ROCKY MOUNTAIN OILFIELD TESTING CENTER

PROJECT TEST RESULTS

IMPROVED ELASTOMER COMPOUND FOR PROGRESSIVE CAVITY PUMPS

Cameron Elastomer Technology

MARCH 23, 1998

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RMOTC Test Report
Number 96PT17

Improved Elastomer Compound for Progressive Cavity Pumps

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Introduction

The purpose of this project was to evaluate improved progressing cavity (PC) pump stator elastomer materials in NPR-3 crude under field conditions. The goal of the project was to test an elastomer material that can be used in high API-gravity (greater than 38' API) crude oils. Currently available materials used for the construction of pump stators swell and fail in contact with such crude oils. This limits the applicability of progressing cavity pumps as a form of artificial lift in oil wells.

Published literature indicates that progressing cavity pumps have substantially lower capital costs to install and use less power than rod pumps. Expanded use of this equipment would result in improved economics for oil producers, delay the abandonment of marginal wells, and reduce energy consumption.

Cameron Elastomer Technology has broad experience in developing rubber compounds for the petroleum industry. They provide sealing elements such as gaskets, o-rings, and other sealing components to their family of equipment manufacturers which sell wellheads, blowout preventers, drilling risers, chokes and valves.

Part one of the test involved the use of a Roper surface transfer pump installed in a flow loop at Cameron's facilities in Katy, Texas. Part Two consisted of a long-term test in producing wells using the compound selected in the earlier test.

Operation

Although the geometry of its pumping elements may seem somewhat complicated, the operation of a progressing cavity pump is surprisingly simple. The key components are the rotor and the stator. The rotor is a single external hilix with a round cross-section, precision machined from high strength steel and chrome plated for hardness. The stator is a double internal helix molded of a tough, abrasion resistant elastomer, permanently bonded inside an alloy steel tube.

As the rotor turns within the stator, cavities are formed which progress from the suction to the discharge end of the pump, conveying the pumped material. The continuous seal between the rotor and the stator keeps the fluid moving steadily, at a fixed flow rate proportional to the rotational speed of the pump.

The elastomer compounds used to mold the stator are usually different types of Nitrile rubber. Unfortunately, nitrile rubber can adsorb aromatic solvents such as benzene xylene and toluene. This can cause the elastomer to swell and soften when exposed to crude oils containing high concentrations of these solvents. Published literature from manufacturers claims that current compounds can be used in crude oils up to 40 degrees API but this may be optimistic. Current operating experience suggests that difficulties increase substantially in crude oils lighter than the low 30 degree API range. The actual aromatic content of the specific crude oil will obviously govern whether or not a PC pump will be effective.

Operating experience at NPR-3 in the mid- 1980's demonstrated that nitrile compounds available at the time were unable to tolerate crude oil from the Shannon formation with gravities in the low 30's. As part of the project planning work, wells with existing PC pumps from that era were pulled in order to evaluate the condition of the stator material. In one well, the stator compound

had swollen to such a degree that the elastomer had extruded 1/2" out the top of the pump. The rotor was also found to be seized completely by the swollen stator.

Anticipated Benefits

Published literature indicates that progressing cavity pumps have substantially lower capital costs to install and use less power than rod pumps. Expanded use of this equipment would result in improved economics for oil producers, delay the abandonment of marginal wells, and reduce energy consumption. PC pumps also handle abrasive materials and other solid much better. This would be an advantage in the open-hole completions of NPR-3, which produce clay and mud from fractured shale reservoirs.

Test Program

Phase I was a test of elastomer compounds in a surface flow loop located at Cameron's facility in Katy, Texas. A Roper(tm) surface transfer pump was used to pump crude oil around a loop while data acquisition equipment measured the pump amperage and pressure for signs of swelling. A standard, commercially available nitrile rubber was used in the stator in order to establish a control case. The test elastomer was run in parallel in order to provide a comparison.

A 55-gallon sample of crude oil from Well 36-STX-23 was used to fill the loop. This well produced crude oil with a corrected API gravity of 40 degrees. The oil is a light, paraffinic crude oil with a high quantity of wax. Natural gas from the well contains large quantities of C3+ hydrocarbons.

Phase 11 of the test included the installation of PC pumps in two shale wells with high API gravities (40' API). Early in Cameron's research program, they decided to construct a mold for an 025 stator. This designation means that the pump has a transfer rate of 25 bbl. per 100 RPM Since the optimum operating range for PC pumps is approximately 350 RPM the pump was designed to lift about 85 bbl. of fluid per day.

Additional support was provided by Griffin Legrand, who manufactured the steel rotors, fitted them to the molded stators, and performed dynamometer testing of the completed pump. Griffin Legrand also provided technical support for the well design and guidance in running and starting up the PC pumps. They also loaned two electro-hydraulic surface units for the test. These units use an electric motor to run a hydraulic system that turns the rod string. This gives the ability to vary rotation speed without the cost of a variable frequency drive. It was originally thought that existing surface units purchased in 1988 could be salvaged, but the equipment lacked certain safety devices that have become customary. Test priorities were as follows:

1. Verify the mechanical design and reliability of the pumping equipment.

    - The equipment design contains expected safety features such as pressure relief valves and sufficient pressure rating for all components. OSHA requirements for equipment guarding, etc. will be enforced.

2. Evaluate the ability of Cameron's PC pump to operate and produce the light crude oil at NPR #3 effectively.

3. Evaluate well performance in order to determine if PC pumping is an effective method of artificial lift in our candidate wells.

   - Wells should show evidence of improved or production or reduced operating expenses compared to rod pumping.

CANDIDATE WELLS

Since Cameron requested candidate wells that produce oil with a gravity of 40' API, a search revealed that the only area of NPR-3 that produced this type of oil was in the south end of the field. Wells in this area produce from the Steele and Niobrara formations which are naturally fractured shale formations. These wells feature an open-hole completion because the shales are fluid sensitive and have been damaged when exposed to oilwell cements. None of the usual sandstone reservoirs at NPR -3 produced oil lighter than about 340 API.

Well 36-STX-23 was completed in 1995 and had been on production on rod pump previously. Paraffin deposition and low fluid inflow had restricted the well's ability to produce. It was producing approximately 5 BOPD under rod pump, with frequent paraffin control treatments.

Well 33-STX-23 had not produced previously to any significant degree. The well tended to produce clay with the crude oil and rod pumps tended to quickly jam. As a result, the productive capacity of the well was unknown.

Neither of these wells were ideal test candidates because they produced significantly less than Cameron's 025 pump was capable of handling, In addition, the open hole completion was also drilled directionally. Beginning at about 1,200 feet, each of the wells were deviated to about 30 degrees from vertical. However, both wells were determined to meet the most important criteria regardless of production and mechanics, the elastomer would be exposed to a hostile environment.

TEST RESULTS:

Phase I - Test Loop

A standard nitrile rubber stator and a stator molded from Cameron's test compound were mounted on a Roper(tm) transfer pump] and tested in the flow loop. A nitrogen blanket was used in order to minimize the evaporation of light aromatic solvents. Both pumps were operated were operated with an 85F for 48 hours and at 150'F. Motor amperage, output pressure, flow rate and fluid temperature were measured continuously during the test. The standard nitrile rubber stator unexpectedly survived the trial. This was unexpected, given the known chemistry of the stator material and the crude oil composition. Cameron hypothesizes that the volatile aromatic solvents evaporated during the test, despite their attempt to control the evaporation. Since the result was indeterminate, it was decided to terminate phase one and proceed with the field trial in wells.

