New developments in coiled tubing equipment

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Introduction

Those who have been riding the coiled tubing (CT) wave for several years often wonder when the growth will slow to more moderate levels. Instead of slowing, the wave seems to be gaining momentum with the addition of new major services such as CT drilling (open hole) and coiled completions. An October 89 article was entitled "The Coiled Tubing Revolution" because CT units were beginning to replace workover rigs and snubbing units for many services. When CT units start replacing drilling rigs this revolution will become an all out war!

Even with the price of oil approaching a five year low, CT activity continues to be strong, even to the point of reaching record highs in some areas. This disparity is an indication of the increasing acceptance of CT as an economical workover method. Although much of the CT excitement is currently focused on CT drilling, CT completions, and CT flowlines, these new services are currently an insignificant portion of the total CT service business. Approximately 75% of the current CT business is split fairly evenly between three conventional services: nitrogen kickoffs, acidizing and cleanouts. The remaining 25% is split between several more recent services including: cementing, fishing, sliding sleeves, logging and cased hole drilling to remove scale, cement, etc.

CT (usually 2" diameter) is being used to drill new slim holes as large as 6 1/8" in diameter and to drill re-entry drain holes to stimulate existing wells. There is significant discussion about completing these wells with a coiled casing/tubing. 3.50" diameter CT is now being manufactured and 4.50" diameter CT is currently being discussed. These large sizes are viable options for replacing conventional jointed tubing completions and flowlines. A few 3.5" completions have been run in Alaska and 3.5" flowlines have been laid in the Gulf of Mexico.

Obviously new equipment is needed to handle these larger CT sizes and innovative services. Increased service complexity increases the demands on the

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equipment in terms of job monitoring and improved CTU control. CT equipment manufacturers such as Drexel are working to develop this new equipment. Since these new services are still somewhat experimental, the new equipment needed isn't clearly defined. This will lead to some "false starts" with some ideas being tried and then dropped. The equipment manufacturers must work closely with the CT service companies and the oil companies to try to make sure that the correct equipment is developed the first time.

This article summarizes several such pieces of equipment that Drexel is developing, based on discussions with various companies, and on its vision of the future in the CT business.

CT Units

Obviously larger CT sizes require larger reels. In conventional CT applications all of the CT required for a job is transported on a single reel. In some cases involving large CT sizes multiple reels are needed, requiring CT connections to be made on sight.

The core diameter of a reel must be large enough to avoid significant ovaling of the CT when it is bent on and off the reel. Usually core diameters 44 to 48 times the CT diameter are used for CT which will be reeled repeatedly. Multiples as low as 37 have been used for shipping and storage reels. When a specialized recessed drum reel trailer is built, a 146" outer diameter reel can be accommodated and still meet the U.S. road restrictions. Weight restrictions limit the weight of the CT which can be carried to about 35,500 lbs. Table 1 gives the typical lengths of CT that can be carried on this type of reel trailer. In remote locations such as Alaska and offshore, larger reels can be accommodated.

Size and weight are not the only considerations when designing a reel for larger CT diameters. The force required to bend the CT increases exponentially with the CT diameter. For example, the force required to bend 3.5" CT is nearly 10 times the force required to bend 2" CT. This increased force requirement increases the torque the reel must provide to spool the CT, increases the power required to run the reel and increases the size of the levelwind mechanism. Thus a reel designed for 2" CT cannot be easily adapted to run 3.5" CT.

The typical CT unit in the field today has an injector capable of pulling CT with 40,000 lbs of force and handling CT up to 1.5" or 1.75" in diameter. Injectors have been developed which are capable of pulling up to 120,000 lbs and running up to 3.5" CT. When applying these large loads to the CT, care must be taken not to mark and damage the CT. Some of these injectors have replaceable inserts in the chains which allow them to be quickly changed from one CT size to another. Drexel - Hydra Rig uses quarter segment inserts backed by a rubber liner allowing the insert to have some flexibility when forced against the CT. This flexibility significantly reduces the damage done to the CT.

