A Built for Purpose Micro-Hole Coiled Tubing Rig (MCTR)

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2 Abstract

This report will serve as the final report on the work performed from the contract period October 2005 thru April 2007. The project "A Built for Purpose Microhole Coiled Tubing Rig (MCTR) purpose was to upgrade an existing state-of-the-art Coiled Tubing Drilling Rig to a Microhole Coiled Tubing Rig (MCTR) capable of meeting the specifications and tasks of the Department of Energy.

The individual tasks outlined to meet the Department of Energy's specifications are listed below.

- Concept and development of lubricator and tool deployment system
- Concept and development of process control and data acquisition
- Concept and development of safety and efficiency improvements
- Final unit integration and testing

The end result of the MCTR upgrade has produced a unit capable of meeting the following requirements.

- Capable of handling 1" through 2-3/8" coiled tubing (Currently dressed for 2-3/8" coiled tubing and capable of running up to 3-1/2" coiled tubing)
- Capable of drilling and casing surface, intermediate, production and liner hole intervals
- Capable of drilling with coiled tubing and has all controls and installation piping for a top drive
- Rig is capable of running 7-5/8" range 2 casing
- Capable of drilling 5,000 ft true vertical depth (TVD) and 6,000 ft true measured depth (TMD)

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4 Introduction

The objective of this project is to develop a state-of-the-art Microhole Coiled Tubing Drilling Rig (MCTR) capable of performing an entire "grass-roots" operation in the 0 – 5000ft TVD range including drilling and casing surface, intermediate, and production and liner holes in an economical manner. The unit will be able to drill with coil and will be able to run at a minimum 7 5/8" range 2 casing. The unit will also meet USDOT regulations and limitations.

The rig will incorporate design changes to improve the economics in drilling and producing from shallow oil and gas reservoirs within the United States and improve recovery rates from these reservoirs.

To complete this project a coiled tubing drilling rig was purchased from Pioneer Energy who had been using the rig to drill with air in Trinidad, Colo. The rig had successfully drilled seven wells for Pioneer and was intended to be used for drilling interests in Kansas. This work in Kansas feel through and the rig was taken to Trinidad, Colo. were it drilled gas wells at the bottom of there lease

Figure 4-1 Evolution 1 rig in Trinidad Colorado on well location

The rig when purchased was outfitted with 3-1/2" coiled tubing and was configured for air drilling up to 3,500 ft. Figure 4-1 shows the unit as received rigged up at a wellsite in Colorado.

5 Executive Summary

This report will provide the final update report on the MCTR project DE-FC26-04NT15474. Below are highlights of the work performed on the MCTR.

- Evolution #1 drilling rig was purchased as the base unit for the MCTR rig modifications
- An operational review of the Evolution #1 unit was performed to determine the overall operational functionality of the unit. Several electrical and hydraulic issues were identified and rectified during the modification and testing phase
- CoilCAT software and hardware was installed on the unit and under went full system testing
- CTInspec a real-time wall thickness and ovality monitor was installed and tested
- CoilSaver a coiled tubing depth and weight monitoring system was installed and tested
- InterAct a wellbore real-time satellite data transmission system was installed and tested
- The telescoping anti-buckling guide was designed and installed on the rig. The telescoping anti-buckling guide under went testing on Sandy Point #3 test well site in Rosharon,Tx.
- The drill floor was modified for easy removal, which allows the BOP stack to be easily reconfigured or maintained without moving the rig. After the modification the drill floor was successfully load tested to verify that the modifications did not alter the load capacity of the floor. The drill floor was further tested on the Sandy Point #3 test well during the installation and removal of the BOP stack.
- The reel center shaft was modified to accept a 3" full bore high pressure swivel. The external and internal iron was replaced with integral high pressure treating iron
- Hand rails were added were needed for safety
- Stairs were extended to reach the ground when the unit was raised to height during operations
- Drawworks cover was redesigned to with stand a person's weight. The drawworks was located such that operators would tend to stand on the drawworks cover during maintenance procedures and were damaging the existing cover
- BOP control panel was redesigned to reflect the new BOP stack and to improve reliability of the BOP controls.

The details of each design task will be detailed in the following sections.

6 Coiled Tubing Drilling Rig Study

During phase 1 of the MCTR project an operational study was performed. This study looked at the current technologies in existence related to coiled tubing drilling. The operational study covered the following topics. Copies of the Operational Study have been sent to the Department of Energy as part of the phase 1 deliverables.

Chapter 1

- Typical Completion
- Coiled Tubing Fatigue Life
- Flow Rates
- Motor Size vrs flow rates
- Coiled Tubing Costs
- Reel Capacity
- Coiled Tubing Weight

Chapter 2

- Rotary Rig Specifications
- CTD Rig Specifications
- Casing Weight Considerations
- Determining Derrick Height
- Injector Size
- Rotary System
- Tool deployment

Chapter 3

- Vehicle Size & Weight
- Permit able loads
- Bridge Formula

Chapter 4

- BOP Requirements
- Diverter Systems
- Choke Manifolds

Chapter 5

- BHA Assemblies
- Vertical Drilling
- Horizontal Drilling

Chapter 6

- Operational Procedures
- Site Preparation
- Rig-Up Procedure
- BHA Pick-Up Procedure
- Pressure Deployment

- Deploying Injector
- Over Balance Drilling
- Under balance gas
- Mist Drilling
- Foam Drilling
- Hole Cleaning
- Lay Down Procedure Over Balance
- Lay Down Procedure Under Balance
- Running Casing
- Cementing Casing
- Directional Drilling

Chapter 7

- New Technology
- OpsCab
- InterACT
- CT InSpec
- Technology Development

Chapter 8

- Personnel Requirements
- Drilling Report
- Automated Controls

Chapter 9

- Work Floor
- Components
- Common Tools

Chapter 10

- Rotary Tables
- Top Drives
- Power Swivels

7 Selection of Coiled Tubing Drilling Rig

During phase 1 of the MCTR project Schlumberger evaluated the Market Analysis and Operational Study created for this project in order to come up with at rig proposal that would meet the requirements of the DOE. As part of this process a concept design was developed and reviewed as a potential solution to the MCTR project. This design would require a rig to be built from scratch. This new rig design would require complete mechanical, software and firmware designs to bring it to a reality. After careful consideration it was determined that the concept rig was completely feasible, but it would take to long to bring it to market. Schlumberger felt that it was better to select a unit that could be taken to market in the short term and gather further data before building a complete new rig. Below is a rendering of the MCTR concept rig with all equipment needed to perform a drilling operation.

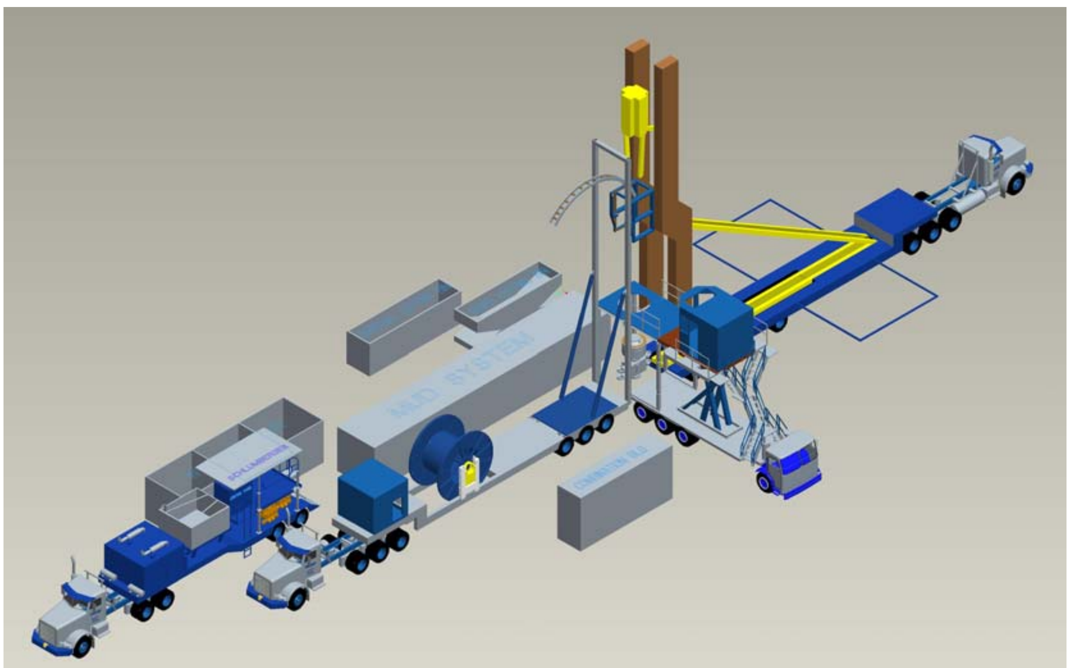


Figure 7-7-1 Concept rig for Microhole Initiative

The concept rig was to be equipped with a 140,000lbf mast that would sit a top a 16 ft drill floor. The drill floor would parallelogram into position allowing it to transport at 13'6". The drill floor would contain a false rotary allowing bit to be torque and slips to be set. All units could be transported under an annual permit thus eliminating single trip permit requirements.

Because a decision was made to reduce the time to market an alternative drilling rig was identified that was available for purchase. A team was sent to perform an audit of the Evolution 1 drilling rig owned and operated by Pioneer Resources. Based on the teams review the Evolution 1 drilling rig it was selected as the base rig to undergo mechanical and control upgrades. These up grades would make the Evolution 1 rig capable of meeting the requirements of the MCTR project. The overall Evolution 1 rig is a three piece unit comprised of a mast unit, pipe trailer and control room.

The Evolution 1 rig was purchased from Pioneer Resources and transported to Rosharon Test facility in Texas. There the rig went through further analysis to determine the modifications required to meet the MCTR requirements.

Figure 7-2 Evolution Control Cabin/Change Room/Tool Room

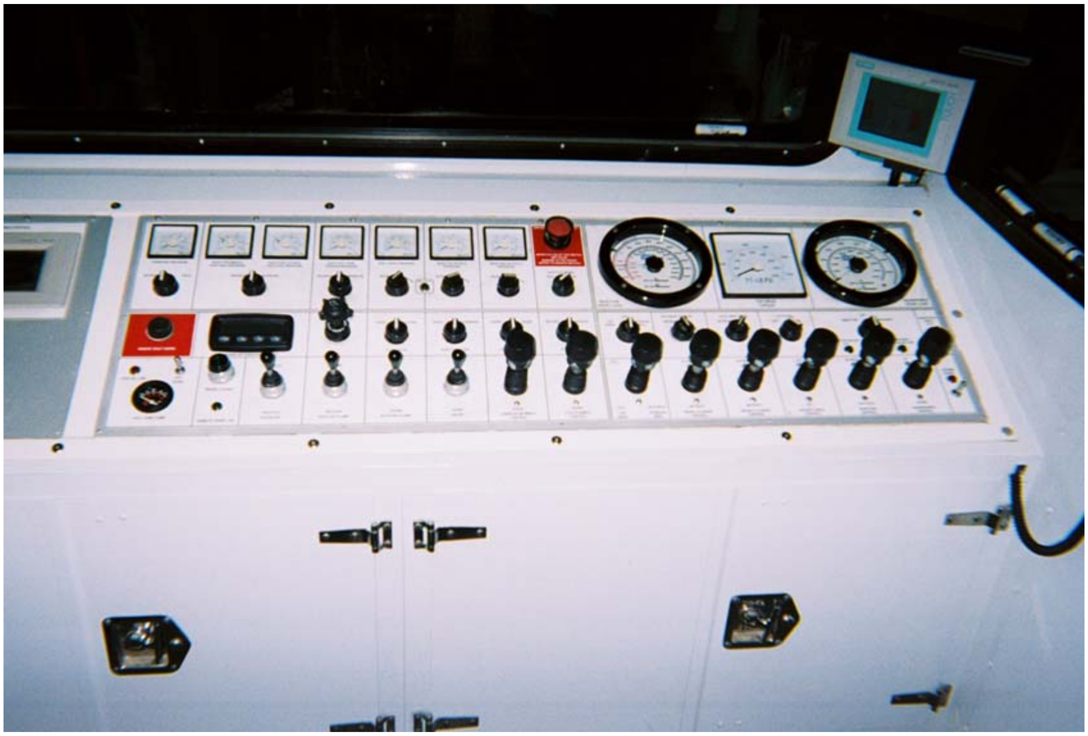


Figure 7-3 Evolution Control Cabin

Figure 7-4 Evolution Change Room

8 Rig Specifications

8.1 General

The Evolution 1 rig is a trailer mounted three piece drilling rig. The pieces are devised of a coiled tubing mast unit, control unit and catwalk trailer. The coiled tubing mast unit is equipped with a mast with drill floor, drawworks, traveling block, storage reel with level wind, injector, truck with hydraulic wet kit and rotary table. The mast is capable of accepting a Foremost RC 240 top drive with all necessary mounting hardware and mounts for service loop. The control unit is divided into three different connecting rooms control room, change room/tool room and pump room/accumulator room. Outside of the control room mounted on the gooseneck of the trailer is a 125 kW generator. The pipe handling system is designed to deliver casing to the rig floor current height of 7ft 6 in. It is equipped with one set of pipe racks that are 15ft 6in long and a hydraulic drill pipe bin.

8.1.1 Mast Unit:

Height = 15′ with minimal lift from jacks
Width = 10ft 9in
Length =
    11'-8" = overhang from mast pivot back to bottom of mast
    59'-0" = mast pivot to fifth wheel
    24'-6" = king pin to front of tractor
    2' = king pin to front of trailer
    95'-2" = front of tractor to back of trailer overhang
    70'-8" = fifth wheel to back of trailer overhang
Weight without coil:
    Steer Axle 16520 lbs Drive Axle 37540 lbs Trailer Axle 63380 lbs
    Gross Weight 117440 lbs
Weight with 3220 ft of 3-1/2" 0.188" wall coiled tubing:
    Steer Axle 17120 lbs Drive Axle 55,960 lbs Trailer Axle 71480 lbs
    Gross Weight 144560 lbs

8.1.2 Control Unit:

Weight:
    Steer Axle 13227 lbs Drive Axle 30048 lbs Trailer Axle 23501 lbs
    Gross Weight 66778 lbs
Width - Estimated at 10ft 6in
Length – 70 ft 5 in
Height –13ft 6in

8.1.3 Catwalk Unit:

Weight:
    Steer Axle 16049 lbs Drive Axle 36177 lbs Trailer Axle 36309 lbs
    Gross Weight 88,535 lbs
Width – 10ft 6in
Length:
    21'-10" = front of tractor to king pin
    59'-10" = king pin to rear of trailer overhang

1'-6"	= king pin to front of trailer
81'-8"	= front of tractor to rear of trailer overhang

8.2 Mast Unit Technical Specification:

(This is taken from the Foremost Technical Specification for the Evolution Unit)

8.2.1 Trailer:

Capacity	90,000lbs
Dimensions	64'3" Overall length 126" Overall Width 50.9" fifth wheel height – unladen 49.9" fifth wheel height – laden 12" ground clearance minimum (fully laden)
Storage Reel	Mounts to support storage reel pillow block bearings, level wind cylinders, drive motor and tensioner. Also provides clearance for chain guard, storage reel and hose runs from tractor.
Gooseneck	Weld in SAE 2" king pin
Suspension	Quad axle Hendrixson air ride suspension. Rearmost suspension lift-able and pin-able in raised position. 50" axle spacing
Axles(4)	F22T 25,000lb rated, Ingersoll axles (10'6" overall width), 16-1/2" x 7" Q brakes, rated 22,500lbs, with type 30/30 air chambers, oil seals, dust shields, Haldex automatic slack adjusters.
Hubs(8)	10 stud aluminum Unimount hubs, Centrifuse brake drums
Wheels(16)	10 hole Alcoa aluminum Unimount disc wheels 8.25 x 22.5
Tires(16)	11R22.5 Goodyear G286, 16 ply tires
Hydraulic jacks	Front &rear outriggers or as required. Includes dual internal counterbalance valves. Capable of raising both ends of the trailer 24" (42" stroke) in a fully laden condition.
Manual jacks	Mechanical landing gear
Mast lift cylinder	Provision for mast raise cylinder support
Electrical system	CMVSS approved. Sealed modular electrical system using Truck-Lite LED lights and Super Seal wiring harnesses.
Air System	CMVSS approved air system. Stainless steel wire braided air lines. Abs exempt. Isolation valve for rearmost axle.
Mud flaps	H.D. Black Rubber mud flaps. Anti-sail brackets as required. Aluminum fender above wheels.

8.2.2 Mast

The mast is a steel fabricated twin tube design which raising/lowering from two multi-stage hydraulic cylinders. The mast is designed to support hoisting from the coiled tubing injector and by the casing winch. The injector is mounted into the mast at a fixed height and is allowed to travel horizontally to move on and off of the mast center line. This provides the clearance for the block to travel past the injector during hoisting operations.

Mast load capacity (Casing)	100,000 lbs
Mast load capacity (Injector)	80,000 lbs
Mast casing length	API Range III – with topdrive removed (34-48 ft) API Range II – with topdrive installed (25-34 ft) Mast length based on following: Trailer at laden road height Top of rotary table bowl – 7' 6" Assuming max. stump height of 24" Top of stump to top side of elevators 51' Overall block and bale length (3' bales) 7' Top side of block to underside of crown 2'10"
Crown sheave assembly	Four 20" diameter sheaves (Encoder on one sheave)
Travel block	Two sheave 50 ton capacity
Crown Saver	Installed at crown
Counter weight	Two 100 lb weights – one on either side of mast. Used To support manual tong wrenches.