Phase II - Well 36-STX-23

This well is approximately 3090' feet deep with a 7-7/8" open hole completion below the casing at 1392'. A pre-test data sheet showing the mechanical configuration is attached at end of the report. The well is directionally drilled starting at approximately 1500 feet. It achieves a 30' maximum deviation at about 2500 feet and continues on a slant to its total depth.

Date	Event
4-11-97	Move in service rig and pull rods and tubin. Pick up stator, tag bar sub, crossover, and 2-7/8" tubing. Landed assembly in well
4-14-97 to 4-17-97	Pump 20 bbl. Hot oil down tubing to melt paraffin. Ran rotor and rods. Finished hooking up equipment
4-17-97	Started well at low rpm in order to trouble-shoot hydraulic equipment. 2 hours run time for the day.
4-21-97	Started well at 80 rpm. And watched. 2 hours run time – making oil.
4-22-97	Started well at 80 rpm and rpoduced for 6 hours – making oil.
4-23-97	Operated for ½ hour and then lost oil flow to surface. Shut down to review situation
4-29-97	Operated for approximately 2 hours. No production
4-30-97	Operated for one hour – no production. Shut down until additional project funding can be secured from DOE.
6-12-97	Pulled rods and tubing. Found that stator had de-bonded from the steel pump body.
6-17-97	Returned well to production via rod pump. Swab testing revealed that poor fluid inflow will make it a poor candidate for a second generation stator.

Summary of activity for this well:

The pump operated for a total of approximately 10 hours before failing. An analysis of the production history for this well shows that the well was not being produced effectively on rod pump before the test. The process of tripping the pump in and out of the well, treating with hot oil, and producing the well for this short period of time, apparently was enough to improve fluid inflow. The well has been showing improvement on rod pump since the test period.

Phase II - Well 33-SBX-23

This well is approximately 2787' feet deep with a 7-7/8" open hole completion below the casing at 1200'. A pre-test data sheet showing the mechanical configuration is attached at end of the report. The well is directionally drilled starting at approximately 1200 feet. It achieves a 30' maximum deviation at about 1800 feet and continues on a slant to its total depth. 33-SHX-23 was actually placed on PC pump a few days ahead of well 36, so some learning is evident here.

Date	Event
4-09-97	Move in service rig and pull rods and tubing. Pick up stator, tag bar sub, crossover, and 2-7/8" tubing. Hit fill in well higher than when we'd started in the morning.
4-10-97	Pump 15 bbl. hot oil down tubing to unplug tubing. Ran rotor and ***original 5/8"*** rods. Finished hooking up equipment. Turned rods with service rig to verify pump action before releasing rig.
4-16-97	Started well at low rpm in order to trouble-shoot hydraulic equipment. Static fluid level in well approximately 600' from surface. Pump ran 2 hours when 5/8" rods parted in an obvious manner. Shut down until additional project funding can be secured from DOE.
6-10-97 6-11-97	Pulled rods and rotor. Replaced rod string with ***used 3/4" rods*** from inventory.
6-12-97	Started well but pump failed to lift fluid to surface. Based on parallel activity at 36-STX-23 on this date, it was decided to move the service rig back here and pull the stator.
6-16-97	Pulled and replaced stator and matching rotor. Elastomer in original rotor had debonded and broken up. Replaced rotor and stator again and returned well to production
6-17-97	Started well. Pump failed to lift fluid to surface. Shut down in order to wait for 2nd generation stator.
10-15-97	Two 2nd generation pumps and rotors arrive at field.
10-16-97 to 10-23-97	Pulled rods and rotor. Found 3/4" rods parted and corkscrewed. Replaced bad rods, cleaned out well and ran new pump.
10-29-97	Returned well to production at 80 rpm
11-2-97	Well went down at 21:00 the previous night. Parted rods again.
11-21-97 to 11-24-97	Pulled well and found ***parted 3/4" rods*** again. Pulled and laid down rod string. Ran used, ***inspected 7/8" rods*** with slim-hole couplings. Returned well to production. Running OK.
1-8-98	Well continues to pump OK but appears to be pumping off. Shut-in temporarily to allow fluid infill into well.
1-13-98 to 1-14-98	Returned to production. Produced for 19 hours before pumping off. Placed on intermittent producing status.
2-03-98 to 3-10-98	Returned to production. Failed to pump up. Shut down after 2-1/2 hours. Continued to periodically try to return well to production. We were never able to get it to pump fluid to surface.

Date	Event
3-24-98 to 3-25-98	Move in and rig up service rig. Pull rods and rotor. Rod string looks in good condition. Flush tubing with hot oil to remove paraffin. Pull tubing and stator. Stator is in good condition - no obvious damage or failure. Perforated tubing sub below pump intake appears to have unscrewed during operation and was left in hole. No attempt to recover. Replaced stator with spare 2nd generation item. Ran rods and rotor and rigged down service rig.
3-26-98	Returned well to production at 80 RPM. Got good pump action and had fluid to surface in 3-1/2 hours.
	Total operating hours on pump - 504.8 Total number of days in the well- 152 days

Summary of activity for this well:

The decision to use the existing 5/8" rods for these two wells was based on an recommendation by support staff at Griffin Legrand. Not only was this advise was obviously flawed, but RMOTC lacked operating experience with PC pumps and did not catch this mistake. Since the 5/8" rods parted immediately on April 16, 1997, we were able to switch to 3/4" rods in 33-SHX-23 from the start. The trial and error process of discovering that 7/8" rods were actually necessary caused substantial delays and cost increases.

The reason for the loss of production appears to be a build-up of paraffin in the pump intake. Unfortunately, the process of unseating the rotor causes the entire hydrostatic column of fluid in the tubing to be dumped through the pump. Obstructions are frequently flushed out and are gone by the time the tubing is brought to the surface.

Based on the apparent paraffin problem in both of the candidate wells, it may be necessary to treat the wells with either a paraffin inhibitor or periodic treatments with hot oil. Other wells in the area have responded well to this type of preventative treatment.

TECHNICAL OBSERVATIONS:

1. Verify the mechanical design and reliability of the pumping equipment.

   - The equipment design contains expected safety features such as pressure relief valves and sufficient pressure rating for all components. OSHA requirements for equipment guarding, etc. will be enforced.

     The surface equipment provided by Griffin Legrand passed rigorous safety inspections with the addition of some minor guarding to prevent the deliberate insertion of fingers into the belts on the drive head.

2. Evaluate the ability of Cameron's PC pump to operate and produce the light crude oil at NPR #3 effectively.

- The stator removed from 33-SHX-23 shows no physical effect from submersion in 40° API crude oil for six months. Operating data such as rotating torque have shown no indication of elastomer swelling.

  A sample of the elastomer was removed from the stator pulled 3-25-98, for analysis by Cameron's chemists. The stator will remain on the RMOTC test site while another candidate well is selected to replace 36-STX-23. The pump will be run into the second well in order to continue its endurance test. A goal of a I -year run is feasible.

