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Recovery Efficiency Test Project
Phase II Activity Report
Volume II

Final Report

W.K. Overbey, Jr.
S.P. Salamy
C.D. Locke

February 1989

Work Performed Under Contract No.: DE-AC21-85MC22002

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
The BDM Corporation
McLean, Virginia

DISCLAIMER

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7915 Jones Branch Drive
McLean, Virginia 22102

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APPENDICES

A SUPPORTING MATERIAL AND PROCEDURES FOR "DATA FRAC" STIMULATION OF ZONE 6 USING NITROGEN AND NITROGEN FOAM

B SUPPORTING MATERIAL AND PROCEDURES FOR STIMULATION NO. 1 NITROGEN GAS FRAC ON ZONE NO. 1

C SUPPORTING MATERIAL AND PROCEDURES FOR STIMULATION NO. 2 IN ZONE NO. 1 USING LIQUID CO_2

D SUPPORTING MATERIAL AND PROCEDURES FOR FRAC NO. 3 ON ZONE NO. 1 USING NITROGEN FOAM AND PROPPANT

E SUPPORTING MATERIAL AND PROCEDURES FOR STIMULATION NO. 4 IN ZONES 2-3 AND 4 USING NITROGEN FOAM AND PROPPANT

F SUPPORTING MATERIALS AND PROCEDURES FOR STIMULATION NO. 5 IN ZONES 5 AND 8

G FRACTURE DIAGNOSTICS REPORTS AND SUPPORTING MATERIALS

APPENDIX A

SUPPORTING MATERIAL AND PROCEDURES FOR "DATA FRAC"
STIMULATION OF ZONE 6 USING NITROGEN AND NITROGEN FOAM

APPENDIX A-1

PRE-FRAC TEST LOG OF FIELD OPERATIONS

August 13, 1987

8:00 a.m. Pool Well Service and Dowell-Schlumberger on location. Nippled down the wellhead and flowlines. Blew down the well to atmosphere.

9:00 a.m. Tripped out of the hole with the tubing to check the packer element on the bottomhole assembly. Packer elements in good condition.

9:45 a.m. Tripped in the hole with the bottomhole assembly + 100 jts tubing.

12:00 noon Brake pads on the workover rig worn out. Shut down. Waiting for mechanic.

2:00 p.m. Shut down overnight.

August 14, 1987

8:00 a.m. Tore down brakes on the rig.

2:00 p.m. Rig mechanic replaced worn out brake pads.

3:30 p.m. Continued tripping in the hole with the tubing. Closed all port collars while tripping in the hole.

6:00 p.m. Positioned the bottomhole assembly over closed port collar #1 at 5746'. Shut down overnight.

August 15, 1987

8:00 a.m. Rigged up Dowell-Schlumber to pressure test port collar #1. with nitrogen.

9:30 a.m. Tested port collar #1 to 1000 psi - held o.k.

10:00 a.m. Blew down tubing. Tripped out of the hole and positioned the bottomhole assembly over port collar #2 at 5555'.

11:05 a.m. Attempted to test port collar #2 with no success.

11:15 a.m. Re-positioned the tubing to repeat the test.

11:50 a.m. Pressure tested port collar #2 to 1000 psi - held o.k.

12:00 noon Pulled out of the hole to port collar #3 at 5464'.

12:30 p.m. Attempted to test port collar #3 with no success.

1:00 p.m. Re-positioned the tubing over port collar #3 in order to repeat the test.

1:20 p.m. Attempted a second test on port collar #3. with no success. Port collar #3 did not test.

1:30 p.m. Pulled out of the hole and positioned the tubing over port collar #4 at 5319'.

2:05 p.m. Pressure tested port collar #4 to 1000 psi - held o.k.

2:10 p.m. Pulled out of the hole and positioned the tubing over port collar #5 at 5229'.

2:30 p.m. Pressure tested port collar #5 to 1000 psi - held o.k.

2:40 p.m. Pulled out of the hole and positioned the tubing over port collar #6 at 5129'.

3:05 p.m. Pressure tested port collar #6 to 1000 psi - held o.k.

3:15 p.m. Pulled out of the hole and positioned the tubing over port collar #7 at 5038'.

3.45 p.m. Pressure tested port collar #7 to 1100 psi - held o.k. Pressure tested port collars #8, #9, #10, #11, #12, #13 and #14 to 500 psi - held o.k. Note: Dowell did not have enough nitrogen on location in order to test port collars #8 - #14 to 1000 psi.

4:00 p.m. Tripping out of the hole with the tubing leaving all port collars except #11 in the closed position. Port collar #11 was left open for the mini-frac in zone #6.

6:00 p.m. Shut down overnight.

August 16, 1987

2:00 p.m. Finished tripping out of the hole with the bottomhole assembly and laid down same.

4:30 p.m. Made up new bottomhole assembly consisting of 2-3/8" bull plug + 2-2 3/8" pup joints + one set Baker bottom isolation cups + 1 jt 2-3/8" tubing + perforated sub. Tripped in the hole with the bottomhold assembly on 133 jts 2-3/8" tubing. (Total length = 4357.91') Top of the Baker Isolation cups at 4346' which is 55' below port collar #11 at 5291'. Note: Installed an Amerada bottomhole pressure recorder in the bottomhole assembly (2000 #Spring - 24 hr clock). Started clock at 4:30 p.m. on 8/16/87.

7:30 p.m. Nippled up the wellhead and flowlines.

8:00 p.m. Shut-in the well and shut down overnight.

August 17, 1987

9:00 a.m. Rigged up Dowell-Schlumberger (D-S) to perform Data-Frac on zone #6. Waited 1 1/2 hrs for treatment monitor vehicle. (TMV).

10:30 a.m. TMV arrived on location. Tested D-S lines to 3000 psi w/ N_2. - found numerous leaks (7 tests). Repaired pressure transducers on TMV unit.

1:17 p.m. Started treatment #1. Faulty transducers on TMV. Shut down and repaired same.

2:20 p.m. Re-started treatment #1. Pumped nitrogen down the 2-3/8" x 4-1/2" annulus at a rate of 2500 scf/minute. Shut in tubing pressure increased from 0# to a maximum of 804# at which pressure the downhole pump rate was equivalent to 8.8 BPM. A total of 62,500 SCF N_2 was pumped during this stage. Total pump time = 25 minutes. One pressure break was seen after 12 minutes of pumping - tubing pressure dropped from 761# to 726#.

2:45 p.m. Shut-down. ISIP = 754# 5 minutes = 707# 10 minutes = 680# Left well shut-in for a total of 55 minutes. Final SITP = 555#

3:41 p.m. Started pumping treatment #2. Pumped nitrogen down the annulus at a rate of 7500 - 10,000 scf/m. Shut-in tubing tubing pressure increased from 555# to 916# at which pressures the downhole pump rates ranged from 38 BPM to 23 BPM. A total of 112,500 SCF N_2 was pumped with a total pump time of 15 minutes. The shut-in tubing pressure stabilized at approximately 900 psig after 7 minutes of pumping and remained stabilized throughout the treatment.

3:56 p.m. Shutdown pumping and shut-in the well. ISIP = 901 psig 5 minutes = 788 psig 10 minutes = 738 psig Total shut-in time = 1 hr 25 minutes. Final SITP = 574 psig.

5:21 p.m. Started pumping treatment #3. Pumped 80 quality foam down the annulus at a downhole rate of 5 BPM. Nitrogen injection rate ranged from 1200 to 1600 Scf/minute while holding the liquid rate constant at 1 BPM. Tagged the foam with 5 millicurries of radioactive scandium 46. A total of 24,000 scf N_2 plus 20 Bbls 2% KCL water was pumped with a total pump time of 20 minutes. The foam was flushed to bottom with 45 Bbls of 80 quality foam at a pump rate of 5 BPM. The flush was tagged with radioactive Iodine #131 for treatment #4. The maximum casing pressure for treatment #3 was 888 psig. Maximum SITP = 907 psig.

5:52 p.m. Shut-down pumping and shut-in the well. Tubing ISIP - 907 psig. 5 minutes = 877 psig. 10 minutes = 873 psig. Total shut-in time = 1 hr Final SITP = 765 psig.

6:50 p.m. Started pumping treatment #4. Pumped 80 quality foam down the annulus at a downhole rate of 15 BPM. Nitrogen injection rate ranged from 4100 scf/minute to 4600 scf/minute while holding the liquid rate at 3 BPM. Tagged the foam with 10 millicurries of radioactive Iodine #131. A total of 74,000 scf N_2 plus 51 Bbls 2% KCL water was pumped with a total pump time of 17 minutes. The foam was flushed to bottom with 33,600 scf N_2 at a rate of 5100 scf/m. (overflushed 35 Bbls).

7:14 p.m. Shut-down pumping and shut-in the well. Tubing ISIP=1114 psig 5 minutes = 1055 psig 10 minutes = 1043 psig. Total shut-in time = 50 minutes Final SITP = 966 psig. Rigged down D-S.

9:45 p.m. SITP = 880 psig SICP = 905 psig Opened the well to the test seperator on a 1/16" choke. Initial gas/N_2 rate = 195 mcfpd.

August 18, 1987

12:00 Mn Gas/N_2 Flowrate = 170 mcfpd FTP =695 psig SICP = 725 psig 1/16" choke.

1:15 a.m. Increased tubing choke to a 17/64". Flowrate increased to 500 mcfpd (Gas/N_2). FTP= 580 psig SICP = 640 psig

2:00 a.m. Increased tubing choke to 48/64".

2:10 a.m. First fluid to surface. Well unloading foam and liquid.

2:30 a.m. Well unloading steady stream of fluid. FTP = 40 psig SICP = 320 psig.

4:30 a.m. FTP = 40 Psig SICP = 40 psig, 48/64" choke.

4:45 a.m. Recovered a total of 6 Bbls fluid. No fluid recovery last 15 minutes. Reduced tubing choke to 36/64". Gas/N_2 rate = 120 mcfpd.

6:00 a.m. FTP = 25 psig SICP = 25 psig Gas/N_2 rate = 93 mcfpd 36/64" choke.

9:00 a.m. FTP = 25 psig SICP = 30 psig Gas/N_2 rate = 76 mcfpd

11:00 a.m. Opened the well to atmosphere. Nippled down the wellhead. Pulled out of the hole with the tubing and bottomhole assembly. Removed the Amerada pressure chart and sent in to be evaluated.

4:30 p.m. Shut down overnight. Left well shut-in overnight.

August 19, 1987

8:00 a.m. Met with Dresser-Atlas wireline on location. Inspected tools for running tracer survey log. Dresser-Atlas

wireline was 9/16" diameter which was too large to safely run inside the 4-1/2" casing outside of the 2-3/8" tubing string. Note: Dresser was instructed to bring 5/16" line.

12:00 noon Ordered out Nowsco coiled tubing unit for 8/20/87.

4:00 p.m. Ordered out special tubing connections for coiled tubing shut-down overnight.

August 20, 1987

6:00 a.m. Nippled down wellhead Rigged up Dresser-Atlas and Nowsco coiled tubing unit.

6:45 a.m. SICP = 205 psig (18 hrs) Blew down well to atmosphere.

8:30 a.m. Run in the hole with gamma ray and temperature logging tools on 9/16" wireline to 3374'. (50° deviation).

9:00 a.m. Made up 2-3/8" side entry sub on bottom of 1" coiled tubing. Run in the hole with the coiled tubing to the top of the loging tools at 3374'.

11:00 a.m. Tagged wireline tools with coiled tubing. Pushed the tools in the hole at a rate of 50ft/minute to a maximum depth of 4666'. (Ran temperature log while running in the hole) Unable to get below 4666'.

12:00 noon Pulled out of the hole with coiled tubing and wireline to 4586'. Attempted to run in the hole at a higher speed with no success.

12:35 p.m. Logged with the spectro-gamma ray from 4578' to 3400' at 12 ft/minute.

2:25 p.m. Tripped back in the hole with logging tools and coiled tubing to 4698'. Logged Run #2 from 4698' to 3400'.

4:55 p.m. Pulled out of the hole with coiled tubing and wireline. Note: Coiled tubing and wireline wrapped around each other while tripping in and out of the hole which made it necessary to cut off tne last 90 + feet of coiled tubing in order to remove it from the hole. Rigged down Dresser and Nowsco.

8:30 p.m. Shut well in and shut down overnight.

August 21, 1987

7:00 p.m. Tripped in the hole with the opening and closing sleeve positioners on 2-3/8" tubing to 4020'. Nippled up the wellhead and flowlines. Note: All port collars are in the closed position except port collar #11 at 4291' (Zone 6).

11:00 a.m. Shut-in the well for a pressure buildup. Flow test will start on 8/22/87. Shut down overnight.

APPENDIX A-2

DATA FRAC ANALYSIS REPORT BY DOWELL SCHLUMBERGER

THE BDM CORPORATION
RECOVERY EFFICIENCY TEST #1
DATAFRAC ANALYSIS

DOWELL SCHLUMBERGER INCORPORATED

I. BACKGROUND

Zone #6 of BDM's Recovery Efficiency Test #1 well was treated with four injections for fluid loss and closure stress analysis. The overall configuration of the well is shown in Figure 1 and the table below.

Table I: ZONES

ZONE	LENGTH (ft)	PORTS OPEN	FRACTURES OBSERVED
8	291	8	1 major, 6 minor
7	91	4	1 major, 3 minor
6	134	4	5 minor
5	602	12	22 minor
4	181	8	8 major, 22 minor
3	365	12	10 major, 12 minor
2	419	4	8 major, 7 minor

Further data is included in Appendix I.

II. DATAFRAC ANALYSIS:

Four DataFRAC treatments were pumped. These were analysed to estimate in-situ stress regimes and leakoff characteristics. These can be summarized as follows:

Table II: DATAFRAC ANALYSIS

ZONE	TREATING FLUID	NOMINAL AVERAGE RATE	IDENTIFIER
6	N_2 *1	9.3bpm	1
6	N_2	29bpm	2
6	Foam *2	5bpm	3
6	Foam	11bpm	4

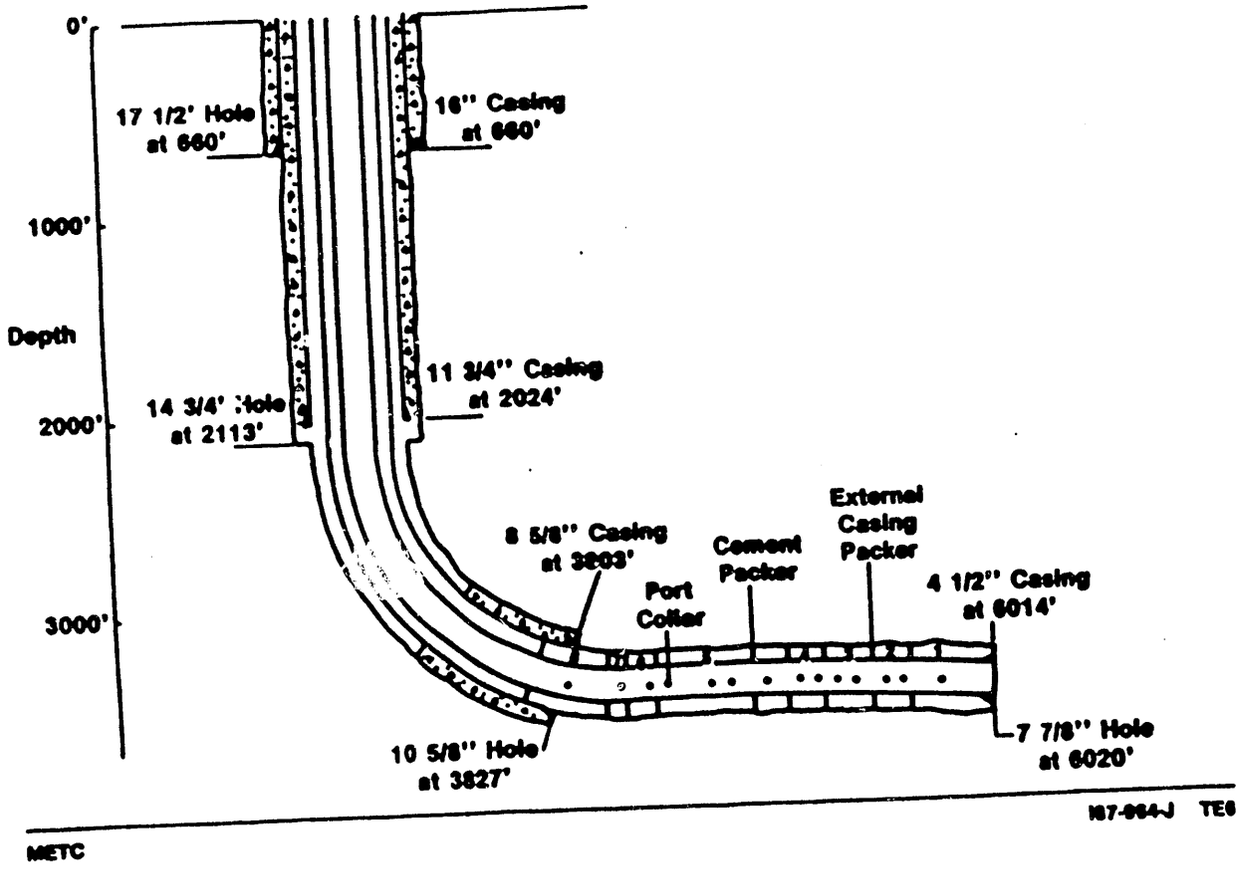
*1 Straight Nitrogen
*2 80 Quality Nitrogen Foam

III. DATAFRAC ANALYSIS FOR A COMPRESSIBLE FLUID:

BACKGROUND

Fracture pressure decline analysis techniques are used to estimate hydraulic fracture geometry, fluid efficiency and in-situ leakoff coefficients.

FIGURE 1: WELLBORE SCHEMATIC (courtesy of BDM)



Dowell Schlumberger currently has three methods available for analyzing fracture pressure decline data when compressible fluids are used. These are:

1. The "Uncorrected Method"
2. The "Pressure Corrected Method"
3. The "G-Function Corrected Method"

A detailed discussion of these techniques is outside the scope of this report. However, a short description is provided below:

The "Uncorrected Method"

As the name suggests, expansion of the fluids due to pressure decline or thermal effects is neglected. This method is generally applied to only slightly compressible fluids.

The "Pressure Corrected Method"

This method uses compressibility data and estimates of formation temperature effects to predict a theoretical pressure decline that would be observed if fluid expansion did not occur. Volume and injection rate are also corrected for expansion effects.

The "G-Function Corrected Method"

This method adjusts the G-Function using the ratio of the slope of the actual pressure decline to the slope of the theoretical pressure decline. This method was used for these analyses.

BASIC FRACTURE PRESSURE DECLINE ANALYSIS METHODOLOGY

The methodology used in fracture pressure decline analysis is:

1. Delineation of the fracture closure period
2. Estimation of closure pressure and closure time
3. Calculation of the Nolte Match Pressure (PSTAR).
4. Use of 2D analytical solutions to calculate
   a) Fluid Efficiency (Vf/Vi)
   b) Hydraulic Geometry (Lf and w)
   c) Total in-situ leakoff coefficient (C)

For a discussion of fracture pressure decline analysis including the "G-Function," and techniques for considering compressible fluids, please consult the references.

REFERENCES

1. Nolte, K.G.: "A General Analysis of Fracturing Pressure Decline Analysis With Application to Three Models," SPE Formation Evaluation (Dec. 1986) 571-583.

2. Soliman, M.Y." "Technique for Considering Fluid Compressibility and Temperature Changes in Mini-Frac Analysis," paper SPE _____ presented at the 1986 SPE Annual Technical Conference and Exhibition, New Orleans.

3. Castillo, J.L.: "Modified Fracture Pressure Decline Analysis Including Pressure-Dependent Leakoff," paper SPE 16417 presented at the 1987 SPE/DOE Low Permeability Reservoirs Symposium, Denver.

4. Martins, J.P., and Harper, T.R.: "Mini-Frac Pressure Decline Analysis for Fractures Evolving From Long Perforated Intervals and Unaffected by Confining Strata," paper SPE 13869 presented at the 1985 SPE/DOE Low Permeability Reservoirs Symposium, Denver.

IV. DATAFRAC ANALYSIS FOR DEVIATED WELLS:

The basic premise of DataFRAC analyses is for analysis of single fracture systems along the axis of the wellbore. To simplistically account for flow into more than one fracture, the following simplifying assumptions were made.

- Assume injected volume is the total injected volume divided by n, where n is the number of fractures taking equal amounts of fluid.
- Assume injection rate is the total injection rate, divided by n, where n is the number of fractures taking equal amounts of fluid.

V. ANALYSIS:

The following assumptions were made for all analyses:

Youngs Modulus	3.5×10^6 psi
Poison's Ratio	0.2
Net Height	200 ft
Gross Height	247 ft
n' (straight N_2)	1.0
n' (80 quality foam)	.45

The raw data, as measured by the Dowell Schlumberger TMV is included in Appendix III.

The first phase of the analysis, for each test, was to evaluate closure stress. This was done by looking at a number of graphical representations of post-shut-in pressure data. These included:

- Cartesian Plot of Pressure vs Time - Generally, this plot reveals little about closure stress levels (1).

- Logarithmic Plot of Pressure Differential vs Time Since Shut-In - Characteristic portions of this plot are unit slope (wellbore and/or fracture system storage), half-slope (linear flow suggesting an open fracture), quarter-slope (suggesting fracture and formation flow), pseudoradial flow (suggesting a closed fracture system) (2).

- Square Root of Time and Superposition Plots - Straight line behavior suggests linear flow (fracture open) (3),(4).

- Horner Plot - Processing post-shut-in data as a Horner plot will provide indications of radial flow if straight line portions exist (5).

- G Plot (Theoretical Nolte Plot) - This is an alternate processing of data, refining Nolte's earlier analyses. It allows discrimination of wellbore storage, continued fracture extension, progressive fracture closure....(6).

(Numbers in parentheses above correlate to columns in Table III.)

Assessment of closure stress was made by using all of the available plotting techniques. The results are shown in the following table.

Table III: CLOSURE STRESS

TEST IDENTIFIER	CLOSURE STRESS (psi)					
	1	2	3	4	5	6
1	?	?	Still Open	825	840	855
2	?	850	960,840	900	850	840
3	?	Still Open	1010?	1060	1050?	1010?
4	?	Wellbore Storage	?	?	?	Has Not Closed

Summarizing this information:

Table IV: CLOSURE STRESS

TEST IDENTIFIER	BOTTOMHOLE*1 CLOSURE STRESS (psi)	BOTTOMHOLE CLOSURE STRESS/3400 FT (psi/ft)
1	825-855 (850)	.25
2	840-960 (850) 1066	.25 .31
3	1010-1060 (1050)	.31
4	Didn't Close	

*1 Values in parentheses adopted for engineering purposes.

The implications may be as follows:

i) Two different stress regimes appear to have been identified (.25 psi/ft, .31 psi/ft)

ii) These probably represent natural fracture systems, which may be open.

iii) Entry into the lower stressed zone is possible at low rates and/or with low viscosity fluids (low rate N_2 injection).

iv) Increased rate with higher viscosity fluids may open up multiply oriented fracture systems.

v) Higher viscosity fluid at low rate (Test 3) definitely went into the higher stressed system. It is uncertain how much went into the lower stressed system.

vi) Shut-in data from test 4 was not monitored long enough to show closure. Processing BDM's flowback information may be extremely informative for substantiating stress regimes.

The questions which arise are:

- Are these different stressed zones fracture systems at acute angles?
- Does the higher stressed zone imply fracturing along the axis of the wellbore?
- Does tagging from the foam fracs provide any indication of orientation under low or high rate conditions?
- Can rate/viscosity control be favorably used to optimize stimulation?

FLUID LOSS COEFFICIENT

Calculation of the total fluid loss coefficient proceeded in an approximate fashion, based on assumptions and limitations described previously. The calculations indicate the following:

Table V: TOTAL FLUID LOSS COEFFICIENT

TEST	NUMBER FRACTURES TAKING FLUID	FLUID LOSS COEFFICIENT ($ft/\sqrt{min}$)
1	1	1.38×10^{-3}
	2	1.10×10^{-3}
	5	8.40×10^{-4}
	10	6.40×10^{-4}
2	1	1.05×10^{-3}
	2	8.3×10^{-4}
	5	6.1×10^{-4}
	10	4.9×10^{-4}
3	1	8.3×10^{-4} 1.02×10^{-3}
	2	8.05×10^{-4}
	5	5.9×10^{-4}
	10	4.7×10^{-4}
4	1	5.95×10^{-4}
	2	4.75×10^{-4}
	4	3.75×10^{-4}
	8	2.75×10^{-4}

The pertinent observations are as follows:

- The leakoff coefficient for n fractures is proportional to the square root of the n′ ratio (i.e. viscosity function) as anticipated.
- Fluid loss and consequently fracture dimensions are smaller for entry into multiple fractures.
- Second injection of individual fluids indicates reduced fluid loss, likely due to compressibility (stiffening) due to injection of the previous DataFRAC stage.

- For design purposes, presume that there is only one fracture when foam is injected, implying C_t = 1.45 ft/$\sqrt{\text{min.}}$
- For design purposes, for nitrogen presume that there are five fractures taking fluid giving C_t = 1.45 ft/$\sqrt{\text{min.}}$ (5 fractures, stage 2).
- It is coincidental that the above calculated coefficients are the same.

GEOMETRY PREDICTIONS

Using calculated/inferred fluid loss coefficients, some estimates of fracture geometry wereprepared, using a pseudo three-dimensional fracture height growth simulator. The scenarios considered are as follows:

Table VI: P3DH SIMULATIONS

TEST CASE	FLUID	RATE (SURFACE) (SCFM)	VOLUME (SURFACE) (SCF)	RESERVOIR*1 THICKNESS (FT)	STRESS*2 CONTRAST (PSI)	Ct	NUMBER FRACTURES
1	N_2	5000	6×10^5	250	200	1.45×10^{-3}	1
2	N_2	5000	1.5×10^6	250	200	1.45×10^{-3}	1
3	N_2	25000	6×10^5	250	200	1.45×10^{-3}	1
4	N_2	25000	1.5×10^6	250	200	1.45×10^{-3}	1
5	N_2	5000	6×10^5	250	200	6.1×10^{-4}	5
6	N_2	5000	1.5×10^6	250	200	6.1×10^{-4}	5
7	N_2	25000	6×10^5	250	200	6.1×10^{-4}	5
8	N_2	25000	1.5×10^6	250	200	6.1×10^{-4}	5

*1 The point of initiation was taken to be 50 ft from the reservoir bottom.

*2 For purposes of illustration stress contrast above and below the Lower Huron was taken to be 200 psi.

The results may be summarized as follows:

Table VII: P3DH SIMULATIONS

TEST CASE	WELLBORE WIDTH (in) (EOJ)	UPPER HEIGHT (ft) (EOJ)	LOWER HEIGHT (ft) (EOJ)	HALF-LENGTH (ft) (EOJ)
1	.013	206	53	468
2	?	?	?	?
3	.036	214	54	959
4	.036	214	54	1551
5	.008	203	52	230
6	?	?	?	?
7	.022	208	53	443
8	.022	208	53	734

Cases 1 to 4 presume entry into one fracture. Predicted widths for the low rate situations are small and suggest that asperity override or other mechanisms of self-propping will be essential. Lengths should be assessed qualitatively only. It seems possible that fluid loss may be higher than anticipated.

Cases 5 to 8 presume entry into 5 fractures. Predicted widths for the low rate situations are small and suggest that asperity override will be required for long term conductivity.

TREATMENT: The actual treatment designed for this well is summarized in Table VIII and in Appendix III. Post shut-in data processing indicates a closure stress in the vicinity of 790 psi. This corresponds to a perceived gradient of .23 psi/ft, based on a depth of 3400 ft and is within experimental accuracy of previous predictions. Fluid loss cannot be calculated because rate was not constant during the treatment. The treatment schedule was simulated as accurately as possible in a pseudo-three-dimensional height growth simulator; assuming five fractures taking fluid.

Table VIII: TREATMENT SCHEDULE

STAGE	RATE (scfm)	VOLUME 10-3 (scf)	VOLUME 10-3 (scf)
1	2000	60	60
2	4000	20	80
3	3000	60	140
4	3500	122	262
5	4000	128	390
6	4500	180	570
7	4800	240	810
8	5000	355	1165

Anticipated results are shown in Figure 2.

FIGURE 2A: MEASURED
BOTTOMHOLE TREATING PRESSURE

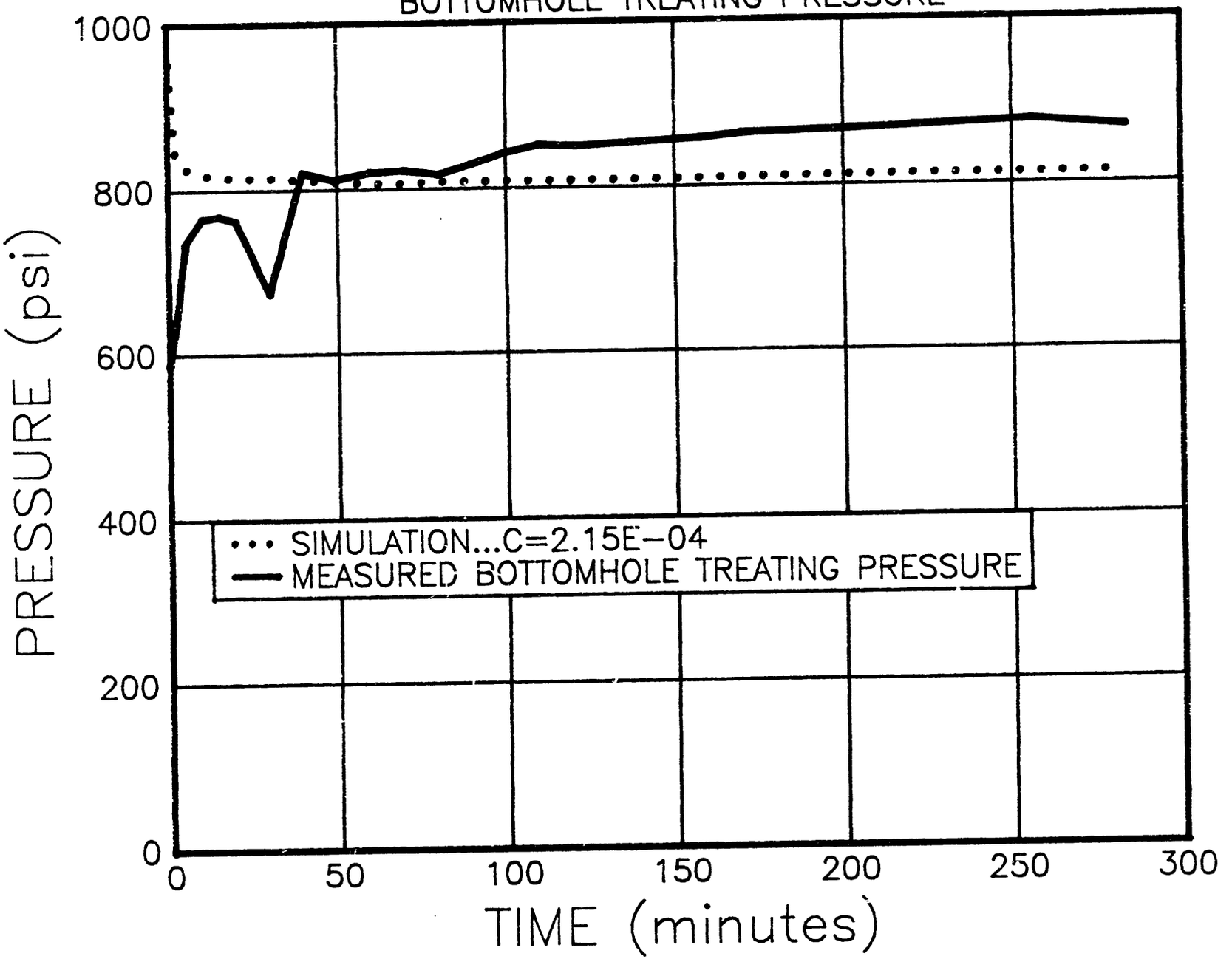


FIGURE 2B: REPRESENTATIVE SIMULATION

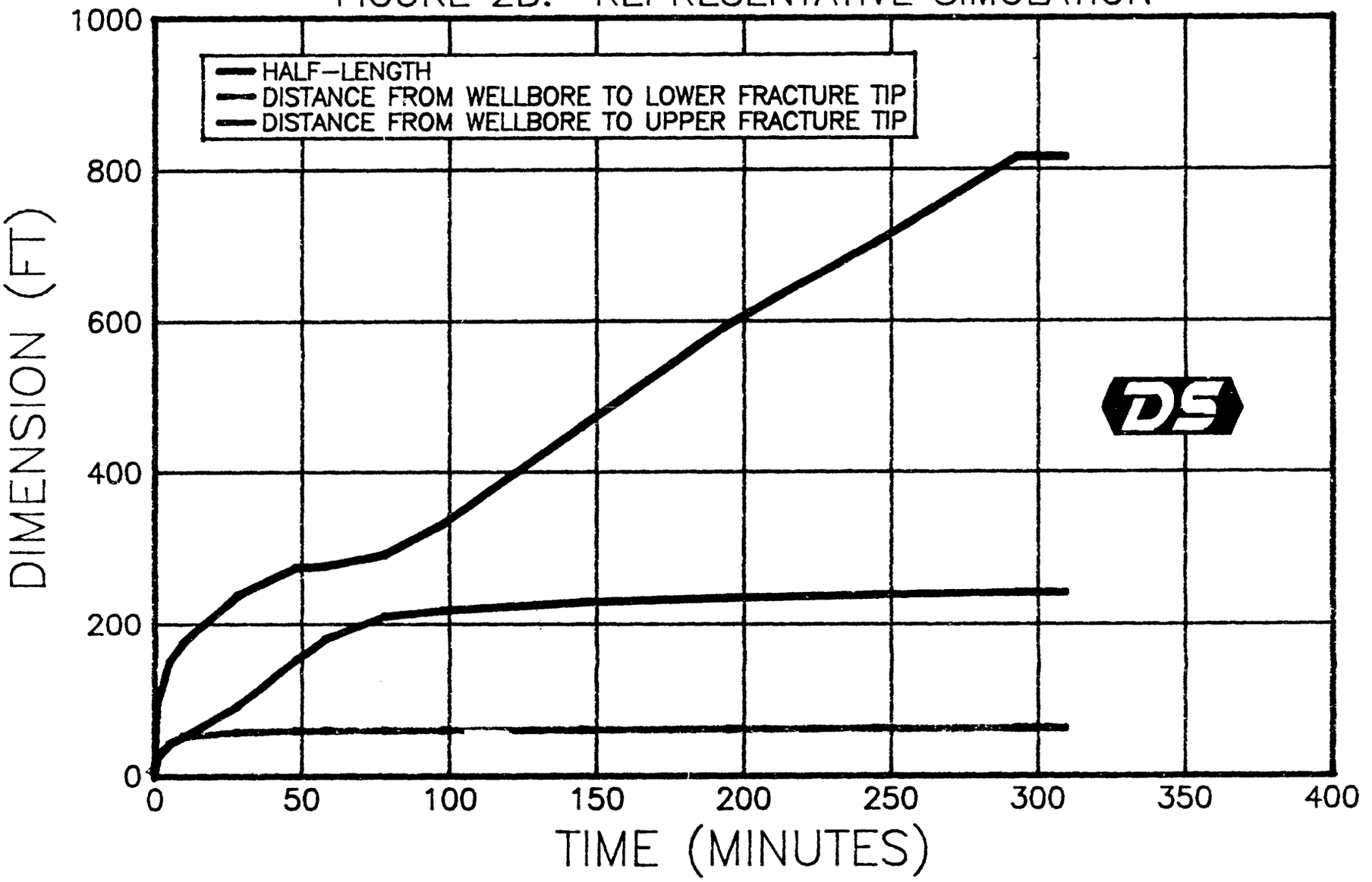
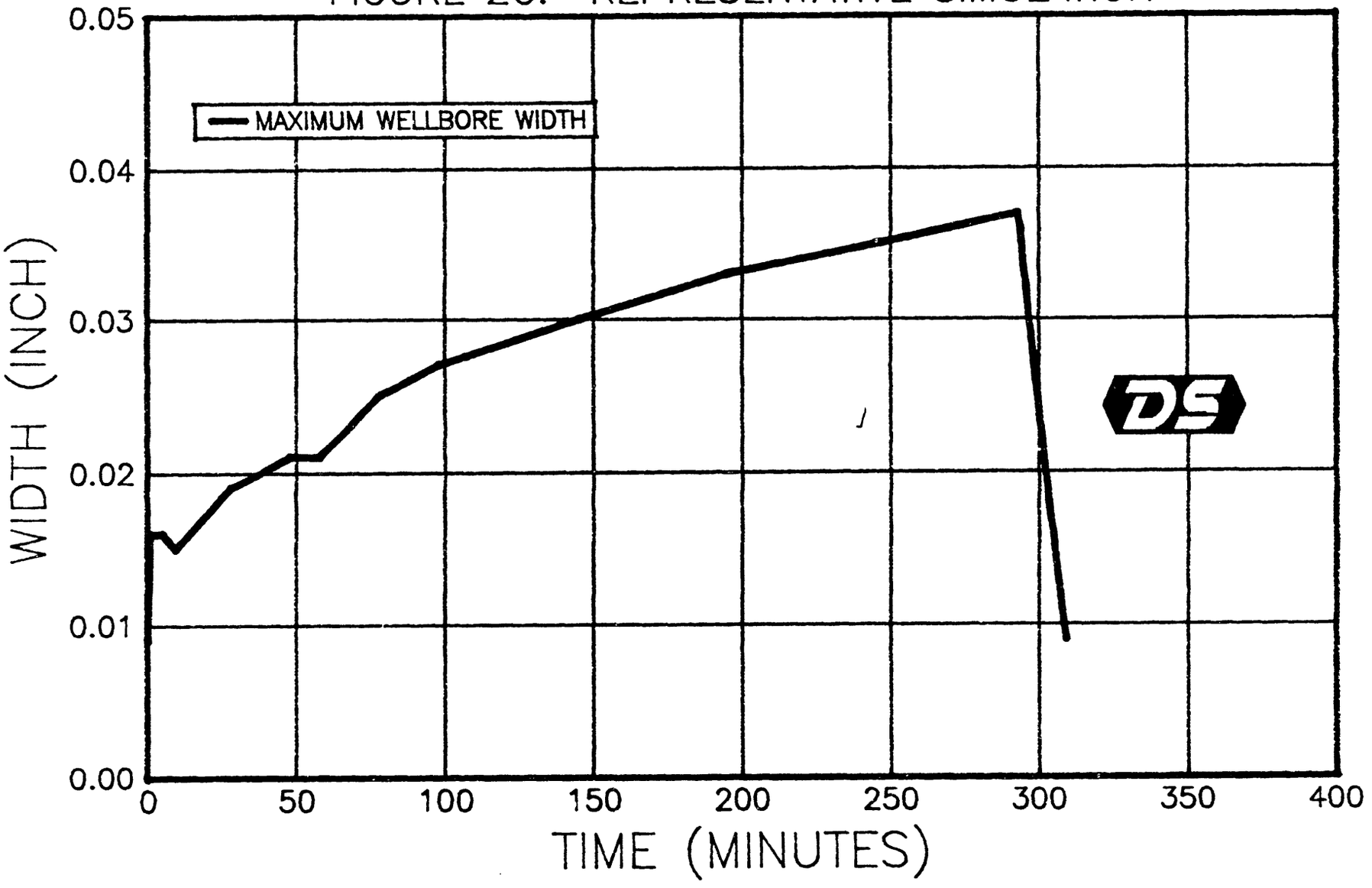


FIGURE 2C: REPRESENTATIVE SIMULATION



SUMMARY:

i) Fluid loss coefficients were ascertained for n fractures accepting fluid. (Refer to Table V.)

ii) Closure stress data shows two stress regimes, .25 and .31 psi/ft., probably indicating individual natural fracture systems.

APPENDIX B

SUPPORTING MATERIAL AND PROCEDURES FOR STIMULATION NO. 1
NITROGEN GAS FRAC ON ZONE NO. 1

B-1 Log of Field Operations to Prepare Well for Stimulation Operations

B-2 Log of Field Operations During Nitrogen Stimulation of Zone #1

B-3 Bottomhole Pressure and Temperature Measurements by Geosciences, Incorporated

B-4 Laboratory Report by Halliburton Services Analyzing Data Collected During Frac Job

APPENDIX B-1

LOG OF FIELD OPERATION TO PREPARE WELL AND TO STIMULATE ZONE #1 WITH NITROGEN GAS

BDM - RET WELL #1
Field Operations 9/22/87 - 9/25/87

Sept. 22, 1987

7:00 a.m. - 8:00 a.m. Met Pool Well Service and Geoservices, Inc. on location. Shut-in tubing pressure = 190 psig (Note: Only Zone #6 is open - the well has been shut-in since 7:30 p.m. on 9/8/87). Blew down the well to atmosphere.

8:00 a.m. - 5:00 p.m. Nippled down the wellhead and tripped out of the hole with 123 joints 2 3/8" tubing + opening and closing sleeve positioners. Made up new bottomhole assembly. Installed Geoservices bottomhole pressure recorders (2) + temperature recorder inside the 2 3/8" tubing. Tripped in the hole with 2 3/8" tubing and isolated port collar #1 @ 5746' with the bottomhole assembly. All port collars except #1 are in the closed position. Tubing detail as follows:

TUBING DETAIL		FOOTAGE
1	2 3/8" Bull Plug	0.68'
1 jt.	2 3/8" 4.7# J-55 Tubing	31.00
1	Baker Bottom Isolation Cups	5.22
1	Closing Sleeve Positioner	3.25
1 jt.	2 3/8" 4.7# J-55 Tubing	32.53
1	2 3/8" perforated sub	2.09
1 jt.	2 3/8" 4.7# J-55 Tubing	32.42
1	Opening Sleeve Positioner	3.25
1	Baker Top Isolation Cups	4.87
176 jts	2 3/8" 4.7# J-55 Tubing	5705.92
	Total	5821.23'(End of Tubing)

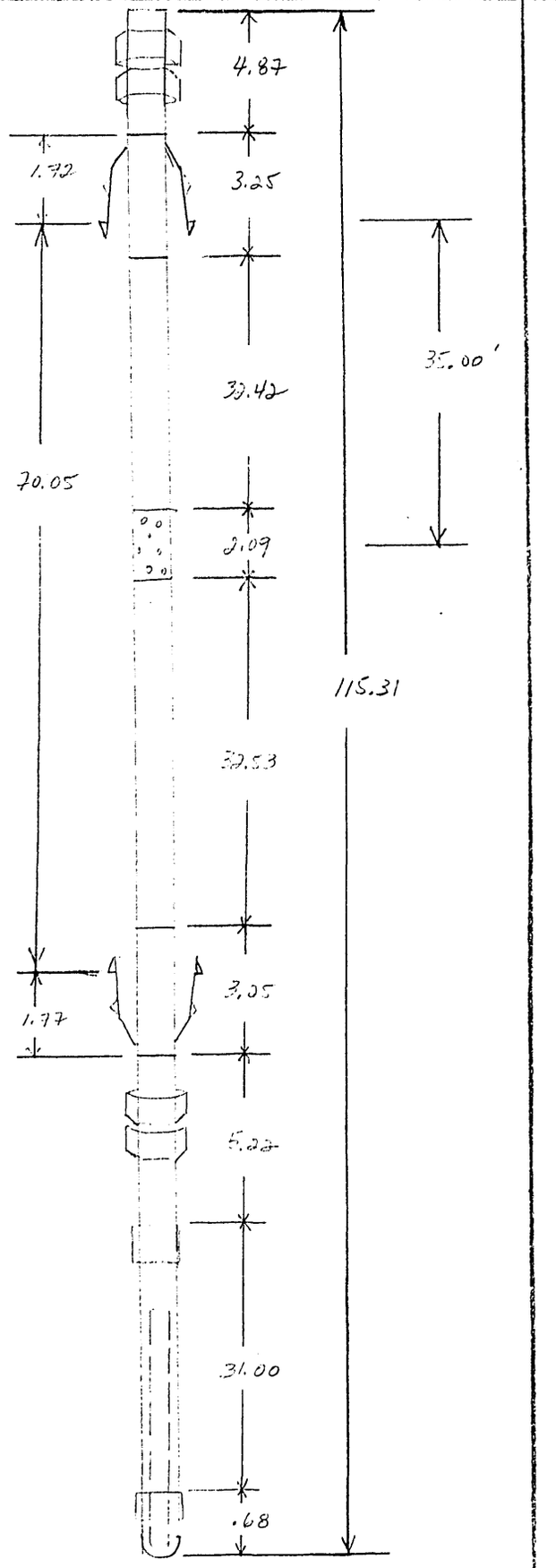
Top Cups @ 5711' Center of Perforated Sub @ 5748'
Bottom Cups @ 5784' Top of BHP recorders @ 5797'

Nippled up the wellhead and shut-in overnight. Note: Bottomhole pressure started recording pressures at 7:42 p.m. on 9/22/87. Scanning pressures every 60 seconds. Bomb will stop at 4:00 p.m. on 9/25/87.

BOM-RET WELL #1

9-22-87

Run #	Depth	Closed	Open
1	5746	174.9	177.0
2	5555	169.0	171.1
3	5454	166.2	168.3
4	5319	161.7	163.7
5	5209	158.7	160.1
6	5079	154.8	156.0
7	4993	152.0	155.2
8	4894	148.6	150.5
9	4795	145.4	147.5
10	4752	144.3	145.0
11	4671	142.0	143.3
12	4542	138.6	139.7
13	4450	135.8	137.9
14	4352	132.7	133.0



Borehole Assembly which was run on 9/22/87 used during Nitrogen breakdown of Zone #1 on 9/23/87.

APPENDIX B-2
LOG OF FIELD OPERATION FOR FRAC

JOB #1 - N_2 FRAC

Sept. 23, 1987

7:00 a.m. - 9:40 a.m. Rigged up Halliburton to pump nitrogen down the 2 3/8" tubing while monitoring pressures on both tubing and casing. Pressure tested equipment to 5000 psi. Held O.K. Note: Hunter Geophysical on location monitoring tilt meters. (8)

9:40 a.m. - 12:30 p.m. Started pumping nitrogen down the tubing (Zone #1) at a rate of 2000 scf/m. Compu-van was not calculating friction pressures. Shut-down. Field operator unable to correct compu-van program. Called Duncan, OK and talked with Mark Van Domilin about programming errors and corrected same.

12:30 p.m. - 7:30 p.m. Pumped nitrogen down 2 3/8" tubing and into Zone #1 @ 5746 as follows:

STAGE	RATE (SCF/m)	VOLUME (SCF)	CUM. VOLUME (SCF)
1	2000	60,000	60,000
2	4000	20,000	80,000
3	3000	60,000	140,000
4	3500	122,000	262,000
5	4000	128,000	390,000
6	4500	180,000	570,000
7	4800	240,000	810,000
8	5000	355,000	1,165,000

Maximum treating pressure = 1565 psig @ 5000 scf/m. ISIP = 776 psig. 5 minutes = 745 psig. 10 minutes = 735 psig. 15 minutes = 725 psig. Rigged down Halliburton.

7:30 p.m. - 12:00 a.m. Opened the well at 7:30 p.m. on an 8/64" tubing choke. Initial tubing pressure = 620 psig. Flowed the well overnight as follows:

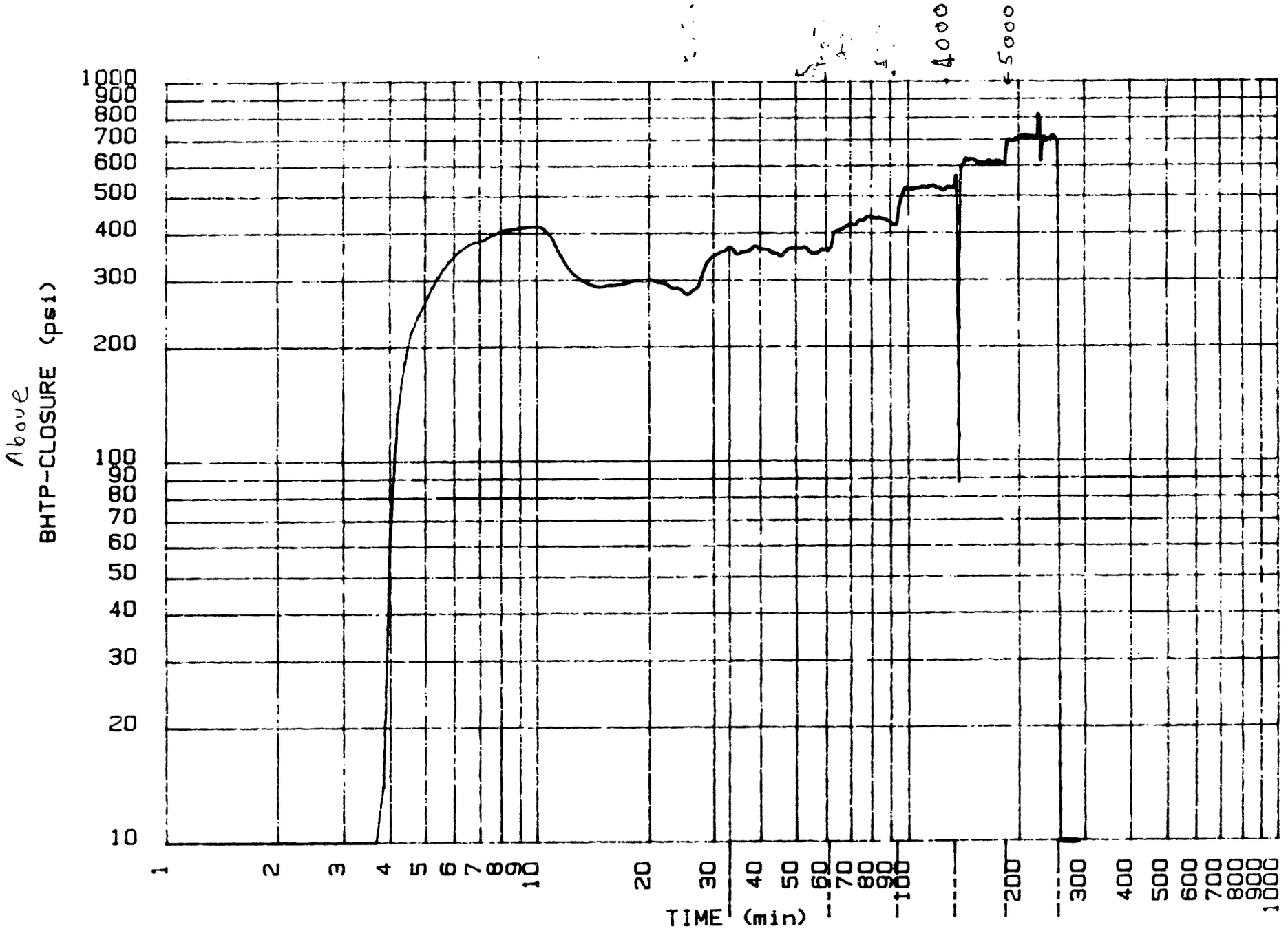
Time	TP (Psig)	CP (Psig)	LP (Psig)	DIFF (Inches)	Gas/N^2 Rate (Mcfpd)	Choke (/64ths)
7:30 pm	620	0	Open	Well	(3/4" plate)	8/64
8:00 pm	609	0	65	86	295	8/64
8:30 pm	590	0	65	84	285	8/64
9:00 pm	580	0	58	82	275	8/64
9:30 pm	569	0	57	80	270	8/64
10:00 pm	557	0	55	78	260	8/64
10:30 pm	546	0	54	79	259	8/64

Time	TP (Psig)	CP (Psig)	LP (Psig)	DIFF (Inches)	GAS/N^2 RATE (mcfpd)	CHOKE (/64ths)
11:00 pm	535	0	53	76	258	8/64
11:30 pm	520	0	52	74	250	8/64
Sept. 24, 1987						
12:00 am	505	0	50	73	245	8/64
12:30 am	493	0	50	71	240	8/64
1:00 am	480	0	48	70	235	8/64
1:30 am	470	0	47	68	230	8/64
2:00 am	460	0	45	66	220	8/64
2:30 am	450	0	44	64	215	Incr. 12/64
3:00 am	310	0	83	100	350	12/64
3:30 am	285	0	70	92	315	12/64
4:00 am	265	0	61	82	280	12/64
4:30 am	249	0	54	74	250	12/64
5:00 am	235	0	48	70	235	12/64
5:30 am	222	0	43	63	215	12/64
6:00 am	209	0	40	58	200	12/64
6:30 am	196	0	36	55	190	12/64
7:00 am	184	0	34	51	175	12/64
7:30 am	172	0	30	50	168	12/64
8:00 am	165	0	30	48	165	12/64
8:30 am	158	0	28	46	158	12/64
9:00 am	151	0	27	44	153	12/64
9:30 am	145	0	26	43	150	12/64
10:00 am	139	0	25	41	143	12/64
10:30 am	134	0	25	40	140	12/64
11:00 am	210	0	Shutin 20 min. to install back press regulator			
11:30 am	165	0	67	10	102	12/64
12:00 Noon	142	0	67	7	86	12/64
12:30 pm	129	0	65	6	78	12/64

Time	TP (Psig)	CP (Psig)	LP (Psig)	DIFF (Inches)	GAS/N^2 RATE (mcfpd)	CHOKE (/64ths)
Sept.24, 1987						
1:00 pm	121	0	65	6	78	12/64
1:30 pm	116	0	65	5	71	12/64
2:00 pm	113	0	65	5	71	12/64
2:30 pm	110	0	65	5	71	12/64
3:00 pm	106	0	65	4	64	12/64
3:30 pm	103	0	65	4	64	12/64
4:00 pm	101	0	65	4	64	12/64
4:30 pm	100	0	64	4	64	12/64
5:00 pm	98	0	63	4	63	12/64
5:30 pm	114	0	67	95	78	Shutin 10 min-- Chg plate to 3/8"
6:00 pm	100	0	68	100	80	12/64
6:30 pm	100	0	80	90	81	12/64
7:00 pm	100	0	80	90	81	12/64
7:30 pm	100	0	80	90	81	12/64
8:00 pm	100	0	82	90	82	12/64
8:30 pm	99	0	81	90	81	12/64
9:00 pm	98	0	80	89	80	12/64
9:30 pm	97	0	79	87	80	12/64
10:00 pm	95	0	77	86	79	12/64
10:30 pm	94	0	76	85	78	12/64
11:00 pm	93	0	75	83	77	12/64
11:30 pm	92	0	74	82	76	12/64
Sept. 25, 1987	90	0	73	81	75	12/64
12:30 am	89	0	72	79	74	12/64
1:00 am	87	0	71	78	72	12/64
1:30 am	86	0	70	77	71	12/64
2:00 am	85	0	70	75	70	12/64
2:30 am	84	0	69	74	69	12/64
3:00 am	83	0	68	72	68	12/64
3:30 am	82	0	67	71	67	12/64
4:00 am	80	0	67	70	66	12/64
4:30 am	80	0	66	68	65	12/64
5:00 am	79	0	66	67	65	12/64
5:30 am	78	0	65	66	64	12/64
6:00 am	77	0	65	65	64	12/64
6:30	77	0	65	63	63	12/64
7:00	76	0	65	62	62	12/64

Sept. 25, 1987(cont'd)

7:00 am - 5:00 pm Shut-in the well at 7:00 am. Nippled down the wellhead. Blew down well to atmosphere. Pulled out of the hole with tubing and closed port collar #1 @ 5746'. Pulled out of the hole to port collar #2 @ 5555'. (Zone #2-#3) Opened port collar #2 and recorded the shut-in tubing pressure for 30 minutes. Final SITP = 158 psig. Blew down the well and tripped in the hole and re-opened port collar #1. Pulled out of the hole with the tubing and bottomhole assembly. All port collars are in the closed position except port collar #1 - Zone #1. Laid down bottom-hole assembly. Recovered pressure bombs (2) and temperature bomb, and sent in to be evaluated. Left all tubing out of the hole. Nippled up flowlines and rigged down, Pool Well Service. Left well flowing to atmosphere overnight. Shut-down.