8.2.3 Injector c/w Mounting Frame & Gooseneck

Make	Stewart & Stevenson
Model	M80
Maximum pull*	80,000 lbs
Snubbing capacity	35,000 lbs
Tubing Speed*	95 ft/min
Maximum tube size	3-1/2"
Hook load	Double acting load cell mounted in injector frame
Depth Counter	Encoder driven from planetary
Gooseneck	120" radius. Base of gooseneck is fitted with a mechanical straightener assembly. Hydraulic cylinder used to fold gooseneck acts as a strut to stabilize and support gooseneck while in operating mode. The gooseneck is mounted to a slew ring that allows the gooseneck to pivot for optimum alignment of coiled tubing to storage reel.
Stripper Assembly	Suited for 3-1/2" tubing

*Note: The above specifications are based on the available hydraulic flow of the provided hydraulic system.

8.2.4 Storage Reel Assembly

Reel Size	144" OD – 114" ID – 66" width (This reel shipped loose)
Capacity	1,100 m (3609 ft) of 2-7/8" - .190 wall
Reel Size	162" OD – 127" ID – 66" width

Capacity	914 m (3000 ft) of 3-1/2" - .190 wall
Reel Mounting	Integral with trailer allowing storage reel to be recessed Between the trailer's main frame rails.
Drive group	Single hydraulic motor with planetary gear reduction designed to hold tension on drum regardless of direction of travel or injector speed. Integral to hydraulic motor drive assembly, fail-safe in line brake (hydraulic pressure needed to release brake)
Retention straps	Ratchet style winches with nylon straps sufficient to retain Storage reel during transport.
Internal reel plumbing	Consisting of ridged 3" – 15000 psi maximum working pressure integral plumbing
Reel shaft swivel	Uses a 3" 10,000 psi full bore coiled tubing swivel
Level wind	Hydraulically driven diamond lead screw. PLC controlled Semi automatic level wind device directs tubing to efficiently spool coiled tubing as the reel rotates.

8.2.5 Top Drive – Provision

The rig is equipped with the necessary hydraulic power source, controls, plumbing and Attaching hardware to accommodate a Foremost RC 240 hydraulic top drive assembly. The top drive is not currently included or the accessory components.

RC 240 Specs.
Maximum Speed – 160 RPM
Maximum Torque – 10,000 ft/lbs

8.2.6 Main Drawworks Winch

The drawworks winch is hydraulically driven with a closed loop piston motor circuit through a planetary reduction. Dynamic braking is provided by the hydraulic system.

Capacity	95,000 lbs (theoretical) with 4-line block (based on bare Drum)
Block Speed	200 ft/min (based on bare drum)
Brakes	Caliper type disc brake (parking)
Drum Capacity	400 ft
Storage reel Capacity	400 ft (for "slip and cut")
Drive group	Hydraulic motor, in-line brake, planetary
Traveling block	50 ton – sheave
Load cell/WOB	Load cell clamped to deadline

8.2.7 Winches

Winches are sized for appropriate lift and cable life as per application. The main winch is used primarily for lifting BHA components, drill pipe etc from the V-door/catwalk or ground. The secondary winch maybe used for positioning the lubricator assembly over the well.

Main Winch – mounted to backside of mast. Cable is strung over the crown and jib assembly as to pull directly in line with well center, side to side, but slightly ahead of well center to the rear. The jib allows to pull to either side of well center left or right, up to 30 degrees either side of well center.

Capacity – 7,250 lbs
Wire rope – 9/16" dia

Secondary Winch – mounted to underside of injector base. Winch is inline with well center, side to side and slightly ahead of well center to the rear.

Capacity – 2,200 lbs
Wire rope – 3/8" dia

8.2.8 Substructure (Rotary table support)

The main purpose of the substructure is to provide support for the rotary table. The substructure is supported between the mast legs in one of two bolting locations as to suit the height of the work floor 3 ft or 7'6" (top of rotary bowl) positions. The rotary table is used primarily to assist in connecting of jointed components such as the BHA, to the coiled tubing or in the case of operation with the top drive, assist in spinning free tool joints. In addition the rotary table bowl can accommodate various sizes of slips necessary to hold back down hole drill strings.

Structure Capacity	100,000 lbs
Make-up & Breakout	2 cylinders with cables mounted over a Samson post
Work Area	Steel checker plate and perforated non-slip plate

8.2.9 Tong Wrench System

The tong wrench system is mounted to the trailer deck directly behind the substructure floor. The system utilizes two independent hydraulic cylinders with cables necessary to operate manual pipe tongs used in the makeup and breakout of threaded connections. Counterweights are provided to assist in lifting and lowering of both the makeup and breakout tong wrenches.

8.2.10 Rotary Table

The rotary table's primary function will be to assist in the makeup and breakout of jointed tubulars quickly and safely.

Rotary Table	ENID Drill Systems Inc. – Super Bowl
Static weight specs	45,500 kg (100,000 lbs)
Rotating weight specs	45,500 kg (100,000 lbs) up to 50 rpm
Dimensions	32" x 48" x 8-5/8"
Weight	Table – 625 kg (1,400 lbs)
	Bushing – 140 kg (320 lbs)
Round Opening	40.6 cm (16")
Drive Square	46.7 cm (18 ½")
Drive	Hydraulic
Performance	2,250 Nm (1,662 ft-lbs) @ 125 RPM

8.2.11 Hydraulic Power Package

Power source	Supplied via transfer case installed in truck
Transfer Case	Cushman model 383 with cooler
Injector/drawworks	Rexroth closed loop system
Storage Reel	Rexroth closed loop system
Auxiliary	Rexroth open loop system
Hydraulic tank	Fabricated steel tank with rubber mounts
Cooler assembly	Remote mounted on trailer deck with hydraulically driven fan rated at 113 deg F
	Hand pump used to operate outriggers in absence of wet kit.

9 Safety Audit of Coiled Tubing Drilling Rig

Part of the objectives related to the MCTR project was to perform a safety audit of the MCTR unit and propose changes that would improve its efficiency and overall safety. For this purpose two technical audits were held to evaluate the rig. The first technical audit was performed with the rig in the transport position, while a second was performed with the unit assembled. The two audits were held to allow the auditors the opportunity to evaluate the unit in both operational conditions

9.1 Pre rig-up safety audit

#	Description	Equipment
1	Remove access at draw works crossover	Mast Unit
2	Remove Hp (hydraulic style) hose under floor	Mast Trailer
3	Remove/replace choke manifold	Catwalk Trailer
4	Remove and replace the manifold iron on the reel	Mast Unit
5	Remove threaded iron on the rack	Catwalk Trailer
6	Remove choke & return lines under trailer	Catwalk Trailer
7	Remove fall arrestor pull down line security post from the ladder on mast	Mast Unit
8	Addition of a second hand bar for 3 point contact to access the hydraulic system	Mast Trailer Tractor
9	Cap the top of the pipe work in above installation	Mast Trailer Tractor
10	Access to install/remove collector from reel hub	Mast Unit
11	Install railings on left and right of trailers as required	All trailers
12	Safety marking color on all elevation changes on the decks	All Trailers
13	Safety marking color on Tong B/O – M/U pylons	Mast Trailer
14	Anti skid covering or pin mat around rotary and DF	Mast unit and Pipe Trailer
15	Ease of access to ladder	Mast Unit
16	More safe & ergonomic mast ladder design	Mast Unit
17	Reel swivel platform rails kick plate safety harness hookups	Mast Unit
18	Kick plate or railing on top of pipe rack tub	Catwalk Trailer
19	Handrail on stair near floor	Catwalk Trailer
20	Safety marking color on trip points at top of stairs	Catwalk Trailer
21	Recoat skid floor with anti slip paint	Catwalk Trailer
22	Investigate structural integrity for rear fenders for accessing hydraulic system & trailers	All Tractors
23	Security lift/lower straps on the injector securing bars	Mast Unit

24	Repair aluminum stairs on entry point	Dog House
25	Emergency exit lighting & directional tape	Dog House
26	Tire chock blocks	All Trucks
27	Drive right system	All Trucks
28	Headache rack	All tractors
29	Lock or restriction of access to drill line cable drum storing excess for slip/cut	Mast Unit
30	Liquid identification label for pipe lube tank	Mast Unit
31	Reel covers for lower section of reel to exclude access when in operation	Mast Unit
32	3 point lifting method for stabilizer mats	All trailers
33	Reel lube points to be lowered or access made	Mast Trailer
34	Rotating machinery sign for both sides of the reel and drawworks	Mast Trailer
35	Catch drip pan on reel	Mast Trailer
36	Stabilizing controls for horse head pogo stick when cutting/removing pipe	Mast Trailer
37	Lifting lug on level wind guide	Mast Trailer
38	Draw works guard	Mast Trailer
39	Protection for draw works cable on deck	Mast Trailer
40	Access to WH/BOP area during operations	Mast/Pipe Trailer
41	Procedure to access injector on mast	Mast Unit
42	Davit arm or other to make accessing both sides of injector safer	Mast Unit
43	Drain holes beside/between the tong pylons	Mast Unit
44	Fairleads on all winch and drill line entry/exit points to mast	Mast Unit
45	Pad Eyes & sling to lift the rotary table	Mast Unit
46	Lifting points and sling to lift lower the rear floor plate	Mast Unit
47	Winch tie down on the mast for crown winch	Mast Unit
48	Guards for tong gauges	Mast Unit
49	Floor extensions around the tong pylons	Mast Unit
50	Remove hose clamps on hose near pylons	Mast Unit
51	Inspect/repair/replace tong cables	Mast Unit
52	Access panels in floor for tong line & hoses	Mast Unit
53	Permanent metal labels for all hose & electrical connections	All Units
54	Hose abrasion protection on lower part of floor	Mast Unit/All Units
55	Safety marking color around drill line	Mast Unit

56	Boots on tong cylinder	Mast Unit
57	Remote lubrication for crown sheaves	Mast Unit
58	Stabbing winch for tubing	Mast Unit
59	Environmental control for under floor	Mast Unit
60	Lifting eye or lug on gooseneck	Mast Unit
61	Winch cable routing as per OFS STD 13	All Trailers
62	Capacity to mechanically raise/lower the floor flap section	Mast Unit
63	Tie down system for the Traveling Block to the Injector	Mast Unit
64	Check and inspect the remote hydraulic actuated valve on the reel manifold	Mast Unit
65	M-8 pump on hydraulic reservoir	Mast Unit
66	Reel swap issues for clearance on hydraulic hoses on internal face of frame rails	Mast Unit
67	Safety marking color on elevators	Catwalk Trailer
68	Pipe inspection on tubulars	Catwalk Trailer
69	Safety marking color on hanging stairs	Catwalk Trailer
70	Access in tractor to Gen set	Mast Unit
71	Control Panel Knobs	Dog House
72	Leg Access	Dog House
73	Accumulator Volumes	Dog House
74	Operation and maintenance manuals	Dog House
75	Double barriers on BOP activation panel	Dog House
76	Crash guard on control panel windows	Dog House
77	Test and calibrate the gas detection system	Dog House
78	Overhead storage cabinets	Dog House
79	Ground cab link	Dog House
80	Liquid storage around the electrical systems	Dog House

9.2 Post rig-up safety audit

#	Description	Equipment
1	Check counterbalance valves on jacking legs.	
2	Add handrails on insides of doghouse doors with stairs.	
3	Make BOP operations two steps.	
4	Move BOP controls closer to other controls – only a nice-to-have.	
5	Protect the top glass in the cabin.	
6	Check welding on all handrails.	
7	Add a “No Heavy Storage” label to the overhead bins.	
8	Add a flammables box to the tool room.	
9	Replace air compressor with a tank-less unit.	
10	Manage the collocation of the mist pump fluid and electrical boxes.	
11	Identify fluid in mist pump tank.	
12	Procure a box for transporting heavy items like the dog-collars.	
13	Address hose chafe point near middle of deck.	
14	Run fireproof BOP hoses into doghouse.	
15	Develop procedure to lock out tool room door while running block.	
16	Check axle weight with 6500ft of 2.375in CT.	
17	Use aluminum on handrails and stairs were possible. Consider MC bolted parts.	
18	Add a bottom rung to the stairs for the wet kit.	
19	Add two sufficient handgrips on steps up to wet kit.	
20	Fix injector lube tank leak.	
21	Improve accessibility of injector lube tank.	
22	Cover 24vdc connections on injector lube tank pump.	
23	Address hose chafe point on blue hose below slip line drum.	
24	Develop procedure to lock out control boxes on mast while running from cabin.	
25	Lock out suction valves on mast wet kit.	
26	Lock out suction valves on catwalk wet kit (requires a different valve).	
27	Move heavy items from travel box under floor to on top of floor.	
28	Modify stairs to be OSHA compliant – Nikki H.	
29	Add handrail on stairs next to pipe tub controls.	
30	Label battery disconnects on catwalk.	
31	Add headache racks on tractors.	
32	Paint corners of Roughneck heater under floor yellow.	
33	Develop a method for handling drive plates.	
34	Add a walkway attached to the injector.	
35	Relocate grease fittings for reel to the non-pressure side at a reasonable height.	
36	Relocate hand pump for mast hydraulic fluid to a level accessible from the ground.	
37	Add grab handles to transition on to and off of the mast ladder.	

38	Relocate grease fittings for gooseneck to an accessible location.	
39	Relocate grease fittings for crown to an accessible location.	
40	Trace down cut wires on Roughneck heater under floor.	
41	Improve accessibility to battery box in front of reel.	
42	Check maintenance bulletin for PTO's and transfer cases.	
43	Add back up pump for stripper.	
44		

9.3 Safety Rig Modifications Performed

After the safety audits were performed each item was reviewed based on its severity and frequency of exposure. Items that resulted in a higher severity or exposure level were items that would be addressed if possible. Also items that could be easily rectified were also identified as they would take minimal time or effort to reduce the risk. The following table shows the tasks that were taken on and the mediation effort that was taken. Not all items identified during the safety audit were rectified. Items that were not rectified either had a severity level that was low or was not feasible to change due to design constraints of the equipment.

#	Safety Item	Mitigation Performed
1	Lifting of coiled tubing drum	Spreader bar purchased and lifting bars designed for reel
2	Pad eyes and sling to lift rotary table	Pad eyes and sling designed for floor removal during floor modification
3	Reel manifold non-integral iron with no traceability	Replaced internal and external reel manifold with FMC integral iron
4	Rotating machinery signs for reel and drawworks	Installed
5	Platform on front of injector for servicing	Designed platform and installed
6	Inspect/repair tong cables	Tong cables pulled for visual inspection
7	Access to generator from tractor	Platform created to access generator
8	Test and calibrate gas detection system	Done
9	Add headache racks to tractors	Done
10	Relocate hand pump on mast unit hydraulics to accessible ground level	Added electric pump to replace hand pump
11	Add pump for stripper	Modified stripper circuit on unit to allow for new stripper
12	Leveling equipment with remote display	Installed leveling sensors onto the rig with displays at the leveling jack control panel
13	Battery disconnect on tractor to protect the batteries	Done
14	Emergency lighting in control cabin	Installed emergency lights, which provide 15 min of lighting to safely move around cabin
15	Drawworks cover strength	Drawworks cover replaced with a stronger cover designed to support the

		weight of an operator
16	Distance from ground to first step on stairs	Installed stair extensions onto all stairs on mast unit
17	Drip pan for reel	Folding drip pan was made to catch drips from reel
18	Railing for pipe elevator tub	Hand railings with kick plates were manufactured and installed on pipe rack
19	Hand rails on mast unit	Hand railing were manufactured for mast unit were not existing
20	Repair Aluminum stairs	Stairs welded and repaired
21	Tie down for crown block onto injector	Crown block traveling bars modified and reinstalled such that crown block is engaged with the mast.
22	Wiring under console loose	Wiring straightened out and re-loomed
23	Add hand rail for access to the stairs accessing wet kit on tractor	Done
24	Add bolt in support bar for printer shelves	Done
25	Safety Color on Gooseneck rest	Done
26	Safety Color on elevation changes on mast unit deck	Installed florescent tape to illuminate transition
27	Flammables box	Installed in BOP control room
28	Repair heater mount on pipe trailer	Repaired cracking mount and installed reinforcements for mount
29	Move heavy items from belly box's to more accessible location	Done
30	Check counter balance valves on jacking legs	Done, confirmed all valves are holding
31	MSDS	Created MSDS inventory of all fluids on rig
32	Lock out suction valves from being closed	Done
33	Update first aide kit	Done
34	Order new slings and lifting gear to replace worn out lifting gear	Done
35	Modify cabin to allow for leg room under control console	Done, Removed doors and bottom kick plate to allow chair to be pulled up to console

36	Winch controls	Color coded winch controls to prevent wrong controls from being used
37	Reinforce reel drive holes on drums	Done, Added plates to strengthen drive holes on drums when pipe is spooled onto drum
38	Relocate grease fittings for gooseneck to an accessible location	Grease fittings can be accessed when mast is down
40	Address hose chafe point on blue hose below slip line drum	Coved and re-routed to clear cable
41	Drain holes beside/ between the tong pylons	Drilled drain holes
42	Remove fall arrestor pull down line security post	Removed
43	Chock Blocks for all trucks	Done
44	Fix external PA speaker	Done
45	Access to WH/BOP area during operations	Removable floor to be designed
46	Manage the co-location of the mist pump fluid and electrical boxes	Mist pump removed from electrical room

10 Safety/Efficiency Improvements

10.1 Floor Modification

It was determined that one major way to improve the efficiency of the MCTR unit was to make the drill floor easily removable. The reasoning behind this decision was based on the fact that the pipe handling trailer needed to be rigged off the well if the BOP stack needed to be changed out. It can be seen from the figure below that the access to the well bay is to small to easily pass a large BOP thru.

It was decided to modify the floor such that it keyed into saddles connected to the mast structure utilizing the original mounting holes. This new keyed saddle mount would allow the floor to be lifted straight up using the blocks and set onto the top of the pipe handling trailer. Once the floor is removed there is plenty of access to the well bay to perform any required operation.