3. Evaluate well performance in order to determine if PC pumping is an effective method of artificial lift in our candidate wells.

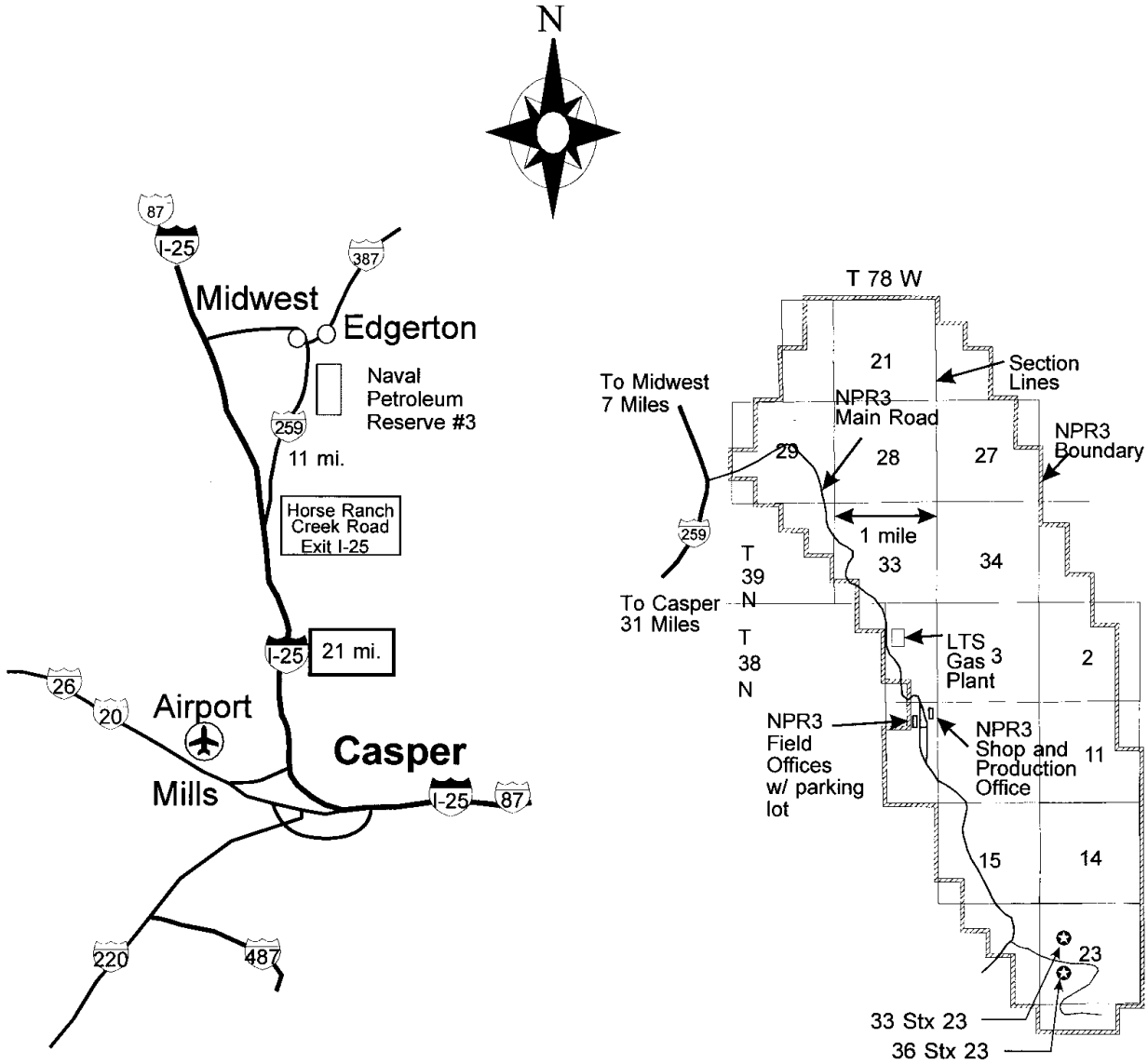
- Wells should show evidence of improved or production or reduced operating expenses compared to rod pumping.

33-SHX-23 has been successfully produced on PC pump for six months. This run time is substantially better than its previous record on rod pump. In fact, it was not possible to effectively produce the well on rod pump. PC pumping would be an obvious improvement if this elastomer material were to become commercially available in a size that is more suited to the actual production rate.

ACKNOWLEDGEMENTS

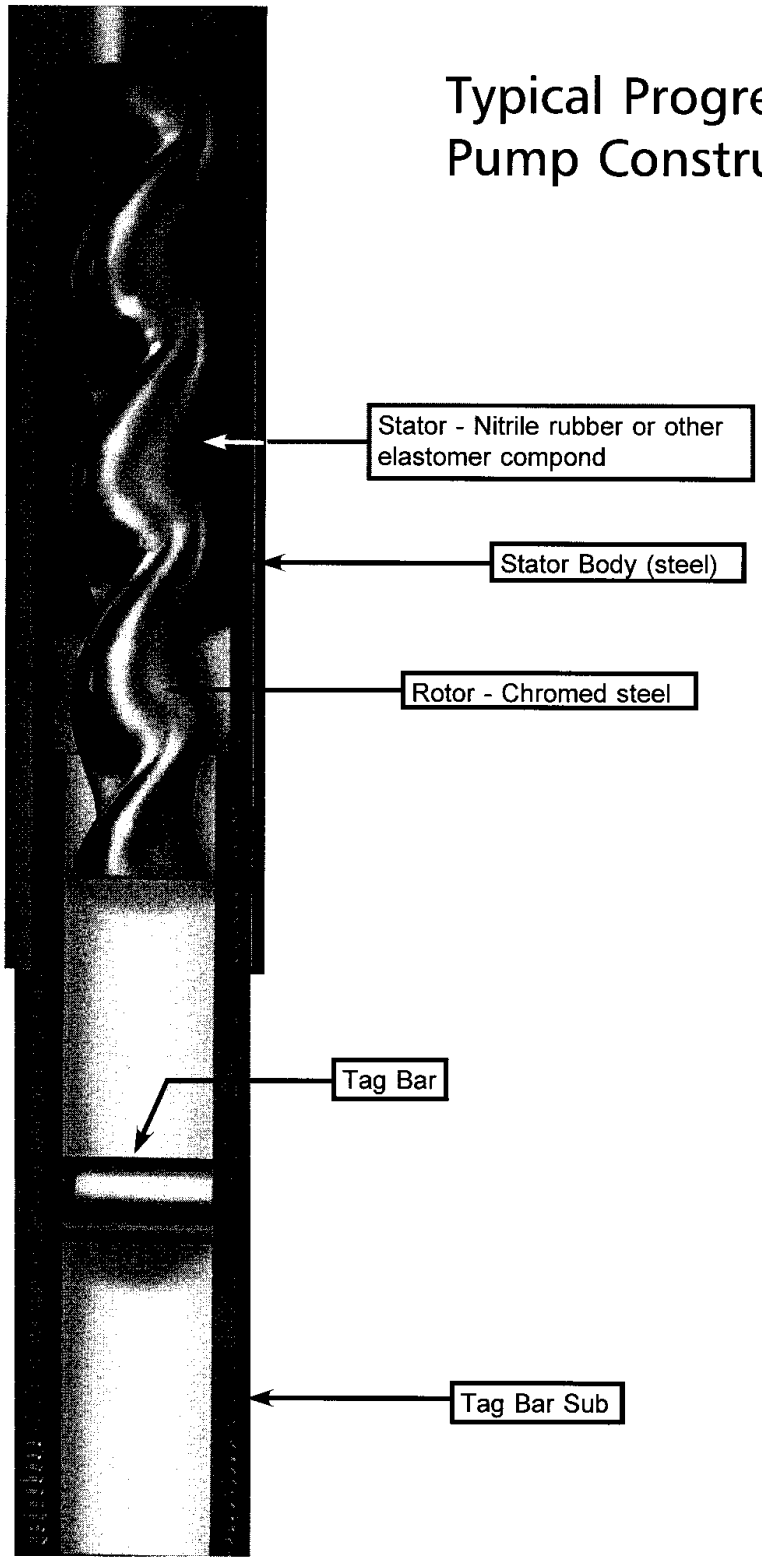
This research was funded by the Department of Energy with work conducted by the Rocky Mountain Oilfield Testing Center (RMOTC). Work was directed by David H. Doyle, PE, RMOTC Project Manager, Brian Meidinger and Dick Webb, RMOTC Field Technicians and Dan Kelly, RMOTC Field Technician. RMOTC is operated by Fluor Daniel (NPOSR), Inc., the Management and Operating Contractor for the Department of Energy Naval Petroleum Oil Shale Reserves in Colorado, Utah, and Wyoming (NPOSR-CUW).