As the complexity of CT services increases the demand on the data acquisition, job monitoring and CTU control system also increases. Drexel - CTES (Coiled Tubing Engineering Services) is working with Martin Decker Totco to develop the CT-MAC (Monitoring and Assisted Control) system to meet this need. Based on the proven MD TOTCO SMART Drilling System, this system monitors many incoming data channels and assists the operator in controlling the unit. The attached brochure describes the CT-MAC in more detail.

Along with the increased requirements for the reel and injector, the

rest of the CT unit seems to be growing also. As job complexity increases the control cabin size must increase to hold more control systems and personnel. The power pack must be larger to supply the additional power requirements for the injector and reel. All of this larger equipment is now available and in use in several parts of the world.

Specialized CT Drilling Equipment

The oil and gas industry to date has used jointed tubulars for drill strings, casing and completions. CT drilling applications often require the ability to work with both continuous (CT) and jointed pipe. In some recent cases a workover rig has been used to pull the existing completion, then CT drilling has been used to drill new open hole in the reservoir. Once the open hole is complete a workover rig is again used to run the completion. There are obvious inefficiencies with this method due to mobilizing and demobilizing several times.

Drexel - Hydra Rig and Dowell have worked together to develop a drilling substructure that will allow both CT operations and jointed pipe operations. At the time of this writing the resulting substructure (shown in figure 1) is being shop tested before going to field testing. It contains a set of casing jacks inside the substructure. These jacks have an 11 ft stroke and are capable of pulling 150,000 lbs. The injector head sits on top of the substructure and can easily be moved on and off the well. With this substructure and a CT unit, it should be possible to switch from a jointed pipe operation to a CT operation in a matter of minutes.

Since it isn't possible to rotate the CT (some have considered driving the CT unit around the wellhead!), CT drilling must be done with downhole motors. Conventional Moyno type positive displacement mud motors are being used successfully. However, the cost of these motors is high. For some CT drilling jobs the cost of the motors has been more than 25% of the total job cost. Moyno type motors are limited in temperature capability and they don't perform well when run on nitrogen or foam. (Nitrogen or foam are often needed instead of mud for underbalanced drilling). Drexel and GriFco have formed a joint venture in which motor technology is being addressed. Improvements and cost reductions are being made on Moyno type motors. Other vane type motors are being tested for use with nitrogen and/or foam drilling. These motors will also work at higher temperatures. Brochures with technical information on both of these types of motors is included.

Drexel is working with Nowsco to develop a single skid mud system for CT drilling (figure 2). A shaker, centrifuge, degasser, mixing system and mud tanks are combined on a single skid. This type of integrated system reduces mobilization costs, rig up time and the location size.

Well Control

One of the most exciting advantages of CT drilling is that it can be used to drill underbalanced safely. Underbalanced drilling increases the rate of penetration (ROP) and decreases the formation damage due to drilling fluids. Underbalanced drilling increases the demands on the well control equipment.

The BOP and Stripper/Packer (stuffing box) are the principal components of the CT well control stack. Drexel - Texas Oil Tools (TOT) has developed a multi-functional, workover BOP capable of operating with jointed pipe and CT (figure 3). This new generation BOP offers several unique features not offered on "conventional"

workover BOP's. These features include sealing rams for both pipe and CT, variable bore rams for multiple sizes of pipe, shear/blind rams for all sizes of CT and ram cavity side doors for quick and easy ram change.

The advent of the larger sizes of CT has prompted the development of larger stripper/packers which, in turn, has added to the overall height of the rig up. Drexel - TOT has now developed a "Radial Stripper" (figure 4) system that will accept the full range of CT sizes while keeping the overall height to a minimum. The Radial Stripper design incorporates an opposing actuator system, similar to that of a BOP, to energize the packer components. Horizontally positioning the actuators outside the body allows for a compact design and permits the actuators to rotate 90 degrees to expose the packer elements for easy replacement. The packer elements are economical replacements and incorporate the unique "interlock" feature for extended life and even wear. Due to the ease in the removal of the packer and bushings through the open portal, these components may be changed with tubing in the well, or expose the full vertical bore to allow passage of tool strings through the stripper.

