JOHNSTON TESTERS

DYNAMIC EVALUATION INDICATOR

DEPLETION INDEX			
FORMATION DAMAGE			
FLUID TYPE			
FLOW RATE			
PERMEABILITY			
PRESSURE			
STIMULATION POTENTIAL			

YOUR **PROFIT POTENTIAL** IS		QUESTIONABLE	

More detailed information appears in the JOHNSTON SPECIAL DATA ANALYSIS

December 3, 1965

Cactus Drilling Corporation
Drawer 71
San Angelo, Texas

RE: Formation Test No. 2
Navajo "A" No. 1
Field Report No. 17664-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 2.16 cu. ft. of gas, 40 cc oil,
and 60 cc water was recovered in the "MFE" Sampler. Gas flowed
to the surface at a weighted average rate of 2800 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 the "After" log failed to record until the
majority of the test interval had been traversed with the logging tool.
The test interval is noted as 6670' - 6760' and the "After" log was
recorded from 6681' - 6579'. Therefore, only 11 feet of the test
interval is available for interpretation. The equipment was completely
checked at the conclusion of this job and the trouble removed.

Please accept our appreciation for your use of this service.

Yours very truly,

A. T. Campbell

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

ATC:mc

JOHNSTON TESTERS

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 <u>2800 MCF/DAY</u> 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 <u>3451 P.S.I.G.</u> AT RECORDER DEPTH. EXTRAPOLATION OF THE FINAL SHUT-IN PRESSURE BUILD-UP INDICATES A MAXIMUM RESERVOIR PRESSURE OF <u>3457 P.S.I.G.</u> AT RECORDER DEPTH. THE DIFFERENCE BETWEEN THE INITIAL AND FINAL SHUT-IN PRESSURE OF 6 P.S.I. IS INSIGNIFICANT.

3. PERMEABILITY: THE CALCULATED TRANSMISSIBILITY FACTOR OF <u>2953 MD.-FT./CP.</u> INDICATES AN AVERAGE EFFECTIVE PERMEABILITY TO GAS OF <u>0.64 MD.</u> FOR THE REPORTED 90 FOOT TEST INTERVAL. THE CALCULATIONS WERE BASED ON A SLOPE OF 950,000 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 0.023 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 <u>2.6</u> INDICATES THAT WELL BORE DAMAGE <u>IS</u> 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 <u>2.6</u> TIMES IF THE WELL BORE DAMAGE ALONE WERE REMOVED.

5. RADIUS OF INVESTIGATION: THE CALCULATED RADIUS OF INVESTIGATION OF THIS TEST IS <u>53 FEET</u> BASED ON AN ASSUMED POROSITY OF 10%, 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 THE NICE INCREASE IN FLOW CAPACITY AS INDICATED ABOVE.

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 #2, 6670' TO 6760'

FIELD REPORT #17664 A

Gas Reservoir Engineering Data

Instrument No. _____ J-007 _____

Field Report No. _____ 17664 A _____

Estimated Damage Ratio	EDR	2.6		Effective Transmissibility	$\frac{Kh}{\mu Z}$	2953	$\frac{Md\text{-}ft.}{Cp.}$
Maximum Reservoir Pressure	P_0	3451 P.S.I.G.		Flow Rate (ESTIMATED) GAS	Q_g	2800	MCF/Day
Slope of Shut-in Curve	M_g	950,000 PSI²/log cycle		Flow Rate LIQUID HYDROCARBONS	Q	42 BBL/DAY	
Potentiometric Surface (Datum Plane, Sea Level)	PS	6194 ft.		Flow Rate WATER	Q	10 BBL/DAY	
Radius of Investigation		53 ft.		⟨ (Effective to GAS)		0.64	Md.