Location Map
Naval Petroleum Reserve #3
Natrona County, Wyoming



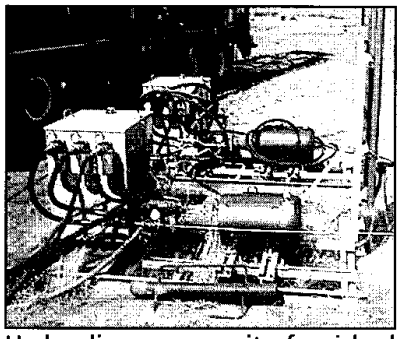
DHD 03/27/98

Typical Progressive Cavity Pump Construction

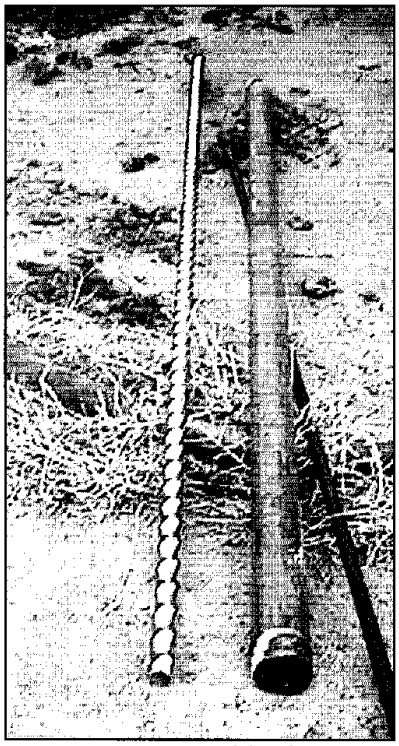


DHD 03/23/98

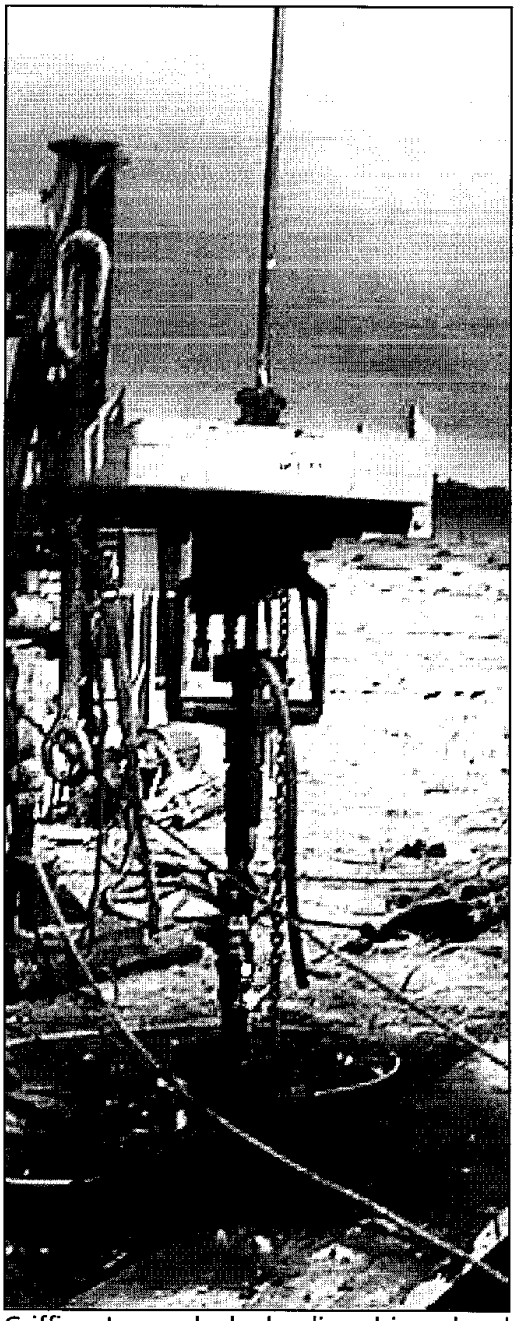
PC Pump Equipment Used on the Test



Hydraulic power units furnished by Griffin Legrand



Rotor & stator used in the test



Griffin Legrand hydraulic drive head (Partially disconnected for well servicing)

RMOTC Well Data Sheet

Well Number: 36 STX 23

Producing Formation: Steele Shale

API Well Number: 49-025-11377

Location: US Naval Petroleum Reserve #3 (Teapot Dome field)
1935' FSL, 1868' FWL (NE/4-SW/4) Section 23, T38N, R78W, Natrona County, WY

Elevations: 5308' GL, 5320' KB

Casing: 8-5/8" 24# J-55 Set at 1392'. Cemented with 500 sx 50-50 Poz. + 2% gel + 3% $CaCl_2$ + 5 #/sk gilsonite. Tail with 100sx class "G" + 3% $CaCl_2$ + 1/4 #/sk flocele

Tubing: 96 joints 2-3/8" used tubing with mud/gas anchor and seating nipple at 2996'.
No tubing anchor or anchor-catcher.

Rods: 119 - 5/8" rods

PBTD: 3090' (7-7/8" open hole below 8-5/8" casing)

Perfs: None - Oils show in natural fracture 2760-2796'.

Present Status: producing approximately 5 BOPD on time clock.
Oil gravity 38 degrees API, 40 degrees, corrected
Water production - trace
solids - trace. produces fine bentonite clays.

Fluid level: Nearly pumped off:

Casing pressure: None. Casing and tubing produce to storage tank - no separation equipment.

Deviation: Directionally drilled - see attached directional surveys.

36 X 23 (DV)

LAAW

WELL # :
36 X 23 (DV)

LOCATION :
NATRONA CO. WYO.

