

# Where is the Coiled Tubing Wave Headed?

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In the late 1980's, the CT service market began a wave of growth and expansion unparalleled by other oilfield services. In 1989 this market was experiencing such rapid growth that it was referred to it as a "CT Revolution"<sup>1</sup>. This wave of growth has continued through the early 1990's with annual growth rates of between 20% and 30%, while many other oilfield service markets have been stagnant or even shrinking. Those of us working with CT often wonder how much longer this wave will last! With the recent advent of open hole CT drilling (CTD) and CT completions (CTC), the wave is increasing in momentum, with no end in sight!

The idea of being able to run a continuous pipe without stopping every 30 ft to make up a joint has intrigued engineers since a CT pipeline was laid across the English Channel by the allied forces during World War II. The first CT units were built in the late 1950's and early 1960's<sup>2</sup>. The first CTD jobs were performed in Canada in the mid 1970's<sup>3,4</sup>. Why did it take until the late 1980's for CT to really take off?

## What are the forces driving the CT market?

Advances in technology made in the late 80's triggered this wave of CT activity. These advances improved the reliability and effectiveness of CT services. The primary technology advancements that triggered this wave were:

- Improvements in CT pipe manufacturing - Increased lengths of the continuous strips of material that the pipe is made from were first produced in 1983. These longer strip lengths decreased the number of welds in a string of CT. Since welds are the major source of failures in CT pipe, decreasing the number of welds improved the reliability of the pipe. New welding methods were developed, with the most notable being the strip biased welds in place of tube to tube butt welds. These biased strip welds, introduced in 1989, are much more reliable than butt welds.
- Improved methods of predicting pipe life and limits<sup>5,6,7</sup> - The life of CT pipe is governed primarily by the fatigue damage caused when the pipe is bent over the reel and the guide arch. Models were developed to predict the fatigue life of the CT to ensure that the pipe was scrapped before it reached the end of its fatigue life and a failure occurred.
- Larger pipe sizes - Previously 1" and 1.25" CT had been used. In 1985 the first 1.5" CT was developed, and in 1986 the first 1.75" CT was developed. These larger sizes (considered medium sizes today!) greatly increased the capabilities of CT services.
- CT Logging - The technology required to use CT to push conventional electric line logging tools into horizontal wells was developed in the late 80's. Though this type of service was limited by the size of the horizontal well market and by high costs, it was the first step toward real time downhole communications with CT.
- Improvements in CT equipment - Many improvements were made to the CT units and monitoring equipment in the late 80's. The first real time CT pipe monitoring device was developed.

At the same time as these technical advancements were being made, economic and environmental demands on the oil industry increased. CT services were often more economical and environmentally friendly than similar services performed with a rig or snubbing unit. CT training efforts were increased to raise the service level performed. These forces combined to increase the acceptance of CT services by the oil industry which allowed the wave to grow.

### **What are the latest CT Applications?**

The wave of CT activity in the late 80's encouraged further spending on R&D, which continued to bring further advances in technology in the early 90's. These advances have focused more on the development of new CT applications, since much of the reliability issue has been solved. CT pipe sizes up to 3.5" and large CT surface equipment to handle these larger pipe sizes, were developed to support these new applications.

#### *CT Drilling (CTD)*

The most exciting CT application developed recently is CTD. When the "first" CTD attempts were performed in 1991, we weren't aware of the work that had been done in the 1970's<sup>3</sup>. The initial experiment performed in the Paris basin<sup>8</sup> was designed to answer the question, "Can CT be used to drill a straight vertical open hole?", which had been answered many years earlier. Shortly after this experiment the first directional re-entry was drilled in the Austin Chalk<sup>9</sup>. The speed at which CTD technology has moved in the three years since these 1991 "firsts" is amazing. This year, there will be approximately 150 "wells" drilled with CT, including the first successful "wells" offshore. A "well" may be anything from a vertical or directional re-entry drainhole in an existing well, to a new shallow well.

What major advantages does CTD have over conventional drilling techniques?

- Under-balanced Drilling - CT was developed for workover services in live wells. Full pressure control without rotating BOPs allows safer under-balanced drilling, which increases the ROP and decreases formation damage. Several at-balance and under-balanced CTD jobs have already proven these advantages.
- Smaller Equipment - The CTD equipment is much smaller than a conventional rig which allows a smaller location and less expensive mobilization costs.
- No Joints - Eliminating joints from the drill string decreases trip time, improves safety and environmental considerations, eliminates joint washouts, improves the borehole stability, reduces the manpower requirements and allows automation of equipment.

What are the major disadvantages of CTD?

- No Pipe Rotation - Not being able to rotate the pipe makes directional drilling more difficult, increases the possibility of sticking and increases pipe drag.
- Limited Pipe Diameter - Typically 2" or 2 3/8" CT is used for CTD. Larger sizes of CT are available, but the fatigue life is much shorter, making the pipe costs too high. These small diameters can only be used to drill holes less than 8" in diameter.

