, enabling the string to reach greater depths compared with conventional coiled tubing. The vertical capability of conventional coiled tubing is limited because the weight of the tubing string increases due to the length of the tubing string in the well. The capability of a conventional coiled tubing string for ultra-deep work depends primarily on the string's total hanging weight and the yield strength of the parent metal, according to the company.

If the hanging weight exceeds the pipe's yield strength, a string separation can occur.

A tapered coiled tubing string is lighter in weight compared with a single string of the same length with the largest diameter. This design provides greater strength at the upper end of the string. As a result, operators can realize up to a 30% increase in depth capability over

conventional coiled tubing strings, according to Halliburton.

In addition to the increased depth capability, the tapered string provides advantages in long horizontal wells, said **Perry Courville**, Halliburton's Product Manager for Coiled Tubing and Hydraulic Workover.

ENABLING TECHNOLOGIES

Numerous technologies were developed to enable DeepReach for deep well operations. These include the transition joints; Halliburton's patented V-Block gripper design; special injector head modifications to the company's patented twin carriage design; variable diameter well control equipment; and adaptation of the simulation program to model and design operations using the tapered OD coiled tubing.

Several field trials have been conducted and more are scheduled this year on the company's path to commercialize the service by year end, according to Mr Courville.

"We expect to be commercial toward the end of this year with limited offerings," he said.

The system was developed as a joint project between **BP** and Halliburton. **Quality Tubing**, **Texas Oil Tools** and **CTES** were also involved in the system's development.

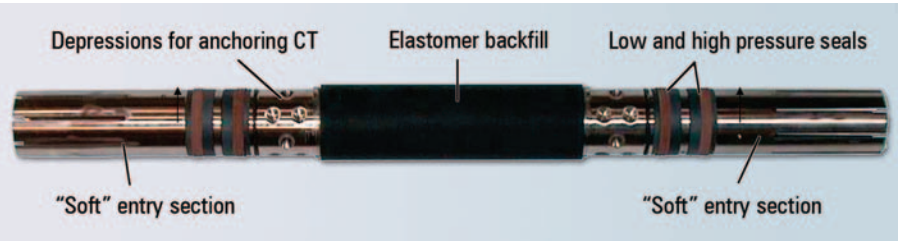
COILED TUBING DRILLING

While the service is intended primarily for intervention operations, it could be used for drilling purposes, according to Mr Courville. He noted that the company doesn't perform a lot of coiled tubing drilling although it is a significant market. He noted that the coiled tubing drilling market doesn't offer enough of a market for a lot of players. Diluting the market with another player, namely Halliburton, is all that would be accomplished should the company enter the coiled tubing drilling business.

DURALINK CONNECTIONS

One problem with utilizing coiled tubing in offshore operations is the weight of the tubing and the reel it is on. In many cases, a rig's or platform's cranes aren't large enough to lift a reel that contains the required length of coiled tubing for a particular applications.

This situation has been resolved by spooling the necessary length of tubing onto two reels and then butt-welding the ends of the tubing together to make one continuous coiled tubing length. However, this method reduces the life of the tubing string.



The Duralink spoolable coiled tubing connector eliminates butt welds and makes connecting coiled tubing strings easier, faster and more reliable than butt welds. The connector is installed with a jig, and no highly skilled expensive welder is required. The connector also eliminates the need for x-rays and other expensive inspections as well as the extra personnel to conduct the inspections.

More importantly, a highly skilled welder is required to make a quality butt weld. Additionally, x-rays are typically taken of the weld so extra equipment is required as well as the personnel to make the inspection. The cost can get very high very quickly.

BJ Services developed its Duralink spoolable coiled tubing connector that eliminates butt welds and makes connecting coiled tubing strings easier and more reliable.

In some cases, according to Mr Crabtree, three spools of tubing were connected using two Duralink connectors. The connections can be installed and monitored by the coiled tubing crew.

To make the connection, the two ends of the coiled tubing strings are drawn into a jig, they are slid into each end of the connector and the connector is crimped to the coiled tubing.

"Each connector is made specifically for the OD and wall thickness and grade of the coiled tubing," Mr Crabtree explained. "Each grade of coiled tubing will bend slightly different, which is why we have been commercializing them on a step-by-step basis."

The most immediate need was the 2 ⅞-in. connector, so that size was addressed first. The company is working on introducing a 1 ¾-in. connector.

Advantages of the connector include superior fatigue life compared with a butt weld, torque, pressure and pull is consistent with coiled tubing and the connector can maintain internal and external pressure integrity during operation.

To date, 10 jobs with Duralink have been completed, all successfully with no connectors having to be replaced during the jobs. Eight of the jobs were previously not considered feasible for coiled tubing.

The connector pressure was tested offshore to 8,500 psi with pumping performed at 16 barrels per minute with 10% HCL at 6,800 psi. A 4 ¾-in. drilling motor with high torque output has been used on the coiled tubing.

The connector service so far has been fully implemented offshore Norway and is available for 2 ⅜-in. and 2 ⅞-in. coiled tubing. Development is ongoing for additional sizes. ■