DATE :
1-11-85

JOB TYPE :
DIRECTIONAL CONTROL

JOB # :
D-2215

SURVEYOR :
JEFF BAYERT

DEPTHS :
0-3429

DECL. :
13.5 EAST

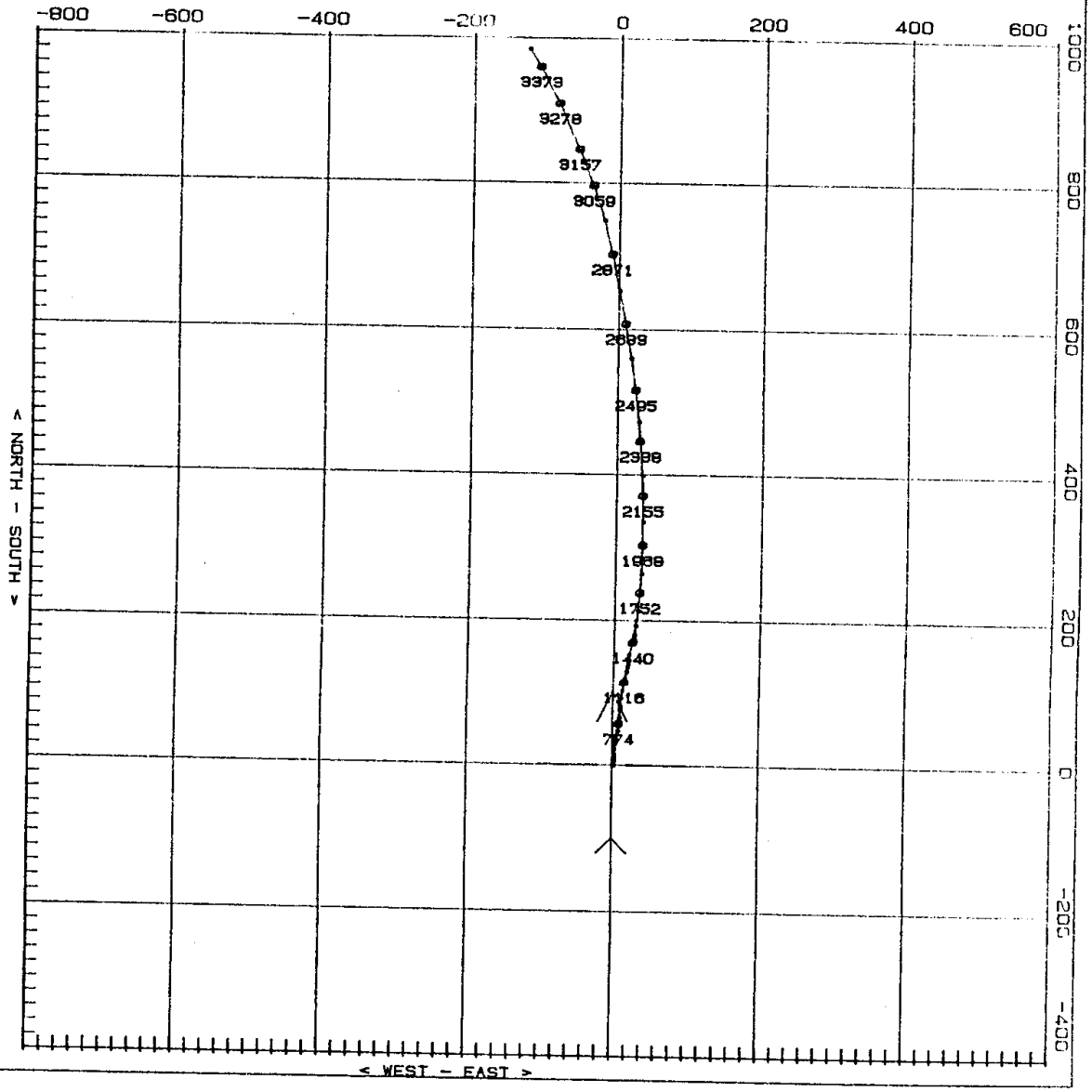
ELEV. :
5320'

FILE # :
RM-A8

****
FINAL STATION DATA:
MD. 3423.00
TVD. 3201.37
N/S 984.79
E/W -124.85

CLOSURE DISTANCE
992.67 FEET
CLOSURE DIRECTION
N 7.23 W

1 IN. = 200 FT.



CUSTOMER : [illegible]

WELL # :35 X 23 (DV)

LOCATION :NATRONA CO. WYO.

DATE :1-11-85

JOB TYPE :DIRECTIONAL CONTROL

JOB # :D-2215

SURVEYOR :JEFF BAYERT

DEPTHS :0-3423

DECL. :13.5 EAST

ELEV. :5320'

FILE # :RM-A6S

METHOD :RADIUS OF CURVATURE

SECTION :N10E

THIS SURVEY IS CORRECT TO THE BEST OF MY KNOWLEDGE AND IS SUPPORTED BY ACTUAL FIELD DATA.

DIC REPRESENTATIVE

FINAL STATION DATA!

MEASURED DEPTH FEET	INCL. ANGLE DEG.	HOLE DIRECTION DEG.	COURSE LENGTH FEET	TRUE VERTICAL DEPTH FEET	SUBSEA DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES N/S Feet	E/W	CLOSURE DISTANCE	DIRECTION DEG.
3423.00	37.25	N 33.00 W	50.00	3201.37	-2118.63	948.10	904.77 N	124.85 W	972.6	at N 07 22 [illegible]

