



December 3, 1965

Cactus Drilling Corporation
Drawer 71
San Angelo, Texas

RE: Formation Test No. 3
Navajo "A" No. 1
Field Report No. 17665-A

Gentlemen:

Enclosed are copies of the Productivity Log obtained during the above referenced test along with a complimentary Special Data Analysis.

The subject test was conducted utilizing our "MFE" and Productivity Logging system of tools. The recovery data indicate the formation contains hydrocarbons and water as 3.20 cu. ft. of gas, 50 cc oil, and 80 cc water was recovered in the "MFE" Sampler. Gas flowed to the surface at a weighted average rate of 1800 MCF/Day. The Special Data Analysis indicates the zone exhibits the characteristics of good permeability and indicates the presence of well bore damage.

The logs obtained "Before" and "After" test are presented for your review. It is noted that an increase in resistivity resulted on the "After" log in the section 6749' - 6754'. The following sections were characterized by a decrease in resistivity: 6738' - 6746', 6756' - 6766', and 6771' - 6778'. The total section where change is indicated is noted as 30 feet. It is our interpretation that these sections produced the formation fluid recovered on this test. With a fresh water mud system, it has been our experience that formation water and oil will normally result in a decrease in resistivity of not necessarily the same magnitude of change while a gas section will show an increase in resistivity. The



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liquid hydrocarbons recovered on this test indicated a gravity of 43.3° API which, in my opinion, may be indicative of oil rather than condensate production. The relatively high gas-oil ratio noted in the "MFE" Sampler, 10,175 cu.ft./bbl, is indicative of a gas zone. Therefore, it is my interpretation that separate gas, oil, and water zones exist within the tested interval. The interval 6749' - 6754' is interpreted as gas production due to the increase in resistivity. The other three sections of interest, zones indicating a decrease in resistivity, are interpreted as the zones giving up the liquid production. The magnitude of change is such that it is not possible to accurately ascertain which of the three sections gave up oil and which produced water. Other available sub-surface data should enhance the interpretation of these three sections.

Please accept our appreciation for your use of this service.

Yours very truly,



A. T. Campbell, Jr.
Manager, Interpretation and
Evaluation

ATC:mc



DYNAMIC EVALUATION INDICATOR

<i>DEPLETION INDEX</i>	
<i>FORMATION DAMAGE</i>	
<i>FLUID TYPE</i>	
<i>FLOW RATE</i>	
<i>PERMEABILITY</i>	
<i>PRESSURE</i>	
<i>STIMULATION POTENTIAL</i>	

YOUR PROFIT POTENTIAL IS	QUESTIONABLE
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MULTI-FLOW EVALUATOR (MFE)

Technical Report and SPECIAL DATA ANALYSIS

The **Multi-Flow Evaluator (MFE)** is a wholly new formation evaluation tool that provides test data on an unlimited number of flow and shut-in pressure tests, plus a pressurized formation fluid sample under final flowing pressure. This sample may be drained at the well site, at our field location, or in your laboratory.

Johnston's **Special Data Analysis** provides valuable calculated data on reservoir pressure, flow capacity, effective permeability, well bore damage, radius of investigation, and potentiometric surface. Included also is a valuable written analysis of these data that can provide important help in planning your completion.

SPECIAL DATA ANALYSIS

DECEMBER 2, 1965

GENTLEMEN:

THE ENCLOSED TEST APPEARS TO BE A GOOD MECHANICAL DRILL STEM TEST DURING WHICH THE TOOLS DID FUNCTION PROPERLY. THE FORMATION PRODUCED ENOUGH RESERVOIR FLUID FOR PROPER IDENTIFICATION. RESERVOIR PRESSURE DRAWDOWN WAS SUFFICIENT AND ADEQUATE SHUT-IN BUILD-UPS DID OCCUR FOR RELIABLE QUANTITATIVE ANALYSIS.

