DRILLING WITH COILED TUBING IN NORTH AMERICA A CASE STUDY

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ABSTRACT

Drilling with coiled tubing had it's beginnings in the late 1970s, but did not become economical until the mid 1990s. Three distinct areas of operations, each with different technologies evolved in North America. In Alaska, operators have drilled over 500 multi-lateral, highly deviated holes in the existing vertical wells, through the 4 ½-inch tubing. Each year the schedule has accelerated and results are significant in volume and economics. In Alberta Province the use of coiled tubing to drill shallow gas has evolved from a curiosity to a 27% market share. There are currently over 50 "built-for-purpose" coiled tubing rigs in Canada drilling over 5,000 wells/year and they continue to grow. Only recently has the lower 48 states begun to apply technologies proven in Alaska and Canada, drilling new shallow gas wells and re-entry for horizontal laterals. Currently active R&D programs are developing the tools to drill in smaller sizes.

BRIEF HISTORY

The use of coiled tubing for well intervention has been an established and growing commercial activity since the early 1960s. However, early attempts to use the technology for drilling, either "grass roots" vertical wells from surface or directional wells from re-entry, were uneconomical. In the early 1990s reliable downhole motors and improved bits became available and the technology became established and growing. Some of the early projects included:

1976 – Flextube drilled 6 grass roots wells in Alberta to 2,000 feet with coil made from welded sections
1992 – Commercial drilling with coiled tubing begins in Alberta
1994 – Coiled tubing used to drill first well extension in Alaska North Slope
1995 – A three-well and five-well pilot program is drilled in the San Juan basin.
Late 1990s – first "built-for-purpose" rigs are built and put into service in Alberta
2001 – 30 well pilot program drilled in Argentina
2001 – 29 well pilot drilled in the New Mexico San Juan basin
2003 – "Second Generation" rigs with rotary capability begin service in Alberta
2004 – First "built-for-purpose" rig deployed in the shallow Niobara gas play in Kansas and Colorado
2005 – 500th reentry well drilled in the North Slope of Alaska

ADVANTAGES, DISADVANTAGE, LIMITATIONS

Drilling with coiled tubing has a number of advantages over rotary drilling with jointed pipe. They include:

- Works like a snubber, can drill on existing wells without killing the well, or underbalanced, can control up to 10,000 psi surface pressure
- Faster penetration – up to 200 ft/hour sustained (world record 254 meters/hour – convert to ft/hr?)
- Faster trips, with no connections to make
- Unit mobility and faster rig up and rig down times with "built–for-purpose" rigs
- Small footprint relative to standard rotary
- Drills a gauge hole
- Generally requires fewer people to operate than equivalent rotary rigs
- With new hybrid rigs, many applications can be accomplished with one piece of equipment
- More effective in precise positioning of tools in horizontal and vertical wells

The disadvantages include:

- Limited capacity due to size and weight of reel
- Due to fatigue failure, tubing must be replace after 30 to 50 trips
- Difficult to fish

The limitations are:

- Depth is limited by reel size and overall weight (road weight restrictions)

● CT hoisting capacity is limited by the injector that controls the penetration rate and insures that the tubing is in tension, not compression
● Hole size is limited by pump requirements
● Tubing life limits cycling
● Rig dimensions restricted by highway regulations
● Limitation on how far the tools can be pushed (or pulled) horizontally, even with tractors

COILED TUBING DRILLING IN ALASKA

Drilling reservoir extensions with coiled tubing was initiated in Alaska in 1994. Drilling was initially underbalanced to mitigate reservoir damage, and soon after began drilling overbalanced. All the drilling is through existing 4 ½- and 3 ½-inch tubing, so clearance and tolerances are challenging. The unit itself consists of a coiled tubing unit mated with a workover rig. They are quite large, but space and roads are not an issue in the North Slope (See Figure 1). The early sidetracks were single horizontal holes, but the majority today is multiple completions. The number of sidetracks has grown over the last ten years from just a few annually to over 50 per year currently, representing a majority of the overall sidetrack wells drilled on the North Slope.

The basic coiled tubing drilled sidetrack begins with setting a 4 - inch by 7-inch whipstock and squeezed cement to abandon the perforations. Then the coiled tubing is used to mill the window and drill a 3 ¾-inch or 4 1/8-inch directional hole. Then a 3 3/16-inch or 2 7/8-inch liner is cemented and perforated to complete the "bighole" sidetrack. Recently a 2 ¾-slimhole branch off of the "bighole" has been drilled and a 2 3/8-inch liner set. One hundred of the 500 hundred sidetracks drilled have been the smaller slimhole.

