INTER-OFFICE LETTER

TULSA LABORATORY

August 11, 1975

29-27S-34W

TO: Mr. W. A. Givens

FROM: L. P. Brown
S. C. Swift

SUBJECT: Pressure Buildup Analysis--
Alexander D-2, Grant County, Kansas

The Alexander D-2 was shut in at 4 p.m. on May 17, 1975. A surface recording, bottomhole pressure gauge was set at 3016 ft (Rkb).

The well had been fractured with a large job prior to the buildup test. Production rates prior to fracturing had been so small that a meaningful buildup test could not be conducted at that time. The post-frac buildup test was run to accomplish four objectives:

1. Determine formation permeability
2. Determine if low productivity is caused by drilling and completion techniques or by low permeability rock
3. Determine the ability of large fracture jobs to remove damage caused by drilling and completion
4. Determine if hydraulic fracture treatments result in significant increases in gas production rates.

Since the formation (Council Grove) was known to be tight, we realized that determination of formation permeability from a buildup test would be difficult after the large frac job. Consequently, wellbore skin and fracture area, whose computation depends on knowledge of formation permeability, would be equally difficult to determine.

After eight days of testing, the pressure had not yet attained semi-log straight line behavior, a requirement for determining permeability. However, the data can be used to estimate a maximum value for formation permeability. Our calculations show that the maximum in-situ permeability to gas is 0.55 md. The method is described in Appendix A.

Using the maximum calculated permeability, it is possible to estimate a minimum fracture area. The method and calculations are shown in Appendix B. Fracture area is 111,900 ft^2. Depending on the choice of fracture height, fracture length ranges from 337 ft (h = 83 ft, the perforated interval) to 210 ft (h = 211 ft, the thickness of the Council Grove interval). Wellbore skin is about -6. This is an excellent stimulation job.

We conclude from the analysis of the buildup test on the Alexander D-2 that

1. Formation permeability within the drainage area of this well is less than 0.5 md.

2. Wellbore skin factor is about -6. At least 112,000 square feet of fracture surface area were created. Excellent stimulation resulted from the treatment.

3. If any damage was done to the reservoir during drilling or completion, its effects were completely eliminated by the fracturing operation.

4. Due to low formation permeability and low pressure, Council Grove wells in this area will not produce at commercial rates without effective fracture treatments. Simple acid cleanup jobs will not result in adequate production rates.