1. FLOW RATE: A WEIGHTED AVERAGE FLOW RATE OF 1800 MCF/DAY OF GAS WAS ESTIMATED FOR THIS TEST.
 2. RESERVOIR PRESSURE: EXTRAPOLATION OF THE INITIAL SHUT-IN PRESSURE BUILD-UP INDICATES A MAXIMUM RESERVOIR PRESSURE OF 3448 P.S.I.G. AT RECORDER DEPTH. EXTRAPOLATION OF THE FINAL SHUT-IN PRESSURE BUILD-UP INDICATES A MAXIMUM RESERVOIR PRESSURE OF 3450 P.S.I.G. AT RECORDER DEPTH. THE DIFFERENCE BETWEEN THE INITIAL AND FINAL SHUT-IN PRESSURE OF 2 P.S.I.G. IS INSIGNIFICANT.
 3. PERMEABILITY: THE CALCULATED TRANSMISSIBILITY FACTOR OF 2297 MD.-FT./CP. INDICATES AN AVERAGE EFFECTIVE PERMEABILITY TO GAS OF 1.6 MD. FOR THE 30 FOOT POROUS INTERVAL. THE POROUS INTERVAL WAS OBTAINED FROM THE PRODUCTIVITY LOG. THE CALCULATIONS WERE BASED ON A SLOPE OF 785,000 P.S.I.²/LOG CYCLE OBTAINED FROM THE FINAL SHUT-IN BUILD-UP PLOT. IT WAS ASSUMED FOR THESE CALCULATIONS: (A) GAS GRAVITY 0.70 (B) VISCOSITY 0.024 CP. (C) AND GAS DEVIATION FACTOR 0.85. THESE FIGURES WERE OBTAINED FROM THE AVAILABLE TECHNICAL LITERATURE.
 4. WELL BORE DAMAGE: THE CALCULATED ESTIMATED DAMAGE RATIO OF 3.15 INDICATES THAT HEAVY WELL BORE DAMAGE IS PRESENT AT THE TIME AND CONDITIONS OF THIS TEST. THIS VALUE INFERS THAT THE RATE OF PRODUCTION OBSERVED AT THE FORMATION FACE DURING THIS TEST MAY BE INCREASED 3.15 TIMES IF THE WELL BORE DAMAGE ALONE WERE REMOVED.
 5. RADIUS OF INVESTIGATION: THE CALCULATED RADIUS OF INVESTIGATION OF THIS TEST IS 91 FEET BASED ON AN ASSUMED POROSITY OF 7%, COMPRESSIBILITY OF 2.2×10^{-4} , AND OTHER ASSUMPTIONS MADE IN NUMBER 3 ABOVE.
 6. GENERAL COMMENTS: THE FORMATION EXHIBITS THE CHARACTERISTICS OF RELATIVELY GOOD PERMEABILITY EFFECTIVE TO THE RESERVOIR FLUID AND INDICATES THE PRESENCE OF WELL BORE DAMAGE. REMOVAL OF WELL BORE DAMAGE BY SOME CHEMICAL TREATMENT SHOULD PROVIDE A NICE INCREASE IN FLOW RATE AS INDICATED ABOVE. IT IS NOTED THAT LIQUID HYDROCARBONS AND WATER WAS RECOVERED IN THE DRILL PIPE AND THE "MFE" SAMPLER. SUCCESSFUL ISOLATION OF THE HYDROCARBON BEARING SECTION SHOULD PROVIDE A WATER FREE PRODUCER.
- THERE WERE NO ANOMALIES NOTED ON THE BUILD-UP PLOT.


A. T. CAMPBELL, JR.
EVALUATION ENGINEER

CACTUS DRILLING CORPORATION
NAVAJO "A" #1, SAN JUAN COUNTY, NEW MEXICO
TEST #3, 6735' TO 6799'