CUSTOMER: BDM CORP/ D.O.E.
DATE: 9-23-87
TYPE JOB: N2 FRAC
START TIME: 13:00:00

FORMATION: DEVONIAN SHALE
TICKET #: 552425
CLOSURE: 750

(RTR5.43)

APPENDIX B-3 BOTTOMHOLE TEMPERATURE AND PRESSURE MEASUREMENTS

Geoservices Inc. Production

Client : BDM CORP. Survey Date : 08/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

Reader Type: DataView DISK I.D. NO.: BDM#1

Skip : 30 Variation : .5

Cal. Date : 08/18/87 Cal. Number : JL#1
Cal. Range : 0-50 C Cal. Temp. : 0-50
Cal. [M] : .0340587 Cal. [I] : 24.6433

Tool Number: 23 Sensor No. : TSS-23

ADDRESS	DAY	TIME HH:MM:SS	dT (hr)	dT (temp)	TEMPERATURE (deg.F)	COMMENTS
2	22	19:44:00			90.07	GAUGES AT 3415' TVD
3	22	19:45:00			90.07	5805' MEASURED DEPTH
4	22	19:46:00			90.07	WELL FLOWING
34	22	20:16:00			90.17	
64	22	20:46:00			90.27	
94	22	21:16:00			90.34	
124	22	21:46:00			90.41	
154	22	22:16:00			90.48	
184	22	22:46:00			90.51	
214	22	23:16:00			90.55	
244	22	23:46:00			90.58	
274	23	00:16:00			90.61	
304	23	00:46:00			90.65	
334	23	01:16:00			90.68	
364	23	01:46:00			90.68	
394	23	02:16:00			90.72	
424	23	02:46:00			90.72	
454	23	03:16:00			90.75	
484	23	03:46:00			90.75	
514	23	04:16:00			90.75	
544	23	04:46:00			90.79	
574	23	05:16:00			90.79	
604	23	05:46:00			90.79	
634	23	06:16:00			90.82	
664	23	06:46:00			90.82	
694	23	07:16:00			90.82	
724	23	07:46:00			90.82	
754	23	08:16:00			90.85	
784	23	08:46:00			90.85	
814	23	09:16:00			90.89	
821	23	09:23:00	0.0000	0.00	90.99	START OF FRAC
838	23	09:40:00	0.2833	0.51	91.50	
844	23	09:46:00	0.3833	0.72	91.70	SHUT DOWN
874	23	10:16:00	0.8833	0.95	91.94	
904	23	10:46:00	1.3833	0.78	91.77	
934	23	11:16:00	1.8833	0.61	91.60	
964	23	11:46:00	2.3833	0.48	91.47	
994	23	12:16:00	2.8833	0.37	91.36	
1007	23	12:29:00	3.1000	0.37	91.36	START UP
1008	23	12:30:00	3.1166	0.41	91.40	RATE @2000 SCF/MIN

Geoservices Inc. Production

Client : BDM CORP. Survey Date : 08/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

ADDRESS	DAY	TIME HH:MM:SS	dT (hr)	dT (temp)	TEMPERATURE (deg.F)	COMMENTS
1027	23	12:49:00	3.4333	0.72	91.70	SHUT DOWN
1038	23	13:00:00	3.6166	0.68	91.67	START UP @4000 SCF/MIN
1046	23	13:08:00	3.7500	0.68	91.67	REDUCE TO 3000 SCF/MIN
1063	23	13:25:00	4.0333	0.44	91.43	INCREASE TO 3500 SCF/MIN
1074	23	13:36:00	4.2166	0.10	90.89	
1084	23	13:46:00	4.3833	0.61	90.38	
1098	23	14:00:00	4.6166	0.92	90.07	INCREASE TO 4500 SCF/MIN
1128	23	14:30:00	5.1166	1.12	89.87	
1133	23	14:35:00	5.2000	1.16	89.83	
1163	23	15:05:00	5.7000	1.12	89.87	
1170	23	15:12:00	5.8166	1.02	89.97	INCREASE TO 4800 SCF/MIN
1200	23	15:42:00	6.3166	0.82	90.17	
1220	23	16:02:00	6.6500	0.99	90.00	INCREASE TO 5000 SCF/MIN
1246	23	16:28:00	7.0833	1.50	89.49	
1262	23	16:44:00	7.3500	2.01	88.98	
1287	23	17:09:00	7.7666	2.52	88.47	
1290	23	17:12:00	7.8166	2.55	88.44	END OF FRAC
1320	23	17:42:00			88.26	
1350	23	18:12:00			88.50	
1380	23	18:42:00			88.74	
1410	23	19:12:00			89.01	
1440	23	19:42:00			89.22	
1470	23	20:12:00			89.39	
1500	23	20:42:00			89.53	
1530	23	21:12:00			89.66	
1560	23	21:42:00			89.80	
1590	23	22:12:00			89.90	
1620	23	22:42:00			89.97	
1650	23	23:12:00			90.00	
1680	23	23:42:00			90.07	
1710	24	00:12:00			90.10	
1740	24	00:42:00			90.14	
1770	24	01:12:00			90.17	
1800	24	01:42:00			90.21	
1830	24	02:12:00			90.24	
1860	24	02:42:00			90.24	
1890	24	03:12:00			90.10	
1920	24	03:42:00			90.00	
1950	24	04:12:00			89.93	
1980	24	04:42:00			89.90	
2010	24	05:12:00			89.93	
2040	24	05:42:00			89.97	
2070	24	06:12:00			90.00	
2100	24	06:42:00			90.07	
2130	24	07:12:00			90.10	
2160	24	07:42:00			90.14	
2190	24	08:12:00			90.17	
2220	24	08:42:00			90.21	
2250	24	09:12:00			90.27	
2280	24	09:42:00			90.27	
2310	24	10:12:00			90.31	

Geoservices Inc. Production

Client : BDM CORP. Survey Date : 08/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

ADDRESS	DAY	TIME HH:MM:SS	dT (hr)	dT (temp)	TEMPERATURE (deg.F)	COMMENTS
2340	24	10:42:00			90.38	
2370	24	11:12:00			90.51	
2400	24	11:42:00			90.48	
2430	24	12:12:00			90.41	
2460	24	12:42:00			90.41	
2490	24	13:12:00			90.41	
2520	24	13:42:00			90.41	
2550	24	14:12:00			90.44	
2580	24	14:42:00			90.48	
2610	24	15:12:00			90.51	
2640	24	15:42:00			90.51	
2670	24	16:12:00			90.55	
2700	24	16:42:00			90.55	
2730	24	17:12:00			90.58	
2760	24	17:42:00			90.61	
2790	24	18:12:00			90.58	
2820	24	18:42:00			90.61	
2850	24	19:12:00			90.65	
2880	24	19:42:00			90.65	
2910	24	20:12:00			90.65	
2940	24	20:42:00			90.68	
2970	24	21:12:00			90.68	
3000	24	21:42:00			90.68	
3030	24	22:12:00			90.68	
3060	24	22:42:00			90.72	
3090	24	23:12:00			90.72	
3120	24	23:42:00			90.72	
3150	25	00:12:00			90.72	
3180	25	00:42:00			90.72	
3210	25	01:12:00			90.72	
3240	25	01:42:00			90.72	
3270	25	02:12:00			90.72	
3300	25	02:42:00			90.75	
3330	25	03:12:00			90.75	
3360	25	03:42:00			90.75	
3390	25	04:12:00			90.75	
3420	25	04:42:00			90.75	
3450	25	05:12:00			90.75	
3480	25	05:42:00			90.75	
3510	25	06:12:00			90.75	
3540	25	06:42:00			90.79	
3570	25	07:12:00			90.79	
3600	25	07:42:00			90.79	
3609	25	07:51:00			90.79	BLOW DOWN WELL
3616	25	07:58:00			90.75	CLOSE #1
3646	25	08:28:00			90.55	OPEN #2: ZONES 2 & 3
3676	25	08:58:00			90.72	
3704	25	09:26:00			90.92	BLOW DOWN WELL
3715	25	09:37:00			91.19	OPEN #1: ZONE 1
3723	25	09:45:00			91.09	OPEN #3: ZONES 2 & 3
3726	25	09:48:00			91.02	CLOSE #2

Geoservices Inc. Production

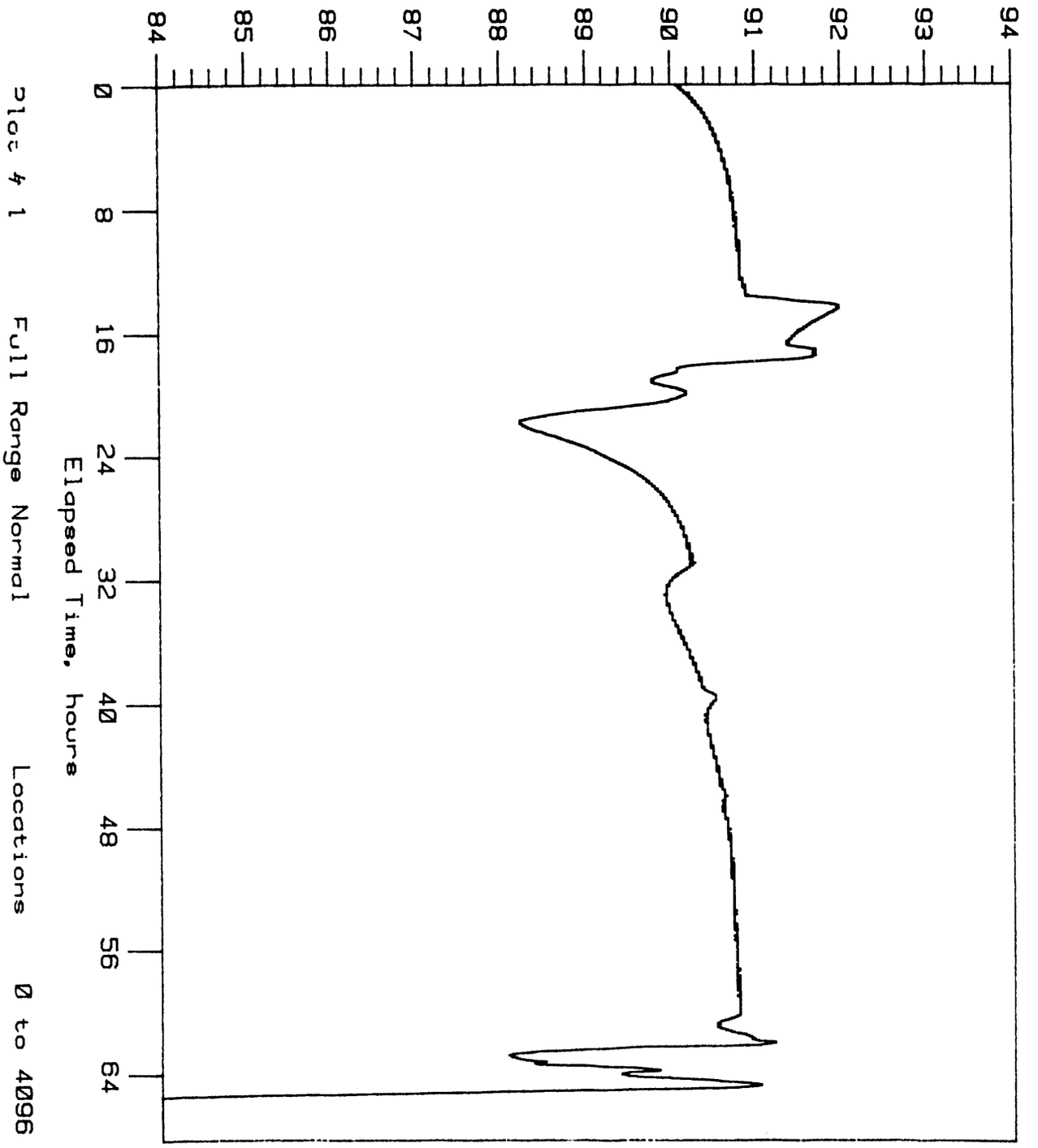
Client : BDM CORP. Survey Date : 08/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

ADDRESS	DAY	TIME HH:MM:SS	dT (hr)	dT (temp)	TEMPERATURE (deg.F)	COMMENTS
3730	25	09:52:00			90.48	
3733	25	09:55:00			89.90	
3736	25	09:58:00			89.49	CLOSE #3
3744	25	10:06:00			88.98	OPEN #4: ZONE 3
3748	25	10:10:00			88.78	CLOSE #4
3751	25	10:13:00			88.50	OPEN #5: ZONE 3
3755	25	10:17:00			88.33	CLOSE #5
3761	25	10:23:00			88.13	OPEN #6: ZONE 4
3785	25	10:47:00			88.26	CLOSE #6
3787	25	10:49:00			88.33	OPEN #7: ZONE 4
3791	25	10:53:00			88.44	CLOSE #7
3793	25	10:55:00			88.47	OPEN #8: ZONE 5
3804	25	11:06:00			88.50	CLOSE #8
3807	25	11:09:00			88.95	OPEN #9: ZONE 5
3812	25	11:14:00			89.32	CLOSE #9
3821	25	11:23:00			89.73	OPEN #10: ZONE 5
3825	25	11:27:00			89.80	CLOSE #10
3827	25	11:29:00			89.76	OPEN #11: ZONE 6
3831	25	11:33:00			89.53	CLOSE #11
3840	25	11:42:00			89.39	OPEN #12: ZONE 7
3845	25	11:47:00			89.46	CLOSE #12
3848	25	11:50:00			89.53	OPEN #13: ZONE 8
3852	25	11:54:00			89.80	CLOSE #13
3854	25	11:56:00			89.97	OPEN #14: ZONE 8
3855	25	11:57:00			90.07	CLOSE #14
3866	25	12:08:00			90.61	
3896	25	12:38:00			90.04	
3899	25	12:41:00			89.53	
3902	25	12:44:00			89.01	
3905	25	12:47:00			88.44	
3908	25	12:50:00			87.86	
3911	25	12:53:00			87.35	
3915	25	12:57:00			86.73	
3918	25	13:00:00			86.19	
3921	25	13:03:00			85.51	
3924	25	13:06:00			84.79	
3927	25	13:09:00			84.11	
3930	25	13:12:00			83.36	
3932	25	13:14:00			82.82	
3934	25	13:16:00			82.27	
3936	25	13:18:00			81.73	
3938	25	13:20:00			81.08	
3940	25	13:22:00			80.47	
3942	25	13:24:00			79.85	
3944	25	13:26:00			79.24	
3946	25	13:28:00			78.59	
3948	25	13:30:00			77.91	
3950	25	13:32:00			77.23	
3952	25	13:34:00			76.55	
3954	25	13:36:00			75.94	
3956	25	13:38:00			75.36	

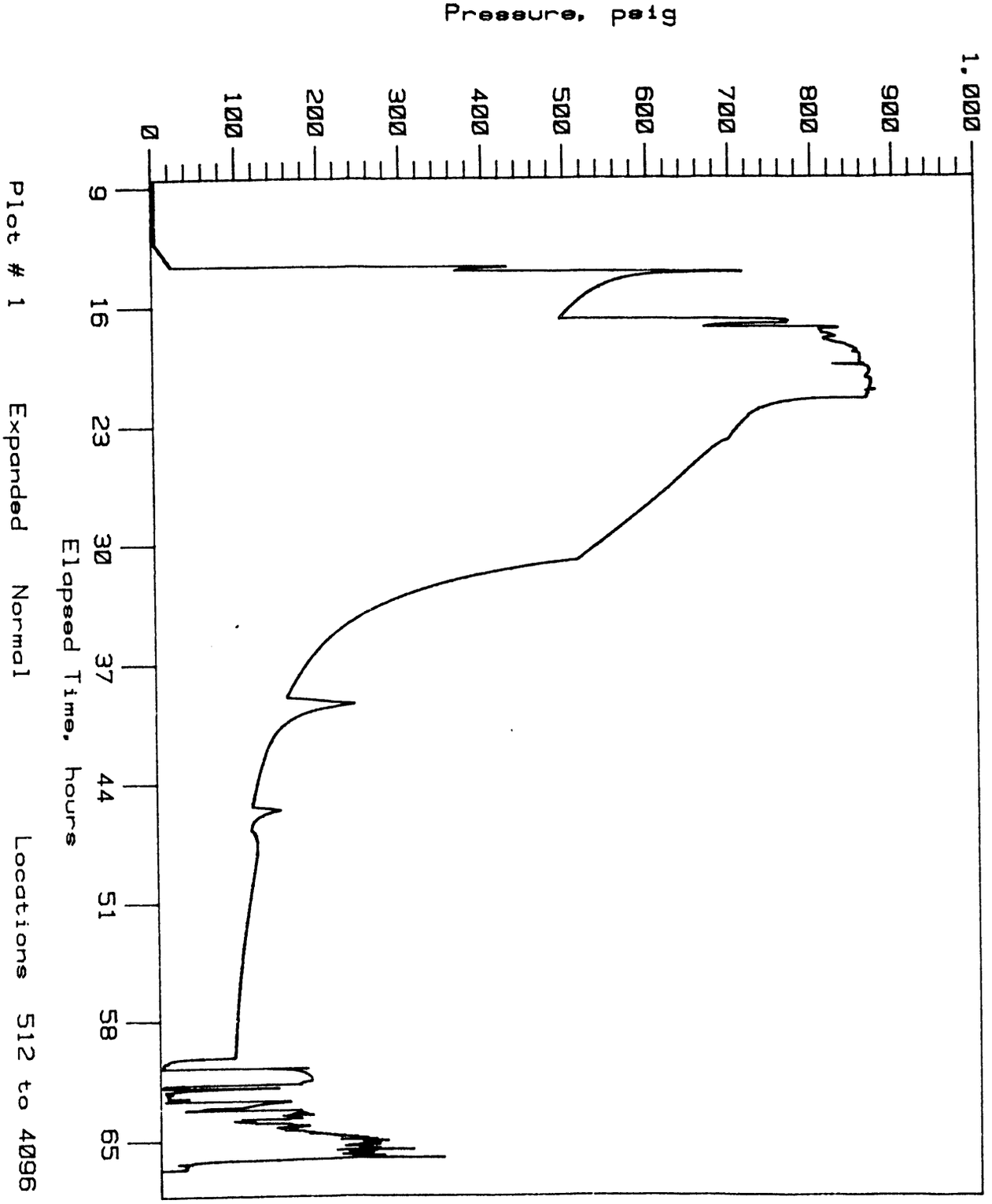
Client : BDM CORP. Survey Date : 08/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

ADDRESS	DAY	TIME HH:MM:SS	dT (hr)	dT (temp)	TEMPERATURE (deg.F)	COMMENTS
3959	25	13:41:00			74.64	
3962	25	13:44:00			74.03	
3965	25	13:47:00			73.31	
3968	25	13:50:00			72.60	
3970	25	13:52:00			71.98	
3971	25	13:53:00			71.41	
3972	25	13:54:00			70.59	
3973	25	13:55:00			69.70	
3974	25	13:56:00			68.82	
3975	25	13:57:00			67.93	
3976	25	13:58:00			67.11	
3977	25	13:59:00			66.40	
3978	25	14:00:00			65.72	
3979	25	14:01:00			65.11	
3980	25	14:02:00			64.56	
3982	25	14:04:00			63.64	
3984	25	14:06:00			62.86	
3986	25	14:08:00			62.21	
3988	25	14:10:00			61.70	
3991	25	14:13:00			60.98	
3994	25	14:16:00			60.40	
3996	25	14:18:00			59.86	
3998	25	14:20:00			59.28	
4001	25	14:23:00			58.74	
4004	25	14:26:00			59.21	END OF SURVEY

Geoservices Inc. Production	
Client: BDM CORP.	Calibration Date 08/18/87
Well : BDM RET #1	Calibration Number JL#1
Field : WILDCAT	Calibration Range 0-50 C
Date : 08/22/87	Calibration Temp. 0-50
Reader: DataView	Corrected Data CD=(M*UD)+I
Disk : BDM#1	M = .0340587
DEMETER Temp. Guage #23	I = 24.6433



Geoservices Inc. Production	
Client: BDM CORP.	Calibration Date 08/23/87
Well : BDM RET #1	Calibration Number JL#1
Field : WILDCAT	Calibration Range 0-2000 psi
Date : 09/22/87	Calibration Temp. 39 C
Reader: DataView	Corrected Data CD=(M*UD)+I
Disk : BDM#1	M = .651466
DEMETER Pressure Guage #23	I = -287.948



APPENDIX B-4 HALLIBURTON SERVICES ANALYSIS OF DATA COLLECTED DURING FRAC JOB

CHEMICAL RESEARCH AND DEVELOPMENT DEPARTMENT

HALLIBURTON SERVICES
DUNCAN, OKLAHOMA

No. T11-D006-87

LABORATORY REPORT

To Mr. G. A. Kozera/Mr. Rick Smith

Halliburton Services

Elkview, WV

Date October 29, 1987

We give below results of our examination of submitted data, including well log, bottomhole pressure data, COMPUVAN™ disk, and treating report.

Submitted by BDM Corp., DOE, and Grace, Shursen, Moore and Associates

Marked Well: RET No. 1
Location: Wayne Co., WV
Formation: Lower Huron Shale
Depth: 6,020 feet TD; 3,415 feet TVD

Purpose

The purpose of this project was to use the supplied data and determine the fracture dimensions by using minifrac analysis for a Perkins-Kerns Model, Christianovich Zheltov's Model, Horizontal or Vertical Penny Model, and Vertical Penny Model where the diameter is greater than pay height (ellipsoid shaped). A further purpose was to determine a Nolte Plot, calculate bottomhole treating rates based on surface rates, and recommend other treating procedure for the succeeding fracturing treatment along the horizontal section.

Discussion

On 9-22-87 a pressure bomb was run into the RET No. 1 to monitor BHFP, BHTP, and BHP before, during, and after a nitrogen fracturing treatment. After the nitrogen treatment, pressure decline was monitored for several hours. This pressure decline data was used in the requested minifrac analysis.

During the treating process, selected data were chosen from the pressure bomb data and used for plotting a Nolte Plot. Thus, the BHTP is measured rather than calculated.

Discussion Cont'd

Surface injection rates and bottomhole rates were calculated assuming that nitrogen behaves as an ideal gas over the temperature at surface (98-137°F) and at bottomhole (±90°F).

Conclusions

Pressure decline data were analyzed to present the different requested fracturing geometries. Plots of bottomhole pressure vs shut-in time (Figure 1) and log of (ISIP-BHTP) vs log shut-in time (Figure 2) were plotted to aid in determining fracture closure pressure.

From the plots, fracture closure was determined to be around 760 psi instead of 850 psi as previously reported. Minifrac analysis was performed using 760 psi and slope values were calculated to be 0.32-0.33. The slope values should be around 1.0. A closure pressure of 730 psi was chosen. Using 730 psi for closure pressure, slope values of 1.0 were obtained. The represented fracture geometries using both closure pressures are presented in the Data Section of this report. There is a possibility that more than one fracture is initiated, thus the multiple closure pressures.

The nitrogen fracturing treatment took approximately 4 hours to perform. All the data points were used and a Nolte Plot was plotted using this data. The Nolte Plot is presented in the Data Section of this report as Figure 3 (page 16). The total COMPUVAN data while pumping nitrogen are presented for reference in the appendix.

To calculate surface rates vs bottomhole rates, eight points were chosen which matched at the same time from the bottomhole pressure bomb. This information is tabulated in Table 1. The bottomhole pressure bomb data are presented in the appendix section along with a table showing the air viscosity vs temperature from API RP27 "Recommended Practice for Determining Permeability of Porous Media".

Recommendations

Since the Lower Huron Shale is water sensitive, the available treating fluids are limited. The use of a gelled hydrocarbon such as diesel or condensate is one possible fluid to place a proppant but since bottomhole flowing pressures are very low (less than 100 psi), this is not practical due to fluid recovery. To improve fluid recovery, a gelled diesel or condensate may be foamed with nitrogen and used to place a proppant in the fracture. With low BHP, closure stresses may approach 3,000-4,000 psi, therefore 20/40 mesh sand at a concentration of 4 to 6 lb/gallon or higher should be placed for effective fracture conductivity. If the formation is "soft", embedment of the proppant may be another problem for consideration.

Recommendations Cont'd

Liquid carbon dioxide may be used to fracture the formation like nitrogen gas treatments. If sufficient cool-down of the formation and tubular goods can be achieved, CO_2 will remain a liquid at a temperature of 80°F and 1,000 psi. See Carbon Dioxide Equilibrium Curve in the Appendix.

Since the bottomhole temperature is around 90°F, the use of the ALCOFOAM fracturing process is not possible. The ALCOFOAM fracturing treatment is not recommended for BHT below 120°F.

It is recommended that in any following treatments a bottomhole pressure bomb be used to measure BHP and BHTP, especially if a "fluid" is used that friction pressures may be difficult or impossible to obtain. By using a pressure bomb, Nolte Plots and any other analysis may be obtained using measured BHP or BHTP rather than calculated values.

Data

Using the following equation, the bottomhole flow rates were calculated from the surface injection conditions. The bottomhole temperature was assumed to be 95°F. The temperature disk contained only BHT data during the production prior to nitrogen injection.

Table 1

	Surface Injection Conditions			Bottomhole Conditions	
Time	P_1 (psi)	V_1 (scf/min.)	T_1 (°R)	P_2 (psi)	V_2 (scf/min.)
13:09	1,042.8	2,842	597.8	813.0	3,384
13:29	1,068.2	2,926	579.0	822.2	3,644
13:39	1,132.1	3,143	569.0	818.2	4,242
14:29	1,227.3	3,583	579.3	850.2	4,954
15:19	1,269.8	3,679	573.6	865.2	5,224
16:09	1,480.7	4,518	558.6	870.4	7,630
16:49	1,553.0	4,727	562.8	867.75	8,343
16:59	1,528.7	4,673	562.1	867.75	8,128

$$\frac{P_2V_2}{T_2} = \frac{P_1V_1}{T_1}$$

where: P_2 = BHP from pressure bomb

T_2 = 95°F (555°R)

V_2 = bottomhole injection rate

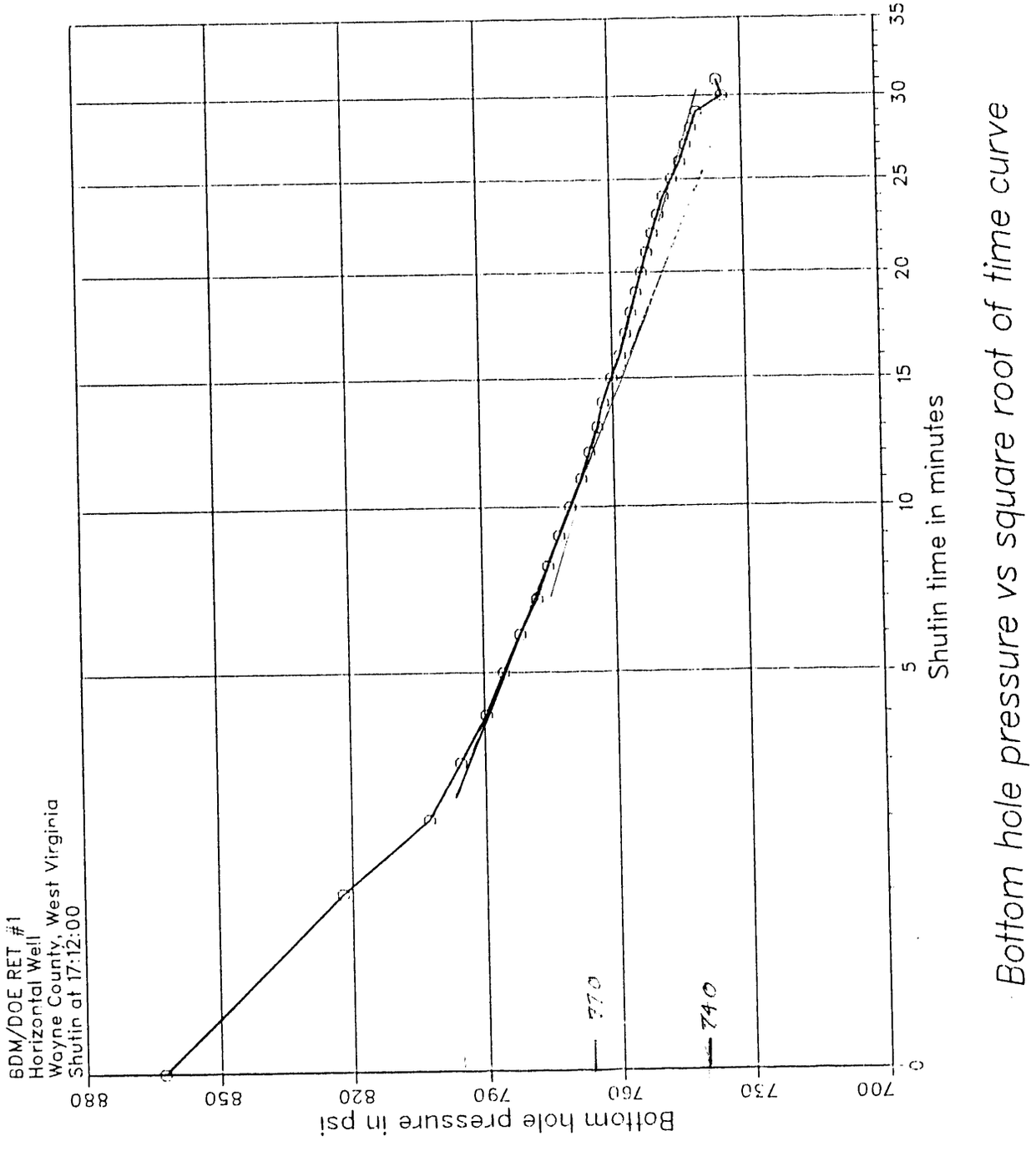
P_1 = surface pressure

V_1 = surface injection rate

T_1 = surface injection temperature

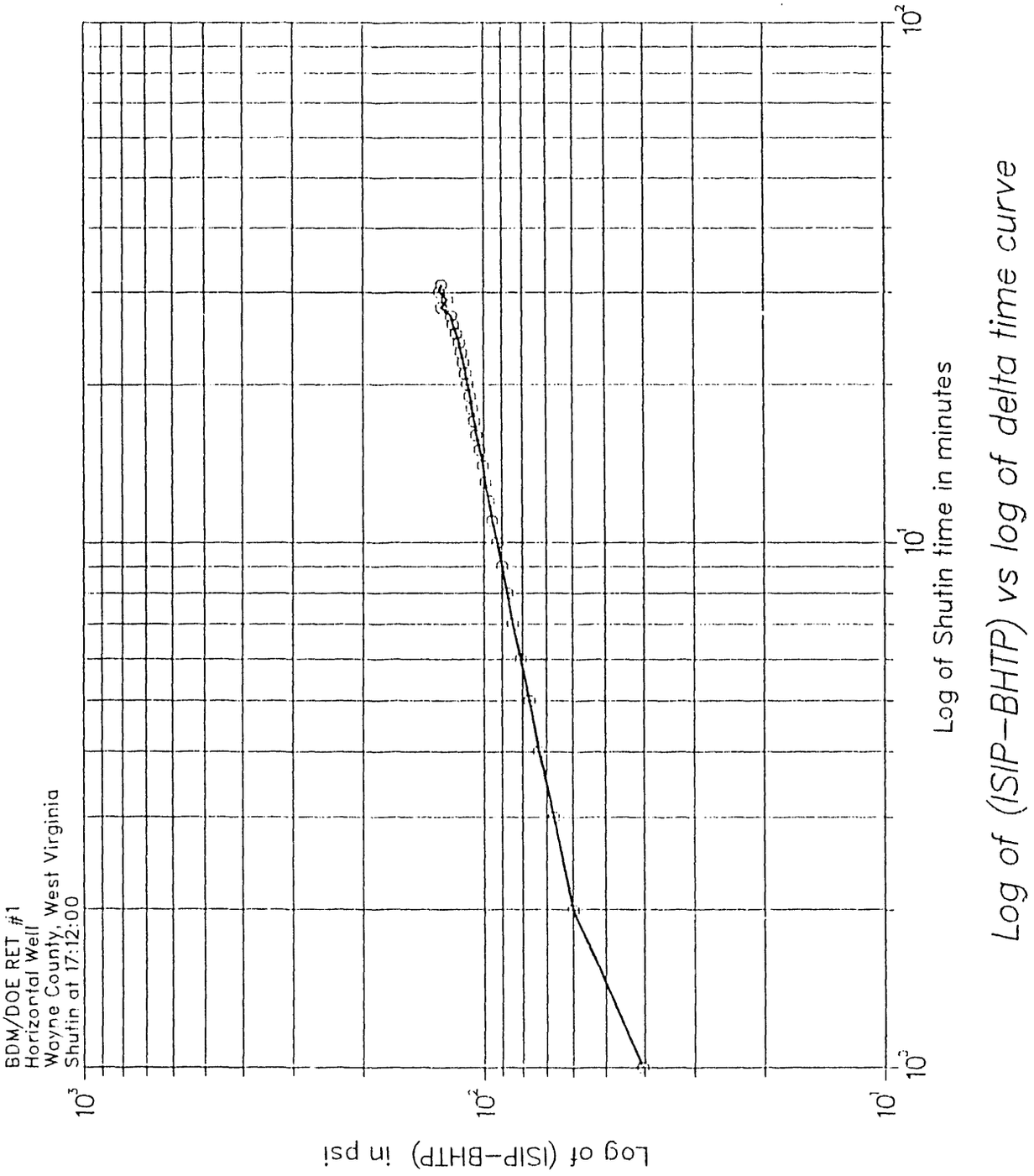
Data

Figure 1



Data Cont'd

Figure 2



Data Cont'd

MINI-FRAC PROGRAM FOR ISO USERS

INPUT DATA

PUMPING RATE..... 12.4 (BBL/MIN)
PUMPING TIME.....252.0 (MIN)
TIME AT ISIP.....252.0 (MIN)
ISIP..... 863. (PSI)
CLOSURE PRESSURE..... 760. (PSI)
GROSS HEIGHT.....247.0 (FT)
NET HEIGHT.....247.0 (FT)
YOUNG'S MODULUS.....0.44E+07 (PSI)
N PRIME.....1.00
VISCOSITY CONSTANT.....0.0
OPTION..... 1

CALCULATED DATA

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.

PERKINS-KERN'S MODEL(SPE# 8311)

SLOPE..... 0.33
PSTAR..... 205.7 (PSI)
CW..... 0.000[illegible] (FT/SQRT(MIN))
FRACTURE LENGTH(TIP TO TIP)...[illegible]. (FT)
AVERAGE WIDTH..... 0.072 (IN)
CLOSURE TIME..... 46. (MIN)
FLUID EFFICIENCY..... 17.2 (%)

Data Cont'd

MINI-FRAC PROGRAM FOR TSO USERS

INPUT DATA

PUMPING RATE	12.4 (BBL/MIN)
PUMPING TIME	252.0 (MIN)
TIME AT ISIP	252.0 (MIN)
ISIP	863. (PSI)
CLOSURE PRESSURE	760. (PSI)
GROSS HEIGHT	247.0 (FT)
NET HEIGHT	242.0 (FT)
YOUNG'S MODULUS	0.44E+07 (PSI)
OPTION	1

CALCULATED DATA

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.

CHRISTIANOVICH AND ZHELTOV'S MODEL

SLOPE	0.02
PSTAR	212.3 (PSI)
CW	0.00154 (FT/SQRT(MIN))
FRACTURE LENGTH(TIP TO TIP)	439. (FT)
AVERAGE WIDTH	0.238 (IN)
CLOSURE TIME	41. (MIN)
FLUID EFFICIENCY	1.9 (%)

Data Cont'd

MINI-FRAC PROGRAM FOR ISO USERS

INPUT DATA

PUMPING RATE	12.4 (BBL/MIN)
PUMPING TIME	252.0 (MIN)
TIME AT ISIP	252.0 (MIN)
ISIP	863. (PSI)
CLOSURE PRESSURE	760. (PSI)
YOUNG'S MODULUS	0.44E+07 (PSI)
OPTION	1

CALCULATED DATA

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.

HORIZONTAL OR VERTICAL PENNY-SHAPED MODEL

SLOPE	0.32
PSTAR	212.3 (PSI)
CW	0.00052 (FT/SQRT(MIN))
FRACTURE RADIUS	315. (FT)
AVERAGE WIDTH	0.355 (IN)
CLOSURE TIME	471. (MIN)
FLUID EFFICIENCY	52.7 (%)

Data Cont'd

MINI FRAC PROGRAM FOR I&D USERS

INPUT DATA

PUMPING RATE..... 12.4 (BPL/MIN)
PUMPING TIME.....252.0 (MIN)
TIME AT ISIP.....252.0 (MIN)
ISIP..... 863. (PSI)
CLOSURE PRESSURE..... 760. (PSI)
NET HEIGHT.....247.0 (FT)
YOUNG'S MODULUS.....0.44E+06 (PSI)
OPTION..... 1

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.

VERTICAL PENNY-SHAPED MODEL(DIAMETER > PAY HEIGHT)

CW..... 0.00094 (FT/SQRT(MIN))
FRACTURE RADIUS..... 343. (FT)
AVERAGE WIDTH..... 0.303 (IN)
CLOSURE TIME..... 606. (MIN)
FLUID EFFICIENCY..... 53.4 (%)

Data Cont'd

MINI-FRAC PROGRAM FOR TSO USERS

INPUT Data

PUMPING RATE..... 12.2 (BBL/MIN)
PUMPING TIME.....250.0 (MIN)
TIME AT ISIP.....252.0 (MIN)
ISIP..... 863. (PSI)
CLOSURE PRESSURE..... 730. (PSI)
GROSS HEIGHT.....247.0 (FT)
NET HEIGHT.....247.0 (FT)
YOUNG'S MODULUS.....0.4810+07 (PSI)
N PRIME.....1.00
VISCOSITY CONSTANT.....0.0
OPTION..... 1

Calculated Data

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.
758.	268.	757.	269.	756.	270.	754.	271.
753.	272.	752.	273.	750.	274.	749.	275.
748.	276.	746.	277.	745.	278.	743.	279.
741.	280.	740.	281.	739.	282.	736.	283.

PERKINS-KERN'S MODEL (SPE# 9311)

SLOPE..... 1.00
PSTAR..... 240.4 (PSI)
CW..... 0.00068 (FT/SQRT(MIN))
FRACTURE LENGTH(TIP TO TIP)..1703. (FT)
AVERAGE WIDTH..... 0.093 (IN)
CLOSURE TIME..... 52. (MIN)
FLUID EFFICIENCY..... 18.7 (%)

Data Cont'd

MINI-FRAC PROGRAM FOR ISIP USERS

INPUT DATA

PUMPING RATE	12.4 (BPL/MIN)
PUMPING TIME	252.0 (MIN)
TIME AT ISIP	252.0 (MIN)
ISIP	863. (PSI)
CLOSURE PRESSURE	730. (PSI)
GROSS HEIGHT	242.0 (FT)
NET HEIGHT	242.0 (FT)
YOUNG'S MODULUS	0.44E+07 (PSI)
OPTION	1

CALCULATED DATA

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.
758.	268.	757.	269.	756.	270.	754.	271.
753.	272.	752.	273.	750.	274.	749.	275.
748.	276.	746.	277.	744.	278.	743.	279.
741.	280.	740.	281.	739.	282.	738.	283.

CHRISTIANOVICH AND ZHELTOV'S MODEL

SLOPE	1.00
PSTAR	791.5 (PSI)
CU	0.0015 (FT/SQRT(MIN))
FRACTURE LENGTH(TIP TO TIP)	573. (FT)
AVERAGE WIDTH	0.276 (IN)
CLOSURE TIME	45. (MIN)
FLUID EFFICIENCY	18.6 (%)

Data Cont'd

MINI-FRAC PROGRAM FOR ISO USERS

INPUT DATA

PUMPING RATE	12.4 (BBL/MIN)
PUMPING TIME	252.0 (MIN)
TIME AT ISIP	252.0 (MIN)
ISIP	863. (PSI)
CLOSURE PRESSURE	730. (PSI)
YOUNG'S MODULUS	0.44E+07 (PSI)
OPTION	1

CALCULATED DATA

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.
758.	268.	757.	269.	756.	270.	754.	271.
753.	272.	752.	273.	750.	274.	749.	275.
748.	276.	746.	277.	744.	278.	743.	279.
741.	280.	740.	281.	734.	282.	736.	283.

HORIZONTAL OR VERTICAL PENNY-SHAPED MODEL

SLOPE	1.00
PSIAP	741.5 (PSI)
CW	0.00065 (FT/SQRT(MIN))
FRACTURE RADIUS	293. (FT)
AVERAGE WIDTH	0.412 (IN)
CLOSURE TIME	479. (MIN)
FLUID EFFICIENCY	53.0 (%)

Data Cont'd

MINI FRAC PROGRAM FOR ISO USERS

INPUT Data

PUMPING RATE	12.4 (BBL/MIN)
PUMPING TIME	252.0 (MIN)
TIME AT ISIP	252.0 (MIN)
ISIP	863. (PSI)
CLOSURE PRESSURE	730. (PSI)
NET HEIGHT	29.0 (FT)
YOUNG'S MODULUS	0.14E+07 (PSI)
OPTION	1

PRESSURE DECLINE DATA

PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)	PRESSURE (PSI)	TIME (MIN)
863.	252.	822.	253.	803.	254.	795.	255.
790.	256.	786.	257.	782.	258.	778.	259.
775.	260.	773.	261.	770.	262.	767.	263.
765.	264.	764.	265.	762.	266.	760.	267.
758.	268.	757.	269.	756.	270.	754.	271.
753.	272.	752.	273.	750.	274.	749.	275.
748.	276.	746.	277.	744.	278.	743.	279.
741.	280.	740.	281.	734.	282.	736.	283.

VERTICAL PENNY-SHAPED MODEL (DIAMETER > PAY HEIGHT)

CW	0.00125 (FT/SQRT(MIN))
FRACTURE RADIUS	229. (FT)
AVERAGE WIDTH	0.436 (IN)
CLOSURE TIME	515. (MIN)
FLUID EFFICIENCY	50.6 (%)

Data Cont'd

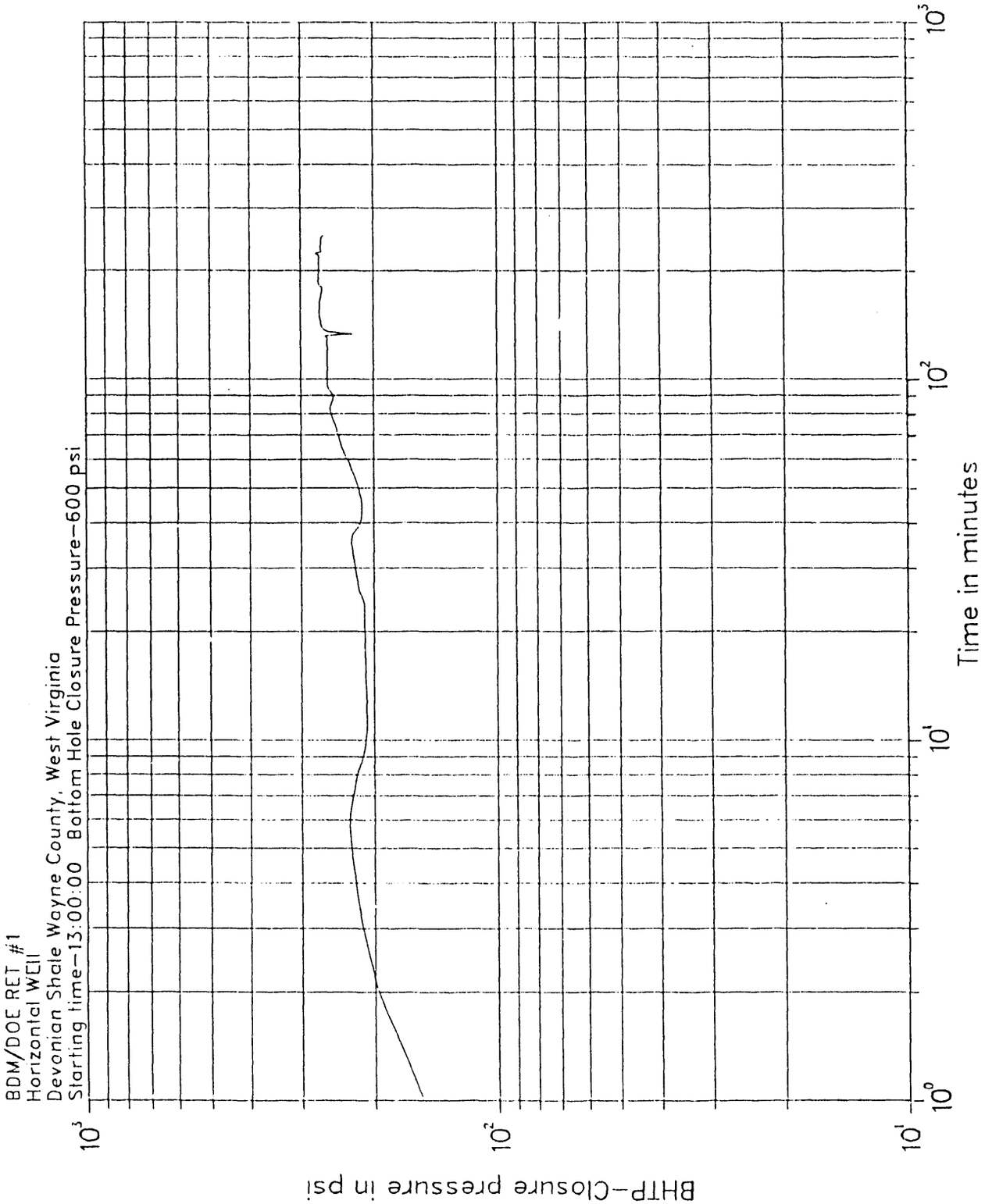
Table 2

(PBRS,4)

TIME	GAS TEMP, deg. F	GAS PRESS, psi	GAS RATE scfm
12:59:00	161.25	530.1	0.000
13:09:00	137.84	1042.8	2241.670
13:19:00	132.79	1069.0	2989.818
13:29:00	119.05	1068.2	2926.386
13:39:00	108.76	1132.1	3143.235
13:49:00	114.94	1138.4	3283.927
13:59:00	114.29	1146.6	3321.457
14:09:00	110.78	1193.5	3478.617
14:19:00	122.58	1226.0	3634.694
14:29:00	119.29	1227.3	3583.092
14:39:00	111.36	1276.4	3760.367
14:49:00	108.10	1323.3	3907.104
14:59:00	106.65	1328.3	3922.607
15:09:00	101.42	1313.7	3852.636
15:19:00	113.59	1359.3	3678.354
15:29:00	100.11	1432.1	4295.406
15:39:00	99.63	1423.0	4218.120
15:49:00	98.70	1419.4	4232.673
15:59:00	95.72	1419.0	4214.896
16:09:00	98.55	1480.7	4514.459
16:19:00	103.19	1525.4	4670.590
16:29:00	102.46	1541.6	4722.456
16:39:00	100.67	1539.9	4693.856
16:49:00	102.83	1553.0	4736.521
16:59:00	102.07	1528.7	4672.870

Data Cont'd

Figure 3



Appendix

(PBR5.4)

BDM/DOE RE1#1 HORIZONTAL WELL page 1

TIME	GAS RATE scfm	GAS TEMP. deg. F	GAS PRESS. psi	GAUGE TEMP. deg. F	GEL TEMP. deg. F
12:59:00	0.000	161.25	530.3	0.00	161.25
13:00:00	0.000	161.25	530.3	0.00	161.25
13:01:00	0.000	161.25	529.0	0.00	161.25
13:02:00	2585.379	161.25	777.4	0.00	161.25
13:03:00	3508.063	157.02	1064.3	0.00	157.02
13:04:00	3457.495	135.90	1160.8	0.00	135.90
13:05:00	3490.130	130.27	1199.9	0.00	130.27
13:06:00	3451.800	128.18	1211.8	0.00	128.18
13:07:00	3497.582	125.23	1220.4	0.00	125.23
13:08:00	3385.564	121.02	1218.4	0.00	121.02
13:09:00	3236.893	109.88	1203.0	0.00	109.88
13:10:00	2878.080	114.84	1113.0	0.00	114.84
13:11:00	2967.844	131.00	1078.3	0.00	131.00
13:12:00	2935.577	130.42	1063.0	0.00	130.42
13:13:00	2892.114	124.39	1054.7	0.00	124.39
13:14:00	2933.171	126.55	1055.9	0.00	126.55
13:15:00	2965.183	129.28	1056.5	0.00	129.28
13:16:00	3048.685	134.27	1062.1	0.00	134.27
13:17:00	3110.895	144.94	1068.0	0.00	144.94
13:18:00	3094.639	147.37	1065.5	0.00	147.37
13:19:00	3090.610	147.88	1065.5	0.00	147.88
13:20:00	2976.966	142.01	1053.3	0.00	142.01
13:21:00	2897.602	131.19	1052.4	0.00	131.19
13:22:00	2857.061	124.22	1048.9	0.00	124.22
13:23:00	2764.980	120.53	1043.4	0.00	120.53
13:24:00	2594.881	107.52	1035.6	0.00	107.52
13:25:00	2811.433	112.39	1042.4	0.00	112.39
13:26:00	2912.836	112.59	1062.8	0.00	112.59
13:27:00	3081.581	111.17	1100.9	0.00	111.17
13:28:00	3086.333	112.97	1112.2	0.00	112.97
13:29:00	3180.191	115.91	1123.7	0.00	115.91
13:30:00	3258.546	120.20	1133.6	0.00	120.20
13:31:00	3305.972	126.67	1140.8	0.00	126.67
13:32:00	3171.663	120.89	1136.2	0.00	120.89
13:33:00	3016.009	102.21	1125.4	0.00	102.21
13:34:00	3044.233	96.72	1125.2	0.00	96.72
13:35:00	3075.790	100.09	1128.8	0.00	100.09
13:36:00	3018.736	94.98	1131.0	0.00	94.98
13:37:00	3074.556	94.43	1133.3	0.00	94.43
13:38:00	3219.537	112.37	1132.8	0.00	112.37
13:39:00	3247.223	119.04	1133.9	0.00	119.04
13:40:00	3208.462	116.66	1133.0	0.00	116.66
13:41:00	3204.237	112.04	1131.6	0.00	112.04
13:42:00	3196.532	111.30	1130.0	0.00	111.30
13:43:00	3144.333	110.33	1127.4	0.00	110.33
13:44:00	3196.705	104.59	1129.1	0.00	104.59
13:45:00	3304.717	109.52	1137.1	0.00	109.58
13:46:00	3342.194	117.21	1143.5	0.00	117.21

Appendix Cont'd

(PBR5.4)

BDM/DOE RFT#1 HORIZONTAL WELL

TIME	GAS RATE scfm	GAS TEMP. deg. F	GAS PRESS. psi	GAUGE TEMP. deg. F	GEL TEMP. deg. F
13:47:00	3416.796	123.80	1149.6	0.00	123.80
13:48:00	3365.799	121.11	1147.7	0.00	121.11
13:49:00	3413.664	120.56	1151.1	0.00	120.56
13:50:00	3466.502	122.93	1156.4	0.00	122.93
13:51:00	3493.238	127.25	1158.4	0.00	127.25
13:52:00	3398.468	124.84	1151.7	0.00	124.84
13:53:00	3288.734	116.70	1141.7	0.00	116.70
13:54:00	3255.377	111.37	1140.7	0.00	111.37
13:55:00	3271.216	109.19	1143.1	0.00	109.19
13:56:00	3260.519	106.70	1141.2	0.00	106.70
13:57:00	3288.994	108.56	1146.5	0.00	108.56
13:58:00	3250.978	108.19	1144.4	0.00	108.19
13:59:00	3270.172	108.16	1144.7	0.00	108.16
14:00:00	3202.175	110.94	1132.1	0.00	110.94
14:01:00	3538.298	112.01	1172.1	0.00	112.01
14:02:00	3548.075	113.46	1194.7	0.00	113.46
14:03:00	3483.343	110.50	1196.8	0.00	110.50
14:04:00	3463.169	108.43	1198.7	0.00	108.43
14:05:00	3503.928	109.34	1202.2	0.00	109.34
14:06:00	3452.429	107.39	1202.7	0.00	107.39
14:07:00	3513.218	109.07	1207.0	0.00	109.07
14:08:00	3562.308	112.15	1213.5	0.00	112.15
14:09:00	3513.341	114.02	1211.7	0.00	114.02
14:10:00	3491.769	107.86	1210.5	0.00	107.86
14:11:00	3550.717	112.48	1213.7	0.00	112.48
14:12:00	3615.573	119.34	1219.5	0.00	119.34
14:13:00	3616.737	121.79	1222.9	0.00	121.79
14:14:00	3632.814	121.72	1224.6	0.00	121.72
14:15:00	3657.485	122.32	1228.7	0.00	122.32
14:16:00	3710.623	128.11	1234.1	0.00	128.11
14:17:00	3721.382	132.44	1234.7	0.00	132.44
14:18:00	3660.299	128.47	1234.0	0.00	128.47
14:19:00	3668.249	127.95	1234.7	0.00	127.95
14:20:00	3646.703	124.45	1233.2	0.00	124.45
14:21:00	3599.982	119.93	1234.2	0.00	119.93
14:22:00	3660.688	120.42	1236.9	0.00	120.42
14:23:00	3624.375	121.40	1233.5	0.00	121.40
14:24:00	3585.781	120.84	1228.7	0.00	120.84
14:25:00	3571.331	118.74	1226.2	0.00	118.74
14:26:00	3516.977	114.88	1221.0	0.00	114.88
14:27:00	3529.546	115.15	1220.8	0.00	115.15
14:28:00	3577.583	118.81	1222.4	0.00	118.81
14:29:00	3516.603	118.21	1215.8	0.00	118.21
14:30:00	3490.781	115.49	1212.4	0.00	115.49
14:31:00	3463.199	115.10	1206.0	0.00	115.10
14:32:00	3541.451	113.65	1220.2	0.00	113.65
14:33:00	3820.758	110.57	1266.1	0.00	110.57
14:34:00	3723.344	105.16	1280.3	0.00	105.16

Appendix Cont'd

(PBR5.4)

BDM/DOE RE#1 HORIZONTAL WELL

TIME	GAS RATE scfm	GAS TEMP. deg. F	GAS PRESS. psi	GAUGE TEMP. deg. F	GEL TEMP. deg. F
14:35:00	3751.804	99.78	1302.7	0.00	99.78
14:36:00	3822.316	99.38	1303.6	0.00	99.38
14:37:00	4029.686	113.20	1325.2	0.00	113.20
14:38:00	4049.478	121.31	1328.3	0.00	121.31
14:39:00	3949.282	118.66	1323.5	0.00	118.66
14:40:00	3889.087	111.06	1319.0	0.00	111.06
14:41:00	3870.144	106.45	1320.0	0.00	106.45
14:42:00	3927.376	107.52	1322.0	0.00	107.52
14:43:00	3889.649	108.20	1322.6	0.00	108.20
14:44:00	3906.530	106.96	1322.2	0.00	106.96
14:45:00	3915.483	108.74	1325.1	0.00	108.74
14:46:00	3915.248	108.60	1324.2	0.00	108.60
14:47:00	3924.611	108.05	1324.9	0.00	108.05
14:48:00	3941.308	109.29	1327.5	0.00	109.29
14:49:00	3886.845	106.97	1325.3	0.00	106.97
14:50:00	3906.775	104.06	1326.5	0.00	104.06
14:51:00	3901.885	105.44	1326.0	0.00	105.44
14:52:00	3881.613	103.96	1325.1	0.00	103.96
14:53:00	3933.201	104.90	1328.6	0.00	104.90
14:54:00	3982.623	109.64	1330.9	0.00	109.64
14:55:00	4048.226	113.07	1335.2	0.00	113.07
14:56:00	3997.305	113.87	1334.2	0.00	113.87
14:57:00	3926.314	109.60	1330.0	0.00	109.60
14:58:00	3804.320	102.04	1323.0	0.00	102.04
14:59:00	3802.919	97.29	1321.7	0.00	97.29
15:00:00	3766.015	95.14	1318.2	0.00	95.14
15:01:00	3769.028	94.20	1308.2	0.00	94.20
15:02:00	3812.086	98.09	1309.9	0.00	98.09
15:03:00	3802.462	98.68	1307.9	0.00	98.68
15:04:00	3821.165	99.52	1308.8	0.00	99.52
15:05:00	3872.605	102.04	1311.6	0.00	102.04
15:06:00	3942.152	105.66	1317.8	0.00	105.66
15:07:00	3945.603	108.20	1320.3	0.00	108.20
15:08:00	3926.091	108.61	1318.7	0.00	108.61
15:09:00	3897.478	105.97	1317.1	0.00	105.97
15:10:00	3862.813	104.71	1315.2	0.00	104.71
15:11:00	3848.330	101.21	1315.2	0.00	101.21
15:12:00	3823.743	99.36	1312.5	0.00	99.36
15:13:00	4070.327	96.99	1352.6	0.00	96.99
15:14:00	3990.552	100.75	1356.7	0.00	100.75
15:15:00	1182.132	124.62	938.4	0.00	124.62
15:16:00	1706.383	130.15	937.7	0.00	130.15
15:17:00	4945.586	135.27	1295.1	0.00	135.27
15:18:00	4721.407	128.92	1425.1	0.00	128.92
15:19:00	4258.337	113.02	1423.7	0.00	113.02
15:20:00	4161.288	97.75	1423.4	0.00	97.75
15:21:00	4189.682	92.81	1430.0	0.00	92.81
15:22:00	4273.577	97.60	1436.1	0.00	97.60