cp

cc: M. S. Kovac
V. W. Rhoades
J. R. Vaughan
J. J. Williams
D. G. Wright

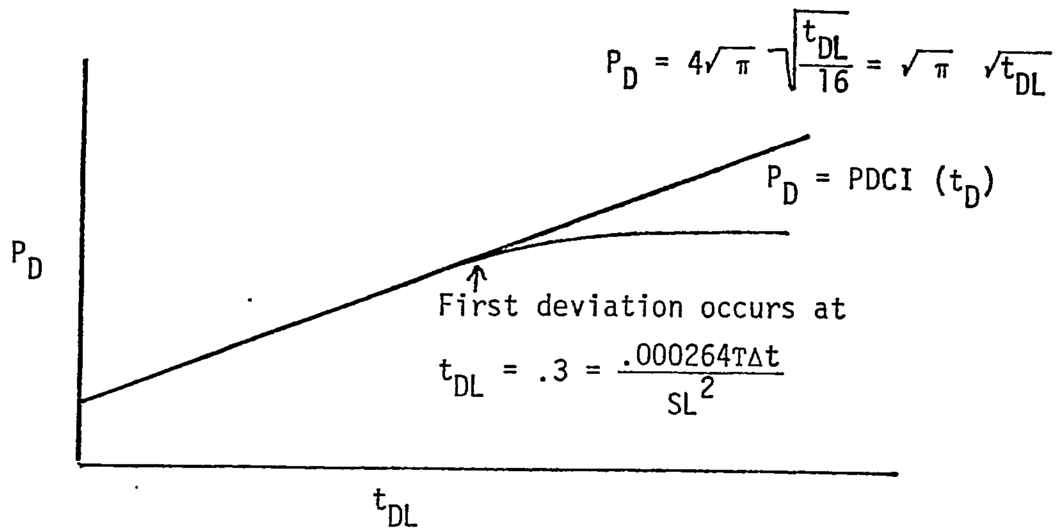
Attachment

Aug. 4, 1975
S. C. Swift

APPENDIX A

PROBLEM: Calculate the maximum $T(=\frac{kh}{\mu})$ value for a well which is still in linear flow after Δt hours of SI.

FIGURE:



SOLUTION:

$$M_L \equiv \frac{dp}{d\sqrt{\Delta t}} = \sqrt{\pi}\ \left[\frac{141.2q\beta}{T}\right] \left[\frac{.000264T}{SL^2}\right]^{1/2} \qquad (1)$$

If L^2 is given by (assumes no deviation has occurred).

$$L^2 = \frac{.000264T\ \Delta t}{.3\ S}$$

Then $M_L = \sqrt{\pi}\left[\frac{141.2q\beta}{T_{max}}\right]\left[\frac{0.3}{\Delta t}\right]^{1/2}$

or $T_{max} = \frac{137}{\Delta t^{1/2}} \frac{q\beta}{M_L}$ ←

CALCULATIONS:

Permeability--Since the test did not reach the semilog straight line, permeability cannot be calculated. However an upper limit can be set on k by calculating that value of k which would have resulted in significant deviation when the test was terminated.

$$\left(\frac{kh}{\mu}\right)_{max} = \frac{137\ q\ [BPD]\ \beta}{\sqrt{\Delta t_{\Sigma}}[hr]\ M_L\ [PSI/\sqrt{hr}]}$$

$$(kh)max = \frac{1375\ q\ [MSCFD]\ T\ [°R]}{\sqrt{\Delta t_{\Sigma}}\ [hr]\ M_L\ [PSI^2/cp/\sqrt{hr}]}$$

Assuming:

T = 550°R

From BHMP vs $\sqrt{T+\Delta t}$ - $\sqrt{\Delta t}$ Plot: $M_L = 1.449 \times 10^6\ PSI^2/cp/\sqrt{hr}$

$$\therefore\ (kh)_{max} = \frac{1375\ (1338.9)\ 550}{\sqrt{230}\ 1.449 \times 10^6} = 46\ md\text{-}ft$$

or assuming: h = 83 ft

k_{max} = 0.55 md ←

WELLBORE AREA

$$A = \frac{163.3\ q\ [MSCFD]\ T\ [°R]}{M_L\ [PSI^2/cp/\sqrt{hr}]} \sqrt{\frac{1}{k\ [md]\ \mu\ [cp]\ c_t\ [PSI^{-1}]\ \phi}}$$

Assuming: $\mu = 0.01$ cp

$\phi = 0.10$

$S_g = 0.30$

$$c_t = \frac{S_g}{P} = \frac{0.30}{300} = 10^{-3}\ PSI^{-1}$$

And using k_{max}

$$A_{min} = \frac{163.3\ (1338.9)\ 550}{1.449 \times 10^6} \sqrt{\frac{1}{0.55\ (.01)\ 10^{-3}\ (.10)}}$$

$A_{min} = 111904\ ft^2$

Assuming h = 83 ft (perforated interval)

4Lh = A (L is half fracture length)

or L = 337 ft

Assuming an infinitely conductive fracture: $r_{eff} = \frac{L}{2}$

which can be used to estimate skin:

$$S = \ln \frac{2r_w}{L}$$

Assuming $r_w = 0.25$ ft

S = -6.5

If h is assumed to be 211 feet, the thickness of the entire Council Grove section