The modification of the floor required that the floor be stiffened as it no longer could rely on the mast to obtain some of its rigidity. New support brackets (saddles) needed to be made to support the floor structure. The floor ends needed to be modified to accept the new support brackets and a retaining plate needed to be created. The retaining plate is needed to prevent the floor from falling out of its support bracket when the mast is lowered. Lifting points were also added to the floor for ease of removal.

The floor was fully load tested after all of the modifications were complete to verify that the new floor design could with stand the necessary loads as designed. The load test was successful and the figures below show how the load test was performed.

Figure 10-1 Access to well bay area

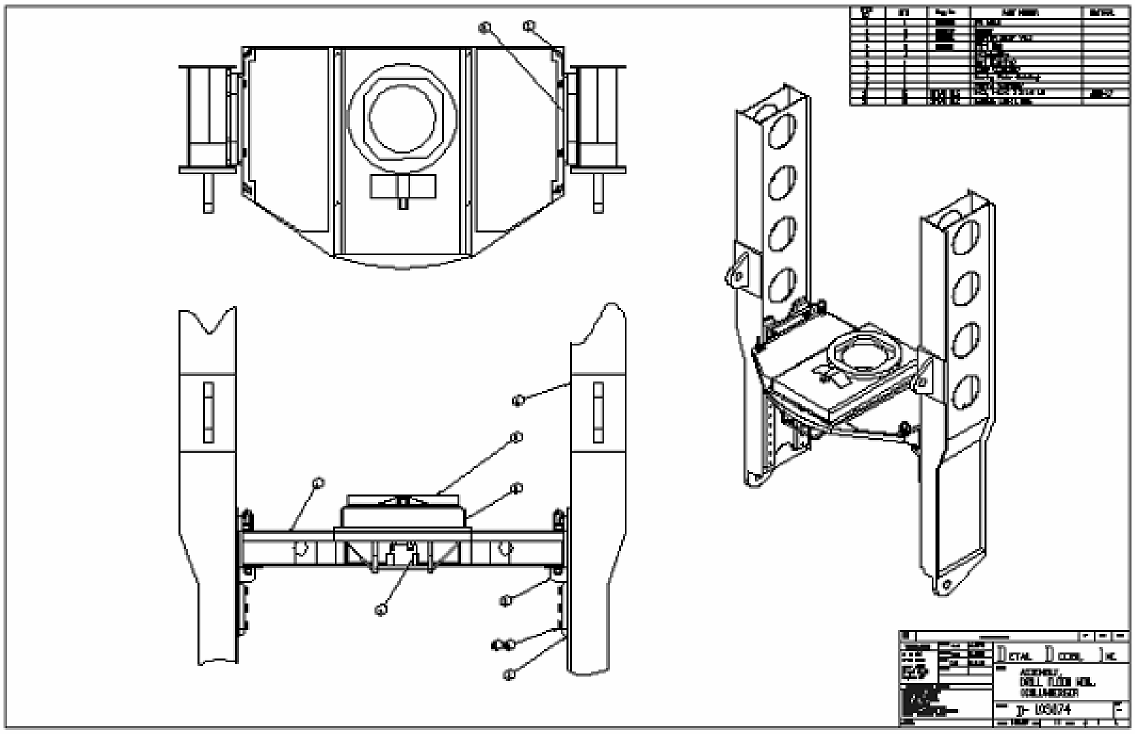


Figure 10-2 Floor modification drawing

Figure 10-3 Floor modification load test

Figure 10-4 Floor modification load test cont'd

Figure 10-5 Floor being removed with blocks

10.2 Reel Swivel Modification

The MCTR rig originally came equipped with a chiksan as a swivel for the coiled tubing reel. Chiksans are treating iron created such that treating iron can make bends as needed in order to connect it properly. The design of a chiksan is such that it can rotate freely when no pressure is applied with little to no wear occurring on the seals or races that hold the chiksan together. A chiksan was not designed to rotate under pressure with no damage occurring to the races or seals. Because of the low pressure the MCTR rig was being used at originally it was assumed that a chiksan would be sufficient. It was realized that for this project that the treating pressures thru 2-3/8" coiled tubing would be much higher than that pumped thru a much shorter 3-1/2" coiled tubing string. A chiksan would not be safe to operate under the expected pressures continually rotating.

A high pressure coiled tubing swivel was selected to be used as a replacement for the chiksan. The coiled tubing swivel is rated for continues rotation at 10,000 psi with a 3" full bore thru the swivel. In order to perform the modification a new reel center shaft needed to be designed to interface with the new swivel. The figures below show how the reel swivel and manifold look before and after the modification.

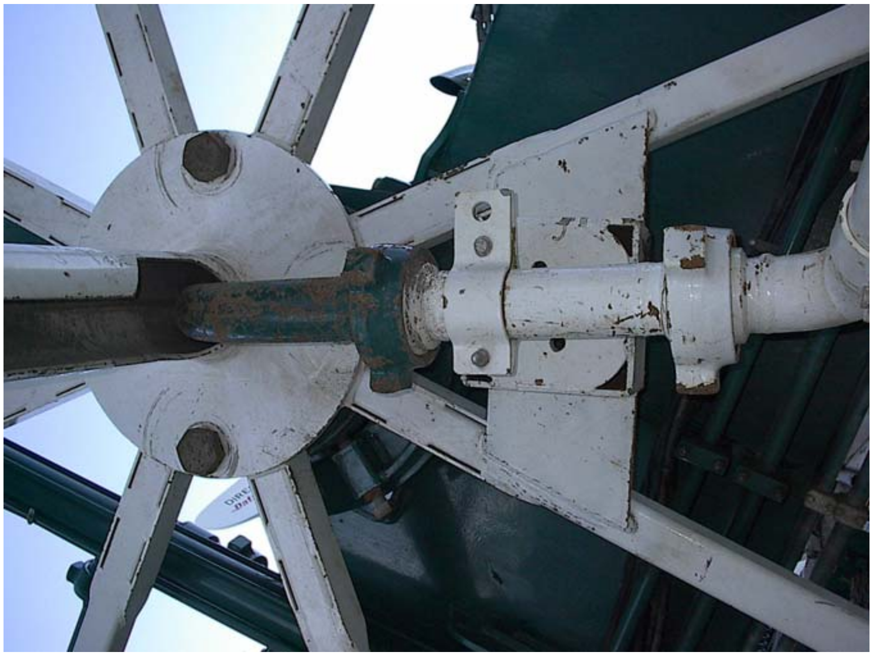


Figure 10-6 Showing original reel center shaft, which connected to external swivel treating iron

Figure 10-7 Coiled Tubing Reel prior to modifying reel swivel and manifold

Figure 10-8 New manifold with swivel folded for transport

Figure 10-9 New external reel manifold with swivel assembled ready for job

10.3 Drawworks Cover Modification

The drawworks cover was modified to support the weight of an operator as the original drawworks cover was used heavily as a work platform by the original crew and was starting to take damage as it was not originally designed to have people standing on it. The new drawworks cover is made out of a heavy expanded metal cover that replaces the original aluminum expanded metal cover.

Figure 10-10   Original drawworks cover prior to modification

Figure 10-11   New drawworks cover with reinforced grating

10.4 Stair/Hand Rail/Work Platform Modifications

From our safety audit the team identified several areas that could be improved by adding hand rails, work platforms or extending stairs. Below are figures that show some of the before and after pictures of the modifications performed. Not all of the modifications have been shown, but the figures below are a representative sample of what was done.

Figure 10-12 Pipe trailer prior to addition of hand rails

Figure 10-13 Addition of hand rails to pipe trailer

Figure 10-14 Rig stairs prior to adding additional step to reduce distance to ground

Figure 10-15 Shows location of work platform added to injector for ease of maintenance

Figure 10-16   Work platform added to generator

10.5 Gas Detectors

Gas detectors were already in existence on the rig, but were not functioning properly. We brought out the manufacture of the gas detectors to repair the system. The manufacture reviewed the installation and found that the installation would not work properly with the sensors that were being used. After much debate it was determined that the best course of action was to rewire the sensors as per the manufactures specification rather than replace the entire system. Once the system was rewired the gas detection system was calibrated and tested successfully.

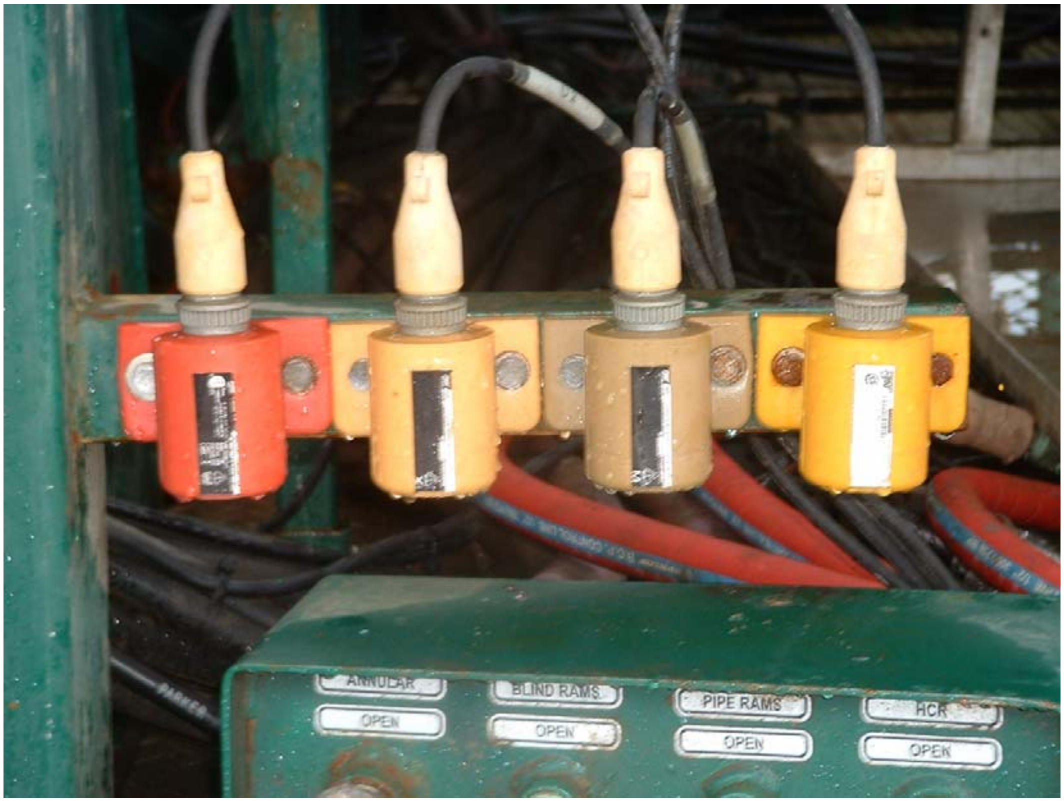


Figure 10-17 Gas detector sensors mounted under floor in well bay

Figure 10-18   Gas detector display with emergency stop

10.6 BOP Control Panel

The original BOP panel was a SEMENS touch panel. This touch panel was programmed for control of an annular preventor, HCR valve, and a spare control valve. These controls were not sufficient for the BOP stack that was proposed for the MCTR unit and would therefore need to be changed. We evaluated having the panel reprogrammed for the new stack, but found that the wiring to the panel and from the SIEMANS modules was very intermittent. Several days were spent trying to trace the intermittent problem with the SIEMANS system wiring and it was finally determined that it would be much faster to pull the system and replace it with a panel that controlled the accumulator system directly.

The new panel designed shows a diagram of the actual BOP stack used and provides double lock out controls to prevent accidental actuation of the BOP circuit. Each ram has an arming switch that isolates the power to actuate the BOP circuit. When the arming switch is turned on a red light appears on the panel indicating that circuit is hot. A separate switch is then used to close or open that specific circuit. The status of the circuit is then indicated by a green light. The green light remains on as long as the circuit is activated even if the arming switch is turned off. This allows the operator to visually see the status of the BOP stack.

Digital pressure read outs were installed to show the status of the accumulator pressure, main hydraulic pressure, and the air pressure for valve actuation.

Figure 10-19 Original Main BOP Control Panel

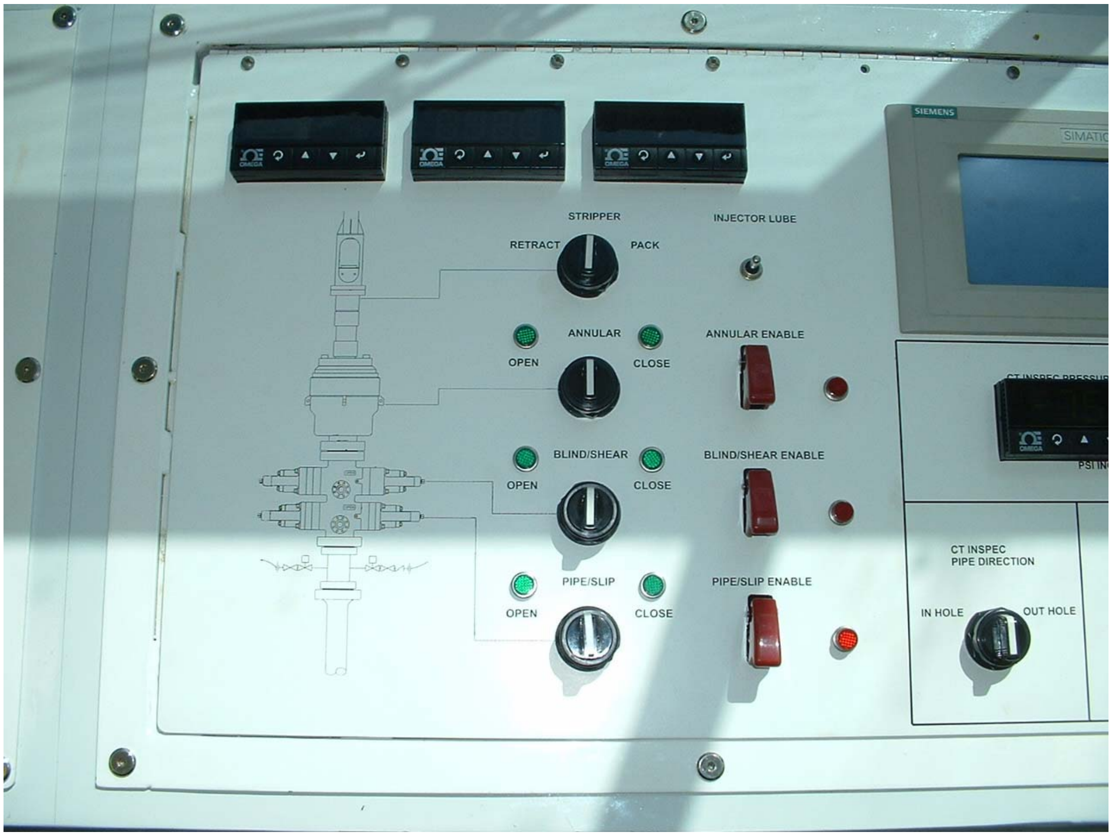


Figure 10-20 New BOP Control panel, which shows standard BOP configuration

10.7 Roll Bar installation

Figure 10-21 Pipe handling tractor prior to addition of roll bar

Figure 10-22 Pipe handling tractor after installing roll bar

Figure 10-23 Mast unit tractor prior to adding roll bar

Figure 10-24 Mast unit tractor after installing roll bar

Figure 10-25 Control cabin tractor prior to installation of roll bar

Figure 10-26 Control cabin tractor after installing roll bar

11 Lubricator and tool deployment

11.1 Tool deployment background

As part of the microhole initiative a requirement was made that the coiled tubing unit be capable of drilling underbalanced. In order for a coiled tubing unit to drill underbalanced it must have the ability to deploy its tool string against wellhead pressure and to drill with positive wellhead pressure. Many grass roots coiled tubing drilling rigs were designed to drill over balanced. These rigs were not equipped with lubricator systems that would allow a tool string to be deployed under pressure. They also do not provide a lubricator system that allows the well to be drilled under pressure.

11.2 Evolution 1 original lubricator system

The Evolution 1 coiled tubing drilling rig was a grass roots coiled tubing drilling rig designed to drill over balanced or with minimal wellhead pressure. The original lubricator system was created using line pipe and an air bladder to form a low pressure seal between the two sections of line pipe. The line pipe was connected to the top of the annular with another low pressure seal. These seals are only good for minimal pressure and are mainly used for containment of fluids that are stripped off of the coiled tubing when pulling out of hole.