The bottom hole assembly (BHA) in many CT operations is 30 to 70 feet long. In a drilling operation this BHA may include drill collars, a steering or MWD tool, a directional control tool, a downhole motor and a bit. Deploying this long BHA into the well safely while maintaining well control when the well is underbalanced is a challenge. Drexel - TOT and Nowsco are working together on a safe deployment system to solve this problem. The attached brochure on the SAFECONN Deployment System contains a schematic showing how this system works. A quick connect tool is run above the BHA. A wireline is used to lower the BHA from a lubricator into the wellhead in the same way logging tools would typically be run. An additional two BOP like rams are used to land and then release the quick connect. A master ram above the BHA is closed, closing in the well. The injector head is then rigged up on the well. The valve is opened and the CT is stabbed into the quick connect. The deployment rams are withdrawn and the BHA is ready to be run into the well. This deployment method allows the BHA to be deployed into the well safely against wellhead pressure.

Future Developments

With all of the new products being developed today the immediate future will be interesting! Many questions still need to be answered regarding the economics of CT drilling, completions and flowlines. Some questions have already been answered for specific geographical areas and niche markets. It is clear that these services are economically viable in some niche markets. However the global impact that these services will have on the oil and gas industry is still not clear.

Both drilling and production platforms with huge multi-section reels built into the platforms are being considered. These platforms would be designed to work primarily with continuous pipe, using joint pipe only in exceptional circumstances. This concept provides a completely new way of looking at our industry with possible improvements in the environmental impact, safety and economics of most operations.

The only thing certain about the future of the CT business is that it will be exciting!