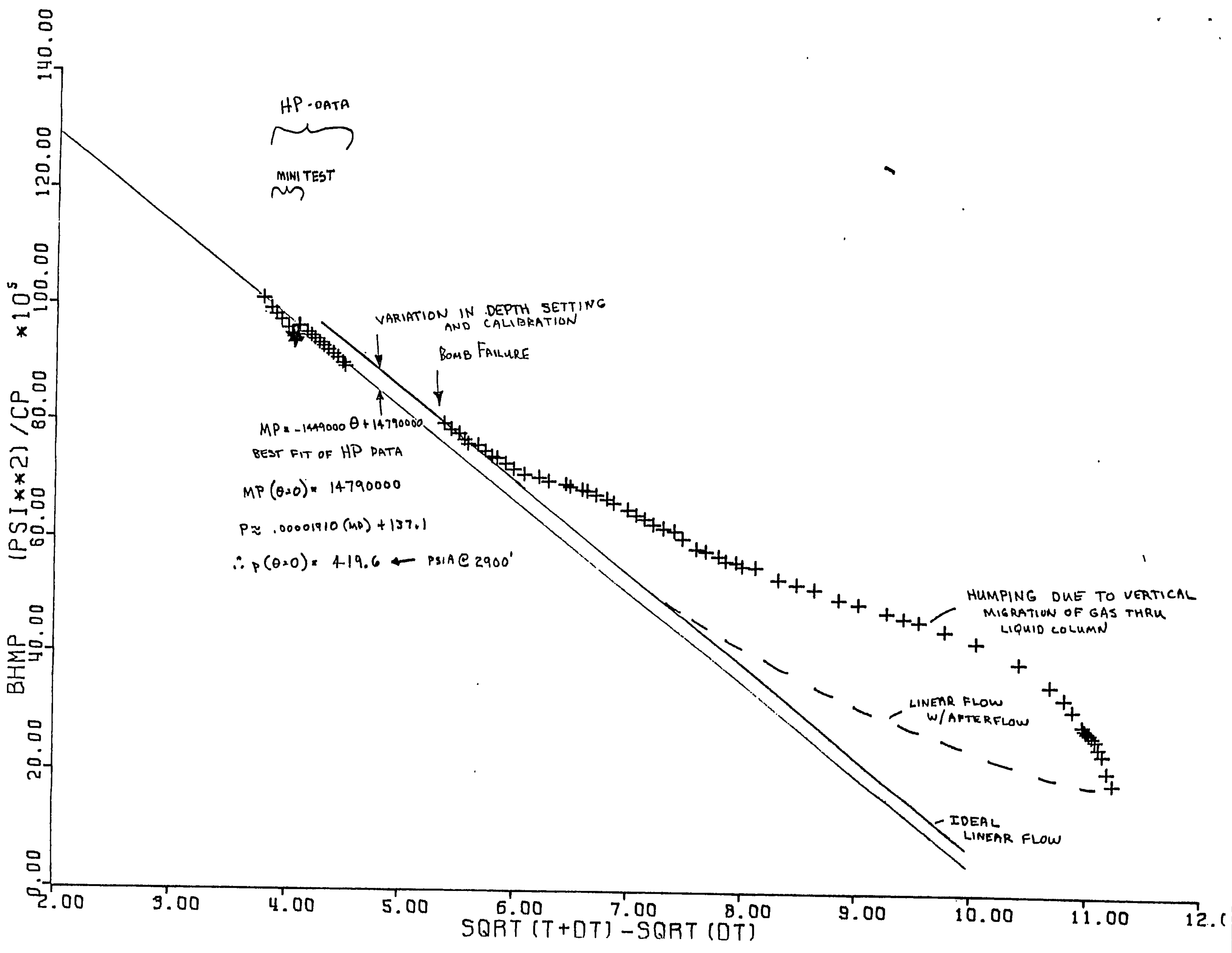
$$k_{max} = \frac{(kh)_{max}}{h} = \frac{46}{211} = .22\ md$$

