# 1R - 279

# REPORTS

# DATE:

1986

Mobil Producing Texas & New Mexico Inc.

December 8, 1986

P.O. BOX 633
MIDLAND, TEXAS 79702

MIDLAND DIVISION

Vacuum Field Waterflow
Management Committee

STATUS REPORT

Attached is the Vacuum Field Geological-Geophysical Committee Status Report which will be delivered in Santa Fe, New Mexico, on Thursday, December 11, 1986.

Sincerely,

William E. Hermance

W. E. Hermance
Chairman
Geological-Geophysical Committee

WEH:lp
CC: New Mexico Oil Conservation Division
Technical Committee Members
Geological-Geophysical Committee Members
Attachments

A:M634246A.WEH

Vacuum Field Waterflow
Management Committee

VACUUM FIELD WATERFLOW
GEOLOGICAL-GEOPHYSICAL COMMITTEE
STATUS REPORT

As requested, the following is a progress report from the Geological-Geophysical Committee concerning the progress made to date towards fulfilling the charges set forth by the Management Committee on September 4, 1986. The Geological-Geophysical Committee held its first meeting September 26, 1986.

To review, the Committee was charged with the following:

1. Prepare a detailed geologic description of all formations.
   1st priority - Interval from surface to the base of the salt.
   2nd priority - Interval below base of salt.

2. Investigate possible use of geophysical data to locate fluid pockets, solution caverns, etc. in the salt section.

3. Formulate the "most likely" condition that would occur with subsidence in the area due to salt dissolution.

The report on the above charges is as follows:

CHARGE 1. The Committee has reviewed the available geologic data for 654 wells across the Vacuum Field area to produce structure maps for Top Rustler, Top Salt, Cowden Anhydrite, and Base Salt. An isopach of the interval from Top Salt to Base Salt was also produced. All data was contoured by computer to remove bias. It is the Committee's opinion that the preliminary maps give a reliable picture of the evaporite section across Vacuum Field. The four mapped horizons reflect the deeper structure through the field while the isopach shows general thinning to the north.

With the approval of the Management Committee, Dr. Dennis Powers of the University of Texas El Paso was hired for one day of consulting on November 17, 1986. The consultation with Dr. Powers was called to review the waterflow problem and to get his expert geological input. Of particular concern to the Geological-Geophysical Committee was the lithologic composition of the evaporite section, and the fluid flow and dissolution behavior that might be expected in the evaporite section.

The evaporite section is comprised of interbedded anhydrite, halite, polyhalite, clays, shales, and some dolomite. Mineralization can be highly variable with some potash deposits possible. Several of the anhydrites and polyhalites appear to be correlatable across the field. It is now the Committee's opinion that fluid flow and storage within the evaporite section will occur along <u>bedding planes</u> and <u>not</u> through a pipe system within the halite itself. Dissolution and cavern formation is most likely to occur in proximity to well bores as the fluid works its way into the bedding planes where flow may be facilitated. The conslutation with Dr. Powers ended with general agreement upon this most likely scenario.

CHARGE 2. The use of geophysical methods has been investigated yielding only two methods which might be considered to investigate the occurrence of cavern formation at the well bore. Both the Borehole Gravimeter and VSP using a downhole source hold some promise in well bores where exceedingly large well bore storage is indicated from some previous test. No other geophysical techniques have the resolution required to investigate this type of problem and no technique has been identified which would hold promise in investigating away from the well bore.

CHARGE 3. The Committee has begun to review the problem of subsidence in the Vacuum Field area. A review of the literature and discussion with Dr. Powers indicates that the continued, or future production of fluid from the evaporite section in monitor wells will undoubtedly increase the probability of occurrence of some future subsidence event. This increased probability would occur as a result of enhancing the rate of fluid flow through the evaporite with an accompanying increased rate and volume of dissolution.

Recommendations:

1. Monitor wells in Vacuum Field should not be completed to produce fluids from the evaporite section other than to monitor pressure and to obtain water samples.

2. The need for surface elevation monitoring in areas of known dissolution and removal of rock volume should be studied and defined.

The Geological-Geophysical Committee proposes to continue examining the waterflow problem in the following areas:

1. Finalize all maps created to date.

2. Attempt to identify specific intervals in the evaporite section through which fluid may be moving.

3. Review subsidence monitoring for areas where large volumes of fluid and rock may have been removed.

4. Determine the composition, continuity, and sealing characteristics of the interval from the surface to the top of the salt to define the contraints upon fluid movement upwards from the evaporite.

The Committee expects to have results in these areas by the end of the first quarter, 1986.

The Geoloigcal-Geophysical Committee will continue to assist the Technical Committee in any way possible in the efforts being made towards a solution of the Vacuum Field Waterflow Problem.

William E. Hermance

W. E. Hermance
Chairman, Vacuum Field Waterflow
Geological-Geophysical Committee

WEH:lp

A:M634246A.WEH

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VACUUM FIELD WATERFLOW COMMITTEE
PHILLIPS PETROLEUM COMPANY STATUS REPORT

December 11, 1986

As the Vacuum Field Waterflow Committee was being formed, Phillips was completing two wells, Lea #18 and Lea #32, in the western portion of the field as monitor wells. These wells flowed for a short time (total production was approximately 60,000 bbls.) and were subsequently shut in. They have been used as pressure monitors since.

Early in the work of the Technical Committee, a Phillips geochemist suggested geochemical and isotopic work on injected and produced waters in the field. As a result, approximately 35 water samples were collected by the operators in the field and sent to Phillips. Phillips then supervised the lab work (Some was done in our own labs.). The results were compiled and analyzed by the Phillips geochemist. His report was approved by the Technical Committee and submitted to the Management Committee, and ultimately to the NMOCD.

Pressure buildup tests run on the Central Vacuum Unit monitor well by Texaco were submitted to and analyzed by Phillips' pressure transient experts. From the storage volume calculated from these tests and in conjunction with the geochemist, tracer tests were designed for possible use in the field. Radioactive and non-radioactive chemical tracers that could be used in these tests were researched. Several pressure transient tests were also designed. These include interference tests between possible sources of the waterflow problem and monitor well(s), as well as between existing and possible future monitor wells. These recommendations and designs have been approved by the Technical Committee and included in their reports. They have also been presented to the NMOCD.

Step rate tests have been run in 63 wells across the field in order to identify the San Andres parting pressure and support present surface injection pressures. According to these tests, we are [redacted] injecting at less than the parting pressure in all injectors. Additional tests will be conducted in the future to expand the areal extent of the parting pressure knowledge.

In order to outline a good logging plan for the committee, Phillips R&S personnel researched and made a recommendation on available logging tools that might be able to locate very small volume fluid movement behind casing in the injection wells. The recommendation is included in the Technical Committee report. The most highly recommended tool is a "scintillation" tracer survey. It is recommended that these tracer/temperature surveys be run across the field, in all injection wells with surface pressures of 900 psi or greater. A large number of the surveys run in the last year have been run with this type of tool. Upward moving channel checks were a part of the survey. However, they were not posted on all of the final drafted copies of every survey. Copies of those channel checks have been requested from the service company. A look at the channel checks in hand show no movement upward out of zone. A completed report on those surveys will be available shortly after the copies are received from the service company. To date, 45 surveys have been run. (They are listed on the attached table.) At least eleven more are proposed for running in the near future. Ultimately, it is our goal to survey every well with 900 psi surface injection pressure or more.

Since our last meeting with the New Mexico Oil Conservation Division in August, Phillips Petroleum Company has proceeded with work outlined by the committee in an attempt to identify problem wells that may be contributing to the Vacuum Field salt water flows. All of the injection wells in the field that are operated at a surface injection pressure of 900 psi or more have been identified. An independent bradenhead and annulus survey has been conducted to be sure that every well is open to the surface and to check for pressure. 121 wells were surveyed (EVGSAU - 101, M. E. Hale - 6, Mable - 2, Lea - 2, and the Vacuum Abo Unit - 10). Results from the survey reveal no problems. A comprehensive report on the results should be complete in the near future.

There are plans for running nuclear logs in three wells. It is anticipated that these logs will be run soon after the first of the year. These logs are to be run through tubing in wells in areas of the field that have had bradenhead pressure. It is also our intention to run Texaco's (R&D) thru-casing nuclear log in the Hale No. 18. This will be a good test of the tool in a well that experienced a waterflow during drilling operations.

In order to identify injection wells with abnormally high storage volumes, falloff tests are being run on all target injection wells. To date, we have completed tests on ten wells. Analysis of these tests are at present incomplete. We are currently testing wells at the rate of three per week. Our present plan is to continue this schedule.

Locations for monitor wells have been chosen. There are three drilling locations, two on EVGSAU and one on the Hale lease. Two alternate locations on EVGSAU have been chosen for well conversions. We plan to work with other operators in the drilling/conversion of these wells in order to gain as much information as possible. Phillips has also obtained a legal opinion concerning the completion of monitor wells outside the unitized interval. Such completion would have to have the approval of the leaseholder.

VACUUM FIELD WATERFLOW COMMITTEE
PHILLIPS PETROLEUM COMPANY STATUS REPORT

DECEMBER 11, 1986

| LEASE NAME | INJECTOR TRACT-WELL | BRADENHEAD TEST | FALLOFF TESTS | TRACER SURVEY | STEP RATE TESTS |
|---|---|---|---|---|---|
| ************ | ********** | ********** | ********* | ******** | ********* |
| EAST VACUUM | 0449-001 | Y | | | |
| G-SA UNIT | 0449-002 | Y | | | |
| | 0524-001 | Y | | Y | Y |
| | 0524-004 | Y | | | |
| | 0524-005 | Y | | | |
| | 0524-006 | Y | | Y | Y |
| | 0546-002 | Y | | | |
| | 1825-002 | Y | | | |
| | 1903-004 | Y | | | |
| | 1904-003 | Y | | | |
| | 1910-003 | Y | | | |
| | 1910-004 | Y | | | |
| | 1911-002 | Y | | | |
| | 1912-004 | Y | | | |
| | 1952-002 | Y | | | Y |
| | 1953-002 | Y | | | |
| | 1978-002 | Y | | | |
| | 2054-003 | Y | | | Y |
| | 2059-003 | Y | | | |
| | 2060-001 | Y | | | |
| | 2060-014 | Y | | | |
| | 2150-001 | Y | | | |
| | 2150-002 | Y | | | |
| | 2155-001 | Y | | | |
| | 2230-003 | Y | | | |
| | 2230-004 | Y | | | |
| | 2230-005 | Y | | | |
| | 2271-003 | Y | | | |
| | 2416-002 | Y | | | |
| | 2418-002 | Y | | | |
| | 2437-003 | Y | | | |
| | 2622-003 | Y | | | |
| | 2622-004 | Y | | Y | Y |
| | 2622-005 | Y | | | |
| | 2622-006 | Y | | Y | Y |
| | 2622-007 | Y | | | |
| | 2642-001 | Y | | | |
| | 2648-002 | Y | | | |
| | 2672-001 | Y | | | |
| | 2717-003 | Y | | | Y |
| | 2717-005 | Y | | Y | Y |
| | 2717-007 | Y | | Y | Y |
| | 2720-006 | Y | | Y | Y |
| | 2720-008 | Y | | | |
| | 2721-001 | Y | | Y | Y |