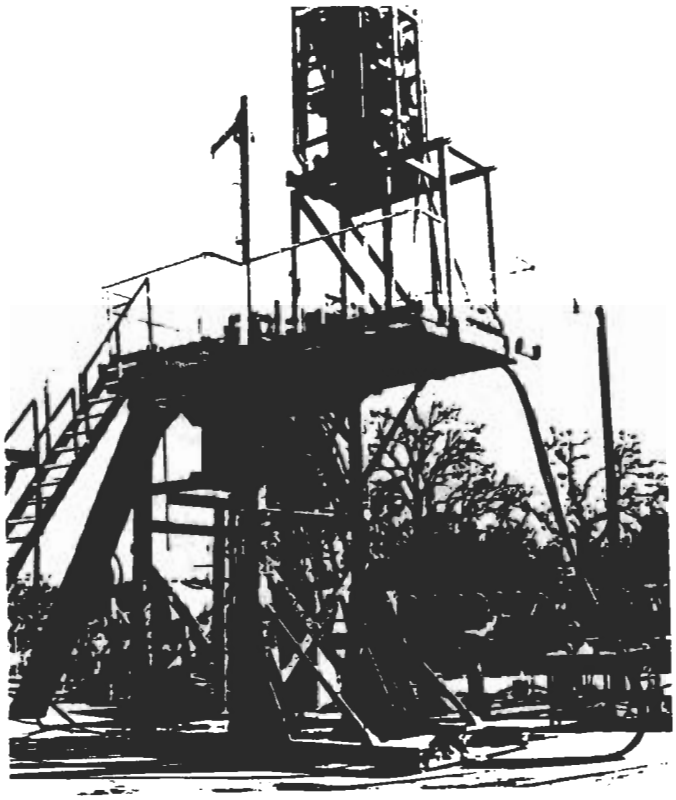

Fig. 1 Drilling Substructure for both Joint and Continuous Pipe

Fig. 2 CT Drilling Fluids Skid

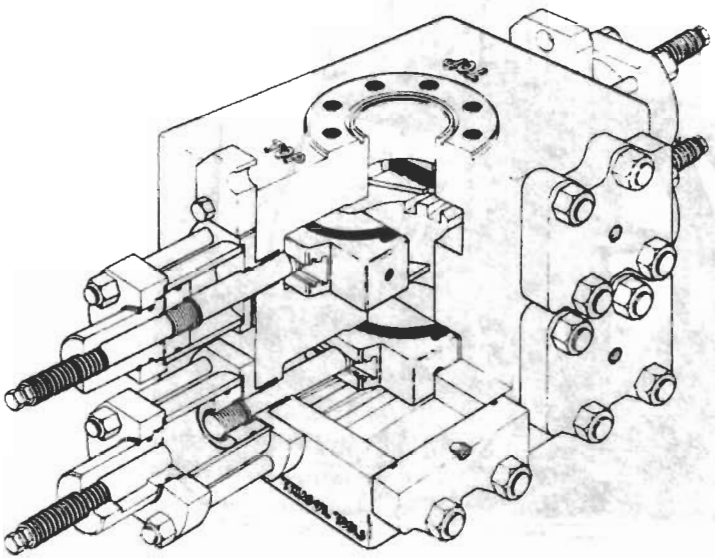

Fig. 3 CT/Workover BOP

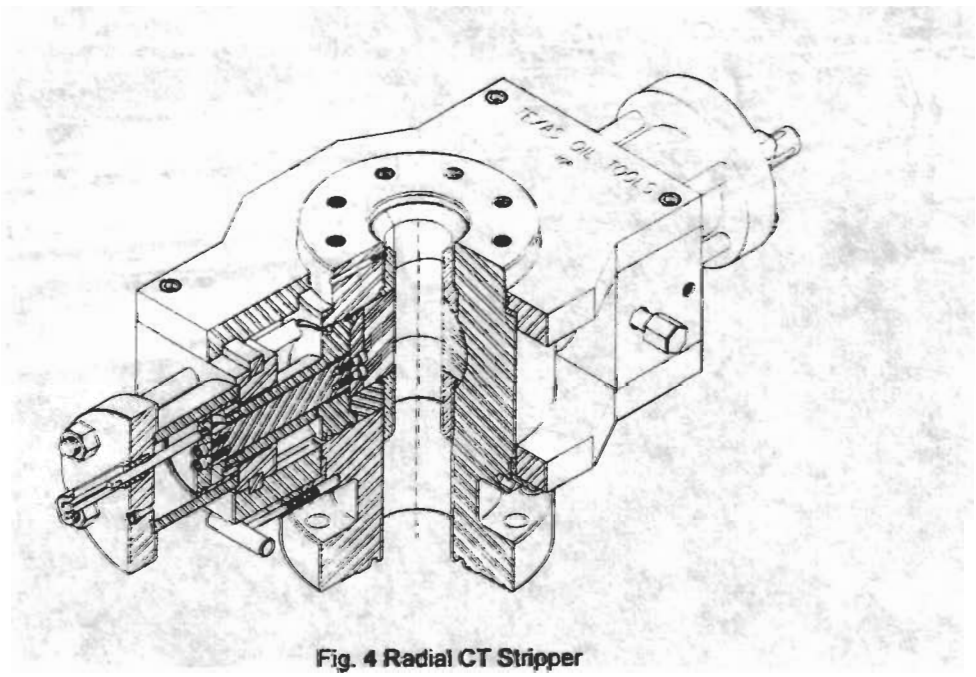

Fig. 4 Radial CT Stripper

Table 1
Maximum CT Lengths for a Reel Trailer
Meeting U.S. Road Restrictions

CT Diameter (in)	Nominal Wall (in)	Core Diameter (in)	Length Capacity (ft)	Length by Weight (ft)
1.750	0.134	77	22,000	15,100
2.00	0.109	88	15,000	15,850
2.375	0.156	104	8,000	9,444
2.875	0.19	126	2,500	NA
3.50	0.203	130*	1,500	NA

** smaller core than 44 multiple*