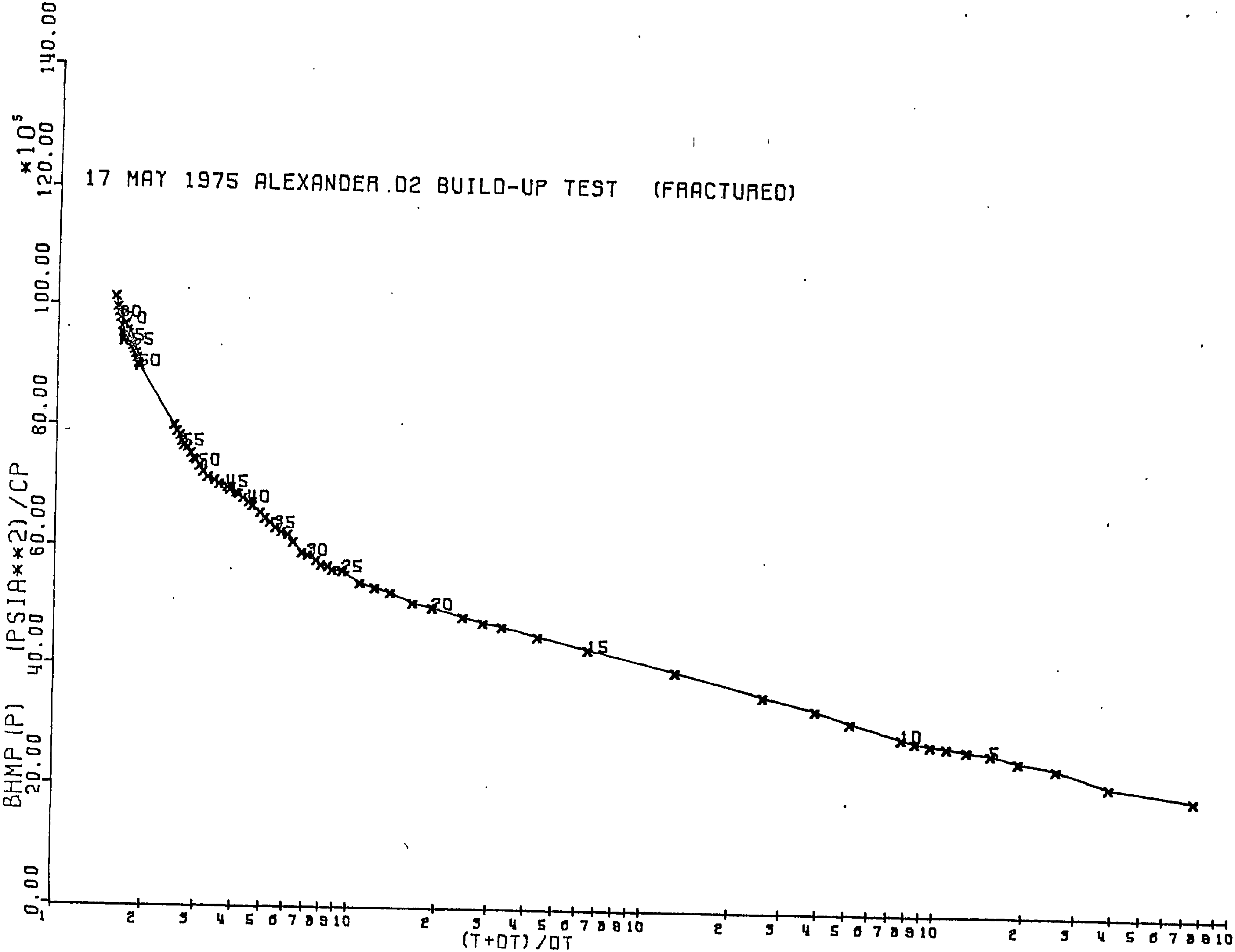
$$A_{min} = \frac{163.3\ (1338.9)\ (550)}{1.449 \times 10^6} \sqrt{\frac{1}{.22\ (.01)\ 10^{-3}\ (.10)}}$$