SLOPE M_G = 11,950,000 -- 11,000,000 = 950,000

Pressure² In Thousands

$$\frac{T + \Delta t}{\Delta t}$$
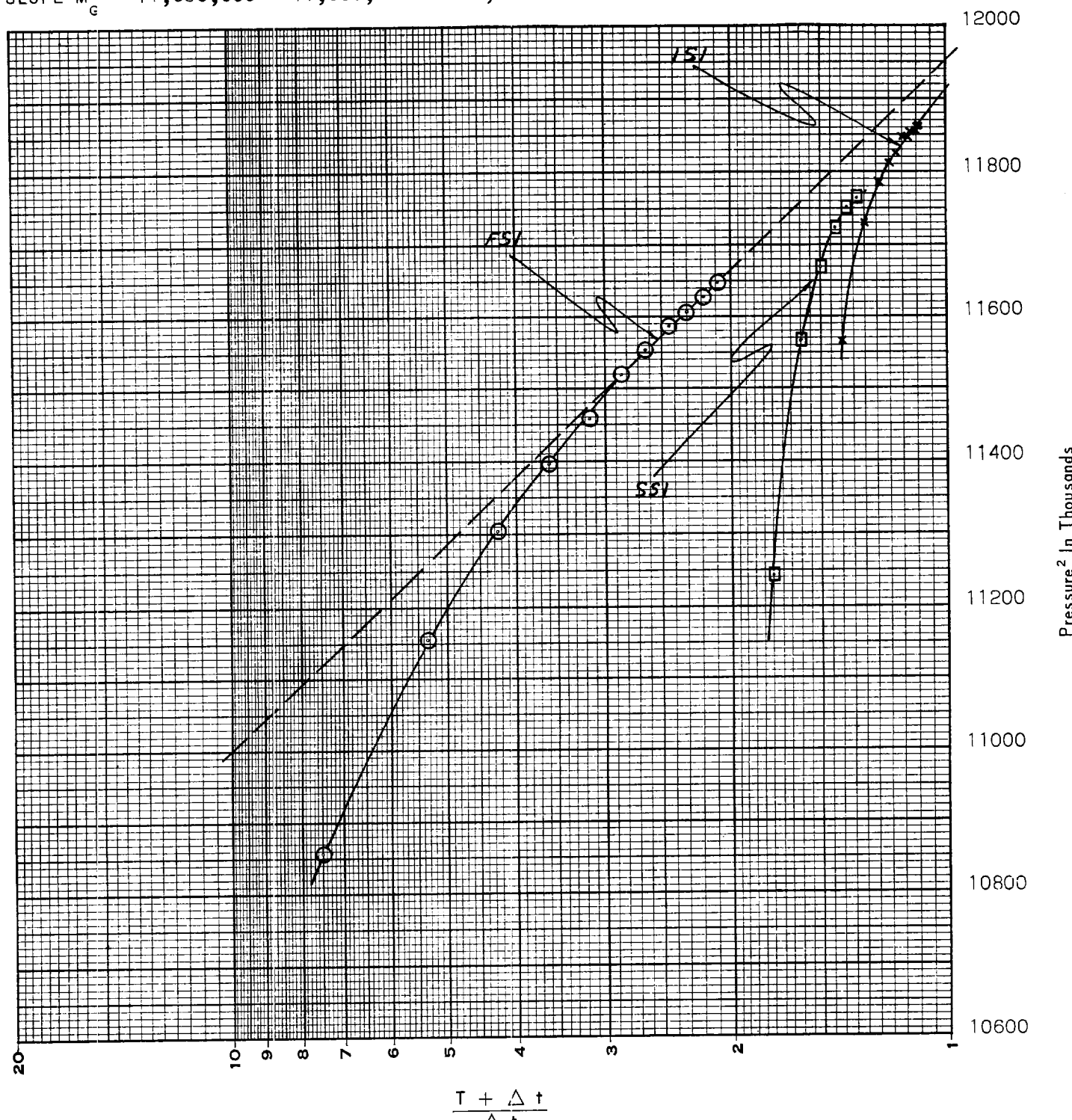
Assumptions made for Calculations for Gas Recoveries