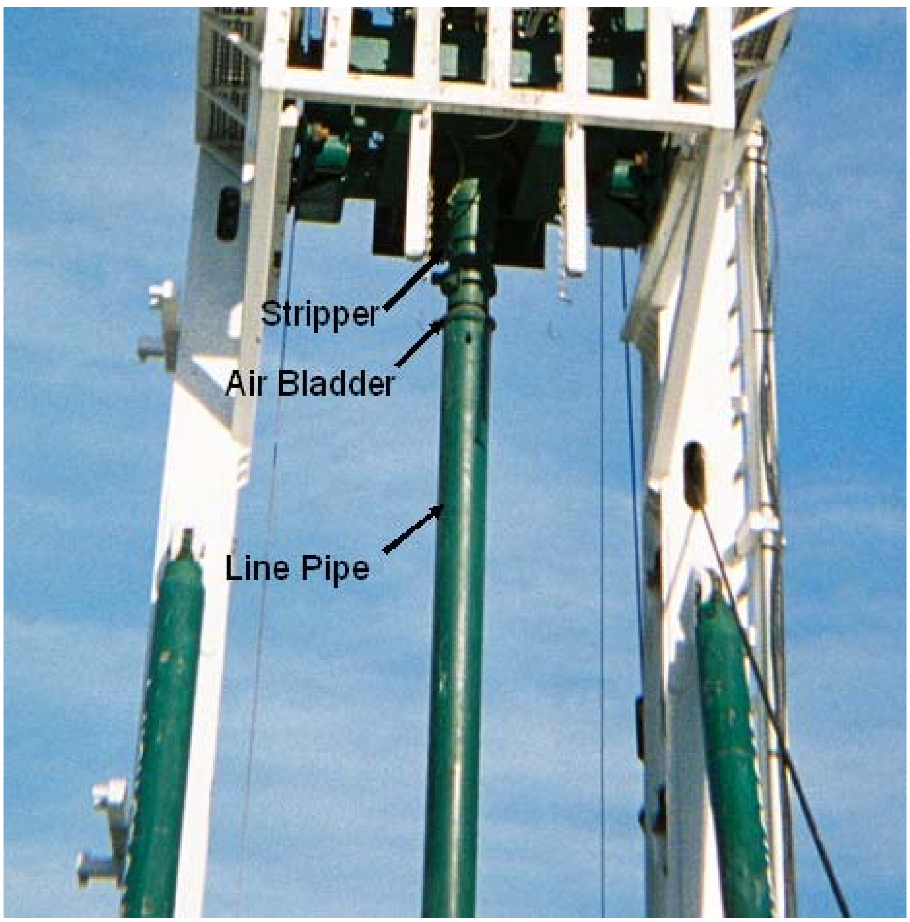


Figure 11-1 Original lubricator system

Figure 11-2 Annular with air bladder seal ring

11.3 Telescoping Anti-Buckling Guide

On normal coiled tubing operations the coiled tubing injector is placed directly on the well control stack. What this means that there is a positive pressure barrier from the wellhead through the blow out preventors to the bottom of the injector head, where the coiled tubing stripper is normally installed. Rigged lubricator sections are generally installed as needed to hide the bottomhole assembly (BHA) until the wellhead is opened and the coiled tubing is run into the well. Recently telescoping lubricators have been developed that allow injectors at fixed heights to connect and disconnect from wellheads while deploying tools. Telescoping lubricators have been used successfully on many operations, but they require good periodic maintenance to insure that the seals are in good condition and capable of holding pressure.

As means of utilizing a telescoping lubricator that would not require the maintenance of a typical telescoping lubricator a telescoping anti-buckling guide was proposed. A telescoping anti-buckling guide inserts between the injector and the coiled tubing stripper. This allows the stripper to move be connected and disconnected from the BOP stack allowing tools to be deployed. It also places the stripper directly on the BOP stack allowing for full wellhead pressure integrity. Because all the wellhead pressure is contained below the stripper the telescoping anti-buckling guide does not require any sealing mechanism. The removal of the sealing mechanism reduces the cost of manufacturing and reduces the maintenance required to sustain the telescoping anti-buckling guide.

From the name telescoping anti-buckling guide it can be ascertained that the guide has two functions. Telescope allowing the connection and disconnection from the BOP stack with out moving the injector head vertically and provide buckling support to the coiled tubing as it travels from the injector to the stripper. Another benefit of the telescoping anti-buckling guide is that it puts the stripper at a workable height making it easier to change packing elements.

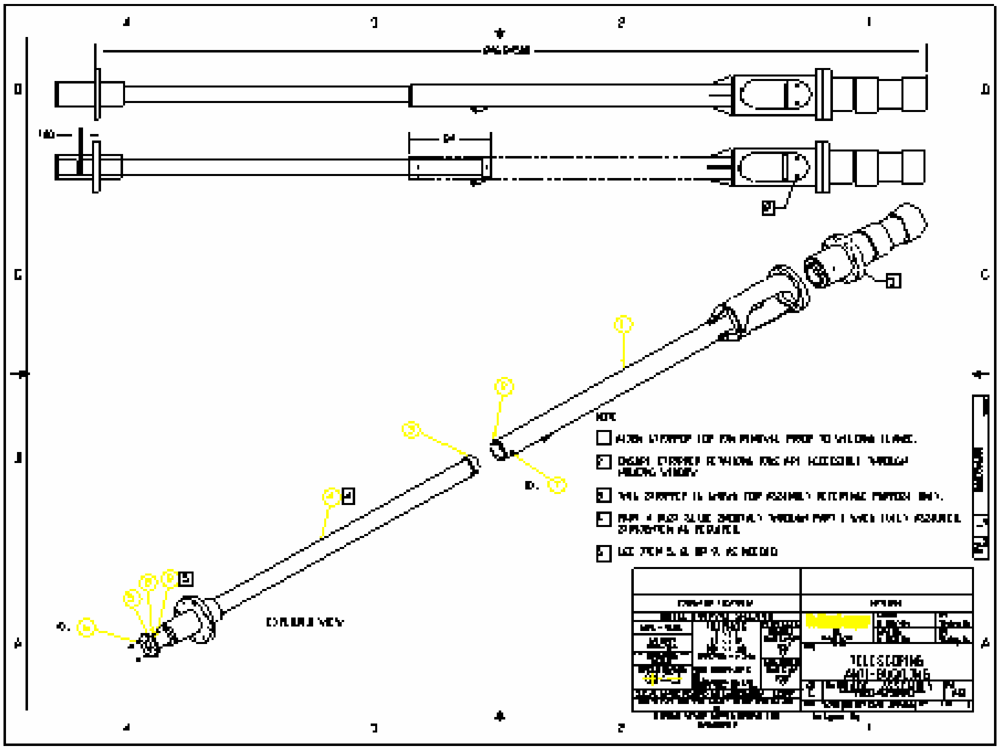


Figure 11-3 Telescoping Anti-buckling Guide

Figure 11-4 Installation of Telecoping Anti-Buckling Guide

Figure 11-5 Connecting Telescoping Anti-Buckling Guide to Lubricator

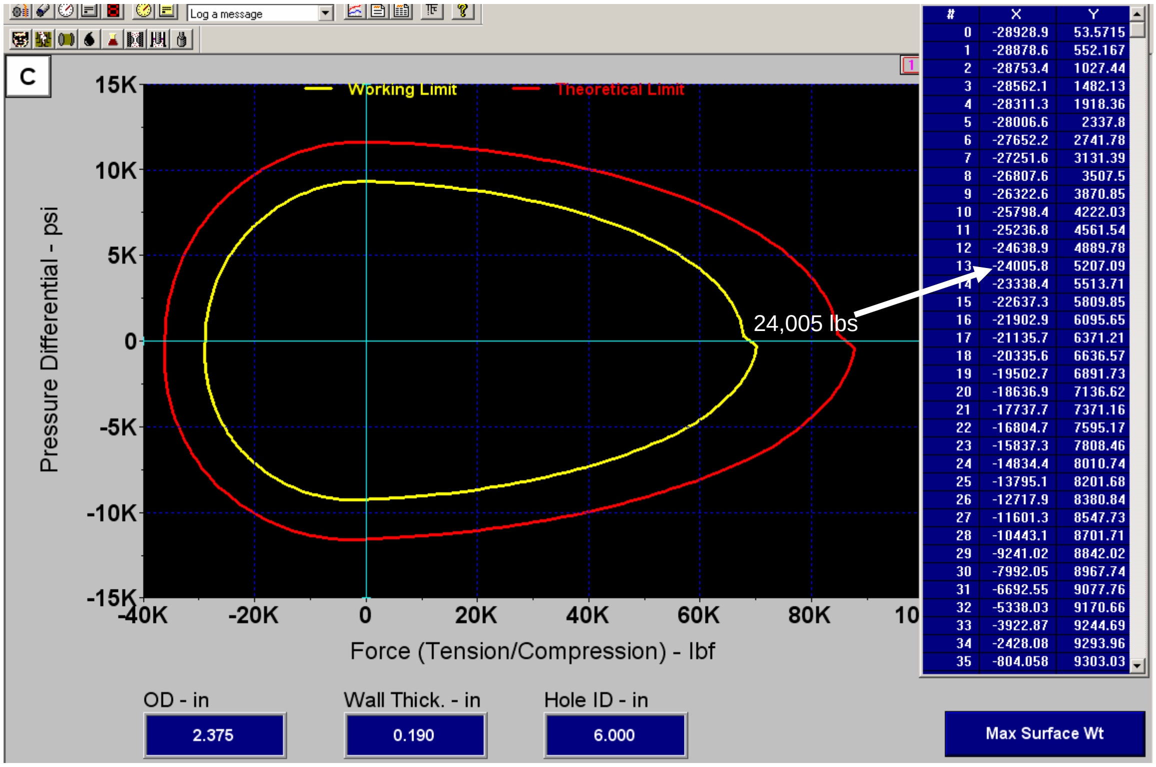
Figure 11-6 Connecting Telescoping Anti-Buckling Guide to Lubricator Cont'd

Figure 11-7 Connecting Telescoping Anti-Buckling Guide to Lubricator Cont'd

11.4 Telescoping Anti-buckling guide analysis

An analysis was performed to identify if there is any issue related to the telescoping anti-buckling guides capacity to support the coiled tubing buckling force when snubbing unto a well with 5,000 psi at surface. The analysis started with taking CoilCat, which is our standard coiled tubing modeling software for determining coiled tubing forces within a wellbore. A model was created within CoilCat to simulate the anti-buckling guide. This model was then run for 2-3/8" and 3-1/2" coiled tubing to determine the maximum snubbing force available at a wellhead pressure of 5,000 psi. The maximum allowable snubbing force was then used to determine a maximum force exerted onto the telescoping guide by looking at the angle created by one cycle of the coiled tubing buckling. It was found that the maximum force exerted on the telescoping anti-buckling guide was created by the 3-1/2" coiled tubing and was in the order of 800 lbs. This value was then used to determine the stress in the smaller upper telescoping guide along with its deflection. As a conservative measure the larger lower guide was not included in the analysis as it would provide additional stiffness to our model. Our analysis shows that the stress and deflection in the smaller upper telescoping guide section is within allowable limits without the additional support provided by the lower telescoping guide section.

2-3/8” HS70 0.190 Wall Coiled Tubing



Cross Sectional Area = 4.28 in^2
Stripper Friction Force = 2000 lbs
Available CT Force = 24005 lbs – 2000 lbs = 22005 lbs

Maximum Allowable WHP = 22005 lbs/4.28 in^2
= 5141 psi

Figure 11-8 Working limit for 2-3/8” Coiled Tubing within upper buckling guide

2-3/8” HS70 0.190 Wall Coiled Tubing Buckling at Stripper

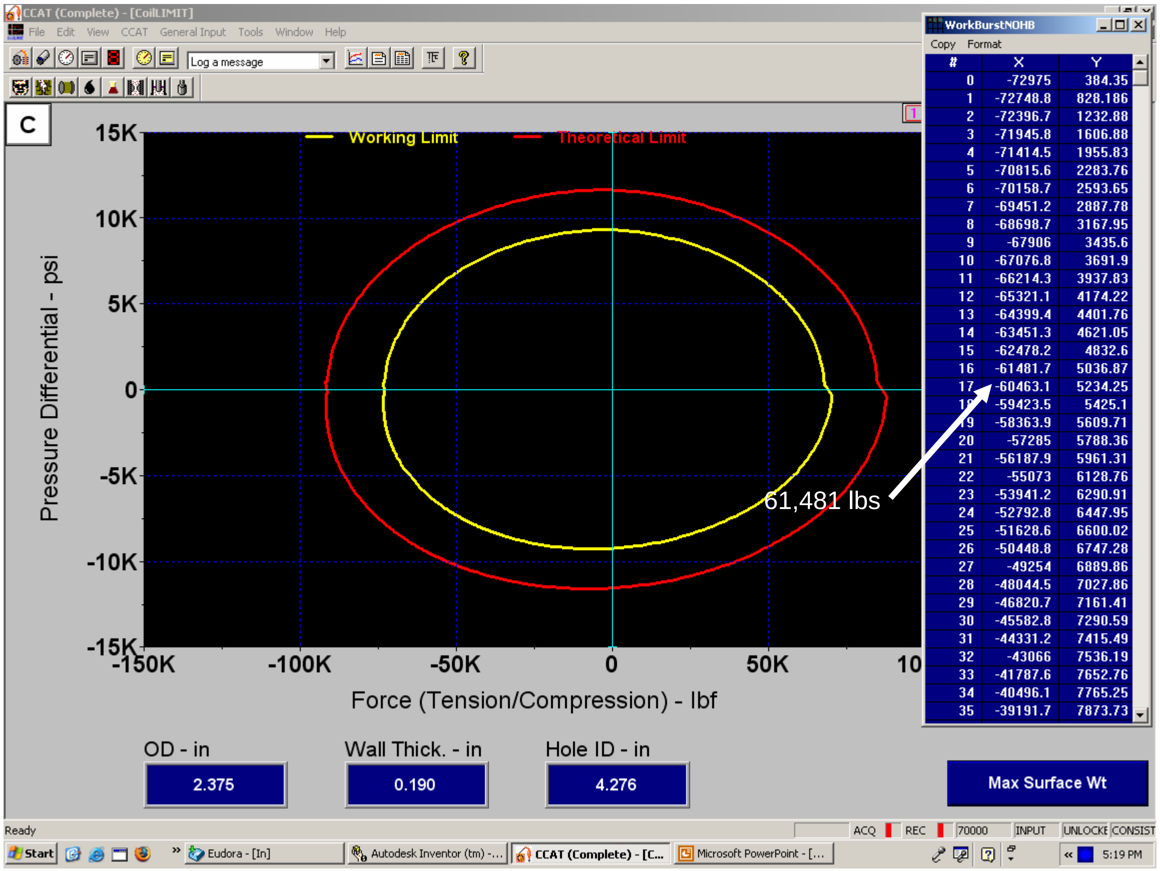
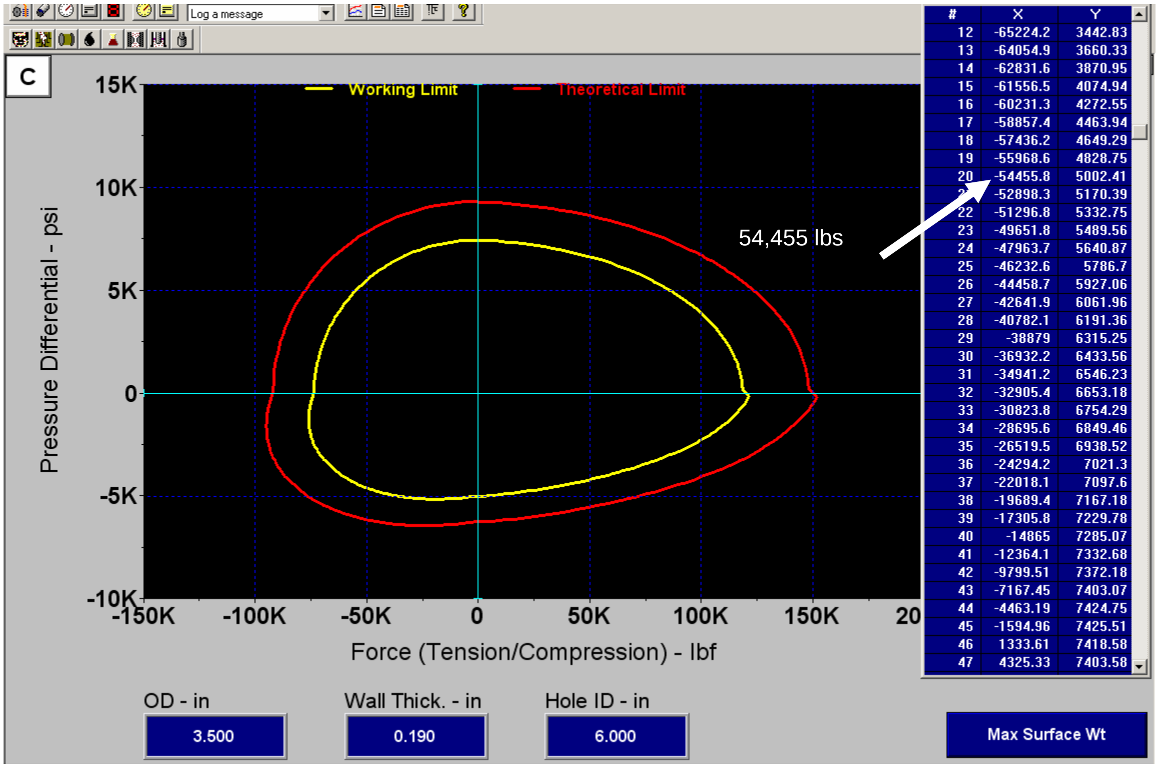


Figure 11-9 Working limit of 2-3/8” Coiled Tubing fully supported by stripper

3-1/2” HS80 0.190 Wall Coiled Tubing



Cross Sectional Area = 9.62 in^2
Stripper Friction Force = 2000 lbs
Available CT Force = 54455 lbs – 2000 lbs = 52455 lbs