$= 176,936\ ft^2$

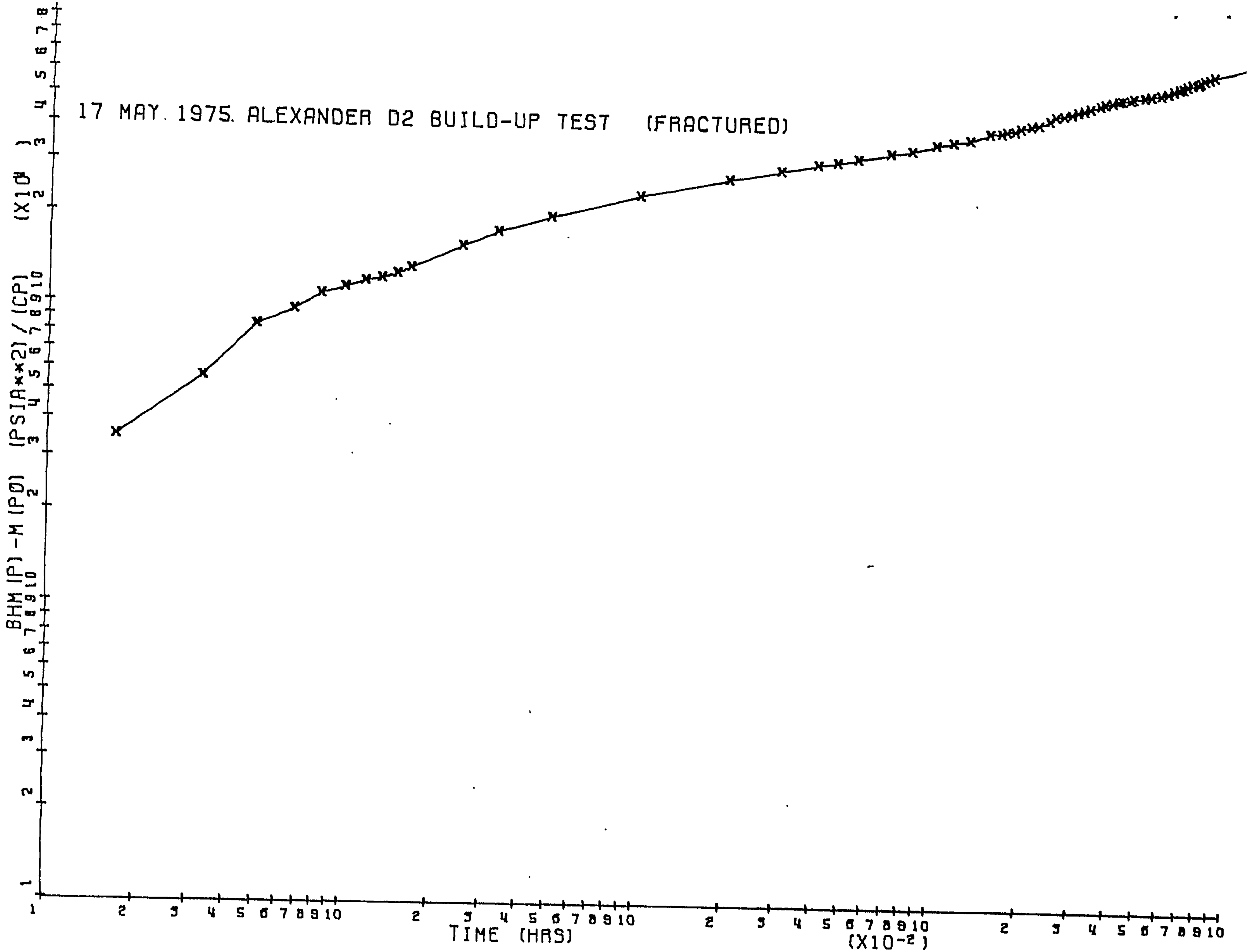
L = 210 ft

$$S = \ln \frac{2 \times .25}{210} = -6.$$


BHMP (PSI**2) /CP *10^5
SQRT (T+DT) -SQRT (DT)
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.0
HP-DATA
MINI TEST
VARIATION IN DEPTH SETTING AND CALIBRATION
BOMB FAILURE
MP = -1449000 θ + 14790000
BEST FIT OF HP DATA
MP (θ=0) = 14790000
P ≈ .00001910 (MP) + 137.1
∴ p (θ=0) = 419.6 ← PSIA @ 2900'
HUMPING DUE TO VERTICAL MIGRATION OF GAS THRU LIQUID COLUMN
LINEAR FLOW W/AFTERFLOW
IDEAL LINEAR FLOW



17 MAY 1975 ALEXANDER.D2 BUILD-UP TEST (FRACTURED)
BHMP (P) (PSIA**2)/CP
*10^5
0.00
20.00
40.00
60.00
80.00
100.00
120.00
140.00
(T+DT)/DT
1
2
3
4
5
6
7
8
9
10
80
70
65
60
55
50
45
40
35
30
25
20
15
10
5



17 MAY 1975 ALEXANDER D2 BUILD-UP TEST (FRACTURED)
BHM(P)-M(PO) (PSIA**2)/(CP) (X10⁴)
TIME (HRS)
(X10⁻²)

INTER-OFFICE LETTER

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TULSA LABORATORY

August 11, 1975

TO: Mr. W. A. Givens

FROM: L. P. Brown

SUBJECT: Progress Report--
Council Grove Drilling and
Stimulation Program

Since the last progress report on the Council Grove study, our activity has been confined to two portions of the program. Additional flow testing has been accomplished and a pressure transient test on the Alexander D-2, Grant County, Kansas, has been conducted and analyzed.

Flow Testing

Cores from the Alexander D-2, Grant County, Kansas, and from the Eckstein A-2, Texas County, Oklahoma, were tested for fresh water sensitivity. The Alexander cores showed no sensitivity to fresh water, while the Eckstein cores were sensitive.

Bill Almon of our geological research staff suggested that the scanning electron microscope might be used to determine what caused permeability reduction in the Eckstein cores. We have provided plug ends from the cores for his study and requested that he send a copy of his observations to your office.