FIELD REPORT #17665 A

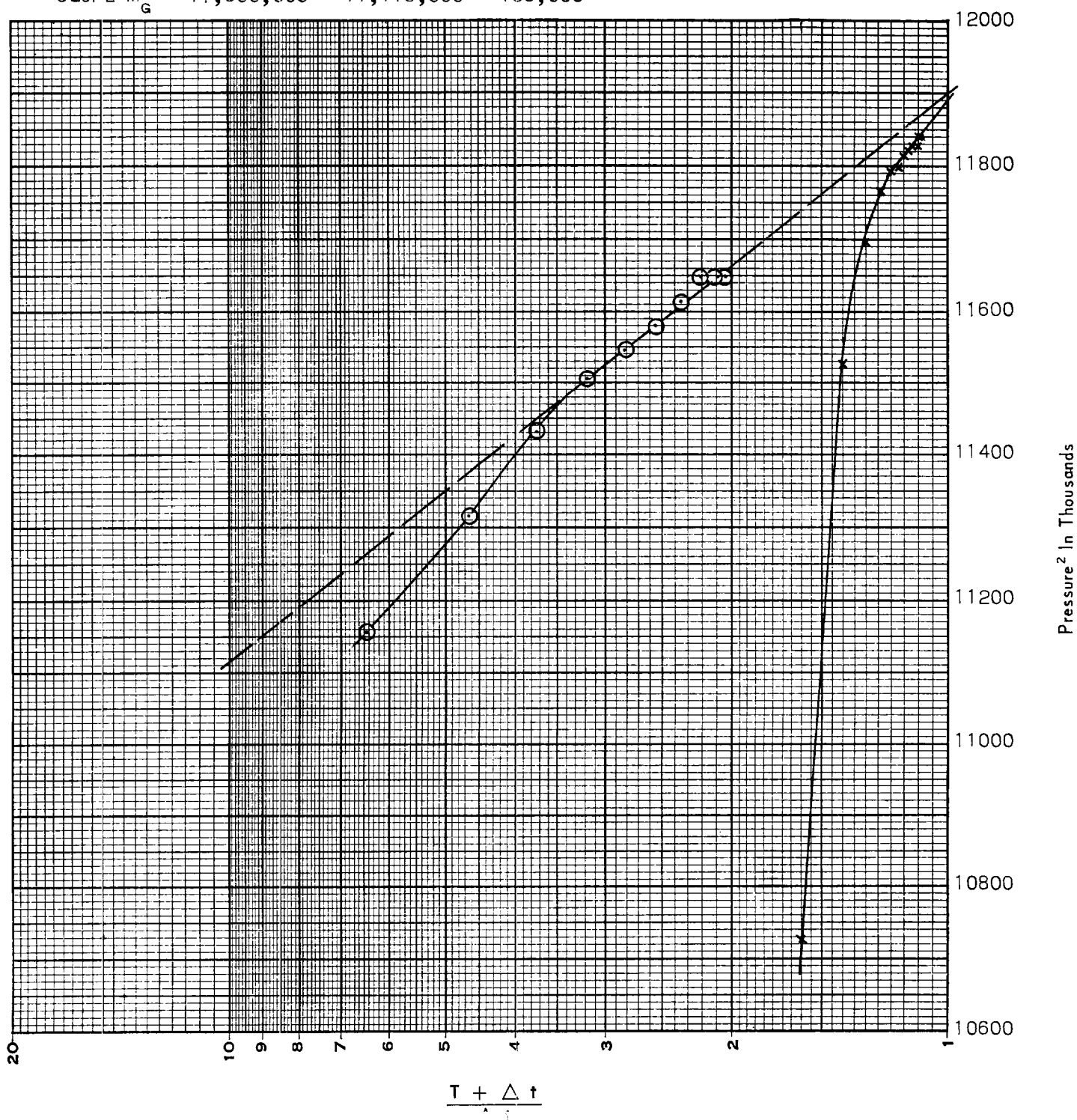
Instrument No. J-007

Gas Reservoir Engineering Data

Field Report No. 17665 A

Estimated Damage Ratio	EDR	3.15	Effective Transmissibility	$\frac{Kh}{\mu Z}$	2297	$\frac{Md-ft.}{Cp.}$
Maximum Reservoir Pressure	P_o	3448 P.S.I.G.	Flow Rate	Q_g	1800	MCF/Day
Slope of Shut-in Curve	M_g	785000 PSI ² /log cycle	Flow Rate	Q		
Potentiometric Surface (Datum Plane, Sea Level)	PS	6210 ft.	Flow Rate	Q		
Radius of Investigation		91 ft.	K (Effective to	GAS)	1.6	Md.

$$\text{SLOPE } M_G = 11,900,000 - 11,115,000 = 785,000$$



Assumptions made for Calculations for Gas Recoveries

1. Q_g is taken as steady state flow and unless stated otherwise at standard conditions 14.7 P.S.I. and 60°F.
2. P_f is final formation flowing pressure at steady state flow.
3. Formation flow is taken as single phase flow. If liquid (condensate) is produced at surface, condensation is assumed to have occurred in drill pipe.
4. Radial flow is assumed.
5. Unless given, gas specific gravity is assumed to be 0.7 (air 1.0) and having pseudo critical temperature at 385° Rankin and pseudo critical pressure of 666 P.S.I.A.
6. Other standard radial flow, steady state assumptions.

Empirical Equations:

$$1. \text{ EDR} = \frac{P_o^2 - P_f^2}{M_g(\log T + 2.65)} \quad \text{where } M_g = \frac{P_1^2 - P_{10}^2}{\text{Log Cycle}}$$

$$2. \text{ Transmissibility } \frac{Kh}{\mu Z} = \frac{1637^\circ T_f Q_g}{M_g}$$

$$3. \text{ P.S.} = \left[P_o \times 2.309 \text{ ft./PSI} \right] - \left[\text{Recorder depth to sea level.} \right]$$

$$4. \text{ Radius of Investigation, } r_{ir} = \sqrt{\frac{Kt}{40\phi(1 - S_w)\mu c}} \quad \text{where } t = \text{time in days}$$