Maximum Allowable WHP = 52455 lbs/9.62 in^2
= 5452 psi

Figure 11-10 Working Limit 3-1/2” Coiled Tubing within upper buckling guide

3-1/2" HS80 0.190 Wall Coiled Tubing   Buckling at Stripper

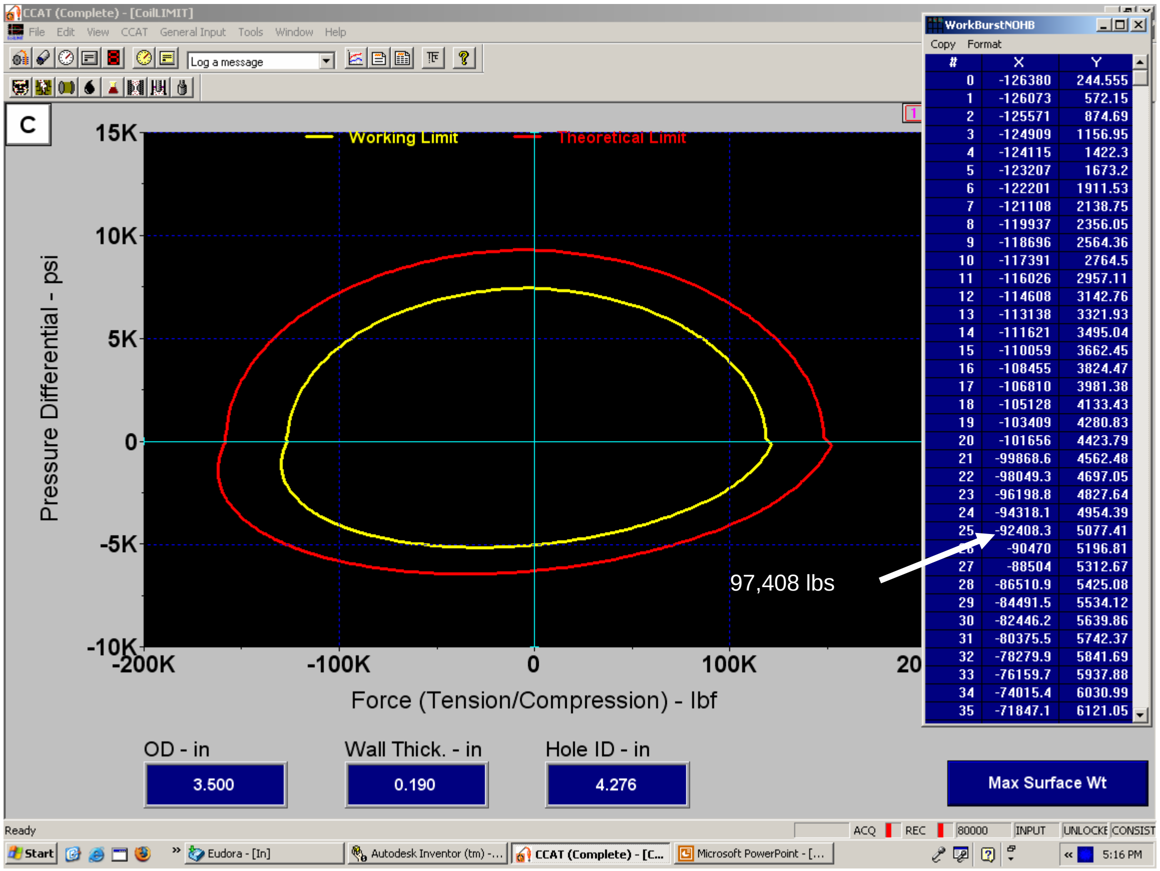


Figure 11-11   Working limit with 3-1/2" coiled tubing fully supported by stripper

Angle of Coiled Tubing in Telescoping Guide one Cycle

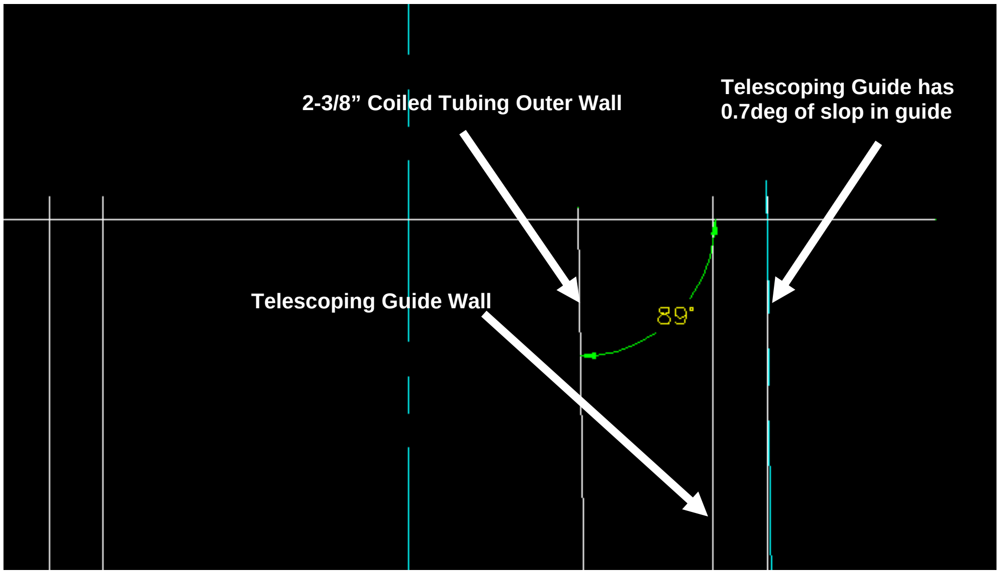
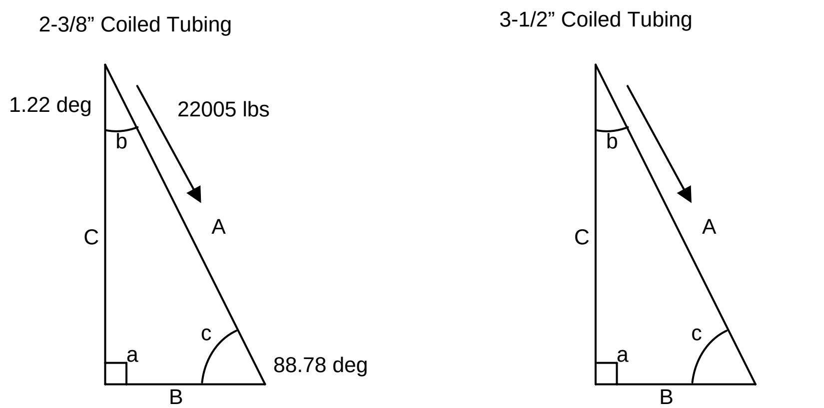


Figure 11-12 Diagram of angle created by coiled tubing within upper telescoping guide

Horizontal Component of Coiled Tubing Snubbing Force on Telescoping Guide



$$\frac{22005}{\text{SIN } 90} = \frac{B}{\text{SIN } 1.22}$$

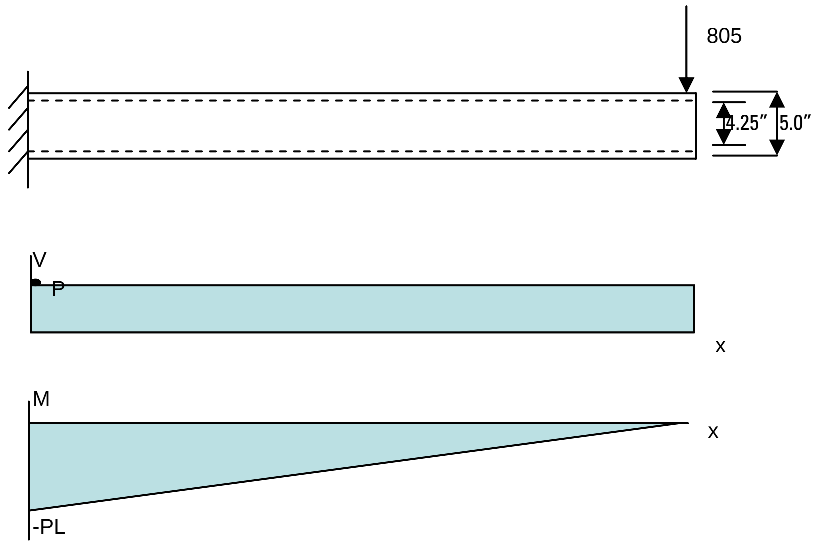
B= 468 lbs

$$\frac{52455}{\text{SIN } 90} = \frac{B}{\text{SIN } .88}$$

B= 805 lbs

Figure 11-13 Calculation of horizontal reaction force of upper telescoping guide to support coiled tubing buckling load

Max Stress on Upper Tube

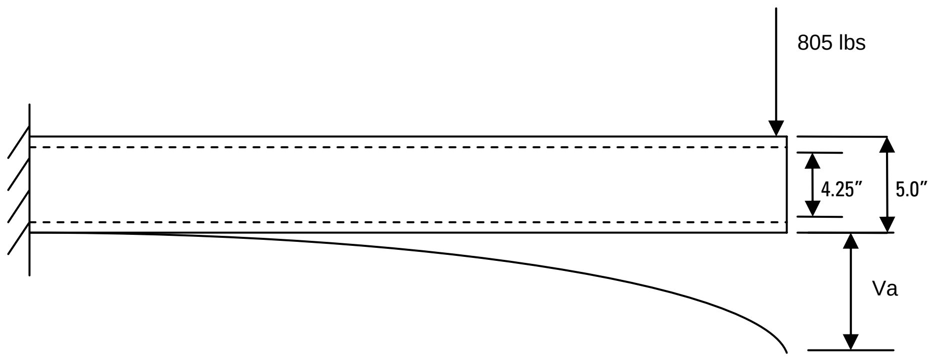


M max = 805 lbs x 151 in = 121.5 k in*lbs

$$\sigma_{max} = \frac{Mc}{I} = 20.7 \text{ ksi}$$

Figure 11-14 Calculation of stress on upper anti-buckling guide

Deflection of Upper Tube



$$Va = -\frac{PL^3}{3EI}$$

I = 14.64
P = 805
L = 151 in
E = 29×10^3 ksi

$$Va = \frac{0.805 \text{ Kip} \times 151^3}{3 \times (29 \times 10^3 \text{ ksi}) \times 14.64}$$

Va = 2.18 in

Figure 11-15 Calculation of deflection of upper anti-buckling guide

11.5 Slickline deployment technique

For this project we elected to adapt the MCTR rig such that slickline deployment techniques could be used. Slickline deployment has been used successfully for many years to deploy long tool strings into wells under pressure. Essentially slickline deployment uses a slickline lubricator, sheave wheel, grease head or stuffing box and a winch to deploy coiled tubing tools into a well.

Slickline deployment begins by assembling a lubricator section together horizontally with the sheave wheel and stuffing box on top. Slickline cable is pulled from a slickline winch mounted on the lubricator and is feed over the sheave wheel and thru the stuffing box. The slickline cable is then pulled all the way through the lubricator until it is pulled out the other end. At this time a slickline connector to coiled tubing cross-over is made up and the coiled tubing BHA is made up in sections. The first section to be made up is a kelly cock valve which provides wellbore isolation thru the tool when deployed. The next section to be made up is the deployment bar which provides a profile for the deployment BOP to set on and create an annular seal. The remaining BHA is made up below the deployment bar. If multiple sections are to be deployed the BHA is made up starting at the bottom of the BHA working upward towards the coiled tubing connector.

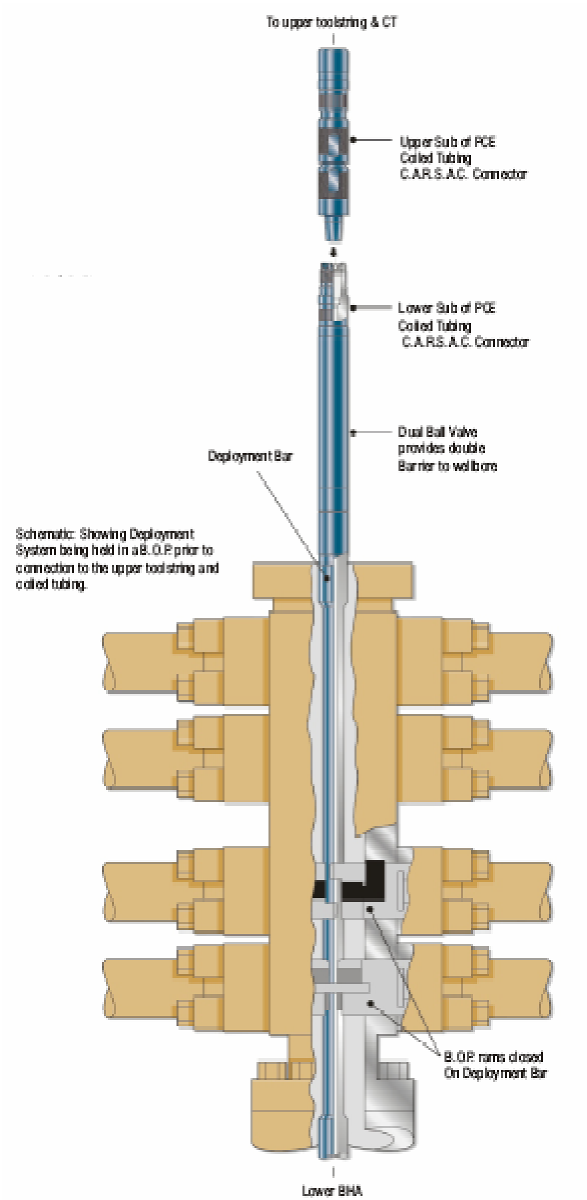


Figure 11-16 Diagram from PCE showing their deployment tools being deployed

Our slickline deployment lubricator was modeled off of the slickline deployment lubricator that Schlumberger has used successfully in Sharjah. Below is the diagram of the slickline deployment lubricator that is used in Sharjah. The main difference between the Sharjah lubricator and the lubricator used for the MCTR project is that the Sharjah lubricator uses a pressurized sheave wheel and grease head, where the MCTR rig uses an open sheave wheel and stuffing box. A stuffing box is used for solid wire, where a grease head is used for braided line. It was determined that for our application 0.125 wire would be acceptable. For BHA loads greater than 2000 lbs braided line should be used for the added strength. Based on the work scope for the MCTR rig we anticipated a BHA weight in the order of 1,600 lbs. An additional change in the layout is that the MCTR lubricator had the winch located in the center of the lubricator which allowed the lubricator to pass unobstructed up the v-door when lifted with the elevators.

The MCTR deployment lubricator set-up is 50 ft long and capable of deploying 45 ft of BHA at a time. The lubricator was constructed from

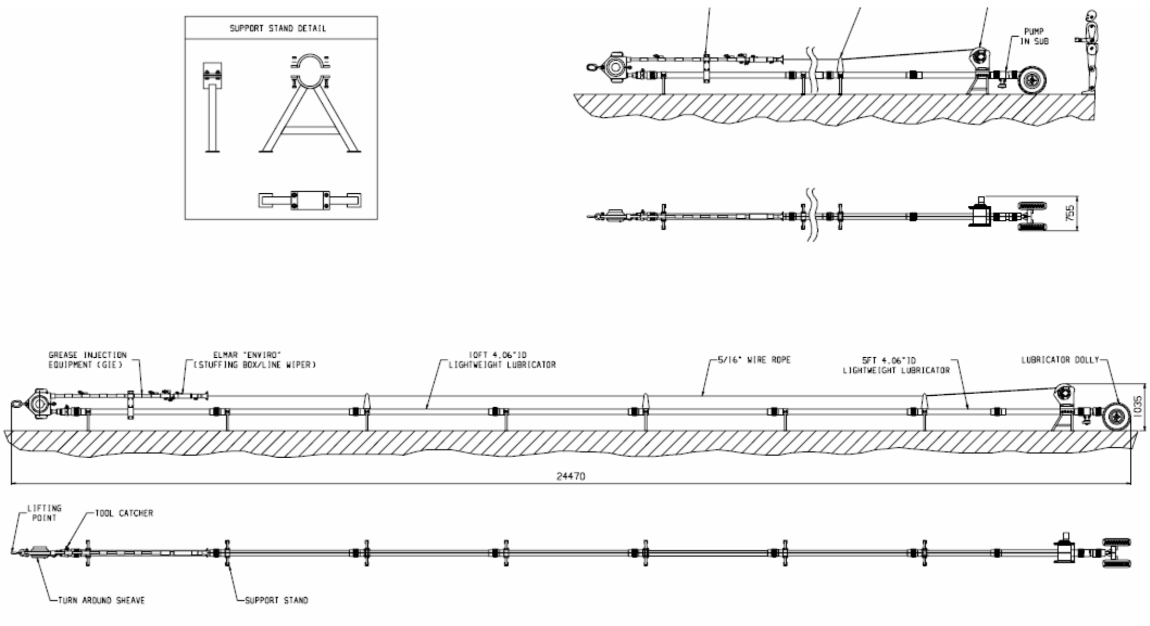


Figure 11-17 Sharjah slickline deployment lubricator diagram

Figure 11-18 Slickline lubricator and deployment bar

Figure 11-19 Demonstration of one type of non-rotational joint for connecting coiled tubing to the bottom hole assembly