| LEASE NAME | INJECTOR TRACT-WELL | BRADENHEAD TEST | FALLOFF TESTS | TRACER SURVEY | STEP RATE TESTS |
|---|---|---|---|---|---|
| EAST VACUUM | 2721-002 | Y | | Y | Y |
| G-SA UNIT | 2738-006 | Y | | | |
| | 2738-007 | Y | Y | Y | Y |
| | 2738-008 | Y | | Y | Y |
| | 2738-009 | Y | | | Y |
| | 2801-005 | Y | | Y | Y |
| | 2801-006 | Y | | Y | Y |
| | 2801-007 | Y | | Y | Y |
| | 2801-012 | Y | | | Y |
| | 2801-015 | Y | Y | Y | Y |
| | 2851-002 | Y | | | |
| | 2864-002 | Y | | | |
| | 2865-001 | Y | | Y | Y |
| | 2913-007 | Y | | Y | Y |
| | 2913-008 | Y | | Y | Y |
| | 2913-009 | Y | | Y | Y |
| | 2923-002 | Y | | | |
| | 2923-003 | Y | | | |
| | 2941-001 | Y | | Y | Y |
| | 2944-001 | Y | | | |
| | 2944-002 | Y | | | |
| | 2947-001 | Y | | Y | Y |
| | 2957-002 | Y | | | |
| | 2963-004 | Y | | Y | Y |
| | 2963-005 | Y | | | |
| | 2980-003 | Y | | Y | Y |
| | 3127-004 | Y | Y | Y | Y |
| | 3127-005 | Y | | Y | |
| | 3127-006 | Y | | Y | |
| | 3127-007 | Y | | Y | |
| | 3202-008 | Y | | Y | Y |
| | 3202-009 | Y | | Y | Y |
| | 3202-010 | Y | Y | Y | Y |
| | 3202-011 | Y | | Y | Y |
| | 3202-013 | Y | Y | Y | Y |
| | 3229-006 | Y | | Y | Y |
| | 3229-007 | Y | | Y | Y |
| | 3229-008 | Y | | Y | Y |
| | 3236-006 | Y | | Y | Y |
| | 3236-008 | Y | | | |
| | 3315-006 | Y | | Y | Y |
| | 3315-007 | Y | | | Y |
| | 3315-008 | Y | | P | Y |
| | 3315-009 | Y | | | |
| | 3328-003 | Y | Y | P | Y |
| | 3332-001 | Y | Y | P | Y |
| | 3333-005 | Y | | P | Y |
| | 3333-006 | Y | | P | Y |
| | 3373-001 | Y | | P | Y |
| | 3374-002 | Y | | P | Y |
| | 3440-004 | Y | | | |
| | 3440-006 | Y | | | |

| LEASE NAME | INJECTOR TRACT-WELL | BRADENHEAD TEST | FALLOFF TESTS | TRACER SURVEY | STEP RATE TESTS |
|---|---|---|---|---|---|
| ************ | ********** | ********** | ********* | ******** | ********* |
| EAST VACUUM G-SA UNIT | 3456-006 | Y | | P | Y |
| | 3456-007 | Y | | P | Y |
| | 3456-009 | Y | | P | Y |
| | 3467-002 | Y | | | |
| M. E. HALE | 14 | Y | | Y | Y |
| | 15 | Y | | Y | Y |
| | 16 | Y | Y | Y | Y |
| | 17 | Y | | Y | Y |
| | 18 | Y | Y | Y | Y |
| | 19 | Y | Y | Y | Y |
| MABLE | 4 | Y | | Y | Y |
| | 5 | Y | | Y | Y |
| LEA | 4 | Y | | | |
| | 6 | Y | | | |
| VACUUM ABO UNIT | 1-9 | Y | | | Y |
| | 4-6 | Y | | | Y |
| | 5-2 | Y | | | |
| | 6-68 | Y | | | |
| | 9-5 | Y | | | Y |
| | 12-2 | Y | | | Y |
| | 13-7 | Y | | | Y |
| | 13-9 | Y | | | |
| | 13-18 | Y | | | |
| | 15-3 | Y | | | |

P -- PROPOSED

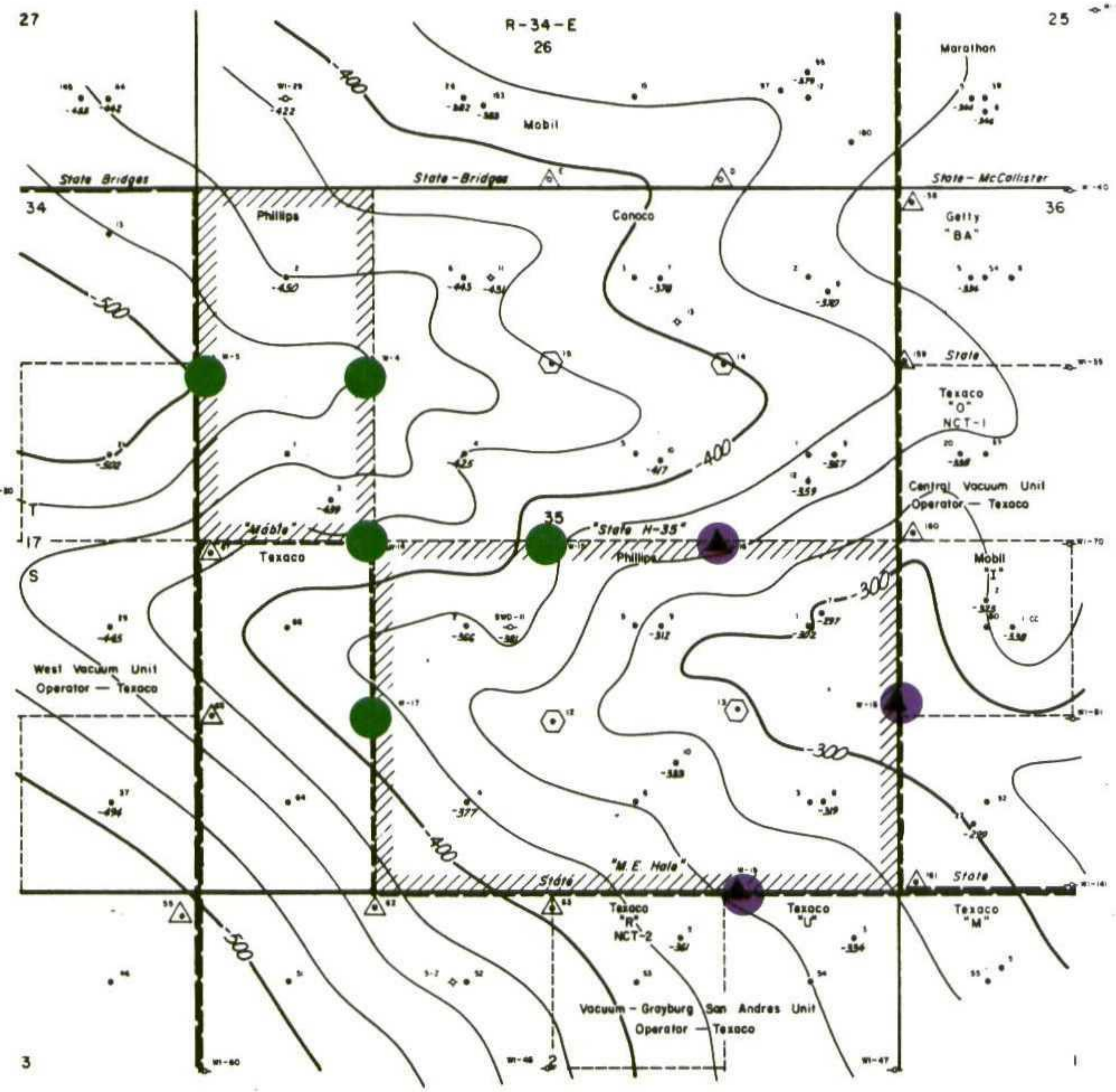
VACUUM FIELD WATERFLOOD COMMITTEE

PHILLIPS PETROLEUM COMPANY STATUS REPORT

December 11, 1986

## Legend for Attached Maps

- (red) Bradenhead Survey
- (brown) Bradenhead Survey & Step Rate Test
- (yellow) Bradenhead Survey, Step Rate Test & Completed Tracer Survey
- (green) Bradenhead Survey & Completed Tracer Survey
- (blue) Bradenhead Survey, Step Rate Test, Completed Tracer Survey & Fall Off Test
- (pink) Bradenhead Survey, Step Rate Test, Fall Off Test & Proposed Tracer Survey
- (purple) Bradenhead Survey, Fall Off Test & Completed Tracer Survey
- (orange) Bradenhead Survey, Step Rate Test & Proposed Tracer Survey



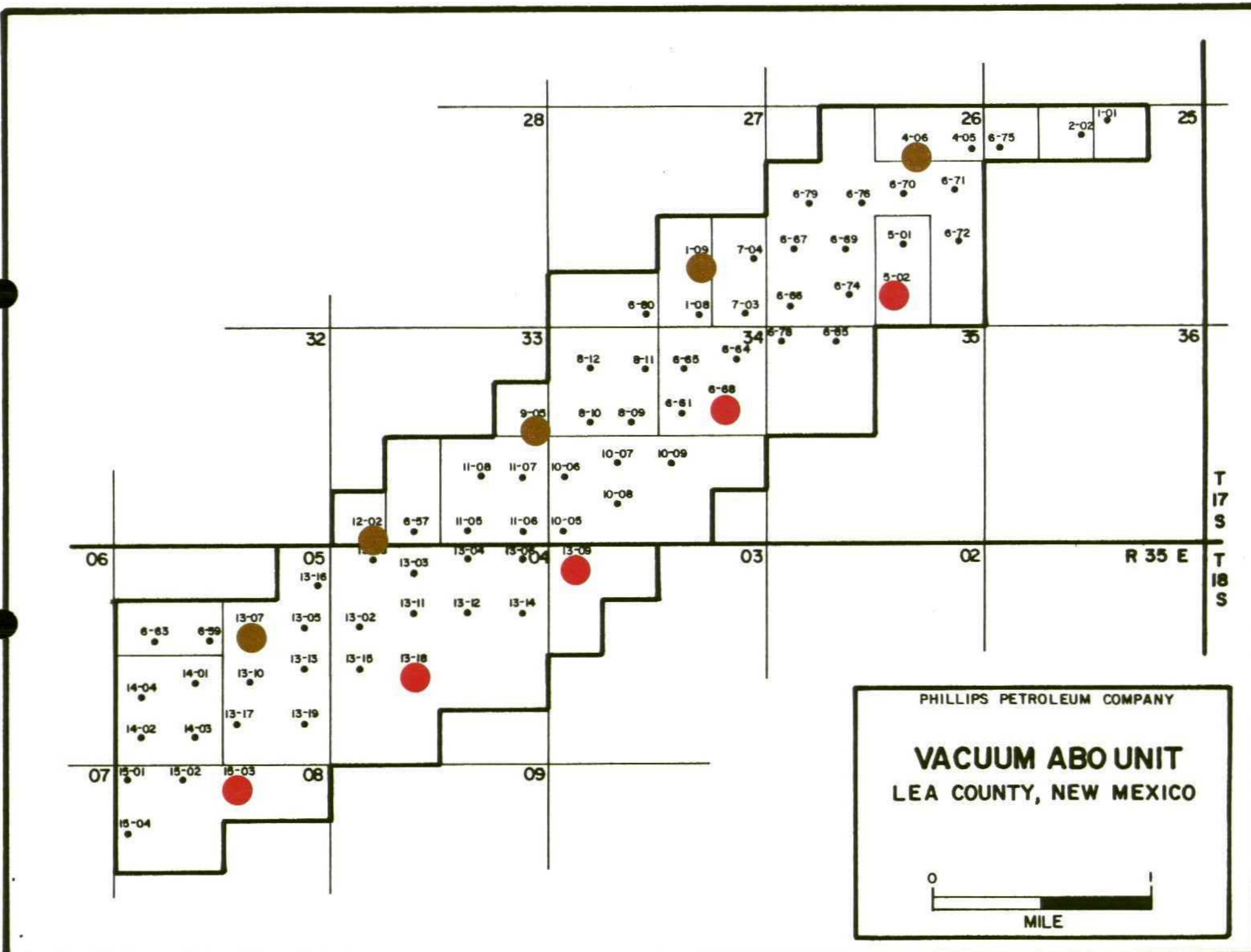

STRUCTURE-TOP SAN ANDRES
HALE-MABLE VACUUM G-SA
PRESSURE MAINTENANCE PROJECT
SECTION 35, T-17-S, R-34-E
VACUUM GRAYBURG-SAN ANDRES FIELD
LEA COUNTY, NEW MEXICO
ORDER NO. R-7103

SCALE

0' 500' 1000' 1500' 2000'

Horizon Mapped ........ Top San Andres
Contour Interval ................ 25'
Type Information ........... Subsurface

