

**MICROHOLE DRILLING TRACTOR  
TECHNOLOGY DEVELOPMENT  
FINAL REPORT**

**DE-PS26-03NT15392-0**

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## **1 PROJECT SUMMARY**

In an effort to increase the U.S. energy reserves and lower costs for finding and retrieving oil, the US Department of Energy created a solicitation to encourage industry to focus on means to operate in small diameter well - Microhole. Partially in response to this solicitation and because Western Well Tool's (WWT) corporate objective to develop small diameter coiled tubing drilling tractor, WWT responded to and was awarded a contract to design, prototype, shop test, and field demonstrate a Microhole Drilling Tractor (MDT). The benefit to the oil industry and the US consumer from the project is that with the MDT's ability to facilitate Coiled Tubing drilled wells to be 1000-3000 feet longer horizontally, US brown fields can be more efficiently exploited resulting in fewer wells, less environmental impact, greater and faster oil recovery, and lower drilling costs.

Shortly after award of the contract, WWT was approached by a major oil company that strongly indicated that the specified size of a tractor of 3.0 inches diameter was inappropriate and that immediate applications for a 3.38-inch diameter tractor would substantially increase the usefulness of the tool to the oil industry. Based on this along with an understanding with the oil company to use the tractor in multiple field applications, WWT applied for and was granted a no-cost change-of-scope contract amendment to design, manufacture, assemble, shop test and field demonstrate a prototype a 3.38 inch diameter MDT.

Utilizing existing WWT tractor technology and conforming to an industry developed specification for the tool, the Microhole Drilling Tractor was designed. Specific features of the MDT that increase its usefulness are 1) Operation on differential pressure of the drilling fluid, 2) On-Off Capability, 3) Patented unique gripping elements 4) High strength and flexibility, 5) Compatibility to existing Coiled Tubing drilling equipment and operations. The ability to power the MDT with drilling fluid results in a highly efficient tool that both delivers high level of force for the pressure available and inherently increases downhole reliability because parts are less subject to contamination. The On-Off feature is essential to drilling to allow the Driller to turn off the tractor and pull back while circulating in cleanout runs that keep the hole clean of drilling debris. The gripping elements have wide contact surfaces to the formation to allow high loads without damage to the formation.

As part of the development materials evaluations were conducted to verify compatibility with anticipated drilling and well bore fluids. Experiments demonstrated that the materials of the tractor are essentially undamaged by exposure to typical drilling fluids used for horizontal coiled tubing drilling.

The design for the MDT was completed, qualified vendors identified, parts procured, received, inspected, and a prototype was assembled. As part of the assembly process, WWT prepared Manufacturing instructions (MI) that detail the assembly process and identify quality assurance inspection points.

Subsequent to assembly, functional tests were performed. Functional tests consisted of placing the MDT on jack stands, connecting a high pressure source to the tractor, and verifying On-Off functions, walking motion, and operation over a range of pressures.

Next, the Shop Demonstration Test was performed. An existing WWT test fixture was modified to accommodate operation of the 3.38 inch diameter MDT. The fixture simulated the tension applied to a tractor while walking (pulling) inside 4.0 inch diameter pipe. The MDT demonstrated 1) On-off function, 2) Pulling forces proportional to available differential pressure up to 4000 lbs, 3) Walking speeds to 1100 ft per hour.

A field Demonstration of the MDT was arranged with a major oil company operating in Alaska. A demonstration well with a Measured Depth of approximately 15,000 ft was selected; however because of problems with the well drilling was stopped before the planned MDT usage. Alternatively, functional and operational tests were run with the MDT inside 4.5 inch tubing at depths of 800-950 ft. The MDT successfully demonstrated On-Off capability, pulled with up to 1465 lbs force, and verified its capability to transmit torque through it from the Orienter. Forces generated by the tractor were limited due to insufficient differential pressure because of the unloaded downhole motor, which is not typical during drilling conditions. Additionally, the Coefficient of Friction between the MDT grippers and the tubing was much less than the anticipated COF of the sandstone formation. Despite these minor limitations, to summarize the MDT operated as expected.

Minor modifications to the MDT are being incorporated to improve gripping capability of the tractor. Additional demonstration wells are being arranged to expand on the project's goals of delivering a fully operational utilitarian tool for use throughout the US to improve reserves.

## **2 BACKGROUND**

Research work performed for U.S. Department of Energy has shown that most of the oil reserves in the US are located in small reservoirs at relatively shallow depth. For conventional drilling with rotary equipment, many of these reservoirs are not financially feasible because the rotary drilling costs are high compared to the return on investment in oil sales from these reservoirs. As a result, these resources are not being exploited and America's dependence on foreign oil grows.

In Canada, the use of Coiled Tubing rather than rotary equipment has resulted in substantial cost reductions and has seen rapid growth of this method in relatively shallow and typically thin reservoirs. Cost reductions are reported in the 30-50% when compared to rotary equipment.

However, in the US coiled tubing drilling has seen little use except in Alaska where the innovative coiled tubing technologies and substantial drilling cost reduction have resulted in its rapid expansion. Currently, over 250 CT wells are drilled in Alaska every year at cost reductions that are as much as 60% less than rotary equipment.

US Department of Energy (DOE) National Energy Technology Laboratory (NETL) in acting on its mission to increase US oil reserves, sought means to stimulate the creation of additional technologies that would bring the economic benefits of coiled tubing drilling to the lower 48 states.