Figure 11-20 Assembling slickline lubricator on pipe trailer

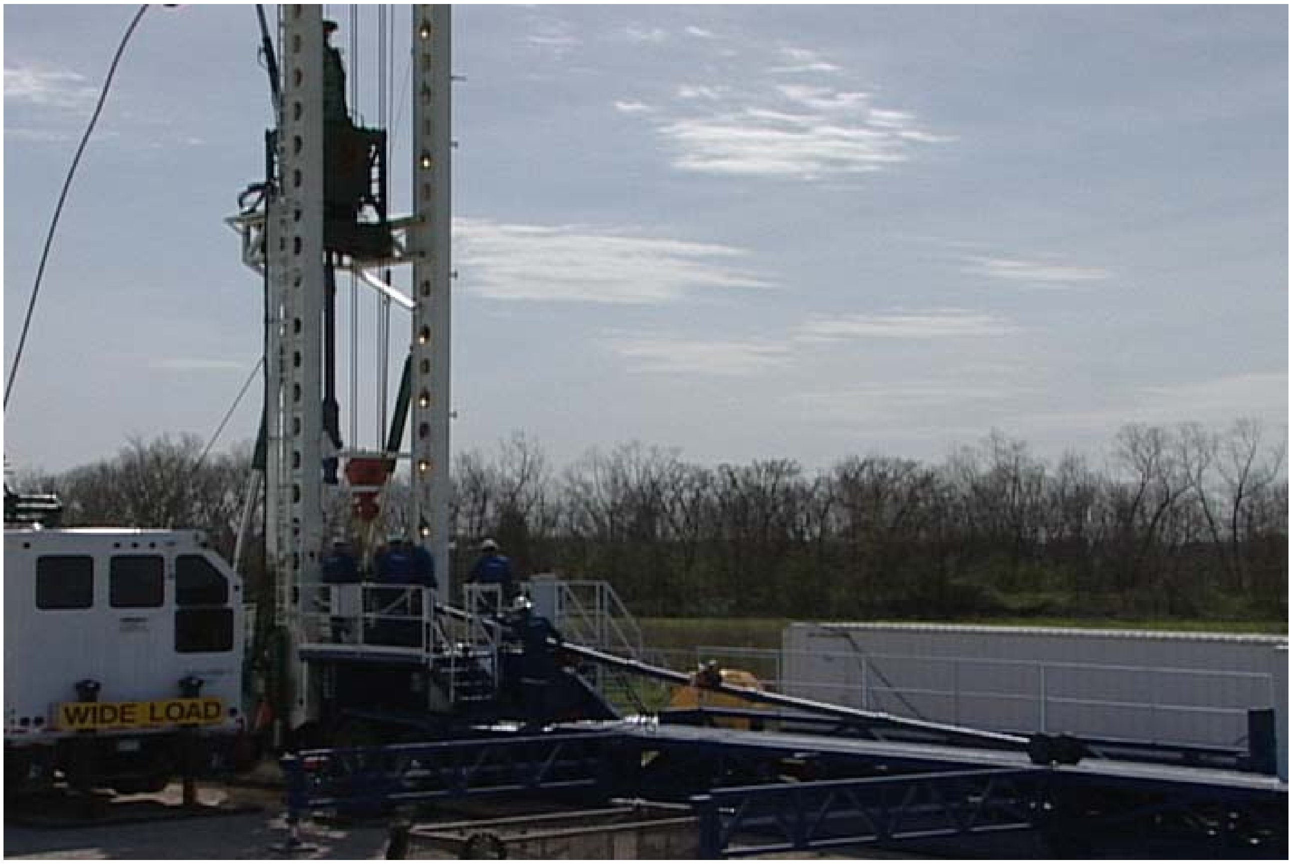


Figure 11-21 Raising slickline lubricator into derrick

Figure 11-22 Raising slickline lubricator into derrick cont'd

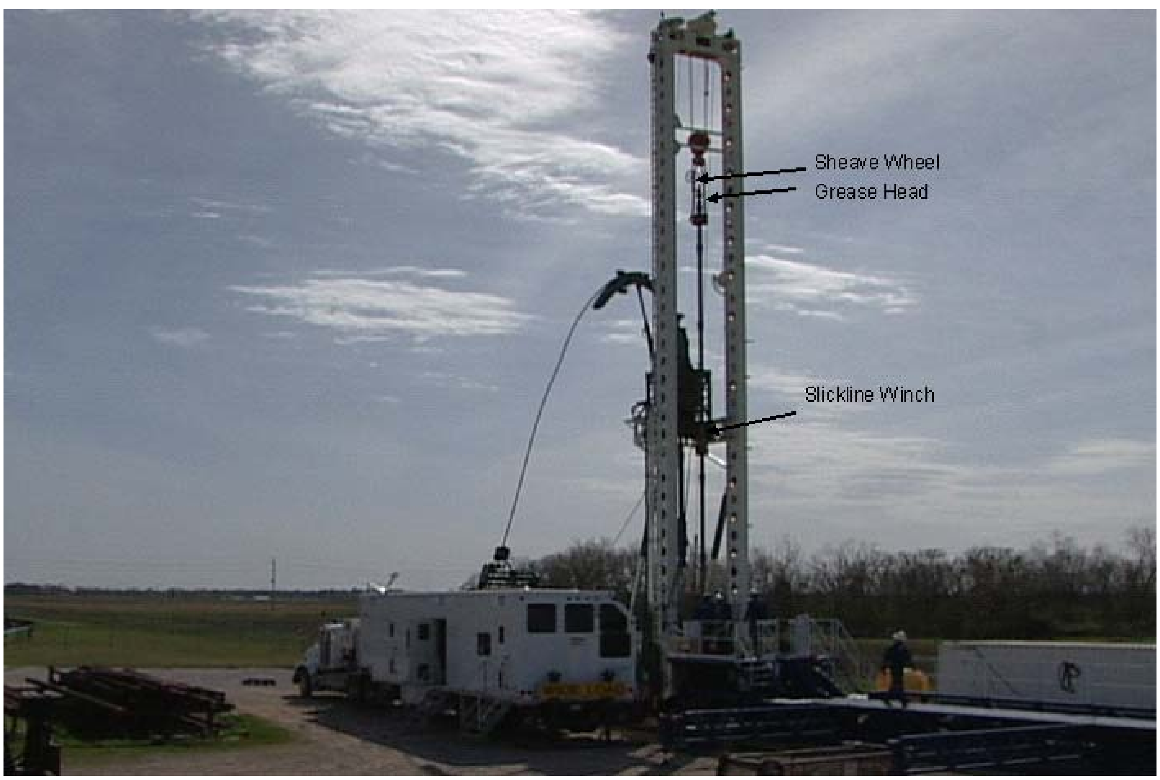


Figure 11-23 Slickline lubricator raised into derrick

11.5.1 Pressure Deployment

STEP	Procedure	Details
1	Measure tools string.	
2	Pick up required lubricator.	
3	Make up crossover.	Cross over from slick line tool string to deployment bar on first section of tools.
4	Install tools.	Pull tools into lubricator and position lubricator over CT BOP.
5	Make up lubricator.	Connect lubricator to CT BOP and bump tool string up against stuffing box.
6	Zero counter.	
7	Confirm RIH depth.	Confirm RIH depth against measurements to ensure deployment bar is placed across pipe rams and slips, leaving enough of the bar above the BOPs to make up and break out the tool string.
8	Slowly open swab valve.	This equalizes the wellbore pressure in the lubricator. **Caution: Opening the swab valve too fast can blow wireline tools up hole and result in breaking the wire line and dropping the tools.**
9	Run tools into wellbore determined depth.	
10	Close pipe and slip rams on deployment bar.	
11	Pull test against slips.	
12	Bleed pressure off lubricator.	
13	Carefully raise lubricator.	Expose deployment bar and break out.
14	Repeat Step 7 through Step 13 for additional segments.	

11.5.2 Deploying Injector

STEP	Procedure	Details
1	Pick up injector and required length of lubricator to cover remaining segment of tool string.	
2	Attach remaining tools to deployment bar.	Record weight-indicator weight before connecting to deployment bar.
3	Strip lubricator over tool string and make up lubricator to BOP.	
4	Ensure all injector settings are reset for running in hole.	Reset inside chain tension to prevent ejection from well.
5	Open slip rams.	

6	Open pipe rams.	Open equalizing port on BOP to prevent damage to pipe ram seals.
7	Zero counter.	Zero counter and POOH to tag stripper. Record distance for reference when reverse deployment is performed.

11.5.3 Lay Down Procedure (Underbalanced Procedure)

STEP	Procedure	Details
1	POOH until connector tags stripper.	Do not exceed weak point when tagging if e-line is used.
2	Zero counter.	RIH to pre-recorded depth in coiled tubing deployment procedure.
3	Close slip rams on deployment bar.	Visually verify closure.
4	Bled pressure off above pipe rams.	Ensure rams are not leaking before proceeding.
5	Strip lubricator up to expose deployment bar.	
6	Break connection at deployment bar.	Watch for trapped pressure.
7	Lay down tools and rig off injector.	
8	Move in deployment lubricator.	
9	Make up crossover to slickline tools.	
10	Make up lubricator and pressure test.	
11	Equalize pressure below tubing rams into lubricator.	
12	Pull test connector.	
13	Open rams.	
14	Pull up hole until tool string tags stuffing box.	
15	RIH to recorded depth.	Recorded depth in Step 7 of deployment procedure.
16	Close pipe and slip rams on deployment bar.	Check that slips are holding by slacking off weight.
17	Bleed pressure off lubricator.	
18	Break off lubricator to expose connection.	
19	Repeat Step 9 through Step 12.	
20	Once all tools are clear of swab valve, close the valve.	
21	Bleed off lubricator, lay down tools.	

12 Process Control and Data Acquisition

The Evolution 1 system is an electric over hydraulic control system, which is well suited to be adapted with current process control and data acquisition equipment available. The installation of this equipment required some modifications to insure that the new hardware interfaced properly with the existing control and monitoring systems. Some of the issues were proper sensor signal levels and the installation of sensors not currently installed on the unit.

After performing these necessary changes Schlumberger was able to install CoilCat 7, which is Schlumberger's state of the art data acquisition system. CoilCat 7 not only records all the parameters that take place on the wellsite, but it provides design capabilities and modeling software that can be used to optimize the job real time and perform force predictions to prevent coiled tubing damage. The installation of CoilCat 7 allowed us to install CT Inspect, which monitors coiled tubing wall thickness and helps aid in predicting coiled tubing pipe failures before they happen.

Another component installed is CoilSaver, which monitors pipe load and will stop injector movement prior to any damage to the well or coiled tubing from occurring.

Below are figures showing the install of the ColiCAT system and related hardware. Also provided below is a treatment report created after running coiled tubing on the test well in Rosharon, Texas. The test report shows some of the information that can be gathered during and operation and recorded for later review

12.1 CoilCAT acquisition system

Figure 12-1 CoilCAT real time monitor for operator

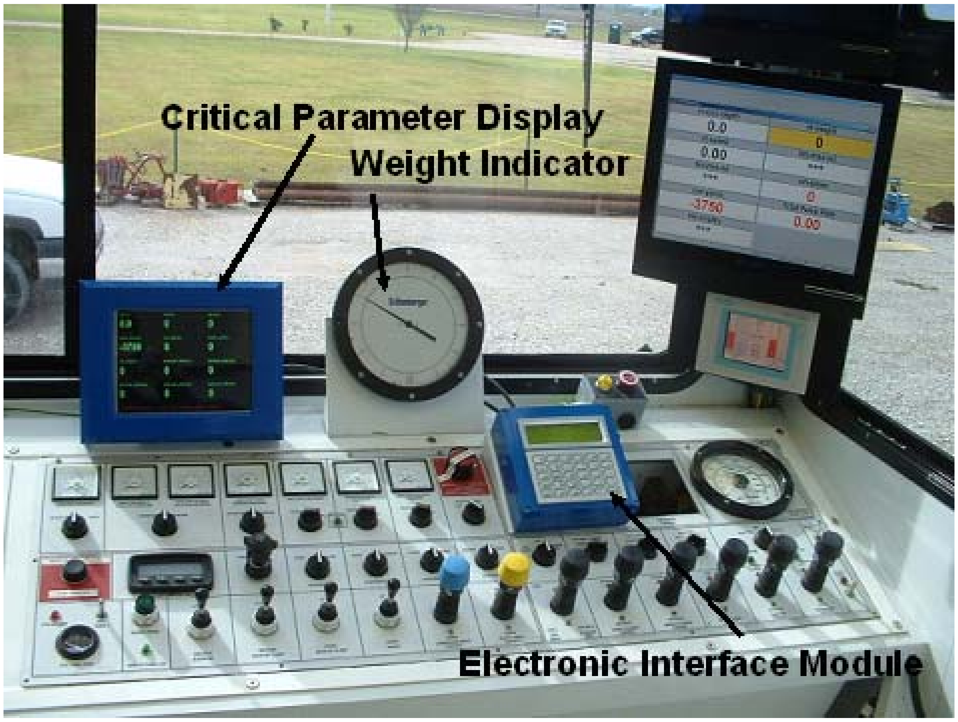


Figure 12-2 CoilCAT operators components

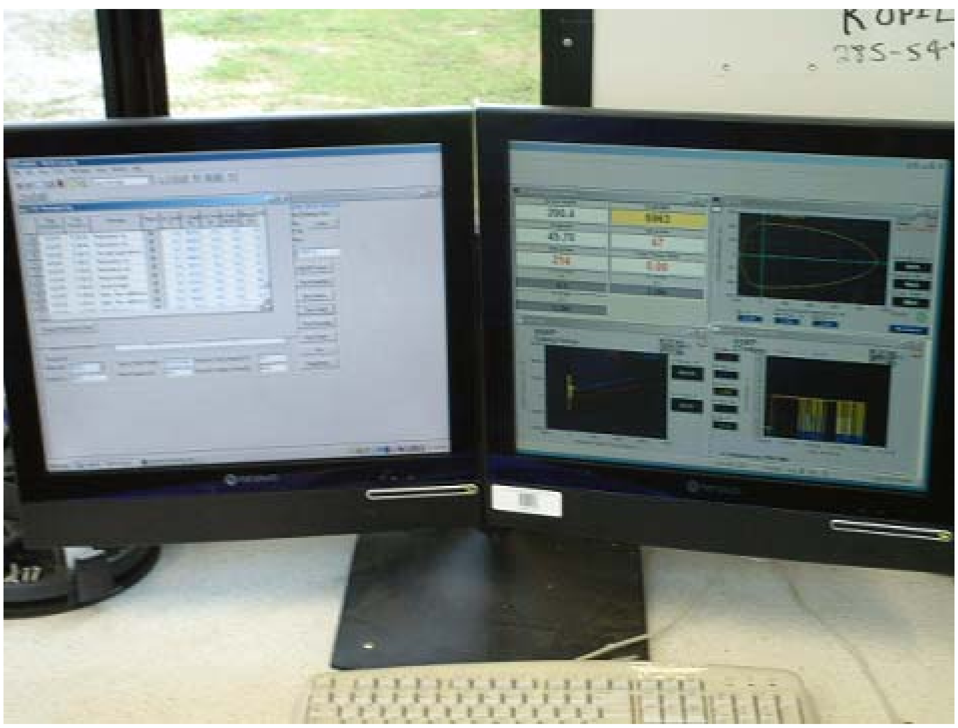


Figure 12-3 Engineers display for CoilCAT

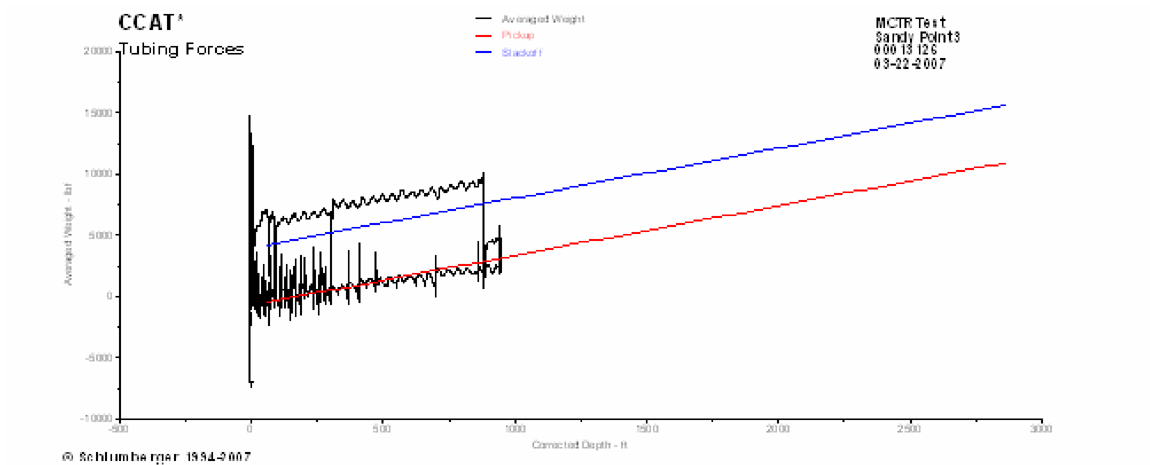


Figure 12-4 Tubing Forces plot after test

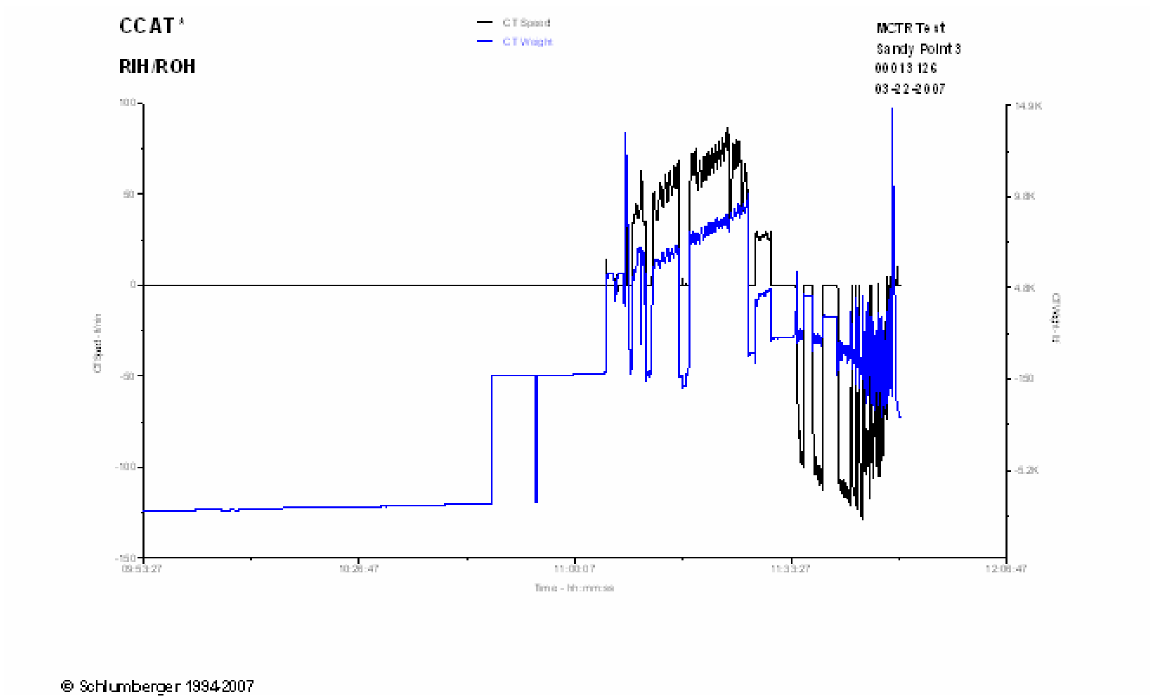


Figure 12-5 Plot of tubing speed vrs. weight

Schlumberger

MCTR Test

CCAT
Treatment Report

Well: Sandy Point 3

CCAT

Field	Rosharon
Formation	
Location	
Country	United States
State Province City	Texas
County Parish	BRAZORIA