▲ --- Injector
⬡ --- Producer


PHILLIPS PETROLEUM COMPANY
VACUUM ABO UNIT
LEA COUNTY, NEW MEXICO
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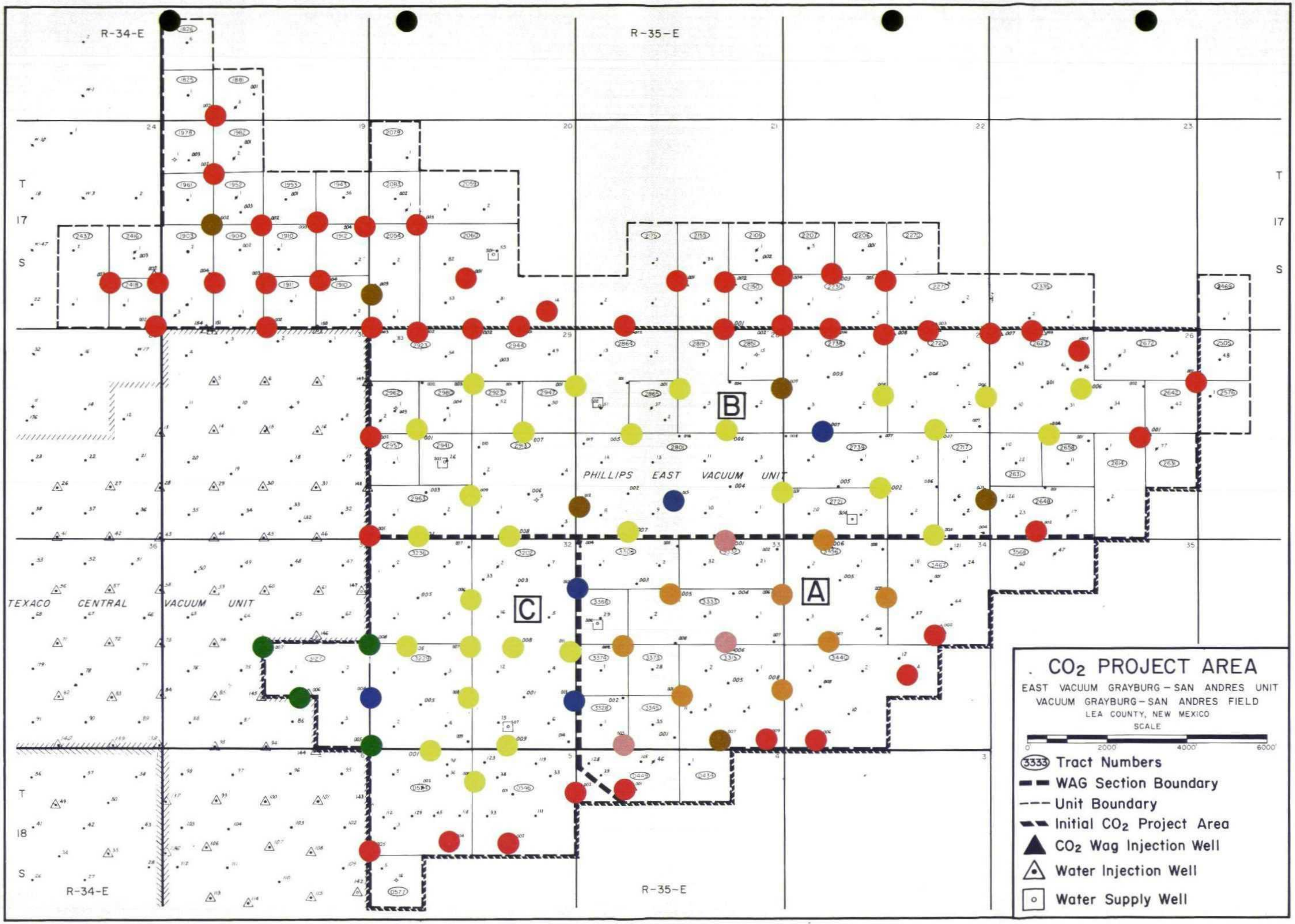
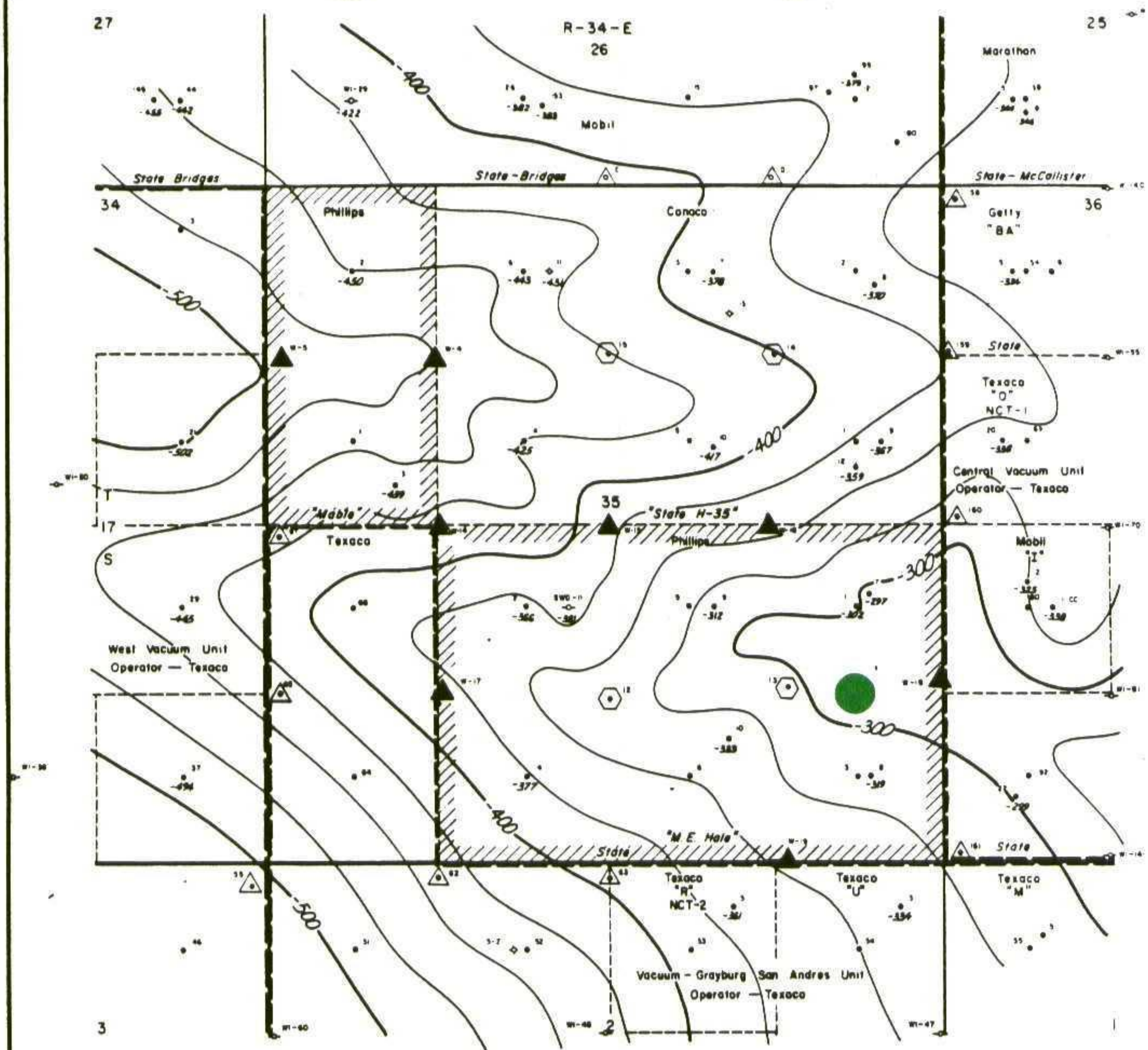
15-02
15-03
15-04



CO2 PROJECT AREA
EAST VACUUM GRAYBURG – SAN ANDRES UNIT
VACUUM GRAYBURG – SAN ANDRES FIELD
LEA COUNTY, NEW MEXICO
SCALE
0
2000
4000
6000
Tract Numbers
WAG Section Boundary
Unit Boundary
Initial CO2 Project Area
CO2 Wag Injection Well
Water Injection Well
Water Supply Well
R-34-E
R-35-E
T 17 S
T 18 S
PHILLIPS EAST VACUUM UNIT
TEXACO CENTRAL VACUUM UNIT
A
B
C




STRUCTURE-TOP SAN ANDRES
HALE-MABLE VACUUM G-SA
PRESSURE MAINTENANCE PROJECT
SECTION 35, T-17-S, R-34-E
VACUUM GRAYBURG-SAN ANDRES FIELD
LEA COUNTY, NEW MEXICO
ORDER NO. R-7103

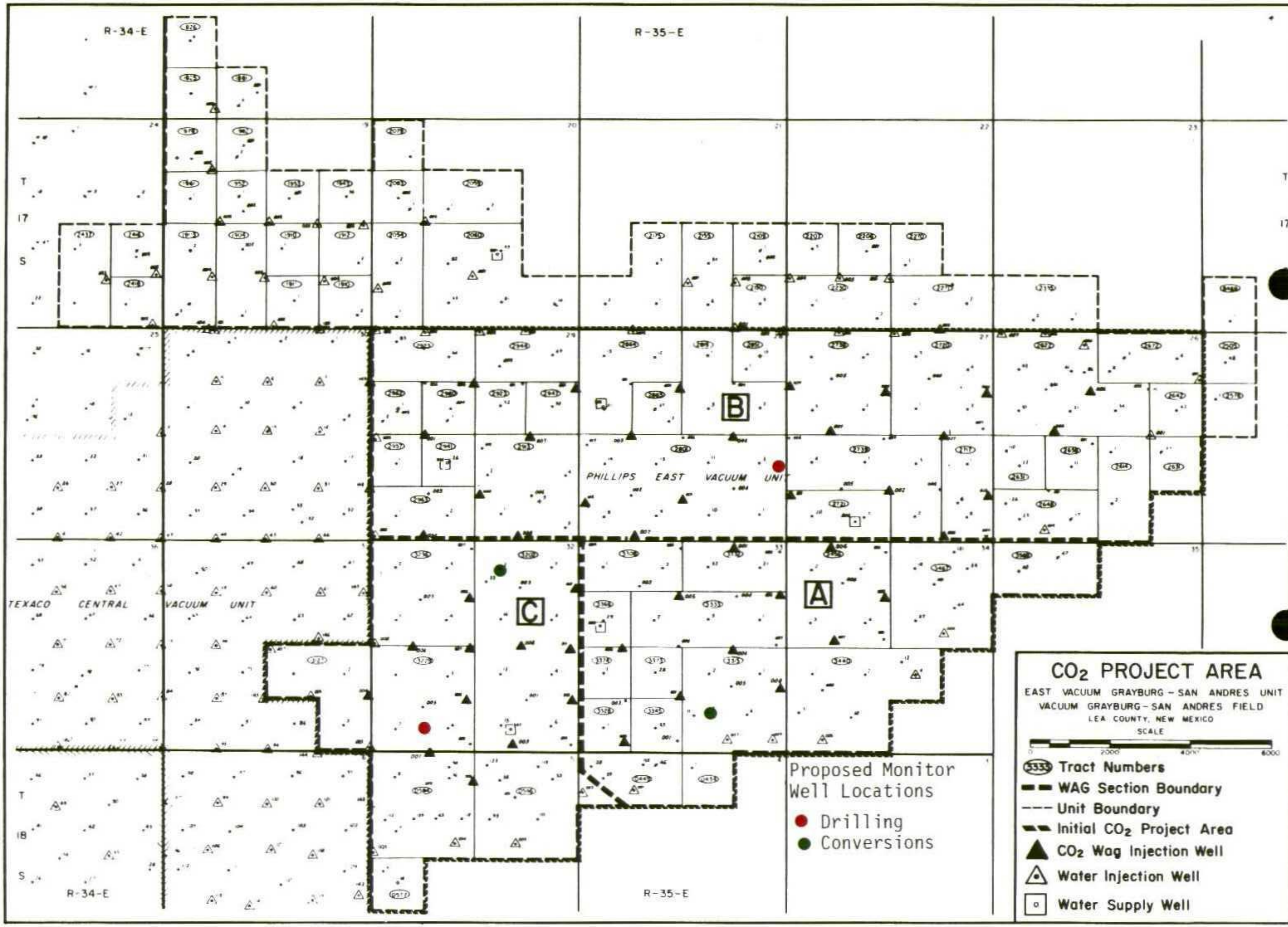
SCALE

0' 500' 1000' 1500' 2000'

Horizon Mapped ........ Top San Andres
Contour Interval ................ 25'
Type Information ........... Subsurface

▲ --- Injector
⊙ --- Producer

Proposed Monitor Well Location


R-34-E
R-35-E
T 17 S
T 18 S
PHILLIPS EAST VACUUM UNIT
TEXACO CENTRAL VACUUM UNIT
A
B
C
Proposed Monitor Well Locations
Drilling
Conversions
CO2 PROJECT AREA
EAST VACUUM GRAYBURG - SAN ANDRES UNIT
VACUUM GRAYBURG - SAN ANDRES FIELD
LEA COUNTY, NEW MEXICO
SCALE
0
2000
4000
6000
Tract Numbers
WAG Section Boundary
Unit Boundary
Initial CO2 Project Area
CO2 Wag Injection Well
Water Injection Well
Water Supply Well

# ENGINEERING REPORT

# VACUUM FIELD WATERFLOW PROBLEM
# ANALYSIS OF WATER INJECTION FALLOFF TESTS

A. G. Pollin
Phillips Petroleum Company

## OBJECTIVE

Determine whether water injection falloff tests can be used to identify wells which have reservoir injection intervals in communication with salt zone caverns and which may be contributing to the Vacuum Field Waterflow Problem.