The US Department of Energy asked for proposals to support the Topic Area of Microhole Coiled Tubing Bottom Hole Assembly; Western Well Tool Incorporated (WWT) elected to respond by providing the Microhole Drilling Tractor (MDT) for coiled tubing drilling. The MDT provides the significant benefit to allow greater measure depth horizontal wells, which are known to more rapidly exploit thin reservoirs than vertical wells. The MDT project's objectives were to design, build, and test a Microhole Drilling Tractor with a maximum outside diameter of 3.00 inches; further, downhole testing of the MDT was initially planned to be at a drilling test facility in the US.

Subsequent to contract award to WWT and approximately at the time of initial design release, representatives from a major oil company, having heard of the Microhole Drilling Tractor project, expressed strong interest in the project and requested information regarding the product's performance specification. Upon technical review, it was the opinion of the oil company that the existing design was not appropriate for typical horizontal drilling applications in Alaska and lower US locations, the area of operations of the oil company. Further, that if the tool size envelop could be increased to accommodate the anticipated 3.75-4.125-inch diameter holes, the oil company would support use of the tractor operations in their area of operation.

WWT submitted and was granted a change of scope by US DOE for the MDT to allow a maximum tool diameter of 3.38 inches. With this allowance, WWT then completely re-designed the MDT to meet the modified requirement of the project. WWT also formally arranged with a major oil company to use the MDT in a demonstration well in Alaska.

This report provides a description of the Microhole Drilling Tractor Design, manufacture, shop testing and finally field testing. This project is part of an on-going effort by WWT for the commercialization of specialty tractors for oilfield applications and specifically the expansion of coiled tubing drilling in the US market.

## **2.1 MICROHOLE DRILLING TRACTOR PROJECT SCHEDULE**

The schedule for the MDT Project is seen in Figure 1 with milestones identified in **bold**. Through-out the project, Monthly Status reports were provided at the beginning of each month for the duration of the project.

The original project duration was approximately 14-months, but because of the re-design, manufacturing delays, and delays in field operations the project was approximately 38 months in duration. The Project is divided into two major Phases with tasks and subtasks. The major Phases are:

- Phase 1: Design of the Microhole Drilling Tractor
- Phase 2: Prototype and Demonstration Testing of the Microhole Drilling Tractor.

For Phase 1: Design of Microhole Drilling Tractor, consists of one Task with numerous subtasks. The Microhole Drilling Tractor consists of four major assemblies with their associated subassemblies – Control Assembly, Forward Shaft Assembly, Aft Shaft Assembly, and Gripper Assembly. These subtasks define the design (calculations and analyses) for the part, the development of 3-dimensional models and preparation of drawings for each of the major components.

For Phase 2, the major Tasks are as follows:

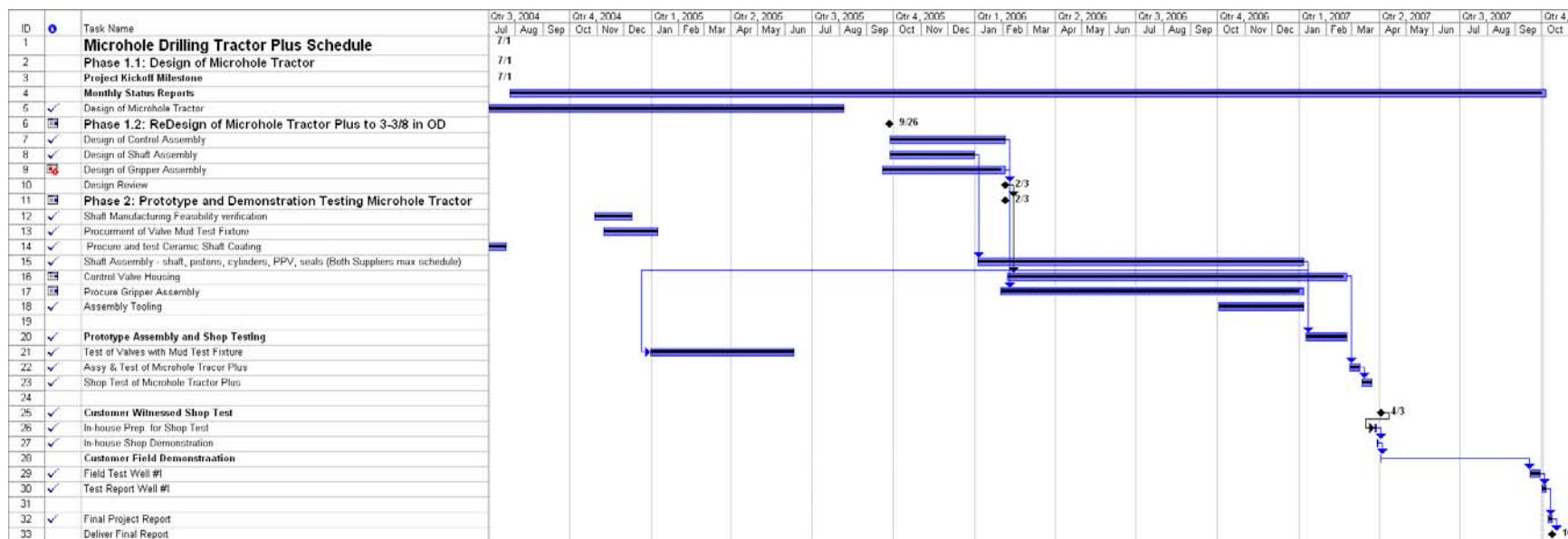
- Prototype Procurement
- Prototype Assembly and Shop Testing
- Customer Witness Shop Testing
- Customer Field Demonstration Testing

For Phase 2, Prototype and Demonstration Testing - the significant components are identified as procurement tasks. For example, Shafts were the longest lead item with a delivery time of approximately 380 days. All other components were procured.