Prepared for	***DOE MCTR TEST REPOI***	***Service Point***	IPC SUGAR LAND
Treatment No.	**00013126**	***Business Phone***	281-285-5557
Date Prepared	03-22-2007	***FAX No.***	

Prepared by BART PATTON
Phone 281-285-5557
E-Mail Address patton6@slb.com

Comments FINAL SYSTEM INTEGRATION TEST OF ALL ACQUISTION COMPONENTS
( )

Section 1: Job Messages

#	Time	Message	Corr Depth (ft)	CT Weight (lbf)	Circ Pres (psi)	Total Pump Rate (bbl/min)	Wellhead Pres (psi)
1	9:53:27	Started Acquisition					
2	9:53:57	Alarm - Min. wall thickness=0.001IN					
3	9:54:27	Stopped Acquisition					
4	9:56:47	Started Acquisition					
5	9:57:36	Alarm - Min. wall thickness=0.001IN					
6	10:44:27	Stopped Acquisition					
7	10:45:12	Started Acquisition					
8	10:46:01	Alarm - Min. wall thickness=0.001IN					
9	10:46:40	Zeroed Depth					
10	10:46:42	Zeroed Depth					
11	10:47:09	Zeroed Weight					
12	10:47:14	Started Recording					
13	10:51:39	Trip weight lower limit exceeded: 5966, Raw 45657	-5.0	26.70	202	0.0	47
14	10:53:54	Zeroed Weight	-5.0	66.00	204	0.0	47
15	10:54:07	Zeroed Weight	-5.0	-6904.20	204	0.0	47
16	10:55:46	Reel brake is on	-5.0	43.80	204	0.0	47
17	10:55:48	Reel brake is off	-5.0	44.70	204	0.0	47
18	10:55:49	Reel brake is on	-5.0	45.30	204	0.0	47
19	11:04:18	Reel brake is off	-5.0	143.00	213	0.0	46
20	11:04:47	Trip weight upper limit exceeded: 5928, Raw 45667	-5.0	2050.00	212	0.0	47
21	11:04:49	Reel brake is on	-4.8	4679.50	212	0.0	47
22	11:05:04	Reel brake is off	-4.7	5393.80	212	0.0	47
23	11:06:18	Trip weight upper limit exceeded: 8997, Raw 46645	-4.7	4097.10	211	0.0	47
24	11:06:21	Reel brake is on	-4.1	4448.20	211	0.0	47
25	11:06:42	Reel brake is off	-4.0	5371.10	212	0.0	47
26	11:08:19	Zeroed Weight	6.6	8313.40	214	0.0	46
27	11:08:20	Zeroed Weight	6.6	8316.50	214	0.0	46
28	11:09:05	Alarm - Min. wall thickness=0.001IN	15.5	5292.70	215	0.0	47
29	11:09:14	Alarm - Min. wall thickness=0.002IN	20.8	5698.60	215	0.0	47
30	11:10:58	Reel brake is on	89.6	-253.00	215	0.0	47
31	11:11:03	Reel brake is off	89.6	41.20	214	0.0	47
32	11:11:04	Reel brake is on	89.6	42.00	214	0.0	47
33	11:11:06	Reel brake is off	89.6	44.13	214	0.0	47
34	11:16:07	Depth Limit Exceeded: CT Halted	299.0	6904.30	215	0.0	47
35	11:16:10	Reel brake is on	301.3	1163.00	214	0.0	47
36	11:16:32	Reel brake is off	301.4	77.00	214	0.0	47
37	11:16:36	Depth Limit Exceeded: CT Halted	301.5	-610.00	215	0.0	47
38	11:16:37	Reel brake is on	301.5	-558.00	215	0.0	47
39	11:17:01	Reel brake is off	301.5	-521.70	215	0.0	47
40	11:26:54	Reel brake is on	881.1	1154.00	223	0.0	47
41	11:27:24	Reel brake is off	881.1	1272.10	223	0.0	47
42	11:30:18	Reel brake is on	945.4	4672.20	222	0.0	47
43	11:33:17	Reel brake is off	945.5	2130.30	228	0.0	47
44	11:33:31	Reel brake is on	945.5	2150.80	231	0.0	47
45	11:33:34	Reel brake is off	945.5	2152.00	230	0.0	47
46	11:39:09	Increase CT Inspec Lube Pressure	699.2	3256.40	235	0.0	47
47	11:40:05	Begin POH CT	699.2	3250.40	236	0.0	47
48	11:49:16	Reel brake is on	-5.3	5774.50	243	0.0	47
49	11:49:20	Reel brake is off	-5.3	4765.00	245	0.0	47
50	11:49:42	Reel brake is on	-4.5	-1382.90	247	0.0	47
51	11:49:42	Alarm - Min. wall thickness=0.001IN	-4.5	-1382.90	247	0.0	47
52	11:49:44	Reel brake is off	-4.4	-1420.50	246	0.0	47
53	11:49:49	Reel brake is on	-4.4	-1386.30	246	0.0	47
54	11:50:26	Stopped Recording	-4.3	-2246.00	246	0.0	47
55	11:50:42	Stopped Acquisition					

Section 2: Tubing Forces Input

Coiled Tubing Data

Stripper Friction Load	500.00 lbf
Pickup Reel Back Tension	1200.00 lbf
Slack-off Reel Back Tension	500.00 lbf

Fluid Data

Internal Fluid Density	8.34 lb/gal
External Fluid Density	7.50 lb/gal
Fluid Level	0.0 ft
Well Head Pressure	0 psi
CT Circulating Pressure	0 psi

Analysis Information

Maximum Tool Depth	2868.0 ft
Analysis Tool Depth	2868.0 ft
Compressive Load on Tool	0.00 lbf
Tensile Load on Tool	0.00 lbf

Friction Data

Open Hole Top MD	2860.0 ft
Open Hole Bottom MD	2869.0 ft
Friction Coefficient RIH	0.40
Friction Coefficient POH	0.18

Section 3: Tubing Forces Results

Did Lockup occur? **NO**

Maximum Pickup Tension	10959.12 lbf
Minimum Slack-off Tension	-1000.00 lbf
Maximum Von Mises Stress POH	8939 psi
Maximum Von Mises Stress RIH	12773 psi
Maximum Percent Yield Stress	14.2 %
Maximum Percent Helical Buckling Load	0.0 %

Tool string will travel to total depth unhindered.

Section 4: Coiled Tubing String

Coiled Tubing String Description

Reel Identification	**Evol 1**
Coiled Tubing Material	HS-90
Reel Core Diameter	124.000 in
Reel Core Width	66.000 in
String Identification	**13897-1a**
Total String Length	3850.0 ft
CT Total Volume	14.9 bbl
Cable Type	None
Cable Weight	0.0 lb/ft
Cable Length	0.0 ft
Cable OD	0.000 in
Plastic Jacket	NO

Coiled Tubing String Segments

Outer Diameter (in)	Nominal Thickness (in)	Minimum Thickness (in)	Segment Length (ft)	Segment Volume (bbl)
2.375	0.190	0.190	3850.0	14.9

Section 5: Coiled Tubing History
Coiled Tubing Job History for String 13897-1a

Job #	Job Date	Job ID	Company	Well Name	Location	Job Description	GN Radius (in)	H_2S Level (ppm)	Corrosion Loss (in)
1	03-22-2007	00013126	MCTR Test	Sandy Point 3		Final Acquisition system integ	120.000	0	0.000

12.2 InterACT real time data transmission

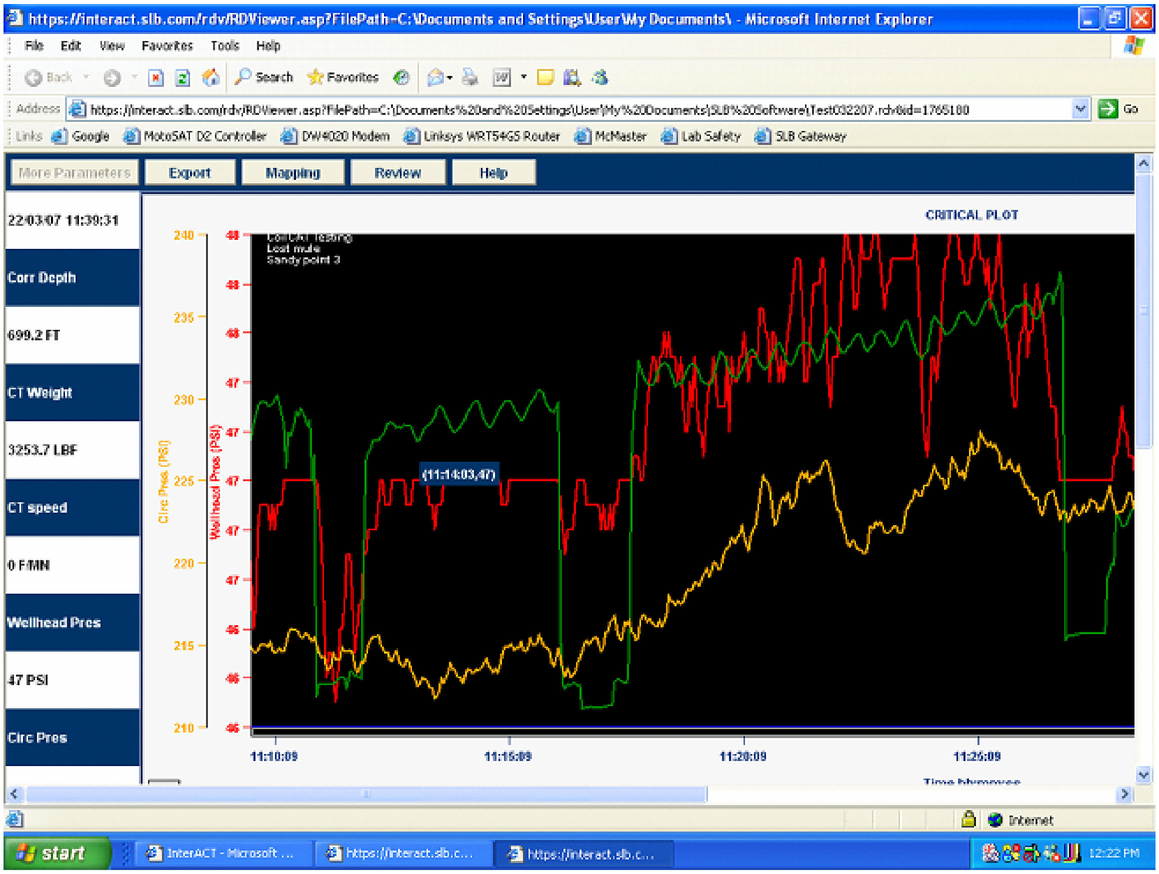


Figure 12-6 Screen shot of InterACT session recorded during test on test well

12.3 CoilSAVER

CoilSAVER is a process control system that works to prevent over pull and over snub on the coiled tubing. CT weight is constantly monitored (10 times per second) and compared against pre-established limits on CT weight. If the CT weight, exceeds the high and low limits the injector is instantly stopped to prevent damage to the coiled tubing and/or well. In addition, the CoilSAVER monitors the rate of weight change. Therefore, if the weight parameter changes substantially over a short period of time the injector is instantly stopped. This feature was created to predict problems. For example, if the BHA hits a downhole obstruction the weight will change very rapidly and the injector will be stopped before the weight limits are reached, thereby predicting and preventing a failure.

Since the weight monitoring is done on a local control network, the CoilSAVER is able to react much quicker than a human operator.

Figure 12-7 Re-setting CoilSAVER after testing trip on test well

12.4 CT InSPEC

CT inspect is a real-time coiled tubing inspection system that is tied in to the CoilCAT data acquisition system. CTInspec monitors wall thickness, tubing ovality and max/min tubing diameter and CoilCAT records this data. In addition, the operator is given and alarm if parameter values exceed the acceptable range. CTInspec can aid in maximizing coiled tubing life, which minimize cost.

CTInSPEC uses ultra sonic measurement to measure the wall thickness of the coiled tubing as it passes thru the CTInSPEC head. These measurements are sent to the CoilCAT data acquisition system and recorded to be saved on the reel data base. The reel data base stores an individual coiled tubing strings life and is tracked from job to job. With CTInSPEC thinning of the coiled tubing can be monitored over time thus allowing the string to be taken out of service or repaired before an incident occurs.

CTInSPEC also monitors ovality of the pipe, which can indicate that the coiled tubing has been over pressured, has excessive cycles or the inside chain tension is set to high. Setting of the inside chain tension to high can be the result of injector block wear and the need to compensate.

Figure 12-8 Installation of CTInSPEC on pipe

Figure 12-9 CTInSPEC Control valves mounted beneath floor

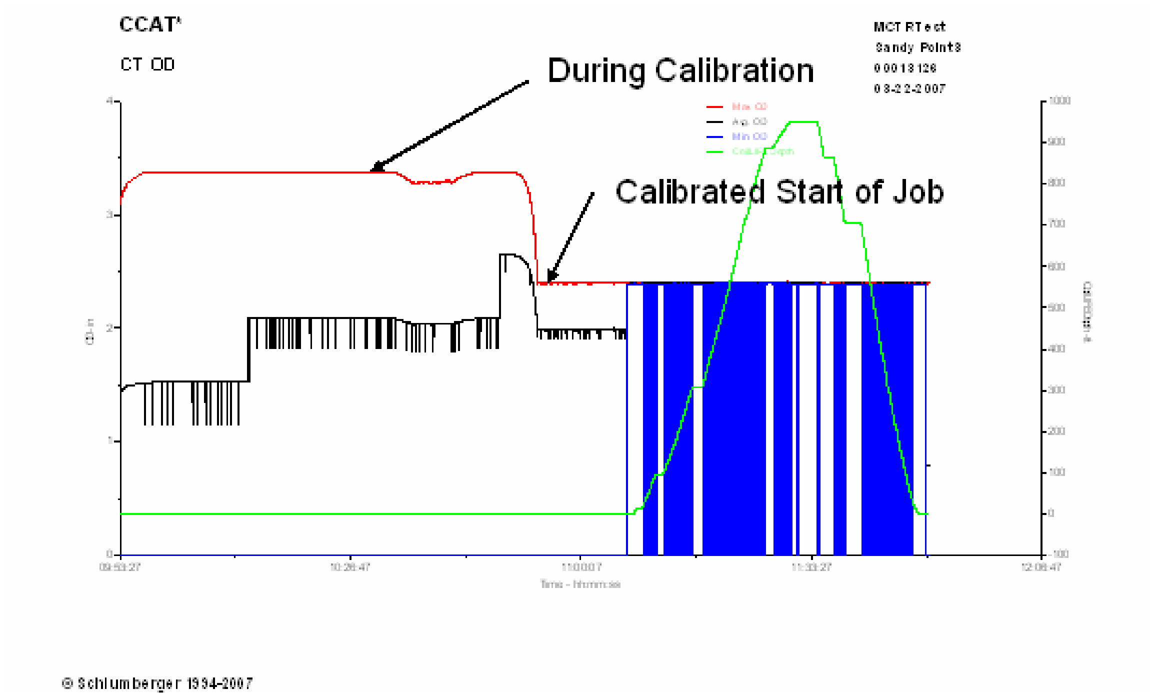


Figure 12-10   Plot from CoilCAT showing results of CTInSPEC

12.5 E-line capability

As part of the MCTR project scope the MCTR unit should be capable of performing wired drilling. The unit as received did not have the provision for using e-line. Essentially to use e-line in coiled tubing there must be a pressure bulk head to maintain pressure in the reel, but allow the e-line cable to be connected to an e-line unit. Also an e-line collector must be mounted to allow the coiled tubing reel to rotate without twisting the cable.

The figures below show how the reel was modified to accept a collector and the internal reel manifold was changed to provide a high pressure T to connect the pressure bulk head.