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

2. Transmissibility $\dfrac{Kh}{\mu Z} = \dfrac{1637°T_f Q_g}{M_g}$

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

4. Radius of Investigation, $r_i = \sqrt{\dfrac{Kt}{40\phi(1 - S_w)\mu c}}$ where $t =$ time in days

Symbols		Dimensions	Symbols		Dimensions
β	Formation volume factor	vol./vol.	Q_c	Rate of oil flow during test	Bbls./day
c	Fluid compressibility	vol./vol./psi.	Q_w	Rate of water flow during test	Bbls./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	Bbls./day/PSI	S_w	Water saturation	%
K	Permeability (effective)	Millidarcies	t	Shut-in time period	minutes
M_g	Slope of shut-in build up	PSI²/log cycle	Δt	Increment time of	
P_f	Final flowing pressure	PSIG		shut-in period	minutes
P_{fsi}	Final shut-in pressure at time t	PSIG	T	Open flow time period	minutes
P_{isi}	Initial shut-in pressure	PSIG	°T_f	Formation temperature	°Rankin
P_o	Maximum reservoir pressure	PSIG	μ	Fluid viscosity	
P_1	Final shut-in build up plot intercept @ 1	PSIG		(Reservoir conditions)	Centipoise
P_{10}	Final shut-in build up plot intercept @ 10	PSIG	Z	Gas deviation factor (compressibility factor)	
P.S.	Potentiometric surface	feet	$\dfrac{Kh}{\mu\beta}$ or $\dfrac{Kh}{\mu Z}$ Transmissibility factor		$\dfrac{\text{Md.} - \text{ft.}}{Cp}$
Q	Rate of flow during test	Bbls./day			

SURFACE INFORMATION

Description (Rate of Flow)		Time	Pressure (P.S.I.G.)	Surface Choke
Opened Tool		0945	–	–
GAS TO SURFACE		0951	–	–
CLOSED FOR INITIAL SHUT-IN		0951	–	–
FINISHED SHUT-IN		1051	–	–
RE-OPENED TOOL		1057	–	–
		1100	6	1"
CLOSED FOR SECOND SHUT-IN		1102	68	"
FINISHED SHUT-IN		1122	–	"
RE-OPENED TOOL		1128	–	"
GAS	1200 MCF/DAY	1130	30	"
GAS	2200 MCF/DAY	1133	70	"
		1140	92	"
GAS	3000 MCF/DAY	1145	98	"
GAS	3100 MCF/DAY	1150	100	"
		1200	100	"
		1210	88	"
		1235	90	"
		1240	92	"
		1250	100	"
GAS	2800 MCF/DAY	1328	90	"
CLOSED FOR FINAL SHUT-IN		1328	90	"
PULLED PACKER LOOSE		1528	–	"

RECOVERY DATA

Description	Amount
FREE OIL (GRAVITY = 48 AT 60° F)	590' (3.79 BBLS)
OIL AND GAS CUT WATER	90' (.44 BBLS)
SALT WATER	90' (.44 BBLS)

EQUIPMENT, HOLE & MUD DATA

Type Test __M. F. E. AND PROD. LOG__
Formation Tested __ISMAY (PENN.)__
Elevation __4954 K.B.__ Ft.
Net Productive Interval __–__ Ft.
Estimated Porosity __–__ %
All Depths Measured From __KELLY BUSHINGS__

EQUIPMENT SEQUENCE

COMPONENTS	Size/Type	Depth/Length/I.D.
DRILL PIPE	4" FH	6040'/
		3.2"
DRILL COLLARS	4½" XH	510'/
		2.25"
CIRCULATING SUB	4½"	
DRILL COLLARS	4½" XH	90'/2.25"
MULTI-FLOW EVALUATOR	5"	
BY-PASS VALVE	3½" MFE	
JARS	3½" HS-1	
SAFETY JOINT	3½" BOWEN	
SAFETY SEAL	4½" MFE	
BOB-TAIL PACKER	6 3/4"	6664'
BOB-TAIL PACKER	6 3/4"	6670'
PERF. ANCHOR	4½" HVY	10'
DRILL COLLAR	4½" XH	30'/2.25"
PERF. ANCHOR	4½" HVY	18'
RECORDER CARRIER	4½" J	6'
RECORDER CARRIER	4½" T	6'
PROD. LOG TOOL		20'

Total Depth __6760__ Ft.
Main Hole/Casing Size __7 7/8"__
Rat Hole/Liner Size __–__
Bottom Choke Size __5/8"__
Mud Type __–__ Wt. __10.8__
Viscosity __43__ Water Loss __8.0__ C.C.