The spare components are obtained to provide maximum assurance that even if the prototype is damaged during testing, parts can be repaired at the test site so that the Customer Field Demonstration will be completed successfully.

The Prototype Assembly and Shop Testing, Customer Witness of Shop Testing, and Customer Field Demonstration Testing conclude the project.

**Figure 1: Microhole Drilling Tractor Project Schedule**





## 2.2 CRITICAL MILESTONES LIST FOR MICROHOLE DRILLING TRACTOR

The critical milestones for the Microhole Drilling Tractor Project are seen in Figure 1. These milestones are as follows:

- **Project Kick-Off Meeting:** The formal initialization of the project with optional D.O.E. attendance began with this meeting.
- **Monthly Status Reports** (each month): Each month for the duration of the project, a status report was delivered that included a summary of technical accomplishments, updated project schedule, and project accounting costs to date.
- **Prototype Assembly and Shop Testing:** The Microhole Drilling Tractor was assembled. D.O.E. representatives were invited to witness tractor shop testing.
- **Customer Witness Shop Test:** Using Western Well Tool's test facilities, a simulated walking test was conducted in an instrumented cased mini-flow loop. MDT walking and control methods were demonstrated.
- **Customer Field Demonstration Test:** WWT conducted tractor demonstration tests at an actual well site.

## 2.3 ECONOMIC BENEFITS FROM MICROHOLE TRACTOR

The Microhole Drilling Tractor offers numerous benefits. Some of these benefits are as follows:

- **Growth of Coiled Tubing Drilling with Microhole Drilling Tractors Will Increase Maximum Horizontal Reach and Stimulate more Drilling:**  
With the availability of the Microhole Drilling Tractor the maximum horizontal displacement could be increased by up to 3000-ft beyond existing technology, thereby increasing the number of CT drilled holes by as much as 30%.

Coiled Tubing drilling of horizontal wells has reached a technological maximum horizontal displacement of about 2000-3000-ft (with most work less than 2000-ft horizontal) before lockup or failure to place sufficient weight on bit (WOB) to drill ahead. By the end of 2003 approximately 7000 wells have been drilled with coiled tubing and a growth of an additional 750 wells per year is expected; of those CT-drilled wells, it is estimated that approximately 88% are less than 5000-ft vertical depth and less than 3000-ft horizontal displacement.

### **Drilling Cost Reduction of 20-55% with Coiled Tubing and Microhole Drilling Tractor in Various Environments:**

A 2002 BP-Arco report stated that north Slope coiled tubing drilling (without a Tractor) was 60% less expensive than rotary rig drilling based on 250 wells with 2,000 ft horizontal sections.

In the lower 48 states, Shell, while drilling in California, reported a possible 25% reduction in costs with Coiled Tubing Drilling of traditional J shaped wells, again without tractors.

Since the use of the MDT will increase the well costs less than 5% but allow 25% to 60% cost reduction, the drilling costs could be expected to be reduced by 20-55%.

## 2.4 INNOVATION ADVANCEMENTS WITH MICROHOLE DRILLING TRACTOR

The Microhole Drilling Tractor allows the use of conventional Coiled tubing to perform drilling tasks that otherwise would require a rotary rig at greater expense. For example, drilling substantial distances horizontally into thin pay zones can be accomplished with the Microhole Drilling Tractor.

The following lists the advancements with the Microhole Drilling Tractor:

- **New Capability:** The Microhole Drilling Tractor will allow drilling of horizontal holes up to 3000-ft horizontally beyond conventional CT drilling.
- **Simple Controls:** Control is simple and direct with use of the injector and pump pressure, thus eliminating need for expensive electrical controls.
- **High Capacity:** The Microhole Drilling Tractor is capable walking with high loads (3500+lbs) though dog-legs up to 15 degrees/100ft.
- **Innovative Grippers:** Gripping for tractor movement is highly reliable, has a long life (>175,000-feet traveled before maintenance), is highly debris and fluid tolerant, can efficiently traverse sand or hole contaminates, does not damage casing, and is proven to operate in both very soft and hard formations.
- **Simple Principle of Operation:** Power is provided by differential pressure of the drilling mud at the tool; this tool literally breathes the drilling mud to produce power.

## 3 PROJECT OBJECTIVES

The objectives of the Microhole Drilling Tractor Project are:

1) Complete design, manufacturing, assembly, shop testing of one configuration of the Microhole Drilling Tractor and

2) Perform specific Shop and Field Drilling operations confirming tool performance.