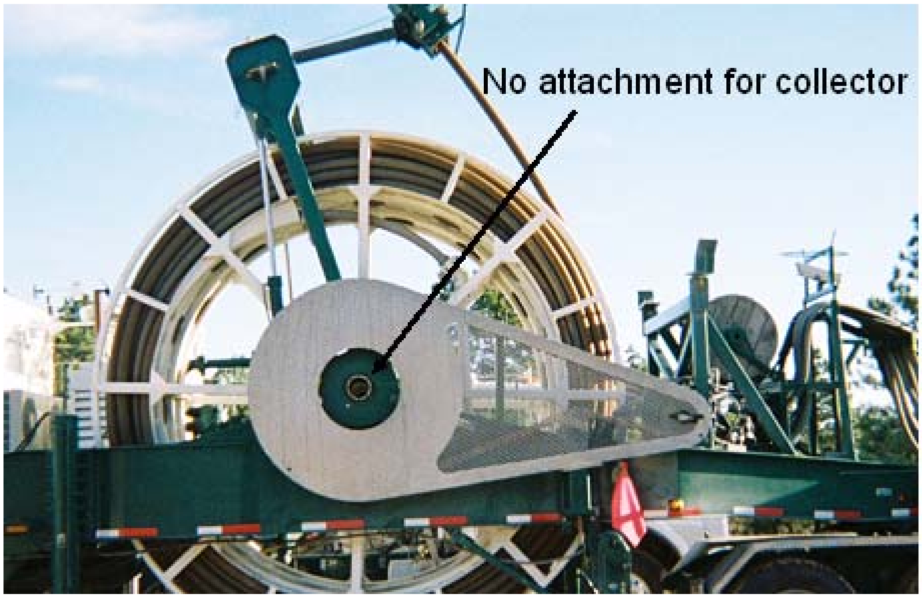


Figure 12-11 Reel prior to modification showing how there was no provision for a collector

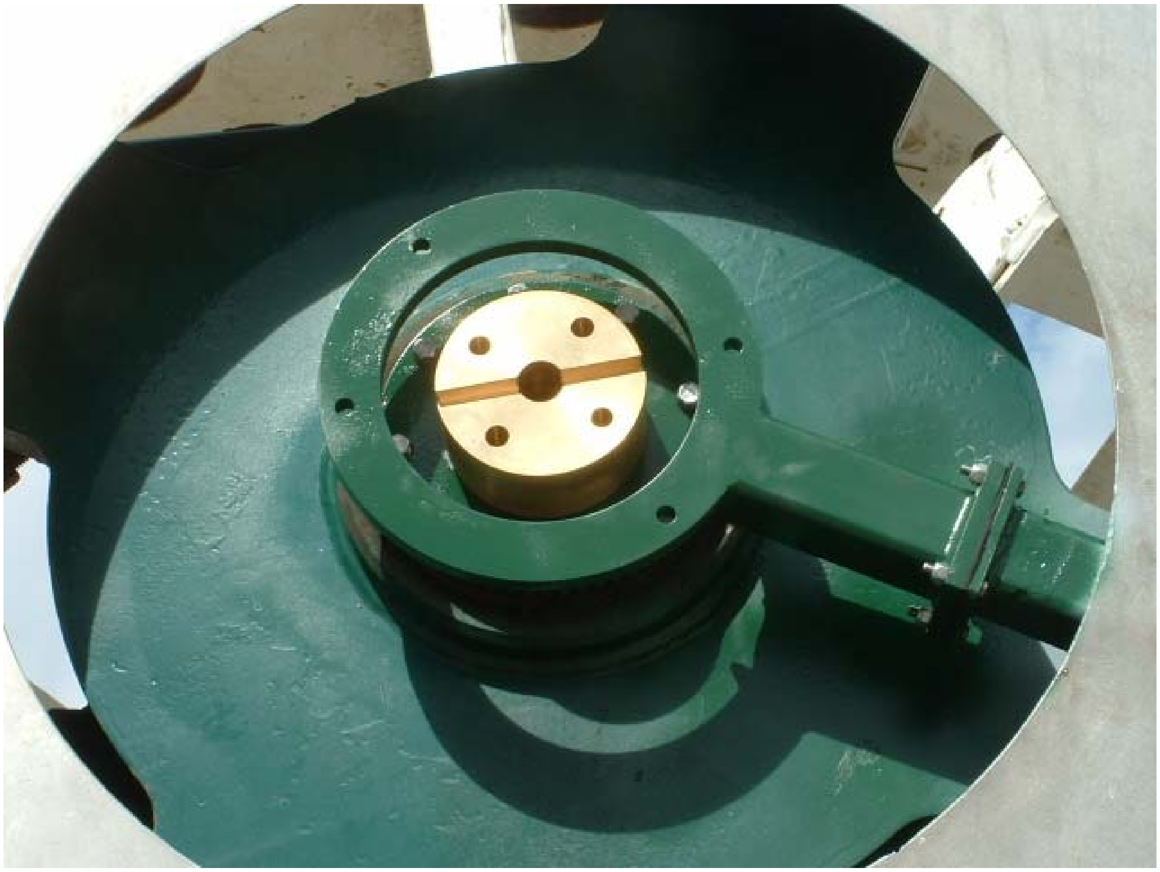


Figure 12-12   Showing reel modification for collector

Figure 12-13 Showing installation of collector

Figure 12-14 Internal Reel manifold with tee to connect pressure bulkhead

13 Field Test

13.1 Procedure

Discussion:

The Evolution Drilling rig has been going through modifications over the last year to adapt Schlumberger technology to an existing coiled tubing drilling rig. The majority of equipment installed is fully commercialized. These products have already gone through rigorous hardware system testing and do not require system testing. The purpose of the test on Sandy Point 3 is to verify that CoilCat, InterAct, CoilSaver and CTInspec are all functioning together as designed. These systems have already been checked individually after their installation on the Evolution test pad; however coiled tubing needs to be run in order to check that all systems are working together and the installation is correct.

The DOE Microhole Project also requires that the Evolution drilling rig demonstrate its ability to deploy coiled tubing bottomhole assemblies under pressure. For this a mock pressure deployment scenario is planned. No pressure will exist for this mock demonstration as it is only designed to demonstrate the procedural steps needed for pressure deployment.

In order to demonstrate the ability of the rig to pull wellbore completions. The Evolution rig will pull the existing 4-1/2” EUE 8rd LCT tubing from the Sandy Point 3 well.

The final purpose for moving over to the Sandy Point 3 wellsite is to video and photo document the rigs operational capabilities for the DOE (Department of Energy) who is partially funding the Microhole Coiled Tubing Drilling Rig project. As part of the deliverables to the DOE we must provide photo graphic evidence of the unit on a test well demonstrating its capabilities as outlined by the DOE contract.

Proposed Operations:

- Rig-up Evolution Rig on Sandy Point 3 well site
- Pull 4-1/2” EUE 8rd completion for disposal (Photo document)
- Rig-up BOP stack onto 13-5/8” 3K wellhead flange for photo documentation
- Perform mock coiled tubing slickline pressure deployment (Photo document)
- Perform Pull test to check K factor on injector weight indicator prior to running into well
- Run in well with coiled tubing to record CoilCAT, InterACT, CTInspec and CoilSaver data

Required Equipment:

QTY	Description
3	7-1/16” Spacer spools, gaskets and bolts
1	13-5/8” 3k by 7-1/16” 5K DSA
1	Manual Casing Spider dressed for 4-1/2” tubing
1	4-1/2” EUE 8rd collar
1	4-1/16” 15k Companion flange by 4-1/2” IF
1	4-1/2” IF Pup joint
1	4-1/2” IF drill pipe elevators
1	4-1/2” Tubing elevators
1	4-1/2” Tubing Tong
1	Sawsall
50 ft	Slickline Riser 5.5” O.D.
1	Slickline Grease Head with sheave wheel
1	Cross-Over from Riser Hand Union to 7-1/16” 5k API

Rental Items to be ordered from: (Quotes have been received)

Key Drilling Rentals
Supreme Rental Company
STS Rental

<u>Procedure:</u>

Move in Evolution Rig onto Sandy Point 3 wellsite

1. Hold Pre-Rig-up safety meeting document JSA and review procedure
2. Move in Evolution Rig onto Sandy Point 3 wellsite
3. Spot Mast unit over well center
4. Move in rig mats and place under stabilizing legs
5. Level rig using newly installed electronic leveling sensors (Verify level using bubble site glass level)
6. Raise mast and extend gooseneck
7. Move in and spot pipe handling trailer of end of mast unit. Pipe trailer tires should be the length of one steel rig mat from the rear most tire of the mast unit.
8. Place rig mats under the pipe trailer and lower pipe trailer onto ground and level.
9. Move in Cabin trailer and align with mast unit
10. Place rig mats under cabin and level cabin
11. Install walkways between cabin and mast unit
12. Install all handrails and lower floor between mast unit and pipe trailer
13. Connect electrical and hydraulic connections between all three units
14. Review rig-up process and document any issues or change in process that may want to be enacted

Pulling Completion

15. Hold pre-job meeting for pulling completion. Record JSA analysis for procedure
16. Install 4-1/2” IF drill pipe elevators onto rig bail
17. Remove rig floor using fast line and pipe handling skate
18. Make-up 4-1/16” 15K companion flange to 4-1/2” IF to wellhead spool
19. Make-up 4-1/2” IF drill pipe pup joint to companion flange

20. Remove bolts from 13-5/8" 3K wellhead flange

21. Connect elevators to 4-1/2" IF pup joint

22. Lift completion with blocks until 13-5/8" wellhead flange is high enough to allow manual casing spider to be placed around tubing onto wellhead. Record weight

23. Check weight against pipe weight calculation in air and buoyant weight to determine if completion is fully intact

24. Set slips around 4-1/2" tubing

25. Remove elevator and unthread tubing hanger spool

26. Thread on 4-1/2" EUE 8rd tubing collar onto tubing

27. Change elevator to 4-1/2" tubing elevator

28. Connect elevator and pull tubing three feet above floor level

29. Set slips

30. Install floor around 4-1/2" tubing

31. Connect elevators

32. Pull spider slips and set floor slips

33. Prepare tubing hydraulic tongs for pulling tubing

34. Stop hold meeting to review job tasks for pulling pipe record any JSA issues.

35. Pull stand of pipe into derrick until next collar joint is aligned with tubing tongs

36. Set slips

37. Connect tubing tongs to break tubing joint. (Note: If tubing collar has been perforated to not attempt to break the joint with the tubing tongs. The pipe will need to be cut **ABOVE** the tubing collar. Leaving the tubing collar for the elevators to engage for the next joint of tubing.)

38. Lay down the joint of pipe onto the pipe handling system. Use the skate to tail the pipe onto the pipe deck. The kickers and paddles are used to role the pipe onto the pipe rack.

39. Repeat steps 35-38 until all joints are removed

Coiled Tubing Pressure Deployment

40. Pull Drill floor

41. Install 13-5/8” 3K x 7-1/6” 5k DSA onto wellhead
42. Install 7-1/16” Spacer spool
43. Install combi BOP
44. Install Annular Preventer
45. Install 7-1/16: Spacer Spool
46. Install Drill floor
47. Install deployment BOP
48. Install cross over flange to deployment riser
49. Make-up deployment riser and slickline sheave
50. Install 5-1/2” casing elevators
51. Make-up BHA and install into deployment riser.
52. Raise deployment riser into mast and connect to the deployment BOP
53. Lower BHA into well and set slips across deployment bar
54. Break off deployment riser and verify position in slips
55. Disconnect slickline
56. Lay down deployment riser
57. Connect coiled tubing to BHA
58. Connect coiled tubing riser to Deployment BOP
59. Insure that all photo documentation has been performed
60. Disconnect coiled tubing riser from Deployment BOP
61. Disconnect coiled tubing from BHA
62. Bring in deployment riser
63. Connect slick line to BHA and connect deployment riser
64. Remove slack from slickline
65. Open slips
66. Remove BHA with slickline

67. Disconnect deployment riser from deployment BOP

68. Laydown deployment riser

69. Break off deployment riser

Coiled Tubing System Test

70. Cut mule shoe onto coiled tubing

71. Make-up 7-1/16" 5k flange to CO62 cross over

72. Connect coiled tubing injector to well stack

73. Follow operational procedures for CTInspec, InterAct and CoilSaver to verify installation

74. Run pipe in and out of well as needed to record data from the test

75. Perform final check of all rig functions and document results

Rig-down

76. Verify all photo documentation has been taken

77. Hold safety meeting to review job procedure and JSA

78. Break of injector from well

79. Remove adapter spools

80. Remove floor

81. Pull BOP stack and cover well

82. Re-install floor

83. Secure injector and telescoping guide

84. Rig-down pipe handling system

85. Lay down and rig out mast unit

86. Rig out control cabin

87. Pull units off pad

13.2 Pulling Completion

To better test the capabilities of the MCTR rig the team elected to pull a 3,000 ft 4-1/2" completion out of one of the test wells. It was felt that by doing this the team would get the best indication of how well the rig flowed.

Once rigged up it took approximately 4hrs to pull the completion. Three of the operators used to pull the completion where trained earlier in the morning on how to operate the rig to pull tubing. This indicates how relatively simple the rig is to operate.

Figure 13-1 Starting to pull 4-1/2" completion from test well

Figure 13-2 Breaking out a connection

Figure 13-3 Connection broke out ready to lay down tubing

Figure 13-4   Laying down tubing

13.3 Pulling Floor

The figures below show the process of removing the floor to install the BOP stack on the test well. The procedure of pulling the floor was performed three times on the test well in order to determine the best method of rigging the blocks to the floor to be pulled. At the end of the test it was determined that a 10' stinger should be used between the block and the floor slings as this allowed the floor to be more easily be positioned on the pipe trailer deck.

Figure 13-5 Preparing to pull floor

Figure 13-6 Floor removed

Figure 13-7 Flow cross being placed on well thru floor opening

Figure 13-8 Preparing to lower 7-1/16" Combi BOP onto well

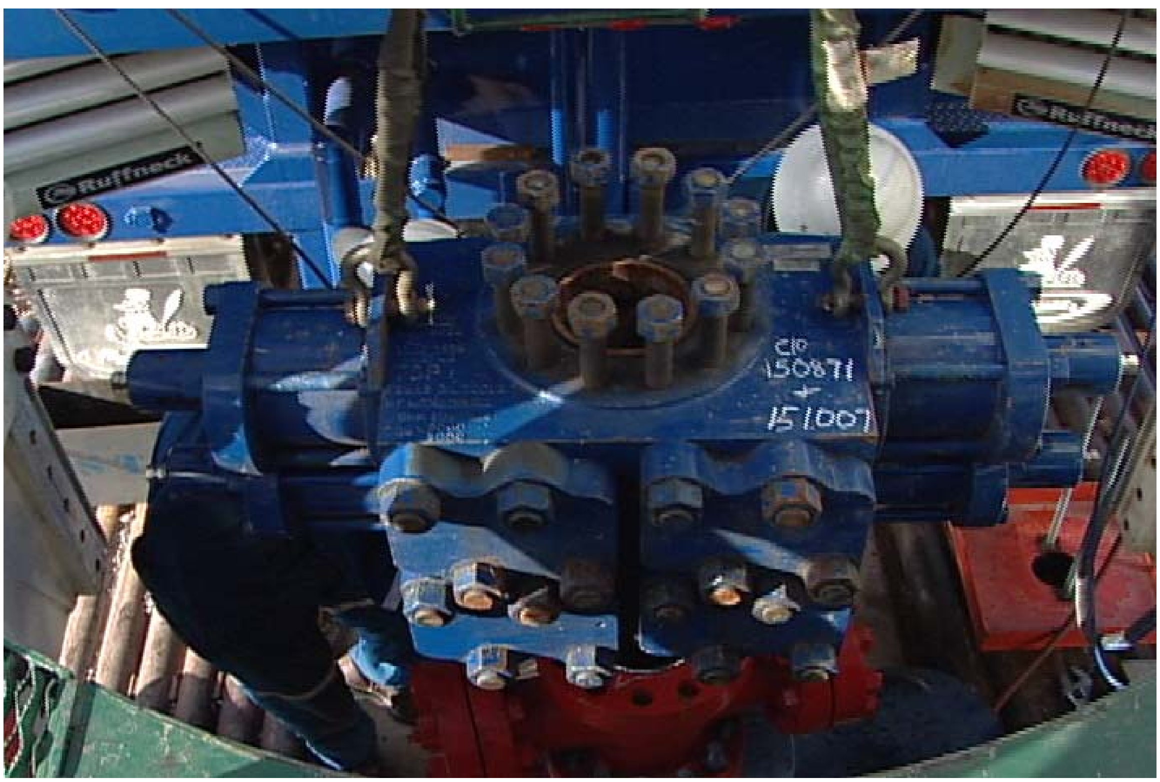


Figure 13-9 BOPs lowered onto flow cross thru floor opening

13.4 Field Test Summary

The modified components on the MCTR rig for the microhole initiative all operated as planed. Several different rig-up arrangements were performed, while removing the drill floor to establish the smoothest pulling procedure and limit human intervention. The slickline lubricator was raised twice into the derrick to establish a method, which allowed the lubricator to be raised smoothly with the blocks without interfering with the injector head. The solution ended up being better coordination between the operator on the pipe trailer and the operator controlling the blocks.

Actual rig-up went smoothly, with a limited crew size for rig-up/rig down operations. During rig-up and rig-down a crew size of 3 was used. When pulling the completion from the well a crew size of six was used. The crew size could have been easily reduced to five, but we had the man power to utilize.

Once the unit is spotted it takes about four hours to rig-up or rig-down the unit with 3 operators. A crew of five for the rig-up or rig-down could easily reduce the time required to 3 hours. One of the longest individual tasks is leveling the mast trailer, which was reduced by installing electronic tilt meters. The electronic tilt meters allow the operator to operate the leveling jacks while watching the reaction on the tilt meters, while leveling the truck. Previous operations required multiple bubble levels to be placed around the unit, which were individually monitored.

The Schlumberger's coiled tubing data acquisition system CoilCAT was adapted to this unit and worked well, including all of its peripheral components. The peripheral components for the CoilCAT data acquisition system include items such as CoilSAVER, CTInSPEC, UTLM and InterACT.

Two spool valves started leaking on the pipe handling system. They were isolated and pulled from the circuit for inspection. After inspecting the spool valves it was found that the valves had been repaired before and the end caps on the spool valves were over torqued and the end caps were deformed. Based on this it was determined to change out the spool valves for one of a much more robust design. After replacing the spool valves the circuit was tested and was found to be fully operational with no leaks.

It was also found during the field test that the original stripper circuit did not provide a constant hydraulic pressure to the stripper. Essentially the stripper pressure is dialed in and the supply valve is then closed, which allows the stripper pressure to bleed off over time. It was determined that this was unacceptable and the circuit was modified to incorporate a proportional pressure regulating valve. A proportional pressure regulating valve allows the operator to electronically dial in a constant flow pressure to the stripper, which compensates for any bleed thru in the stripper circuit. This keeps the stripper at a constant pressure during the full operation and allows the pressure to be increased or decreased as needed.

14 Commercialization Plan for Rig

Currently plans are being made to determine how to commercialize the MCTR unit. To date no definite plans have been made.