Symbols	Dimensions	Symbols	Dimensions
β	Formation volume factor vol./vol.	Q_o	Rate of oil flow during test Bbbls./day
c	Fluid compressibility vol./vol./psi.	Q_w	Rate of water flow during test Bbbls./day
EDR	Estimated damage ratio	Q_g	Rate of gas flow during test MCF/day
ϕ	Formation porosity fractional	r_i	Radius of investigation feet
h	Net producing interval feet	r_w	Well bore radius inches
J	Productivity index Bbbls./day/PSI	S_w	Water saturation %
K	Permeability (effective) Millidarcies	t	Shut-in time period minutes
M_g	Slope of shut-in build up PSI ² /log cycle	Δt	Increment time of shut-in period minutes
P_f	Final flowing pressure PSIG	T	Open flow time period minutes
P_{fsi}	Final shut-in pressure at time t PSIG	$^{\circ}T_f$	Formation temperature °Rankin
P_{isi}	Initial shut-in pressure PSIG	μ	Fluid viscosity (Reservoir conditions) Centipoise
P_o	Maximum reservoir pressure PSIG	Z	Gas deviation factor (compressibility factor)
P_1	Final shut-in build up plot intercept @ 1 PSIG	$\frac{Kh}{\mu\beta}$ or $\frac{Kh}{\mu Z}$	Transmissibility factor $\frac{\text{Md.} - \text{ft.}}{C_p}$
P_{10}	Final shut-in build up plot intercept @ 10 PSIG		
P.S.	Potentiometric surface feet		
Q	Rate of flow during test Bbbls./day		

In making any interpretation, our employees will give Customer the benefit of their best judgment as to the correct interpretation. Nevertheless, since all interpretations are opinions based on inferences from electrical, mechanical or other measurements, we cannot, and do not, guarantee the accuracy or correctness or any interpretations, and we shall not be liable or responsible, except in the case of gross or wilful negligence on our part, for any loss, costs, damages or expenses incurred or sustained by Customer resulting from any interpretation made by any of our agents or employees.

[illegible]

RECOVERY DATA	
Description	Amount
FREE OIL (GRAVITY = 44 AT 68°F)	330' (3.37 EBLs)
MUD CUT OIL	180' (.88 EBLs)
MUDDY WATER	90' (.44 EBLs)
SALT WATER	180' (.88 EBLs)

[illegible]

Type Test _____ M. F. E. & PROD. LOG
 Formation Tested _____ DESERT CREEK
 Elevation _____ 4954 K.B. _____ Ft.
 Net Productive Interval _____ 30 (EST.) _____ Ft.
 Estimated Porosity _____ 7 _____ %
 All Depths Measured From _____

COMPONENTS	Size/Type	Depth/Length/ I.D.
DRILL PIPE	4" FH	6250' /
		3.2"
DRILL COLLARS	4 $\frac{1}{2}$ " XH	360' /
		2.25"
CIRCULATING SUB	4 $\frac{1}{2}$ "	
DRILL COLLARS	4 $\frac{1}{2}$ " XH	90' / 2.25"
MULTI-FLOW		
EVALUATOR	5"	
BY-PASS VALVE	3 $\frac{1}{2}$ " MFE	
JARS	3 $\frac{1}{2}$ " HS-1	
RECORDER CARRIER	3 $\frac{1}{2}$ " J	6'
RECORDER CARRIER	3 $\frac{1}{2}$ " T	6'
SAFETY JOINT	3 $\frac{1}{2}$ " BOWEN	
BY-PASS SUB	3 $\frac{1}{2}$ "	
SAFETY SEAL		
BOB-TAIL PACKER	6 3/4"	6729'
BOB-TAIL PACKER	6 3/4"	6735'
PERF. ANCHOR	4 $\frac{1}{2}$ " HVY	34'
DRILL COLLARS	4 $\frac{1}{2}$ " XH	30' / 2.25"
BOB-TAIL PACKER	6 3/4"	6799'
PERF. ANCHOR	4 $\frac{1}{2}$ " HVY	8'
DRILL COLLARS	4 $\frac{1}{2}$ " XH	150' /
		2.25"
PROD. LOG TOOL		20'

Total Depth	697	697	697	Ft.
Main Hole/Casing Size	7 7/8"			
Rat Hole/Liner Size	-			
Bottom Choke Size	5/8"			
Mud Type	FRESH WATER GEL	Wt.	10.8	
Viscosity	44	Water Loss	8.0	C.C.
Cushion Type	Amount	Pressure		

No. Reports Requested 18(4x's)



MULTI-FLOW EVALUATOR FLUID SAMPLE REPORT

Date 11-25-65 / Field Report No. 17665 A

Company CACTUS DRILLING CORPORATION

Well NAVAJO "A" #1 Field WILD CAT

County SAN JUAN State NEW MEXICO

Test Interval 6735' To 6799' Test No. 3

Type of Test M. F. E. AND PROD. LOG Recovery Description 330' FREE OIL, 180' MUD
CUT OIL, 90' MUDDY WATER, 180' SALT WATER

Bot. Hole Temp. 152 °F. Recorded Pressures: ISI * 3441 psig.
SSI - psig.
FF 542 psig.
FSI 3413 psig.