The sidetrack program has been very effective and economic in mitigating declining production. Since it began in 1994, it is estimated that 270 million barrels of reserves have been added, producing an incremental 25,000 barrels/day. The wells cost an average of $1.5 million, which equates to $3 to $4 per barrel of incremental oil. They are drilled at an average rate of 400 ft/day, taking about 2 weeks to complete. The record for this type well was set in the Kuparuk Unit, drilled 2,630 feet at a mean depth of 18,350 feet. The overall cost is approximately 30% less than the equivalent rotary sidetrack. This technology has been developed and improved over the last decade and has begun to be used elsewhere in the world, including the lower 48 states.

COILED TUBING DRILLING IN CANADA

Over 90% of the wells drilled from the surface (grassroots) with coiled tubing are drilled in Alberta Province, Canada. In the early 1990s coiled tubing drilling was a curiosity. Today, the 50 or more "built-for-purpose" coiled tubing drilling rigs command a 27% market share of drilling in Alberta. The reasons for the technical and economic success of this industry have come together to form a "perfect storm" for success in the area. They include:

● A suitable basin for drilling with many shallow, dry gas wells in a relatively small geographic area
● Relatively soft predictable formations
● An experienced and innovative work force
● Evolution of state-of–the-art mud motors, drill bits, coiled tubing and other related products
● The speed of drilling and rigging up and down saves the operator both time and money

The first coiled tubing rigs built specifically for drilling were built in the late 1990s. They are mobile and have a mast and draw works for setting casing, but require a workover rig to precede them to drill and set the surface casing. By 2000, 15 of these rigs were working full time. These rigs have penetration rates that routinely top 600 feet/hour and have exceeded 900 ft/hour. They are quickly mobilized and can drill two and up to three shallow wells in a day. In the early 2000s, manufacturers began producing second generation, or "hybrid" trailer style coiled tubing rigs, so called because they have a top drive and drill with rotated pipe, or with coil. This allows a single rig to set the surface casing and drill the well. There are 38 hybrid rigs operating in the area today, with normal working depths to 5,000 feet. (See Figure 2) The number of active rigs and wells drilled with coiled tubing has doubled since 2003 to over 50 rigs and 5,000 wells drilled. This explosive growth has been fueled by the development of the shallow coalbed methane wells in Alberta that are well suited for the "cookie cutter" economics of coiled tubing drilling.

COILED TUBING DRILLING IN THE LOWER 48 STATES

In spite of the success of the coiled tubing drilling industry in Alberta, it has not taken hold in the lower 48 states until very recently. To a large degree, the success of the coiled tubing drilling industry in Alberta is due to the large number of shallow gas locations in a relatively small area, allowing the rigs to move continuously from location to location and long term contracts with operators. Most of the coiled tubing drilling experiments in the lower 48 were single well, or several well pilots, with standard coiled tubing equipment as opposed to rigs built specifically for drilling. As a result, crews were just getting up the learning curve of drilling by the end of the project. Operators in the areas where coiled tubing drilling could compete (an estimated 4,000 to 5,000 wells per year are accessible to coiled tubing drilling) have historically been unwilling to commit the acreage and drilling schedule for a sustained program and the subsequent improved economics.

All of that is beginning to change. In 2005 a domestically owned built-for-purpose coiled tubing drilling rig drilled over 220 wells in the Niobara shallow gas play in Western Kansas and Eastern Oklahoma. Twenty three of these wells were drilled and documented in a DOE co-funded project in their Microhole program. Forty of the wells have been drilled slim/micro hole with 2 7/8-inch production tubing set. The rig is very similar to the Canadian models. It has top drive rotary capability, 5,000 ft. depth capacity, zero discharge mud system, handles coiled tubing sizes of 1-inch through 2 5/8-inch. It is trailer mounted and meets U.S. Dept. of Transportation limitations. It averages 400 ft/hr penetration rates and can drill one 3,000 ft. well/day, including rigging up, down, and moving.

A second project has recently been completed in the Texas Panhandle in a low pressure, mostly depleted gas field in the Cleveland formation at 8,000 feet depth. This 10-well project was conducted to demonstrate the transferability of the sidetrack technology employed in Alaska to mature reservoirs in the lower 48 states. Pre-drill economics were estimated to develop new reserves at an average of $0.98/MCF, with 1.5 BCF reserves per well and initial production of 1.5 million cubic feet/day. Costs were estimated to be 40% less than a grass roots well drilled with rotary equipment. Actual results have not yet been released to the public. The coiled tubing unit, though not built-for-purpose, has drilled a number of horizontal re-entries in Arkansas. Drilling time was six days/well. The contractors and downhole equipment were the same as those utilized in the North Slope. Operationally, a whipstock was set at 7,400 feet and a 3.8-inch window milled in the 5 ½-inch casing. The build section was drilled with a 4 1/8-inch PDC bit and the horizontal section drilled with a 3 ¾-inch bit approximately 1,500 feet laterally. If successful, there will be thousands of similar candidate fields that can be exploited utilizing this technology.