Appendix Cont'd

(PBR5.4)

BDM/DOE RE1#1 HORIZONTAL WELL page 4

TIME	GAS RATE scfm	GAS TEMP. deg. F	GAS PRESS. psi	GAUGE TEMP. deg. F	GEL TEMP. deg. F
15:23:00	4253.433	98.80	1433.7	0.00	98.80
15:24:00	4159.938	95.89	1430.6	0.00	95.89
15:25:00	4223.694	92.70	1429.9	0.00	92.70
15:26:00	4339.701	102.40	1434.4	0.00	102.40
15:27:00	4325.033	106.43	1432.2	0.00	106.43
15:28:00	4361.969	107.62	1434.8	0.00	107.62
15:29:00	4368.189	108.41	1436.5	0.00	108.41
15:30:00	4353.091	109.52	1433.4	0.00	109.52
15:31:00	4343.519	109.49	1432.8	0.00	109.49
15:32:00	4268.479	106.16	1426.8	0.00	106.16
15:33:00	4211.181	101.97	1423.4	0.00	101.97
15:34:00	4226.323	98.31	1421.8	0.00	98.31
15:35:00	4173.484	95.98	1417.9	0.00	95.98
15:36:00	4146.134	94.40	1417.5	0.00	94.40
15:37:00	4110.603	93.11	1419.6	0.00	93.11
15:38:00	4184.603	93.96	1420.5	0.00	93.96
15:39:00	4175.180	94.28	1417.0	0.00	94.28
15:40:00	4167.513	95.50	1414.3	0.00	95.50
15:41:00	4128.492	94.71	1414.6	0.00	94.71
15:42:00	4196.236	94.65	1417.2	0.00	94.65
15:43:00	4215.909	94.71	1416.9	0.00	94.71
15:44:00	4270.059	99.65	1422.9	0.00	99.65
15:45:00	4294.490	101.81	1424.3	0.00	101.81
15:46:00	4271.600	101.53	1421.9	0.00	101.53
15:47:00	4249.190	100.68	1420.9	0.00	100.68
15:48:00	4274.507	101.61	1422.2	0.00	101.61
15:49:00	4249.471	101.70	1419.6	0.00	101.70
15:50:00	4156.610	93.87	1414.4	0.00	93.87
15:51:00	4191.350	93.24	1416.0	0.00	93.24
15:52:00	4250.659	96.14	1421.7	0.00	96.14
15:53:00	4254.135	97.22	1423.5	0.00	97.22
15:54:00	4203.590	95.98	1420.3	0.00	95.98
15:55:00	4214.113	95.44	1419.6	0.00	95.44
15:56:00	4295.534	97.38	1423.9	0.00	97.38
15:57:00	4272.546	99.56	1422.9	0.00	99.56
15:58:00	4152.100	95.90	1412.1	0.00	95.90
15:59:00	4147.855	92.48	1414.2	0.00	92.48
16:00:00	4167.902	92.05	1413.5	0.00	92.05
16:01:00	4135.259	91.05	1408.9	0.00	91.05
16:02:00	4138.544	90.86	1409.4	0.00	90.86
16:03:00	4468.567	90.39	1465.7	0.00	90.39
16:04:00	4543.487	93.25	1499.6	0.00	93.25
16:05:00	4780.327	100.35	1522.2	0.00	100.35
16:06:00	4741.334	105.70	1523.6	0.00	105.70
16:07:00	4725.245	105.43	1524.2	0.00	105.43
16:08:00	4730.925	108.24	1522.0	0.00	108.24
16:09:00	4715.028	109.35	1519.5	0.00	109.35
16:10:00	4716.152	110.39	1516.4	0.00	110.39

Appendix Cont'd

(PBR5.4)

BBM/DOE RET#1 HORIZONTAL WELL

TIME	GAS RATE scfm	GAS TEMP. deg. f	GAS PRESS. psi	GAUGE TEMP. deg. f	GEL TEMP. deg. f
16:11:00	4637.747	109.32	1517.9	0.00	109.32
16:12:00	4738.032	107.64	1523.4	0.00	107.64
16:13:00	4616.087	101.50	1522.7	0.00	101.50
16:14:00	4546.647	95.65	1520.3	0.00	95.65
16:15:00	4659.441	96.97	1527.0	0.00	96.97
16:16:00	4721.855	103.88	1532.8	0.00	103.88
16:17:00	4708.577	104.52	1533.5	0.00	104.52
16:18:00	4673.282	101.88	1532.4	0.00	101.88
16:19:00	4630.983	98.90	1531.1	0.00	98.90
16:20:00	4597.352	95.72	1531.0	0.00	95.72
16:21:00	4662.314	96.15	1536.4	0.00	96.15
16:22:00	4771.170	103.31	1543.8	0.00	103.31
16:23:00	4730.631	103.45	1542.6	0.00	103.45
16:24:00	4723.943	101.60	1544.3	0.00	101.60
16:25:00	4784.037	105.01	1545.8	0.00	105.01
16:26:00	4760.888	106.42	1545.7	0.00	106.42
16:27:00	4758.166	106.22	1545.3	0.00	106.22
16:28:00	4737.109	104.58	1542.4	0.00	104.58
16:29:00	4697.837	101.87	1539.3	0.00	101.87
16:30:00	4707.881	100.73	1538.4	0.00	100.73
16:31:00	4674.795	99.65	1537.3	0.00	99.65
16:32:00	4698.576	99.82	1539.7	0.00	99.82
16:33:00	4657.884	99.57	1539.5	0.00	99.57
16:34:00	4636.324	98.58	1537.3	0.00	98.58
16:35:00	4668.584	98.53	1537.8	0.00	98.53
16:36:00	4707.206	99.51	1539.7	0.00	99.51
16:37:00	4741.729	103.14	1544.2	0.00	103.14
16:38:00	4730.435	104.20	1543.7	0.00	104.29
16:39:00	4715.146	102.37	1541.0	0.00	102.37
16:40:00	4747.537	103.11	1541.2	0.00	103.11
16:41:00	4725.242	104.31	1539.8	0.00	104.31
16:42:00	4671.342	101.47	1535.4	0.00	101.47
16:43:00	4622.799	98.86	1531.8	0.00	98.86
16:44:00	5501.481	108.09	1624.9	0.00	108.09
16:45:00	4531.540	85.80	1642.6	0.00	85.80
16:46:00	5102.152	94.26	1556.9	0.00	94.26
16:47:00	4815.780	121.70	1585.5	0.00	121.70
16:48:00	4011.135	116.80	1428.3	0.00	116.30
16:49:00	4423.206	91.08	1458.3	0.00	91.08
16:50:00	4939.439	108.47	1519.7	0.00	108.47
16:51:00	4848.655	113.99	1526.5	0.00	113.99
16:52:00	4846.457	115.04	1542.9	0.00	115.04
16:53:00	4835.792	114.63	1543.0	0.00	114.63
16:54:00	4635.494	108.53	1522.4	0.00	108.53
16:55:00	4399.786	91.04	1517.0	0.00	91.04
16:56:00	4433.814	84.53	1516.5	0.00	84.53
16:57:00	4615.285	91.88	1524.6	0.00	91.88
16:58:00	4635.598	96.35	1527.7	0.00	96.35

Appendix Cont'd

(PBRS:4)

EDM/DOE RE1#1 HORIZONTAL WELL page 6

TIME	GAS RATE scfm	GAS TEMP. deg. F	GAS PRESS. psi	GAUGE TEMP. deg. F	GFI TEMP. deg. F
16:59:00	4613.503	96.15	1528.4	0.00	96.15

Appendix Cont'd

PROPOSED TARGET INFORMATION OUTPUT

PROPOSED DIRECTION . . . . . S 37.00 E

SURVEY STATION PARAMETERS OUTPUT

NO.	M.D. (FT)	INC. (DEG)	DIRECTION N/S	AZM (DEG)	E/W	LOCATION (FT) +N / -S	+E / -W	TVD
1	.00	.00	N	.00	E	.0	.0	.0
2	2000.00	.00	S	1.00	E	.0	.0	2000.0
3	2083.00	.50	S	.01	E	-.4	.0	2083.0
4	2101.71	.87	S	3.49	E	-.6	.0	2101.7
5	2133.76	2.62	S	3.35	E	-1.6	.1	2133.7
6	2165.58	4.52	S	9.00	E	-3.5	.3	2165.5
7	2197.00	5.59	S	26.24	E	-6.2	1.1	2196.8
8	2229.00	6.50	S	41.00	E	-9.0	3.0	2228.6
9	2271.00	9.80	S	51.60	E	-13.1	7.3	2270.7
10	2340.00	12.50	S	49.00	E	-21.6	17.5	2337.9
11	2403.00	15.50	S	47.00	E	-31.8	28.9	2399.0
12	2465.00	18.00	S	42.00	E	-44.5	41.4	2458.4
13	2528.00	20.80	S	40.40	E	-60.3	55.2	2517.8
14	2591.00	24.50	S	40.00	E	-78.8	70.8	2575.9
15	2655.00	27.50	S	39.00	E	-100.4	88.7	2633.4
16	2718.00	30.00	S	37.00	E	-124.3	107.3	2688.7
17	2781.00	32.75	S	38.00	E	-150.3	127.3	2742.4
18	2844.00	35.80	S	39.00	E	-178.1	149.4	2794.5
19	2931.00	39.20	S	40.00	E	-219.0	183.0	2863.5
20	2993.00	41.60	S	40.00	E	-249.7	208.9	2910.7
21	3057.00	44.00	S	39.00	E	-283.3	236.5	2957.7
22	3120.00	46.20	S	37.80	E	-318.3	264.2	3002.1
23	3182.00	48.40	S	38.00	E	-354.2	292.2	3044.2
24	3240.00	48.00	S	35.00	E	-389.0	318.0	3082.8
25	3272.00	46.00	S	34.00	E	-408.2	331.2	3104.7
26	3345.00	47.00	S	34.00	E	-452.1	360.8	3154.9
27	3373.00	49.60	S	33.60	E	-469.5	372.4	3173.5
28	3437.00	53.50	S	30.00	E	-512.1	398.8	3213.3
29	3468.00	55.50	S	30.00	E	-533.0	411.5	3231.3
30	3500.00	57.60	S	31.00	E	-557.0	425.0	3249.0
31	3532.00	59.90	S	33.00	E	-580.2	439.5	3265.6
32	3563.00	62.20	S	32.00	E	-603.0	454.1	3280.6
33	3594.00	64.50	S	34.00	E	-626.3	469.2	3294.5
34	3661.00	69.00	S	34.00	E	-677.3	503.6	3320.9
35	3725.00	72.20	S	35.00	E	-727.0	537.8	3342.2
36	3787.00	74.00	S	34.00	E	-775.9	571.4	3360.2
37	3869.00	74.50	S	37.00	E	-840.2	617.2	3382.5
38	3915.00	81.00	S	37.00	E	-891.6	656.0	3396.5
39	3998.00	88.00	S	39.00	E	-941.0	694.6	3402.5
40	4043.00	92.00	S	39.00	E	-976.0	722.9	3402.5
41	4131.00	92.00	S	39.00	E	-1090.9	816.0	3397.3
42	4382.00	91.00	S	38.00	E	-1240.4	934.8	3392.3
43	4666.00	90.00	S	37.00	E	-1465.7	1107.7	3389.8
44	4983.00	89.00	S	35.00	E	-1722.1	1294.0	3392.6
45	5078.00	88.50	S	34.00	E	-1981.6	1472.4	3399.5
46	5599.00	88.00	S	31.00	E	-2235.3	1634.0	3408.7
47	6020.00	87.00	S	29.00	E	-2599.6	1844.3	3427.0

Appendix Cont'd

Geoservices Inc. Production

Client	: BDM CORP.	Survey Date	: 09/22/87
Field Id.	: WILDCAT	Well No.	: BDM RET #1
Reader Type	: Data Trieva	DISK I.D. NO.	: BDM01
Temp	: 1	Variation	: 1
Cal. Date	: 09/23/87	Cal. Number	: JL01
Cal. Range	: 0-2000 psi	Cal. Temp.	: 39 C
Cal. [illegible]	: .0051496	Cal. III	: -207.948
Test Number	: 23	Sensor No.	: PSS-23

########	DAY	TIME HH:MM:SS	dT (hr)	dP (psig)	PRESSURE (psig)	COMMENTS
2	22	19:44:00			3.91	GOUGES AT BOTTOM
3	22	19:45:00			3.91	WELL OPEN TO FLOW OVERNIGHT
13	22	19:55:00			3.91	
23	22	20:05:00			3.91	
33	22	20:15:00			3.91	
43	22	20:25:00			3.91	
53	22	20:35:00			3.91	
63	22	20:45:00			3.91	
73	22	20:55:00			3.91	
83	22	21:05:00			3.91	
93	22	21:15:00			3.91	
103	22	21:25:00			3.91	
113	22	21:35:00			3.91	
123	22	21:45:00			3.91	
133	22	21:55:00			3.91	
143	22	22:05:00			3.91	
153	22	22:15:00			3.91	
163	22	22:25:00			3.91	
173	22	22:35:00			3.91	
183	22	22:45:00			3.91	
193	22	22:55:00			3.91	
203	22	23:05:00			3.91	
213	22	23:15:00			3.91	
223	22	23:25:00			3.91	
233	22	23:35:00			3.91	
243	22	23:45:00			3.91	
253	22	23:55:00			3.91	
263	23	00:05:00			3.91	
273	23	00:15:00			3.91	
283	23	00:25:00			3.91	
293	23	00:35:00			3.91	
303	23	00:45:00			3.91	
313	23	00:55:00			3.91	
323	23	01:05:00			3.91	
333	23	01:15:00			3.91	
343	23	01:25:00			3.91	
353	23	01:35:00			3.91	
363	23	01:45:00			3.91	
373	23	01:55:00			3.91	
383	23	02:05:00			3.91	

Appendix Cont'd

Geoservices Inc. Production

Client : DOM CORP. Survey Date : 09/22/87
Field Id. : WILDCAT Well No. : DOM RET #1

CLOCK	DAY	TIME HH:MM:SS	dT (hr)	dP (psig)	PRESSURE (psig)	COMMENTS
393	23	02:15:00			3.91	
403	23	02:25:00			3.91	
413	23	02:35:00			3.91	
423	23	02:45:00			3.91	
433	23	02:55:00			3.91	
443	23	03:05:00			3.91	
453	23	03:15:00			3.91	
463	23	03:25:00			3.91	
473	23	03:35:00			3.91	
483	23	03:45:00			3.91	
493	23	03:55:00			3.91	
503	23	04:05:00			3.91	
513	23	04:15:00			3.91	
523	23	04:25:00			3.91	
533	23	04:35:00			3.91	
543	23	04:45:00			3.91	
553	23	04:55:00			3.91	
563	23	05:05:00			3.91	
573	23	05:15:00			3.91	
583	23	05:25:00			3.91	
593	23	05:35:00			3.91	
603	23	05:45:00			3.91	
613	23	05:55:00			3.91	
623	23	06:05:00			3.91	
633	23	06:15:00			3.91	
643	23	06:25:00			3.91	
653	23	06:35:00			3.91	
663	23	06:45:00			3.91	
673	23	06:55:00			3.91	
693	23	07:05:00			3.91	
693	23	07:15:00			3.91	
703	23	07:25:00			3.91	
713	23	07:35:00			3.91	
723	23	07:45:00			3.91	
733	23	07:55:00			3.91	
739	23	08:01:59			4.56	WELL SHUT IN TO RIG
740	23	08:02:00			4.56	UP FOR THE FRAC - Zone #1
744	23	08:06:00			5.86	Perf Cotton #1 @ 5746' open
749	23	08:11:00			7.17	
755	23	08:17:00			8.47	
759	23	08:22:00			9.77	
766	23	08:29:00			11.97	
771	23	08:33:00			12.30	
776	23	08:38:00			13.60	
781	23	08:43:00			14.98	
786	23	08:48:00			16.29	
792	23	08:54:00			17.59	
797	23	08:59:00			18.89	
803	23	09:05:00			20.20	
810	23	09:12:00			21.50	
814	23	09:16:00			22.80	

Appendix Cont'd

Coreservice, Inc. Production

Client : DOM CORP. Survey Date : 09/22/87
Field Id. : WILDCAT Well No. : DOM RET #1

ADDRESS	DAY	TIME HH:MM:SS	dt (hr)	dP (psia)	PRESSURE (psia)	COMMENTS
819	23	09:21:00			29.32	
820	23	09:22:00			97.07	
821	23	09:23:00	0.00007	0.00	241.69	START OF PROC - Pumping @ 2000 scf/m down 2 3/8" tbg.
822	23	09:24:00	0.0166	167.43	409.12	
823	23	09:25:00	0.0333	198.27	439.97	
824	23	09:26:00	0.0500	177.70	418.09	
825	23	09:27:00	0.0666	167.43	409.12	
826	23	09:28:00	0.0833	159.61	401.30	
827	23	09:29:00	0.1000	152.44	394.14	
828	23	09:30:00	0.1166	145.93	387.62	
829	23	09:31:00	0.1333	140.72	382.41	
830	23	09:32:00	0.1500	134.85	376.55	
831	23	09:33:00	0.1666	133.55	375.24	
832	23	09:34:00	0.1833	131.60	373.29	
833	23	09:35:00	0.2000	130.29	371.99	
834	23	09:36:00	0.2166	128.99	370.68	
835	23	09:37:00	0.2333	127.69	369.38	
836	23	09:38:00	0.2500	126.38	368.08	
838	23	09:40:00	0.2833	183.06	424.76	
839	23	09:41:00	0.3000	210.39	452.08	
840	23	09:42:00	0.3166	317.26	558.96	
841	23	09:43:00	0.3333	300.46	622.15	
842	23	09:44:00	0.3500	427.36	669.06	
843	23	09:45:00	0.3666	462.54	704.23	
844	23	09:46:00	0.3833	474.27	715.96	SHUT DOWN PUMPS - Halliburton Comp. Van not working properly -
845	23	09:47:00	0.4000	430.62	672.31	
846	23	09:48:00	0.4166	408.47	650.16	
847	23	09:49:00	0.4333	394.14	635.83	
848	23	09:50:00	0.4500	385.02	626.71	
849	23	09:51:00	0.4666	377.20	618.89	
850	23	09:52:00	0.4833	371.34	613.03	
851	23	09:53:00	0.5000	365.47	607.17	
852	23	09:54:00	0.5166	360.91	602.61	
853	23	09:55:00	0.5333	357.00	598.70	
854	23	09:56:00	0.5500	353.75	595.44	
855	23	09:57:00	0.5666	350.49	592.18	
856	23	09:58:00	0.5833	347.88	589.58	
857	23	09:59:00	0.6000	345.28	586.97	
858	23	10:00:00	0.6166	342.67	584.36	
859	23	10:01:00	0.6333	340.72	582.41	
860	23	10:02:00	0.6500	338.11	579.80	
861	23	10:03:00	0.6666	336.81	578.50	
862	23	10:04:00	0.6833	334.85	576.55	
863	23	10:05:00	0.7000	332.90	574.59	
864	23	10:06:00	0.7166	331.60	573.29	
865	23	10:07:00	0.7333	330.29	571.99	
866	23	10:08:00	0.7500	328.34	570.03	
867	23	10:09:00	0.7666	327.04	568.73	
868	23	10:10:00	0.7833	325.73	567.43	
869	23	10:11:00	0.8000	324.43	566.12	
870	23	10:12:00	0.8166	323.13	564.82	

$\frac{VP}{T} = \frac{\Sigma V}{3}$

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Appendix Cont'd

Geoservices Inc. Production

Client : BDM CORP. Survey Date : 09/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

ADDRESS	DAY	TIME HH:MM:SS	dI (Inc)	dP (psig)	PRESSURE (psig)	COMMENTS
871	23	10:13:00	0.0333	321.82	563.52	
873	23	10:15:00	0.0666	319.87	561.56	
874	23	10:16:00	0.0833	318.57	560.26	
876	23	10:18:00	0.0166	316.61	558.31	
878	23	10:20:00	0.9500	314.66	556.35	
880	23	10:22:00	0.9833	312.70	554.40	
882	23	10:24:00	1.0166	311.40	553.09	
883	23	10:25:00	1.0333	310.10	551.79	
885	23	10:27:00	1.0666	308.14	549.84	
887	23	10:29:00	1.1000	306.84	548.53	
889	23	10:31:00	1.1333	305.54	547.23	
891	23	10:33:00	1.1666	303.58	545.28	
893	23	10:35:00	1.2000	302.28	543.97	
895	23	10:37:00	1.2333	300.98	542.67	
897	23	10:39:00	1.2666	299.67	541.37	
899	23	10:41:00	1.3000	298.37	540.07	
901	23	10:43:00	1.3333	297.07	538.76	
903	23	10:45:00	1.3666	295.77	537.46	
905	23	10:47:00	1.4000	294.46	536.16	
907	23	10:49:00	1.4333	293.16	534.85	
909	23	10:51:00	1.4666	291.86	533.55	
912	23	10:54:00	1.5166	290.55	532.25	
914	23	10:56:00	1.5500	289.25	530.94	
916	23	10:58:00	1.5833	287.95	529.64	
919	23	11:01:00	1.6333	286.64	528.34	
921	23	11:03:00	1.6666	285.34	527.04	
924	23	11:06:00	1.7166	284.04	525.73	
927	23	11:09:00	1.7666	282.74	524.43	
930	23	11:12:00	1.8166	280.78	522.48	
934	23	11:16:00	1.8833	279.48	521.17	
936	23	11:18:00	1.9166	278.18	519.87	
939	23	11:21:00	1.9666	276.87	518.57	
942	23	11:24:00	2.0166	275.57	517.26	
945	23	11:27:00	2.0666	274.27	515.96	
949	23	11:31:00	2.1333	272.96	514.66	
952	23	11:34:00	2.1833	271.66	513.36	
955	23	11:37:00	2.2333	270.36	512.05	
958	23	11:40:00	2.2833	269.06	510.75	
962	23	11:44:00	2.3500	267.75	509.45	
965	23	11:47:00	2.4000	266.45	508.14	
969	23	11:50:00	2.4500	265.15	506.84	
972	23	11:54:00	2.5166	263.84	505.54	
976	23	11:58:00	2.5833	262.54	504.23	
979	23	12:01:00	2.6333	261.24	502.93	
983	23	12:05:00	2.7000	259.93	501.63	
987	23	12:09:00	2.7666	258.63	500.33	
991	23	12:13:00	2.8333	257.33	499.02	
996	23	12:18:00	2.9166	256.03	497.72	
999	23	12:21:00	2.9666	254.72	496.42	
1003	23	12:25:00	3.0333	253.42	495.11	
1007	23	12:29:00	3.1000	325.73	567.43	START UP PUMPING AGAIN Pressure down 2 3/8"

Appendix Cont'd

Geoservices Inc. Production

Client : BDM CORP. Survey Date : 09/22/87
Field Id. : WILCOX Well No. : BDM RET #1

PROBE SS	DAY	TIME HH:MM:SS	dT (hr)	dP (psig)	PRESSURE (psig)	COMMENTS
1008	23	12:30:00	3.1166	393.49	635.10	
1009	23	12:31:00	3.1333	449.39	682.08	
1010	23	12:32:00	3.1500	472.96	714.66	
1011	23	12:33:00	3.1666	491.06	733.55	
1012	23	12:34:00	3.1833	504.89	746.58	
1013	23	12:35:00	3.2000	517.05	753.75	
1014	23	12:36:00	3.2166	519.87	761.56	
1015	23	12:37:00	3.2333	525.73	767.43	
1016	23	12:38:00	3.2500	527.69	769.38	
1018	23	12:40:00	3.2833	529.64	771.34	
1019	23	12:41:00	3.3000	528.34	770.03	
1021	23	12:43:00	3.3333	527.04	768.73	
1026	23	12:48:00	3.4166	519.87	761.56	
1027	23	12:49:00	3.4333	487.39	728.99	
1028	23	12:50:00	3.4500	471.01	712.70	
1029	23	12:51:00	3.4666	460.59	702.28	
1030	23	12:52:00	3.4833	452.77	694.46	
1031	23	12:53:00	3.5000	446.91	688.66	
1032	23	12:54:00	3.5166	442.35	684.04	
1033	23	12:55:00	3.5333	438.44	680.13	
1034	23	12:56:00	3.5500	435.18	676.87	
1035	23	12:57:00	3.5666	432.57	674.27	
1036	23	12:58:00	3.5833	429.97	671.66	
1037	23	12:59:00	3.6000	427.36	669.06	
1038	23	13:00:00	3.6166	433.88	675.57	
1039	23	13:01:00	3.6333	512.65	753.75	
1040	23	13:02:00	3.6500	565.05	796.74	
1041	23	13:03:00	3.6666	573.29	814.98	
1042	23	13:04:00	3.6833	581.76	823.45	
1043	23	13:05:00	3.7000	586.97	828.66	
1044	23	13:06:00	3.7166	589.59	831.27	
1045	23	13:07:00	3.7333	583.71	825.41	
1046	23	13:08:00	3.7500	579.15	820.85	
1047	23	13:09:00	3.7666	571.31	813.03	
1048	23	13:10:00	3.7833	568.09	809.77	
1049	23	13:11:00	3.8000	566.78	808.47	
1052	23	13:14:00	3.8500	568.09	809.77	
1055	23	13:17:00	3.9000	569.38	811.07	
1063	23	13:25:00	4.0333	573.29	814.98	
1064	23	13:26:00	4.0500	576.55	818.24	
1066	23	13:28:00	4.0833	579.15	820.85	
1067	23	13:29:00	4.1000	580.46	822.15	
1068	23	13:31:00	4.1333	582.41	824.10	
1071	23	13:33:00	4.1666	584.36	826.06	
1073	23	13:35:00	4.2000	586.32	828.01	
1074	23	13:36:00	4.2166	585.02	826.71	
1076	23	13:38:00	4.2500	580.46	822.15	
1077	23	13:39:00	4.2666	576.55	818.24	
1078	23	13:40:00	4.2833	574.59	816.29	
1079	23	13:41:00	4.3000	573.29	814.98	
1081	23	13:43:00	4.3333	571.99	813.68	

Appendix Cont'd

Coreservices Inc. Production

Client : BDM Corp. Survey Date : 09/22/87
Field Id. : WILCOX Well No. : BDM RFT #1

PROCESS DAY	TIME DD HH:MM:SS	dT (hr)	dP (psig)	PRESSURE (psig)	COMMENTS
1004 23	13:46:00	4.3833	573.29	814.98	
1006 23	13:48:00	4.4166	575.24	816.94	
1008 23	13:50:00	4.4500	577.20	818.89	
1009 23	13:51:00	4.4666	578.59	820.20	
1010 23	13:52:00	4.4833	579.00	821.50	
1011 23	13:53:00	4.5000	581.11	822.80	
1012 23	13:54:00	4.5166	582.41	824.10	
1013 23	13:55:00	4.5333	583.71	825.41	
1014 23	13:56:00	4.5500	585.67	827.36	
1016 23	13:58:00	4.5833	587.62	829.32	
1018 23	14:00:00	4.6166	591.53	833.22	
1019 23	14:01:00	4.6333	593.49	835.18	
1021 23	14:03:00	4.6666	596.09	837.79	
1022 23	14:04:00	4.6833	597.39	839.08	
1024 23	14:06:00	4.7166	599.35	841.04	
1026 23	14:08:00	4.7500	601.30	843.00	
1028 23	14:10:00	4.7833	602.61	844.30	
1029 23	14:11:00	4.8000	603.91	845.60	
1031 23	14:13:00	4.8333	605.86	847.56	
1033 23	14:15:00	4.8666	607.17	848.86	
1034 23	14:16:00	4.8833	608.47	850.16	
1036 23	14:18:00	4.9166	610.42	852.17	
1038 23	14:20:00	4.9500	611.73	853.42	
1039 23	14:21:00	4.9666	613.03	854.72	
1043 23	14:25:00	5.0333	611.07	852.77	
1045 23	14:27:00	5.0666	609.77	851.47	
1047 23	14:29:00	5.1000	608.47	850.16	
1049 23	14:31:00	5.1333	609.77	851.47	
1050 23	14:32:00	5.1500	611.73	853.42	
1051 23	14:33:00	5.1666	613.68	855.37	
1052 23	14:34:00	5.1833	614.98	856.68	
1054 23	14:36:00	5.2166	616.29	857.98	
1056 23	14:38:00	5.2500	616.29	857.98	
1058 23	14:40:00	5.2833	616.94	858.63	
1059 23	14:41:00	5.3000	616.94	858.63	
1061 23	14:43:00	5.3333	615.64	857.33	
1063 23	14:45:00	5.3666	615.64	857.33	
1065 23	14:47:00	5.4000	616.94	858.63	
1067 23	14:49:00	5.4333	616.94	858.63	
1068 23	14:50:00	5.4500	616.94	858.63	
1070 23	14:52:00	5.4833	618.24	859.93	
1072 23	14:54:00	5.5166	618.89	860.59	
1074 23	14:56:00	5.5500	618.89	860.59	
1076 23	14:58:00	5.5833	618.89	860.59	
1077 23	14:59:00	5.6000	618.89	860.59	
1079 23	15:01:00	5.6333	618.89	860.59	
1081 23	15:03:00	5.6666	618.89	860.59	
1083 23	15:05:00	5.7000	618.89	860.59	
1085 23	15:07:00	5.7333	618.89	860.59	
1086 23	15:08:00	5.7500	618.89	860.59	
1088 23	15:10:00	5.7833	618.89	860.59	
1090 23	15:12:00	5.8166	618.89	860.59	
1092 23	15:14:00	5.8500	618.89	860.59	
1094 23	15:16:00	5.8833	618.89	860.59	
1095 23	15:17:00	5.9000	618.89	860.59	
1097 23	15:19:00	5.9333	618.89	860.59	
1099 23	15:21:00	5.9666	618.89	860.59	
1101 23	15:23:00	6.0000	618.89	860.59	
1103 23	15:25:00	6.0333	618.89	860.59	
1104 23	15:26:00	6.0500	618.89	860.59	
1106 23	15:28:00	6.0833	618.89	860.59	
1108 23	15:30:00	6.1166	618.89	860.59	
1110 23	15:32:00	6.1500	618.89	860.59	
1112 23	15:34:00	6.1833	618.89	860.59	
1113 23	15:35:00	6.2000	618.89	860.59	
1115 23	15:37:00	6.2333	618.89	860.59	
1117 23	15:39:00	6.2666	618.89	860.59	
1119 23	15:41:00	6.3000	618.89	860.59	
1121 23	15:43:00	6.3333	618.89	860.59	
1122 23	15:44:00	6.3500	618.89	860.59	
1124 23	15:46:00	6.3833	618.89	860.59	
1126 23	15:48:00	6.4166	618.89	860.59	
1128 23	15:50:00	6.4500	618.89	860.59	

Appendix Cont'd

Geoservices Inc. Production

Client : BDM CORP. Survey Date : 09/22/87
Field Id. : WILDCAT Well No. : BDM RET #1

HUNDRESS	DAY	TIME HH MM:SS	dT (hr)	dP (psig)	PRESSURE (psig)	COMMENTS
1212	23	15:54:00	6.5166	624.10	865.80	
1220	23	16:07:00	6.6500	626.71	868.40	
1221	23	16:09:00	6.6666	628.66	870.36	
1224	23	16:06:00	6.7166	629.97	871.66	
1227	23	16:09:00	6.7666	628.66	870.36	
1229	23	16:11:00	6.8000	629.97	871.66	
1239	23	16:21:00	6.9666	629.32	871.01	
1249	23	16:31:00	7.1333	628.66	870.36	
1259	23	16:41:00	7.3000	628.01	869.71	
1261	23	16:43:00	7.3333	633.22	874.92	
1262	23	16:44:00	7.3500	635.18	876.87	MAX. FRAC PRESSURE
1263	23	16:45:00	7.3666	632.57	874.27	
1264	23	16:46:00	7.3833	626.71	868.40	
1265	23	16:47:00	7.4000	623.45	865.15	
1266	23	16:48:00	7.4166	624.76	866.45	
1267	23	16:49:00	7.4333	626.06	867.75	
1277	23	16:59:00	7.6000	626.06	867.75	
1278	23	17:00:00	7.6166	624.76	866.45	
1288	23	17:10:00	7.7833	624.10	865.80	
1290	23	17:12:00	7.8166	620.85	862.54	SHUT DOWN PUMPS
1291	23	17:13:00			822.15	
1292	23	17:14:00			802.61	
1293	23	17:15:00			795.44	
1294	23	17:16:00			789.58	
1295	23	17:17:00			785.67	
1296	23	17:18:00			781.76	
1297	23	17:19:00			777.85	
1298	23	17:20:00			775.24	
1299	23	17:21:00			772.64	
1300	23	17:22:00			770.03	
1301	23	17:23:00			767.43	
1302	23	17:24:00			766.47	
1303	23	17:25:00			763.52	
1304	23	17:26:00			762.22	
1305	23	17:27:00			760.26	
1306	23	17:28:00			759.31	
1307	23	17:29:00			757.69	
1308	23	17:30:00			756.70	
1309	23	17:31:00			754.40	
1310	23	17:32:00			753.09	
1311	23	17:33:00			751.79	
1312	23	17:34:00			750.49	
1313	23	17:35:00			749.19	
1314	23	17:36:00			747.88	
1316	23	17:38:00			745.93	
1318	23	17:40:00			743.97	
1320	23	17:42:00			742.67	
1321	23	17:43:00			741.37	
1323	23	17:45:00			740.07	
1325	23	17:47:00			738.20	
1326	23	17:48:00			735.50	

Appendix Cont'd

VISCOSITY OF AIR AT ONE ATMOSPHERE

Viscosity,* μ, in micropoises
(1 micropoise = 10^{-6} poise)

A: Temp., Deg F.	30	40	50	60	70	80	90	100
0	.....	174.0	176.8	179.6	182.4	185.0	187.7	190.4
1	.....	174.3	177.0	179.9	182.6	185.3	188.0	190.7
2	171.8	174.6	177.3	180.1	182.9	185.6	188.3	190.9
3	172.1	174.9	177.6	180.4	183.2	185.9	188.5	191.2
4	172.4	175.1	177.9	180.7	183.4	186.1	188.8	191.4
5	172.7	175.4	178.2	181.0	183.7	186.4	189.1	191.7
6	172.9	175.7	178.5	181.2	183.9	186.6	189.3	192.0
7	173.2	176.0	178.7	181.5	184.2	186.9	189.6	192.3
8	173.5	176.2	179.0	181.8	184.5	187.2	189.8	192.6
9	173.7	176.5	179.3	182.1	184.8	187.4	190.1	192.8
								193.1

B: Temp., Deg C.	0	10	20	30	40
0	171.8	176.8	181.8	186.6	191.4
1	172.3	177.3	182.3	187.1	191.9
2	172.8	177.8	182.8	187.6	192.4
3	173.3	178.3	183.25	188.1	192.9
4	173.8	178.8	183.7	188.6	193.3
5	174.3	179.3	184.2	189.1	193.8
6	174.8	179.8	184.7	189.5	194.3
7	175.3	180.3	185.2	190.0	194.7
8	175.8	180.8	185.7	190.5	195.2
9	176.3	181.3	186.2	191.0	195.7

*Calculated from Sutherland's equation:

$$\frac{\mu}{\mu_o} = \left[\frac{T_o + C}{T + C}\right]\left[\frac{T}{T_o}\right]^{3/2} \qquad (41)$$

wherein: the temperatures are measured above absolute zero (—273 C.), and C is taken as 120 deg for air.† The standard viscosity is μ_o = 183.25 micropoises at T_o = 23 C. = 296 K., based upon independent observations by six investigators, evaluated by Birge.‡

†Montgomery, R. B.: *J. Meteorology*, 4, 193 (1947).
‡Birge, Raymond T.: *Am. J. Phys.*, 13, 63 (1945).

VISCOSITY OF VARIOUS GASES

Gas	Temperature Range, Deg C.	C	$K \times 10^6$	Average Error, Per Cent
Argon	—183 to 827	133.	19.00	0.3
Carbon dioxide	— 98 to 1052	233.	15.52	1.0
Helium	—258 to 817	97.6	15.13	9.5
Hydrogen	—258 to 825	70.6	6.48	5.1
Nitrogen	—191 to 825	102.	13.85	0.4
Oxygen	—191 to 829	110.	16.49	0.8

The viscosity of various gases* at atmospheric pressure and any reasonable temperature may be calculated by Sutherland's equation:

$$\mu = \frac{KT^{3/2}}{T + C} \qquad (42)$$

wherein:

μ = viscosity, in poises.

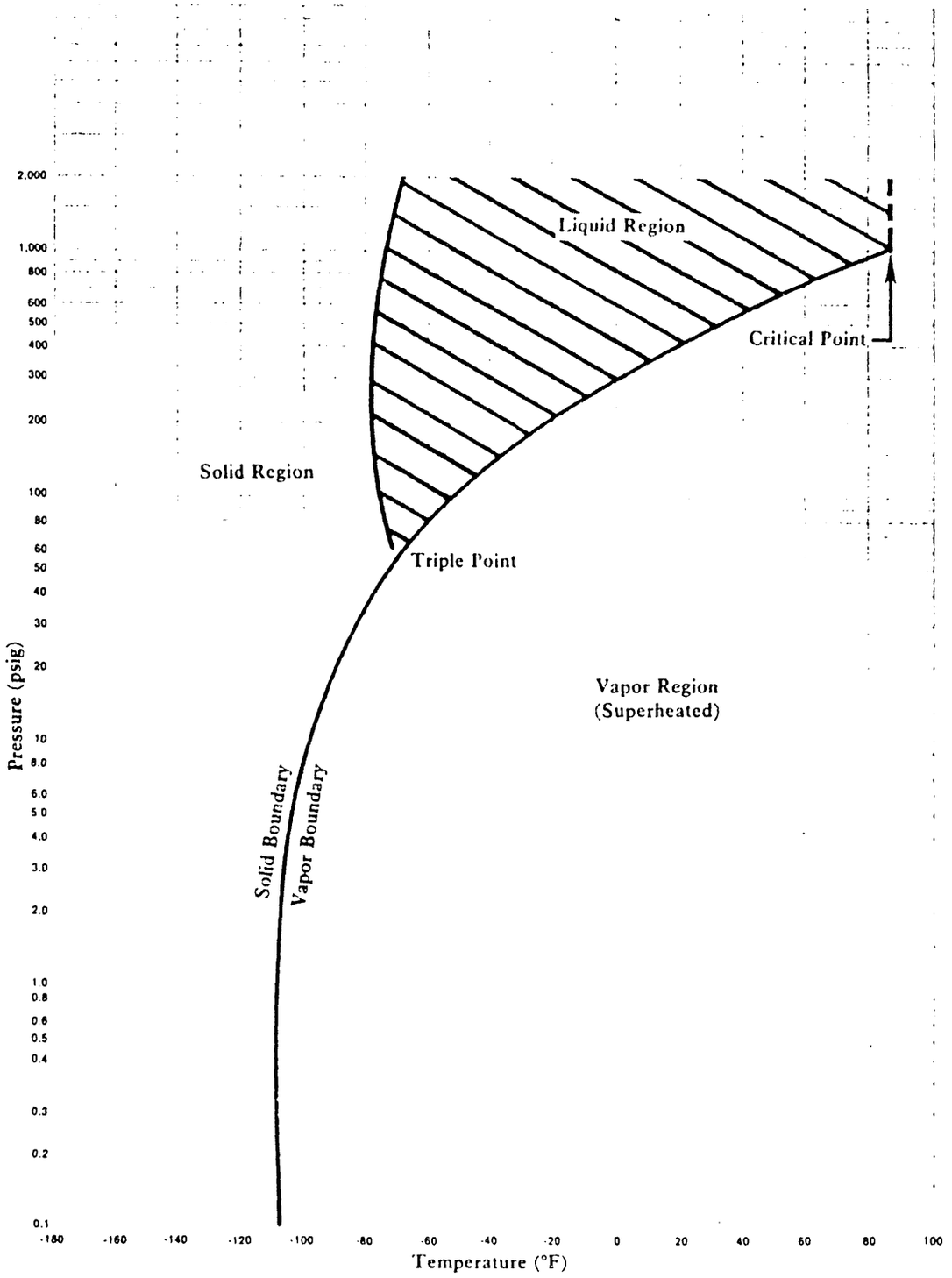
T = absolute temperature, in degrees Kelvin.

C and K are constants tabulated above.

*Licht, Wm., Jr. and Stechert, Dietrich G., *J. Phys. Chem.*, 48, 23 (1944).

Appendix Cont'd

Carbon Dioxide Equilibrium Curve.



Keywords

BDM/DOE RET No. 1 Wayne Co. West Virginia
Horizontal Well Data Only Lower Huron Shale

Abstract

Examine submitted data to determine fracturing geometry by minifrac analysis of fracturing treatment of 100% nitrogen and make calculation of Nolte analyses, bottomhole treating rates and additional recommendation for additional treatments in horizontal section.

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Respectfully submitted,

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11-12-87

rdf

APPENDIX C

SUPPORTING MATERIAL AND PROCEDURES FOR STIMULATION NO. 2 IN ZONE NO. 1 USING LIQUID CO_2

APPENDIX C-1
LOG OF FIELD OPERATIONS FOR FRAC JOB #2

DOE/BDM/RET #1
FIELD REPORTS
12/1/87-12/5/87

Dec. 1, 1987

8:00 am - 9:00 am — MIRU Pool Well Service Rig #652. Well flowing through test meter. Zone #1 (PC #1) is the only zone open to the wellbore. Gas rate = 60# x 44" = 50 MSCFPD (uncorrected). Caught gas sample off tubing. Shut-in the well at 8:00 AM and ND wellhead. Opened well up to atmosphere and blew down same. Prepared to TIH.

9:00 am - 10:00 am — Made up BHA with Geoservice pressure gauges (2) and temperature gauge (1) installed. Set gauges to scan pressures every two (2) minutes. (BHA consists of 2 3/8" bull plug + 1 Jt. 2 3/8" tbg + bottom isolation cups + 1 Jt. 2 3/8" tbg + closing sleeve positioner + 4 ft. pup joint + 2 ft. perforated sub + opening sleeve positioner + 1 Jt. 2 3/8" tbg + top isolation cups, overall length = 121.18').

10:00 am - 5:15 pm — TIH with BHA on 2 3/8" tbg. Obtained 1 hr. shut-in pressures on all zones while TIH as follows:

Time	Zone	Interval	Port Collar Isolated	Port Collar Depth	SITP (Psig)	SIBHP (Psig)
12:14 pm	8	3745-4095	13	3960	90	104
1:16 pm	8	3745-4095	13	3960	98	114
1:40 pm	7	4104-4194	12	4147	30	44
2:40 pm	7	4104-4194	12	4147	75	99
2:50 pm	6	4203-4337	11	4291	160	180
3:50 pm	6	4203-4337	11	4291	174	202
4:12 pm	5	4346-4811	9	4595	140	161
5:15 pm	5	4346-4811	9	4595	161	189

5:15 pm - 5:30 pm — Secured well for the night. Left Zone #1 (only) blowing to atmosphere.

Dec. 2, 1987

7:20 am - 1:30 pm — TIH with tbg and continued obtaining 1-hour shut-in pressures as follows:

Dec. 2, 1987 (cont'd)

Time	Zone	Interval	Port Collar Isolated	Port Collar Depth	SITP (Psig)	SIBHP (Psig)
7:40 am	5A	4848-4986	8	4894	125	160
8:45 am	5A	4848-4986	8	4894	144	191
8:57 am	4	4994-5176	6	5129	115	171
9:57 am	4	4994-5176	6	5129	121	174
10:07 am	3	5185-5411	4	5319	70	145
11:07 am	3	5185-5411	4	5319	101	156
11:17 am	2	5420-5602	2	5555	60	139
12:20 pm	2	5420-5602	2	5555	95	146
12:30 pm	1	5611-6020	1	5746	50	84
1:30 pm	*1	5611-6020	1	5746	85	139

*Left Zone #1 open to wellbore.

1:30 pm - 6:40 pm — Prepared to TOOH with tbg. Obtained a 2nd 1-hr shut-in pressure on all zones to compare to 1st shut-in pressure as shown below. Flowed each zone (#2-6,8) for 30 minutes to purge tubing and caught gas samples on each.
Note: The 2nd shut-in pressure is used to show any pressure changes in each zone as a result of flowing (purging) adjacent zones.

Time	Zone	Interval	SITP (Psig)	SIBHP (Psig)	Remarks
1:45 pm	2	5420-5602	65	133	Open Zone 2 Isolated for 1 Hr B.U.
3:00 pm	2	5420-5602	92	143	Purging Tubing
3:30 pm	2	5420-5602	-	133	Caught gas sample. Closed Zone 2
3:53 pm	3	5185-5411	55	116	Open Zone 3. Isolated for 1 Hr B.U.
4:53 pm	3	5185-5411	89	139	Purging Tubing
5:20 pm	3	5185-5411	-	123	Caught gas sample. Closed Zone 3.
5:40 pm	4	4994-5176	115	171	Open Zone 4. Isolated for 1 Hr B.U.
6:40 pm	4	4994-5176	121	176	1-Hr Shut-in PSI

Dec. 2, 1987 (cont'd)

6:40 pm SDON. Left well SION with Zone #4 open to tubing. Note: Zone #1 isolated from Zone #4 with bottom isolation cups.

Dec. 3, 1987

6:55 am - 3:30 pm

Time	Zone	Interval	SITP (Psig)	SIBHP (Psig)	Remarks
6:55 am	4	4994-5176	121	176	Zone 4 - 13 Hr SI
6:55 am	4	4994-5176	-	176	Purging tubing
7:20 am	4	4994-5176	-	171	Caught Gas sample, Closed Zone 4
7:45 am	5A	4848-4986	125	184	Open Zone 5A. Isolated for 1 hr B.U.
8:48 am	5A	4848-4986	147	200	Purging tubing.
9:20 am	5A	4848-4986	-	167	Caught gas sample. Closed Zone 5A
9:35 am	5	4346-4811	70	157	Open Zones, Isolated for 1 hr B.U.
10:30 am	5	4346-4811	90	176	Purging tubing.
11:00 am	5	4346-4811	-	164	Caught gas sample. Closed Zone 5
11:17 am	6	4203-4337	45	159	Open Zone 6 Isolated for 1 Hr. B.U.
12:15 pm	6	4203-4337	75	174	Purging tubing.
12:45 pm	6	4203-4337	-	166	Caught gas sample. Closed Zone 6
12:53 pm	7	4104-4194	45	159	Open Zone 7. Isolated for 1 hr B.U.
1:55 pm	7	4104-4194	71	169	Closed Zone 7. No sample taken.
2:01 pm	8	3745-4095	70	155	Open Zone 8. Isolated for 1 hr B.U.
3:00 pm	8	3745-4095	93	167	Purging tubing.
3:30 pm	8	3745-4095	-	144	Caught gas sample. Closed Zone 8.

Dec. 3, 1987 (cont'd)

3:30 pm - 5:30 pm — TOOH with tubing. Found the last 5 Jts. 2 3/8" tubing and BHA full of fluid. (Note: distance from top of fluid to bottom of BHA is 284 ft.) LD BHA. Sent BHP recorders in for analysis. SDON.

Dec. 4, 1987

7:30 am - 2:30 pm — PU same BHA and TIH to test ECP's #1-7, and CTC packer. Note: ECP #8 was not tested since there has not been any gas seen on the 8 5/8" casing string at the surface since it was set. Each packer was tested by opening a port collar above and below the packer then isolating the port collar below with the BHA on the end of the tubing string. Nitrogen was then pumped down the tubing with Dowell/Schlumberger at a rate of 2000-5000 SCF/m. If the packer were leaking, nitrogen would be circulated out the open port collar below the packer, around the packer, back in the open port collar above the packer, and up the 2 3/8" x 4 1/2" annulus. Thus, any strong nitrogen blow seen at the surface would indicate a packer failure. All packers tested OK to 500 psi (surface N_2 Pump Pressure) except ECP #2 and the CTC packer. A strong nitrogen blow was seen on both ECP #2 @ 5411' and the CTC Packer at 4811'. Thus ECP #2 did not test and CTC Packer did not test.

Isolated port collar #2 @ 5555' with the BHA with all port collars open. (except PC #12 @ 4147') Attempted to reverse out all fluid from the wellbore with nitrogen (50,000 SCF) by circulating down the 2 3/8" x 4 1/2" annulus, out port collar #3 @ 5464', back in port collar #2 @ 5555', and up the 2 3/8" tubing. Approximately 1 Bbl of fluid was recovered.

2:30 pm - 4:30 pm — RD Dowell-Schlumberger and NU the wellhead. Open the well to pipeline at 3:00 pm. Zone #1 is flowing up the 2 3/8" tubing and Zones #2-6, 8 are flowing up the 2 3/8" x 4 1/2" annulus. Zone #7 was left shut-in due to low productivity. Initial flowrate from Zone 1 (tubing) was 74 MCFPD w/ 95 psig FTP. Initial flowrate from Zones 2-6, 8 (casing) was 126 MCFPD w/95 psig FCP. (Rates are uncorrected) Left well flowing down pipeline overnight.

Dec. 5, 1987

9:30 am — Tubing - Zone #1: Gas Rate = 77 MCFPD FTP = 70 PSIG LP = 65 PSIG

Casing - Zones #2-6, 8: Gas Rate = 138 MCFPD FCP = 70 PSIG
NOTE: Gas rates are uncorrected for gas gravity, CO_2 & N_2 content, or temperature.

Caught a composite gas sample at Cabots meter run. Left well flowing down pipeline.

APPENDIX C-2
TESTING AFTER FRAC & CLEAN-UP

BDM/DOE/ENEGER RET #1 - TEST PROCEDURES
December 1, 1987

CURRENT WELL CONDITIONS

The well is currently producing from Zone #1 thru port collar #1 located at 5746 feet. The gas is flowing up the 4-1/2" 10.5#/ft casing with no tubing in the hole. All gas is being metered and flared to atmosphere. The well has been flowing under those conditions since Zone #1 was stimulated with CO_2 on November 8, 1987. Current gas production is 40-50 mcfpd at 60 psi FTP.

TEST OBJECTIVES

The objectives of this test are as follows:

1) Obtain shut-in pressures on Zones #2 thru #8 while Zone #1 continues to flow.

2) Catch a gas sample on all zones for qualitative analysis.

3) Pressure test all external casing packers (8).

4) Evaluate all data collected in Steps 1, 2, and 3 and determine which zones are communicated.

PROCEDURE

1) MIRU Pool Well Service. Catch gas sample from the tubing (Zone #1). Open well up to atmosphere and ND the wellhead. Prepare to trip in the hole with tubing.

2) Make up BHA. BHA consists of 2-3/8" bull plug + 1 jt 2-3/8" tubing + bottom isolation cups + 1 jt 2-3/8" tubing and closing sleeve positioner + 4 ft pup joint (2-3/8") + 2 ft perforated sub + opening sleeve positioner + 1 jt 2-3/8" tubing + top isolation cups. Quartz bottomhole pressure recorders (2) + temperature recorder (1) will be installed inside the bottom joint of tubing (see Figure 1). TIH with the BHA on 2-3/8" tubing.

3) Locate Zone 8 through PC #13 at 3960 feet. Install a 2" ball valve on top of the 2-3/8" tubing string at the surface and shut-in same. Open PC #13. Hook up surface equipment to monitor the shut-in tubing pressure at the surface. Monitor the pressure for a sufficient period of time (30 minutes to 1 hour) to allow the pressure to stabilize. Once the pressure stabilizes, close PC #14 and bleed down the tubing. Care should be taken so as not to flow the well (from port collar #13) any more than what is required to pressure up the 2-3/8" tubing string.

TABLE I

SUMMARY OF PORT COLLARS
THRU WHICH EACH ZONE WILL BE TESTED
(SEE STEPS 3, 4, 5 & 6)

ZONE	INTERVAL	PORT COLLAR TO BE TESTED THRU	DEPTH TO PORT COLLAR
8	3745 - 4095	13	3960'
7	4104 - 4194	12	4147'
6	4203 - 4337	11	4291'
5	4346 - 4811	9	4595'
5A	4848 - 4986	8	4894'
4	4994 - 5176	6	5129'
3	5185 - 5411	4	5319'
2	5420 - 5602	3	5464'
*1	5611 - 6020	1	5746'

* Zone #1 will be open during the entire test.

TABLE II

PERTINENT DATA RELATIVE TO TESTING OF EXTERNAL CASING PACKERS
(SEE STEPS 8 and 9)

ECP TO BE TESTED		PC OPEN ABOVE ECP		PC ISOLATED BELOW ECP		*N2 REQ'D AT
NO.	DEPTH	NO.	DEPTH	NO.	DEPTH	500 PSI (scf)
1	5602	2	5555	1	5746	7650
2	5411	4	5319	3	5464	5620
3	5176	6	5129	5	5229	5790
4	4986	8	4894	7	5038	5300
CTC	4811	9	4595	8	4894	4835
5	4337	11	4291	10	4383	7060
6	4194	12	4147	11	4291	4345
7	4095	13	3960	12	4147	3880
8	3736	--	--	14	3832	5720
						50,200 scf

* Nitrogen requirements include only the volumes required to pressure the 2-3/8" tubing and 4-1/2" x 7-7/8" annulus to 500 psi.

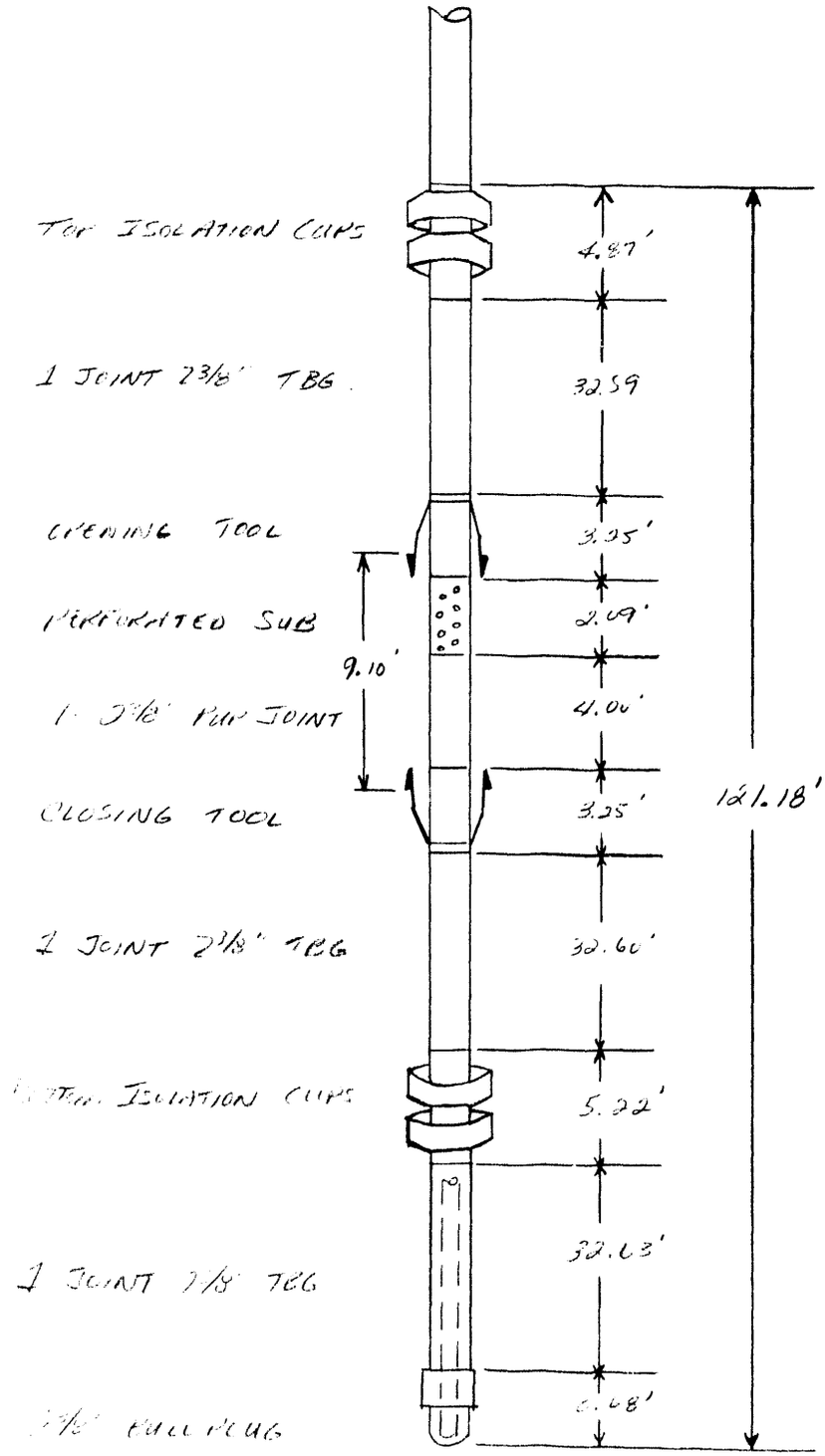

TOP ISOLATION CUPS
4.87'
1 JOINT 2 3/8" TBG
32.59
OPENING TOOL
3.25'
PERFORATED SUB
2.09'
9.10'
1 - 2 3/8" PUP JOINT
4.00'
CLOSING TOOL
3.25'
121.18'
1 JOINT 2 3/8" TBG
32.60'
BTM. ISOLATION CUPS
5.22'
1 JOINT 2 3/8" TBG
32.63'
2 3/8" BULL PLUG
2.48'

FIGURE 1

4) Repeat Step 3 for Zones 7, 6, 5, 5A, 4, 3, and 2 while tripping in the hole. Use the same shut-in period for all zones (see Table 1).