## **4 MICROHOLE DRILLING TRACTOR TECHNICAL DESCRIPTION**

### **4.1 MICROHOLE DRILLING TRACTOR OVERVIEW**

The Microhole Drilling Tractor (MDT) is a high force / moderate speed / low cost conveyance device that facilitates running heavy bottom hole assemblies and extends maximum achievable horizontal hole. The MDT is powered by differential pressure of the drilling fluid between the bore and the annulus and controlled by the surface pump and coiled tubing injector.

The Microhole Drilling Tractor incorporates specific design features of the previous WWT Tractors modified to accommodate performance requirements for drilling. Specifically, the following:

- **Power:** Power is provided by the differential pressure of the drilling mud.
- **ON-OFF Control:** An internal Start-Stop valve is controlled by starting and stopping the surface mud pumps that cycles the tractor ON an Off.
- **Speed Control:** Speed is governed by the rate that coiled tubing is fed into the hole by the injector.
- **Torque:** Torque will be transmitted through the Microhole Drilling Tractor and delivered to the coiled tubing.
- **Mud Flow Rates:** Mud used by the tractor (1-8 gpm) is discharged from the tractor.
- **Tractor Steering:** Flexible Microhole Drilling Tractor shafts will allow turning in any direction up to 15-degrees/100 feet while drilling; the MDT will slide into hole at up to 50 degrees/100 feet of curvature.
- **Typical Drilling Muds:** Design of components exposed to drilling mud will incorporate superior materials and design features.

### **4.2 KEY COMPONENTS OF MICROHOLE DRILLING TRACTOR**

The Microhole Drilling Tractor is best described through an understanding of the principles of operation and description of major components that follow.

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No. DE-PS26-03NT15392-0 "Microhole Technology Development"10-25-08

The Microhole Drilling Tractor will consist of three major assemblies – Control Assembly, Forward Shaft Assembly, and the Aft Shaft Assembly.

Photo 1 shows approximately half of a Microhole Drilling Tractor. The Control Assembly's function is to direct the mud flow to the forward and aft shaft assemblies that provide the pull and thrust of the tractor. The Control Assembly includes a Start-Stop valve as well as other valves that control the direction of mud flow through the tractor and control the sequencing process. The Control Assembly is made from a corrosion resistant material not susceptible to hydrogen sulfide embrittlement.



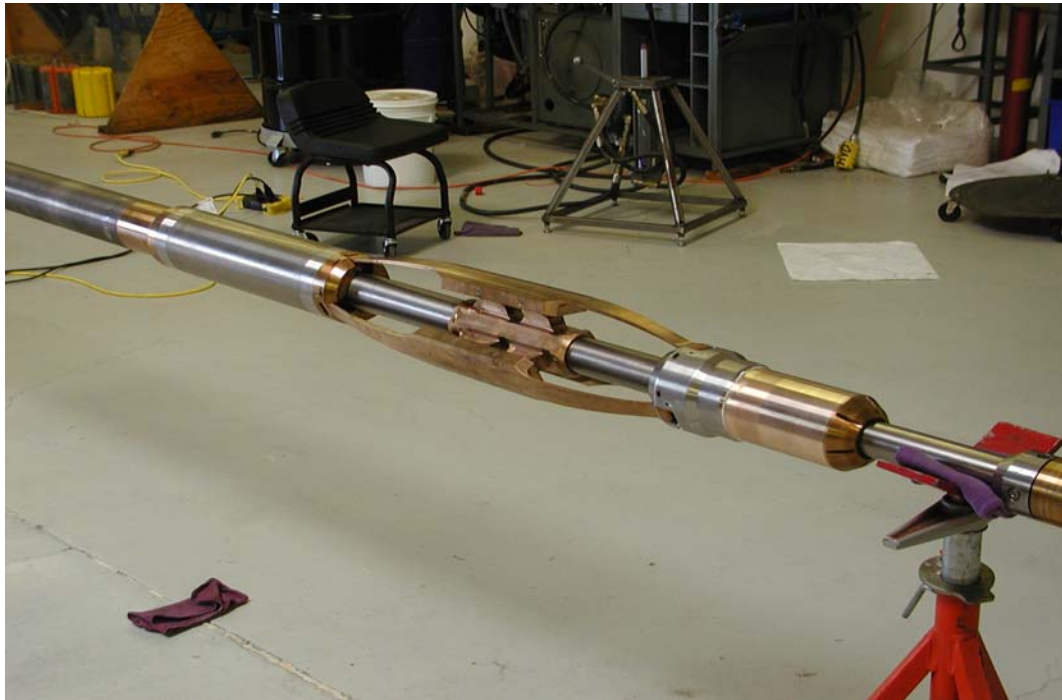
**Photo 1: Approximately half of Microhole Drilling Tractor showing the Tool Joint (far left), Shaft Assembly with Gripper (center) and Control Assembly (far right)**

The two Shaft Assemblies consist of shaft, cylinders, tool joint, and grippers. The shaft assemblies provide the structural integrity for the power distribution, the hole wall gripping, and connections to the BHA and the Control Assembly.

The Microhole Drilling Tractor is equipped with the patented gripping element, Roller-Toe Grippers (RTG) that are placed on the Shaft assemblies. The RTG has seen substantial previous testing and operational experience by WWT and was modified for the Microhole Tractor Project. The RTG has demonstrated the ability to grip in formations with compressive strengths of Gumbo Shale (500-psi) to Hard Cement (5000-psi) to Steel (60,000-psi). The RTG has seen multiple fatigue tests where it operated with up to 6000-lbs thrust for the equivalent of 175,000-ft of tractor

walking. The RTG has seen a variety of debris tests that verify its operation in mud and cuttings filled environments. Photo 2 shows an actuated Roller Toe Gripper on a Shaft assembly.