MEASURED DEPTH FEET	INCL. ANGLE DEGS.	HOLE DIRECTION DEGS.	COURSE LENGTH FEET	TRUE VERTICAL DEPTH FEET	SUBSEA DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES N/S feet	E/W	CLOSURE DISTANCE FEET	CLOSURE DIRECTION DEGS.
0.00	0.00	N 00.00 E	0.00	0.00	-5320.00	0.00	0.00 N	0.00 E	0.00at	N 00.00 E
15.00	.75	S 27.50 E	15.00	15.00	-5305.00	-.08	.09 S	.05 E	.10at	S 27.50 E
45.00	.50	S 45.00 E	30.00	45.00	-5275.00	-.23	.30 S	.28 E	.42at	S 43.13 E
76.00	.50	S 61.00 E	31.00	76.00	-5244.00	-.33	.43 S	.53 E	.69at	S 50.53 E
105.00	.75	N 39.50 E	29.00	104.99	-5215.01	-.22	.37 S	.81 E	.89at	S 65.47 E
133.00	.75	N 19.50 E	28.00	132.99	-5187.01	.12	.05 S	.99 E	.99at	S 87.04 E
162.00	1.00	N 17.00 E	29.00	161.99	-5159.01	.56	.37 N	1.13 E	1.19at	N 71.84 E
192.00	1.50	N 13.00 E	30.00	191.98	-5128.02	1.21	1.00 N	1.30 E	1.64at	N 52.30 E
249.00	2.00	N 02.00 W	57.00	249.96	-5071.04	2.94	2.73 N	1.46 E	3.10at	N 28.18 E
307.00	3.25	N 02.00 W	58.00	306.89	-5013.11	5.54	5.39 N	1.37 E	5.56at	N 14.27 E
336.00	4.00	N 02.50 W	29.00	335.83	-4984.17	7.33	7.22 N	1.30 E	7.33at	N 10.19 E
370.00	4.75	N 00.00 W	34.00	369.74	-4950.26	9.88	9.81 N	1.24 E	9.89at	N 07.21 E
400.00	5.00	N 01.50 E	30.00	399.63	-4920.37	12.39	12.36 N	1.27 E	12.42at	N 05.88 E
432.00	5.50	N 05.00 E	32.00	431.49	-4888.51	15.30	15.28 N	1.44 E	15.35at	N 05.38 E
494.00	6.00	N 04.00 E	62.00	493.18	-4826.82	21.48	21.47 N	1.93 E	21.56at	N 05.13 E
557.00	6.50	N 10.00 E	63.00	555.91	-4764.12	28.33	28.27 N	2.79 E	28.41at	N 05.64 E
619.00	6.75	N 13.50 E	62.00	617.39	-4712.61	35.49	35.27 N	4.28 E	35.53at	N 06.91 E
711.00	8.00	N 12.00 E	92.00	708.63	-4611.37	47.27	46.75 N	6.87 E	47.20at	N 10.37 E
774.00	8.50	N 05.00 E	63.00	770.98	-4549.02	55.30	55.72 N	8.22 E	56.33at	N 08.39 E
805.00	8.75	N 04.00 E	31.00	801.63	-4518.37	60.93	60.36 N	8.59 E	60.96at	N 08.09 E
836.00	9.25	N 03.50 E	31.00	832.24	-4487.76	65.75	65.20 N	8.79 E	65.80at	N 07.77 E
900.00	10.00	N 03.50 E	64.00	895.34	-4424.66	76.39	75.08 N	9.56 E	76.48at	N 07.13 E
929.00	10.25	N 03.00 E	29.00	923.87	-4396.11	81.45	80.97 N	9.83 E	81.56at	N 06.93 E
992.00	10.50	N 07.00 E	63.00	985.91	-4334.09	92.49	92.05 N	10.81 E	92.66at	N 06.77 E
1052.00	10.00	N 10.00 E	60.00	1045.00	-4275.00	102.89	102.30 N	12.35 E	103.03at	N 06.99 E

MEASURED DEPTH FEET	HOLE ANGLE DEGS.	HOLE DIRECTION DEGS.	COURSE LENGTH FEET	TRUE VERTICAL DEPTH FEET	SUBSEA DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES N/S Feet	E/W	CLOSURE DISTANCE FEET	CLOSURE DIRECTION DEGS.
1116.00	15.00	N 12.50 E	64.00	1108.03	-4211.97	114.00	113.20 N	14.52 E	114.13at N 07.36 E	
1147.00	10.00	N 12.00 E	31.00	1139.56	-4181.44	119.38	118.46 N	15.66 E	119.47at N 07.57 E	
1209.00	10.00	N 10.00 E	62.00	1199.61	-4120.39	130.14	129.03 N	17.71 E	130.24at N 07.81 E	
1247.00	9.50	N 12.00 E	38.00	1237.06	-4082.94	136.59	135.34 N	18.94 E	136.66at N 07.92 E	
1271.00	9.75	N 12.00 E	24.00	1260.73	-4059.27	140.59	139.27 N	19.78 E	140.67at N 08.08 E	
1303.00	10.00	N 12.00 E	32.00	1292.25	-4027.75	146.57	144.64 N	20.92 E	146.13at N 08.22 E	
1440.00	15.50	N 10.00 E	137.00	1427.07	-3972.93	170.45	169.57 N	23.57 E	170.49at N 08.62 E	
1471.00	10.50	N 09.50 E	31.00	1457.55	-3942.45	176.10	174.13 N	26.53 E	176.14at N 08.66 E	
1504.00	11.00	N 09.00 E	33.00	1489.97	-3930.03	182.23	180.21 N	27.52 E	182.30at N 08.68 E	
1566.00	12.00	N 07.50 E	62.00	1550.72	-3769.28	194.60	192.44 N	29.29 E	194.66at N 08.65 E	
1659.00	13.75	N 06.00 E	93.00	1641.39	-3678.62	215.27	213.02 N	31.72 E	215.32at N 08.42 E	
1752.00	16.50	N 04.00 E	93.00	1731.15	-3588.85	239.46	237.19 N	33.84 E	239.59at N 08.11 E	
1845.00	17.00	N 03.00 E	93.00	1820.20	-3499.80	266.09	263.94 N	35.49 E	266.32at N 07.65 E	
1968.00	20.00	N 05.00 E	123.00	1936.83	-3393.17	304.69	302.95 N	36.50 E	305.14at N 06.86 E	
2061.00	21.00	N 00.00 E	93.00	2023.94	-3296.06	336.76	335.52 N	36.50 E	337.50at N 06.29 E	
2155.00	22.50	N 02.00 W	94.00	2111.25	-3209.75	370.95	370.34 N	35.89 E	372.08at N 05.53 E	
2227.00	24.00	N 03.00 W	72.00	2177.40	-3142.60	398.69	398.73 N	34.65 E	400.24at N 04.96 E	
2338.00	25.50	N 04.50 W	111.00	2278.20	-3041.80	443.83	445.10 N	31.61 E	446.22at N 04.06 E	
2401.00	26.50	N 05.00 W	63.00	2334.82	-2985.18	470.54	472.63 N	29.32 E	473.53at N 03.55 E	
2495.00	28.00	N 07.50 W	94.00	2418.39	-2901.61	511.85	515.41 N	24.64 E	515.97at N 02.73 E	
2589.00	29.25	N 09.00 W	94.00	2500.90	-2819.10	554.62	559.97 N	19.18 E	560.27at N 01.95 E	
2683.00	31.50	N 11.00 W	94.00	2581.97	-2738.01	599.28	606.77 N	9.92 E	606.86at N 00.93 E	
2776.00	31.00	N 11.50 W	93.00	2661.50	-2658.50	644.24	654.09 N	.51 E	654.09at N 00.[illegible] E	
2871.00	31.00	N 12.00 W	95.00	2742.93	-2577.07	690.69	702.00 N	9.45 W	702.03at N 00.77 W	
2965.00	31.00	N 16.00 W	94.00	2823.50	-2496.50	733.91	749.96 N	21.16 W	749.26at N 01.61 W	

MEASURED DEPTH FEET	INCL. ANGLE DEGS.	HOLE DIRECTION DEGS.	COURSE LENGTH FEET	TRUE VERTICAL DEPTH FEET	SUBSEA DEPTH FEET	VERTICAL SECTION FEET	RECTANGULAR COORDINATES N/S feet	E/W	CLOSURE DISTANCE FEET	CLOSURE DIRECTION DEGS.
3059.00	32.00	N 26.00 W	94.00	2903.65	-2416.35	777.27	795.66 N	36.34 W	796.49at	N 02.61 W
3157.00	34.00	N 23.00 W	98.00	2985.83	-2334.17	822.77	845.22 N	55.95 W	847.1[illegible]at	N 03.78 W
3278.00	36.00	N 24.00 W	121.00	3084.95	-2235.05	880.64	908.96 N	83.57 W	912.79at	N 05.25 W
3373.00	36.75	N 30.50 W	95.00	3161.44	-2158.56	923.61	959.14 N	109.13 W	965.32at	N 06.49 W
3423.00	37.25	N 33.00 W	50.00	3201.37	-2118.63	948.15	984.79 N	124.85 W	992.67at	N 07.22 W