5) After obtaining the shut-in pressure on Zone #1, hook up the flowlines at the surface and prepare to flow Zone #2. Open the well on a sufficient choke size to purge the tubing within 30 minutes. Measure all gas with the Barton two-pen meter. Once the tubing has been adequately purged (less than 5 mscf at these pressure ranges), catch a gas sample to be used for the qualitative analysis. Shut-in the well at the surface. Nipple down the pressure monitoring equipment and flowlines. Close PC #3. Bleed down the tubing to atmosphere.

6) TOOH with tubing and repeat Steps 3 and 5 above for Zones #3 thru #8. NOTE: The second shut-in pressure will be used to show how much (if any) any given zone was depleted as a result of flow testing adjacent zones in Step 5.

7) TOOH with tubing. Remove quartz pressure recorders (2) and temperature recorder (2) from BHA and send in to be evaluated.

8) Trip back in the hole with BHA to test external casing packers (8) and CTC packer (1). Open PC #2 at 5555 feet. Continue TIH and locate PC #1 at 5746 feet. Isolate PC #1 between the top and bottom isolation cups. NOTE: PC #1 is already in the open position. RU nitrogen pump truck and pump down the 2-3/8" tubing at a rate of 500-1000 scf/m. If nitrogen circulates up the 2-3/8" x 4-1/2" annulus, the ECP is not holding. If the tubing pressures up to 500 psi and the nitrogen does not circulate up the 2-3/8" x 4-1/2" annulus, the ECP is holding. If this test shows that the ECP is not holding, TOOH with tubing to blank pipe and pressure up on tubing to ensure that the isolation cups are holding.

9) Repeat Step 8 for all ECP's and the CTC packer (see Table II).

10) TOOH with tubing and BHA. Hook up wellhead equipment to continue flow testing Zone #1.

11) RD Pool Well Service.

APPENDIX D

SUPPORTING MATERIAL AND PROCEDURES FOR FRAC NO. 3 ON ZONE NO. 1
USING NITROGEN FOAM AND PROPPANT

APPENDIX D-1
FRAC #3 FIELD OPERATIONS
ZONE #1 N_2 FOAM/PROPPANT

DOE-BDM-RET #1

Field Operations

January 18-21, 1988

Jan. 18, 1988	Well flowing down Cabot Pipeline at the following rates:
8:00 am - 9:30 am	Zone #1 (Tubing) =11 MCFPD FTP 55 PSIG LP 30 PSIG Zones #2-6, 8 (Casing) 61 MCFPD FCP 65 PSIG LP 30 PSIG Zone #7 - Shut-in. Pool Well Service on location (MIRU Pool on Friday, 1/15/88). Shut-in Cabot's pipeline. Blew down tubing and casing to atmosphere, ND Wellhead.
9:30 am - 12:30 pm	TOOH with 173 Jts 2 3/8" tbg and BHA. (121.18') Left Zone #1 open to the wellbore (PC #1 @ 5746'). Closed all other port collars while TOOH.
12:30 pm - 4:30 pm	Laid down BHA. Made up new BHA. BHA consists of 2 3/8 tbg collar + bottom isolation cups (2 cups facing down) + top isolation cups (2 cups facing up) + 4 ft pup joint. (Overall length of BHA = 15.09') TIH with BHA on 172 jts 2 3/8" tbg. End of tubing at 5615'. Bottom of cups at 5613'. Top of cups at 5607'. NU wellhead. Left well venting to atmosphere. SDON.
Jan. 19, 1988	
7:00 am - 11:45 am	MIRU NOWSCO Well Service. Due to bad road conditions, pulled all trucks on and off location with a dozer.
11:45 am - 12:20 pm	Pressured 2 3/8" x 4 1/2" annulus to 390 PSIG with 21,000 SCF N_2 at a rate of 1200 SCF/min. NOTE: Unable to hold high pressures on the annulus due to slow leak at PC #3 at 5464'. Pressure bleeds off slowly. Monitored casing pressure throughout the frac job. Pressure tested all surface equipment to 3800 PSI.
12:20 pm - 4:00 pm	Fracture stimulated Zone #1 down 2 3/8" tubing through PC #1 at 5746' as follows:

Jan. 19, 1988 (cont'd)

Time	Stage	TP	CP	Rate (BPM) Clean LIQ.	Rate (BPM) Down-hole FOAM	Volume (Bbls) Clean LIQ.	Volume (Bbls) Down-hole FOAM	REMARKS
12:20 pm	1	90	375	3.0	-	0	-	Start 20 Ton CO_2 Pre-Pad
12:29 pm	1	170	360	2.5	-	20	-	
12:37 pm	1	230	330	2.9	-	50	-	
01:00 pm	1	240	300	3.0	-	119	-	Start 7000 gal 85Q N_2 Foam Pad
01:05 pm	2	1410	290	1.5	10.0	5	33	
01:07 pm	2	1530	260	1.5	10.0	8	53	
01:19 pm	2	1540	250	1.5	-	25	167	Start 6000 gal 85 Q N_2 Foam w/ 1/2 PPG 20/40 Sand
01:28 pm	3	1530	250	1.5	10.0	41	274	
01:31 pm	3	1380	250	1.5	10.0	46	310	Start 4000 gal 85 Q N_2 Foam w/1 PPG 20/40 sand
01:41 pm	4	1580	250	1.5	10.0	60	405	Start 3333 gal 85 Q N_2 foam w/1½ PPG 20/40 sand
01:46 pm	5	1610	245	1.5	10.0	70	472	
01:48 pm	5	1600	245	1.5	10.0	72	484	Start 4000 gal 85Q N_2 Foam w/2 PPG 20/40 sand

Jan. 19, 1988 (cont'd)

Time	Stage	TP	CP	Rate (BPM) Clean LIQ.	Rate (BPM) Down-hole FOAM	Volume (Bbls) Clean LIQ.	Volume (Bbls) Down-hole FOAM	REMARKS
01:50 pm	6	1650	240	1.5	10.0	75	504	
01:54 pm	6	1750	240	1.5	10.0	82	551	
01:58 pm	6	1760	240	1.5	10.0	86	579	Start N_2 Flush 3000 SCF/min
02:02 pm	7	1560	240	-	-	-	-	Shut Down. (12,000 SCF N_2 Flush)

ISIP - 1270# (Difficult to pick with straight N_2).

5 minutes - 770#

10 minutes - 730#

15 minutes - 700#

Held N_2 pump rate constant at 3000 SCF/min throughout the entire job. Liquid phase of the 85 quality foam consisted of 50% methanol and 50% 2% KCL water. Total sand pumped - 20,000 lbs 20/40 mesh. Total liquid to recover = 86 Bbls. Tagged the 7000 gal foam pad with 1 millicurrie liquid antimony #124. Tagged the proppant with 8 millicuries bead iridium #192 Foam Additives: 2 GPT CSA-5 Clay STA, 5 lb/1000 gal IS-600 iron stabilizer, 7 GPT SF-2 foamer. RD NOWSCO. NU Flowlines. Opened the well at 4:00 pm and flowed as follows:

Jan. 19, 1988 (cont'd)

	TIME	FTP	SICP	CHOKE	Remarks
4:00 pm - 8:30 pm	4:00 pm	530	205	8/64"	Open to tank
	4:30 pm	445	205	8/64"	Open to tank
	5:00 pm	290	200	8/64"	Open to tank
	5:30 pm	130	190	8/64"	Open to tank
	6:00 pm	55	190	8/64"	Open to tank
	6:30 pm	75	190	8/64"	Open to tank
	7:00 pm	45	185	8/64"	Open to tank
	7:30 pm	35	180	8/64"	Open to tank
	8:00 pm	15	175	8/64"	Open to tank
	8:30 pm	0	175	-	Well Died.

Left well venting to tank overnight. No fluid recovery.

Jan. 20, 1988

8:00 am - 4:00 pm FTP = 0 PSIG, SICP = 175 PSIG. Well dead. RU NOWSCO coiled tubing unit and N_2 truck. RIH with 1" coiled tubing to clean out any sand fill as follows:

Time	Coiled Tbg Depth (ft.)	Hole Angle At Depth (Deg.)	Coiled Tbg* Weight (lbs)	N_2 Rate (SCF/min)	Remarks
9:15 am	0	0°	0	0	Start RIH w/C.T.
9:25 am	2500	19°	1500	0	RIH at 250 ft/min
9:44 am	3500	58°	1600	1000	Start N_2
9:55 am	3500	58°	1600	0	Stop N_2 Add ball valve in line.
10:15 am	3600	65°	1700	1000	Start N_2
10:30 am	3700	70°	1000	1000	Pump Press-2400PSI
10:32 am	4000	90°	1100	1000	RIH @ 115 ft/min
10:37 am	4600	90°	950	1400	Incr. N_2 rate - Pump Press 2750 PSI

Jan. 20, 1988 (cont'd)

TIME	Coiled Tbg Depth (ft)	Hole Angle At Depth (Deg.)	Coiled Tbg* Weight (lbs)	N_2 Rate (SCR/Min)	Remarks
10:41 am	5000	89°	750	1400	RIH @ 120 ft/min
10:43 am	5300	89°	Pushing	1400	Circ. N_2 w/some Foam to surface
10:50 am	5600	88°	Pushing	1400	Pmp Press 2900PSI
10:55 am	5685	88°	Tag Bridge	1400	Set down on sand bridge POOH-5600'
11:00 pm	5600	88°	Pushing	1400	Unable RIH,POOH to 5300'
11:10 pm	5300	89°	Pushing	1400	Pmp Press-2750PSI RIH @ 34 ft/min
11:30 pm	5685	88°	Pushing	1400	Cleaning out sand
11:34 pm	5700	88°	Pushing	1400	Pmp Press-2700PSI
11:35 pm	5743	88°	Tag Bridge	1400	Clean sand bridge
11:43 pm	5784	88°	Tag Bridge	1400	Clean sand bridge
11:52 pm	5800	88°	Pushing	1550	Pmp Press-3000PSI Incr. N_2 Rate
12:01 pm	5885	88°	Pushing	1550	Circ. N_2 Foam and sand
12:10 pm	6008	87°	Tag TD	1600	Tagged PBTD @6008' Incr N_2 to 1600
12:15 pm	6008	87°	3000	1600	Start POOH w/C.T.
12:30 pm	5150	89°	-	-0-	Lost prime on N_2 pump truck-switch to Nowsco Air Compressor - 330 SCF/min
1:30 pm	0	0°	-	-0-	Out of Hole w/ C.T., RD NOWSCO

*Coiled tubing weight shown was recorded while running in the hole. Pertinent coiled tubing data as follows:

1.000" O.D.	Yield Strength - 50,000 PSI
0.870" I.D.	Tensile Strength - 70,000 PSI
0.649 lbs/ft.	Max. W.P. - 4,000 PSI
	Theo. Burst Pressure - 9100 PSI

Jan. 20, 1988 (cont'd)

1:30 pm - 2:15 pm — RD NOWSCO coiled tubing unit and N_2 truck. Prepare to TOOH with tubing.

2:15 pm - 5:00 pm — POOH with 2 3/8" tubing and BHA and LD same.

5:00 pm - 6:00 pm — PU 2 3/8" bull plug + 1 jt. 2 3/8" tubing + 2' perforated sub and started TIH on 2 3/8" tubing. Shut down overnight at 6:00 pm.

Jan. 21, 1988

7:00 am - 9:00 am — Continued TIH with 2 3/8" tbg. to PBTD at 6008'. Spaced out tubing with three 4 ft pup joints and NU wellhead. Bottom of 2 3/8" bull plug at 6006'. Top of the perforated sub at 5971'. Bottom of the perforated sub at 5973'.

9:00 am - 10:00 am — RU Dresser Atlas Wireline with packoff. Tied NOWSCO N_2 truck into the tubing. Hooked up an N_2 vent line from the 2 3/8" x 4 1/2" annulus to the pit.

10:00 am - 4:00 pm — RIH with Dresser Prism logging tools (1 - 11/16" O.D.) on 5/16" wireline. Overall tool length - 9 ft. Summary of logging activities as follows:

TIME	Wireline Depth Ft.	Hole Angle Depth (Deg)	Wireline* Weight (lbs)	Wireline Speed (ft/min)	N_2 Rate SCF/Min	Remarks
10:00 am	0	0	0	390	0	Start RIH with logging tools.
10:08 am	3000	42°	545	30	0	Stop RIH. Start N_2 rate at 700 SCF/Min.
10:15 am	3150	47°	497	107	700	
10:18 am	3400	50°	524	208	700	Pump Press-250 PSI
10:20 am	3700	70°	536	210	700	
10:21 am	3900	75°	540	210	700	Maintaining speed with no increase in weight.
10:22 am	4000	90°	400	30	800	Lost weight. Incr. N_2 rate.
10:28 am	4145	92°	385	30	1000	Losing weight Increase N_2 rate
10:29 am	4170	92°	560	72	1100	Increased N_2 rate
10:31 am	4300	92°	525	58	1100	

Jan. 21, 1988 (cont'd)

TIME	Wireline Depth Ft.	Hole Angle Depth (Deg)	Wireline* Weight (lbs)	Wireline Speed (ft/min)	N_2 Rate SCF/min	Remarks
10:33 am	4340	91°	550	68	1500	Incr N_2 rate
10:38 am	4600	90°	600	81	1500	Pump Press - 600 PSI
10:42 am	4850	90°	600	28	1700	Incr. N_2 rate
10:50 am	4950	89°	640	55	2000	Circ. N_2 and foam to surf. Incr. N_2 rate
10:54 am	5000	89°	635	30	2000	Circ. N_2 and foam
11:00 am	5150	89°	635	25	2000	Pump Press. 600 PSI
11:05 am	5250	89°	635	44	2000	Circ. N_2 and foam
11:20 am	5750	88°	610	90	2000	Wellbore dry Circ. N_2 only
11:28 am	5980	88°	0	0	2000	Pumped tools past perf. sub at 5971-5973' Lost all wt.
11:30 am	5980	88°	980	10	0	Stopped N_2 Logging out of the hole
01:00 pm	5080	89°	880	10	0	Logging
01:50 pm	4570	90°	845	10	0	Logging
02:30 pm	4180	92°	803	10	0	Logging
02:57 pm	3900	75°	805	10	0	Stop logging at 3900'. RIH for repeat.
03:00 pm	3900	75°	550	220	2000	RIH
03:05 pm	5040	89°	650	200	2000	Able to maintain higher line speed due to dry wellbore
03:08 pm	5500	88°	650	215	2000	
03:10 pm	5900	88°	640	200	2000	

Jan. 21, 1988 (cont'd)

TIME	Wireline Depth Ft.	Hole Angle Depth (Deg)	Wireline* Weight (lbs)	Wireline Speed (ft/min)	N_2 Rate SCF/min	Remarks
3:15 pm	5980	88°	0	0	2000	Tools down - prepare to log repeat. Stopped N_2
4:00 pm	5600	88°	850	10	0	Logged repeat to 5600'. Stop logging

*Wireline weight is that weight as indicated by Dresser Atlas while running in the hole or while being pushed in the hole with nitrogen. The wireline operator maintained a lower wireline speed on the first run to avoid any potential problems.

4:00 pm - 4:20 pm — Finished POOH with wireline. NOTE: Prism Log is a Spectral Gamma Ray Log which was run through both 2 3/8" tubing and 4 1/2" casing. RD NOWSCO N_2 truck and Dresser Atlas Wireline. Prepare to TOOH with tubing.

4:20 pm - TOOH with 2 3/8" tubing to 3453'. NU wellhead. NU Flowlines. (left 106 jts 2 3/8" tubing in the hole - 80 jts 2 3/8" tubing out of the hole). Opened the well up to the test meter (2" x 3/8") at 6:00 pm with back pressure regulator set at 55 PSIG. NOTE: Only Zone #1 (PC #1 at 5746') is open to the wellbore. All other port collars are closed. RD Pool Well Service. Shut down.

APPENDIX D-2

FRAC JOB ON ZONE #1 N_2 FOAM CLEAN UP OPERATION

DOE - BDM - RET #1
FIELD OPERATIONS
2/10/88 - 2/11/88

2-10-88 MIRU Pool double pole rig #491. SDON.

2-11-88

7:00 - 8:15 am Well venting to atmosphere thru test meter (2" x 3/8"). FTP = 55 psig (Zone 1). SICP = 82 psig (Zone 1). Uncorrected gas rate = 30 mcfpd (Zone 1 only). No flowlines. Blew down the well to atmosphere. Prepared to TIH with tubing.

8:15 - 9:30 am TIH with 2-3/8" tubing. Tagged PBTD at 6008' (no sand fill). Laid down one jt of tubing. NU wellhead. Tubing in hole (bottom to top): 2-3/8" bull plug + 1 jt 2-3/8" tubing + 2 ft perforated sub + 183 jts 2-3/8" tubing. Top of perforated sub at 5958'. End of tubing at 5994'. Port collar #1 at 5746'.

9:30 - 12:45 pm Waited on NOWSCO nitrogen pump truck for 3-1/4 hours.

12:45 - 3:45 pm RU NOWSCO to reverse. Circulate all fluid from the wellbore with nitrogen. Cooled down. Started pumping at 700 scfpm and 200 psig. Increased rate to 1400 scfpm and pumped for 20 minutes. Maximum pump pressure of 400 psi. Only a slight blow on the 2-3/8 tbg. Shut down. Switched nitrogen pump lines to pump conventionally down the 2-3/8" tubing and up the 2-3/8" x 4-1/2" annulus. Pumped conventionally for a total of 1 hour with initial rate of 1400 scfpm at 300 psi and final rate of 2300 scfpm at 700 psi. Had water/foam to surface after only 10 minutes. Well dried up. Rec'd 1 bbl fluid (est). Pumped a total of 130,000 scf nitrogen. RD NOWSCO. Prepared to TOOH with tbg.

3:45 - 6:00 pm TOOH with 105 jts 2-3/8" tbg. SDON.

2-12-88

0730 - 1500 Finished TOOH with 2-3/8" tubing. LD perforated sub and 2-3/8" bull plug. PU new BHA and TIH on 2-3/8" tbg. New BHA consists of: (Btm to top). 2-3/8" tbg collar + BTM isolation cups + top isolation cups + 4 ft pup jt + closing sleeve positioner + 2 ea 4 ft pup jts + opening sleeve positioner + 4 ft pup jt. (Overall length = 33.84'). Distance from top of BHA to opening positioner = 5.87. Distance from top of BHA to closing positioner = 16.96'. Spacing between opening and closing positioners = 11.05.

NOTE: Btm isolation cups are facing down and top isolation cups are facing up (see sketch).

Opened PC #14 at 3832' and PC #13 at 3960'. Set down at 3996' with BHA. Unable to get below 3996' with BHA. POOH with tbg and closed PC #13 at 3960'. NU wellhead Zone 8 (PC #14) open to the casing and Zone 1 (PC #1) open to the tubing. End of tubing at 3974'. Hooked up pressure recorder with chart. Left well shut-in overnight. SDON.

2-13-88

0730 - 18 hr SITP = 140 psig (Zone #1)
18 hr SICP = 124 psig (Zone #8).
MIRU NOWSCO coiled tubing unit. NOWSCO air compressor froze up. Thawed out same. Started RIH with coiled tbg at 10:25 a.m. Started air at 1800' with 900 psig initial pump pressure. RIH with coiled tbg at a very slow rate from 2000' to 4000' to allow time to clean sand off of the coiled tubing prior to RIH - sand on coiled tbg was from NOWSCO's previous cleanout job on another well.

Did not tag any sand bridges while RIH. Tagged PBTD with coiled tbg at 6008'. Picked up 2 ft off bottom and circulated the hole with air and soap at 300 scf/ minute for 70 minutes.

NOTE: Foam concentrated with water and soap. A total of 5 bbls was pumped.

Circulated slugs of foam to surface with a trace of sand. Started POOH with coiled tbg at 2:25 p.m. Continued pumping air at 300 scf/min. while POOH. Out of the hole with coiled tbg at 4:00 p.m. Detail of coiled tubing run at follows:

TIME	COILED TBG DEPTH (ft)	RUNNING WEIGHT (lbs)	PUMP PRESSURE (psig)	REMARKS
9:30 am	0	0	0	Thawing out air compressor.
10:25	0	0	0	Start RIH with C.T.
10:40	1800	500	900	Start air only @ 300 scf/min.
11:00	2800	750	900	Cleaning sand off C.T. from previous job. Slow (10 ft/min).
11:30	3250	950	900	Cleaning C.T.
11:45	3420	1250	900	Cleaning C.T.
12:20 pm	3800	1450	1050	Start soap.
12:30	4250	1500	1600	Did not tag any sand in low spot of wellbore.
1:00	5550	1000	1300	Stop soap.
1:02	5650	800	1250	Light mist to surface.
1:07	5885	650	1250	
1:10	5960	500	1200	Circ foam slug to surface w/trace of sand.
1:15	6008	TD	1200	Tagged PBTD. Pumped remaining 4 bbls of soap & water w/air.
2:15	6006	TD	1100	Circ on bottom
2:25	6006	3000	1050	Start POOH w/C.T. Light mist w/slugging foam.
2:35	5500	2800	1050	POOH @ 40-50 ft/min. Slugging.
3:00	4500	2650	1000	Slugging foam to surface.
3:10	4100	2500	1000	Circ sand and foam to surface.
3:35	2500	1500	1000	Circ air/mist to surface
3:40	1500	1250	1000	" " " " "
4:00	0	0	0	Shut down.

2-13-88 (continued)

2:00 - 6:30 pm RD NOWSCO coiled tbg unit. ND wellhead and TIH with tbg. Tagged sand with isolation cups at 3996'. Unable to go below 3996' with BHA. POOH w/tbg to 3974'. NU wellhead. Left well venting to atmosphere. SDON.

2-14-88

8:00 am-1:30 pm Re-spotted Pool Rig. ND wellhead. TOOH w/tbg and BHA. Closed PC #14 while TOOH. Found bottom isolation cups packed with frac sand. Cleaned cups. Found them to be in good condition.

1:30 - 6:00 pm — TIH w/160 jts tbg to 5210' to check sand fill and hole conditions from Zone 8 to Zone 4. Tripped tbg past low spot in the wellbore around 3996' with no problem. NOTE: Appears to be only a small amount of sand around 3996' which packs around the bottom isolation cups. Started out of the hole with the tbg. Pulled 20 jts and SDON. Zone 1 (PC #1 at 5746') is the only zone open to the wellbore. Left well venting overnight.

2-15-88

7:00 am-12 N — Finished TOOH w/tbg. PU BHA (see detail on 2-12-88) and TIH on 115 jts 2-3/8" tbg. End of tubing at 3778'. (218 ft above low spot at 3996' and 54 ft above top port collar #14 at 3832'). NU wellhead. Shut-in the well (Zone 1) at 12:00 noon. Shut down. Ordered out coiled tubing unit and nitrogen truck. Coiled tubing unit will not be available until 2/17/88.

2-16-88 — Shut down. Waiting on NOWSCO coiled tbg unit.

BDM-DOE-RET #1

2/17/88 Shut down. Waiting on NOWSCO coiled tubing unit.

2/18/88

10:00 am - 11:00 am SITP = 165 PSIG (Zone #1). Location and lease road are very muddy. Pulled NOWSCO on location with a dozer.

11:00 am - 12:30 pm RU NOWSCO to run 1" coiled tubing inside the 2 3/8" tbg set at 3778'. RIH with coiled tubing to 1400'. Found numerous holes in the coiled tubing due to acid, which was left in the coiled tbg from the day before. RD NOWSCO coiled tubing unit and nitrogen truck. Hooked up Zone #1 to vent gas through the seperator with 55 PSIG back pressure. Released the Pool rig crew. Shut down at 3:00 p.m. Waiting on NOWSCO to replace the bad coiled tubing.

2/25/88

8:00 am - 3:30 pm Zone #1 flowing through the test meter with 55 PSIG FTP. Uncorrected gas rate = 55 PSIG x 30" = 40 MCFPD. RU NOWSCO coiled tubing unit and nitrogen truck. RIH with coiled tubing as follows:

	COILED TUBING				
TIME	DEPTH (FT)	PRESSURE (PSIG)	WEIGHT (LBS)	N2 RATE (SCFPM)	REMARKS
9:30 am	0	0	0	0	Start RIH
9:52 am	3100	0	1400	0	
10:18 am	3500	1050	1200	700	Start Pumping N2 Down C.T.
10:24 am	3700	1000	1200	700	Pumped 2 Bbl Foam slug - 3200 PSI Max
10:27 am	3800	2150	1250	1000	Increased N2 Rate to 1000 SCF/Min.
10:47 am	4500	2200	1000	1000	Finished washing thru low spot in csg.
10:58 am	4900	1600	0	700	Pumped 2nd - 2 Bbl foam slug-3600 PSI max. Circ. water to surface. No foam.
11:03 am	5100	2400	0-250	1000	Increased N2 rate to 1000 SCF/Min.

2/25/88 (cont'd)

11:35 am	5700	1950	Pushing	1000	Reduced N2 rate to 600 SCF/min.
11:43 am	5750	1150	Pushing	600	Pumped 9 Bbl Foam slug - Set down at 5750'. Increased N2 rate to 200 SCF/min.
11:55 am	5780	3300	0	2000	Washing thru sand bridge.
12:05 pm	5785	3600	0	2200	Increased N2 rate to 2200 SCF/min. Circ light foam and water to surface. No sand.
12:20 pm	5785	0	0	0	NOWSCO - out of N2 - switch to air.
12:27 pm	5919	800	1250	(air)300	Washed past bridge. RIH with C.T.
12:40 pm	6008	1050	0	300	Tagged PBTD w/ C.T. Circ. air and foam to surface.
12:45 pm	6008	1050	0	300	Start POOH w/ C.T. to 4000' @ 100 ft/min.
1:00 pm	4000	1000	250	300	RIH w/ C.T. Back to PBTD.
1:35 pm	5600	950	250	300	Circ. Foam slugs to surface. No sand
2:00 pm	6008	950	0	300	Circ. w/air w/ C.T. at PBTD.
2:15 pm	6000	950	-	300	POOH w/C.T. at 100 ft/min.
2:33 pm	3830	950	2600	300	Reduce C.T. speed to 50-60 ft/min.
3:30 pm	0	0	0	0	Out of the hole w/C.T.

NOTE: There was never any appreciable amount of sand circulated to surface while circulating with nitrogen or air. Recovered only 2-3 Bbls of the 13 Bbls fluid which was pumped. Concluded that the isolation cups on the 2 3/8" tubing failed and/or we were pumping into the formation.

2/25/88 (cont'd)

3:30 pm - 6:30 pm RD NOWSCO. ND the wellhead and continued TIH with 2 3/8" tubing which was set at 3778'. TIH with tubing and tagged port collar #14 at 3832' with the isolation cups (164 ft higher than before). Unable to work tubing past 3832'. TOOH with tubing and LD the BHA. Swabbed water, foam, and sand while TOOH with tubing. Found sand packed on top of the isolation cups thus indicating that the cups failed while circulating with the coiled tubing and nitrogen. SDON.

2/26/88

7:00 am - 1:00 pm RIH with 1 jt 2 3/8" tubing plus closing tool on 2 3/8" tubing. Unable to get below port collar #3 at 5464' with the closing tool. NU stripping head to attempt to wash the sand off of port collar #3.

1:00 pm - 7:00 pm RU Pool Foam Air unit to reverse circulate the hole thus attempting to wash the sand out of the 2 3/8" x 4 1/2 " annulus and port collars and up the 2 3/8" tubing. Circulated with foam as follows:

TIME	SURFACE CASING PRESSURE (PSIG)	AIR RATE (SCFPM)	SOAP RATE (GPM)	REMARKS
1:30 pm	50	500	0	Loading the hole with air while reciprocating the pipe thru the stripping head
1:45 pm	125	500	0	Working pipe. Unable to get below 5464'
2:00 pm	125	500	4	Start soap
2:50 pm	150	500	8	Increase soap
3:20 pm	550	500	8	Foam to surf. Unable to get below 5464'
3:30 pm	575	500	8	Foam and sand to surface
4:30 pm	550	500	8	Circ. good foam w/ sand
5:00 pm	SD	0	0	Shut down. Clutch burned out on foam air unit

Foam air unit broke down at 5:00 pm. Unable to flush the hole with air only. Vented the annulus pressure off through the tubing so as to avoid circulating any sand back into the annulus. RD the foam air unit. ND the stripping head. Note: Unable to get below 5464' with the closing tool. Prepared to TOOH. SDON at 7:00 pm.

2/27/88

7:30 am - 4:00 pm TOOH with the tubing and closing tool. PU new BHA and TIH. New BHA consists of: (BTM to TOP) 2 3/8" tbg collar + 1 jt 2 3/8" tbg + closing tool + 4 ft pup jt + 4 ft pup jt + opening tool + 4 ft pup jt + bottom isolation cups + top isolation cups + 4 ft pup jt. Overall length of the BHA is 66.40'. Note: Baker Service Tools replaced the worn cups on the isolation tool with new cups. TIH with the BHA past the low area in the casing with no problems. Opened zones #8, #6, #5 and #4 while TIH. Landed the tubing at 5211' (EOT) with zones #8, #6, #5 and #4 isolated in the 2 3/8" x 4 1/2" annulus and zone #1 isolated in the 2 3/8" tubing. Closing tool is at 5176' and the opening tool is at 5165'. The bottom of the isolation cups is at 5158' and the top of the cups is at 5151'. The following table summarizes the status of all port collars and zones in the well:

ZONE	PC#	DEPTH	STATUS
8	14	3832	open
8	13	3960	open
7	12	4147	closed
6	11	4291	open
5	10	4383	open
5	9	4595	open
5	8	4894	open
4	7	5038	open
4	6	5129	closed
3	5	5229	closed
3	4	5319	closed
2	3	5464	closed
2	2	5555	closed
1	1	5746	open

NU wellhead. Left well venting to the stock tank while metering both the tubing and casing pressures and flowrates. Shut down.

APPENDIX E

SUPPORTING MATERIAL AND PROCEDURES FOR STIMULATION NO. 4
IN ZONES 2-3 AND 4 CONSISTING OF 138,000 GALLONS OF NITROGEN FOAM
AND 225,000 POUNDS OF 20/40 MESH SAND

E-1 Log of Field Operations During Frac Job and Well Clean-Up Operations

E-2 Report on Frac Operations by Operator (NOWSCO)

APPENDIX E-1
FRAC JOB ON ZONES 2-3 & 4 - FRAC AND CLEAN UP

BDM - DOE - RET #1

5/23/88
8:00 am - 8:00 pm

Pool Well Service on location. Zone #1 flowing down pipeline through both tubing and casing. All remaining zones are closed. Blew down the well to atmosphere. ND Wellhead and POOH w/ tubing (only 4 jts of 2-3/8" tubing were in the hole). PU Baker #43A wireline set retrievable bridge plug adapted with a size #10 Model "J" Hydro setting tool and TIH on 173 jts 2-3/8" tubing. RU NOWSCO and pressured up on tubing to set the RBP as follows:

TIME	TP (PSI)	N_2 RATE (SCFPM)	HOOK WEIGHT (LBS)	REMARKS
12:22 pm	0	650	17,500	Start N_2
12:30 pm	500	650	17,500	Gas still venting
12:35 pm	750	650	17,500	
12:40 pm	950	650	17,000	
12:42 pm	1075	1000	15,000	RBP SET. No gas flow out annulus. Increased rate.
12:48 pm	1550	1000	12,500	
12:55 pm	2000	2000	12,000	Increased rate
1:00 pm	3000	2000	10,000	
1:08 pm	4000	1000	8,000	Decreased rate
1:14 pm	4500	950	7,500	Decreased rate
1:20 pm	5000	950	7,000	

Shut down N_2 with 5000 psi on the tubing. (Max. Allow. pump pressure for NOWSCO N_2 pump truck.) Picked up on tubing 2000 lbs above string weight while holding 5000 psi pressure on tubing and sheared off the RBP. Tubing and casing equalized when the tool sheared and the N_2 bled off through the 2-3/8" x 4½" annulus. Released all pressure off the tubing and RD NOWSCO. Re-tagged RBP with 5000 lbs set down weight. RBP set at 5645' (center of rubber elements) TOOH w/ tbg. and LD Model "J" setting tool. PU Halliburton's opening tool positioner + 1 jt 2-3/8" tbg. + 2' perforated sub and TIH on 2 3/8" tbg. Opened port collars #2 thru #9. SDON.

5/24/88
8:00 am - 3:00 pm

Continued TOOH and opened PC #10 thru #14. LD opening tool and PU closing tool and TIH. Closed PC #7 thru #14. Left PC #2 thru #6 open for the frac job. TOOH. Replaced 4½" DEMCO frac valve with a rental 4½" DEMCO frac valve (NOWSCO). SDON.

5/25/88
8:00 am -

RU NOWSCO and fracture stimulated zones 2, 3, and 4 down 4½" casing as follows:

5/25/88 (cont)

No RA material in pad or flush. Total CO_2= 20 tons. Total N_2= 1,061,151 SCF. Foam additives as follows:

1 GPT Clay std CSA-5, 5#/1000 gal Iron Stab 600, 5 GPT SFII Foamer, 10#/1000 gal Gel, 1 GPT Breaker F, ½ GPT Buffer 5C, 2% KCL. RD NOWSCO and NU flowlines. Opened the well at 12:45 pm and flowed as follows:

TIME	FCP (PSI)	CHOKE (in.)	REMARKS
12:45 pm	920	8/64	Open to pit. Blowing N_2.
1:00 pm	870	8/64	
1:15 pm	820	9/64	
1:30 pm	600	16/64	
1:45 pm	420	22/64	Fluid to surface w/ Tr. sand.
2:00 pm	390	32/64	Rec. 20-30 BPH Fluid w/ Tr. sand.
3:00 pm	370	32/64	Tr. sand.
4:00 pm	350	32/64	Sand increasing.
4:30 pm	310	40/64	Rec'd approx. 100 Bbls fluid.
5:00 pm	185	44/64	Sand increasing.
5:15 pm	185	48/64	2" flex hose cut out. Shut-in to change out same.
5:50 pm	410	32/64	Re-open to pit w/ end choke.
6:00 pm	320	32/64	30-40 BPH w/ sand.
7:00 pm	265	32/64	
7:30 pm	250	32/64	End choke cut out. Shut-in. Ordered out smaller end chokes.

Total Fluid Recovered= 160 Bbls. Load left to recover= 499 Bbls. Left well shut-in overnight.
NOTE: RD Pool @ 5:00 pm.

5/26/88

6:30 am Removed flex hose from flowline. Cut and threaded 2" line pipe and hooked up same from wellhead to the pit. Shut down. Waiting on end chokes.

1:45 pm Opened well on ¼" end choke and flowed as follows:

TIME	FCP (PSI)	CHOKE (in.)	REMARKS
1:45 pm	450	1/4	Open to pit.
2:00 pm	370	1/4	Trace sand w/ fluid.
3:00 pm	375	1/4	Trace sand w/ fluid.
4:00 pm	355	1/4	Sand increasing.
5:00 pm	355	1/4	Sand increasing.
5:30 pm	355	1/4	¼" choke cut out. Shut-in.
10:00 pm	380	1/8	Open on 1/8" end choke.
11:00 pm	370	1/8	Trace sand.
5/27/88 12:00 MN	360	1/8	Trace sand w/ fluid.
6:00 am	320	1/8	Sand cleaning up.
10:00 am	290	1/8	Increase choke to ¼".
11:00 am	265	1/4	Trace sand w/ fluid.
12:00 Noon	255	1/4	Cleaning up.
1:00 pm	235	1/4	Clean fluid w/ N_2 and gas.

5/25/88 (cont)

		CLEAN FLUID VOL.(GALS)		FOAM VOL.(GALS)		PUMP RATES			
TIME	CP	STAGE	TOTAL	STAGE	TOTAL	CLEAN FLUID (BPM)	N_2 SCFPM	FOAM BPM	REMARKS
9:45 am		PRESSURE TEST SURFACE EQUIPMENT TO 3000 psi.							
9:53 am	110	0	0	0	0	0	-	0	Start N_2 press. up.
9:55 am	400	0	0	0	0	0	0	0	SD N_2.
9:56 am	400	0	0	0	0	11-15	0	0	Start CO_2 pre-pad.
10:04 am	100	0	0	0	0	-	0	0	SD CO_2.
10:07 am	400	9,600	0	48,000	0	8.0	11,500	40	Start 80Q N_2 foam pad.
10:11 am	1380	-	1,300	-	6,510	7.9	11,300	40	Press. broke.
10:36 am	1330	1,000	9,600	5,000	48,000	8.0	11,730	40	Start ½ ppg.
10:39 am	1270	1,000	10,600	5,000	53,000	8.0	11,660	40	Start 1 ppg.
10:41 am	1250	-	11,300	-	56,500	8.0	11,250	40	
10:42 am	1320	1,000	11,600	5,000	58,000	8.0	11,300	40	Start 1½ ppg.
10:44 am	1320	-	12,400	-	62,000	8.0	11,770	40	
10:45 am	1360	2,000	12,600	10,000	63,000	8.0	11,830	40	Start 2 ppg.
10:51 am	1400	2,000	14,600	10,000	73,000	8.0	11,400	40	Start 2½ ppg.
11:07 am	1400	11,000	16,600	55,000	83,000	8.0	11,600	40	Start 3 ppg.
11:09 am	1410	-	17,300	-	86,500	6.1	8,960	30	Reduce rate due to surface leak.
11:10 am	1170	-	18,000	-	90,000	6.1	8,960	30	
11:17 am	1120	-	22,000	-	110,000	6.0	8,240	30	
11:32 am	1140	-	26,000	-	130,000	6.0	8,450	30	
11:39 am	1200	0	27,000	0	138,000	0	11,650	22	Start N_2 flush.
11:43 am	1360	0	27,000	0	138,000	0	0	0	Shut down.

ISIP= 1150# 5 min.= 1130# 10 min.= 1090# 15 min.= 1090#
Max TP= 1410# @ 40 BPM Avg. TP= 1350# @ 40 BPM
Load to recover= 657 Bbls. Total Foam= 138,000 gals.
Total Sand= 225,000# 20/40 Mesh. Tagged Sand Laden Foam w/ 40 millicurries of liquid Scandium 46.

5/27/88 (cont)

Installed pressure recorder on casing and left well flowing to the pit on a ¼" end choke overnight. Recovered 9 Bbls. (est) load water last 24 hrs. Cum Load Recovered= 169 Bbls. Load left to recover= 490 Bbls.

6/14/88

8:00 am - 9:00 am — Pool Well Service on location. Zones #2, #3, and #4 are flowing up the 4½"casing through open port collars #2, #3, #4, #5, and #6 at 5555', 5464', 5319', 5229', and 5129' respectively. Venting all gas to atmosphere through the test meter. Gas rate = 44 mcfpd (uncorrected) with 50 psig flowing pressure. (2" x 5/8" plate, 5" diff., 50# LP) Blew down the well to atmosphere and ND the wellhead.

9:00 am - 11:45 am — PU Baker Washerover Type Retrieving Head and TIH on 2-3/8" tbg. Stuck tool at 3640 ft. Unable to move up or down. RU stripping head and Pool Foam Air unit.

11:45 am - 8:00 pm — Pumped down the 2-3/8" tbg with foam air at a rate of 500 scf/min w/ 4 gpm soap. Worked pipe free. Circulated water, foam and sand to surface. Washed down through scattered sand from 3640 ft to 3810 ft. Recovering large volumes of 20/40 frac sand. TIH to 4688' w/ no tbg drag. Attempted to pump down tbg with foam air with no success. Max. pump pressure of 950 psig w/ no circulation. POOH w/ tbg (no excess drag) to 4365'. Broke circulation with foam air down tbg with 600 psig max pump pressure. Circulated foam saturated w/ frac sand. Continued pumping until 8:00 pm (2¼ hours). SDON. Recovered an estimated 30 Bbls load water and 5000 lbs frac sand today.

6/15/88

7:00 am - 9:45 pm — Continued pumping down 2-3/8" tbg set at 4365' with foam air at a rate of 500 scf/min with 4 to 5 gpm soap. Circulated out foam saturated with frac sand. SD at 9:15 am and PU Baker's circulating swivel. Switched lines to reverse circulate with foam air. Resumed pumping at 9:50 am. Circulated foam with sand. Stopped pumping liquid (air only) at 11:20 am. Continued pumping air until the well dried up. SD at 11:50 am. TIH w/ tbg and tagged sand at 4721'. PU swivel and washed with foam air from 4721' to 4754'. Recovered foam with sand. Jetted the hole dry with air only and SD pumping at 2:10 pm. TIH w/ tbg and tagged sand at 5080'. PU swivel and washed with foam air from 5080' to 5112'. Recovered foam with sand. Jetted the hole with air and SD pumping at 3:40 pm. TIH w/ tbg and tagged sand at 5275'. Washed with foam air from 5275' to 5309'. SD at 4:20 pm. TIH w/ tbg to 5600'. Did not set down on sand bridge; however, experienced excess drag while tripping pipe. PU swivel and washed from 5600' to 5635' with foam air. SD pumping at 6:20 pm. TIH w/ tbg and tagged sand fill

6/15/88 (cont)

on top of RBP (set @ 5645') at 5640'. PU swivel and washed from 5640' to 5645'. Unable to latch RBP with retrieving tool. PU on tbg 5 ft. Rotated tbg two(2) complete revolutions with power tongs (at surface) and worked 1/4 turn downhole. Caught RBP with retrieving tool and opened the RBP by-pass. Continued circulating through the by-pass with foam air for ½ hour. No increase in gas blow was seen. PU on tool and released RBP with 5000# overpull. Reverse circulated foam (with sand) and gas to surface for one(1) hour. Circulated with air only for ½ hour. Started TOOH with RBP at 8:30 pm. Pulled 6 jts and RBP hung up with bottom of RBP at 5448' (16 ft above PC #3 at 5464'). Unable to go up or down. While working the pipe, the well kicked off up the tubing blowing sand and foam. Hooked up flowlines to the tubing and shut down overnight. Left well blowing to the pit overnight. Recovered 35 Bbls load water and 7,000 lbs frac sand today (est.).

6/16/88

7:00 am - 8:45 pm

Well still blowing light mist up the tubing. Tubing still stuck at 5448'. Reverse circulated with foam air for 1¼ hours. Unable to circulate foam to surface with a maximum pump pressure of 150 psi at 500 scfpm air with 2½ gpm soap. Pumped down tubing with foam air and tubing pressured up to 800 psi with no leak off. Tubing plugged with sand. Bled pressure to 200 psi in order to surge the sand out of the tubing with no success. Surged the tubing 3 additional times with only a trace of sand and foam to surface. Installed Baker's rotating swivel and worked the pipe while pumping down the tubing. Pipe came free. Circulated conventionally with foam air. Had foam and sand to surface after 1 hour. Recovered large amounts of sand while circulating. After pumping for 4 hours, the sand concentration was reduced to a trace. Shut down foam air unit and started TOOH with RBP. Pulled 4 joints and RBP hung up at 5300'. Worked same free and continued TOOH. Pulled 36 joints and shut down due to the well flowing large volumes of sand with traces of shale up the tubing. PU swivel and reverse circulated with foam air for 2 hours. Unable to clean out the well due to the formation giving up frac sand. Shut down foam air and continued TOOH. The well continued to blow foam with sand while TOOH. (The rig crew wore protective goggles during the trip.) Recovered all tools. NU the wellhead and flowed zones 1, 2, 3, and 4 up the casing overnight (to the pit). SDON. Recovered 15 Bbls load water and 4,000 lbs frac sand today (est.).

6/17/88
7:00 am - 11:45 pm

RD foam air unit. PU 2-3/8" tapped bull plug, 2 ft perforated sub, 2 jts 2-3/8" tbg, 2 ft perforated sub and TIH on 2-3/8" tbg. Tagged sand bridge at 3725'. Unable to knock thru the bridge with the tbg. Called foam air unit back to the location and RU same. Pumped conventionally with air at 500 scfpm while working tbg. Washed through a sand bridge from 3725' to 3740'. Continued TIH with tbg and tagged a sand bridge at 5720'. Washed conventionally with foam air from 5720' to 5735' (scattered). Hit a solid sand bridge at 5735'. Washing at a rate of 10 minutes/foot. Shut down foam air unit and packed off the wellhead. Top perforated sub at 5665' to 5667'. Bottom perforated sub at 5732' to 5734'. End of tubing at 5735'. RU Dowell Schlumberger and pumped down tbg with nitrogen at a rate of 500 to 2000 scfpm in order to clear the tubing of any sand. SD. RU Atlas wireline with lubricator. Continued pumping nitrogen at a rate of 500 scfpm for 5 minutes. Started RIH with spectra gamma ray tool on 7/32" cable while pumping nitrogen at 500 scfpm. Lost tool weight at 4044'. Increased N_2 rate to 1200 scfpm. (max. rate required to pump tools to the end of the tubing.) Tied in wireline to steel line measurement (i.e. 2 foot perforated sub in the tbg string). Started logging at 8:00 pm at a rate of 10-15 fpm. Logged up to 3700 ft. Finished logging at 11:00 pm. POOH with wireline and RD Atlas and Dowell. Shut down at 11:45 pm. Left well SION. Recovered 5 Bbls load water and 500 lbs frac sand today (est.).

6/18/88
7:00 am - 4:00 pm

ONSITP= 100#. ONSICP= 100#. Opened the well to the pit and blew down same. ND wellhead and started out at the hole with the tbg. Pulled 15 ft and stuck tbg at 5720'. PU swivel and circulated conventionally with air at a rate of 500 scfpm. Worked pipe 3,000 to 5,000 lbs above string weight and freed same. Continued circulating the hole with air for 2 hours while working the pipe. TOOH with tbg to 3098'. NU wellhead. Tubing left in the hole: 2-3/8" bull plug, 2 foot perforated sub, 2 jts 2-3/8" tbg, 2 foot perforated sub, 95 jts 2-3/8" tbg. End of tubing at 3098'. Bottom perforated sub at 3095' to 3097'. Top perforated sub at 3028' to 3030'. RD foam air unit. RD Pool Well Service. Left well shut-in for build up. SD at 4:00 pm. Recovered 2 Bbls load water and 200 lbs frac sand today (est.).

APPENDIX E-2
REPORT ON FRAC OPERATIONS BY OPERATOR (NOWSCO)

NOWSCO Well Service
950 GREENTREE ROAD • PITTSBURGH, PA 15220
PHONE (412) 937-1411 • FAX (412) 937-1405

June 1, 1988

Mr. Bill Overbey
BDM Corporation
1199 Van Voorhis Rd., Suite 4
Morgantown, WV 26505

Dear Bill,

Please find attached a post job report for the R.E.T. #1 well we just fractured for you. I hope you will find it useful in designing future treatments.

I would also like to take this opportunity to thank you again for awarding the treatment to NOWSCO Well Services.

Please feel free to call me at any time should you need clarification of this report.

Sincerely,

Tom Udick

TABLE OF CONTENTS

1. GENERAL OBJECTIVES

SIMPLY STATED, THE OBJECTIVE OF THE TREATMENT WAS TO SUCCESSFULLY FRACTURE THE FORMATION USING THE FOLLOWING FLUIDS/GASES AND THEIR RESPECTIVE VOLUMES:

20 TON	CO2 PREPAD
48,000 GAL	80 QUALITY FOAM PAD
90,000 GAL	80 QUALITY SAND LADEN FLUID

THE FOAM PAD WAS NOT GELLED, WHILE THE SAND LADEN FLUID CONTAINED APPROXIMATELY 15#/1,000 GALLONS GELLING AGENT.

THE TOTAL AMOUNT OF SAND TO BE PLACED WITHIN THE CREATED FRACTURE WAS 225,000 LBS 20/40 MESH OTTAWA SAND.

2. MATERIAL REQUIREMENTS

THE FOLLOWING MATERIALS WERE REQUIRED TO PERFORM THE TREATMENT:

EQUIPMENT		MATERIALS		
1	BLENDER	225,000	LBS	20/40 SAND
1	CO2 PUMPER	4,700	LBS	KCl SALT
1	H20 PUMPER	27.6	GAL	CSA-5 CLAY CONTROL
2	HV N2 PUMPERS	27.6	LBS	BREAKER F
1	CO2 TRANSFER PUMP	138	LBS	IS-600 Fe CONTROL
1	SAND SLIDE	138	GAL	SF-2 FOAMER
4	SAND TRUCKS	276	LBS	LSR1NB GELLING AGENT
1	CHEMICAL TRUCK	14	GAL	NOWPHIX 5L BUFFER
3	N2 TRANSPORTS	20	TON	CO2
1	DENSIOMETER	1,029,222	SCF	NITROGEN
1	N2 FLOWMETER			
1	CO2 TRANSPORT			
1	FRAC VALVE			

3. QUALITY CONTROL

A. FOAM QUALITY

THE TREATMENT WAS DESIGNED TO HAVE A CONSTANT GAS TO LIQUID RATIO RATHER THAN A CONSTANT BOTTOM HOLE RATE. THE REASONS FOR THIS WERE:

1. THE NITROGEN UNITS COULD ESTABLISH THEIR RATE AND MAINTAIN IT MORE EASILY

2. THE WATERSIDE PUMPER COULD BE ADJUSTED EASILY TO COMPENSATE FOR THE ADDITION OF SAND, WHILE THE BLENDER COULD MAINTAIN A CLEAN FLUID RATE OF 8 BPM

3. THE 4:1 RATIO OF GAS BARRELS TO LIQUID BARRELS WOULD NOT VARY DURING THE TREATMENT

B. NITROGEN RATE

THE NITROGEN RATE WAS RECORDED THROUGHOUT THE TREATMENT USING A HARMONIC NITROGEN FLOWMETER. THE RATE FLUCTUATED BETWEEN 11,000 SCF/MIN TO APPROXIMATELY 12,500 SCF/MIN DURING THE EARLY STAGES OF THE TREATMENT. A GRAPH SHOWING THE NITROGEN RATE VERSUS TIME IS INCLUDED IN THE GRAPH SECTION.

C. SAND CONCENTRATION

THE SAND CONCENTRATION WAS CONTINUOUSLY RECORDED USING A DENSIOMETER. A GRAPH OF THE SAND CONCENTRATION VERSUS TIME IS GIVEN IN THE GRAPH SECTION.

SAND WAS DELIVERED TO THE BLENDER BY SAND TRUCKS. A SAND HOG WAS CONSIDERED, BUT DUE TO THE LOGISTICS AND THE LOCATION OF THE WELL, IT WAS FELT BEST TO USE THE SAND UNITS.

THE EFFECT OF CHANGING SAND UNITS CAN BE SEEN ON THE GRAPH SHOWING SAND CONCENTRATION VERSUS TIME. (THIS GRAPH IS ALSO INCLUDED IN THE GRAPH SECTION.) SEVERAL DEPRESSIONS ARE NOTICEABLE IN THE CURVE WHICH CORRESPONDS TO THE TRUCK CHANGES. ONCE THE SAND UNITS WERE CHANGED OUT, THE CONCENTRATION WAS QUICKLY RECOVERED.

RECOMMENDATIONS FOR FUTURE JOBS WOULD BE TO USE THE SAND HOG (IF POSSIBLE) WHICH COULD FACILITATE A MORE EVEN SAND CONCENTRATION.

3. QUALITY CONTROL (CONTINUED)

D. FLUIDS

THE PH OF THE WATER USED FOR THE TREATMENT WAS APPROXIMATELY 5.0. THE FLUID TEMPERATURE WAS 65 F.

THREE 250 BBL TANKS WERE PLACED ON LOCATION. ALL THREE TANKS WERE PREMIXED WITH KCl SALT, WHILE ONLY TWO OF THE TANKS WERE PREMIXED WITH NOWPHIX 5L BUFFER AND LSR1NB GELLING AGENT.

THE GELL BREAKER, IRON CONTROL FOAMING AGENT AND CLAY STABILIZER WERE ADDED WHILE PUMPING AND NOT PREMIXED.

THE CONCENTRATIONS FOR THE VARIOUS ADDITIVES WERE:

CSA-5 CLAY CONTROL	1/1000 GALS
IS-600 IRON CONTROL	5/1000 GALS
SF-2 FOAMING AGENT	5/1000 GALS
NOWPHIX 5L BUFFER	.5/1000 GALS
BREAKER F GELL BREAKER	1/1000 GALS
LSR1NB GELLING AGENT	13/1000 GALS

A FIELD RHEOMETER WAS NOT USED ON THIS TREATMENT.

4. JOB SUMMARY

THE PROPPANT WAS SUCCESSFULLY INJECTED INTO THE FORMATION USING THE FLUID VOLUMES RECOMMENDED. THE SAND SCHEDULE WAS QUITE AGGRESSIVE IN TERMS OF ATTAINING THE MAXIMUM SAND CONCENTRATION VERY QUICKLY. ALL VOLUMES OF FLUIDS INJECTED WERE AS PER DESIGN.

THE ONLY OPERATIONAL PROBLEM OCCURRED WHEN THE NITROGEN LINE BLEW A SEAL, THUS ALLOWING A GAS LEAK TO DEVELOP. RATHER THAN STOP THE TREATMENT AND CHANCE A SCREEN-OUT, THE DECISION WAS MADE TO CONTINUE THE TREATMENT AT A LOWER INJECTION RATE. THE DOWNHOLE RATE WAS REDUCED TO 30 BPM CLEAN RATE FROM 40 BPM. THE WELLHEAD PRESSURE RESPONDED ACCORDINGLY BY DECREASING APPROXIMATELY 400 PSI.

THE JOB WAS TERMINATED AT 12:04:30 AND TRUCKS WERE OFF LOCATION BY 1:00 P.M.