The MDT Gripper consists of a cylinder-piston assembly, toes, and operating sleeve. When the RTG piston is pressurized the operating sleeve moves a ramp beneath the toes, which are moved radially outwards contacting and gripping the hole wall.



**Photo 2: Actuated Microhole Drilling Tractor Gripper**

#### **4.3 PRINCIPLES OF OPERATION**

WWT's Microhole Drilling Tractor operates on simple and reliable principles of hydraulics and mechanics that results in thrusting the bit into the formation and pulling the drill string behind as it moves down hole.

The Microhole Tractor Walking process consists of several steps. The steps involve the expanding of the Forward Roller-toe Gripper against the hole wall, thrusting the bit forward and pulling the drill string as the Microhole Drilling Tractor progresses, expanding Aft Roller-toe Gripper against the hole wall, deflating Forward Roller-Toe (the forward RTG deflates while the aft RTG expands) Gripper, and pushing the bit forward and pulling the drill string into the new position. The process then repeats itself. Thus, this cycle allows the Microhole Drilling Tractor to "walk" down a hole while pulling the drill string behind it, and while drilling the hole.

#### 4.4 MICROHOLE DRILLING TRACTOR SPECIFICATION

Table1 defines the Specification for the Microhole Drilling Tractor:

**Table 1: Microhole Drilling Tractor Specification**

| <b>Specification</b>         | <b>Property*</b>          |
|------------------------------|---------------------------|
| Tractor Outside Diameter     | 3-3/8-inches              |
| Tractor Inside Diameter      | 0.625-inches              |
| Maximum Pull-Thrust          | 3500-lbs at 1000-psid*    |
| Maximum Speed (@ no load)    | 1000-ft/hr                |
| Tool Length                  | 23-ft                     |
| Gripper Expansion Diameter   | 4.2-inches                |
| Maximum Dogleg Severity      | 15-degrees/100-ft         |
| Operating Flow Range         | 20-112-GPM                |
| Maximum Hydrostatic Pressure | 15000-psi                 |
| Maximum Temperature          | 350 degree F              |
| Materials                    | Copper-Beryllium, Inconel |

#### 4.5 SHOP DEMONSTRATION

##### 4.5.1 SHOP TEST OBJECTIVE

Using WWT test facilities, a walking test was conducted using a closed loop capable of quantifying the operational capabilities of the DT 338 Microhole Drilling Tractor in a controlled environment. The test was observed by representatives of BP and D.O.E./NETL

The objectives of the test are to demonstrate the DT338's capabilities during simulated down-hole testing, including the following.

- Load Capacity (Weight on Bit), Demonstrate pulling capacity 3000-3500 lbs .
- ON-OFF: Demonstrate that reliable and repeatable turning the tractor ON-OFF
- Gripping in 4.0 Inch Diameter Casing: Demonstrate walking in 4.0 inch casing
- Non-Transmission of Torque Through the Tractor: Demonstrate that torque is freely transmitted though the tractor.

##### 4.5.2 TEST SETUP

Testing was performed in the facilities of Western Well Tool and followed the setup instructions outlined in Test Instruction 013. The test fixture was operated by WWT engineers and complied with the requirements of the observers.

After loading the DT338 into the test fixture (AT302024) the following tests were performed:

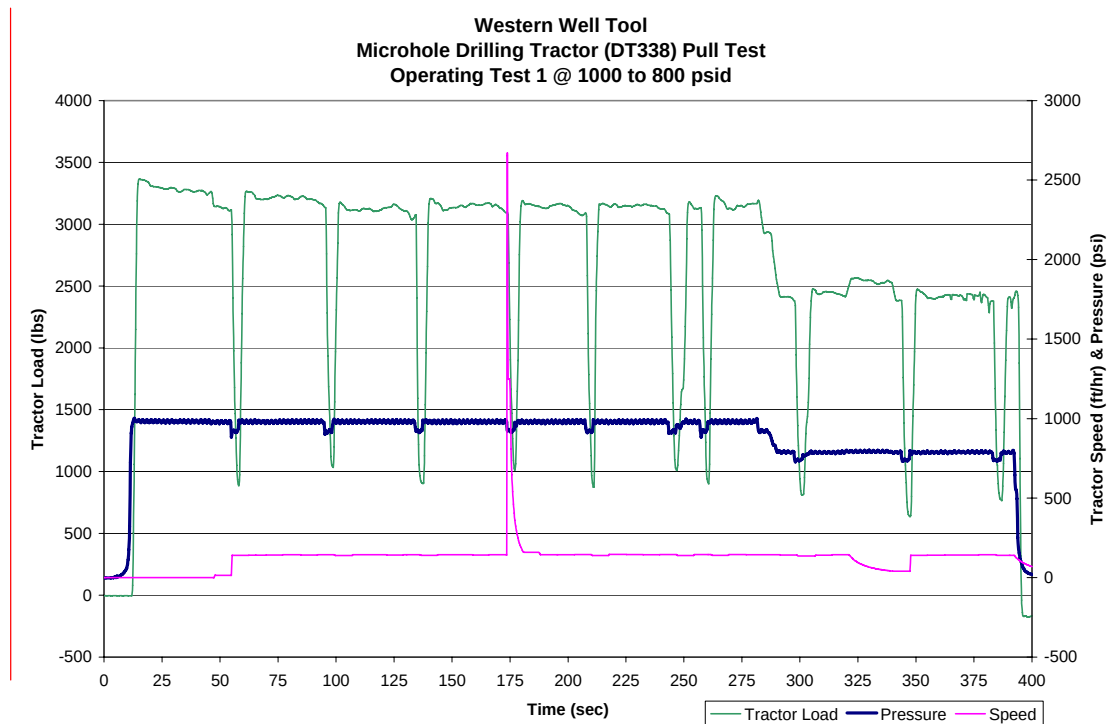
1. Pull test operating at 1000 psid reducing pressure to 800 psid.
2. Pull test operating at 800 to 600 psid. This test should show a gradual reduction in load capacity until the tractor stops cycling.
3. Tractor restart, the pressure is increased until 1000 psid then dropped to zero then returned to 1000 psid. (The pressure cycle is required to reactivate the tractor.)