Pressure Transient Testing

Analysis of pressure transient tests on the Alexander D-2, reported in a separate inter-office letter, allowed an estimate of fracture effectiveness to be made. Wellbore skin was about -6. Formation permeability in the drainage area of the well was less than 0.5 md. Effective fracture area created was about 112,000 square feet. This indicates that excellent results were obtained from the stimulation treatment.

Conclusions

Several conclusions may be made by studying the data generated to date.

1. Formation sensitivity to stimulation fluids may be controlled by the use of KCl water.

2. Fracturing is required in order to achieve reasonable production rates in this low permeability, low pressure formation.

3. Simple acid cleanup jobs will not result in adequate stimulation.

4. Large effective fractures can be created in the Council Grove formation. These fractures overcome any damage caused during drilling or completion operations.

5. The effect of fluid retention in the formation after stimulation has not been studied. With regard to conclusion 1, no exotic surfactants are required to get the fluid off the formation quickly. Rapid cleanup may be desirable to avoid flaring excessive amounts of gas, however.

Several members of your staff have asked if foam frac could be an effective treatment for the Council Grove. I believe a foam frac treatment, using KCl water as the base fluid, should be investigated. We will be happy to assist you in the design of a foam frac job. As with the Alexander, fracture effectiveness should be determined by pressure transient tests.

cp

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