CLOSURE DISTANCE = 992.67 FEET.
CLOSURE DIRECTION = N 7.23 W

RMOTC Well Data Sheet

Well Number: 33 STX 23

Producing Formation: Steele Shale

API Well Number: 49-025-10993

Location: US Naval Petroleum Reserve #3 (Teapot Dome field)
1415' FNL, 1874' FWL (SE/4-NW/4) Section 23, T38N, R78W, Natrona County, WY

Elevations: 5296' GL, 5308' KB

Casing: 8-5/8" 24# J-55 Set at 1200'. Cemented with 450 sx 50-50 Poz. + 2% $CaCl_2$ + 5 #/sk gilsonite. Tail with 75sx class "G" + 2% $CaCl_2$ + 1/4 #/sk Kwikseal

Tubing: 84 joints 2-3/8" used tubing with mud/gas anchor and seating nipple at 2678'.
No tubing anchor or anchor-catcher.

Rods: 106 - 5/8" rods

PBTD: 2787' (7-7/8" open hole below 8-5/8" casing)

Perfs: None - Oils show in natural fracture at unknown depth. Well was originally a dry hole. Oil was found during preparation for P&A.

Present Status: producing approximately 5 BOPD on intermittant production
Oil gravity 38 degrees API, 40 degrees, corrected
Water production - trace
solids - trace. produces fine bentonite clays sufficient to quickly stick rod pump

Fluid level: Nearly pumped off: Static fluid level near surface.

Casing pressure: None. Casing and tubing produce to storage tank - no separation equipment.

Deviation: Directionally drilled - see attached directional surveys.

EASTMAN CHRISTENSEN

SUB-SURFACE DIRECTIONAL SURVEY

LAWRENCE-ALLISON & ASSOCIATES WEST, INC.
COMPANY

33 X 23
WELL NAME

NATRONA, WYOMING
LOCATION

JOB NUMBER	TYPE OF SURVEY	DATE
410-938	SINGLE SHOT	9/23/87

SURVEY BY
STEVE COCHRAN

OFFICE
RM 410

========= NORTRAK NAVIGATION SURVEY PROGRAM Ver: 2.00PC (03-31-86) =========

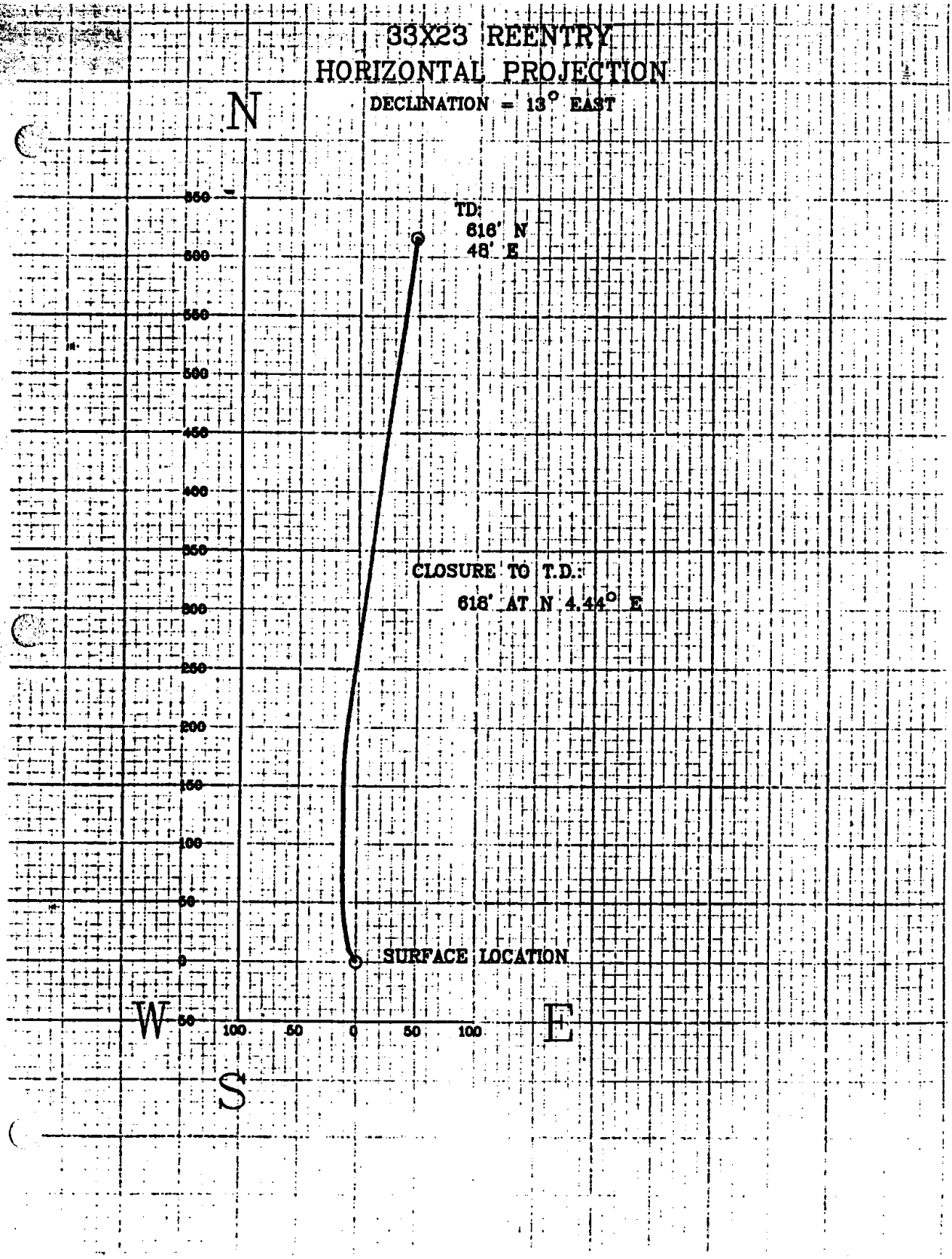
Date: 9/23/1987 Time: 17:17:18 PAGE: 1
Filename: "LAW3323.SRV" Description: "LAWRENCE ALLISON & ASSOC. "
Target Coordinates: 616.0 N 48.0 E Target TVD: 2700.000
ng Radius of curvature method.