#### 4.5.3 SHOP TEST RESULTS

The results are shown in the graphs below and described for a typical test.

##### Operating Test 1

Pressure was increased to the required 1000 psid. The graph in Figure 2 shows the tractor walking at a speed of approximately 140 ft/hr and exerting an average load of 3150 lbs during the test. Pressure was then dropped to 800 psid the tractor continues to walk at 140 ft/hr and the average load dropped to just under 2500 lbs for the remainder of the test. Results were as expected.



## **Figure 2: Shop Demonstration Operating Test Illustrating Microhole Drilling Tractor Pulling Capacity**

### Operating Test 2

During test two the pressure started at 800 psid. The tractor continued to walk while the pressure was decreased to 600 psid. At 600 psid the tractor stopped sequencing. The results were as expected.

### Operating Test 3

Testing of the Start /Stop function by cycling pressure was tested in the third operational test. The results show what would happen after pressure has been restored to 1000 psid. (Tractor has cycled to the Off position) The tractor showed no movement and exerted no load. Fluid would continue to flow through the Tractor in the Off position allowing continued circulation of drilling fluids, removal of cuttings, etc. After the pressure was dropped to near zero and returned to normal operating pressure (1000 psid was used in this test as normal operating pressure) the tractor restarted and continued walking at approximately 140 ft/hr and exerted approximately 3400 lbs of load. Results were as expected.

Finally, the Grippers on the shafts were manually rotated on the shafts during the walking process demonstrating that torque was not delivered to the grippers.

## **4.6 FIELD DEMONSTRATION WELL**

### **4.6.1 FIELD DEMONSTRATION WELL OBJECTIVES**

Western Well Tool arranged a first field demonstration of the Microhole Drilling Tractor with a major oil company operating in Alaska.

The objectives of the demonstration of the DT338 during the program are the following:

1. On-Off Capability: Demonstrate that the DT338 can successfully be turned on an off to allow normal drilling operations.
2. Pulling Capacity: Demonstrate that the DT338 can pull the design loads when provided with anticipated differential pressure from the drilling fluids
3. Walking Speeds: Verify that the DT338 can walk in cased and open hole at speed controlled by the injector
4. Starting Drill Bit: Verify that the DT338 can be used to start the drilling process without excessive stalling of the downhole motor.
5. Weight on Bit: Verify that the DT338 can provide significant amounts of weight on bit to facilitate drilling in various formations.



6. Compatibility with Drilling Operations: Verify that the DT338 can be used with existing Bottom Hole Assemblies (BHA) with significant change in operating procedure or equipment.

#### 4.7 DEMONSTRATION WELL AT PRUDHOE BAY ALASKA

In September 2007, a major oil company informed WWT that it intended to use the DT338 in a first demonstration well, the X-30 in Prudhoe Bay using the Nordic 2 rig, a modern, fully enclosed, state of the art CT rig shown in Photo 3.



**Photo 3: Nordic 2 Rig in Prudhoe Bay September 2007**

Two DT338 were shipped to Anchorage and subsequently to Prudhoe Bay. Oil Company and WWT representative met in Anchorage in a pre-well meeting to review drilling operations, tractor operational procedures, and review safety plans.

##### 4.7.1 ASSEMBLY AND TEST:

WWT personal assembled two DT338 Tractors in the pipe shed / catwalk area of the rig. The Tractors were subsequently functionally tested on surface and the DT338 Tractor operation was demonstrated to all drilling and company personal. The primary DT338 was scribed at the tool joints for tool orientation and placed into the