These advantages make CTD very interesting, but the disadvantages limit the wells in which CTD can be applied. The ideal drilling system would be able to work with both jointed pipe and CT, utilizing the advantages of both drilling techniques. Recently two types of hybrid systems have been built for this purpose. One system built in Europe has a mast like structure for running jointed pipe, as part of a CTD substructure (photo). Other hybrid systems have been built which use snubbing jacks for running jointed pipe, built into the CTD substructure<sup>10</sup> (photo).

The following are the major CTD applications to date:

- Shallow vertical wells - A series of 68 shallow injection wells is currently being drilled in California. At the time of this writing, 32 have been completed. The learning curve has reduced the time required to complete a well from 45 hours to 25 hours! In this case the CTD costs are similar to the costs of drilling the same wells with a rig. Another series of shallow gas vent wells are being drilled from a barge in Venezuela.
- Re-entry wells - CT has been used to mill windows in the casing and drill directional drainholes into the formation. It has also been used to re-enter existing wells and deepen them without directional control. Some of the most exciting areas for this application are areas with large completions, where re-entry drilling can be performed through the existing completion. Current areas interested in this technique are Alaska and the North Sea.

#### *CT Completions (CTC)*

Leaving CT in wells is not new. In fact, it has been done ever since the first CT units were built. However, leaving CT in wells *on purpose* is a more recent development!

Many permanent installations were performed in the late 80's in which 1" through 1.75" CT strings were hung inside the completion to reduce the flow area. This restriction increases the velocity in gas wells, allowing them to unload liquids. Such strings, called velocity strings, were the first intentional permanent CT installations. Recently, plastic tubing has been hung in shallow gas wells in Canada to perform this function.

The advent of the larger CT sizes in the 90's has allowed the development of CTC. Gas lift mandrels have been developed which can be installed inside the CT and will withstand the bending when being spooled. Other completion "jewelry", including production packers and sub surface safety valves, have been modified or developed to work with CT. Some 3.5" completions are being run in Alaska and are being considered in other areas.

The biggest challenge for CTC is the logistics associated with very large heavy reels. For a reel to contain much 3.5" CT, it needs to be 15 ft in diameter or larger. Offshore cranes are often not capable of lifting these huge reels. Solutions to these problems are being developed. Connectors have been developed which allow several reels of CT to be transported to location and then connected together, while deploying the completion in the well. CT is now being spooled from a storage reel on a boat to a work reel on a platform, avoiding the need to lift the entire weight at one time.

Again, hybrid systems which handle both jointed pipe and CT are needed. When an existing jointed completion is being replaced by a CTC, a system is needed for handling both. Hybrid completions will be developed which contain portions of CT and portions of jointed pipe.

## Telemetry

Telemetry systems provide a means of real time communication by which downhole sensor data can be transmitted to surface. Some telemetry systems are bi-directional, allowing commands to be transmitted from surface to downhole tools. These systems are not an application themselves, but rather provide the communication link which makes more complex applications possible. There are currently four types of telemetry systems being used with CT:

### Electric Line Telemetry

As mentioned previously, the first electric line was installed inside CT in the late 80's. CT strings with electric lines installed are still being used to perform CT logging applications. Conventional logging tools are attached to the end of the CT and pushed into horizontal wells, primarily for production logging and perforating applications. These applications typically do not use the ability of the CT to convey fluids because the logging tools were developed to be run on an electric cable.

Recently, purpose-built tools with electrical sensors have been developed which allow a fluid to be conveyed through the tool. These tools are being used to make downhole measurements while well treatments, such as matrix acidizing, are being performed. Other such tools have been developed for directional drilling applications to measure the inclination, azimuth and orientation of the bottom hole assembly (BHA). Some of these tools use the bi-directional communications capability of the electric line to send orientation commands from surface to the BHA. Other tools use mechanical or hydraulic commands for orientation control.

Development projects are underway which will significantly reduce the cost of installing an electric line inside the CT (today each installation costs about \$20,000). Purpose-built cables are being developed for CT applications. These improvements will reduce the costs and improve the reliability of electric line telemetry with CT, which will encourage the development of even more specialized downhole tools.

### Pressure Pulse Telemetry

Systems in which pressure pulses are transmitted up through the drilling fluid have been used for many years to transmit directional drilling and logging data to surface during drilling operations with conventional jointed pipe. These systems are commonly known as MWD, "measurement while drilling". Recently these systems have been adapted to work with CT for CTD applications.

MWD systems have the advantage of not requiring an electric line inside the CT. They have the disadvantage of requiring a liquid drilling fluid. These systems do not work when there is a gas in the drilling fluid such as air or nitrogen. In some CTD applications, a gas is used as, or with the drilling fluid for underbalance or at balance drilling. MWD systems also have the disadvantage of transmitting the data at a slow rate.

### Magnetic Telemetry

Recently telemetry systems have been developed which provide bi-directional communication by transmitting radio waves through the earth. These systems were first developed to transmit data during well testing operations. They are currently being used with CT to transmit data

during well treatments and CTD operations.