BDM PUMP SCHEDULE
80 QUALITY N2 FOAM FRAC
225,000 LB 20/40 SAND

STAGE NO.	STAGE CLEAN VOLUME (GALS)	STAGE CLEAN VOLUME (BBLS)	TOTAL CLEAN VOLUME (BBLS)	SURFACE SAND VOLUME (LB/GAL)	DOWNHOLE SAND CONCEN (LB/GAL)	STAGE SAND VOLUME (LBS)	TOTAL SAND GONE (LBS)	STAGE DIRTY VOLUME (BBLS)	TOTAL DIRTY VOLUME (BBLS)	STAGE FOAM VOLUME (GALS)	FLUID NAME	REMARKS	CLEAN WATER RATE (BPM)	DIRTY WATER RATE (BPM)	START STAGE AT CLEAN BBL	END STAGE AT CLEAN BBL NO.
1				0	0	0	0	0	0		CO2 PAD	18-20 BPM	0	0	0	
2	9600	229	229	0	0	0	0	229	229	48000	80 QUALITY FOAM	PAD - UNGELLED FLUID	8.0	8.0	0	229
3	1000	24	253	2.5	0.5	2500	2500	27	256	5000	80 QUALITY FOAM	10 LB BASE GELLED FLUID	8.0	8.9	229	253
4	1000	24	277	5.0	1.0	5000	7500	29	285	5000	80 QUALITY FOAM	10 LB BASE GELLED FLUID	8.0	9.8	253	277
5	1000	24	301	7.5	1.5	7500	15000	32	317	5000	80 QUALITY FOAM	10 LB BASE GELLED FLUID	8.0	10.7	277	301
6	2000	48	349	10.0	2.0	20000	35000	70	387	10000	80 QUALITY FOAM	10 LB BASE GELLED FLUID	8.0	11.6	301	349
7	2000	48	397	12.5	2.5	25000	60000	75	462	10000	80 QUALITY FOAM	10 LB BASE GELLED FLUID	8.0	12.6	349	397
8	11000	262	659	15.0	3.0	165000	225000	441	903	55000	80 QUALITY FOAM	10 LB BASE GELLED FLUID		13.5	397	659
9						DISPLACE TO TOP PERFORATION ONLY											

0-229 CLEAN BBLS - 80 QUALITY N2 FOAM - NO GELL IN BASE FLUID
229-253 CLEAN BBLS - 80 QUALITY N2 FOAM - 10 LB/1000 GEL IN BASE FLUID - 2.5 LB/GL SAND
253-277 CLEAN BBLS - 80 QUALITY N2 FOAM - 10 LB/1000 GEL IN BASE FLUID - 5.0 LB/GL SAND
277-301 CLEAN BBLS - 80 QUALITY N2 FOAM - 10 LB/1000 GEL IN BASE FLUID - 7.5 LB/GL SAND
301-349 CLEAN BBLS - 80 QUALITY N2 FOAM - 10 LB/1000 GEL IN BASE FLUID - 10.0 LB/AL SAND
349-397 CLEAN BBLS - 80 QUALITY N2 FOAM - 10 LB/1000 GEL IN BASE FLUID - 12.5 LB/L SAND
397-659 CLEAN BBLS - 80 QUALITY N2 FOAM - 10 LB/1000 GEL IN BASE FLUID - 15.0 LB/L SAND
659-X CLEAN BBLS - DISPLACEMENT

BDM
PROP/FLUID SCHEDULE

CLEAN BBL MARK	FOAMER/ IS-600 GONE	BREAKER/ CLAY STABILIZER GONE	NITROGEN GONE MSCF	SAND GONE LBS
0	0	0	0	0
24	5	1	25.4	0
48	10	2	50.8	0
72	15	3	76.2	0
96	20	4	101.6	0
120	25	5	127	0
144	30	6	152.4	0
168	35	7	177.8	0
192	40	8	203.2	0
216	45	9	228.6	0
240	50	10	254	1,200
264	55	11	279.4	4,875
288	60	12	304.8	11,079
312	65	13	330.2	19,785
336	70	14	355.6	29,955
360	75	15	381	41,190
384	80	16	406.4	53,790
408	85	17	431.8	68,130
432	90	18	457.2	83,250
456	95	19	482.6	98,370
480	100	20	508	113,490
504	105	21	533.4	128,610
528	110	22	558.8	143,730
552	115	23	584.2	158,850
576	120	24	609.6	173,970
600	125	25	635	189,090
624	130	26	660.4	204,210
648	135	27	685.8	219,330
657	137.5	27.5	696	225,000

CALCULATIONS:

HYDROSTATIC PRESSURE FOR VARIOUS SAND CONCENTRATIONS:

SAND CONCENTRATION (LB/GAL)	ESTIMATED HYDROSTATIC PRESSURE IN 80 QUALITY FOAM
2.5	0.10 PSI/FT
5.0	0.11 PSI/FT
7.5	0.12 PSI/FT
10.0	0.13 PSI/FT
12.5	0.138 PSI/FT
15.0	0.144 PSI/FT

ANTICIPATED WELLHEAD PRESSURES:

PAD STAGE	1810 PSI
2.5 LB/GAL STAGE	1765 PSI
5.0 LB/GAL STAGE	1731 PSI
7.5 LB/GAL STAGE	1697 PSI
10.0 LB/GAL STAGE	1663 PSI
12.5 LB/GAL STAGE	1636 PSI
15.0 LB/GAL STAGE	1616 PSI

TOTAL FRICTION AT 40 BPM WAS EXPECTED TO BE ABOUT 1154 PSI. THIS VALUE IS BELIEVED TO BE INVALID SINCE WELLHEAD PRESSURES WERE CONSIDERABLY LOWER THAN THOSE ANTICIPATED. A COPY OF THE FRICTION CHART IS ALSO INCLUDED IN THE GRAPH SECTION.

5. GRAPHS & PLOTS

TIME	WATER PUMP RATE (BPM)	N2 RATE (SCF/MIN)	PRESSURE (PSI)	SAND (LB/GAL)	EVENT
9:50:00	0	0	0	0	PRESSURE TEST
9:50:30	1	0	3100	0	
9:51:00	0	0	3100	0	
9:51:30	0	0	0	0	OPEN MASTER VALVE
9:52:00	0	0	0	0	
9:52:30	0	0	100	0	
9:53:00	0	0	200	0	
9:53:30	0	200	200	0	START N2-PRESSURE UP WELL
9:54:00	0	400	300	0	
9:54:30	0	600	300	0	
9:55:00	0	700	0	0	
9:55:30	5	500	200	0	START CO2 PAD
9:56:00	11	50	150	0	
9:56:30	12	0	150	0	
9:57:00	12	0	200	0	
9:57:30	11.5	0	250	0	
9:58:00	11	0	0	0	
9:58:30	11	0	0	0	
9:59:00	11	0	0	0	
9:59:30	11	0	0	0	
10:00:00	11	0	0	0	
10:00:30	11	0	0	0	
10:01:00	10.5	0	0	0	
10:01:30	11	0	0	0	
10:02:00	10.5	0	0	0	
10:02:30	10	0	0	0	
10:03:00	10	0	0	0	
10:03:30	10	0	100	0	
10:04:00	8	0	200	0	
10:04:30	0	0	100	0	STOP CO2
10:05:00	0	0	300	0	
10:05:30	2.5	600	700	0	START PAD
10:06:00	1	1300	400	0	
10:06:30	0	200	400	0	STOP PAD-TRUCK THROTTLE STUCK
10:07:00	1	0	400	0	RE-START PAD
10:07:30	8	0	700	0	
10:08:00	8	900	1000	0	
10:08:30	8	1100	1200	0	
10:09:00	8	1100	1200	0	
10:09:30	8	1100	1300	0	
10:10:00	8	1200	1300	0	
10:10:30	8	1100	1300	0	
10:11:00	8	1200	1400	0	
10:11:30	8	1150	1400	0	
10:12:00	8	1100	1400	0	
10:12:30	8	1200	1400	0	
10:13:00	8	1100	1400	0	
10:13:30	8	1100	1400	0	

TIME	WATER PUMP RATE (BPM)	N2 RATE (SCF/MIN)	PRESSURE (PSI)	SAND (LB/GAL)	EVENT
10:14:00	8	1200	1400	0	
10:14:30	8	1200	1400	0	
10:15:00	8	1200	1400	0	
10:15:30	8	1200	1400	0	
10:16:00	8	1250	1400	0	
10:16:30	8	1100	1400	0	
10:17:00	8	1200	1400	0	
10:17:30	8	1200	1400	0	
10:18:00	8	1200	1400	0	
10:18:30	8	1200	1400	0	
10:19:00	8	1150	1400	0	
10:19:30	8	1200	1400	0	
10:20:00	8	1100	1400	0	
10:20:30	8	1200	1400	0	
10:21:00	8	1200	1400	0	
10:21:30	8	1200	1400	0	
10:22:00	8	1250	1400	0	
10:22:30	8	1100	1400	0	
10:23:00	8	1200	1400	0	
10:23:30	8	1200	1350	0	
10:24:00	8	1150	1200	0	
10:24:30	8	1200	1200	0	
10:25:00	8	1200	1200	0	
10:25:30	7	1200	1200	0	
10:26:00	8	1200	1200	0	
10:26:30	8	1200	1200	0	
10:27:00	8	1200	1200	0	
10:27:30	7	1150	1200	0	
10:28:00	8	1250	1200	0	
10:28:30	8	1150	1200	0	
10:29:00	8	1250	1200	0	
10:29:30	8.5	1200	1200	0	
10:30:00	8.5	1200	1200	0	
10:30:30	8.5	1250	1200	0	
10:31:00	8	1200	1200	0	
10:31:30	8.5	1200	1200	0	
10:32:00	8	1200	1200	0	
10:32:30	8	1200	1200	0	
10:33:00	8	1100	1200	0	
10:33:30	8.5	1150	1200	0	
10:34:00	8	1200	1200	0	
10:34:30	8	1150	1200	0	
10:35:00	8	1200	1200	0	
10:35:30	8	1250	1200	0	
10:36:00	8	1200	1200	0	
10:36:30	9	1200	1200	0	
10:37:00	9	1150	1200	1	START 2.5 #/GAL SAND
10:37:30	8.5	1200	1300	4	

TIME	WATER PUMP RATE (BPM)	N2 RATE (SCF/MIN)	PRESSURE (PSI)	SAND (LB/GAL)	EVENT
10:38:00	8	1200	1300	3	
10:38:30	8	1200	1300	4	
10:39:00	8	1200	1300	5	START 5 #/GAL SAND
10:39:30	9	1200	1300	6	
10:40:00	8	1200	1300	6	
10:40:30	8	1200	1300	5	
10:41:00	8	1200	1300	5	
10:41:30	8	1150	1300	5	
10:42:00	8	1150	1300	5	
10:42:30	9	1150	1300	6	START 7.5 #/GAL SAND
10:43:00	8	1200	1300	7	
10:43:30	8	1200	1300	8	
10:44:00	8	1250	1300	8	
10:44:30	8	1300	1350	8	
10:45:00	8	1200	1350	8	START 10 #/GAL SAND
10:45:30	8	1200	1350	8	
10:46:00	8	1200	1350	9	
10:46:30	8.5	1250	1350	11	
10:47:00	8	1200	1400	10	
10:47:30	8	1200	1400	10	
10:48:00	8	1200	1400	11	
10:48:30	8	1200	1400	10	
10:49:00	8.5	1150	1400	11	
10:49:30	8.5	1200	1400	10	
10:50:00	8	1100	1400	10	
10:50:30	8	1150	1400	10.5	
10:51:00	8	1200	1400	11	
10:51:30	8.5	1200	1400	11	START 12.5 #/GAL SAND
10:52:00	8	1200	1450	12	
10:52:30	8	1200	1400	12	
10:53:00	8	1200	1400	12	
10:53:30	8	1150	1400	13	
10:54:00	8	1100	1450	12	
10:54:30	8	1200	1450	12	
10:55:00	8	1150	1450	12	
10:55:30	8	1200	1450	12	
10:56:00	8	1200	1450	12.5	
10:56:30	8	1200	1450	12.5	
10:57:00	8	1200	1450	13	START 15 #/GAL SAND
10:57:30	9	1250	1400	12.5	
10:58:00	9	1200	1400	12	
10:58:30	9	1100	1400	12.5	
10:59:00	7	1200	1350	13	
10:59:30	6.5	1100	1300	13	DECREASE DOWNHOLE RATE-LINE LEAK
11:00:00	6	1000	1300	11	
11:00:30	6	1000	1200	14	
11:01:00	6	900	1200	13	
11:01:30	6	900	1200	15.5	

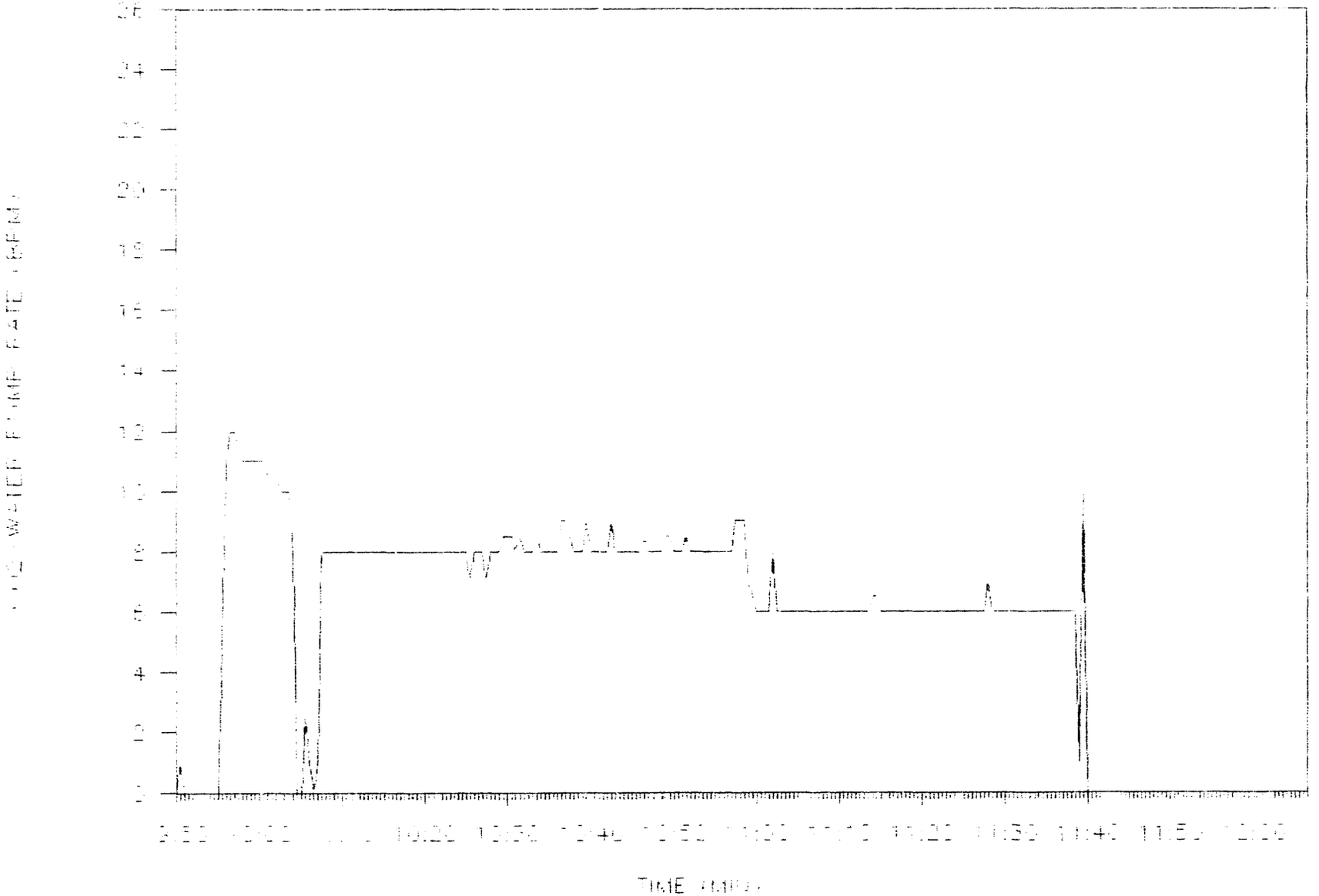
TIME	WATER PUMP RATE (BPM)	N2 RATE (SCF/MIN)	PRESSURE (PSI)	SAND (LB/GAL)	EVENT
11:02:00	8	950	1150	16	
11:02:30	6	900	1150	6	
11:03:00	6	900	1100	11	
11:03:30	6	900	1100	13	
11:04:00	6	900	1100	14	
11:04:30	6	900	1100	14.5	
11:05:00	6	900	1100	15	
11:05:30	6	900	1100	14	
11:06:00	6	900	1100	14	
11:06:30	6	900	1100	14	
11:07:00	6	900	1100	14	
11:07:30	6	900	1100	13.5	
11:08:00	6	900	1100	14	
11:08:30	6	900	1100	15	
11:09:00	6	900	1100	16	
11:09:30	6	850	1100	15	
11:10:00	6	850	1100	15	
11:10:30	6	850	1100	15	
11:11:00	6	900	1100	15.5	
11:11:30	6	900	1100	15.5	
11:12:00	6	850	1100	15.5	
11:12:30	6	800	1100	15	
11:13:00	6	850	1100	15	
11:13:30	6	900	1100	14	
11:14:00	6.5	900	1100	13.5	
11:14:30	6.5	900	1100	10.5	
11:15:00	6	1100	1100	12	
11:15:30	6	1100	1100	14	
11:16:00	6	1150	1150	14	
11:16:30	6	1150	1150	14	
11:17:00	6	1150	1150	15	
11:17:30	6	1150	1150	15	
11:18:00	6	1150	1150	15	
11:18:30	6	1150	1150	15	
11:19:00	6	1150	1150	16	
11:19:30	6	1100	1100	15	
11:20:00	6	1100	1100	15.5	
11:20:30	6	1100	1100	15	
11:21:00	6	1100	1100	14.5	
11:21:30	6	1150	1150	14.5	
11:22:00	6	1150	1150	15.5	
11:22:30	6	1150	1150	16	
11:23:00	6	1150	1150	16	
11:23:30	6	1150	1150	15	
11:24:00	6	1150	1150	16	
11:24:30	6	1150	1150	15	
11:25:00	6	1150	1150	15	
11:25:30	6	1150	1150	15.5	

TIME	WATER PUMP RATE (BPM)	N2 RATE (SCF/MIN)	PRESSURE (PSI)	SAND (LB/GAL)	EVENT
11:26:30	6	1150	1150	15	
11:26:30	6	1150	1150	15.5	
11:27:00	6	1150	1150	15	
11:27:30	6	1150	1150	15	
11:28:00	7	1150	1150	15	
11:28:30	6	1150	1150	8	
11:29:00	6	1100	1100	14	
11:29:30	6	1150	1150	14.5	
11:30:00	6	1150	1150	15	
11:30:30	6	1150	1150	16	
11:31:00	6	1200	1200	15	
11:31:30	6	1150	1150	15	
11:32:00	6	900	1150	14.5	
11:32:30	6	900	1150	15.5	
11:33:00	6	900	1200	15	
11:33:30	6	900	1200	16	
11:34:00	6	850	1200	15	
11:34:30	6	900	1200	14.5	
11:35:00	6	900	1200	15	
11:35:30	6	900	1200	15	
11:36:00	6	900	1200	15	
11:36:30	6	900	1200	14	
11:37:00	6	900	1200	15	
11:37:30	6	850	1200	16	
11:38:00	6	900	1200	15	
11:38:30	6	900	1200	14	
11:39:00	1	850	1200	14	
11:39:30	10	900	1200	14	
11:40:00	0	950	1100	0	STOP SAND-225,000 IN
11:40:30	0	1000	1150	0	START N2 FLUSH
11:41:00	0	1050	1200	0	
11:41:30	0	1200	1300	0	
11:42:00	0	1200	1300	0	
11:42:30	0	1150	1400	0	
11:43:00	0	1200	1200	0	
11:43:30	0	100	1150	0	SHUT DOWN
11:44:00	0	0	550	0	SHUT IN WELL HEAD
11:44:30	0	0	0	0	TO FIX LEAK
11:45:00	0	0	0	0	
11:45:30	0	0	0	0	
11:46:00	0	0	0	0	
11:46:30	0	0	0	0	
11:47:00	0	0	0	0	
11:47:30	0	0	250	0	OPEN WELL HEAD
11:48:00	0	0	1150	0	
11:48:30	0	0	1150	0	
11:49:00	0	0	1100	0	
11:49:30	0	0	1100	0	

TIME	WATER PUMP RATE (BPM)	N2 RATE (SCF/MIN)	PRESSURE (PSI)	SAND (LB/GAL)	EVENT
11:50:00	0	0	1100	0	
11:50:30	0	0	1100	0	
11:51:00	0	0	1100	0	
11:51:30	0	0	1100	0	
11:52:00	0	0	1100	0	
11:52:30	0	0	1100	0	
11:53:00	0	0	1100	0	
11:53:30	0	0	1100	0	
11:54:00	0	0	1100	0	
11:54:30	0	0	1100	0	
11:55:00	0	0	1100	0	
11:55:30	0	0	1100	0	
11:56:00	0	0	1100	0	
11:56:30	0	0	1100	0	
11:57:00	0	0	1100	0	
11:57:30	0	0	1100	0	
11:58:00	0	0	1100	0	
11:58:30	0	0	1100	0	
11:59:00	0	0	1100	0	
11:59:30	0	0	1050	0	
12:00:00	0	0	1050	0	
12:00:30	0	0	1050	0	
12:01:00	0	0	1050	0	
12:01:30	0	0	1050	0	
12:02:00	0	0	1050	0	
12:02:30	0	0	1050	0	
12:03:00	0	0	1050	0	
12:03:30	0	0	1050	0	
12:04:00	0	0	1000	0	
12:04:30	0	0	0	0	SHUT IN WELL-RIG DOWN
12:05:00	0	0	0	0	
12:05:30	0	0	0	0	
12:06:00	0	0	0	0	
12:06:30	0	0	0	0	

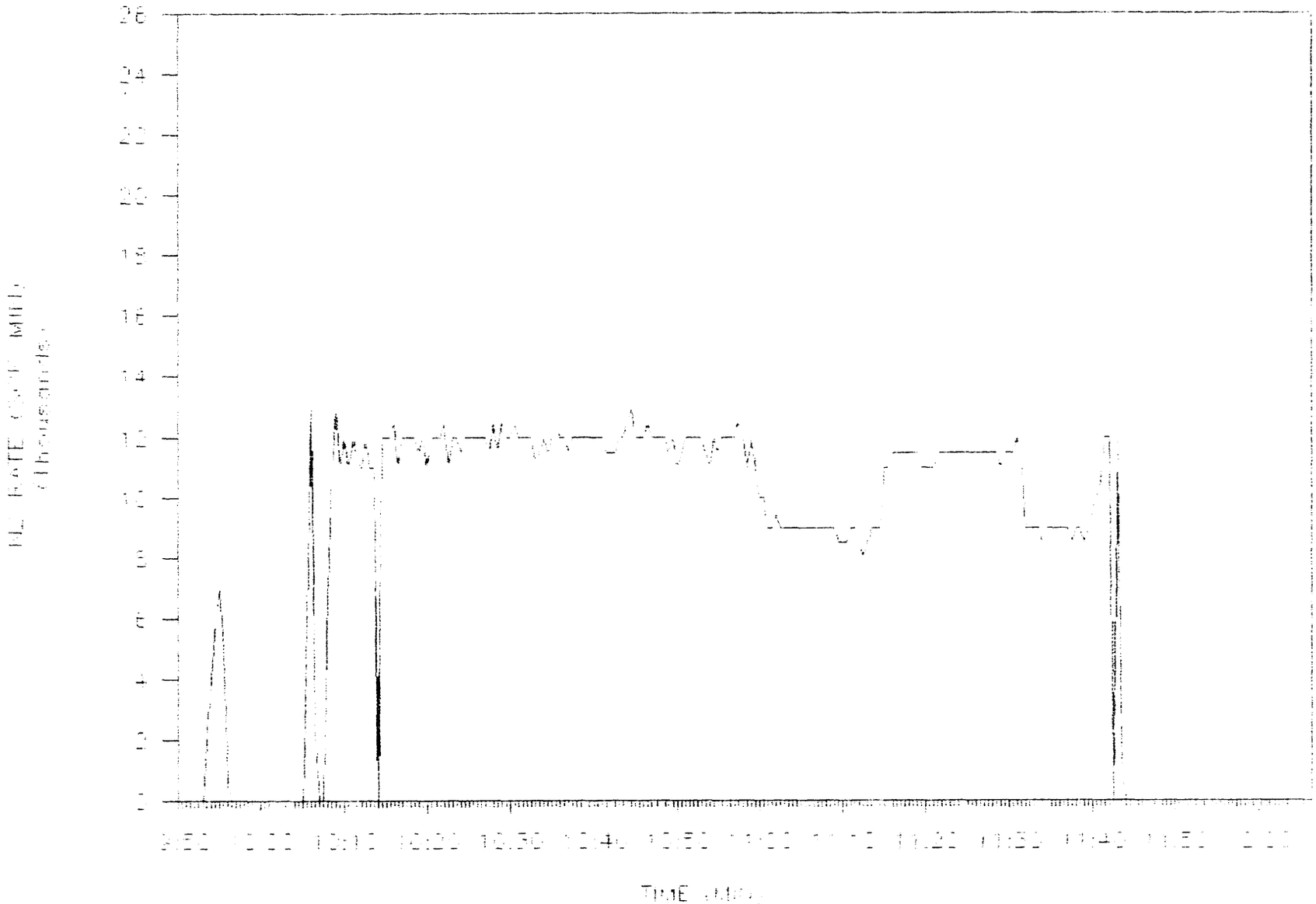
R.E.T. #1

STRIP CHART



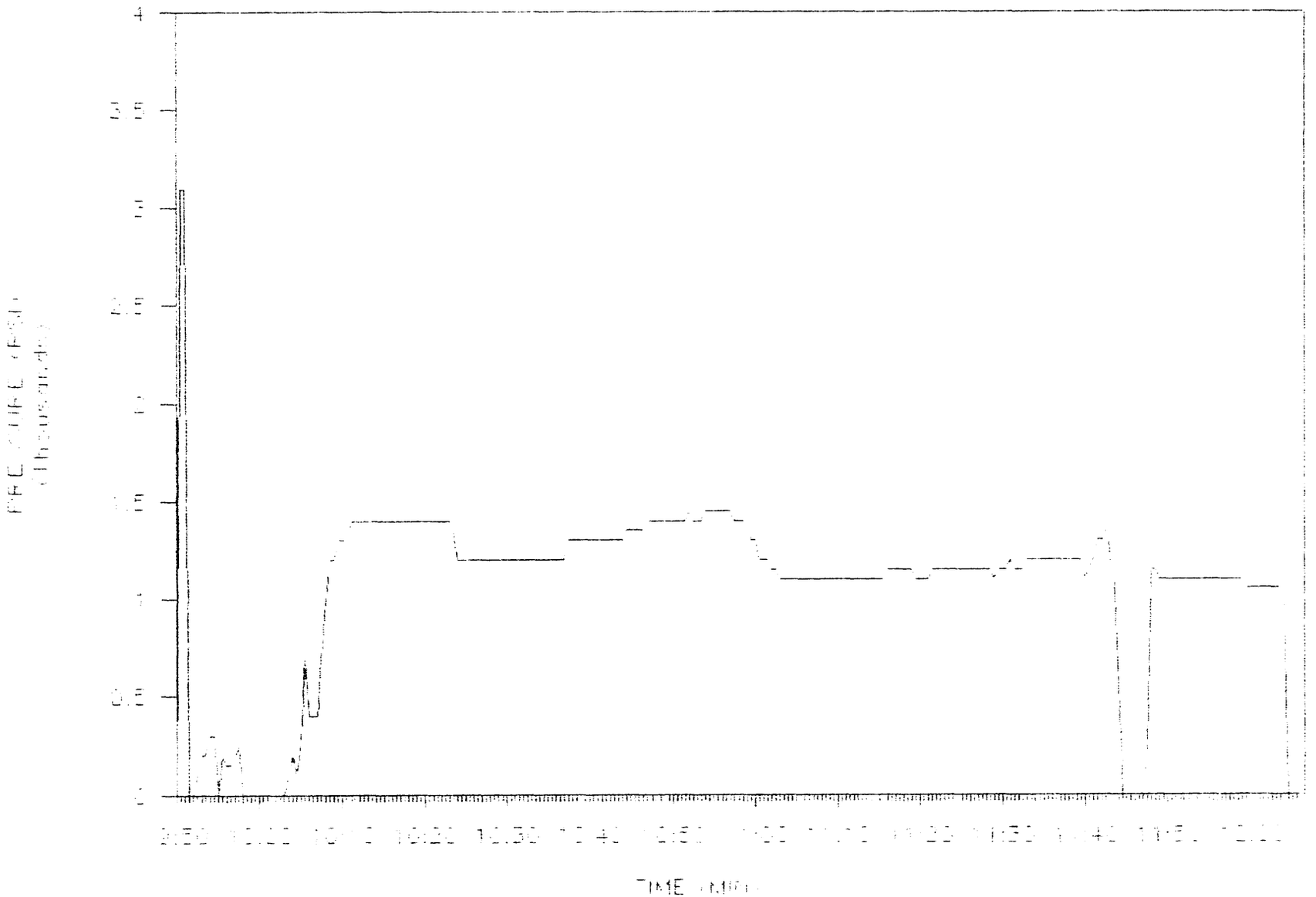
P.E.T. #1

STRIP CHART



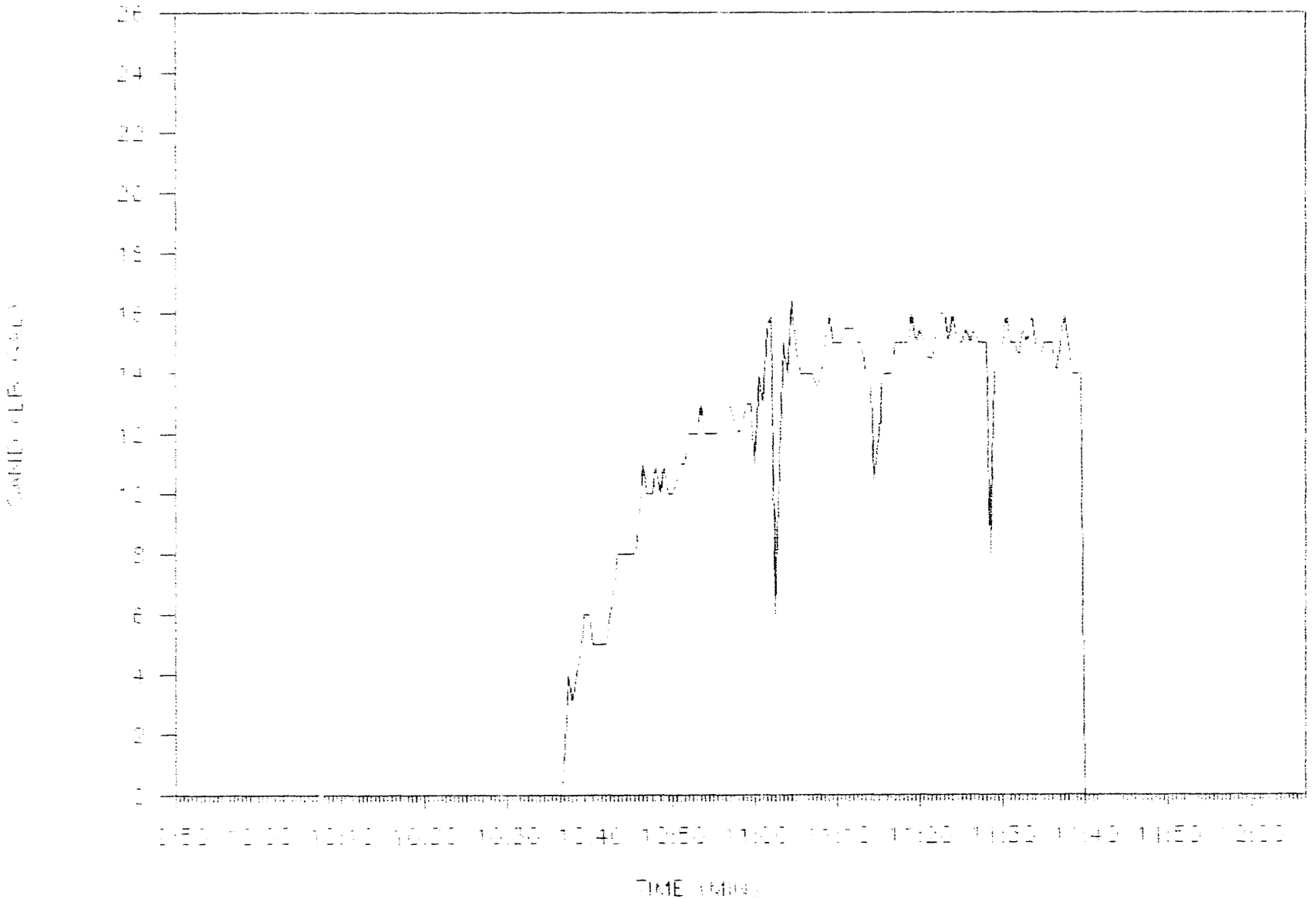
F.E.T. #1

STRIP CHART



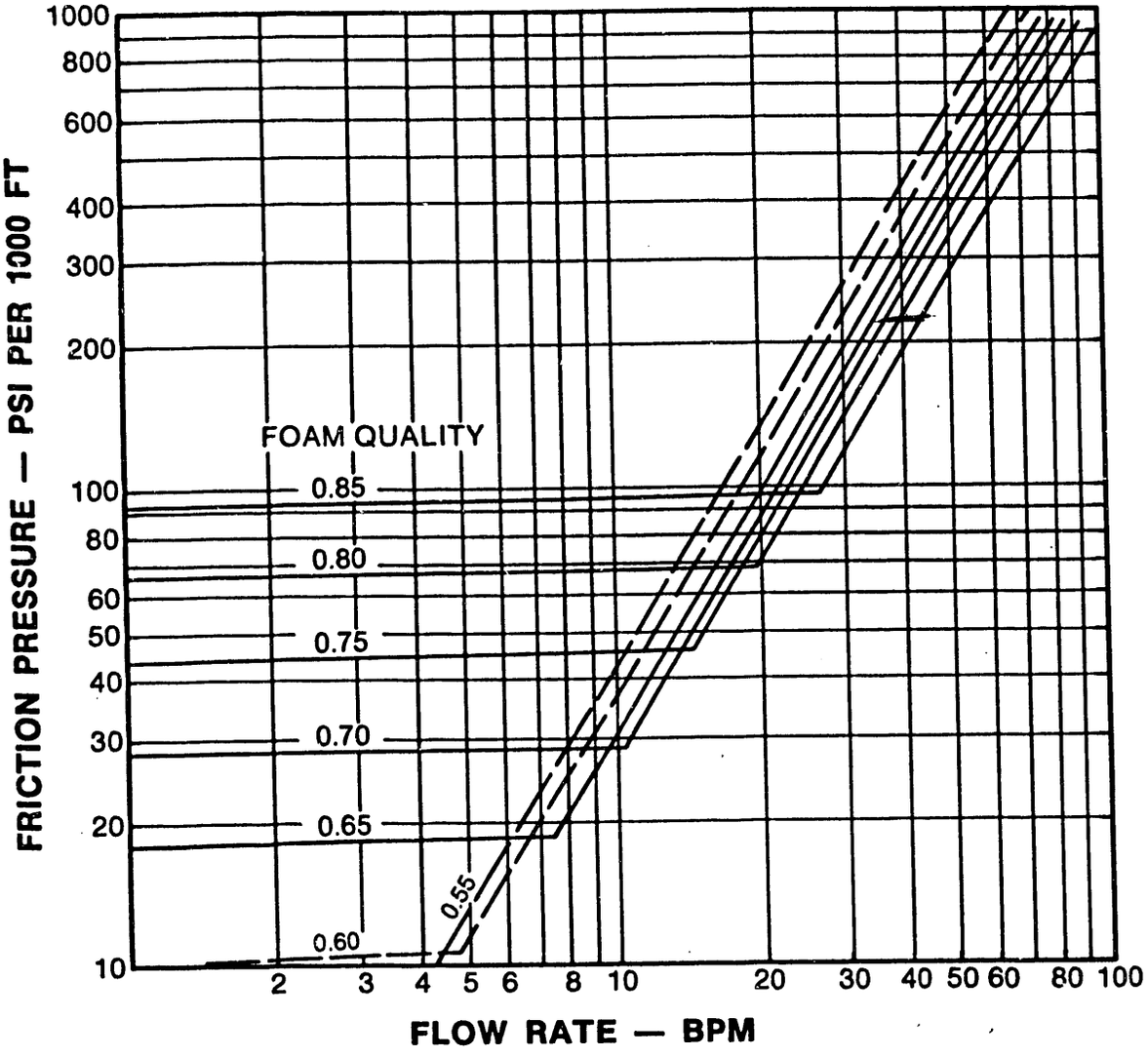
P.E.T. #1

STRIP CHART

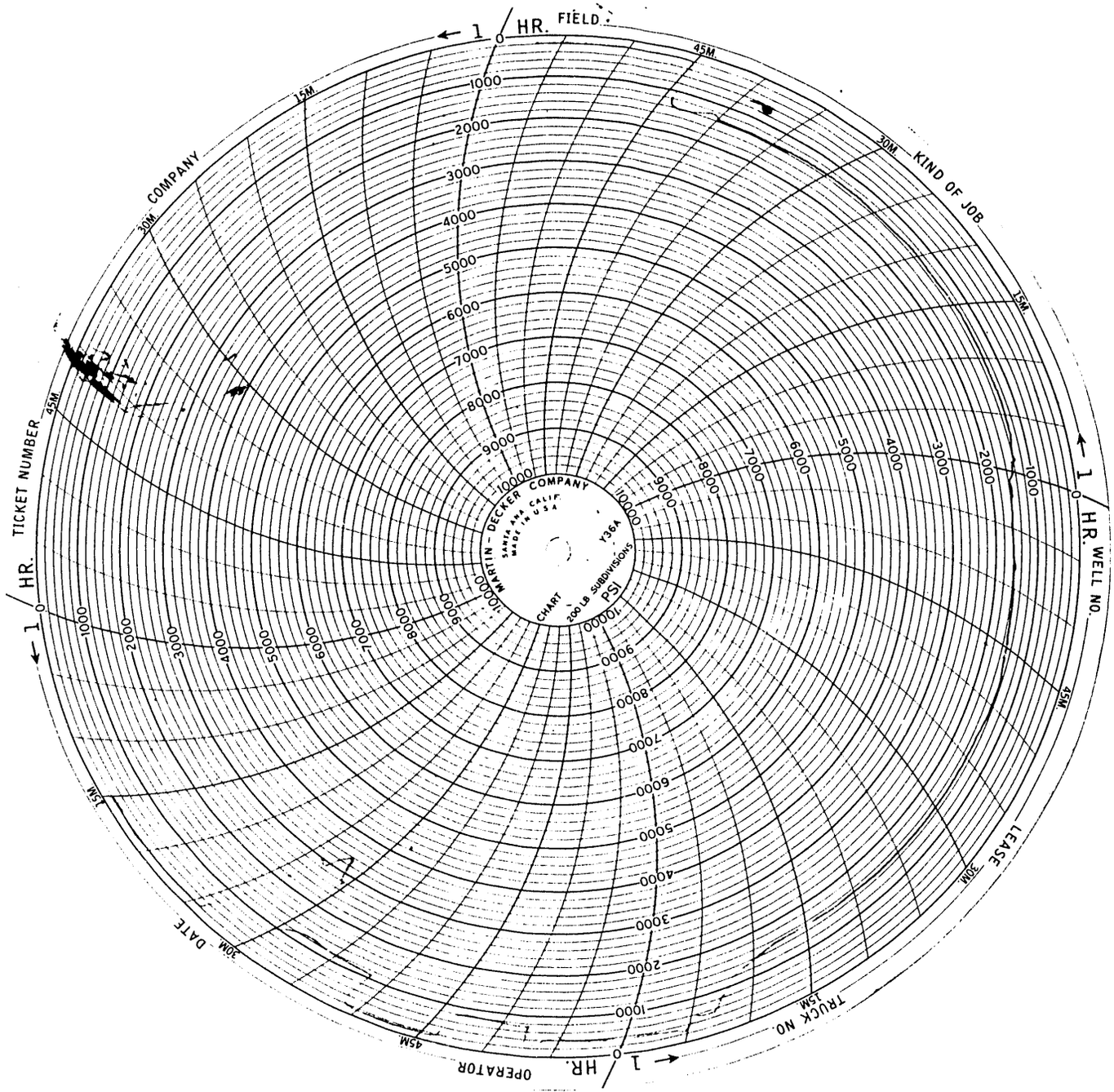


FOAM FRICTION PRESSURE

PIPE DATA: 4½-IN. OD CASING — 11.6 LB PER FT



6. TREATMENT RECORDINGS


FIELD
HR.
1
0
45M
15M
30M
KIND OF JOB
WELL NO.
LEASE
TRUCK NO
OPERATOR
DATE
COMPANY
TICKET NUMBER
MARTIN - DECKER COMPANY
SANTA ANA CALIF.
MADE IN U.S.A.
Y36A
CHART
200 LB SUBDIVISIONS
PSI
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

BDM - RET #1

7. RECOMMENDATIONS

IT IS RECOMMENDED THAT A SMALL BREAKDOWN AND PUMP IN BE DONE BEFORE FRACTURING THE NEXT ZONE. THE REASON FOR THIS RECOMMENDATION IS THAT A HIGHER THAN EXPECTED FRACTURE GRADIENT MAY HAVE BEEN INFLUENCING THE WELLHEAD PRESSURE. THE ISIP AFTER THE TREATMENT WAS 1150 PSI. CALCULATING THE FRACTURE GRADIENT GIVES:

$$\text{ISIP/DEPTH} + \text{HYDROSTATIC} = P_{fg}$$

THEREFORE, 1150/3390 = .34

EVEN IF WE ELIMINATE THE HYDROSTATIC PRESSURE OF THE NITROGEN, THIS NUMBER IS SUBSTANTIALLY HIGHER THAN EXPECTED. PLEASE NOTE, HOWEVER, THAT AN ISIP VALUE TAKEN AT THE END OF A TREATMENT LIKE THIS WILL ALMOST ALWAYS BE HIGHER THAN EXPECTED. PERFORMING THE INITIAL BREAKDOWN TEST MAY HAVE ALLOWED US TO DO REAL TIME PLOTTING OF THE DATA (FOR NOLTE/SMITH LOG-LOG ANALYSIS).

AS STATED BEFORE, A SAND HOG (MOUNTAIN MOVER, ETC.) WOULD BE RECOMMENDED FOR SUBSEQUENT TREATMENTS SHOULD THE SAND VOLUME DICTATE AND THE WEATHER PERMIT IT.

8. TREATMENT REPORT AND FIELD INVOICE

NOWSCO

NOWSCO WELL SERVICE (U.S.) INC.

TREATMENT REPORT
FRACTURING

TYPE OF TREATMENT: Foam Frac - CO_2 Pad	CUSTOMER: B.D.M.	MO. DAY YEAR: 5-25-88
NAME OF WELL: Ted #1	ADDRESS:	SERVICE ORDER: 8487

FORMATION	DEPTH	BAFFLE SIZE	FRAC BALL	CASING	PERF. DEPTH	NO. & SIZE OF PERFS
1. Shale	3390 Wet. Dep			4½	5129 - 5555	
2.				10.5		
3.						
4.						

HORSEPOWER	TOTAL FLUID	TOTAL SAND	BREAKDOWN 1	INST. PRESS 1	BREAKDOWN 2	INST. PRESS 2	BREAKDOWN 3	INST. PRESS 3	BREAKDOWN 4	INST. PRESS 4
	654	22500		1150						

TIME A.M. P.M.	PRESSURE	CUM FLUID	STAGE FLUID	RATE	LBS/GAL	COMMENTS
9:53	110					Start N_2 Pre Pad
9:55	400					Stop
9:55.4	100		112	11-15		Start CO_2
10:04	100					Stop
10:07	400	Foam	229	40		Start Foam Pad
10:36.2	1300	1145	24	40	.5	Start 20/40
10:39.2	1300	1265	24	40	1	Inc 20/40
10:42.2	1300	1385	24	40	1.5	Inc 20/40
10:45.2	1350	1505	48	40	2	Inc 20/40
10:51.2	1400	1745	48	40	2.5	Inc 20/40
11:07.2	1400	1985	262	40-30	3	Inc 20/40
11:09.2	1410	3295	31,929.3	30		Change Rate
11:39.3	1200					Flush
11:43.4	1200					Stop pumps.

R. Todd.

1. CHEMICAL	AMOUNT
Ph. 5	
Temp H_2O - 65	
Gelstructure - 15 lb	
N_2 - 1,029,222	
CSA5 - 27.6 gals	
BACAKEF - 27.6 lbs	
FS60W - 138 lbs	
2. SFZ - 138 gals	
LSRINB - 276 lbs	
Nowplex - 14 gals	
KCL - ~~5247~~ 4701	
CO_2 - 20 ton	
20/40 - 2250. SKS.	
3.	
4.	

B-002 InFORMertic/Anchor Forms & Systems

ACIDIZING / FRACTURING / NITROGEN INVOICE NO. _____

NOWSCO
3000 OLD AIRPORT RD.
WOOSTER, OHIO 44691
(216) 264-8885

CUSTOMER B.D.M.
ADDRESS 1199 Van Voorhis Rd
Morgantown, W.Va.
26505.

DATE 5-25-88
SERVICE ORDER NO. A 8484
ASSOC. NOWSCO REF. NO. 8323.
P.O. NUMBER
QUOTE NO.
SERVICE ENG. R. Tudel.
STATION MGR. APP.

I HAVE READ AND UNDERSTOOD ALL OF THE CONTRACT TERMS ON THE BACK OF THIS DOCUMENT AND VOLUNTARILY ENTER INTO THIS CONTRACT ON BEHALF OF THE CUSTOMER. I FURTHER REPRESENT AND WARRANT TO NOWSCO THAT I HAVE BEEN DULY AUTHORIZED BY THE CUSTOMER TO ENTER INTO THIS CONTRACT ON ITS BEHALF AND TO EXECUTE THE SAME AS THE CUSTOMER'S AGENT. I DO HEREBY, ON BEHALF OF THE CUSTOMER, AUTHORIZE NOWSCO TO PROCEED WITH ITS DELIVERY OF ITS PRODUCTS, SUPPLIES, MATERIALS AND SERVICES IN ACCORDANCE WITH THE TERMS CONTAINED HERE IN.

B.D.M.
Customer
William K. Overbay Jr.
Agent

NAME OF WELL Ret #1 Wayne 1857 | PERMIT NO. 47099-1857
TWP. | COUNTY Wayne | STATE W.Va. | TYPE OF TREATMENT Foam Frac

PRICE LIST REFERENCE	MATERIAL & EQUIPMENT	QUANTITY	UOM	UNIT PRICE	AMOUNT
323-276	BLENDER	1	EA		800.00
103-001	VT-1200 PUMPERS	1	EA		2700.00
330-020	VT.-900	1	EA		2000.00
501-450	H V N2 PUMPERS	2	EA	1000.00	2000.00
501-451	EACH ADDITIONAL 1000 SCF/MIN				
	CO^2 TRANSPORTS		EA		
508-414	N2 TRANS 3 MINI SXhrs	6 HRS=18	EA	50.00	900.00
304-203	MILEAGE ON UNITS 50X8	400	M	2.25	900.00
307-217	80/100 MESH SAND		SK		
307-219	20/40 MESH SAND	2250	SK	6.60	14850.00
307-220	10/20 MESH SAND		SK		
301-210	PROPPANT PUMPING CHG 100 MESH 20/40	2250	SK	.25	562.50
301-211	PROPPANT PUMPING CHG 10/20		SK		
304-225	SAND CONC CHG - FOAM FRAC LB/gal 15/gal	18060	GALS	.16	2889.60
310-231	SAND CARTAGE TO LOC	5625	T/M	.80	4500.00
310-231	RETURN SAND CARTAGE		T/M		
	BALL INJECTOR - REMOTE/MANUAL		EA		
	BALL SEALERS		EA		
718-507	3⅛" FRAC BALL		EA		
718-506	3½" FRAC BALL		EA		
718-505	3¾" FRAC BALL		EA		
718-508	3" FRAC BALL		EA		
	N_2 Flowmeter	1			750.00
110-015	Densometer	1			300.00
330-030	CO_2 Booster Pump	1			1200.00
110-001	Frac Valve	1			300.00
	2753 Stewart				

PRICE LIST REFERENCE	MATERIAL & EQUIPMENT	QUANTITY	UOM	UNIT PRICE	AMOUNT
	% ACID		GAL		
	INHIBITOR		GAL		
209-134	IS-300 IRON SEQ		GAL		
206-125	WS-6ONE SURFACTANT		GAL		
230-162	CSA-3 CLAY STAB		GAL		
230-164	CSA-5 CLAY STAB	27.6	GAL	21.00	579.60
209-136	600 IRON STAB	138	lbs	5.85	807.30
239-100	CHEMICAL & ACID HAULING	6	HRS	50.00	300.00
239-200	ACID TRANSPORT		HRS		
313-244	LSRINB GELLANT	276	LBS	5.50	1518.00
313-255	GEL BREAKER F	27.6	lbs	10.00	276.00
315-100	GEL BUFFER 5L	14	Gals	9.00	126.00
	FRICTION REDUCER				
328-281	SFL FOAMER	138	GALS	18.25	2518.50
321-273	KCL SALT 4701		LBS	.20	940.20
330-010	CO^2 PRODUCT	20	TON	163.40	3268.00
501-405	N2 PRODUCT FIRST 50.000 SCF	50,000	SCF	1.25	625.00
501-407	N2 PRODUCT ADDITIONAL SCF	950,000	SCF	1.15	10,925.00
501-409	N2 PRODUCT IN EXCESS OF 1.000.000 SCF	29,223	SCF	1.00	292.22
					56,827.92
	DISCOUNTS AND/OR QUOTE APPLY ONLY IF PAID WITHIN 30 DAYS.	Less	33%		18,753.21
		TOTAL			38,074.71

UNIT NO.	EMPLOYEE	UNIT NO.	EMPLOYEE
687	R Tudel	5558	Jim Goldfee
713	Smith, Bennett	5560	Geist
6304	Egler	4502	Pough
6208	Olson	2706	Bailey
6768	D. Tudel	2598	Moore
5553	Sexton	2752	Eastman
555	McDaniel	2754	Homer

I, ON BEHALF OF THE ABOVE-NAMED CUSTOMER, DO HEREBY ACKNOWLEDGE RECEIPT AND ACCEPTANCE OF AND FROM NOWSCO WELL SERVICE, LTD., THE ABOVE-DESCRIBED SERVICES, PRODUCTS, SUPPLIES AND MATERIALS.

B.D.M.
Customer
William K. Overbay Jr.
Agent

WHITE - ORIGINAL • WHITE - HEAD OFFICE • GREEN - CUSTOMER COPY • YELLOW - STATION COPY • GOLDENROD - BOOK COPY

PDQ PRINT SHOP INC — CLARKSBURG WV

APPENDIX F

SUPPORTING MATERIALS AND PROCEDURES
FOR STIMULATION NO. 5 IN ZONES 5 AND 8

F-1 Log of Frac Operations for Frac Job on Zones 5 and 8

F-2 Log of Cleanout Operations for Frac Job on Zones 5 and 8

F-3 Report of Frac Operations by NOWSCO on Frac Job on Zones 5 and 8

APPENDIX F-1
LOG OF FIELD OPERATIONS TO FRAC AND CLEAN OUT

RET #1 WELL HISTORY

FRAC OF ZONES 5 & 8
AUGUST 31, 1988

August 29, 1988

8:00 a.m. Blow well down to atmosphere. Well made a little bit of foam.

11:00 a.m. Rig up Pool Well Service. Nipple down flowing equipment and nipple up wellhead. Pick up 2' perforated sub and bull plug. Run in hole with 153 joints tubing. No fill in the hole. Drag 15,000 down and 18,000 up at 4080'; 13,000 down and 19,000 up at 4982'.

2:30 p.m. Pull out of hole with tubing.

5:30 p.m. Shut-in for night.

August 30, 1988

8:00 a.m. Wait on Tamm bridge plug to arrive.

5:30 p.m. Tamm bridge plug arrived on location. Make up bridge plug with 2' perforated sub and bull plug on bottom. Run in hole. Had to work tubing past 3950 - 4010'. Set middle of bridge plug element at 4952'. Rig up Nowsco.

8:30 p.m. Inflate bridge plug with N_2 to 1600 psi. Rotate to the right and set down 10,000 lbs on plug. Rotate left and release "J" slot.

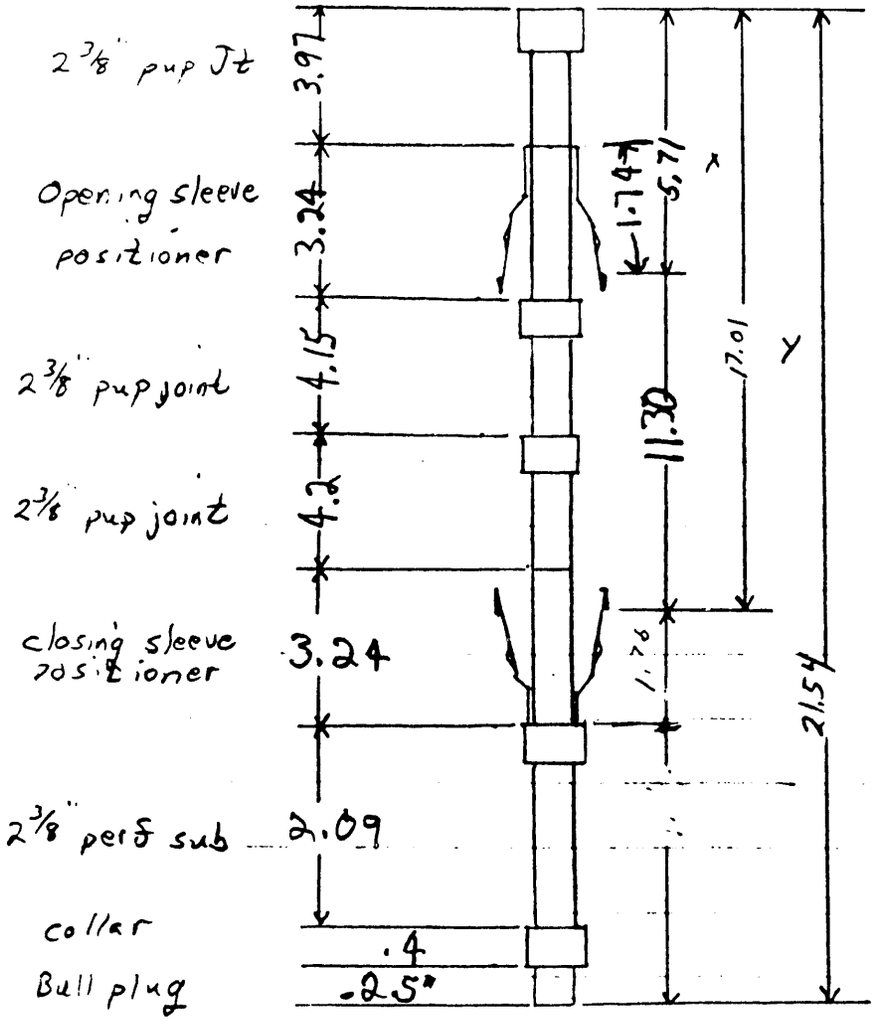
10:00 p.m. Pull 1 joint and shut-in for night.

August 31, 1988

7:30 a.m. Pull out of hole with tubing. Spent 3/4 hour repairing rig (throttle valve). Gas is coming out of well which means the port collars or bridge plug are leaking (more likely the port collars). Tubing pulled tight at 3825' coming out.

11:00 a.m. Make up Halliburton opening and closing sleeve positioner as shown in Figure 1-8/31. Run tubing in the hole. Hit numerous place where it acted like it was pushing something.

Figure 1-8/31



Opening & Closing Tool 8/31/88

Tagged bridge plug. Has not moved. Pull out of hole opening port collars #8, 9, and 10. The closing tool kept hanging up on the port collars and ECPs. Was stuck several times. Had to pull to 35,000 lbs to release it. Close PC #11 and 12. Pipe became stuck with top positioning sleeve at 4025'. Rig up Nowsco and circulate conventionally at 2000 scfm. Recovered fluid rust, and pipe dope. Continued pulling out of hole. Ope PC #13 and 14. Closing sleeve still hanging up.

5:00 p.m. Finished pulling out of hole. Closing sleeve was in good condition. No reason it should have been hanging up. Rig up Nowsco to frac Zones 5 and 8. Pressure casing with nitrogen to 420 psi. Frac as shown in the attached table.

8:04 p.m. SICP 1000 psi. Rig up to flow back after frac. Open at 8:21 p.m. on 1/4" end choke.