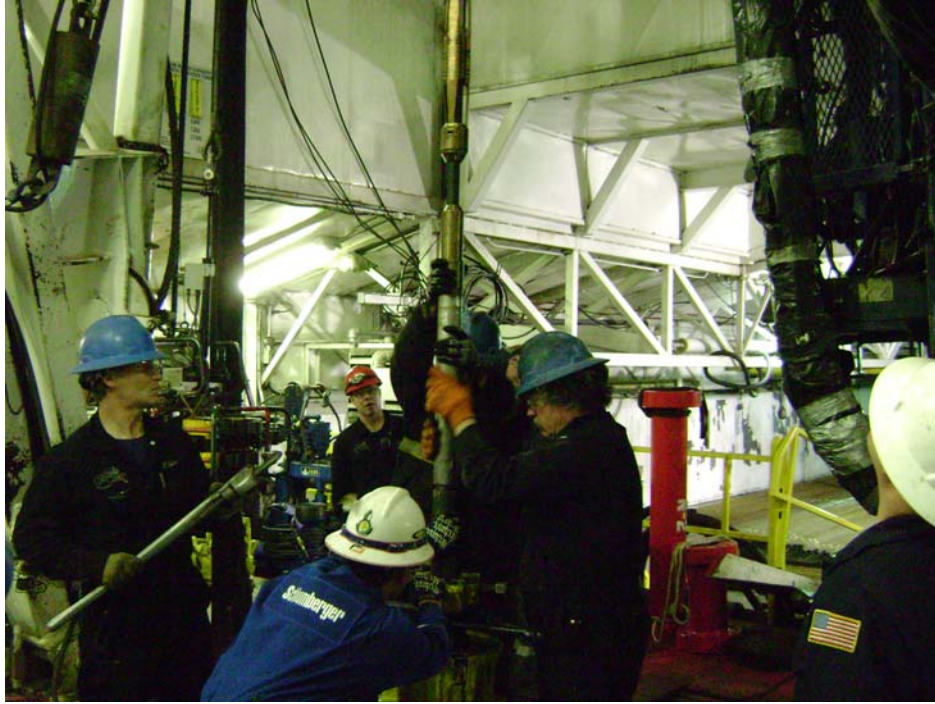
lifting “shuck”. Photo 4 shows that tractor in the Pipe shed prior to use in the Demonstration Well.



**Photo 4: Tractor in Pipe Bay at Nordic 2 Rig Prudhoe Bay, X-30 Well**

#### 4.7.2 BHA ASSEMBLY:

The DT338 was lifted using the catwalk slide and tugger line from the rig floor. The lifting shuck was stabbed in the mouse hole directly in front of the well. A 2 3/8 Pac lifting sub was used to lift the DT338 out of the shuck, where the C-Plate Sub was torqued to 2,600 ft-lbs to the DT338 tool joint. The DT338 was then stabbed into the FVS / Motor / Bit lift that was hung off in the well and torqued to 2,600 ft-lbs. The DT338 was then RIH and hung off on the Baker C-Plate. The remaining CoilTrak (Trademark) tools were made up into the BHA. Photo 5 shows the Microhole Drilling Tractor being lowered into the well.



**Photo 5: Microhole Drilling Tractor (DT330) being lower into the X-30 Well Prudhoe Bay**

#### 4.7.3 DOWNHOLE TEST X-30 WELL:

The downhole test was run between 800 feet and 950 feet bit depth. The WOB sub was zeroed per standard operational procedures. The initial state of the DT338 was in the off position as the pump rate was increased to 2.4 bpm. At this point, the tubing pressure was approximately 3,750 psi and the  $\Delta P$  Sub measured 900 psi. The WOB sub reached a max of -1,860 lbs. The pump rate was decreased to 0 bpm and the tubing was RIH 10 feet to change the location of the bit inside the casing. The pumps were increased to 2.4 bpm and the DT338 was activated with the CT injector brake on.

This would provide a “Dead Pull” test to see the maximum force the tractor produced in the casing. At this rate, the tubing pressure was 3,600 psi and the  $\Delta P$  Sub measured 700 psi at the DT338. The drop in tubing pressure associated with the same pump rate indicates the activation of the Tractor. The pump rate was increased to 2.5 bpm to achieve a higher  $\Delta P$  Sub measurement of approximately 900 psi. At this point the WOB sub recorded an increase of 1,300 lbs of tension and the injector load pin recorded an increase of 1,465 lbs. Spikes in WOB sub data indicate the Tractor was cycling during the dead pull test. The Tractor was then RIH to a depth of 846 feet at injector rates of 1, 5 and 10 fpm. However, data from this test was inconclusive.