## CONCLUSIONS

1. Water injection falloff tests are not as definitive as has been anticipated as an aid in identifying suspect wells. The nondecisiveness is caused by lack of very early time data in the tests analyzed as well as onset of changing liquid levels during the tests, and is exacerbated by the existence of highly negative skins.

2. Five wells have been identified from the analysis as suspect. Six additional wells have been identified as possibly suspect, and fifteen wells have been identified as nonsuspect. Because of the sensitivity of the analysis to measurements of initial shut-in bottomhole pressure and the nonuniqueness of many of the typecurve matches, no well should be considered as contributing to the Waterflow Problem without additional confirming data.

## RECOMMENDATIONS

1. Log those wells which have been identified as suspect or possibly suspect.

2. Obtain earlier time data (less than one minute) in all new water injection falloff tests. Retest suspect wells where the old tests lack early time data.

## THEORY

Wellbore storage has long been recognized as affecting short time transient pressure behavior; few cases have been described in the literature, however, where the determination of the storage volume was the major objective of the test. The goal of this investigation was to determine whether standard water injection falloff tests could serve as a tool for identifying wells in the Vacuum Field in which a storage cavern has been created in the Salado Formation by the upward channelling of injected water from the reservoir injection interval. Such a cavern would be in communication with the injector wellbore and would significantly increase storage domination of the early time pressure transient data during an injection falloff test.

The wellbore storage constant, C, is defined by

$$C = \Delta V/\Delta P \qquad (1)$$

where C is the wellbore storage constant in BBLs/psi, $\Delta V$ is the change in volume of fluid in the wellbore (or cavern) in BBLs, and $\Delta P$ is the change in bottomhole pressure in psi.

When the wellbore is completely full of a single phase fluid (compressive storage), equation (1) becomes

$$C = V_{wb}c \qquad (2)$$

where $V_{wb}$ is the total wellbore (or cavern) volume in BBLs and c is the compressibility of the fluid in the wellbore. When the liquid level in the wellbore is changing (changing liquid level storage), equation (1) becomes

$$C = 144V_u/\rho \qquad (3)$$

where $\rho$ is the density of injection fluid in lbs/cu ft and $V_u$ is the linear volume of the wellbore in BBLs/ft. For normal (i.e., no cavern) wellbores filled with a relatively incompressible fluid, the storage constant due to a changing liquid level is several orders of magnitude greater than the storage constant due to fluid compression; for a wellbore in communication with a storage cavern, the compressive storage constant may equal or exceed the changing liquid level storage constant. The two types of storage can act sequentially or simultaneously and can complicate the analysis when domination by one type shifts to domination by the other type.

Data accumulated during the time interval when storage completely dominates a welltest is characterized by a unit slope on a log-log plot of $\Delta P$ vs $\Delta t$; the storage constant (and from it the storage volume) can be calculated from

$$C = qB\Delta t/24\Delta p \qquad (4)$$

where q is the injection rate in BBL/day prior to shut in and B is the formation volume factor of the injected fluid. Even if storage completely dominates a test, the unit slope can be obscured by an error in the recorded pressure at the exact moment of shut in, and may become identifiable only after correcting the apparent pressure.

Data accumulated during the time interval when storage only partially controls or influences a welltest rather than completely dominates it will show a gradual transition from a unit slope to standard semilog (i.e., a straight line on a plot of P vs log $\Delta t$) behavior. Storage volumes are difficult to quantize from such tests but may be estimated by matching a log-log plot of the data using one of several different standard typecurves developed for separate use with stimulated and non-stimulated wells. Even if the matching procedure is assisted by use of pressure derivative function typecurves (i.e., $d\Delta p/d\Delta t$ vs t on a log-log plot), the typecurve match may be nonunique, with a resulting range of computed storage volumes. The reservoir parameters derived from such alternate matches may all be reasonably consistent with parameters obtained from classical semilog methods. The difficulty in obtaining a unique typecurve match increases if the storage mechanism changes during a test or if the falloff test character is not well defined.

RESULTS & DISCUSSION:

A total of 28 water injection falloff tests run between 1980 and 1986 were examined. The tests include 10 on the ARCO-operated State Vacuum Unit (5 in 1980, 5 in 1982), 3 on the Phillips-operated East Vacuum Grayburg San Andres Unit (1986), 13 on the Texaco-operated Central Vacuum Unit (11 in 1985, 2 in 1986), and 2 on the Texaco-operated Vacuum Grayburg Unit (1986). None of the tests contained pressure data at shut-in times earlier than 5 minutes; sixteen tests did not contain pressure data at times earlier than 15 minutes.

Wells were classified as suspect, possibly suspect, or non-suspect based on analyses using one or more of the following:

1. Appearance of a unit slope on a log-log plot of $\Delta P$ vs $\Delta t$. At sufficiently short shut-in times (seconds or less), even wells with normal wellbore volumes (approximately 30 BBLs for a 4500 ft well with a packer and 2 7/8" tubing) should show a unit slope. At the shut-in times available in the tests analyzed, however, only wells with very large storage volumes will show unit slopes and many of these will be past the unit slope period and into the transition zone between unit slope and semi-log behavior.

The appearance of a unit slope can be masked by an incorrect reading for bottomhole pressure ($P_O$) at the exact moment of shut-in. Adjustment of $P_O$ was attempted by extrapolation of early time data on a Cartesian plot. A negative adjustment will usually accentuate a possible unit slope; a positive adjustment will deaccentuate one. The possibility of a false correction exists, especially if early time pressure data changes rapidly or must be extrapolated extensively to zero $\Delta t$.

2. Typecurve matches on VERTICAL FRACTURE WITH STORAGE (UNIFORM FLUX) or VERTICAL FRACTURE WITH STORAGE (INFINITE PERMEABILITY) typecurves. The choice between use of propped or unpropped typecurves was made empirically. The zero dimensionless storage constant ($C_{Df}$ or $C_{Dxf}$) lines on these typecurves are coincident with standard propped and unpropped fracture typecurves; a match to either of these lines indicates essentially zero (very small) storage. Note that the definition of $C_{Dxf}$ listed on the UNIFORM FLUX typecurve must include "h" in the denominator for dimensional consistency.

3. Typecurve matches on FINITE CAPACITY VERTICAL FRACTURE (CONSTANT RATE) typecurves. A match to this typecurve implies a long or poorly conductive fracture. Storage (of undefined magnitude, but potentially large considering the time frame of the data) is indicated if the approach to this typecurve is from below. Nonunique matches are common. Wells which showed bilinear flow (1/4 slope) were usually matched to these curves.

4. Typecurve matches on FLOPETROL's WELLBORE STORAGE AND SKIN (with PRESSURE DERIVATIVE) typecurve. The pressure derivative function significantly helps in positioning the data on the most appropriate $C_De^{2S}$ curve. The negative skin of the wells makes the analysis more difficult, since it tends to push to earlier times the time at which a unit slope (or a transition with strong character) appears.

Many of the wells analyzed using this typecurve showed onset of a changing liquid level 0.5 to 2.0 hours after shut-in. Since different values of C (and therefore $C_D$) are associated with compressive storage and changing liquid level storage, a changing storage mechanism permits (and may even require) discarding some of the data points before typecurve-matching the data. The analysis may not be unique because the transition from influence by one mechanism to influence by the other (or by a combination of both) is not abrupt and the number of data points that should be ignored after the column of liquid can no longer be completely supported by the reservoir is not clear-cut.

The expected linear volume of typical strength 2 7/8" tubing is about 0.005 BBL/ft. Because of the uncertainties associated with interpreting the test data when the liquid level changes, wells have been classified as possibly suspect only when the calculated value of $V_u$ exceeds this value several times.

Wells were classified as fractured (single vertical fracture solution) or non-fractured based either on the linearity of a Cartesian plot of P vs $t^{1/2}$ or on the shape of the pressure derivative function. The presence of a falling liquid level was assumed whenever bottomhole pressure dropped below 2200 psi (approximate average well depth of 4500 ft and injection water density of 66 lbs/cu ft). Whenever possible, reservoir parameters (kh, k, S and $X_f$) were calculated from the typecurve matches and compared with Miller-Dyes-Hutchinson (MDH) values. Matches were rejected and the data rematched if unreasonable reservoir parameters resulted.

The results of the falloff test analysis for the 28 welltests are summarized in Tables 1 and 2; the conclusions are summarized in Table 3. The five wells classified as suspect from the analysis are as follows:

State Vacuum Unit #7
State Vacuum Unit #11

Central Vacuum Unit #113
Central Vacuum Unit #120

Vacuum Grayburg San Andres Unit #49

It is strongly recommended that additional test information (logs, early time welltests) be obtained on these wells (and on the six additional wells classified as possibly suspect) as part of the current testing program.

Typecurves used in the analysis are included as Appendix A. Log-log plots of the welltests are shown in Appendix B; typecurve match points are listed in Table 4.

TABLE 1. FALLOFF TEST ANALYSIS SUMMARY

| | | SQRT ΔT LINEAR FLOW | LIQUID LEVEL CHANGE? | UNIT SLOPE | UNIT SLOPE AFTER $P_o$ ADJ? | $C_{Dxf}$ or $C_{Df}$ | FINITE CAPACITY VERTICAL FRACTURE? | $C_De^{2S}$ |
|---|---|---|---|---|---|---|---|---|
| ARCO SVU | | | | | | | | |
| 2 | 1982 | Y (4-81 HR) | N | N | | | Y | |
| 4 | 1980 | Y (8-99 HR) | N | N | | | Y | |
| 7 | 1980 | Y (2-81 HR) | Y (55 HR) | N | | | Y | |
| 7 | 1982 | Y (4-81 HR) | N | ? | Y (- 8) | 0.010 | | |
| 11 | 1982 | Y (4-81 HR) | N | Y | Y ( 0) | | | |
| 13 | 1980 | N | Y (72 HR) | N | | 0.000 | | |
| 15 | 1980 | Y (1-25 HR) | Y (24 HR) | N | | | Y | |
| 17 | 1980 | N | N | N | | 0.001 | | |
| 17 | 1982 | Y (1-80 HR) | N | ? | Y (- 8) | 0.005 | | |
| 19 | 1982 | Y (0-90 HR) | N | N | | | | |
| Phillips EVGSAU | | | | | | | | |
| 3315-006 | 1986 | N | Y (60 HR) | N | | 0.000 | | |
| 3328-003 | 1986 | N | Y (40 HR) | N | | 0.000 | | |
| 3332-001 | 1986 | Y (16-81 HR) | Y (30 HR) | N | | | Y | |
| Texaco CVU | | | | | | | | |
| 25 | 1985 | N | Y (.5 HR) | N | | | | 1 |
| 57 | 1985 | N | Y (.5 HR) | N | | | | 10 |
| 58 | 1985 | N | Y (.5 HR) | N | | | | 10 |
| 72 | 1985 | N | Y (.5 HR) | N | | | | 100 |
| 73 | 1985 | N | Y (.5 HR) | N | | | | 100 |
| 100 | 1986 | Y (2-20 HR) | Y (40 HR) | N | | 0.000 | | |
| 113 | 1985 | Y (3-55 HR) | N | Y | Y (-17) | | | |
| 120 | 1985 | Y (4-64 HR) | N | ? | Y (- 3) | | | |
| 134 | 1985 | Y (0-06 HR) | N | ? | N (+ 5) | 0.010 | | 0.3 |
| 135 | 1985 | Y (2-30 HR) | N | ? | N (+20) | | | |
| 138 | 1986 | N | Y ( 2 HR) | N | | | | 1 |
| 156 | 1985 | N | Y ( 2 HR) | N | | | | 1 |
| 157 | 1985 | N | Y (.5 HR) | N | | | | 100 |
| Texaco VGSAU | | | | | | | | |
| 35 | 1986 | Y (9-48 HR) | N | N | | | Y | |
| 49 | 1986 | Y (0-16 HR) | Y (48 HR) | ? | N (+24) | 0.050 | | |