DATE	TIME	PRESSURE	REMARKS
8/31/88	8:21 p.m.	960	Opened to pit.
	8:43 p.m.	750	
	8:47 p.m.	715	Shut-in & change to 1/2" choke.
	8:57 p.m.	715	Open to pit.
	9:00 p.m.	590	
	9:11 p.m.	510	Started making fluid.
	9:22 p.m.	500	Shut-in & change to 3/4" choke.
	9:25 p.m.	520	Open to pit.
	9:30 p.m.	455	
	9:40 p.m.	460	Recovered 35 bbls total.
	10:15 p.m.	400	Recovered 61 bbls total.
	10:30 p.m.	353	
	10:35 p.m.	350	Recovered 78 bbls total.
	10:45 p.m.	340	Started making small amount prop.
	11:00 p.m.	305	
	11:30 p.m.	280	Recovered 96 bbls total.
9/1/88	12:00 mid	285	
	12:30 a.m.	225	
	1:00 a.m.	180	
	1:30 a.m.	130	Making fluid intermittently and small amount prop.
	2:30 a.m.	75	Misting.
	4:00 a.m.	28	Not making any more fluid.
	4:30 a.m.	26	Change to 1/2" choke.
	4:45 a.m.	30	Can smell gas.

	6:00 a.m.	20	
	7:00 a.m.	15	
	7:40 a.m.	0	Recovered 104 bbls total.
	7:50 a.m.	0	Shut-in.
	8:00 a.m.	38	Building pressure.
	11:50 a.m.	162	Open to pit on 3/4" choke. Recovered approx. 1-1/2 bbls H_2O. Total 105.5 bbls.
	12:00 noon	110	
	12:28 p.m.	51	Shut-in.
	12:35 p.m.	100	
	1:30 p.m.	145	Open to pit.
	1:35 p.m.	75	
	2:00 p.m.	20	No fluid.
	2:30 p.m.	0	Shut-in.
	2:40 p.m.	43	
	3:00 p.m.	60	
	4:00 p.m.	100	
	4:30 p.m.	110	Rig up to flow thru meter.
	5:15 p.m.	110	Rate 230 mcfpd.
	8:00 p.m.	65	Rate 173 mcfpd. Shut-in to build pressure.
	9:30 p.m.	122	Open to pit to unload fluid. Pressure dropped to 35 psi, then started to unload fluid. Recovered approx. 1.5 bbls; total 107 bbls.
	10:15 p.m.	10	Shut-in.
	10:30 p.m.	62	
	11:00 p.m.	78	
9/2/88	12:00 mid	102	Open to pit on 3/4" choke. No fluid.
	12:30 a.m.	20	Shut-in.
	1:00 a.m.	80	
	2:00 a.m.	112	
	3:00 a.m.	129	
	4:00 a.m.	139	Opened to pit on 3/4" choke. Made only fine mist of fluid.
	4:45 a.m.	10	Shut-in.
	5:00 a.m.	55	
	6:00 a.m.	83	
	7:00 a.m.	108	
	8:00 a.m.	124	
	9:00 a.m.	134	
	9:30 a.m.	139	
	9:38 a.m.	140	Open to pit on 3/4" choke. Made only fine mist of fluid.
	9:55 a.m.	42	Rig up to flow thru meter.

TIME	CP	BACK PRESSURE	DIFFERENTIAL	GAS RATE (SG=0.72)
10:05 a.m.	66	35	100	135 mcfpd
10:15 a.m.	67	38	104	142 mcfpd
10:45 a.m.	64	64	96	177 mcfpd
12:00 n	62	62	60	138 mcfpd
1:00 p.m.	60	60	48	121 mcfpd
2:00 p.m.	45	45	92	145 mcfpd
3:00 p.m.	40	40	68	118 mcfpd

Left well flowing thru meter. Total fluid recovered: 107 bbls. Load remaining: 269 bbls.

FRAC OF ZONES 8 & 5 - RET #1
August 31, 1988

		CLEAN FLUID VOLUME		FOAM VOLUME					
TIME	CP	STAGE	TOTAL	STAGE	TOTAL	CLEAN FLUID (bpm)	N_2 (scfm)	FOAM (bpm)	REMARKS
5:35 pm	0	0	0	0	0	0	0	0	Pressure casing w/N_2.
5:39 pm	420	0	0	0	0	12.1	0	0	Start 40 tons CO_2 prepad.
6:07 pm	460	3360	0	22,333	0	3.8	6,000	25	Start 85Q N_2 pad.
6:24 pm	1030	--	2,520	---	16,800	3.7	12,000	25	
6:30 pm	1230	1008	3,360	6,667	22,333	7.5	12,000	50	Start 1/2 ppg.
6:33 pm	1280	2016	4,368	13,333	29,000	7.5	12,000	50	Start 1 ppg.
6:40 pm	1430	2016	6,384	13,333	42,333	7.6	12,000	50	Start 1-1/2 ppg.
6:46 pm	1490	2016	8,400	13,333	55,666	7.8	12,000	50	Start 2 ppg.
6:53 pm	1490	5376	10,416	36,225	69,000	7.4	12,000	50	Start 2-1/2 ppg.
7:00 pm	1500	--	12,967	---	86,012	8.4	12,000	50	
7:11 pm	1510	--	15,792	---	105,225	0	10,000	--	Start flush.
7:13 pm	1380	--	15,792	---	105,225	0	10,000	--	Finish flush.

ISIP = 1280 psi; 5 min = 1210 psi; 10 min = 1160 psi; 15 min = 1140 psi.
Max TP = 1530 @ 50 bpm; Average TP = 1400 psi @ 50 bpm.
Load to Recover 376 bbls. Total foam: 105,225 gals.
Total sand: 150,000 lbs 20/40 mesh.

HISTORY OF RET #1 WELL CLEAN-OUT OPERATIONS
AFTER FRAC JOB ON ZONES #5 & #8 (10/13-21/88)

10/13/88

2:30 p.m. Arrive on location. Pool Services already rigged up. Well flowing 63 mcfpd to pipeline. Shut in well. Blow down. Nipple down wellhead and nipple up stripper head.

3:30 p.m. Start in the hole with "J" tool and a 2' perforated sub.

5:20 p.m. Tagged sand at 3764'. Rigged up the foam air unit. Circulate conventionally at 500 scfm and 4 gpm soap. Washed down to 3780'.

7:00 p.m. Shut down for night. Left well open to atmosphere.

10/14/88

7:30 a.m. Rigged up and established circulation (conventional). Tag sand again at 3829'. Wash to 3844'.

9:15 a.m. Attempt to break circulation at 3879'. Tubing plugged. Pressured tubing to 800 psi and blew back twice. Would not unplug. Tried to pull out of hole. Tubing stuck. Rig up and pump down annulus. Pull out of hole to 2869'. Pump down tubing with air only. Pressure went to 600 psi, then tubing unplugged. Ran tubing to 3683'. Pump conventionally with air and foam. No circulation.

2:00 p.m. Ran tubing to 3748'. Wash from 3748' to 3846'. Tagged sand at 3846'. No circulation.

5:00 p.m. Wash to 3878'. Tag sand again at 3894'. Wash on solid sand for two hours. Made 8' to 3902'. Had to spud tubing to make progress. When the end of tubing tags sand, the air and foam diverts through perforated sub and holes in "J" tool. Partial returns.

7:00 p.m. Shut down for night with end of tubing at 3846'. Left open to atmosphere.

10/15/88

7:30 a.m. Rigged down circulating equipment. Lay down perforated sub and "J" tool.

10:30 a.m. Run in hole with open-ended tubing. Tag sand at 3852'. (Taking a little weight.)

12:30 p.m. Rig up circulating equipment. Establish circulation conventionally at 500 scfm and 4 gpm soap. Wash to 3907'. Had no problem washing past 3902'.

2:00 p.m. Wash to 3940'. Had some sand. No returns. Wash solid sand from 3947' to 3972'. No returns.

4:00 p.m. Wash to 4008'; some sand. Solid sand to 4015'. Very little sand to 4054'. Solid sand to 4059'. Very little sand to 4070'. Partial returns.

5:30 p.m. Circulate 1 hour with partial returns. Got very little sand out of well. Pull tubing to 3600'. Shut down for night with well open to atmosphere.

10/16/88

7:30 a.m. Well had blown a lot of sand up through the tubing over night. Run in hole with tubing. Started taking weight at 3789'. rigged up to reverse circulate with 500 scfm air. No soap. Continued to pump air while making connections. Partial returns. Wash to 4005'.

9:00 a.m. Tagged sand at 4005'. Washed to 4070'. Well stopped circulating. Switch air to tubing. Pressure increased to 300 psi then dropped to 125 psi when the well unloaded foam and some sand.

10:30 a.m. Switched back to reverse circulation with 500 scfm air. Washed to 4298'. Getting foam and lots of sand up tubing.

11:30 a.m. Stop. Circulate 1/2 hour. Getting very little foam but lots of sand up tubing. Washed to 4526'.

12:00 Stop and circulate 1/2 hour. Little foam and sand. Wash to 4721'. Flow from tubing slowed.

1:00 p.m. Stop and circulate. Getting some foam and almost no sand in returns.

1:30 p.m. Wash to 4949' (top of bridge plug). Circulate.

2:30 p.m. Pulled tubing to 4689'. Tubing getting stuck at times.

3:00 p.m. Rig up and reverse circulate.

4:30 p.m. Started making very heavy sand with foam and shale.

5:30 p.m. Returns cleaned up. Pull tubing to 2000'. Still getting stuck periodically.

7:00 p.m. Shut down for night. Left well open to atmosphere.

10/17/88

7:30 a.m. Well flowing white foam with no sand. Finished pulling tubing out of the hole.

8:30 a.m. Pick up "J" tool and run in hole.

10:00 a.m. Rig up circulating equipment and start circulating at 3746'. Reversing with 500 scfm and no foam. Tag sand at 3886'.

11:00 a.m. Had to spud through 20' of sand in 15 minutes. Air diverting through slots in side of "J" tool. Circulate 15 minutes. Run tubing from 3909' to 3924'. Spud through sand to 3941'. Circulate 15 minutes.

12:00 Spud through sand to 3961', then couldn't make any more progress in one hour. Very little sand in the returns.

1:30 p.m. Pull out of hole.

4:00 p.m. Shut down for night. Left well open to atmosphere. Time for a new game plan.

10/18/88 Had the "J" tool modified at a machine shop to cover slots in sides. Waiting on air package capable of 1050 scfm.

10/19/88

9:00 a.m. Pick up modified "J" tool and 4' pup joint. Run in hole. Tag sand at 3929'. Rig up to reverse circulate.

11:30 a.m. Wait on air compressor one hour.

12:30 p.m. Rig up air compressor. Start pumping at 200 psi. Washed to 3978'. Had foam to surface (no sand). Circulate 5 minutes. Wash to 4108'. Steady returns of foam but very little sand.

2:00 p.m. Made very heavy sand for a few minutes, then mostly air with very little sand.

2:30 p.m. Washed to 4564'. Returns are air with a little sand. Very little fluid.

3:00 p.m. Washed to 4629'. Tubing unloaded lots of foam with very heavy sand. Circulate.

3:30 p.m. Returns dried up. Washed to 4950'. No fluid or sand.

4:00 p.m. Circulate 1/2 hour.

4:30 p.m. Throttle air compressors back to an idle. "J" onto retrievable bridge plug. Release bridge plug. Flow up tubing stopped.

5:00 p.m. Start out of hole with tubing. Left air pumping down annulus with no returns up tubing. Shut off air with bridge plug at 3800'.

7:00 p.m. Shut down for night with bridge plug at 1275'. Annulus shut in. No problems pulling tubing.

10/20/88

7:30 a.m. Pull out of hole. Rig down stripper head. Took a long time for the well to blow down. Strong gas blow. Lay down retrievable bridge plug. Last 30' of tubing filled with sand. Pick up a 4' pup joint, Halliburton opening tool, and another 4' pup joint.

9:30 a.m. Run in hole. Install stripper head at 3756'.

1:00 p.m. Tagged sand at 5254'. Had no problem getting to this point. Start reverse circulating with 1050 scfm air and no foam. Washed sand to 5329'. Run pipe to 5352'.

1:45 p.m. Started making mist. Stop and circulate 10 minutes. Ran tubing to 5547' with strong returns up tubing. Getting some foam and sand.

2:15 p.m. Circulate; eat lunch.

2:45 p.m. Ran tubing to 5720'. Tagged small sand bridge. Ran tubing to 5807'; 61' past last port collar.

3:15 p.m. Circulate for one hour, 45 minutes. Unloaded water and some sand.

5:00 p.m. Returns dried up and flowing only traces of sand. Idle compressors back to half throttle. Pull out of hole opening port collars. Tubing completely dry with only a trace of sand. Opened PC #2, 3, and 4. Could not locate PC #5 (probably already open).

5:45 p.m. Got hung up in PC #7. Could go down but could not come up. Work tubing from 15,000 to 20,000 lbs over string weight. Would not pull through. Work pipe 1/2 hour. Located opening tool in PC and pulled 1000 lbs over string weight. Rotated tubing with tongs. Tool popped free.

6:15 p.m. Continued pulling out of hole. Well circulating some dry sand once in a while. Pulled 6 to 10,000 lbs over string weight in PC #8, 9, and 10 (supposed to be open). Opened PC #12. Hung up in PC #13. Pulled 20,000 lbs over. Would not pull through. Rotated out of port collar as before. Pull tubing to 3723'. Still making dry air and trace of sand.

7:15 p.m. Shut down for night. Left tubing open to atmosphere and annulus shut-in.

10/21/88

8:00 a.m. Finished pulling out of hole. Laid down opening tool. Nipple down stripped head. Nipple up wellhead. Pick up bull plug with 1/4" tap, 2' perforated sub, and a 2' slotted sub.

11:30 a.m. Runi n hole with 115 joints of tubing. Land tubing at 3748'.

1:30 p.m. Land tubing in wellhead. Hook wellhead up to flow line. Got well shut in at approximately 2:30 p.m.

3:45 p.m. Tubing pressure 40 psi. Start flowing well to flow line.

4:00 p.m. Flow rate 54.1 mcfpd.

4:15 p.m. Flow rate 68.8 mcfpd.

4:30 p.m. Flow rate 86.5 mcfpd and still increasing. Left location with well flowing to pipeline.

MEMORANDUM

TO: Bill Overbey
FROM: Richard S. Carden

DATE: 10/24/88

RE: RET #1 post frac, clean out operations, Oct. 13-21, 1988

The post frac, clean out operations took longer than anticipated. Initially, three days had been scheduled for the operations; however, the actual time required was nine days. The additional time spent was due to problems with hole cleaning.

Originally, Pool's foam air unit was used to try and clean out the well. The unit is capable of pumping 500 scfm of air at 800 psi along with soap for better hole cleaning capacity. Theoretically, 500 scfm should be enough to clean the well. According to Angel (Volume Requirements for Air and Gas Drilling), a circulation rate of 250 scfm should be sufficient to clean the well. In horizontal wells, additional volume is required, and the rated capacity of 500 scfm should have been enough for conventional circulation. A rate of less than 100 scfm would be required for reverse circulation.

Unfortunately, the foam air unit was not capable of cleaning the well; either with conventional or reverse circulation. The bottomhole pressure in the RET #1 well is not sufficient to support the hydrostatic pressure induced by a column of foam. Therefore, the well could not be consistently circulated with foam. Even while reverse circulating with air only, the air velocity was not sufficient to clean the well. Too much of the 500 scfm was being lost to the formation.

An air compressor capable of 1050 scfm at 800 psi was used to clean the well. Some of the air volume was lost to the formation; however, enough was circulated back to the surface to carry the sand and foam remaining in the well. For future operations, the higher capacity compressor is recommended.

APPENDIX F-2

LOG OF FIELD OPERATIONS TO FRAC AND CLEAN OUT

MEMORANDUM

TO: Bill Overbey DATE: 10/24/88
FROM: Richard S. Carden

RE: RET #1 post frac, clean out operations, Oct. 13-21, 1988

The post frac, clean out operations took longer than anticipated. Initially, three days had been scheduled for the operations; however, the actual time required was nine days. The additional time spent was due to problems with hole cleaning.

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An air compressor capable of 1050 scfm at 800 psi was used to clean the well. Some of the air volume was lost to the formation; however, enough was circulated back to the surface to carry the sand and foam remaining in the well. For future operations, the higher capacity compressor is recommended.

HISTORY OF RET #1 WELL CLEAN-OUT OPERATIONS
AFTER FRAC JOB ON ZONES #5 & #8 (10/13-21/88)

10/13/88

2:30 p.m. Arrive on location. Pool Services already rigged up. Well flowing 63 mcfpd to pipeline. Shut in well. Blow down. Nipple down wellhead and nipple up stripper head.

3:30 p.m. Start in the hole with "J" tool and a 2' perforated sub.

5:20 p.m. Tagged sand at 3764'. Rigged up the foam air unit. Circulate conventionally at 500 scfm and 4 gpm soap. Washed down to 3780'.

7:00 p.m. Shut down for night. Left well open to atmosphere.

10/14/88

7:30 a.m. Rigged up and established circulation (conventional). Tag sand again at 3829'. Wash to 3844'.

9:15 a.m. Attempt to break circulation at 3879'. Tubing plugged. Pressured tubing to 800 psi and blew back twice. Would not unplug. Tried to pull out of hole. Tubing stuck. Rig up and pump down annulus. Pull out of hole to 2869'. Pump down tubing with air only. Pressure went to 600 psi, then tubing unplugged. Ran tubing to 3683'. Pump conventionally with air and foam. No circulation.

2:00 p.m. Ran tubing to 3748'. Wash from 3748' to 3846'. Tagged sand at 3846'. No circulation.

5:00 p.m. Wash to 3878'. Tag sand again at 3894'. Wash on solid sand for two hours. Made 8' to 3902'. Had to spud tubing to make progress. When the end of tubing tags sand, the air and foam diverts through perforated sub and holes in "J" tool. Partial returns.

7:00 p.m. Shut down for night with end of tubing at 3846'. Left open to atmosphere.

10/15/88

7:30 a.m. Rigged down circulating equipment. Lay down perforated sub and "J" tool.

10:30 a.m. Run in hole with open-ended tubing. Tag sand at 3852'. (Taking a little weight.)

12:30 p.m. Rig up circulating equipment. Establish circulation conventionally at 500 scfm and 4 gpm soap. Wash to 3907'. Had no problem washing past 3902'.

2:00 p.m. Wash to 3940'. Had some sand. No returns. Wash solid sand from 3947' to 3972'. No returns.

4:00 p.m. Wash to 4008'; some sand. Solid sand to 4015'. Very little sand to 4054'. Solid sand to 4059'. Very little sand to 4070'. Partial returns.

5:30 p.m. Circulate 1 hour with partial returns. Got very little sand out of well. Pull tubing to 3600'. Shut down for night with well open to atmosphere.

10/16/88

7:30 a.m. Well had blown a lot of sand up through the tubing over night. Run in hole with tubing. Started taking weight at 3789'. rigged up to reverse circulate with 500 scfm air. No soap. Continued to pump air while making connections. Partial returns. Wash to 4005'.

9:00 a.m. Tagged sand at 4005'. Washed to 4070'. Well stopped circulating. Switch air to tubing. Pressure increased to 300 psi then dropped to 125 psi when the well unloaded foam and some sand.

10:30 a.m. Switched back to reverse circulation with 500 scfm air. Washed to 4298'. Getting foam and lots of sand up tubing.

11:30 a.m. Stop. Circulate 1/2 hour. Getting very little foam but lots of sand up tubing. Washed to 4526'.

12:00 Stop and circulate 1/2 hour. Little foam and sand. Wash to 4721'. Flow from tubing slowed.

1:00 p.m. Stop and circulate. Getting some foam and almost no sand in returns.

1:30 p.m. Wash to 4949' (top of bridge plug). Circulate.

2:30 p.m. Pulled tubing to 4689'. Tubing getting stuck at times.

3:00 p.m. Rig up and reverse circulate.

4:30 p.m. Started making very heavy sand with foam and shale.

5:30 p.m. Returns cleaned up. Pull tubing to 2000'. Still getting stuck periodically.

7:00 p.m. Shut down for night. Left well open to atmosphere.

10/17/88

7:30 a.m. Well flowing white foam with no sand. Finished pulling tubing out of the hole.

8:30 a.m. Pick up "J" tool and run in hole.

10:00 a.m. Rig up circulating equipment and start circulating at 3746'. Reversing with 500 scfm and no foam. Tag sand at 3886'.

11:00 a.m. Had to spud through 20' of sand in 15 minutes. Air diverting through slots in side of "J" tool. Circulate 15 minutes. Run tubing from 3909' to 3924'. Spud through sand to 3941'. Circulate 15 minutes.

12:00 Spud through sand to 3961', then couldn't make any more progress in one hour. Very little sand in the returns.

1:30 p.m. Pull out of hole.

4:00 p.m. Shut down for night. Left well open to atmosphere. Time for a new game plan.

10/18/88 Had the "J" tool modified at a machine shop to cover slots in sides. Waiting on air package capable of 1050 scfm.

10/19/88

9:00 a.m. Pick up modified "J" tool and 4' pup joint. Run in hole. Tag sand at 3929'. Rig up to reverse circulate.

11:30 a.m. Wait on air compressor one hour.

12:30 p.m. Rig up air compressor. Start pumping at 200 psi. Washed to 3978'. Had foam to surface (no sand). Circulate 5 minutes. Wash to 4108'. Steady returns of foam but very little sand.

2:00 p.m. Made very heavy sand for a few minutes, then mostly air with very little sand.

2:30 p.m. Washed to 4564'. Returns are air with a little sand. Very little fluid.

3:00 p.m. Washed to 4629'. Tubing unloaded lots of foam with very heavy sand. Circulate.

3:30 p.m. Returns dried up. Washed to 4950'. No fluid or sand.

4:00 p.m. Circulate 1/2 hour.

4:30 p.m. Throttle air compressors back to an idle. "J" onto retrievable bridge plug. Release bridge plug. Flow up tubing stopped.

5:00 p.m. Start out of hole with tubing. Left air pumping down annulus with no returns up tubing. Shut off air with bridge plug at 3800'.

7:00 p.m. Shut down for night with bridge plug at 1275'. Annulus shut in. No problems pulling tubing.

10/20/88

7:30 a.m. Pull out of hole. Rig down stripper head. Took a long time for the well to blow down. Strong gas blow. Lay down retrievable bridge plug. Last 30' of tubing filled with sand. Pick up a 4' pup joint, Halliburton opening tool, and another 4' pup joint.

9:30 a.m. Run in hole. Install stripper head at 3756'.

1:00 p.m. Tagged sand at 5254'. Had no problem getting to this point. Start reverse circulating with 1050 scfm air and no foam. Washed sand to 5329'. Run pipe to 5352'.

1:45 p.m. Started making mist. Stop and circulate 10 minutes. Ran tubing to 5547' with strong returns up tubing. Getting some foam and sand.

2:15 p.m. Circulate; eat lunch.

2:45 p.m. Ran tubing to 5720'. Tagged small sand bridge. Ran tubing to 5807'; 61' past last port collar.

3:15 p.m. Circulate for one hour, 45 minutes. Unloaded water and some sand.

5:00 p.m. Returns dried up and flowing only traces of sand. Idle compressors back to half throttle. Pull out of hole opening port collars. Tubing completely dry with only a trace of sand. Opened PC #2, 3, and 4. Could not locate PC #5 (probably already open).

5:45 p.m. Got hung up in PC #7. Could go down but could not come up. Work tubing from 15,000 to 20,000 lbs over string weight. Would not pull through. Work pipe 1/2 hour. Located opening tool in PC and pulled 1000 lbs over string weight. Rotated tubing with tongs. Tool popped free.

6:15 p.m. Continued pulling out of hole. Well circulating some dry sand once in a while. Pulled 6 to 10,000 lbs over string weight in PC #8, 9, and 10 (supposed to be open). Opened PC #12. Hung up in PC #13. Pulled 20,000 lbs over. Would not pull through. Rotated out of port collar as before. Pull tubing to 3723'. Still making dry air and trace of sand.

7:15 p.m. Shut down for night. Left tubing open to atmosphere and annulus shut-in.

10/21/88

8:00 a.m. Finished pulling out of hole. Laid down opening tool. Nipple down stripped head. Nipple up wellhead. Pick up bull plug with 1/4" tap, 2' perforated sub, and a 2' slotted sub.

11:30 a.m. Runi n hole with 115 joints of tubing. Land tubing at 3748'.

1:30 p.m. Land tubing in wellhead. Hook wellhead up to flow line. Got well shut in at approximately 2:30 p.m.

3:45 p.m. Tubing pressure 40 psi. Start flowing well to flow line.

4:00 p.m. Flow rate 54.1 mcfpd.

4:15 p.m. Flow rate 68.8 mcfpd.

4:30 p.m. Flow rate 86.5 mcfpd and still increasing. Left location with well flowing to pipeline.

APPENDIX F-3
REPORT ON FRAC JOB BY NOWSCO IN ZONES 5 & 8

NOWSCO Well Service
950 GREENTREE ROAD • PITTSBURGH, PA 15220
PHONE (412) 937-1411 • FAX (412) 937-1405

September 21, 1988

Mr. Bill Overbey
BDM Corporation
1199 Van Voorhis Road, Suite 4
Morgantown, West Virginia 26505

Dear Bill,

Attached is the post job report for fracturing the last zones on your R.E.T. #1 well. As before, I hope you find it useful in analyzing your wells post stimulation performance.

I apologize for not being able to make the job.

Should you need clarification of any part of this report, please call me at any time at (412) 937-1411. We will be glad to help out in any way possible.

Thanks again for using NOWSCO as your service company.

Sincerely,

Tom Udick

TABLE OF CONTENTS

1. GENERAL OBJECTIVE

The objective of the treatment was to stimulate the shale formation using the following fluids and gases and their respective volumes:

40 Ton	CO_2 Prepad
22,400 Gal	85 Quality Non-Stabilized Foam Pad
82,880 Gal	85 Quality Sand Laden Fluid (Also Non-Stabilized)

The base fluid for this treatment did not include gelling agents; however, Methanol was added at 25% per volume.

The total amount of sand placed was 150,000 lbs. of 20/40 Ottawa.

2. MATERIAL REQUIREMENTS

Equipment	Material	
1 Blender	150,000 lbs	20/40 Ottawa
1 VT-900 (CO_2)	94 bbl	Methanol
1 VT-1200 (H_2O)	8 gal	CSA-5 Clay Control
3 H.V. N_2 Pumpers	3,500 lbs	KCl Salt
1 CO_2 Transfer Pump	79 lbs	IS-600 Fe Control
3 Sand Units	79 gal	SF-2 Foamer
1 Chemical Truck	40 Ton	CO_2
2 Mini N_2 Transports	746,000 SCF	Nitrogen
1 Densiometer	1 gal	NOWCIDE 308
2 CO_2 Transports		

NB: An N_2 flowmeter was requested but could not be delivered to the wellsite due to a scheduling error.

3. QUALITY CONTROL

(A) Sand Concentration:

The sand concentration was continuously monitored using a densiometer. A graph of the sand concentration vs. time is supplied in Section 5.

There was considerable difficulty in maintaining a constant sand concentration due to wet sand in one of the units (No. 5555). There are also several points of lower density due to changing out sand units.

(B) Nitrogen Rate:

The nitrogen rate could not be monitored due to the absence of the nitrogen flowmeter. NOWSCO apologizes for failing to have this unit on location. All efforts will be made to ensure this problem does not occur in the future. From experience, we estimate the nitrogen flow rate to have been between 12,000 and 12,300 SCF/min. Total nitrogen pumped indicates this to be very probable.

(C) Foam Quality was maintained around 85%. A constant gas/liquid ratio was maintained and the fluid side rate was increased to compensate for sand addition.

(D) Fluids: KCl, NOWCIDE 308 and Methanol were the only additives premixed on this treatment. The clay control agent, foamer and iron control agent were added on the fly.

The concentrations for the various additives were:

Methanol	25% of fluid volume
CSA-5 Clay Control	.5 gal/1000 gal
IS-600 Fe Control	5 lbs/1000 gal
SF-2 Foamer	5 gal/1000 gal
NOWCIDE 308	.5 gal/tank
KCl	167 lbs/1000 gal

4. JOB SUMMARY

The fluid volumes, additives and proppant volumes were added as per design (with exception to varying density). All stages were started and terminated as designed.

The CO_2 prepad was pumped at 12 BPM, the pad fluid at 25 BPM (total foam rate) and the proppant stages pumped at 50 BPM (gas and liquid rate) with increases for sand addition.

The job started at 3:04 p.m. and terminated at 7:14 p.m.

BDM PUMP SCHEDULE

85 QUALITY FOAM FRAC
150,000 LBS. SAND

STAGE NO.	STAGE CLEAN VOLUME (GALS)	STAGE CLEAN VOLUME (BBLS)	TOTAL CLEAN VOLUME (BBLS)	SURFACE SAND CONCEN (LB/GAL)	DOWNHOLE SAND CONCEN (LB/GAL)	STAGE SAND VOLUME (LBS)	TOTAL SAND CONE (LBS)	STAGE DIRTY VOLUME (BBLS)	TOTAL DIRTY VOLUME (BBLS)	STAGE FOAM VOLUME (GALS)	FLUID NAME	REMARKS	CLEAN WATER RATE (BPM)	DIRTY WATER RATE (BPM)	START STAGE AT CLEAN BBL	END STAGE AT CLEAN BBL NO.
1	40 TON	0	0	0	0	0	0	0	0	0	CO2 PAD	12 BPM	0	0	0	0
2	3350	80	80	0	0	0	0	80	80	22333	85 Q FOAM	25 BPM	3.8	3.8	0	80
3	1000	24	104	3.3	0.5	3300	3300	27	107	6667	85 Q FOAM	50 BPM	7.5	8.6	80	104
4	2000	48	152	6.7	1.0	13400	16700	61	168	13333	85 Q FOAM	50 BPM	7.5	9.8	104	152
5	2000	48	200	10.0	1.5	20000	36700	68	236	13333	85 Q FOAM	50 BPM	7.5	10.9	152	200
6	2000	48	248	13.3	2.0	26600	63300	75	311	13333	85 Q FOAM	50 BPM	7.5	12.0	200	248
7	5375	128	376	16.2	2.5	86700	150000	215	526	36225	85 Q FOAM	50 BPM	7.5	13.0	248	376
8											FLUSH WITH N2					

1.) 40 TON CO2 PAD @ 12 BPM
2.) 0 - 80 CLEAN BBLS - 85 QUALITY FOAM PAD
3.) 80 - 104 CLEAN BBLS - 85 QUALITY FOAM PAD + 3.3 PPG 20/40 SAND
4.) 104 - 152 CLEAN BBLS - 85 QUALITY FOAM PAD + 6.7 PPG 20/40 SAND
5.) 152 - 200 CLEAN BBLS - 85 QUALITY FOAM PAD + 10.0 PPG 20/40 SAND
6.) 200 - 248 CLEAN BBLS - 85 QUALITY FOAM PAD + 13.3 PPG 20/40 SAND
7.) 248 - 376 CLEAN BBLS - 85 QUALITY FOAM PAD + 16.2 PPG 20/40 SAND
8.) DISPLACE TO TOP PERF WITH N2

BDM CORPORATION

RET #1

CHEMICAL CONSUMPTION
(ADDED ON FLY)

CLEAN VOLUME (BBLS)	CSA-5 CLAY CONTROL (GALS)	IS-600 Fe CONTROL (LBS)	SF-2 FOAMER (GALS)
0	0	0	0
24	0.5	5	5
48	1.0	10	10
71	1.5	15	15
95	2.0	20	20
119	2.5	25	25
143	3.0	30	30
167	3.5	35	35
190	4.0	40	40
214	4.5	45	45
238	5.0	50	50
262	5.5	55	55
286	6.0	60	60
310	6.5	65	65
333	7.0	70	70
357	7.5	75	75
376	8.0	80	80

5. GRAPHS AND PLOTS

BDM CORPORATION

TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
03:04	2000 SCF	0	0	N2	PUMP N2 TO CLEAN TUBING
03:05	2000 SCF	300	0	N2	
03:06	2000 SCF	400	0	N2	
03:07	2000 SCF	450	0	N2	
03:08	2000 SCF	500	0	N2	
03:09	2000 SCF	500	0	N2	
03:10	2000 SCF	500	0	N2	
03:11	2000 SCF	550	0	N2	
03:12	2000 SCF	500	0	N2	
03:13	2000 SCF	500	0	N2	
03:14	2000 SCF	500	0	N2	
03:15	2000 SCF	450	0	N2	STOP N2
03:16	-	300	0		
03:17	-	250	0		
03:18	-	200	0		
03:19	-	200	0		
03:20	-	150	0		
03:21	-	150	0		
03:22	-	100	0		
03:23	-	100	0		
03:24	-	0	0		
SHUTDOWN WAIT ON RIG			0		

BDM CORPORATION

TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
05:30:00	0	0	-	-	-
05:30:30	0	0	-	H2O	PRIME LINES
05:31:00	0	0	-	-	-
05:31:30	1.0	100	-	H2O	START PRESSURE-TEST LINES
05:32:00	-	600	-	H2O	
05:32:30	-	3600	-	H2O	
05:33:00	-	3500	-	H2O	
05:33:30	-	3600	-	H2O	
05:34:00	-	3450	-	H2O	
05:34:30	-	3300	-	H2O	BLEED LINES
05:35:00	-	0	-	-	
05:35:30	-	0	-	-	
05:36:00	-	0	-	-	
05:36:30	6000 MIN	100	-	N2	PRESSURE UP ON WELL
05:37:00	6000	250	-	N2	BEFORE STARTING CO2
05:37:30	6000	300	-	N2	
05:38:00	6000	300	-	N2	
05:38:30	6000	300	-	N2	
05:39:00	6000	400	-	N2	
05:39:30	6000	450	-	N2	
05:40:00	6000	450	-	N2	STOP N2 - 24,000 PUMPED
05:40:30	-	450	-	-	-
05:41:00	2	411	0	CO2	START CO2 PAD
05:41:30	5	311	0	CO2	
05:42:00	7	250	0	CO2	
05:42:30	9	250	0	CO2	
05:43:00	12	0	0	CO2	
05:43:30	12	0	0	CO2	
05:44:00	12	0	0	CO2	
05:44:30	12	0	0	CO2	
05:45:00	12	0	0	CO2	
05:45:30	12	0	0	CO2	
05:46:00	12	0	0	CO2	
05:46:30	12	0	0	CO2	
05:47:00	12	0	0	CO2	
05:47:30	12	0	0	CO2	
05:48:00	12	0	0	CO2	
05:48:30	12	0	0	CO2	
05:49:00	12	0	0	CO2	
05:49:30	12	0	0	CO2	
05:50:00	12	0	0	CO2	
05:50:30	12	0	0	CO2	
05:51:00	12	0	0	CO2	
05:51:30	12	0	0	CO2	

BDM CORPORATION

TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
05:52:00	12	0	0	CO2	
05:52:30	12	0	0	CO2	
05:53:00	12	0	0	CO2	
05:53:30	12	0	0	CO2	
05:54:00	12	0	0	CO2	
05:54:30	12	0	0	CO2	
05:55:00	12	50	0	CO2	
05:55:30	12	100	0	CO2	
05:56:00	12	100	0	CO2	
05:56:30	12	100	0	CO2	
05:57:00	12	100	0	CO2	
05:57:30	12	100	0	CO2	
05:58:00	12	100	0	CO2	
05:58:30	12	150	0	CO2	
05:59:00	12	150	0	CO2	
05:59:30	12	150	0	CO2	
06:00:00	12	150	0	CO2	
06:00:30	12	150	0	CO2	
06:01:00	12	200	0	CO2	
06:01:30	12	200	0	CO2	
06:02:00	12	200	0	CO2	
06:02:30	12	200	0	CO2	
06:03:00	12	200	0	CO2	
06:03:30	12	200	0	CO2	
06:04:00	0	200	0	-	CO2 PAD IN
06:04:30	0	200	0	-	
06:05:00	0	200	0	-	
06:05:30	0	200	0	-	
06:06:00	0	200	0	-	
06:06:30	0	250	0	-	
06:07:00	2.0	300	0	85Q FOAM	START PAD @ 20 BPM
06:07:30	3.5	400	0	85Q FOAM	DOWNHOLE RATE
06:08:00	3.5	500	0	85Q FOAM	
06:08:30	3.5	600	0	85Q FOAM	
06:09:00	3.0	650	0	85Q FOAM	
06:09:30	3.0	700	0	85Q FOAM	
06:10:00	3.0	750	0	85Q FOAM	
06:10:30	3.0	800	0	85Q FOAM	
06:11:00	3.0	900	0	85Q FOAM	
06:11:30	2.5	900	0	85Q FOAM	
06:12:00	3.0	900	0	85Q FOAM	
06:12:30	3.5	900	0	85Q FOAM	
06:13:00	3.5	1000	0	85Q FOAM	
06:13:30	4.0	1000	0	85Q FOAM	

BDM CORPORATION

TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
06:14:00	4.0	1050	0	85Q FOAM	
06:14:30	3.0	1000	0	85Q FOAM	
06:15:00	3.0	1000	0	85Q FOAM	
06:15:30	3.5	1000	0	85Q FOAM	
06:16:00	3.0	1000	0	85Q FOAM	
06:16:30	3.0	1000	0	85Q FOAM	
06:17:00	3.0	1050	0	85Q FOAM	
06:17:30	3.0	1100	0	85Q FOAM	
06:18:00	3.0	1100	0	85Q FOAM	
06:18:30	3.0	1100	0	85Q FOAM	
06:19:00	3.0	1100	0	85Q FOAM	
06:19:30	3.0	1100	0	85Q FOAM	
06:20:00	3.0	1100	0	85Q FOAM	
06:20:30	3.0	1100	0	85Q FOAM	
06:21:00	3.0	1050	0	85Q FOAM	
06:21:30	3.0	1050	0	85Q FOAM	
06:22:00	3.0	1050	0	85Q FOAM	
06:22:30	3.0	1050	0	85Q FOAM	
06:23:00	3.0	1050	0	85Q FOAM	
06:23:30	3.0	1050	0	85Q FOAM	
06:24:00	3.0	1050	0	85Q FOAM	
06:24:30	3.0	1050	0	85Q FOAM	
06:25:00	3.0	1050	0	85Q FOAM	
06:25:30	3.0	1050	0	85Q FOAM	
06:26:00	3.0	1050	0	85Q FOAM	
06:26:30	3.0	1050	0	85Q FOAM	
06:27:00	3.0	1100	0	85Q FOAM	
06:27:30	3.0	1100	0	85Q FOAM	
06:28:00	3.0	1100	0	85Q FOAM	
06:28:30	3.0	1100	0	85Q FOAM	
06:29:00	3.0	1100	0	85Q FOAM	
06:29:30	3.0	1100	0	85Q FOAM	
06:30:00	3.0	1100	0	85Q FOAM	
06:30:30	3.0	1100	0	85Q FOAM	
06:31:00	7.0	1150	0	85Q FOAM	START 3.3 LB/GAL & 50 BPM
06:31:30	6.0	1200	1.5	85Q FOAM	DOWNHOLE RATE
06:32:00	7.0	1250	3.0	85Q FOAM	
06:32:30	7.5	1300	2.0	85Q FOAM	
06:33:00	8.0	1300	3.0	85Q FOAM	
06:33:30	7.5	1300	3.5	85Q FOAM	
06:34:00	7.5	1300	3.0	85Q FOAM	
06:34:30	7.5	1300	3.0	85Q FOAM	START 6.7 LB/GAL
06:35:00	8.0	1250	6.0	85Q FOAM	
06:35:30	7.5	1150	6.5	85Q FOAM	

BDM CORPORATION

TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
06:36:00	7.5	1300	6.0	85Q FOAM	
06:36:30	7.5	1300	6.0	85Q FOAM	
06:37:00	8.0	1300	6.5	85Q FOAM	
06:37:30	7.5	1300	7.0	85Q FOAM	
06:38:00	7.5	1350	7.0	85Q FOAM	
06:38:30	7.0	1350	7.0	85Q FOAM	
06:39:00	7.0	1400	6.5	85Q FOAM	
06:39:30	7.5	1400	6.0	85Q FOAM	
06:40:00	7.5	1450	6.0	85Q FOAM	
06:40:30	7.5	1450	6.0	85Q FOAM	
06:41:00	7.5	1450	6.5	85Q FOAM	START 10 LB/GAL
06:41:30	7.5	1450	10.0	85Q FOAM	
06:42:00	7.5	1400	10.0	85Q FOAM	
06:42:30	7.5	1400	10.0	85Q FOAM	
06:43:00	7.5	1350	10.0	85Q FOAM	
06:43:30	7.0	1350	10.0	85Q FOAM	
06:44:00	7.5	1350	10.5	85Q FOAM	
06:44:30	7.5	1350	10.0	85Q FOAM	
06:45:00	7.0	1400	9.0	85Q FOAM	
06:45:30	7.0	1450	10.0	85Q FOAM	
06:46:00	7.0	1450	9.0	85Q FOAM	
06:46:30	7.0	1500	9.0	85Q FOAM	
06:47:00	7.0	1500	9.0	85Q FOAM	
06:47:30	7.5	1500	10.0	85Q FOAM	START 13.3 LB/GAL
06:48:00	7.5	1500	10.0	85Q FOAM	
06:48:30	7.0	1500	12.0	85Q FOAM	
06:49:00	7.5	1500	13.0	85Q FOAM	
06:49:30	7.0	1500	13.0	85Q FOAM	
06:50:00	7.0	1500	13.0	85Q FOAM	
06:50:30	8.0	1500	12.5	85Q FOAM	
06:51:00	7.5	1500	8.0	85Q FOAM	
06:51:30	7.5	1500	8.0	85Q FOAM	
06:52:00	7.5	1500	13.0	85Q FOAM	
06:52:30	7.5	1500	13.0	85Q FOAM	
06:53:00	7.5	1500	14.0	85Q FOAM	
06:53:30	7.5	1500	13.5	85Q FOAM	
06:54:00	9.0	1500	12.0	85Q FOAM	
06:54:30	6.5	1500	15.0	85Q FOAM	START 16.2 LB/GAL
06:55:00	8.0	1500	17.0	85Q FOAM	
06:55:30	6.5	1550	13.5	85Q FOAM	
06:56:00	7.0	1550	16.5	85Q FOAM	
06:56:30	7.0	1550	16.0	85Q FOAM	
06:57:00	7.0	1550	17.0	85Q FOAM	
06:57:30	7.0	1550	16.5	85Q FOAM	

BDM CORPORATION

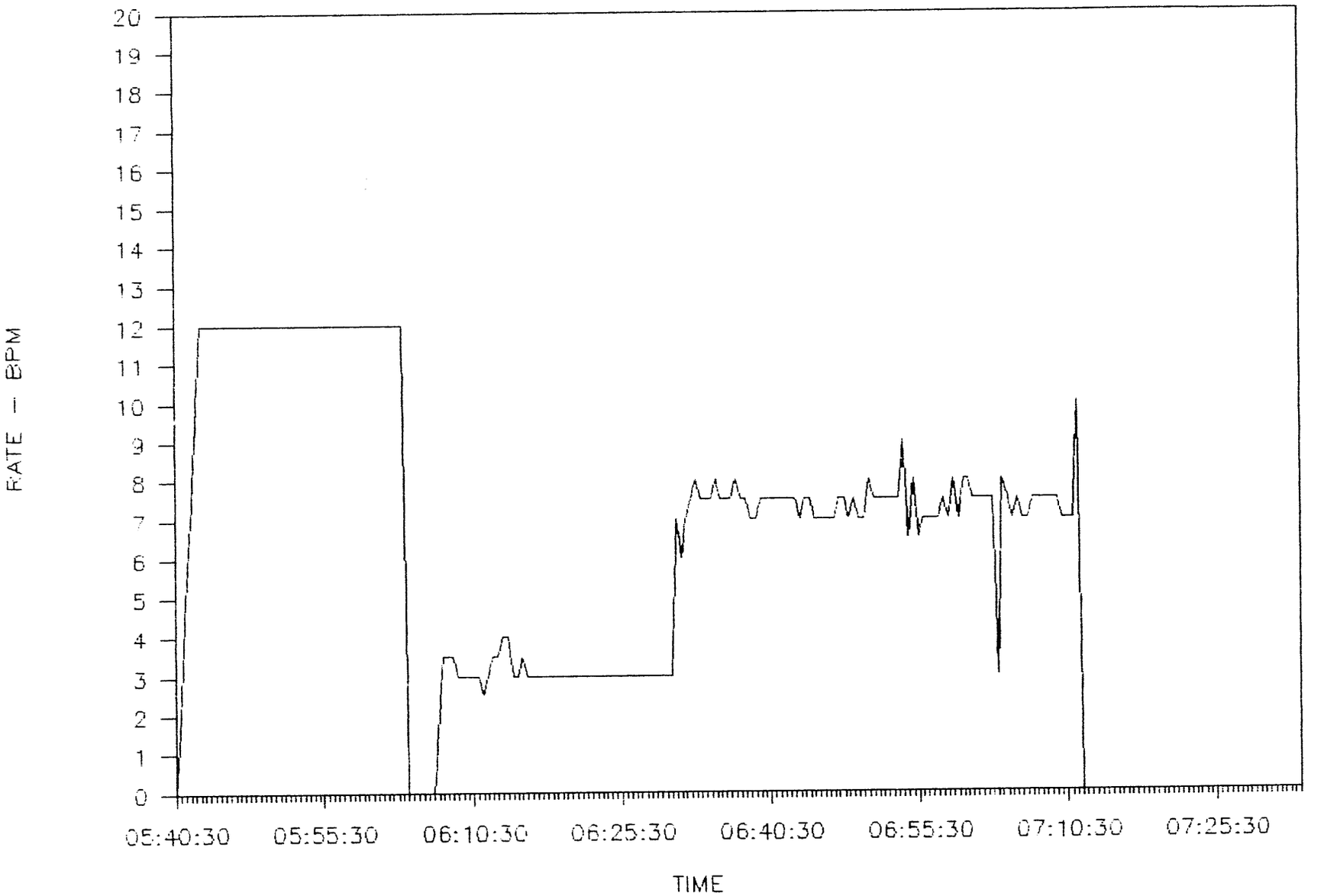
TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
06:58:00	7.5	1550	16.5	85Q FOAM	
06:58:30	7.0	1550	15.0	85Q FOAM	
06:59:00	8.0	1550	17.0	85Q FOAM	
06:59:30	7.0	1550	15.0	85Q FOAM	
07:00:00	8.0	1500	15.0	85Q FOAM	
07:00:30	8.0	1500	10.0	85Q FOAM	
07:01:00	7.5	1500	10.0	85Q FOAM	
07:01:30	7.5	1500	11.0	85Q FOAM	
07:02:00	7.5	1500	14.0	85Q FOAM	
07:02:30	7.5	1500	13.5	85Q FOAM	
07:03:00	7.5	1500	15.0	85Q FOAM	
07:03:30	3.0	1500	14.0	85Q FOAM	
07:04:00	8.0	1500	17.0	85Q FOAM	
07:04:30	7.5	1500	12.0	85Q FOAM	
07:05:00	7.0	1500	15.0	85Q FOAM	
07:05:30	7.5	1500	16.5	85Q FOAM	
07:06:00	7.0	1500	17.0	85Q FOAM	
07:06:30	7.0	1500	16.5	85Q FOAM	
07:07:00	7.5	1500	17.0	85Q FOAM	
07:07:30	7.5	1550	16.5	85Q FOAM	
07:08:00	7.5	1550	16.5	85Q FOAM	
07:08:30	7.5	1550	16.5	85Q FOAM	
07:09:00	7.5	1550	16.5	85Q FOAM	
07:09:30	7.5	1550	16.0	85Q FOAM	
07:10:00	7.0	1550	17.0	85Q FOAM	
07:10:30	7.0	1550	17.0	85Q FOAM	
07:11:00	7.0	1550	16.0	85Q FOAM	
07:11:30	10.0	1500	16.0	85Q FOAM	
07:12:00	10000 SCF	1350	16.0	N2	SAND IN - START N2
07:12:30	10000 SCF	1250	CUT	N2	DISPLACEMENT
07:13:00	10000 SCF	1300	0	N2	
07:13:30	10000 SCF	1350	0	N2	
07:14:00	10000 SCF	1350	0	N2	
07:14:30	10000 SCF	1400	0	N2	N2 DISPLACEMENT DONE -
07:15:00	0	1300	0	0	24,000 PUMPED
07:15:30	0	1300	0	0	
07:16:00	0	1250	0	0	
07:16:30	0	1250	0	0	
07:17:00	0	1250	0	0	
07:17:30	0	1250	0	0	
07:18:00	0	1250	0	0	
07:18:30	0	1200	0	0	
07:19:00	0	1200	0	0	
07:19:30	0	1200	0	0	

BDM CORPORATION

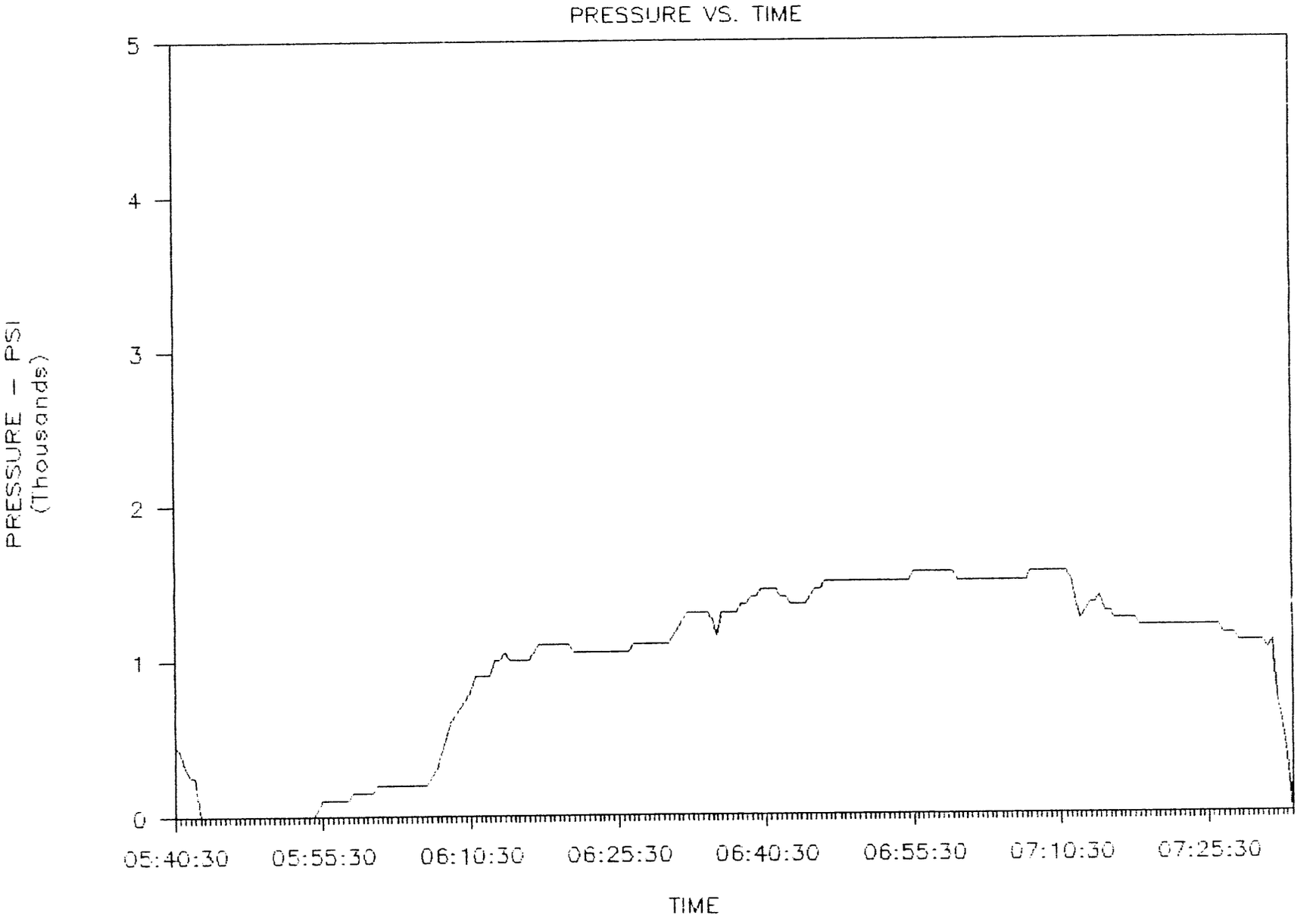
TIME	PUMP RATE (BPM)	PRESSURE (PSI)	SAND CONCEN (LB/GAL)	FLUID TYPE	EVENT
07:20:00	0	1200	0	0	5 MIN ISIP
07:20:30	0	1200	0	0	
07:21:00	0	1200	0	0	
07:21:30	0	1200	0	0	
07:22:00	0	1200	0	0	
07:22:30	0	1200	0	0	
07:23:00	0	1200	0	0	
07:23:30	0	1200	0	0	
07:24:00	0	1200	0	0	
07:24:30	0	1200	0	0	
07:25:00	0	1200	0	0	10 MIN ISIP
07:25:30	0	1200	0	0	
07:26:00	0	1200	0	0	
07:26:30	0	1200	0	0	
07:27:00	0	1150	0	0	
07:27:30	0	1150	0	0	
07:28:00	0	1150	0	0	
07:28:30	0	1100	0	0	
07:29:00	0	1100	0	0	
07:29:30	0	1100	0	0	
07:30:00	0	1100	0	0	
07:30:30	0	1100	0	0	15 MIN ISIP
07:31:00	0	1100	0	0	
07:31:30	0	1050	0	0	
07:32:00	0	1100	0	0	
07:32:30	0	750	0	0	
07:33:00	0	550	0	0	
07:33:30	0	350	0	0	
07:34:00	0	0	0	0	

BDM – R.E.T. #1

PUMP RATE VS. TIME

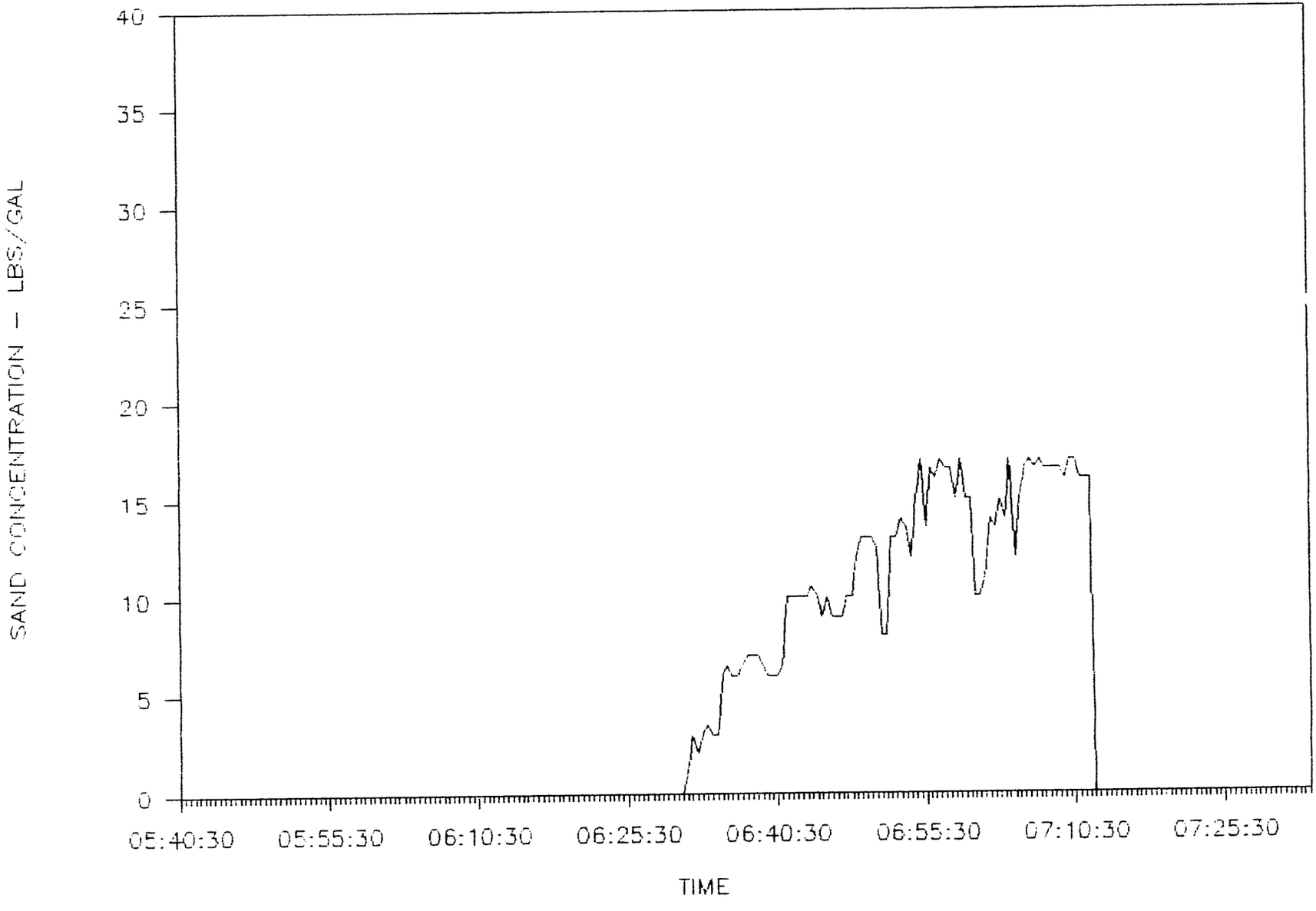


BDM – R.E.T. #1


PRESSURE VS. TIME
PRESSURE – PSI
(Thousands)
5
4
3
2
1
0
05:40:30
05:55:30
06:10:30
06:25:30
06:40:30
06:55:30
07:10:30
07:25:30
TIME

BDM – R.E.T. #1

SAND CONCENTRATION VS. TIME



6. TREATMENT REPORT

7. RECOMMENDATIONS

In relation to the fracturing fluid used, NOWSCO would like to offer the following information for consideration:

1. If no gell is to be used on future treatments, we would recommend doing one or more of the following to ensure job success:

   (A) Decrease the Methanol content since it is a very strong anti-foam agent.