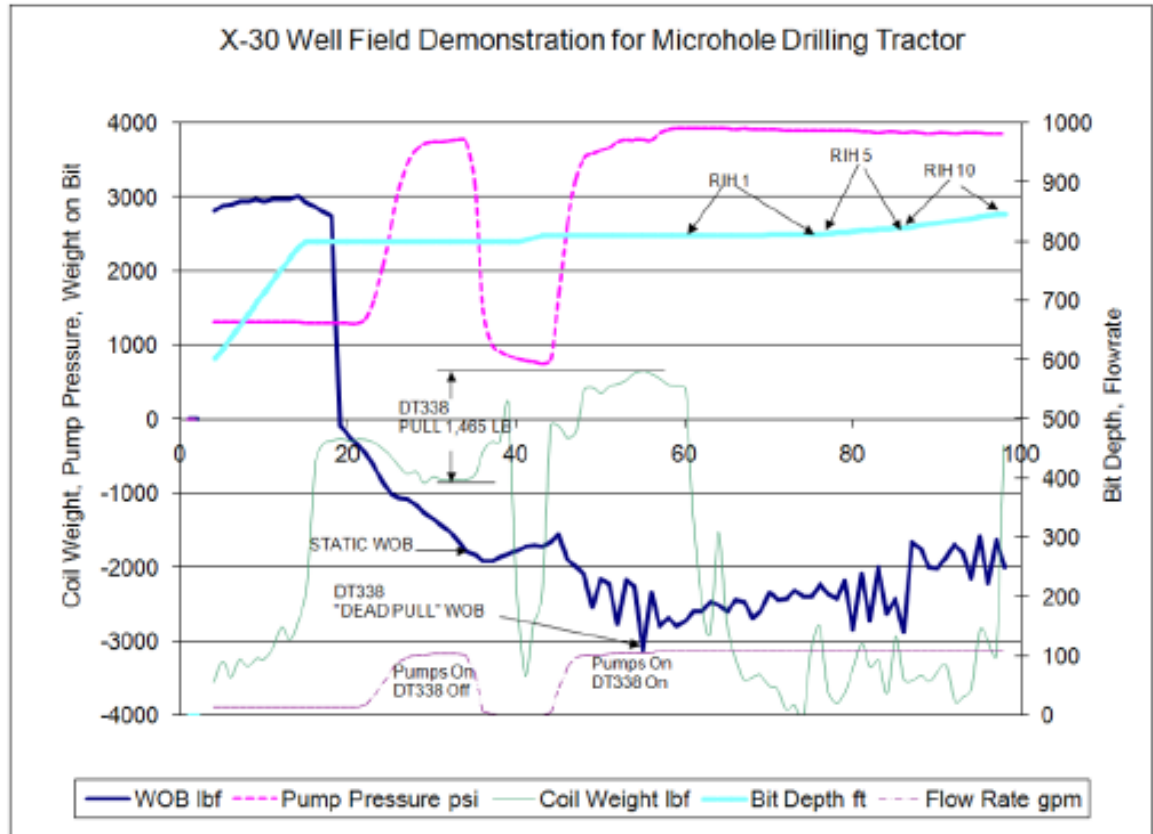


Figure 2: Plot of Coil Tubing Weight and Differential Pressure during “Walking Demonstration” of the DT338 tractor in Cased Hole Section of X-30 Well Prudhoe Bay

Figure 2 shows a short part of the Dead Pull and Walking Tests of the DT338 in the X-30 well. These results show that cycling the pump pressure on and off turns the DT338 on and off as reflected in the Coil Weight. Next, note that the tractor force generated about 1465 lbs with Pump Pressure of 3600 psi, this corresponds to a downhole differential pressure of about 700 psi.

Several factors affected the overall results of the DT338 test. The close physical proximity to the injector allowed for the Tractor pull force to be lost in the natural fluctuations of the injector weight readings. The WOB and  $\Delta P$  readings were collected every 12 seconds making it difficult to use in a real time application. The low differential pressure at the Tractor (free spin motor work only) resulted in lower overall Tractor power. Additionally, the 5% lubricants in the mud inside the new chrome tubing provided a C.O.F. much lower than the anticipated sandstone formation. Empirical calculations indicate a C.O.F. in the range of 0.15 between the Beryllium Copper gripping elements and the casing.



#### 4.7.4 POST RUN FUNCTIONALITY TEST:

After the downhole test, the DT338 was setup on the catwalk for a functional test and to displace the drilling mud out of the Tractor. The Tractor On/Off sequence was in the anticipated position and the Tractor functioned as expected. A visual inspection of the DT338 revealed no major damage. The gripping elements that contact the casing showed minimal wear but supports the theory of slippage due to low C.O.F. between the gripping elements and the smooth casing.

#### **4.8 MICROHOLE DRILLING TRACTOR PROJECT'S RESULTS FROM DEMONSTRATION WELL**

The results from the first Microhole Drilling Tractor (DT338) on the X-30 well performed in cased hole 800 feet from surface were the following:

1. On-Off Demonstrated: The DT338 successfully demonstrated ON-OFF capability with the cycling of on and off of the surface pumps.
2. Pull Force: The DT338 demonstrated that it pulled with the various amounts of pressure. The amount of force was not as large as anticipated probably because the Coefficient of Friction between Tractor gripper elements and casing was less than anticipated.
3. Walking Speeds: Various walking speeds (controlled by injector) were demonstrated.
4. Tractor Compatibility to Normal CT Drilling Operations: The tractor operations were compatible with existing procedures including tractor pick up, lay down, make up and break out, powering up, walking.

### **5 PROJECT SUMMARY**

The objectives of the Microhole Drilling Tractor Project were achieved. Western Well Tool successfully designed, manufactured, shop tested, and field demonstrated a 3.38 inch diameter drilling tractor. The Microhole Tractor demonstrated its ability to turn on and off, walk in a cased hole, walk at various speeds, successfully integrate into field bottom hole assemblies. Although well conditions prohibited the demonstration of the tractor drilling in open hole, plans are to continue with tool development by drilling in additional wells in Alaska.

### **6 RECOMMENDATIONS**

The following are recommendations for the Microhole Drilling Tractor Project and tool.

1. Additional Field Demonstrations: With the simple product improvements incorporated into the Microhole Drilling Tractor, additional field

demonstrations should be repeated, hopefully with increasing difficulty.

2. Gripping Elements: Retrofit friction elements into the toes to increase the Coefficient of Friction when gripping casing or open hole formation.

## **7 ACKNOWLEDGEMENTS**

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Western Well Tool wishes to express its thanks to World Oil Magazine for selecting the Microhole Drilling Tractor as a finalist for the “New Horizons Award” for 2008.