TABLE 2. COMPARISON OF CALCULATED RESERVOIR PARAMETERS

| | | RESERVOIR PARAMETERS FROM TYPECURVE MATCHES | | | | RESERVOIR PARAMETERS FROM MDH ANALYSIS | |
|---|---|---|---|---|---|---|---|
| | | kh | k | S | $X_f$ | k | S |
| ARCO SVU | | | | | | | |
| 2 | 1982 | 7 | 0.2 | -5.5 | 131 | 0.3 | -5.2 |
| 4 | 1980 | 9 | 0.3 | -3.6 | 20 | 0.1 | -4.3 |
| 7 | 1980 | 14 | 0.3 | -6.5 | 364 | 1.0 | -5.7 |
| 7 | 1982 | 14 | 0.3 | -6.5 | 354 | 1.0 | -5.7 |
| 11 | 1982 | ? | | | | 1.5 | -5.7 |
| 13 | 1980 | 6 | 0.1 | -3.8 | 24 | 0.1 | -4.2 |
| 15 | 1980 | 8 | 0.2 | -5.7 | 170 | 2.1 | -5.6 |
| 17 | 1980 | 2 | 0.04 | -4.0 | 30 | 0.05 | -4.2 |
| 17 | 1982 | 5 | 0.1 | -5.1 | 90 | 0.2 | -4.7 |
| 19 | 1982 | ? | | | | 1.0 | -5.5 |
| Phillips EVGSAU | | | | | | | |
| 3315-006 | 1986 | 239 | 1.3 | -3.4 | 27 | 1.3 | -5.2 |
| 3328-003 | 1986 | 306 | 2.2 | -6.3 | 474 | 1.5 | -5.4 |
| 3332-001 | 1986 | 72 | 0.5 | -5.5 | 208 | 1.3 | -5.8 |
| Texaco CVU | | | | | | | |
| 25 | 1985 | 886 | 5.2 | -3.6 | | 4.9 | -3.6 |
| 57 | 1985 | 714 | 4.4 | -2.0 | | 4.9 | -1.5 |
| 58 | 1985 | 1113 | 6.0 | -3.8 | | 5.9 | -3.3 |
| 72 | 1985 | 1594 | 7.9 | -2.0 | | 8.5 | -1.8 |
| 73 | 1985 | 1537 | 6.5 | -1.8 | | 6.6 | -1.7 |
| 100 | 1986 | 131 | 0.9 | -4.7 | 97 | 1.6 | -5.3 |
| 113 | 1985 | ? | | | | 1.8 | -4.6 |
| 120 | 1985 | ? | | | | 1.0 | -3.0 |
| 134 | 1985 | 95/100 | 1.5/1.5 | -4.9 | 96 | 1.8 | -4.5 |
| 135 | 1985 | ? | | | | 2.3 | -5.3 |
| 138 | 1986 | 532 | 3.5 | -4.0 | | 4.3 | -4.0 |
| 156 | 1985 | 189 | 1.6 | -3.4 | | 1.5 | -3.4 |
| 157 | 1985 | 261 | 2.1 | -1.4 | | 1.8 | -2.0 |
| Texaco VGSAU | | | | | | | |
| 35 | 1986 | ? | | | | 2.6 | -5.6 |
| 49 | 1986 | 570 | 2.9 | -5.2 | 152 | 2.7 | -5.2 |

TABLE 3. FALLOFF TEST CONCLUSION SUMMARY

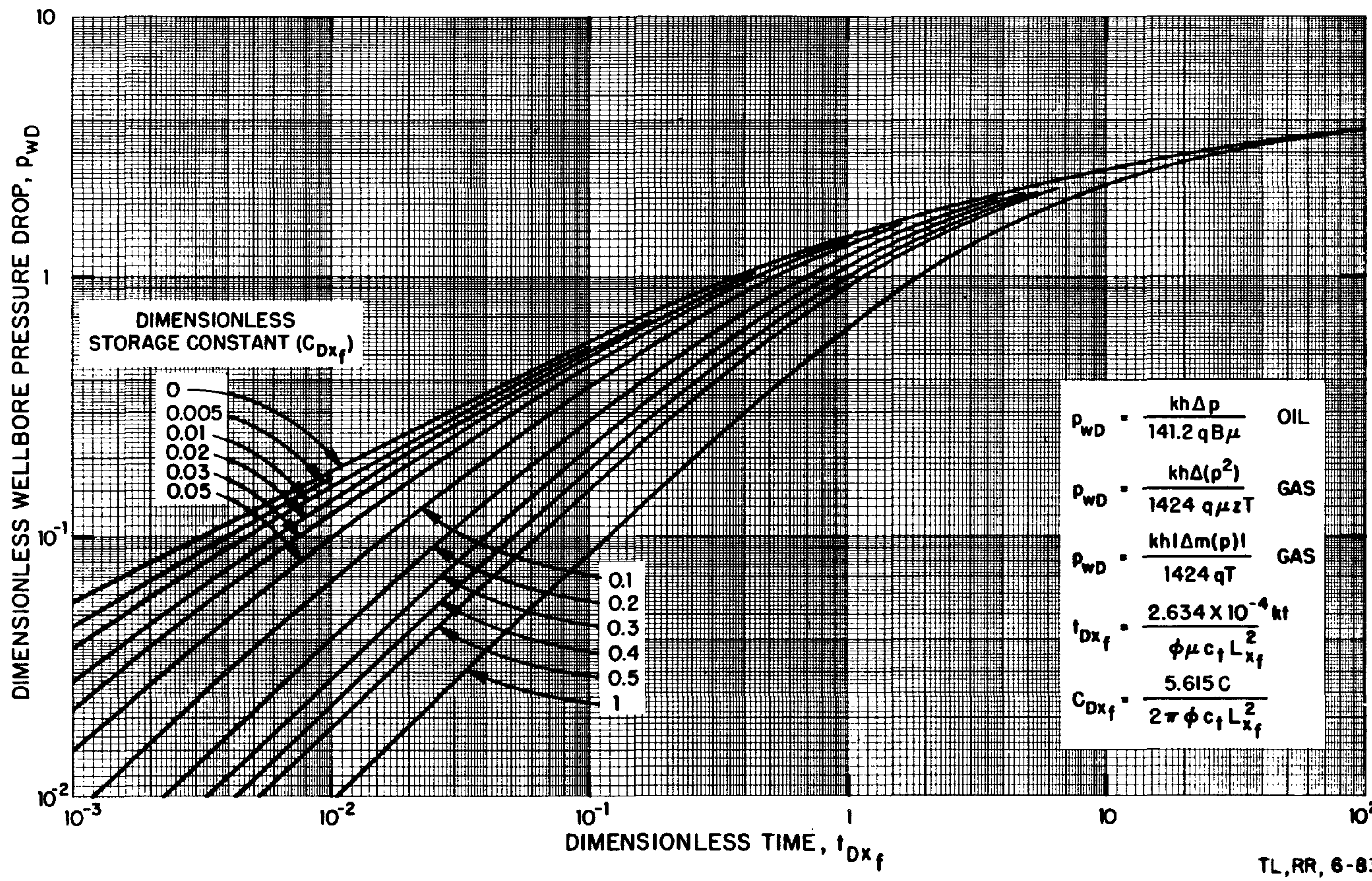
| | C (BBL/psi) | $V_{wb}$ (BBLS) | $V_u$ (BBL/ft) | Is Well Suspect? | |
|---|---|---|---|---|---|
| ARCO SVU | | | | | |
| 2 | | | | ? | Small deviation, FINITE CAPACITY VERTICAL FRACTURE typecurve |
| 4 | 0.000 | 0 | | No | No deviation, FINITE CAPACITY VERTICAL FRACTURE typecurve |
| 7 | | | | No | No deviation, FINITE CAPACITY VERTICAL FRACTURE typecurve |
| 7 | .210/.083 | 70000/28000 | | Yes | High comp storage, unit slope/VERT FRACT W STORAGE (UNIFORM FLUX) |
| 11 | 0.200 | 67000 | | Yes | High comp storage, unit slope |
| 13 | 0.000 | 0 | | No | $C_{Df}$ = 0, VERT FRACT W STORAGE (INFINITE PERM) typecurve |
| 15 | | 0 | | No | No deviation, FINITE CAPACITY VERTICAL FRACTURE typecurve |
| 17 | 0.000 | 3 | | No | Low comp storage, VERT FRACT W STORAGE (INFINITE PERM) typecurve |
| 17 | 0.018 | 6000/800 | | ? | Mod comp storage, adj unit slope/VERT FRACT W STORAGE (INFINITE PERM) |
| 19 | | | | No | Deviation from above on typecurve matches, possible skin on fracture |
| Phillips EVGSAU | | | | | |
| 3315-006 | | 0 | | No | $C_{Dxf}$ = 0, VERT FRACT W STORAGE (UNIFORM FLUX) typecurve |
| 3328-003 | 0.000 | 0 | | No | $C_{Dx}$ = 0, VERT FRACT W STORAGE (INFINITE PERM) typecurve |
| 3332-001 | 0.000 | 0 | | No | No deviation, FINITE CAPACITY VERTICAL FRACTURE typecurve |
| Texaco CVU | | | | | |
| 25 | 0.018 | | 0.008 | No | Low changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 57 | 0.008 | | 0.004 | No | Low changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 58 | 0.031 | | 0.014 | No | Low changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 72 | 0.100 | | 0.046 | ? | Mod changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 73 | 0.071 | | 0.033 | ? | Mod changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 100 | 0.000 | 0 | | No | $C_{Df}$ = 0 VERT FRACT W STORAGE (INFINITE PERM) typecurve |
| 113 | 0.190 | 62000 | | Yes | High comp storage, unit slope |
| 120 | 0.100 | 34000 | | Yes | High comp storage, unit slope |
| 134 | .005/.020 | 1600/6600 | | ? | Mod comp storage, VERT FRACT W STOR (UNIF FLUX)/wellbore stor & skin |
| 135 | | | | ? | Deviation, FINITE CAPACITY VERTICAL FRACTURE/no other typecurve match |
| 138 | 0.025 | | 0.011 | No | Low changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 156 | 0.009 | | 0.004 | No | Low changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| 157 | 0.017 | | 0.008 | No | Low changing liquid level storage, WELLBORE STORAGE & SKIN typecurve |
| Texaco VGSAU | | | | | |
| 35 | | | | No | No deviation (assuming variable capacity fracture) FINITE CAPACITY VERTICAL FRACTURE typecurve |
| 49 | 0.188 | 63000 | | Yes | High comp storage, VERT FRACT W STORAGE (UNIFORM FLUX) typecurve |