   (B) Increase the foamer concentration from 5 gallons to 7 gallons per 1000. This would allow for better foam half-life and proppant transport.

These recommendations are made to eliminate or at least decrease the possibility of screenout from occurring.

NOWSCO also recommends that BDM/DOE also consider using a CO_2 treatment. We believe a CO_2 polyemulsion foam should be a very viable treatment for these wells.

Our reasons for recommending CO_2-based jobs are:

1. We anticipate better fluid returns after fracturing due to carbonation of the injected water.

2. Lower wellhead pressures.

8. FIELD INVOICE AND STRIP CHART

ACIDIZING / FRACTURING / NITROGEN INVOICE NO. _____

NOWSCO
3000 OLD AIRPORT RD.
WOOSTER, OHIO 44691
(216) 264-8885

CUSTOMER C.D.M.
ADDRESS 1179 Van Voorhis Rd.
Morgantown W.Va.

DATE 5/31/88
SERVICE ORDER NO. A 8949
ASSOC. NOWSCO REF. NO. 8369
P.O. NUMBER
QUOTE NO.
SERVICE ENG. Jim Paugh
STATION MGR. APP.

I HAVE READ AND UNDERSTOOD ALL OF THE CONTRACT TERMS ON THE BACK OF THIS DOCUMENT AND VOLUNTARILY ENTER INTO THIS CONTRACT ON BEHALF OF THE CUSTOMER. I FURTHER REPRESENT AND WARRANT TO NOWSCO THAT I HAVE BEEN DULY AUTHORIZED BY THE CUSTOMER TO ENTER INTO THIS CONTRACT ON ITS BEHALF AND TO EXECUTE THE SAME AS THE CUSTOMER'S AGENT. I DO HEREBY, ON BEHALF OF THE CUSTOMER, AUTHORIZE NOWSCO TO PROCEED WITH ITS DELIVERY OF ITS PRODUCTS, SUPPLIES, MATERIALS AND SERVICES IN ACCORDANCE WITH THE TERMS CONTAINED HEREIN. C.D.M.
Customer
W.K. Paugh
Agent

NAME OF WELL C.D.M. K.E.T. #1 | PERMIT NO.
TWP. | COUNTY | STATE W.Va
TYPE OF TREATMENT 1-Stage CO_2 + Foam

PRICE LIST REFERENCE	MATERIAL & EQUIPMENT	QUANTITY	UOM	UNIT PRICE	AMOUNT
	BLENDER	1	HR	[illegible]	
	VT-1200 PUMPERS	1	HR	[illegible]	700.00
	PUMPER CO_2	1	EA	[illegible]	3960.00
501-450	H.V. N_2 PUMPERS	3		[illegible]	2,000.00
501-451	EACH ADDITIONAL 1000 SCF/MIN				
	CO_2 TRANSPORTS	4	HRS	60.00	240.00
508-414	N_2 TRANS	2	HRS	50.00	100.00
	MILEAGE ON UNITS 50 X 7	350	M	2.35	822.50
307-217	80/100 MESH SAND		SK		
307-219	20/40 MESH SAND	1500	SK	6.60	9,900.00
307-220	10/20 MESH SAND		SK		
301-210	PROPPANT PUMPING CHG 100 MESH 20/40	1500	SK	.55	825.00
301-211	PROPPANT PUMPING CHG 10/20		SK		
	SAND CONC CHG - FOAM FRAC LB/gal 16.2	12432	GALS	.08	1,034.12
310-231	SAND CARTAGE TO LOC	3750	T/M	1.00	3,750.00
310-231	RETURN SAND CARTAGE		T/M		
	BALL INJECTOR - REMOTE/MANUAL		EA		
	BALL SEALERS		EA		
718-507	3¼" FRAC BALL		EA		
718-506	3⅛" FRAC BALL		EA		
718-505	3¼" FRAC BALL		EA		
718-508	3 FRAC BALL		EA		
[illegible]	Methanol	3941	GAL	1.75	1,397.00
226-[illegible]	Biocide 3.0P	1	7/A	36.50	36.50
[illegible]	Densimeter	1	EA	30.00	30.00
	CO_2 Vent Pump	1	EA	250.00	250.00

PRICE LIST REFERENCE	MATERIAL & EQUIPMENT	QUANTITY	UOM	UNIT PRICE	AMOUNT
	% ACID		GAL		
	INHIBITOR		GAL		
209-134	IS-300 IRON SEQ		GAL		
206-125	WS-60NE SURFACTANT		GAL		
230-162	CSA-3 CLAY STAB		GAL		
230-164	CSA-5 CLAY STAB	5	GAL	12.00	60.00
209-136	IS-60 IRON STAB	#1		5.25	5.25
239-100	CHEMICAL & ACID HAULING	6	HRS	50.00	300.00
239-200	TRANSPORT Methanol	4	HRS	50.00	200.00
	GELLANT		LBS		
	GEL BREAKER				
	GEL BUFFER				
	FRICTION REDUCER				
328-281	SF-2 FOAMER	1	GALS	12.00	12.00
321-273	KCL SALT	350	LBS	.80	280.00
330-010	CO_2 PRODUCT	40	TONS	600.00	24,000.00
501-405	N_2 PRODUCT FIRST 50,000 SCF	50,000	SCF	0.32	16,000.00
501-407	N_2 PRODUCT ADDITIONAL SCF	496,000	SCF	1.25	620,000.00
501-409	N_2 PRODUCT IN EXCESS OF 1 000 000 SCF		SCF	1.15	
	CO_2 77%	297.50			41,650.00
	Foam 23%	311.32		20.00	6,226.40
	TOTAL				62,226.40

UNIT NO.	EMPLOYEE
6105	Paugh
713	Sexton
6757	Dailey
5555	Griffith
5556	Hardman
5553	Todd
6301	Spitler

UNIT NO.	EMPLOYEE
6304	Lantz
2573	McDaniel
6573	Estes
2503	Harner
2754	Hammond

I, ON BEHALF OF THE ABOVE-NAMED CUSTOMER, DO HEREBY ACKNOWLEDGE RECEIPT AND ACCEPTANCE OF AND FROM NOWSCO WELL SERVICE, LTD., THE ABOVE-DESCRIBED SERVICES, PRODUCTS, SUPPLIES AND MATERIALS.

C.D.M.
Customer
Agent

WHITE - ORIGINAL • WHITE - HEAD OFFICE • GREEN - CUSTOMER COPY • YELLOW - STATION COPY • GOLDENROD - BOOK COPY

PDQ PRINT SHOP INC — CLARKSBURG WV

NOWSCO

NOWSCO WELL SERVICE (U.S.) INC.

TREATMENT REPORT
FRACTURING

TYPE OF TREATMENT CO^2 & Foam	CUSTOMER B. D. M	MO. DAY YEAR 8 31 88
NAME OF WELL B.D.M. - R.E.T. #1	ADDRESS Morgantown, W. Va	SERVICE ORDER 8949

FORMATION	DEPTH	BAFFLE SIZE	FRAC BALL	CASING	PERF. DEPTH	NO. & SIZE OF PERFS.
1. Shale	4900			4½	3932 - 4894	
2.						
3.				10.5		
4.						

HORSEPOWER	TOTAL FLUID	TOTAL SAND	BREAKDOWN	INST. PRESS	BREAKDOWN	INST. PRESS	BREAKDOWN	INST. PRESS	BREAKDOWN	INST. PRESS
	376	1500 sks	1	1280	2	2	3	3	4	4

TIME A.M. (P.M.)	PRESSURE	CUM. FLUID	STAGE FLUID	RATE	LBS/GAL	COMMENTS
						Safety Meeting
						Pressure Test
3:04	0		32,000	2,000/min		Pump N^2 down tubing
3:15	500					Stop Pumps
				6,000/min		Pressure Casing
			24,000			Stop Pumps
				12		CO^2 Pad
		$H2^2$	Foam			
6:07	370	80	528	25		Foam Pad
6:31	1120	104	158.4	50	½	Start 20/40 Mesh
6:34.4	1280	152	316.8	50	1	Inc 20/40 Mesh
6:41	1420	200	316.8	50	1½	Inc 20/40 Mesh
6:47.6	1500	248	316.8	50	2	Inc 20/40 Mesh
6:53.8	1520	376	844.8	50	2½	Inc 20/40 Mesh
7:12	1300			10,000/min		Flush (N^2)
7:14.4	1340		24000			

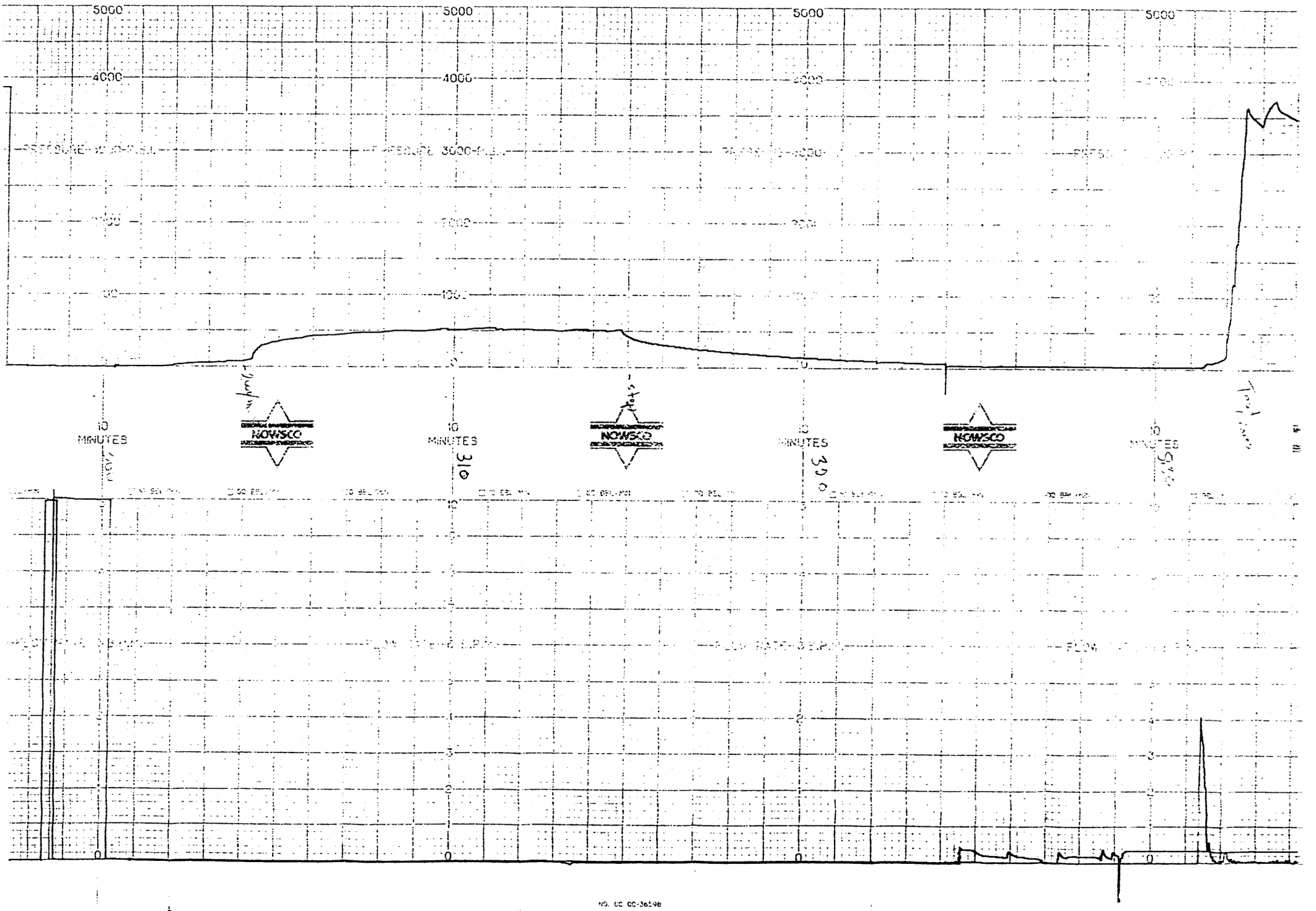
1. CHEMICAL	AMOUNT
C.S.A-S - 8 gal	
IS-600 - 79 lbs	
CO^2 - 40 tons	
Methanol - 3948 gal	
K.C.L. - 3500 lbs	
[redacted]	
N^2 - 746,000	
SF-1 - 79 gal	
Nowcide 308 - 1 gal	
20/40 Mesh - 1500 sks	

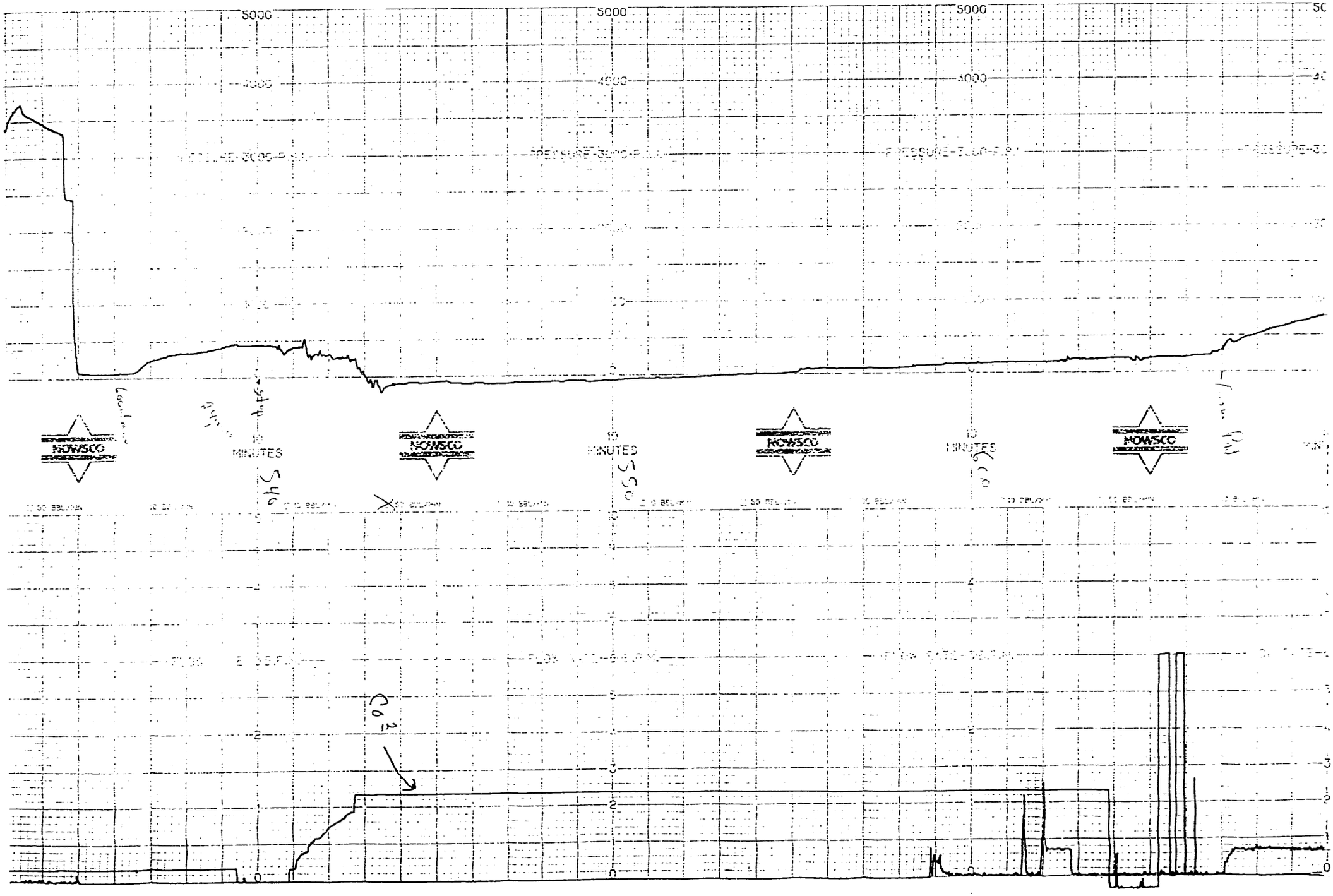
3.

5 min - 1210
10 min - 1160
15 min - 1130

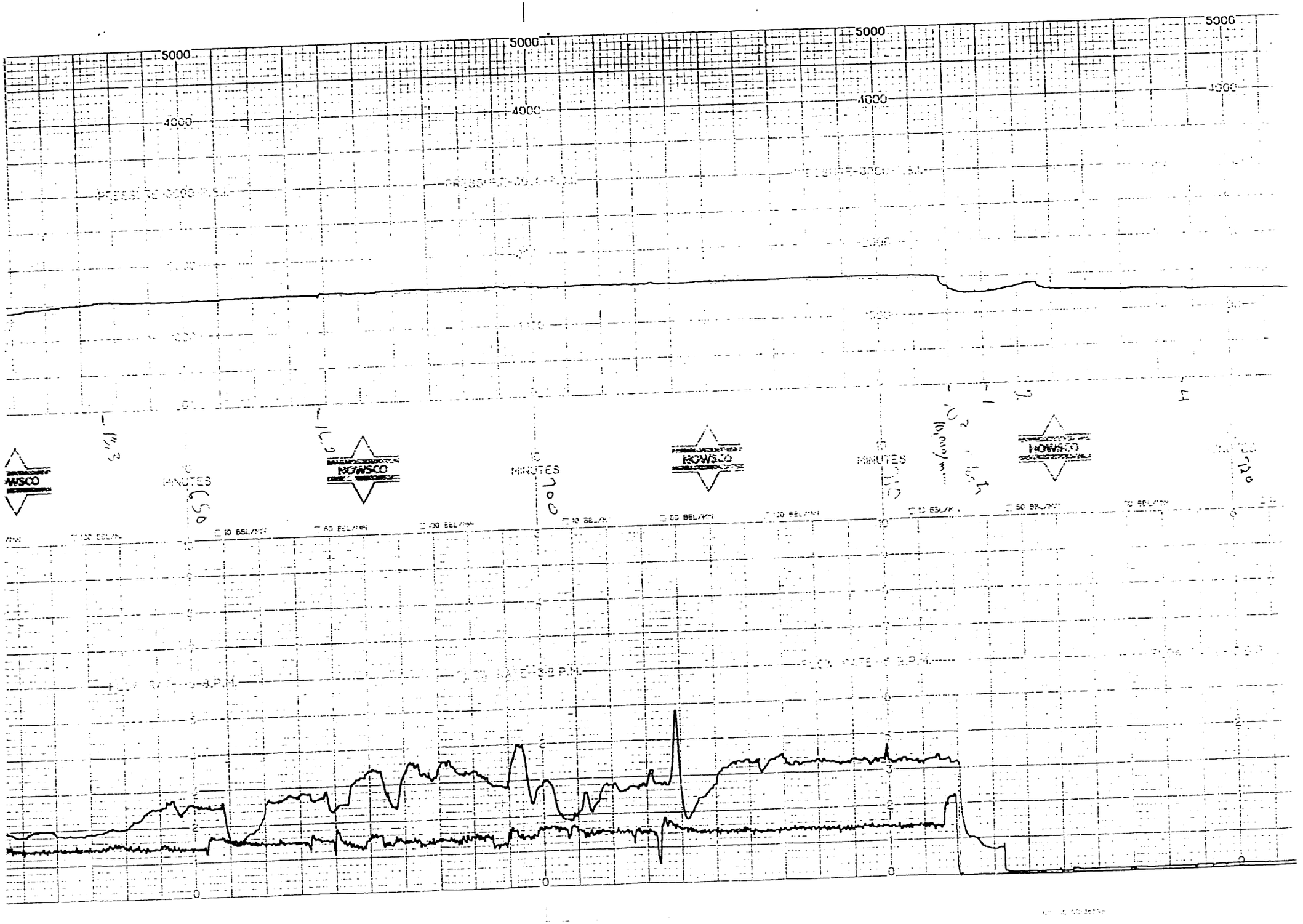
[redacted]

4. Jim Paugh


5000
4000
3000
2000
1000
0
10
MINUTES
NOWSCO
FLOW


5000
4000
3000
2000
1000
0
10
MINUTES
HOWSCO
CO2


5000
4000
PRESSURE-3000-P.S.I.
MINUTES
NOWSCO
0
1
2
3


5000
4000
MINUTES
HOWSCO

13
730
10
720
4

NOWSCO Well Service
950 GREENTREE ROAD • PITTSBURGH, PA 15220
PHONE (412) 937-1411 • FAX (412) 937-1405

October 12, 1988

Mr. Bill Overbey
BDM Corporation
1199 Van Voorhis Road, Suite 4
Morgantown, West Virginia 26505

Dear Bill,

Please find attached the plot of PFrac-Pcl vs. time you requested.

Several points are worth noting with respect to the graph itself and the data used:

1. It appears a screenout was imminent if we believe the data.

2. It is possible that two major fractures were developed, one from the nine to 20 minute time frame and one from 20 minutes onward.

3. The friction data used may or may not be correct. About all we can say with respect to this is that these graphs didn't appear to be relevant during the first job. However, these values should be "relative."

4. We estimated a bottom hole closure pressure of 850 psi for the analysis.

Hope this "very generalized" graph can help in some way.

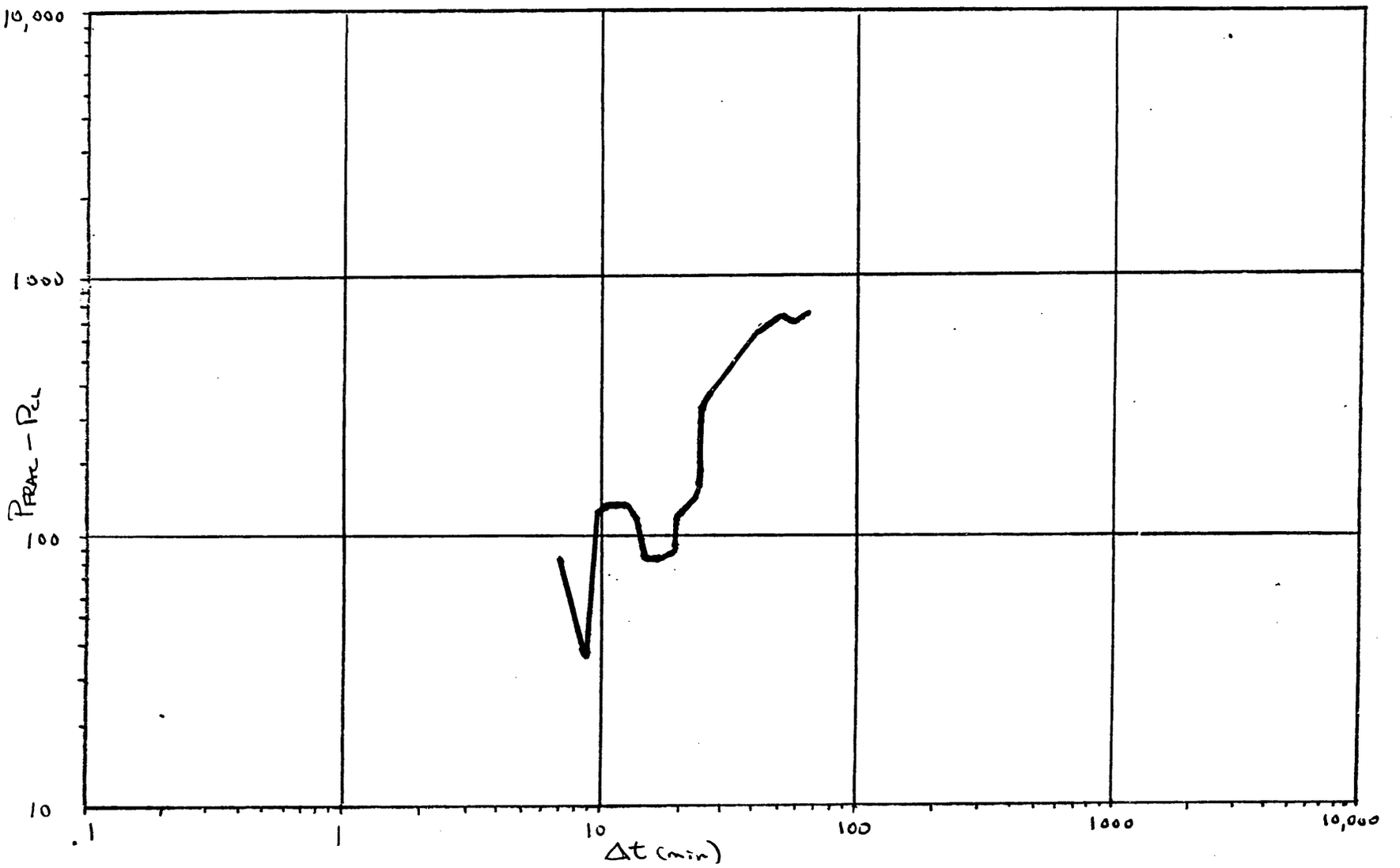
For future jobs, possibly you could leave a small ID string (dead string) in the hole and treat down the annulus, thus allowing you to record bottom hole frac pressure. You could also run an Amerada RPG-3 on bottom.

Sincerely,

Tom Udick

BDM

$P_{FRAC} - P_{CL}$ vs Time



APPENDIX G
FRACTURE DIAGNOSTICS REPORTS AND SUPPORTING MATERIALS

* * * * *

FINAL REPORT

RECOVERY EFFICIENCY TEST WELL #1
CABWAYLINGO STATE FOREST
WEST VIRGINIA

PREPARED FOR:

THE BDM CORPORATION
1199 VAN VOORHIS ROAD, SUITE 4
MCCLEAN, WEST VIRGINIA 22102-3396

ATTENTION:

MR. W. K. OVERBEY, JR.

BY

HUNTER GEOPHYSICS
188 SOUTH WHISMAN ROAD
BUILDING A
MOUNTAIN VIEW, CALIFORNIA 94041
(415)961-3714

SUBMITTED OCTOBER 5, 1987

* * * * *

INTRODUCTION

Hunter Geophysics monitored the well in Cabwaylingo State forest, West Virginia, in an effort to determine the orientation and dimensions of the fracture. A circular array of eight instruments was placed above the approximate location of the first zone to be stimulated (Figure 1). On September 23 the well was stimulated with an injection interval of 12:59 to 17:20 hours. (Appendix A provides general information on use of tiltmeter monitoring operations.)

SITE PREPARATION

Hunter Geophysics' standard site is drilled approximately 20 feet in depth for several reasons. The 20 foot depth reduces the amount of noise and/or drift created by surface conditions such as rain, thermal effects, and local traffic. The magnitude of the noise, due to these variables, is always an unknown until a site is actually instrumented and data collected. In general, a site drilled to a depth of 20 feet will reduce the noise to a level that allows a signal from a fracture to be measured very easily. Hunter has never experimented with sites of less depth using instruments presently being manufactured.

Site preparation for this project is constrained by access and environmental impact. Eight sites were prepared at an average depth of 4 to 6 feet. The magnitude of drift and noise due to weather and thermal effects is expected to be higher in shallow sites, but the magnitude cannot be predicted. The sites were very remote, considering the amount of noise created by local traffic. It was hoped that reduction in local traffic noise might compensate for the increased noise due to other variables.

Actual site preparation was conducted from September 10 to September 15. This entailed drilling of sites and cementing of instrument casings in the hole. The installation of tiltmeters followed, beginning on September 15 and ending on September 16.

SITE STABILIZATION

Collection of data immediately after installation of tiltmeters has historically shown that a stabilization period of approximately 3 to 7 days is required. A high drift rate continues during this period until the instrument settles into the site and "locks in". Once the instruments "lock in" it may be possible to monitor earth tides, if conditions are favorable. The time needed for the tiltmeter to "lock in" after being installed in a shallow site is unknown.

The average drift rate of an instrument installed and "locked in" in a site prepared to 20 feet in depth is approximately 1 to 4 microradians per day. The range of a Hunter instrument is 10 microradians full scale.

DATA COLLECTION

All eight sites were powered-up on September 16 to begin the stabilization period. Data collection did not start at this time due to high rate of drift that made the tiltmeters go offscale in a matter of hours. It was hoped that the a one week site stabilization will occur thus decreasing site noise.

Data collection began September 21 to obtain two days of background data prior to stimulation. The tiltmeters continued to present high rate of drift and go offscale in a few hours. This observed rate of drift is on the order of 2 to 6 microradians per hour. Since the tilmeters consistently drifted offscale, continuous data could not be collected. Such large gaps in data sets prevent Hunter from using any signal processing to help retrieve a signal from the data.

Several hours before the stimulation, the tiltmeters were re-zeroed or leveled up to give the instrument the maximum range of tilt. It was hoped that the instruments would stay on scale for the duration of the stimulation. Actual data collected for the stimulation is as follows:

Site #1 - channel 1, data showed no signal due to site noise.
channel 2, drifted offscale during stimulation.

Site #2 - channels 3 and 4 show no signal due to site noise.

Site #3 - channel 5, drifted offscale during stimulation.
channel 6, data showed no signal due to site noise.

Site #4 - channels 7 and 8 both drifted offscale prior to the stimulation.

Site #5 - channels 9 and 10 show no signal due to site noise.

Site #6 - channel 11, drifted offscale prior to the stimulation.
channel 12, data showed no signal due to site noise.

Site #7 - channels 13 and 14, site did not collect data, unable to re-zero tiltmeter due to large amount of drift.

Site #8 - channel 15, drifted offscale during stimulation.
channel 16, drifted offscale prior to stimulation.

Data collected during the stimulation is shown in Appendix B.

Background data after the stimulation continued to have a high rate of drift and would also go offscale. On September 25, two days after stimulation and a full ten days after the instruments were installed, data collection ended.

CONCLUSIONS

The recorded rate of drift proved to be much larger than what is predicted from conventional sites and is probably due to the shallowness of the sites. Drift rate was sufficiently large and random enough to prevent Hunter from extracting the stimulation signal from the data. Noise due to rain, thermal effects and local variables is too large in sites prepared to only 4 to 6 feet in depth. At the time data collection was stopped, the drift rate had not shown any signs of slowing down or becoming more stable. There is presently no evidence to indicate that the drift rate will slow to a level that will allow Hunter to monitor future stimulations successfully under current site conditions.

APPENDIX A

A BRIEF REVIEW OF THE USE OF TILTMETERS TO MONITOR HYDRAULIC FRACTURE AND ASSOCIATED PRODUCTION OPERATIONS

INSTRUMENTS AND INSTALLATION

The tiltmeters used by Hunter Geophysics are essentially very sensitive "bubble levels", and while Hunter custom builds our own instrumentation, the basic theory follows instruments originally developed by the U.S. Department of Defense.

A schematic of the sensor is seen in Figure 1. The sensor consists of a container with a curved surface (the curvature of this surface is greatly magnified for this schematic) which is filled with two liquids having different electrical properties. The position of the small bubble of fluid in the center changes as the sensor is tilted, thereby changing the resistance between the five electircal contacts. By measuring the resistance changes, the tilt change can be determined along two directions (along the lines of electrodes A-E-C and B-E-D).

While simple in theory, the instruments are remarkably accurate. Utilizing state-of-the-art electronics (custom designed and manufactured by Hunter) the instruments achieve a resolution on the order of 1.0×10^{-9} radians or 1 nano-radian. This is equivalent to a change in height from New York to Los Angeles of less than 1/4 of an inch. However, to utilize this resolution the proper installation of the instruments must be: 1) protected from temperature changes; 2) adequately coupled to the earth and; 3) positioned so that the tilt recorded in two directions corresponds to "known" directions. The tiltmeters are typically installed 10 to 20 feet deep as shown schematically in Figure 2. They are installed, using techniques proprietary to Hunter, in a manner to insure adequate coupling to the earth, and to align the two "axes" of the sensor with magnetic North-South and East-West.

DATA AQUISITION

The changes in resistance created by tilting the bubble sensor are electronically converted into a voltage which is proportional to the tilt of the instrument. The voltage is then recorded in one of two ways. For many field installations, cables are run from each instrument site to a central data collection point; there the voltage is converted to a digital number and stored by a computer for later analysis. In some situations, the size of the array or the local topography makes hard-wiring the instruments difficult or impossible therfore, radio telemetry is used to transmit the data to a central location. When radio telemetry is utilized, a separate data logger is located at each tiltmeter site. These small data loggers record the data independent of the radio transmission and computer storage. Thus, they supply a backup in case of radio transmission problems.

The recorded magnetic North-South and magnetic East-West tilts are corrected and stored, and analyzed, in terms of true North-South. Therefore, all maps, displays, and results reported by Hunter are in terms of true North-South coordinates.

SENSE OF TILT AND FRACTURE SIGNAL

Along each axis of the tiltmeter, tilt can be in two directions. For example, the tilt of the East-West axis instrument can be down to the East or down to the West. The sense of the instruments is arbitrarily defined so that tilt "down-to-the-East" is positive (or for the North-South axis of the instrument, the tilt "down-to-the-north" is positive). This is illustrated in figures 3 and 4. Figure 3a shows a possible position of a tiltmeter shortly before a fracture stimulation. Due to the original installation and from drift, the instrument is not level but is currently positioned down-to-the East. If the time is early morning, the sun rising in the east will cause temperature changes which will cause the ground to the East to swell - thus the "drift" of the instrument will be "down-to-the-West" and the data from the East-West channel of the tiltmeter will be decreasing, as seen in Figure 4.

Shortly after the stimulation begins, the tilt at the earth's surface is due to the hydraulic fracture which is superimposed on the overall trend. If the fracture causes the East-West tilt at this particular site to be down-to-the-East, the tiltmeter would respond as seen in Figures 3b and 4. The "signal" is the tilt associated with the hydraulic fracture and this is measured as the difference between the recorded data, and an extrapolation of what the data would have been if the hydraulic fracture had not occurred. For this example, the "signal" is negative, illustrating that the fracture created a tilt at this instrument site which was down-to-the-West. A similiar signal is then measured for the North-South axis of this instrument, and for the two axes of each of the other instruments.

TILT VECTORS

"Tilt Vectors" are used as a convenient way of pictorially displaying the tilt signals. The convention used is that the tilt vector for a particular site points "downhill". For example, assume that the tiltmeter discussed above is No. 8 in an eight element circular array as seen in Figure 5. If the hydraulic fracture which created the down-to-the-West signal at this site caused no North-South tilt, then the tilt vector for this site (site no. 8) would point to the West as seen in Figure 5a. That is, the total amount of tilt at site No. 8 caused by the hydraulic fracture was enough to rotate the surface down-to-the-West.

If the hydraulic fracture, in addition to causing the down-to-the-West tilt, had caused a down-to-the-North tilt (e.g. a positive signal on the North-South axis of the tiltmeter), the tilt vector would point West (down-to-the-West) and North (down-to-the-North), or North-West as seen in Figure 5b.

Since the length of the tilt vectors is proportional to the magnitude of the tilt, a tilt vector map or display is a convenient method of presenting the data from an array of tiltmeters. This array of "measured tilt vectors" is then compared to theoretical values which are generated from computer models for various hydraulic fracture geometries and orientations.

TILT FROM HYDRAULIC FRACTURES

The first analysis is to examine the pattern of the tilt vector display. A hydraulic fracture will deform the earth's surface in a predictable manner, with figure 6 showing schematic 3-D representations of the surface deformation for vertical and horizontal fractures.

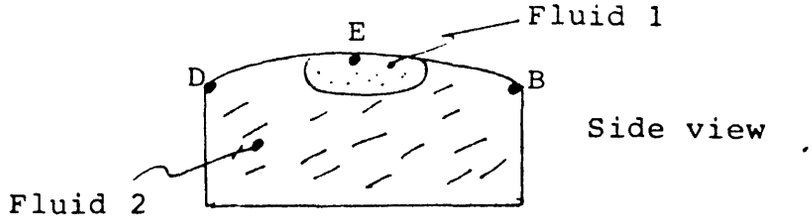
Figure 7 shows a cross section of the surface deformation for a vertical fracture, with the cross section being perpendicular to the "strike" or azimuth of the hydraulic fracture. For instruments located away from the fracture by about 40% of the depth, the tilt is maximum, and is down toward the fracture. Thus a theoretical tilt vector array for a North-South vertical fracture would appear as seen in Figure 7b.

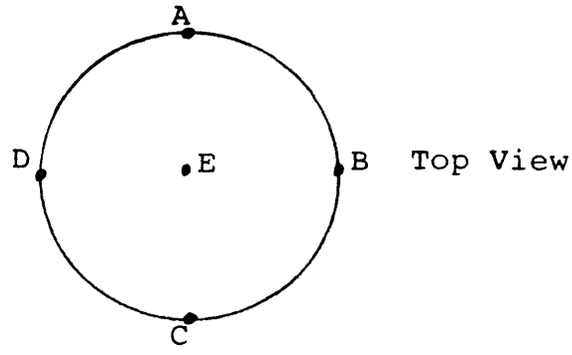
Figure 8 shows tilt vector patterns for both a vertical and horizontal fracture. As one might expect, the horizontal fracture creates a simple, radially symmetric array of tilt vectors which all point away from the center of the horizontal fracture.

The obvious difference between the appearance of these two tilt vector arrays illustrates the point that the "tilt pattern" is primarily influenced by the orientation (e.g. vertical versus horizontal and azimuth of the fracture). The examples above have illustrated the tilt pattern for the two primary orientations of hydraulic fracture, however it should be noted that more complex patterns are possible. As an example of this, consider the tilt patterns for "dipping" fracture with a strike (or azimuth) of North-South and a dip of 45 degrees. The normal geologic definition of "dip" is employed where dip is measured clockwise, with positive viewed "northerly" along the strike of the fracture. Thus a North-South fracture with a dip of 45 degrees is dipping down to the East. Note that vertical fracture would have a dip of 90 degrees.

The discussion above has concentrated on the "pattern" of tilts created by a hydraulic fracture. It is this pattern which is the primary indicator of fracture orientation and azimuth. The magnitude of the tilt is less sensitive to fracture orientation than to fracture volume (in addition, of course, to being extremely sensitive to fracture depth). Within limits it is volume that determines the magnitude of the tilts, as opposed to any individual injection dimension. That is, a "larger, narrower" fracture will create a tilt field which is almost identical to a "shorter, wider" fracture. Even though this represents some restriction on the use of the tiltmeters or other surface deformation data for determining fracture dimensions, the surface measurements do give a reliable measurement of fracture volume. Often, tilt magnitude used in conjunction with other data such as fracture pressures or post-frac performance can provide the required constraint for fracture volume needed to define fracture dimensions such as penetration and width.

SCHEMATIC OF TILT SENSOR





Schematic of Two-Axis Tilt Sensor
Utilized in Hunter Geophysics Tiltmeters.

Figure 1

Typical Tiltmeter Installation

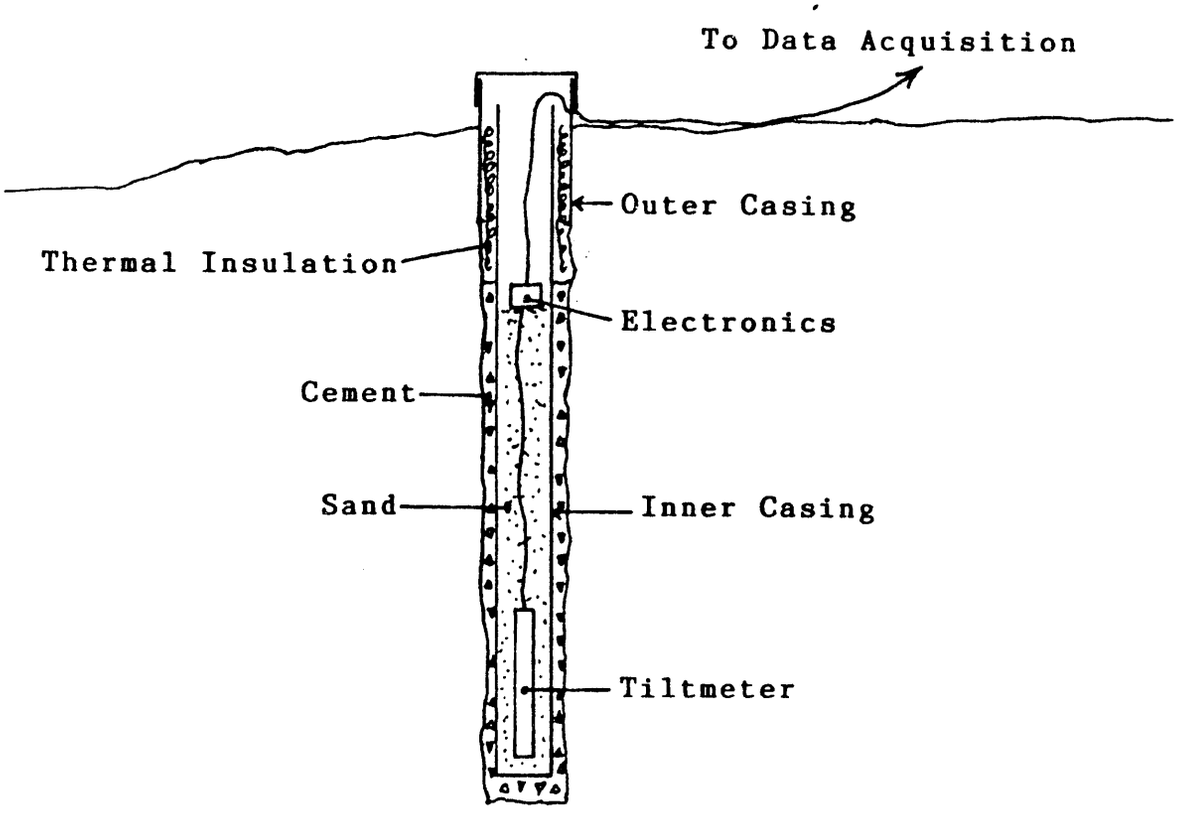
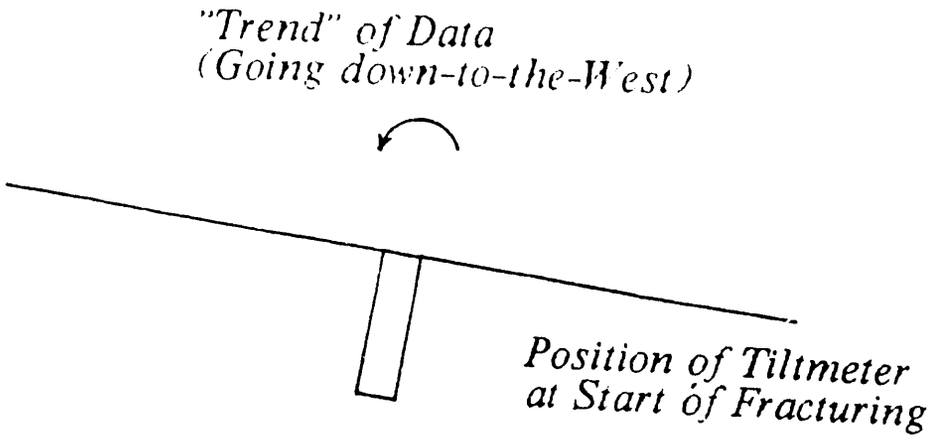


Figure 2


"Trend" of Data
(Going down-to-the-West)
Position of Tiltmeter
at Start of Fracturing

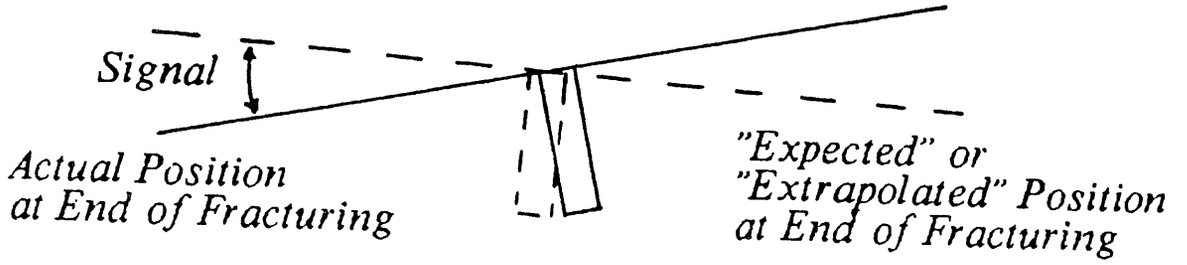
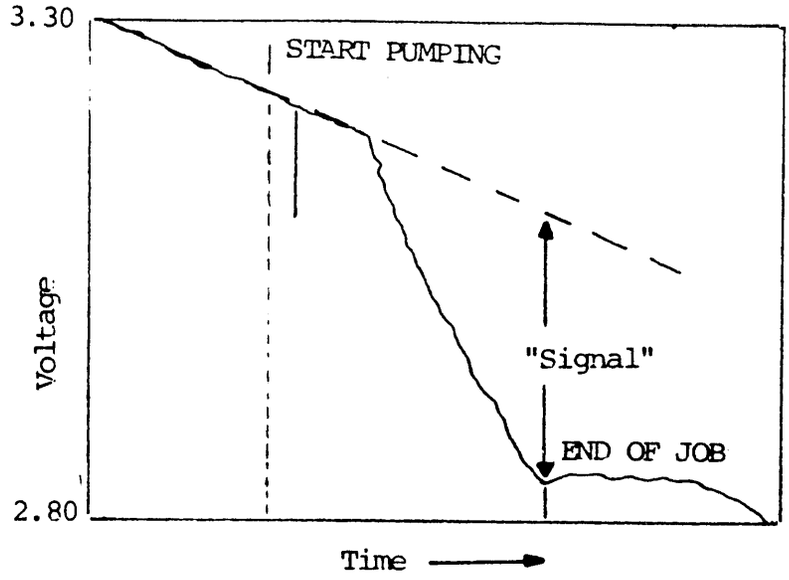

Signal
Actual Position
at End of Fracturing
"Expected" or
"Extrapolated" Position
at End of Fracturing

Figure 3



Raw "East-West" Tilt Data From a Tiltmeter Located Approximately 100 feet North-West of a Well Which is Approximately 2000 feet Deep.

Figure 4 - Typical Tilt Signal and Example of Picking Hydraulic Related Tilt.

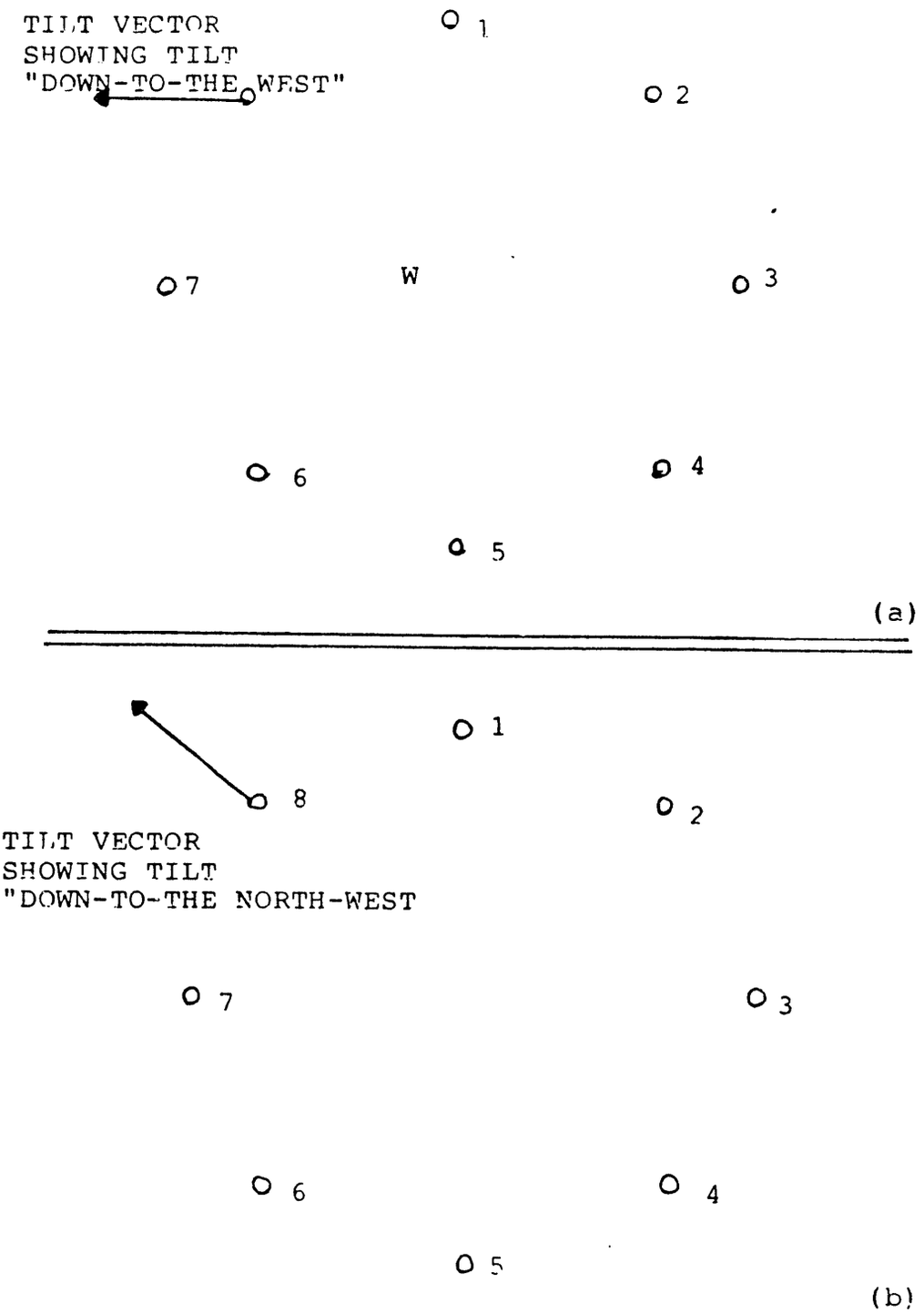
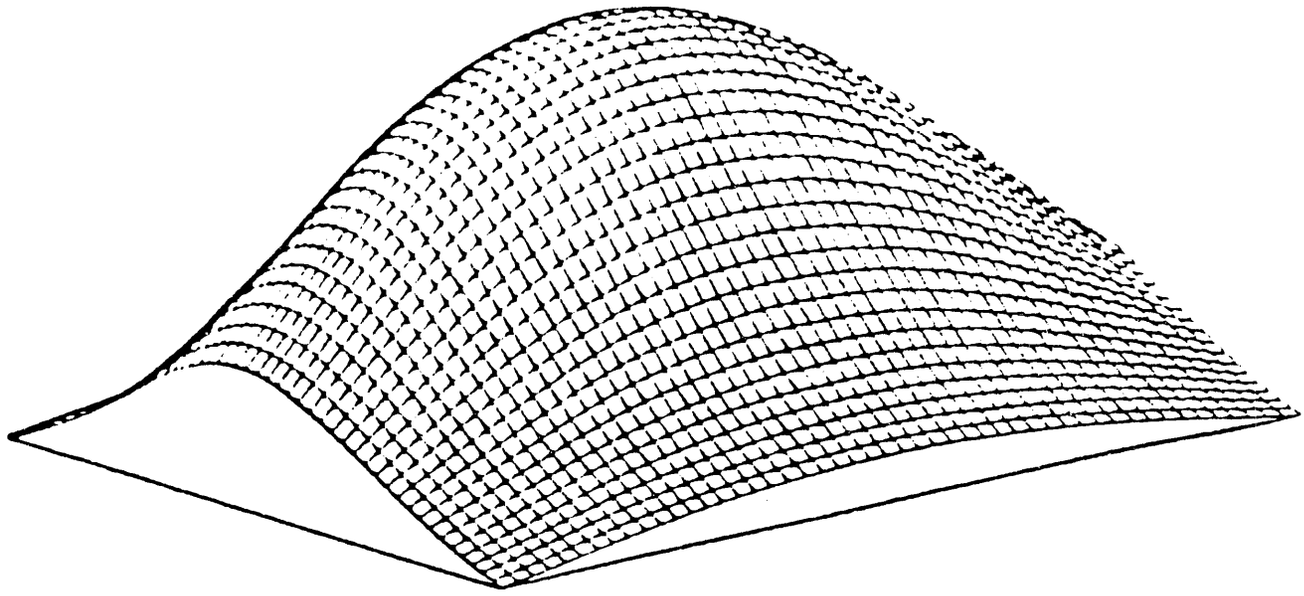
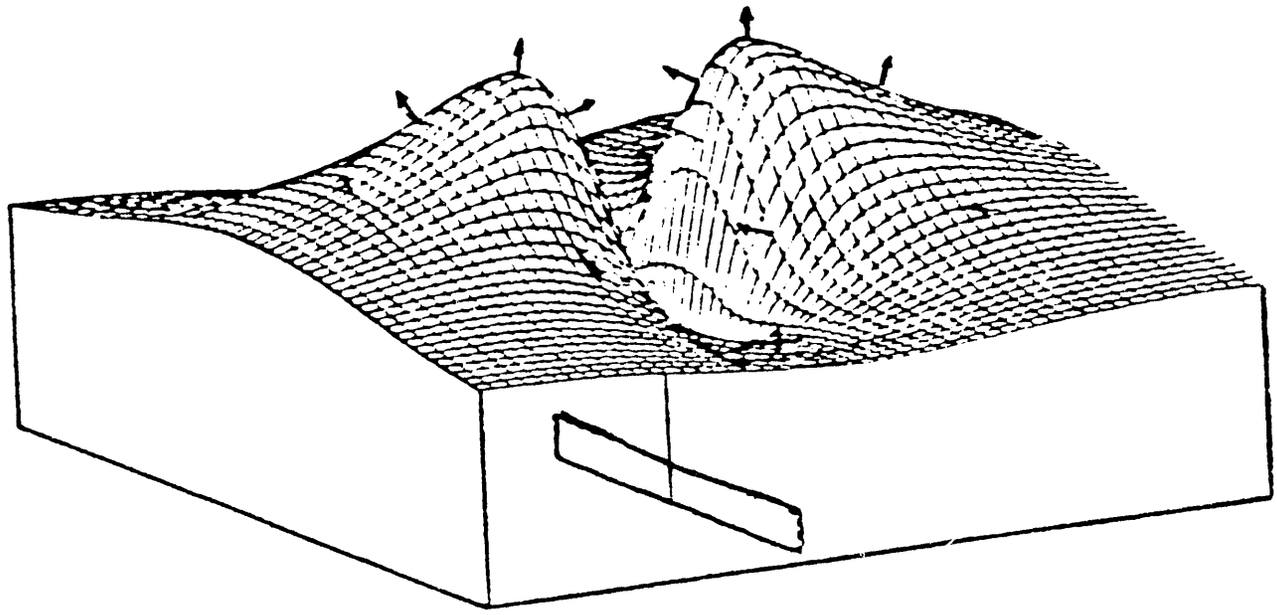


Figure 5 - TYPICAL TILT VECTOR MAP



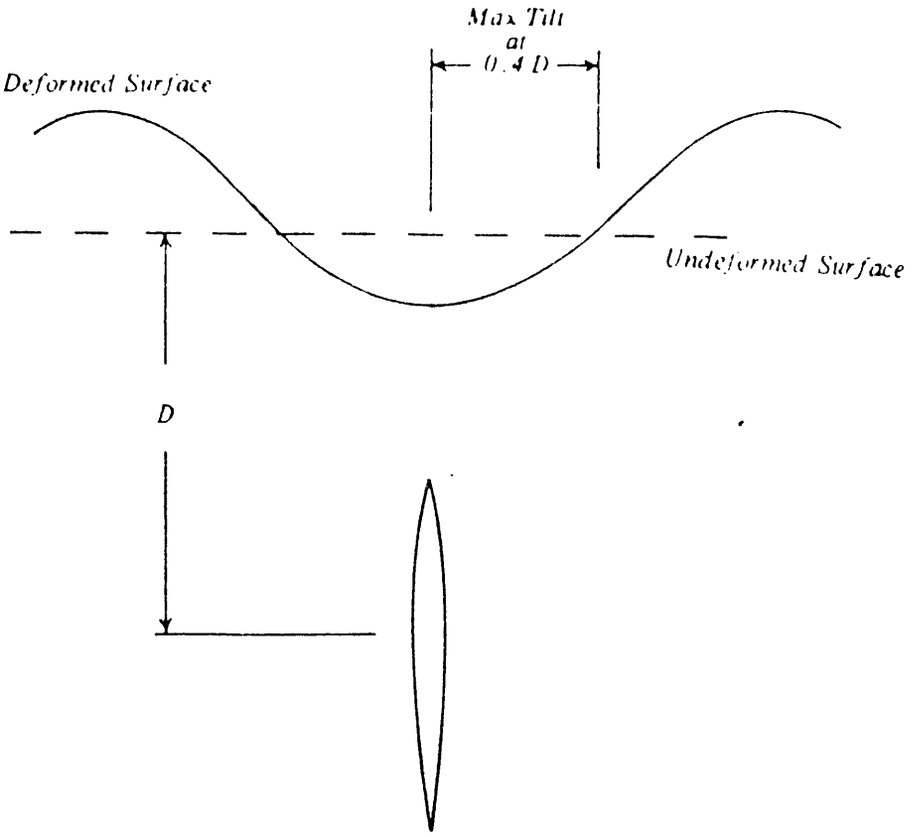
HORIZONTAL FRACTURE



VERTICAL FRACTURE

HYDRAULIC FRACTURE INDUCED
SURFACE DEFORMATION

Figure 6



Surface deformation (a) and Tilt vectors for a vertical fracture (b).