Cushion Type	Amount	Pressure
	NONE	

Remarks: __LOCATION: 880' FEL, 550' FNL, SEC. 29, T-31-N, R-18-W__

Address __DRAWER 71; SAN ANGELO, TEXAS__

Company __CACTUS DRILLING CORPORATION__ Field __WILD CAT__
Well __NAVAJO "A" #1__ Location __SEE REMARKS__
Test Interval __6670' TO 6760'__ Test # __2__ Date __11-21-65__

County __SAN JUAN__ State __NEW MEXICO__ Field Report No. __17664 A__
Technician __BARTLETT (HOBBS)__ Test Approved By __MR. E. W. RUSSELL__ No. Reports Requested __18 (4x's)__

MULTI-FLOW EVALUATOR
FLUID SAMPLE REPORT

Date _____ 11-21-65 _____   Field Report No. __17664 A__

Company ___ CACTUS DRILLING CORPORATION _____

_____

Well _____ NAVAJO "A" #1 _____   Field __ WILD CAT _____

County _____ SAN JUAN _____   State __ NEW MEXICO _____

Test Interval 6670' _____   To 6760' _____   Test No. _____ 2 _____

Type of Test M. F. E. AND PROD. LOG _____   Recovery Description ___ 590' FREE OIL, 90'

_____ OIL AND GAS CUT WATER, 90' SALT WATER _____

Bot. Hole Temp. __152__ °F.   Recorded Pressures:
- ISI __* 3444__ psig.
- SSI __* 3430__ psig.
- FF __534__ psig.
- FSI __* 3413__ psig.

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

EVALUATOR SAMPLER UNIT

Sample Drained: [X] On Location   [ ] Service Center   [ ] Other _____

[ ] Laboratory-Name _____
Address _____

Sampler Pressure _____ 250 _____ psig. at Surface

Recovery:
- Cu. Ft. Gas __2.16__
- cc. Oil __40__
- cc. Water __60__
- cc. Mud __-__
- Total Liquid cc. __100__

Gravity __48__ °API __60__ °F.
Gas/Oil Ratio 8585 CU.FT./BBL.

	RESISTIVITY			CHLORIDE CONTENT	
Recovery Water	.20	@ 56	°F.	25,000	ppm.
Recovery Mud	-	@ -	°F.		
Recovery Mud Filtrate	-	@ -	°F.	-	ppm.
Mud Pit Sample	1.6	@ 70	°F.		
Mud Pit Sample Filtrate	-	@ -	°F.	400	ppm.

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

FORMATION WATER.

PRESSURE DATA

Instrument No.		J-007			
Capacity (P.S.I.G.)		6400			Field Report No. _____ 17664 A
Instrument Depth		6728'			
Instrument Opening		INSIDE			
Pressure Gradient P.S.I./Ft.		–			
Well Temperature °F.		152			TIME DATA

						Time Given		Time Computed	
Initial Hydrostatic Mud	A	3835							
Initial Shut-in	B	* 3444				66 Mins.		67 Mins.	
Initial Flow	C	971				6 Mins.		6 Mins.	
SECOND FLOW	C-4	515				5 Mins.		3 Mins.	
SECOND SHUT-IN	B-1	* 3430				26 Mins.		27 Mins.	
Final Flow	D	534				120 Mins.		121 Mins.	
Final Shut-in	E	* 3413				120 Mins.		119 Mins.	
Final Hydrostatic Mud	F	3717							

Remarks:	C-1	472	C-7	567	
	C-2	530	C-8	538	
	C-3	550	C-9	585	
	C-5	820			
	C-6	512			

*Shut in pressure did not reach static reservoir pressure.   Clock Travel _____ 0.02033 _____ inches per min.