# TABLE 4. TYPECURVE MATCH POINTS

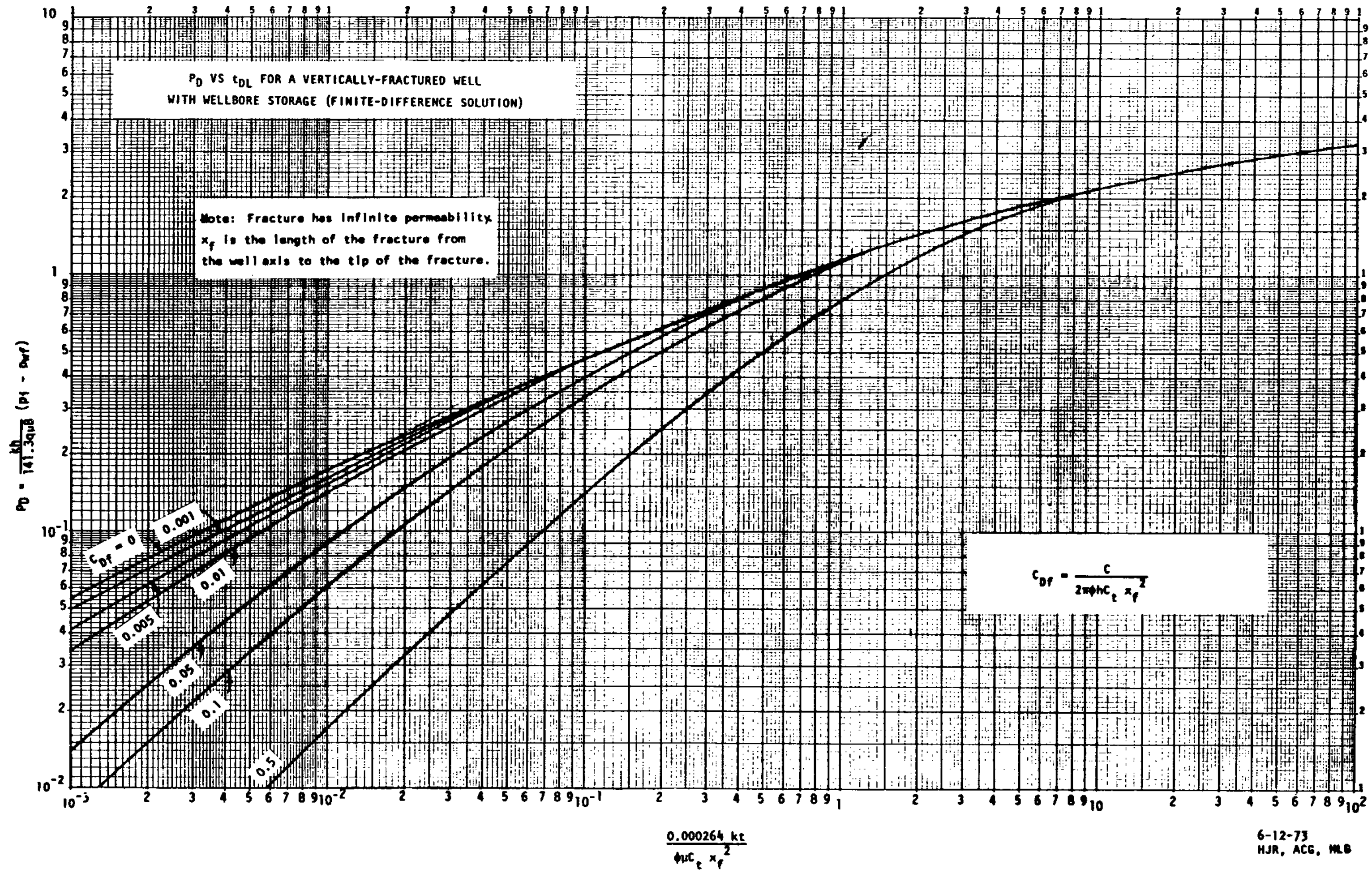
| | ORDINATE | | ABSCISSA | | CURVE | TYPECURVE |
|---|---|---|---|---|---|---|
| ARCO SVU | | | | | | |
| 2 | $P_D = 0.5$ | $\Delta P = 350$ | $t_{DXf}/F_{CD}^2 = 4x10^{-5}$ | $\Delta t = 10$ | $F_{CD} = 30$ | FCVF |
| 4 | $P_D = 1$ | $\Delta P = 260$ | $t_{DXf}/F_{CD}^2 = 10^{-3}$ | $\Delta t = 22$ | $F_{CD} = 50$ | FCVF |
| 7 | $P_D = 0.1$ | $\Delta P = 255$ | $t_{DXf}/F_{CD}^2 = 10^{-8}$ | $\Delta t = 0.98$ | $F_{CD} = 300$ | FCVF |
| 7 | $P_D = 0.01$ | $\Delta P = 20$ | $t_D = 0.01$ | $\Delta t = 20$ | $C_{DXf} = 0.01$ | VFWS(UF) |
| 11 | unit slope only | | | | | |
| 13 | $P_D = 0.1$ | $\Delta P = 60$ | $t_D = 1$ | $\Delta t = 28$ | $C_{Df} = 0$ | VFWS(IP) |
| 15 | $P_D = 0.01$ | $\Delta P = 110$ | $t_{DXf}/F_{CD}^2 = 10^{-7}$ | $\Delta t = 20$ | $F_{CD} = 100$ | FCVF |
| 17 | $P_D = 1$ | $\Delta P = 770$ | $t_D = 0.1$ | $\Delta t = 12$ | $C_{Df} = 0.001$ | VFWS(IP) |
| 17 | $P_D = 0.1$ | $\Delta P = 85$ | $t_D = 0.1$ | $\Delta t = 32$ | $C_{Df} = 0.005$ | VFWS(IP) |
| 19 | -- | | | | | |
| Phillips EVGSAU | | | | | | |
| 3315-006 | $P_D = 0.1$ | $\Delta P = 48$ | $t_D = 1$ | $\Delta t = 18$ | $C_{DXf} = 0$ | VFWS(UF) |
| 3328-003 | $P_D = 0.1$ | $\Delta P = 50$ | $t_D = 1$ | $\Delta t = 46$ | $C_{Df} = 0$ | VFWS(IP) |
| 3332-001 | $P_D = 0.01$ | $\Delta P = 16$ | $t_{DXf}/F_{CD}^2 = 10^{-7}$ | $\Delta t = 0.44$ | $F_{CD} = 50$ | FCVF |
| Texaco CVU | | | | | | |
| 25 | $P_D = 1$ | $\Delta P = 210$ | $t_D/C_D = 1000$ | $\Delta t = 99$ | $C_De^{2S} = 1$ | WSS |
| 57 | $P_D = 0.1$ | $\Delta P = 20$ | $t_D/C_D = 100$ | $\Delta t = 5.6$ | $C_De^{2S} = 10$ | WSS |
| 58 | $P_D = 1$ | $\Delta P = 170$ | $t_D/C_D = 100$ | $\Delta t = 14$ | $C_De^{2S} = 10$ | WSS |
| 72 | $P_D = 5.2$ | $\Delta P = 1000$ | $t_D/C_D = 3.2$ | $\Delta t = 1$ | $C_De^{2S} = 100$ | WSS |
| 73 | $P_D = 1$ | $\Delta P = 180$ | $t_D/C_D = 100$ | $\Delta t = 23$ | $C_De^{2S} = 100$ | WSS |
| 100 | $P_D = 0.1$ | $\Delta P = 72$ | $t_D = 1$ | $\Delta t = 42$ | $C_{Df} = 0$ | VFWS(IP) |
| 113 | unit slope only | | | | | |
| 120 | unit slope only | | | | | |
| 134 | $P_D = 1$ | $\Delta P = 155$ | $t_D = 1$ | $\Delta t = 25$ | $C_{DXf} = 0.01$ | VFWS(UF) |
| 134 | $P_D = 0.68$ | $\Delta P = 100$ | $t_D/C_D = 10.1$ | $\Delta t = 10$ | $C_De^{2S} = 0.3$ | WSS |
| 135 | -- | | | | | |
| 138 | $P_D = 1$ | $\Delta P = 360$ | $t_D/C_D = 100$ | $\Delta t = 23$ | $C_De^{2S} = 1$ | WSS |
| 156 | $P_D = 1$ | $\Delta P = 410$ | $t_D/C_D = 100$ | $\Delta t = 23$ | $C_De^{2S} = 1$ | WSS |
| 157 | $P_D = 0.1$ | $\Delta P = 31$ | $t_D/C_D = 100$ | $\Delta t = 32$ | $C_De^{2S} = 100$ | WSS |
| Texaco VGSAU | | | | | | |
| 35 | -- | | | | | |
| 49 | $P_D = 0.1$ | $\Delta P = 70$ | $t_D = 1$ | $\Delta t = 33$ | $C_{DXF} = 0.05$ | VFWS(UF) |

# APPENDIX A

VERTICAL FRACTURE WITH STORAGE (UNIFORM-FLUX)