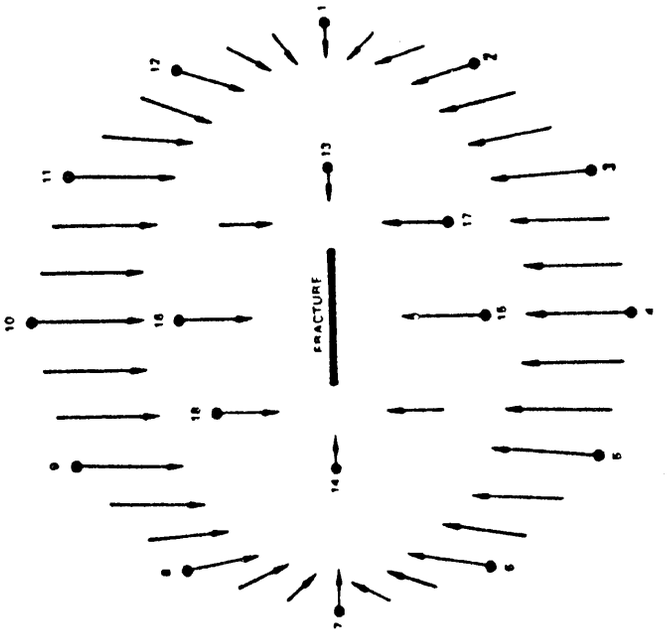
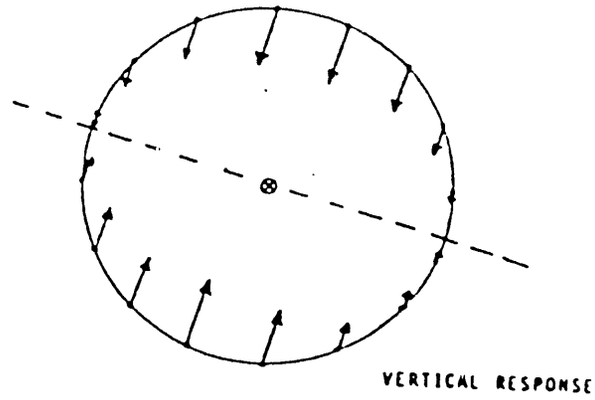


Figure 7



Tilt Vector "patterns"
for horizontal and
vertical fractures.

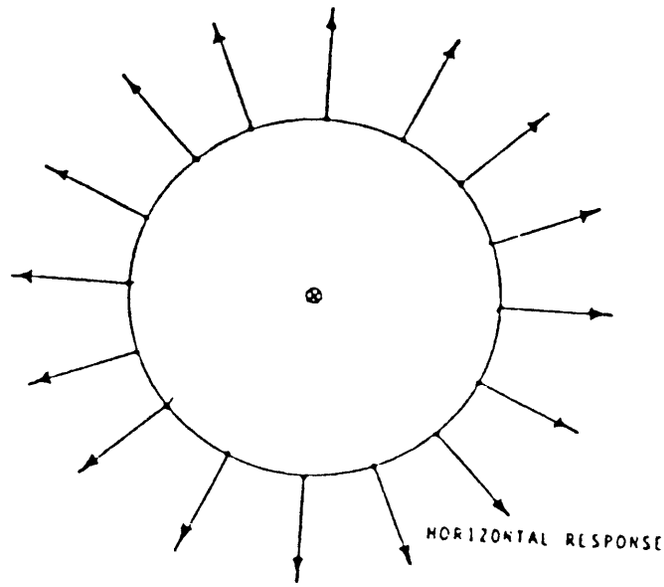
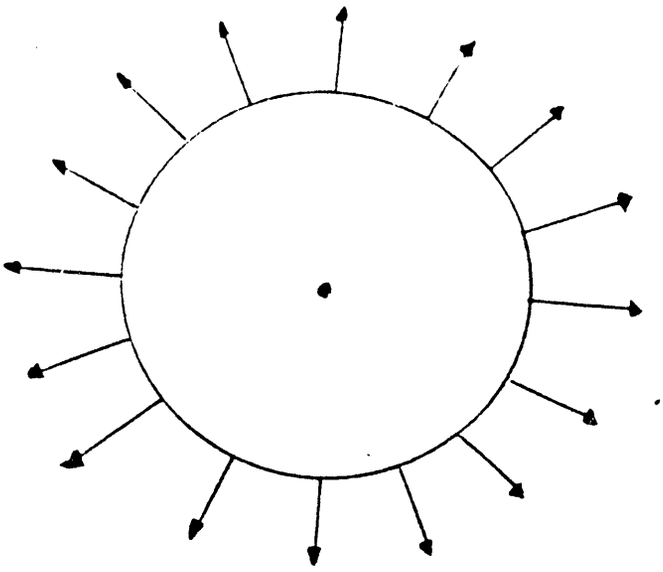


Figure 8



TILT VECTOR RESPONSE FOR A HORIZONTAL RADIAL FRACTURE AND FOR A 45 DEGREE DIPPING FRACTURE.

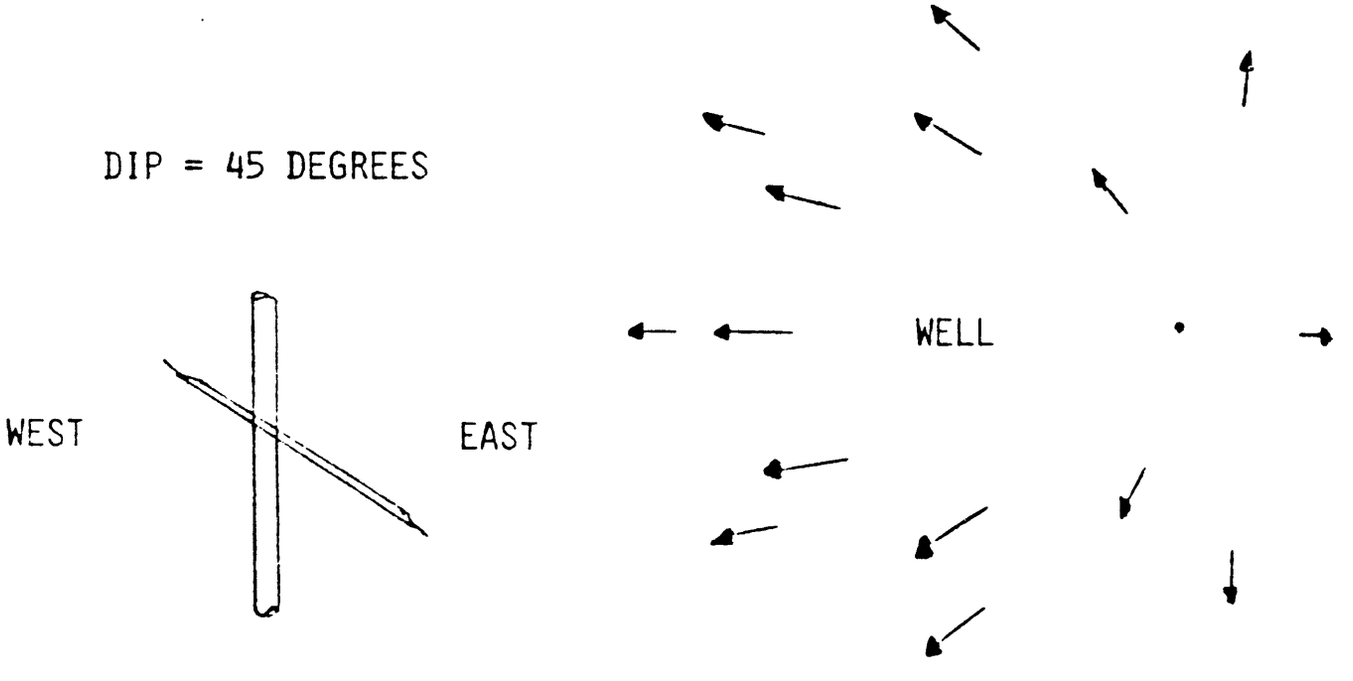
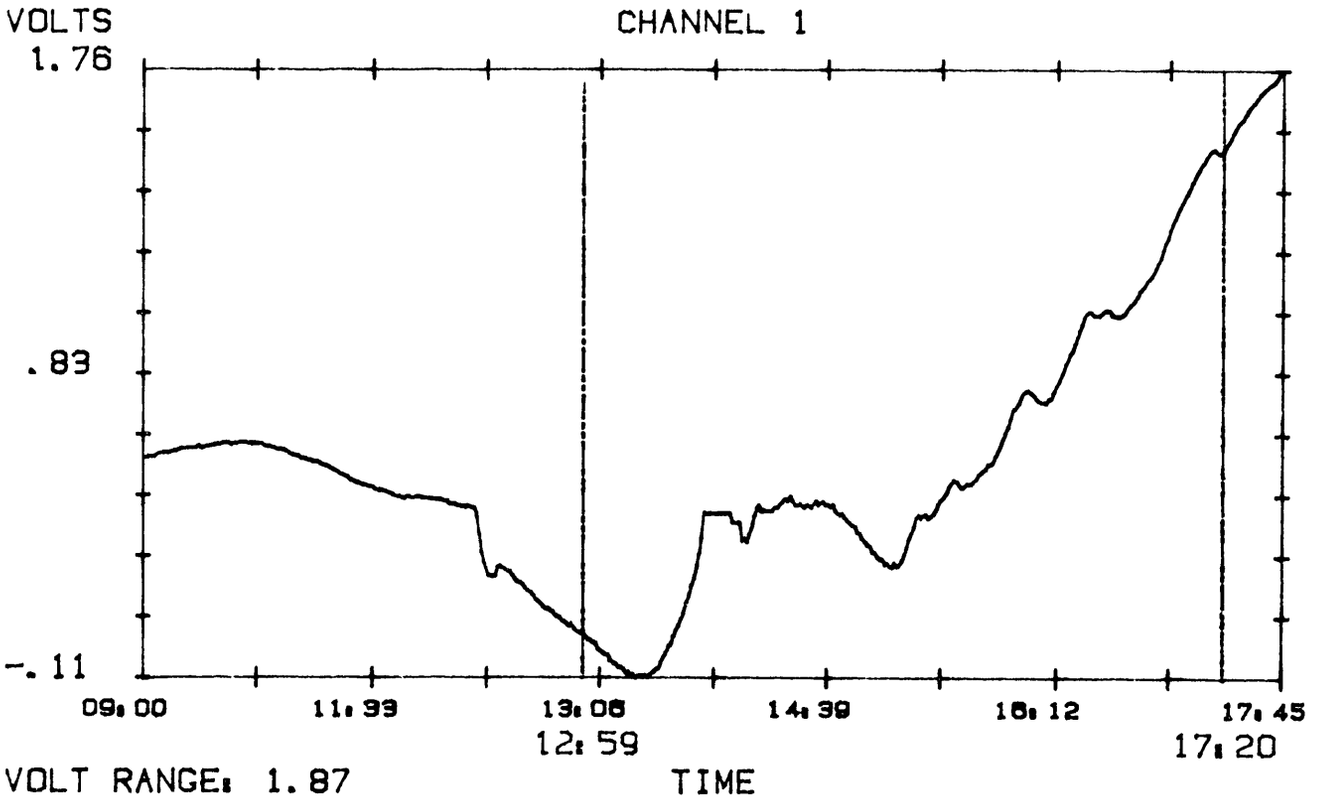
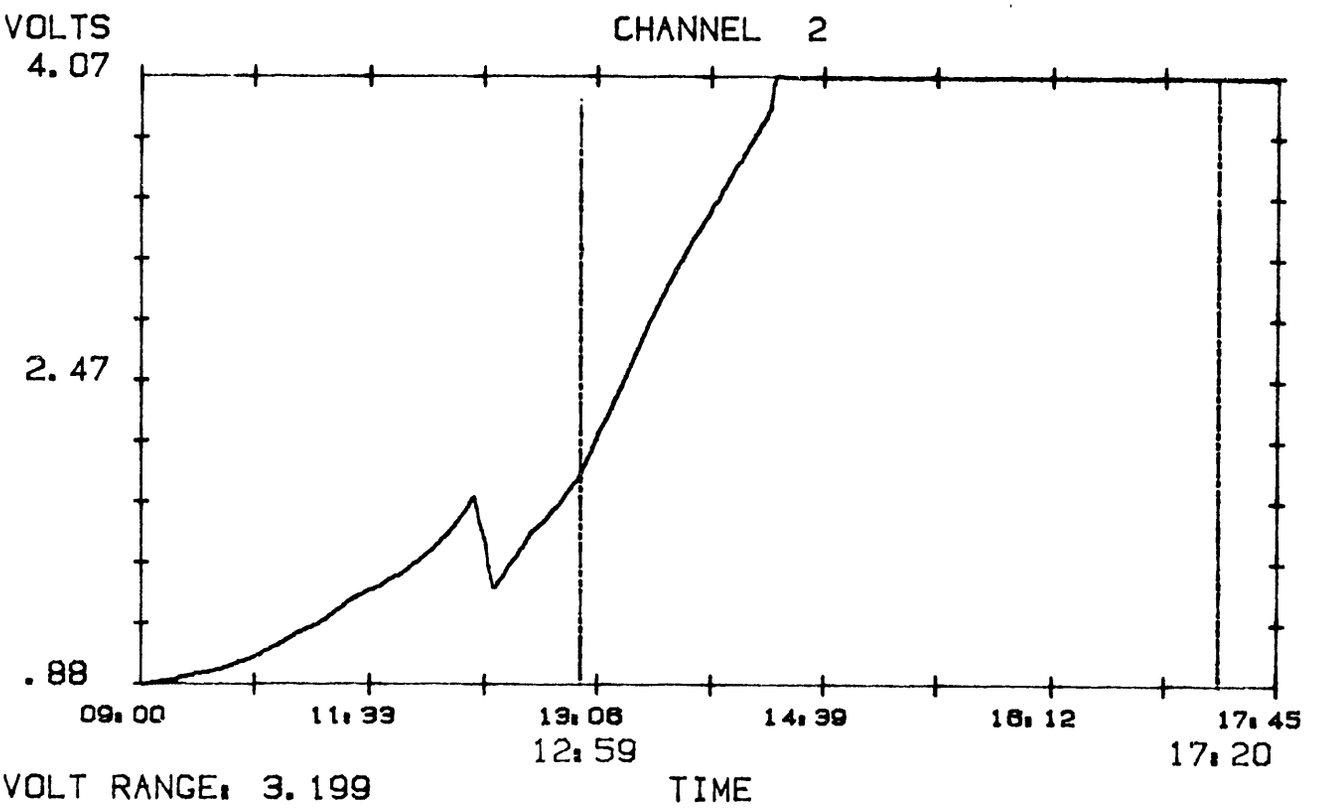


Figure 9

APPENDIX B

RAW TILTMETER DATA FOR THE STIMULATION





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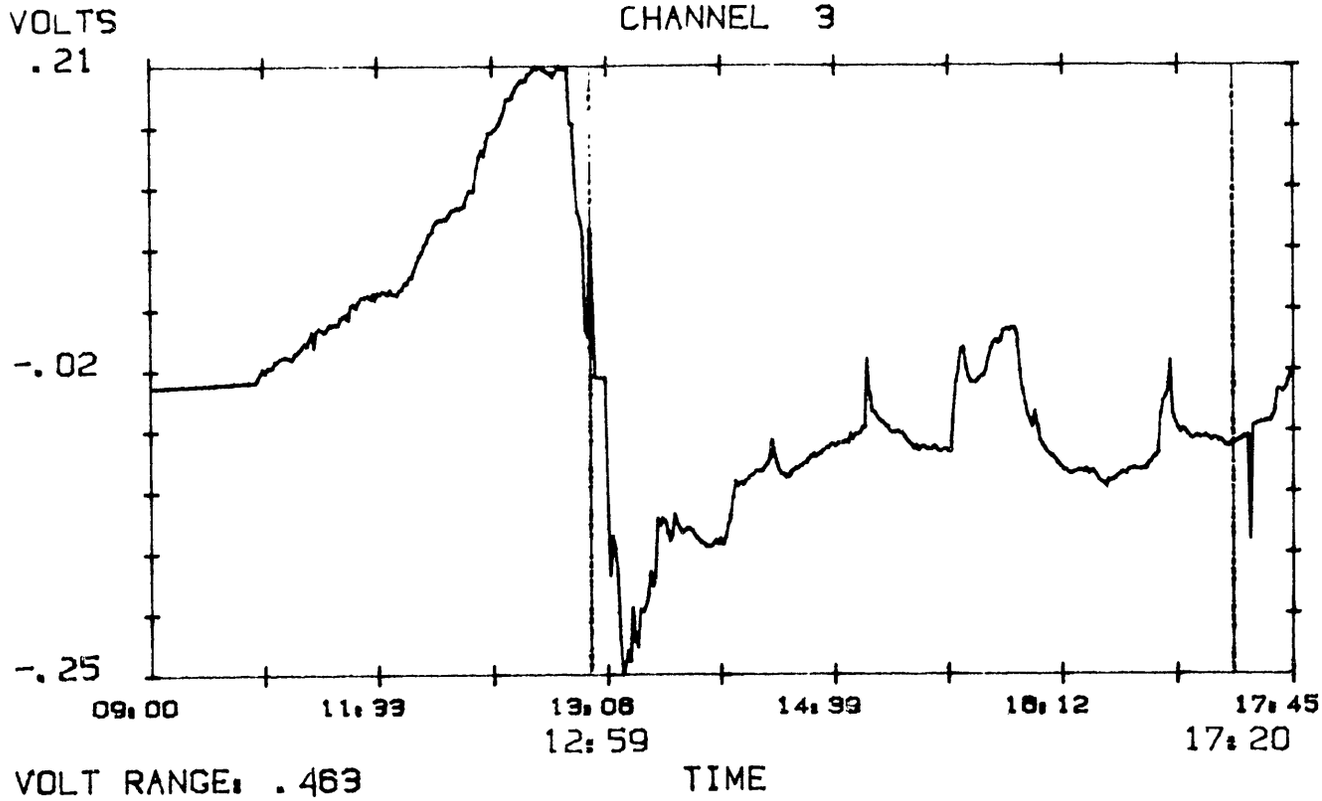
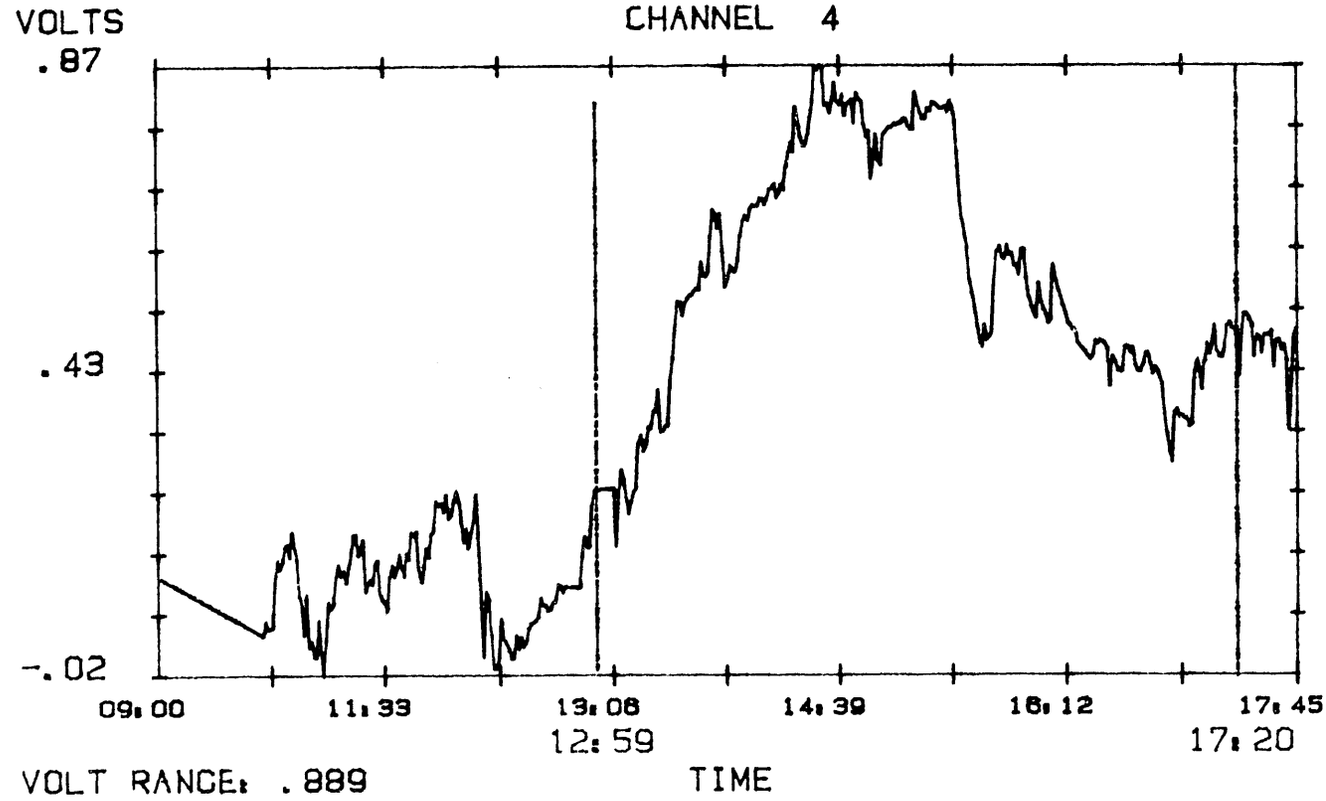
STOP 09:23:17:45:00
EVENT (HR:MN) _____

HUNTER GEOPHYSICS 1987





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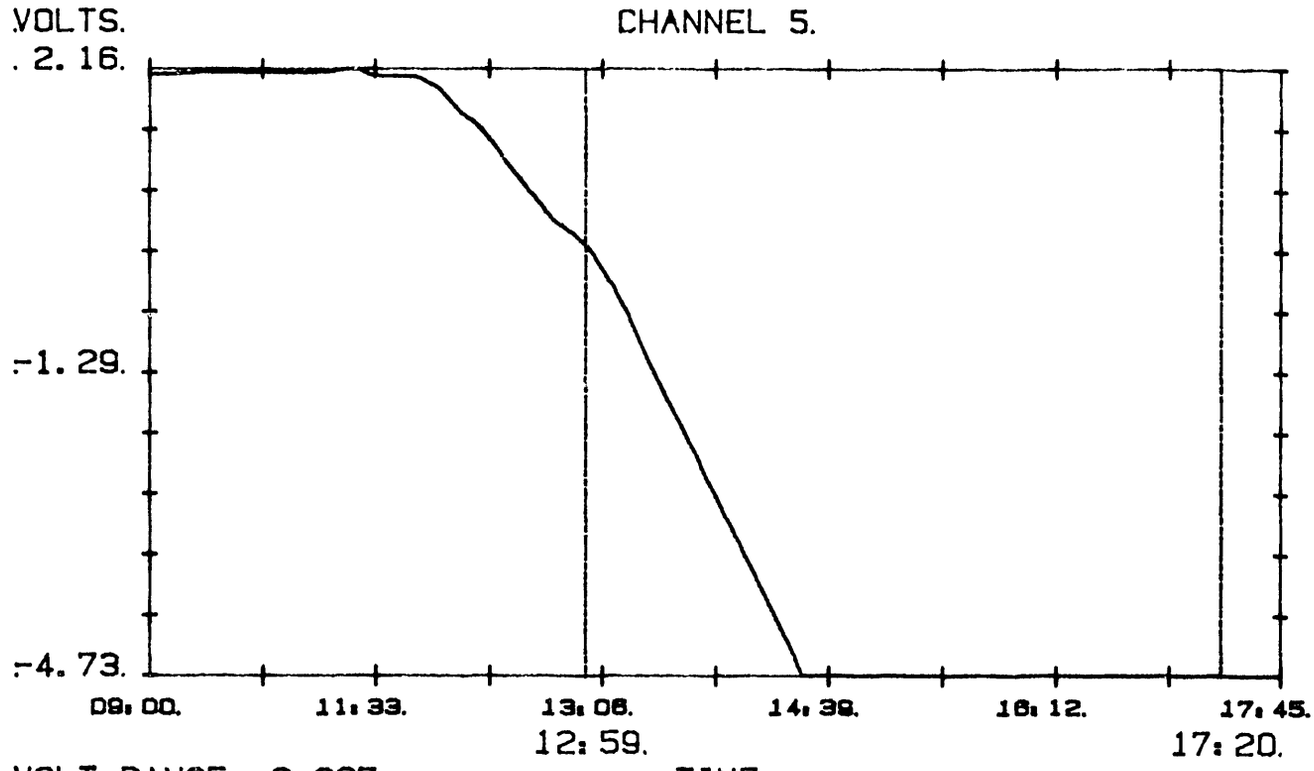

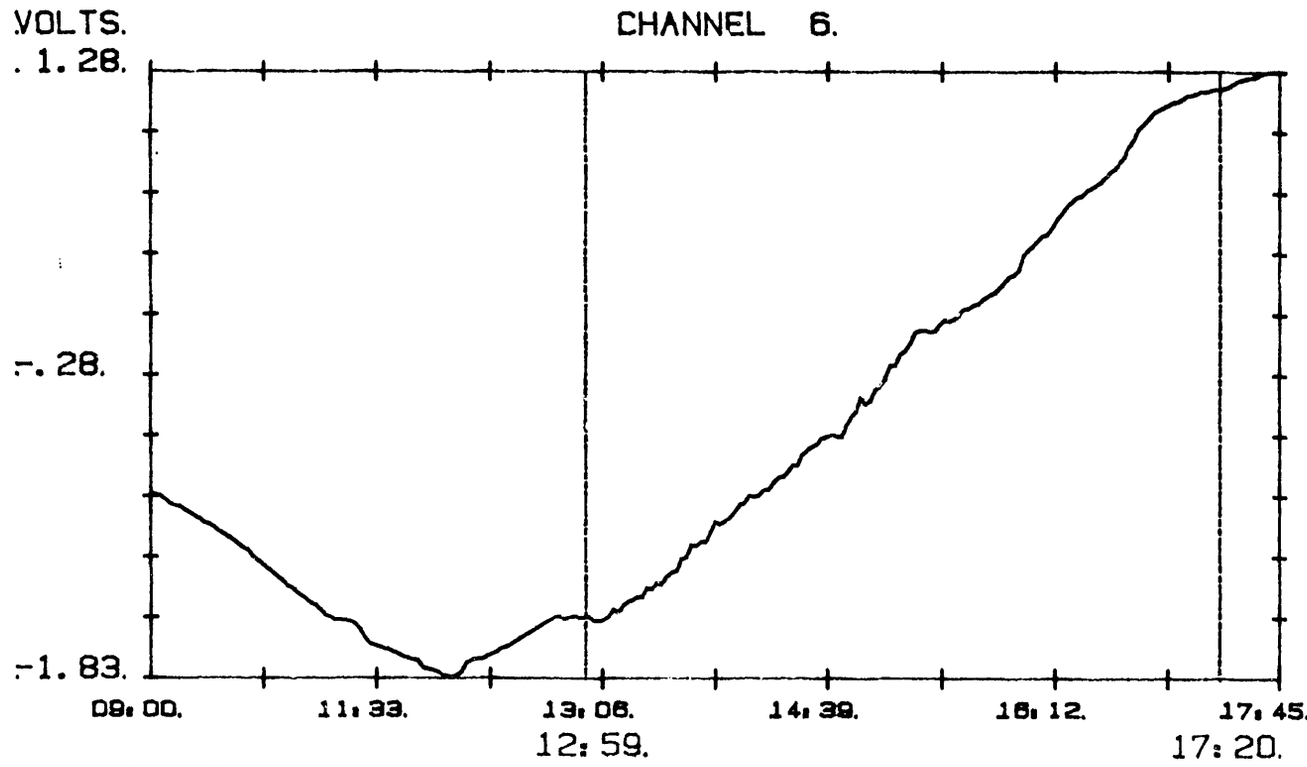

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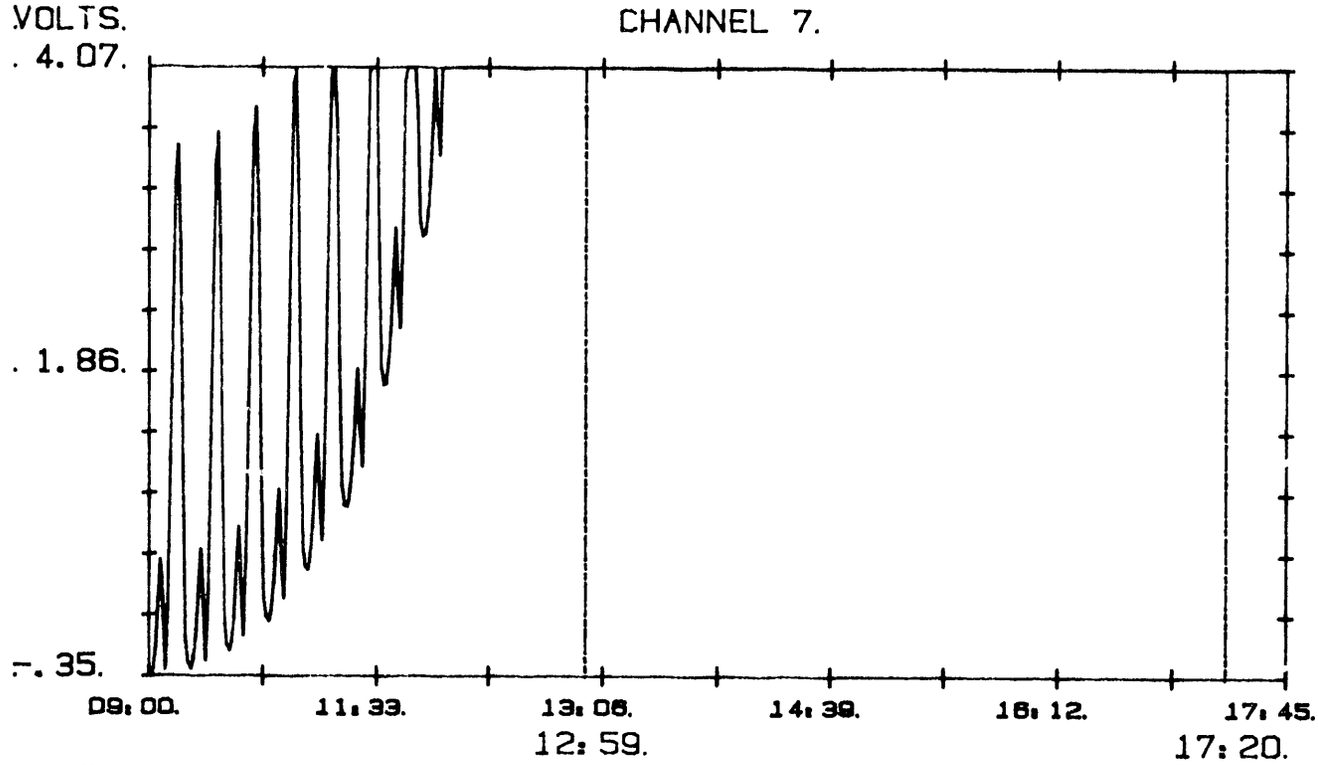

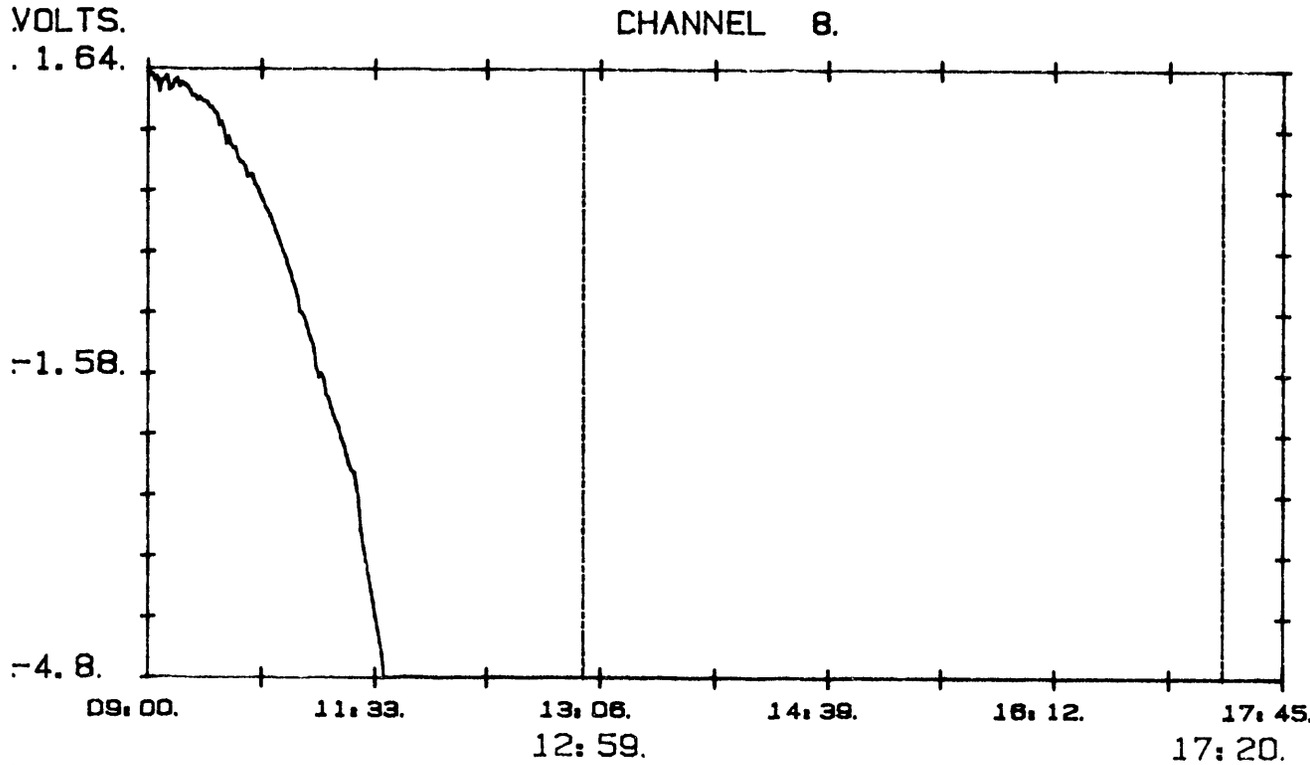

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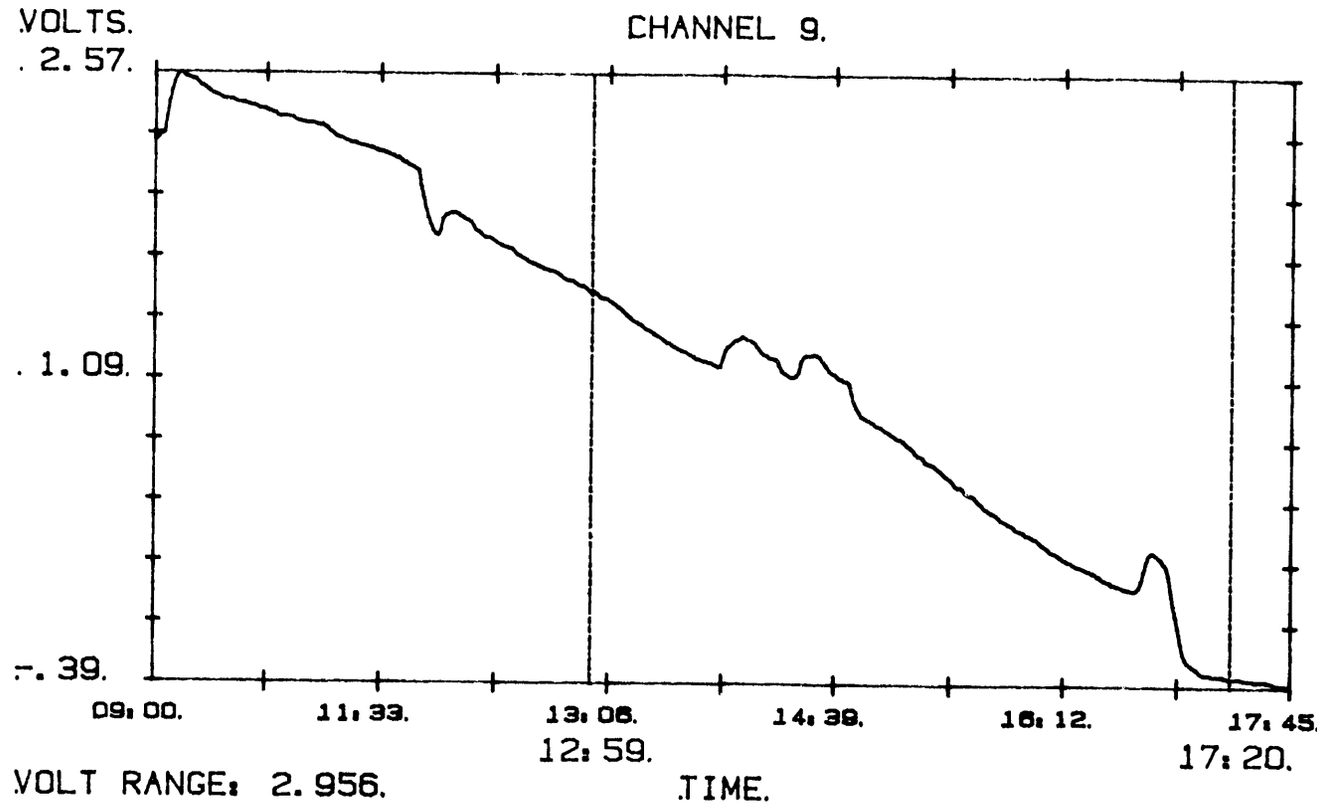

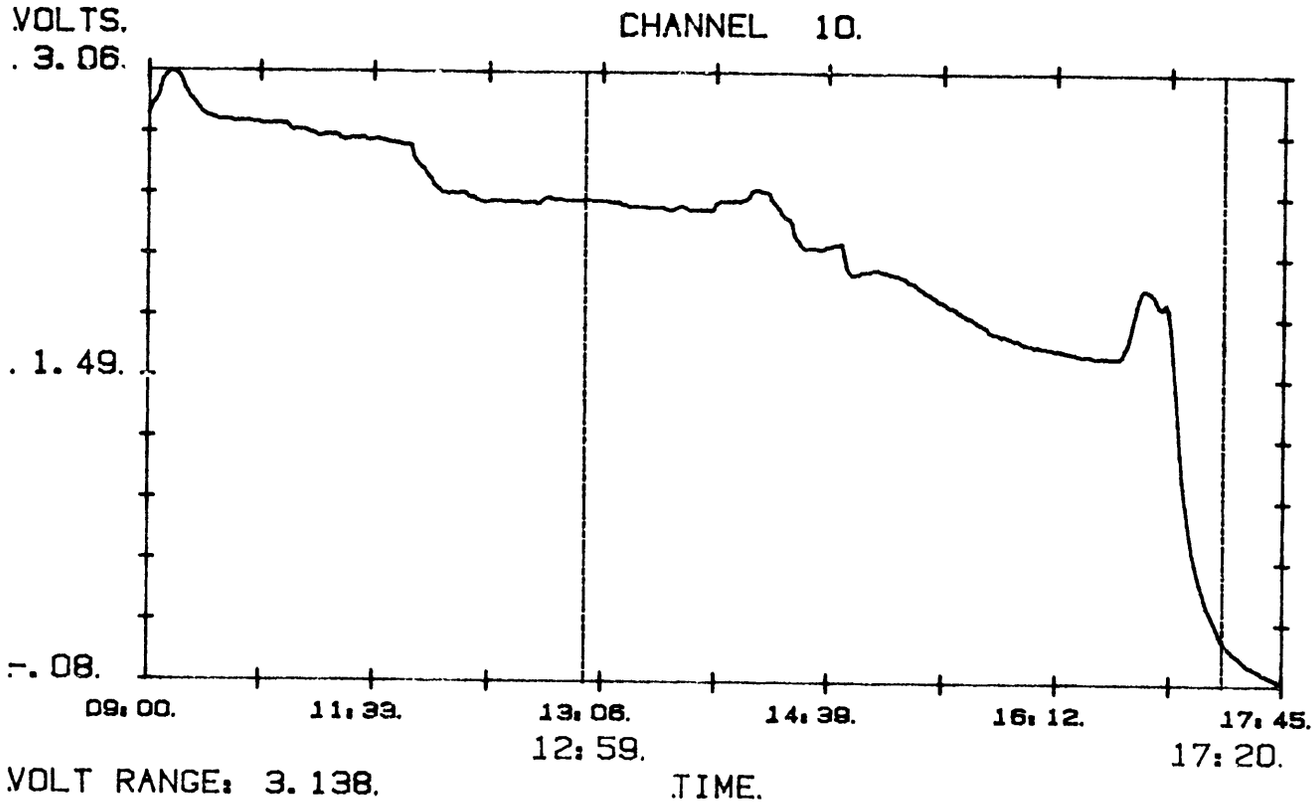

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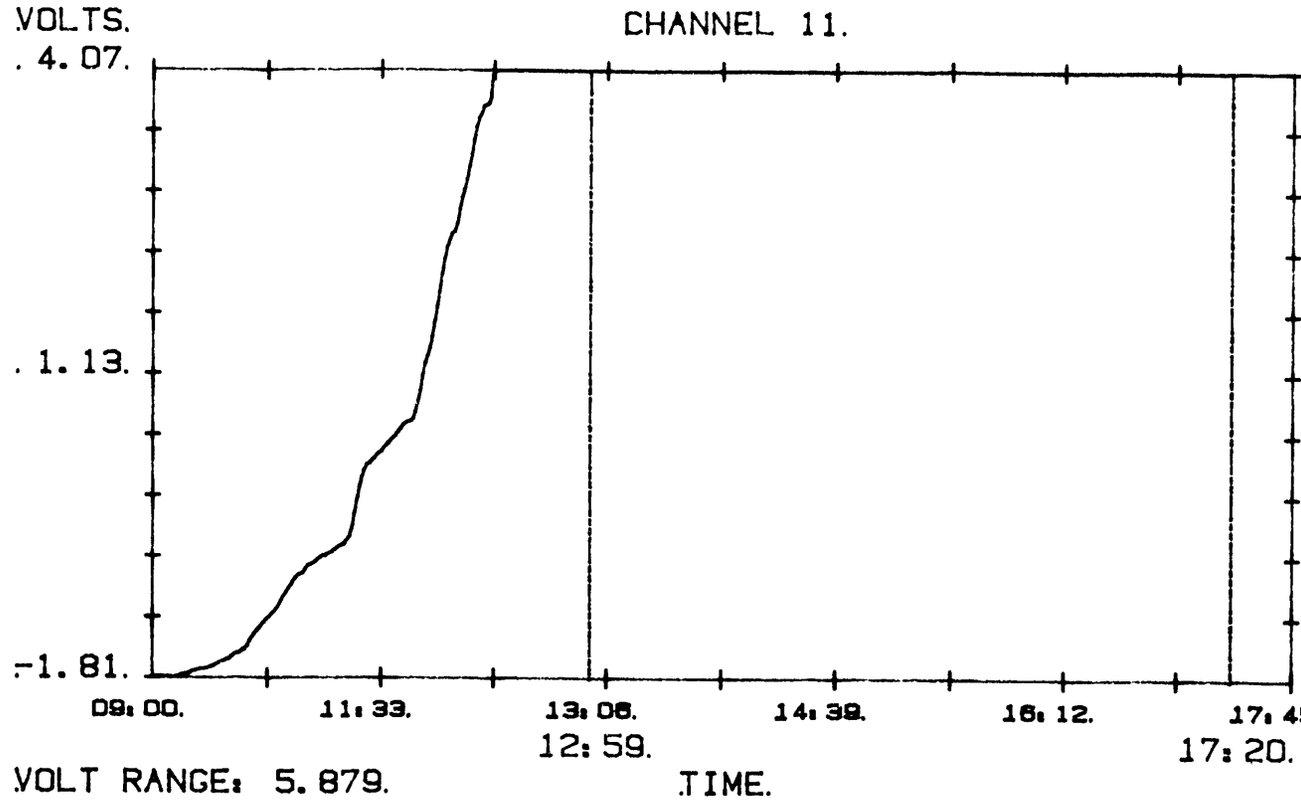

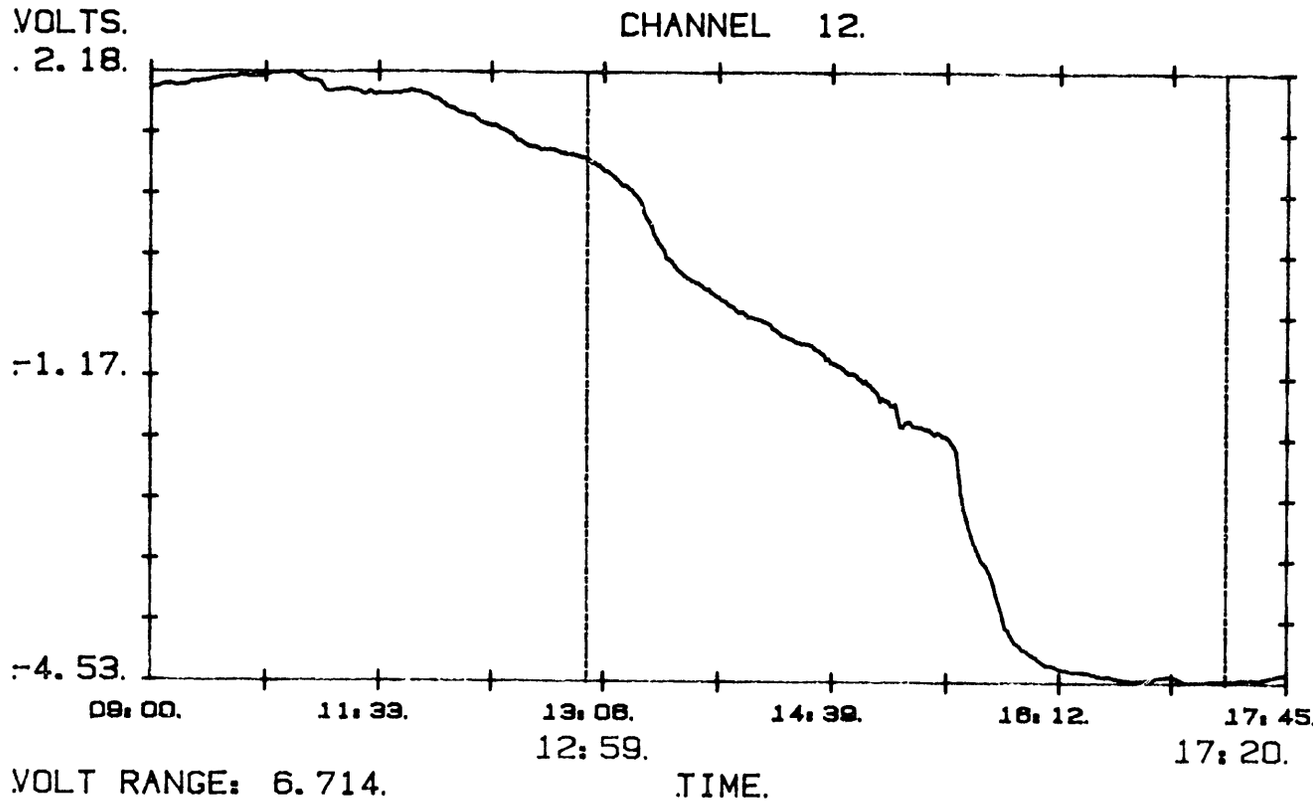

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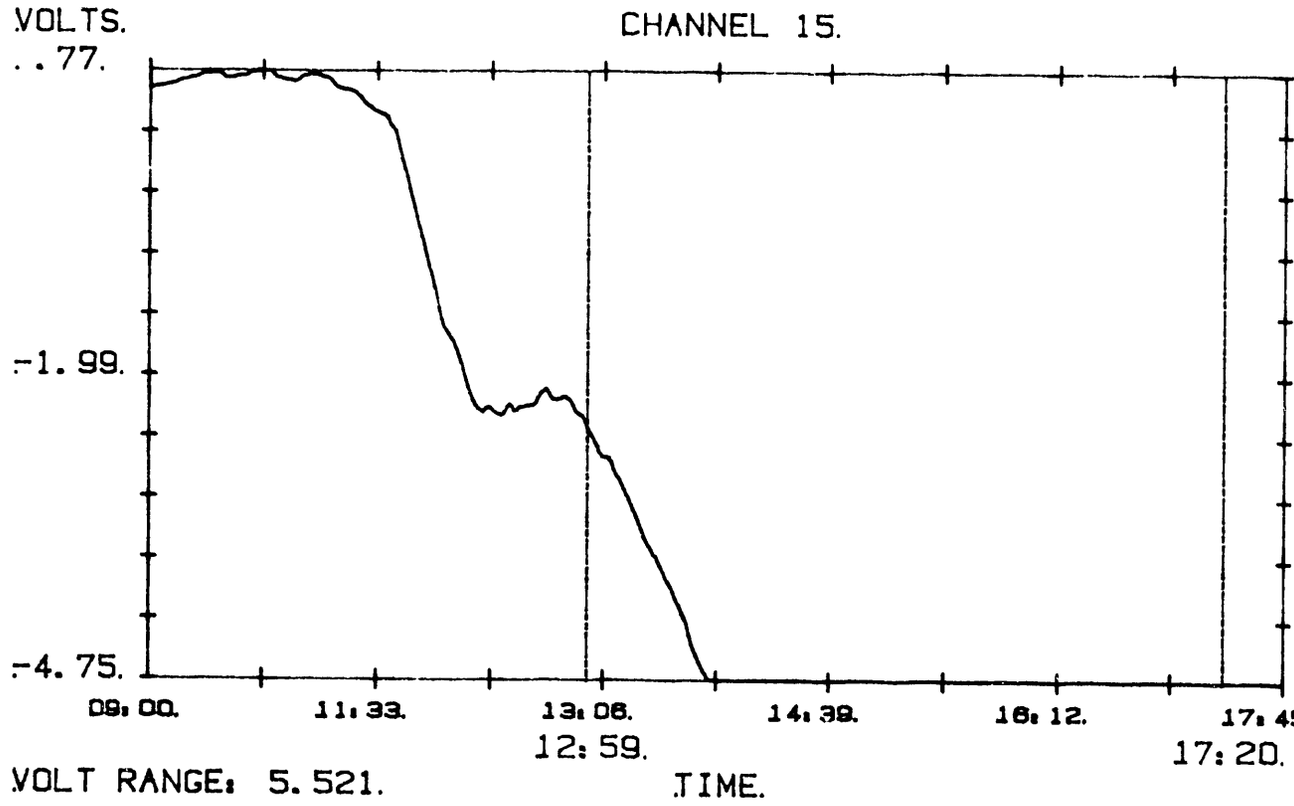

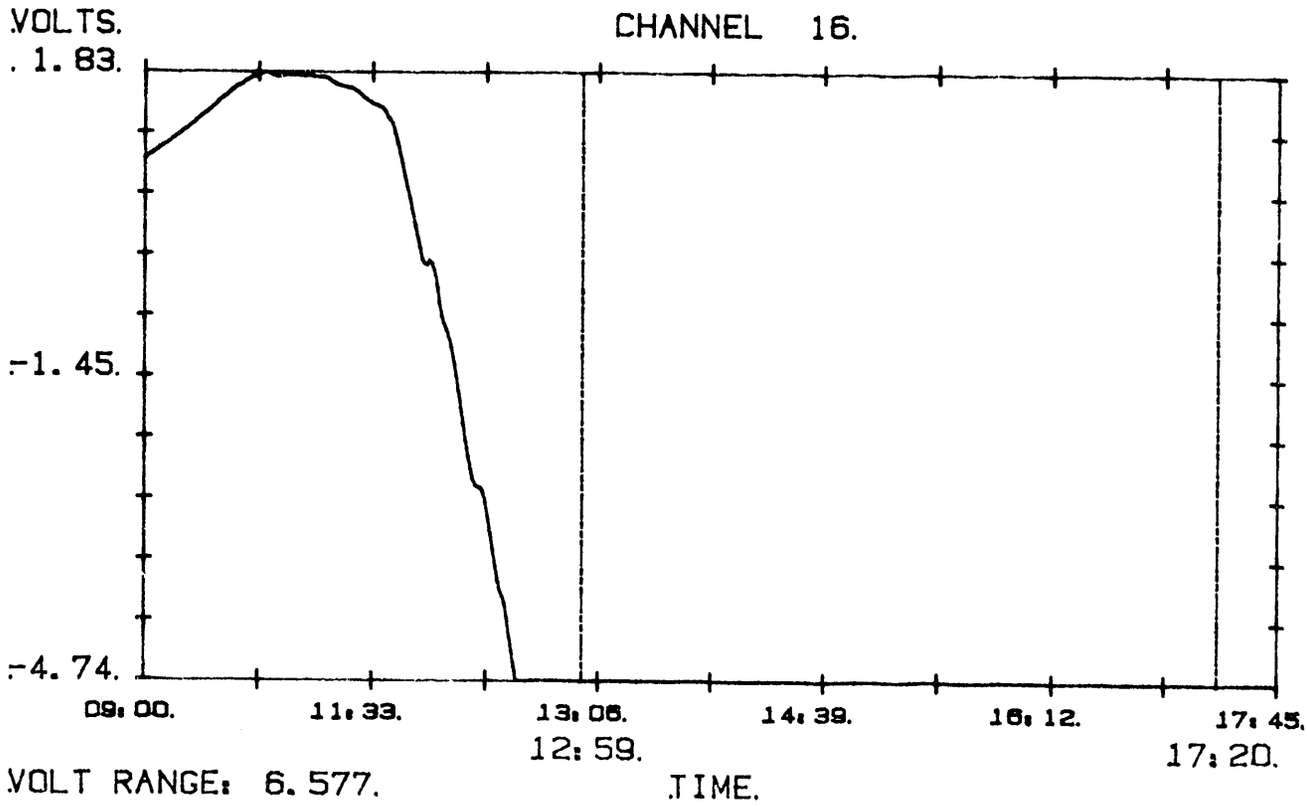

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DATE
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4/03/92