PRESSURE INCREMENTS

INITIAL SHUT-IN			SECOND SHUT-IN			FINAL SHUT-IN		
Point Minutes	Pressure	$\frac{T+\Delta t}{\Delta t}$	Point Minutes	Pressure	$\frac{T+\Delta t}{\Delta t}$	Point Minutes	Pressure	$\frac{T+\Delta t}{\Delta t}$
C-2 0	530		C-4 0	515		D 0	534	
5	2402	2.200	3	1882	4.000	10	3041	14.000
10	3215	1.600	6	2731	2.500	20	3295	7.500
15	3401	1.400	9	3184	2.000	30	3340	5.333
20	3425	1.300	12	3353	1.750	40	3362	4.250
25	3433	1.240	15	3401	1.600	50	3376	3.600
30	3437	1.200	18	3416	1.500	60	3385	3.167
35	3439	1.171	21	3424	1.429	70	3394	2.857
40	3442	1.150	24	3428	1.375	80	3399	2.625
45	3442	1.133	B-1 27	3430	1.333	90	3404	2.444
50	3443	1.120				100	3407	2.300
55	3443	1.109				110	3410	2.182
60	3443	1.100				E 119	3413	2.092
65	3444	1.092						
B 67	3444	1.090						

GUIDE TO IDENTIFICATION OF DRILL STEM TEST PRESSURE CHARTS

JOHNSTON TESTERS

FIELD
REPORT NO.   RECORDER NO.   CAPACITY   REPORTS REQUESTED
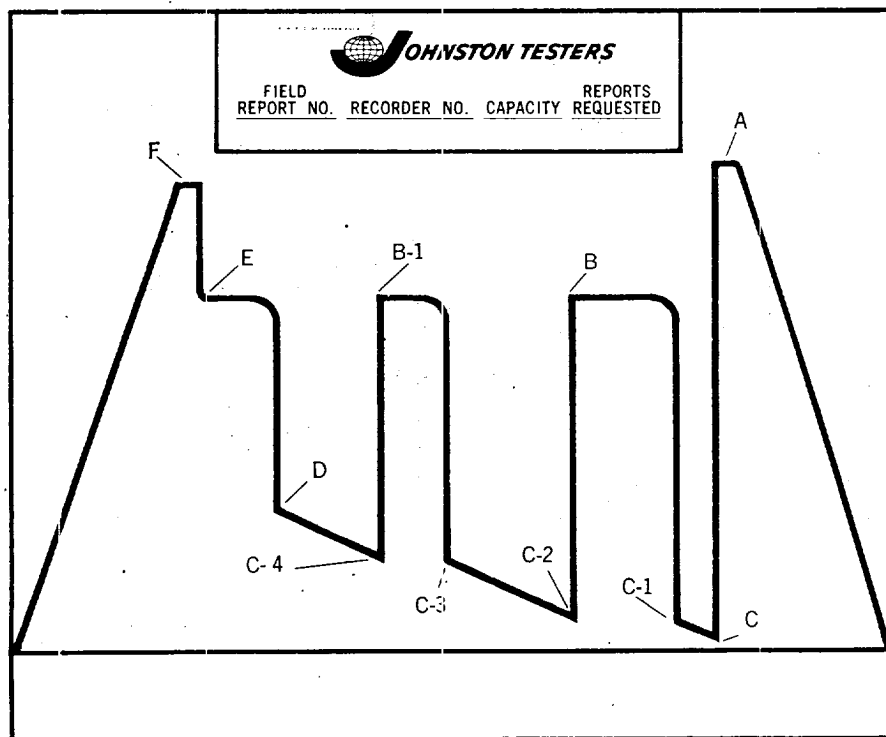
A. Initial Hyd. Mud
B. Initial Shut-in
C. Initial Flow
D. Final Flow
E. Final Shut-in
F. Final Hyd. Mud

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.

A WORLD OF EXPERIENCE

JOHNSTON TESTERS

FIELD
REPORT NO.   RECORDER NO.   CAPACITY   REPORTS REQUESTED
17664 A   J-007   6400#   18-