Like pressure pulse MWD systems, magnetic telemetry systems have the advantage of not requiring an electric line inside the CT. Magnetic telemetry systems can also work when there is a gas in the drilling fluid. However, radio waves do not transmit well through some types of formations. This limits the areas and depths in which these systems will work. Also the data rates of magnetic telemetry systems are slow due to the long radio waves used.

### Fiber Optic Telemetry

A fiber optic cable inside of CT with a video camera on the end of the CT has been run for the first time very recently. Fiber optic cable allows transmission of data at the very high rates needed for video. This fiber optic telemetry system was developed for use with a conventional wireline logging system. It has now been adapted to operate with CT which provides the advantage of being able to circulate a clear fluid into the area around the camera to increase downhole visibility.

Other types of telemetry systems are being considered for CT. As these various systems improve, the ability to provide advanced CT applications will continue to expand.

### *Flowlines*

CT is being used for flowlines both onshore and offshore. Plastic coatings have been developed which protect the CT from external corrosion. Specialized equipment has been developed for laying these CT flowlines. The costs associated with laying these flowlines are significantly less than the laying costs associated with conventional jointed pipe flowlines. The CT flowline market is certain to grow due to these cost savings.

There is still room for development for CT flowlines. Standards need to be developed for corrosion resistance. Internal coatings are being considered. Purpose-built installation equipment needs to be developed. These developments will continue to occur and fuel this growing market.

### **Future Vision**

The following points summarize the author's vision of the future CT industry:

- The future isn't just CT and it isn't just jointed pipe. The future will involve hybrid systems capable of handling both types of pipe.
- Hybrid drilling and completion systems will be developed for semisubmersibles and drill ships.
- Production platforms will be developed which are centered around CTC with large built-in reels capable of holding these completions. These facilities will be used not only for completions, but in the drilling phase to drill and complete the lower sections of the wells.
- Improvements in CT telemetry systems will enable more advanced applications to be developed in which real time downhole communications are required.
- CT technology will dramatically change the oil and gas industry over the next decade.

## References

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- 5 Smith, Lawrence: "Methods of Determining the Operational Life of Individual Strings of Coiled Tubing," SPE Workovers and Well Intervention Seminar, November 1989, Aberdeen
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- 7 Newman, K. and Newburn, D.: "Coiled Tubing Life Modelling," SPE paper 22820, 66th Annual Technical Conference and Exhibition, Dallas, October 1991
- 8 E. Traonmilin and K. Newman: "Slim Hole Drilling Experiment with Coiled Tubing," Oil & Gas Journal, February 1992
- 9 Ramos, A.B. Jr. *et al.*: "Horizontal Slim-Hole Drilling With Coiled Tubing: An Operator's Experience," JPT (Oct. 1992) 1119.
- 10 Newman, K., Doremus, D.: "Hybrid Coiled Tubing / Snubbing Drilling and Completion System," SPE paper 28300, SPE Annual Technical Conference & Exhibition, New Orleans, September 1994

## Photo's and Figures

Photo from Oilweek August 2/76 page 7, lower left. - shows CTD in 1976

Photo of recent CTD job on land - like the one on page 31 of the June 27 1994 Oil and Gas Journal

Photo of the hybrid snubbing/CT drilling and completion unit - I'll supply

Photo of Nowasco's mast on their CTD sub structure.

## Ken Newman - Publications List

- 1 Ackert, D., Beardsell, M., Corrigan, M., Newman, K.: "The Coiled Tubing Revolution," The Oilfield Review, October 1989, pp. 4-16
- 2 Newman, K., Corrigan, M. and Cheatham, J.: "Safely Exceeding the Critical Buckling Load in Highly Deviated Holes," SPE paper 19229, Offshore Europe, Aberdeen, September 1989.
- 3 Newman, K., Corrigan, M., Hehoe, G., Douglas, A., Torre, A.: "Assisted Lift Production Logging with Coiled Tubing," SPE paper 90142, Eighth Offshore South East Asia Conference, Singapore, December 1990
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- 6 Thomeer, H. and Newman, K.: "Safe Coiled-Tubing Operations," SPE paper 23266, The First International Conference on Healthy, Safety and Environment, The Hague, November 1991
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- 11 Adrichem, W. and Newman, K.: "Validation of Coiled-Tubing Penetration Predictions in Horizontal Wells," SPE paper 24765, 67th Annual Conference and Exhibition, Washington D.C., October 1992
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- 13 Ackers, M., Doremus, D., Newman, K.: "An Early Look at Coiled-Tubing Drilling," Oilfield Review, July 1992, pp. 45-51
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- 20 Newman, K., Doremus, D.: "Hybrid Coiled Tubing / Snubbing Drilling and Completion System," SPE paper 28300, 69th Annual Technical Conference and Exhibition, September 1994
- 21 Newman, K.: "Where is the Coiled Tubing Wave Headed," Petroleum Engineer International, September 1994