**Shut-in Pressure did not reach static reservoir pressure.*

EVALUATOR SAMPLER UNIT

Sample Drained: ☒ On Location ☐ Service Center ☐ Other
☐ Laboratory Name
Address

Sampler Pressure 500 psig. at Surface

Recovery: Cu. Ft. Gas 3.2
cc. Oil 50
cc. Water 80
cc. Mud -
Total Liquid cc. 130

Gravity 44 °API 68 °F.
Gas/Oil Ratio 10175 CU.FT./BBL.

RESISTIVITY

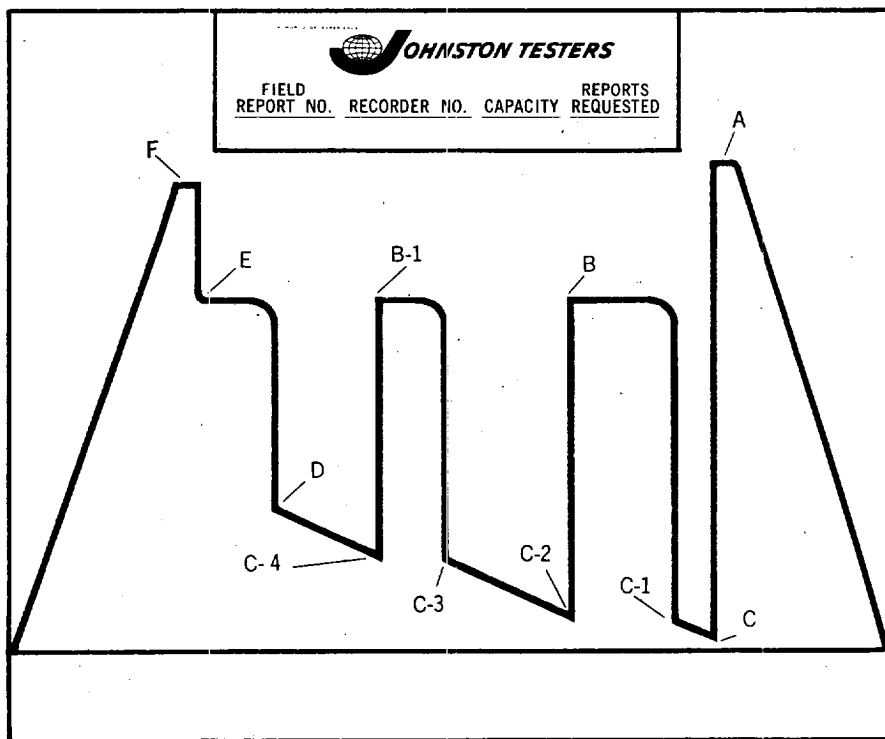
Recovery Water .17 @ 64 °F.
Recovery Mud - @ - °F.
Recovery Mud Filtrate - @ - °F.
Mud Pit Sample 1.8 @ 70 °F.
Mud Pit Sample Filtrate - @ - °F.

CHLORIDE CONTENT

25,000 ppm.
- ppm.
400 ppm.

Remarks THIS APPEARS TO BE A TEST OF A ZONE CONTAINING HYDROCARBONS AND
FORMATION WATER.

GUIDE TO IDENTIFICATION OF DRILL STEM TEST PRESSURE CHARTS



- A. Initial Hyd. Mud
- B. Initial Shut-in
- C. Initial Flow
- D. Final Flow
- E. Final Shut-in
- F. Final Hyd. Mud

The following points are either fluctuating pressures or points indicating other packer settings, (testing different zones).

- A-1, A-2, A-3, etc. Initial Hyd. Pressures
- B-1, B-2, B-3, etc. Subsequent Shut-in Pressures
- C-1, C-2, C-3, etc. Flowing Pressures
- D-1, D-2, D-3, etc. Subsequent Final Flow Pressures
- E-1, E-2, E-3, etc. Subsequent Final Shut-in Pressures
- F-1, F-2, F-3, etc. Final Hyd. Mud Pressures
- Z — Special pressure points such as pumping pressure recorded for formation breakdown.