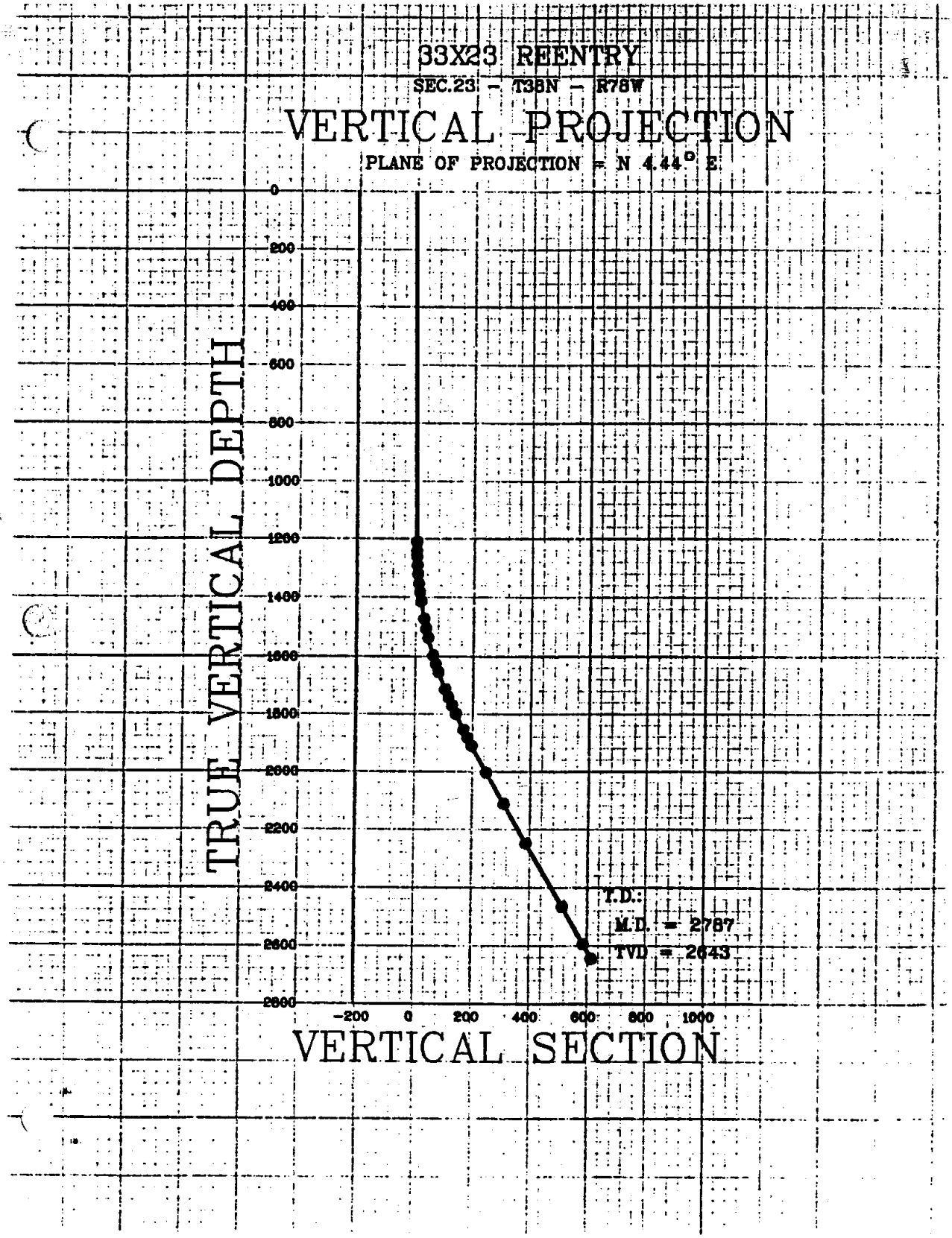
S #	MEASURED DEPTH (feet)	DRIFT ANGLE (deg)	DRIFT DIRECTION (deg)	COURSE LENGTH (feet)	TRUE VERTCAL DEPTH (feet)	VERTCAL SECTION (feet)	--- RECTANGULAR COORDINATES (feet)	-SEVERITY DG/100FT	DOGLEG
0	0.0	0.00	- 0 -	0.0	0.0	0.0	0.0 N	0.0 E	0.00
1	1209.0	1.00	N 32.00 W	1209.0	1208.9	8.5	8.9 N	5.6 W	0.08
2	1240.0	1.25	N 22.00 W	31.0	1239.9	9.0	9.5 N	5.9 W	1.02
3	1257.0	1.75	N 11.00 W	17.0	1256.9	9.4	9.9 N	6.0 W	3.38
4	1288.0	3.25	N 8.00 W	31.0	1287.9	10.7	11.2 N	6.2 W	4.86
5	1319.0	5.00	N 8.00 W	31.0	1318.8	12.9	13.5 N	6.5 W	5.65
6	1351.0	6.50	N 11.00 W	32.0	1350.7	16.0	16.6 N	7.1 W	4.78
7	1382.0	8.00	N 12.00 W	31.0	1381.4	19.8	20.5 N	7.8 W	4.86
8	1413.0	9.50	N 11.00 W	31.0	1412.0	24.3	25.1 N	8.8 W	4.86
9	1472.0	12.00	N 7.00 W	59.0	1470.0	35.0	35.9 N	10.5 W	4.42
10	1506.0	13.25	N 3.00 W	34.0	1503.2	42.3	43.3 N	11.1 W	4.48
11	1538.0	14.50	N 2.00 W	32.0	1534.2	50.0	51.0 N	11.5 W	3.98
12	1601.0	17.75	N 1.00 W	63.0	1594.8	67.4	68.5 N	11.9 W	5.18
13	1633.0	19.00	Due N	32.0	1625.1	77.4	78.6 N	12.0 W	4.03
14	1663.0	20.00	Due N	30.0	1653.4	87.4	88.6 N	12.0 W	3.33
[illegible]	1726.0	22.00	Due N	63.0	1712.2	109.9	111.2 N	12.0 W	3.17
16	1757.0	23.25	Due N	31.0	1740.8	121.8	123.1 N	12.0 W	4.03
17	1788.0	24.25	N 1.00 W	31.0	1769.2	134.2	135.6 N	12.1 W	3.48
18	1820.0	25.00	N 1.00 E	32.0	1798.3	147.5	148.9 N	12.1 W	3.50
19	1882.0	26.50	N 3.00 E	62.0	1854.1	174.4	175.8 N	11.2 W	2.80
20	1913.0	27.00	N 6.00 E	31.0	1881.8	188.4	189.7 N	10.1 W	4.64
21	1945.0	28.00	N 7.00 E	32.0	1910.2	203.1	204.4 N	8.4 W	3.44
22	2051.0	29.00	N 8.00 E	106.0	2003.4	253.7	254.6 N	1.8 W	1.05
23	2176.0	29.50	N 8.00 E	125.0	2112.4	314.6	315.0 N	6.7 E	0.40
24	2332.0	30.00	N 7.00 E	156.0	2247.9	391.9	391.8 N	16.8 E	0.45
25	2584.0	30.00	N 9.00 E	252.0	2466.1	517.7	516.6 N	34.3 E	0.40
26	2731.0	29.50	N 7.00 E	147.0	2593.7	590.5	588.8 N	44.5 E	0.76
27	2787.0	29.50	N 7.00 E	56.0	2642.5	618.0	616.2 N	47.8 E	0.00

--- Final Closure Direction: N 4.44 E
--- Final Closure Distance: 618.016 feet

33X23 REENTRY
HORIZONTAL PROJECTION

DECLINATION = 13° EAST




33X23 REENTRY
SEC.23 - T38N - R78W
VERTICAL PROJECTION
PLANE OF PROJECTION = N 4.44° E
TRUE VERTICAL DEPTH
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
T.D.:
M.D. = 2787
TVD = 2643
-200
0
200
400
600
800
1000
VERTICAL SECTION