Besides these two projects, one of the large service companies is designing, building and testing a state-of-the-art, built-for-purpose drilling rig under the DOE Microhole program mentioned above. In addition, a number of new rigs are under construction in Canada and several are slated for delivery to the U.S. The DOE Microhole program is also co-funding a number of related projects designed to make coiled tubing drilling faster, cheaper and more environmentally friendly, including high speed motors, bits, smaller bottom hole assemblies for measurement while drilling (MWD) and logging while drilling (LWD) as well as basic research in tubing strength.

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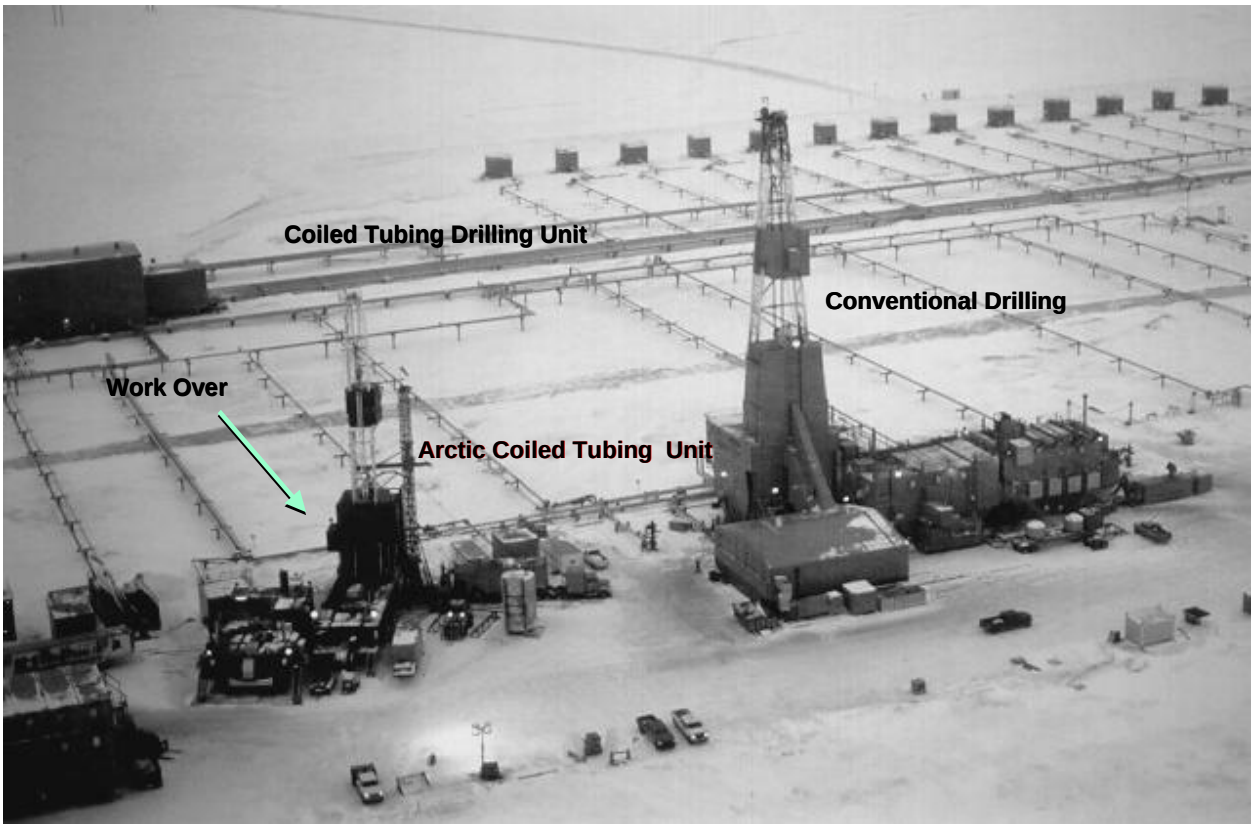

Figure 1 - North Slope CT Drilling Equipment – Courtesy ConocoPhillips

Figure 2 - Canadian CT Drilling Rig – Courtesy Technicoil Corp.

Figure 3 - U.S. CT Drilling Rig – Courtesy GTI