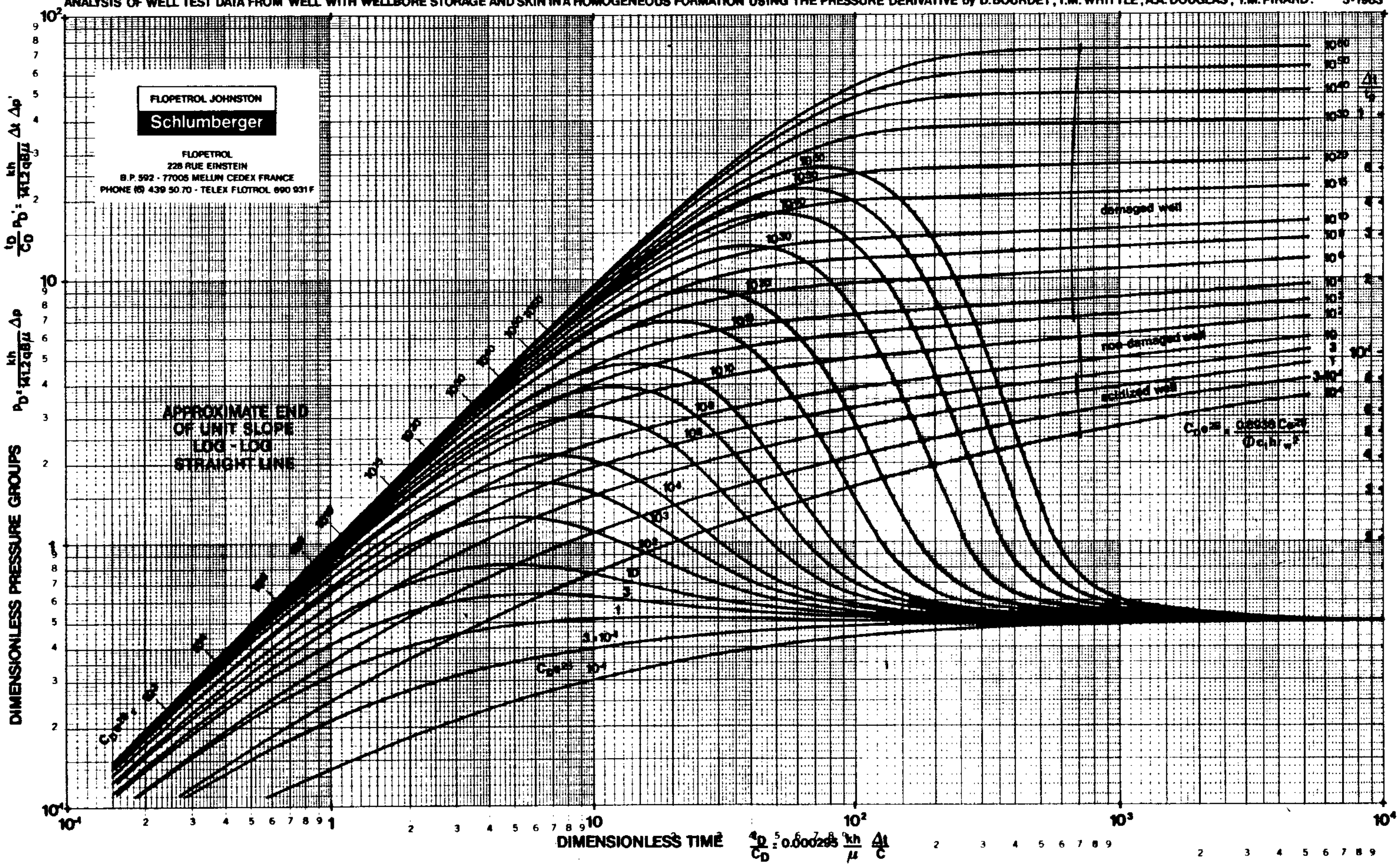



TL, RR, 6-83




6-12-73
HJR, ACG, MLB

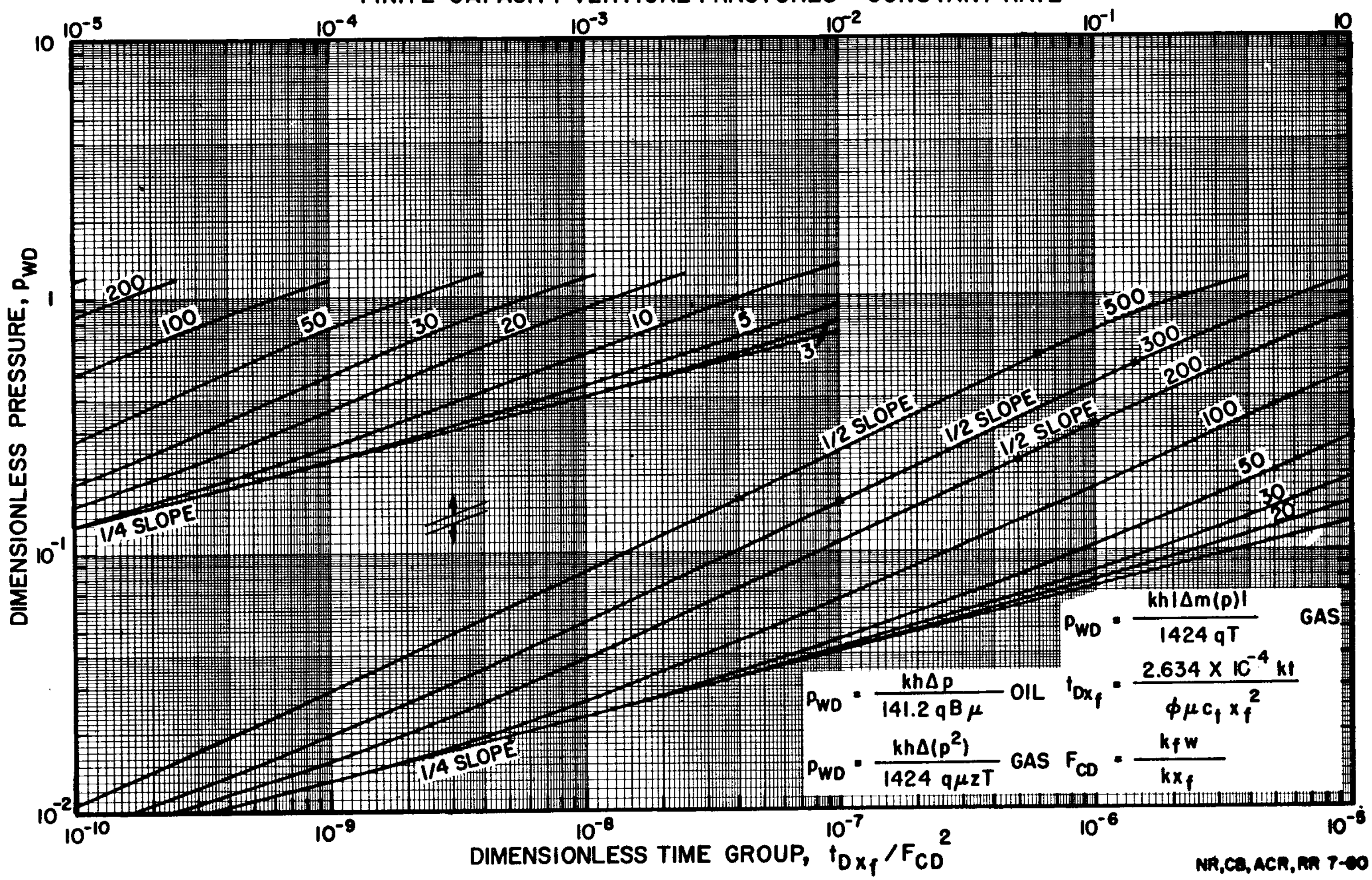
The use of this type-curve is described in World Oil - May 1983:
ANALYSIS OF WELL TEST DATA FROM WELL WITH WELLBORE STORAGE AND SKIN IN A HOMOGENEOUS FORMATION USING THE PRESSURE DERIVATIVE by D. BOURDET, T.M. WHITTLE, A.A. DOUGLAS, Y.M. PIRARD. 5-1983




# TYPE-CURVE FOR A WELL WITH WELLBORE STORAGE AND SKIN. RESERVOIR WITH HOMOGENEOUS BEHAVIOR

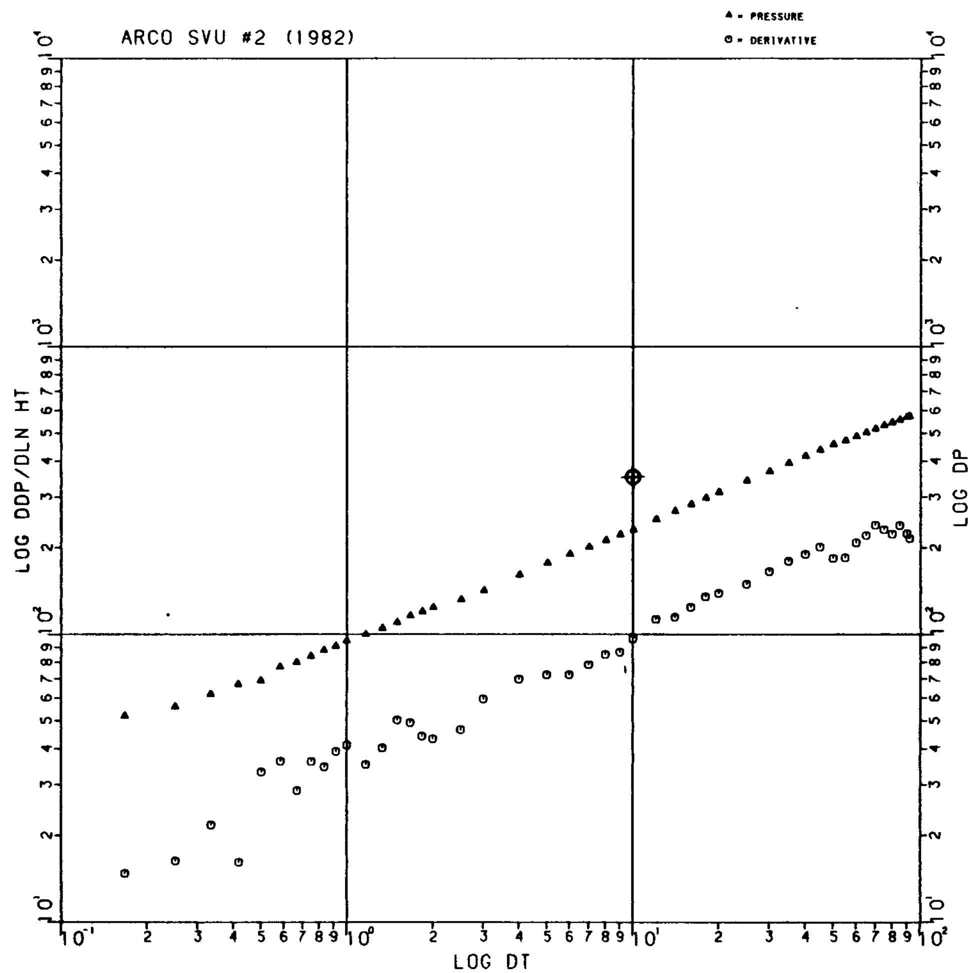
## IN TERMS OF DIMENSIONLESS PRESSURE AND DIMENSIONLESS PRESSURE DERIVATIVE

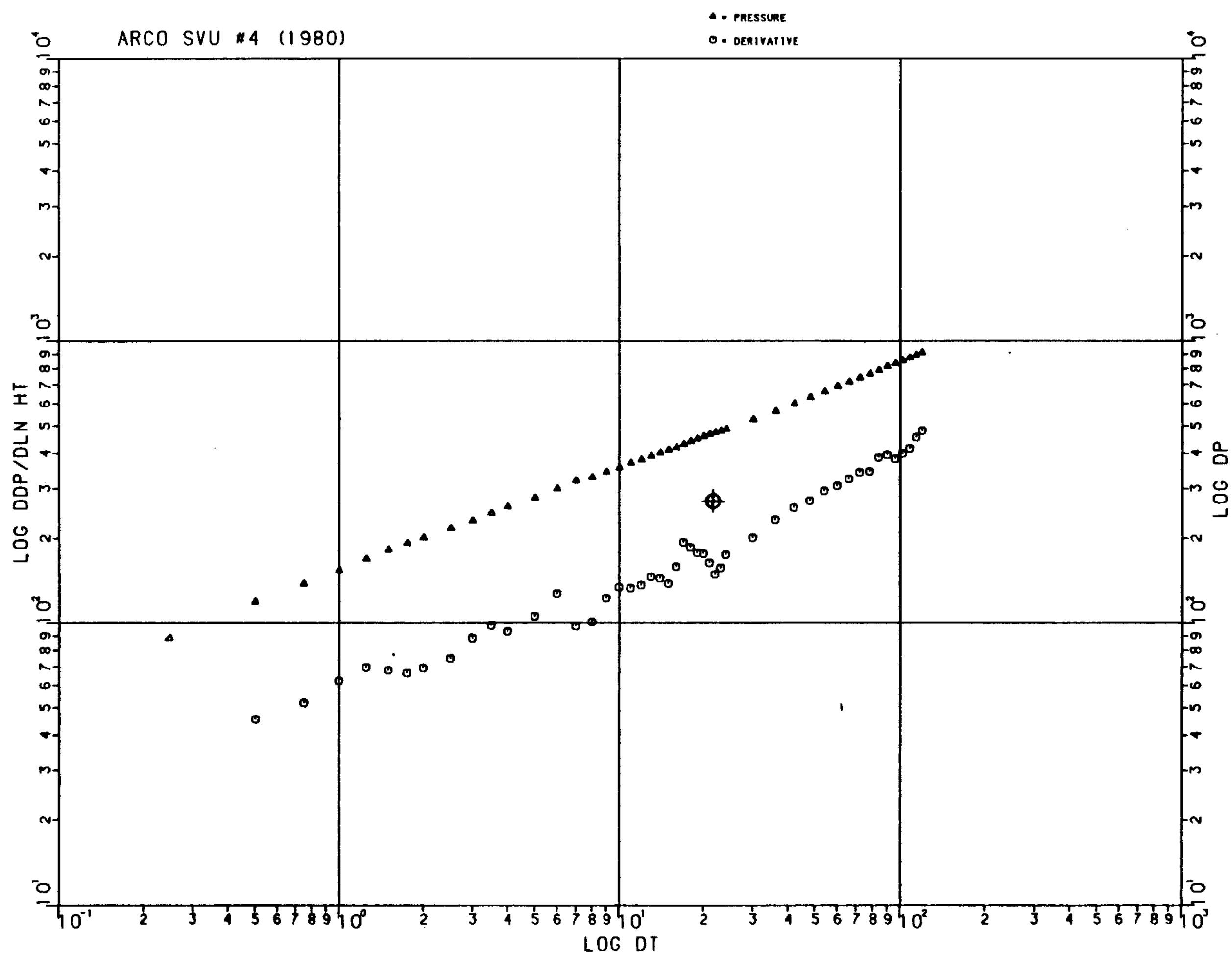
FINITE CAPACITY VERTICAL FRACTURES - CONSTANT RATE

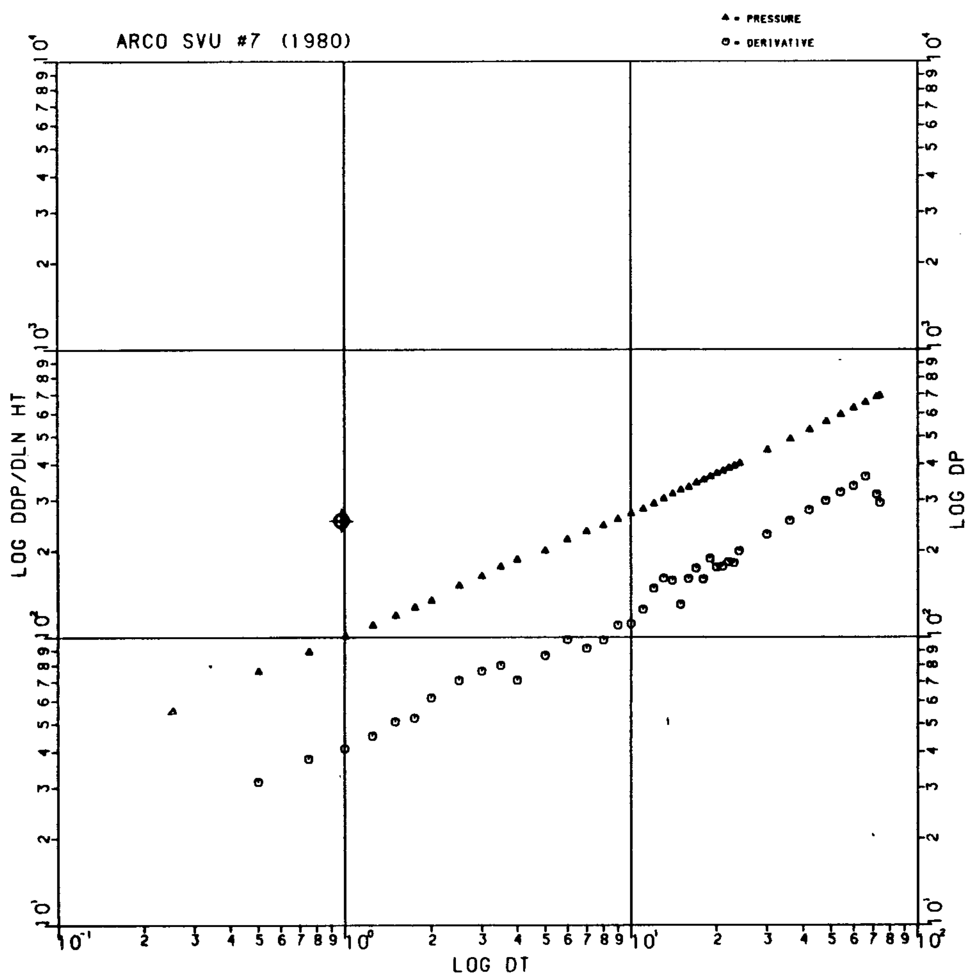



NR, CB, ACR, RR 7-80

# APPENDIX B


ARCO SVU #2 (1982)
▲ = PRESSURE
⊙ = DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT


ARCO SVU #4 (1980)
▲ = PRESSURE
⊙ = DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT



ARCO SVU #7 (1980)
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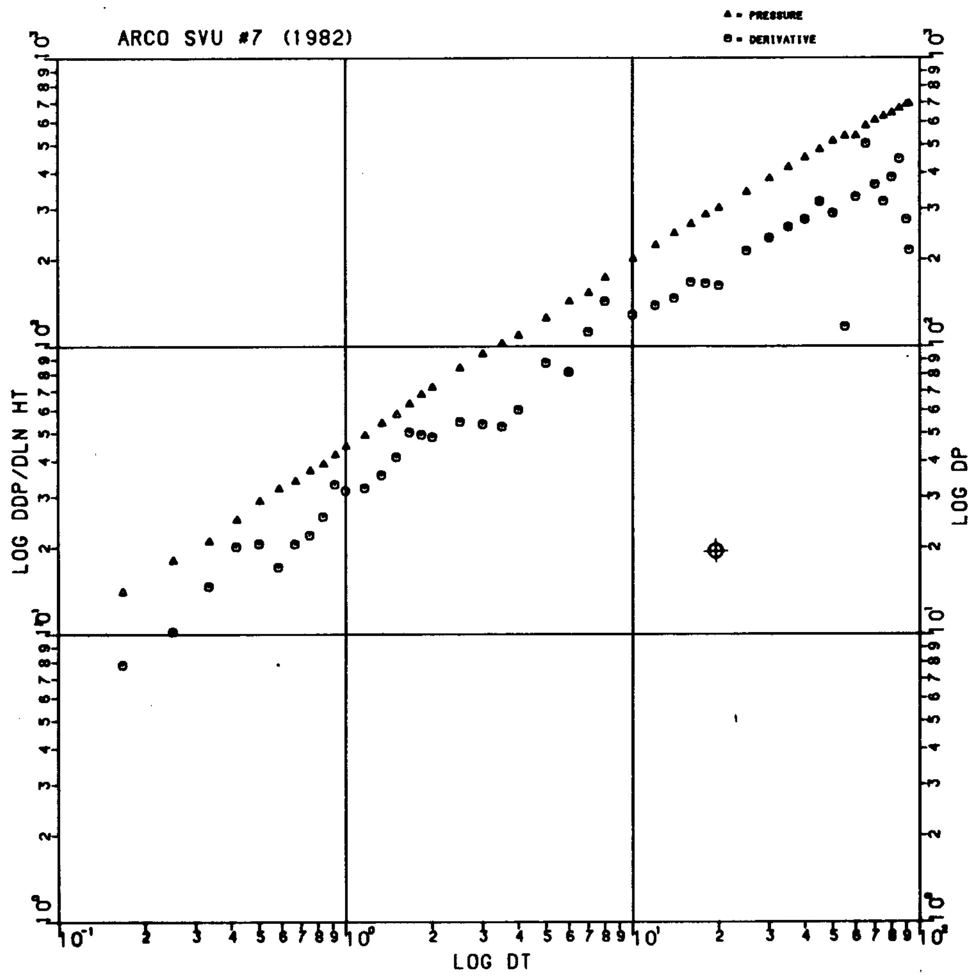
⊙ = DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT



ARCO SVU #7 (1982)
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⊖ = DERIVATIVE
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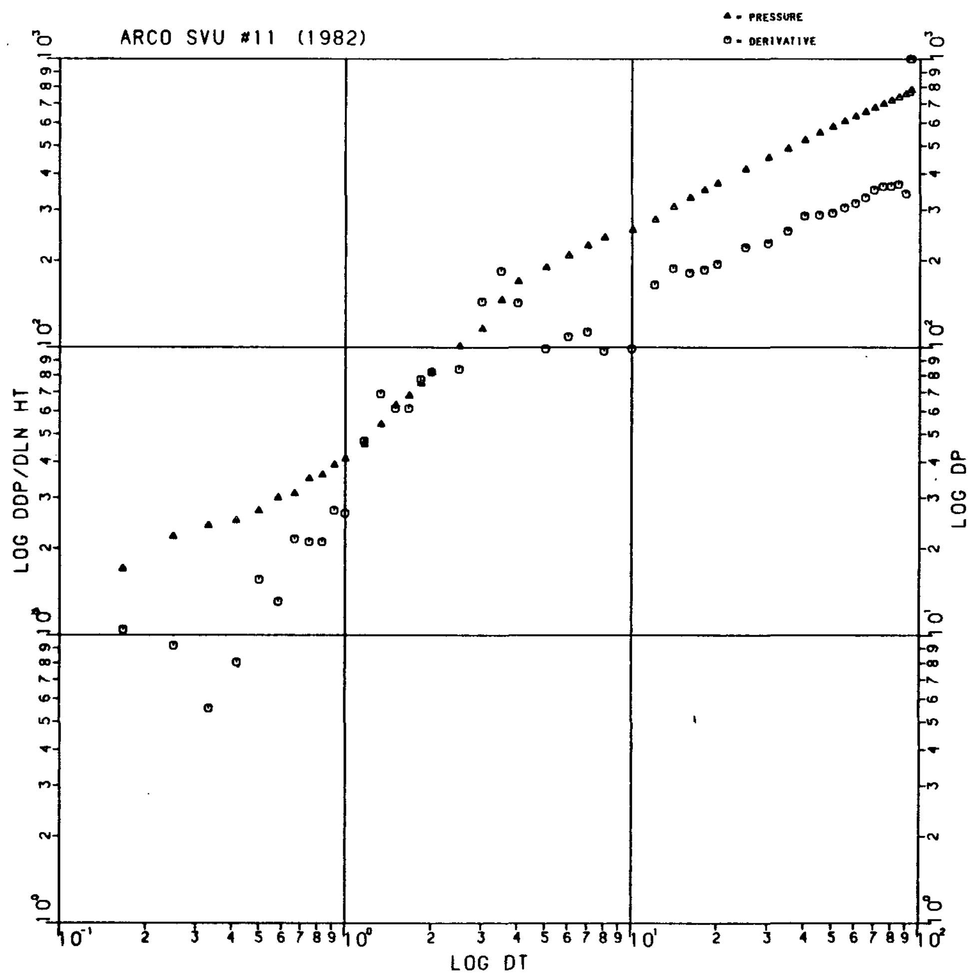
LOG DP
LOG DT


ARCO SVU #11 (1982)
▲ = PRESSURE
⊙ = DERIVATIVE
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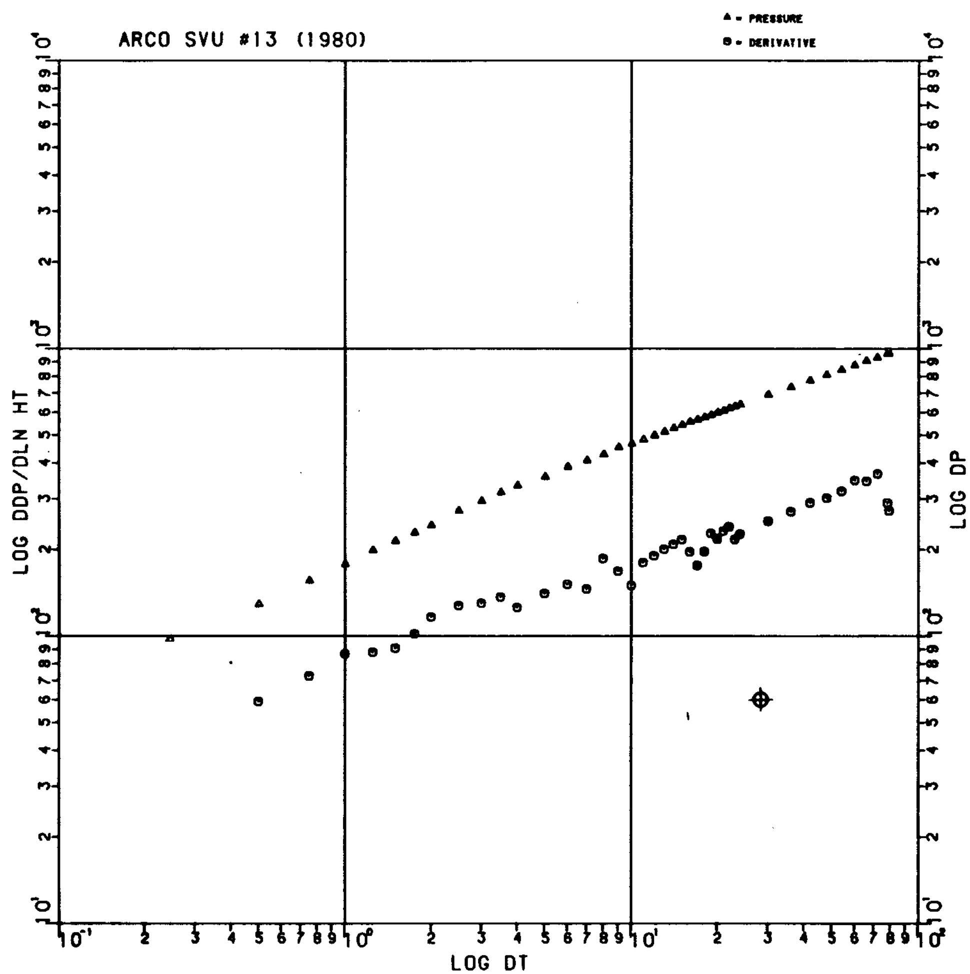
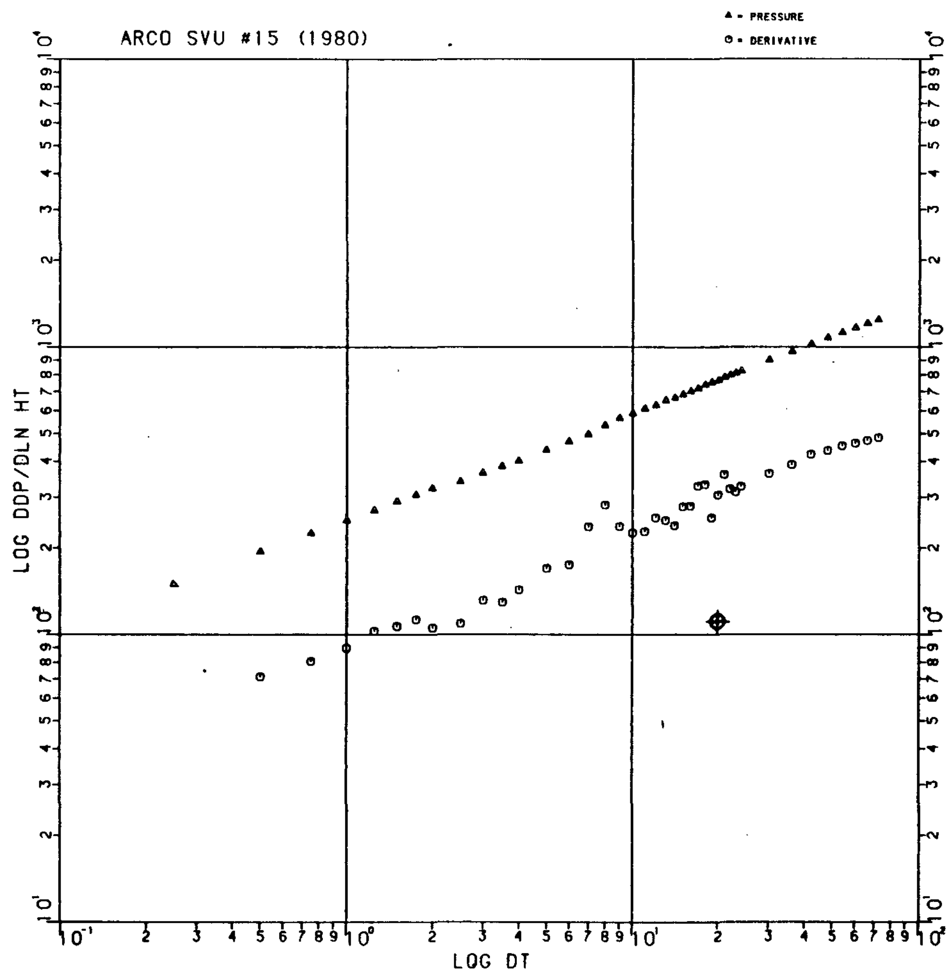
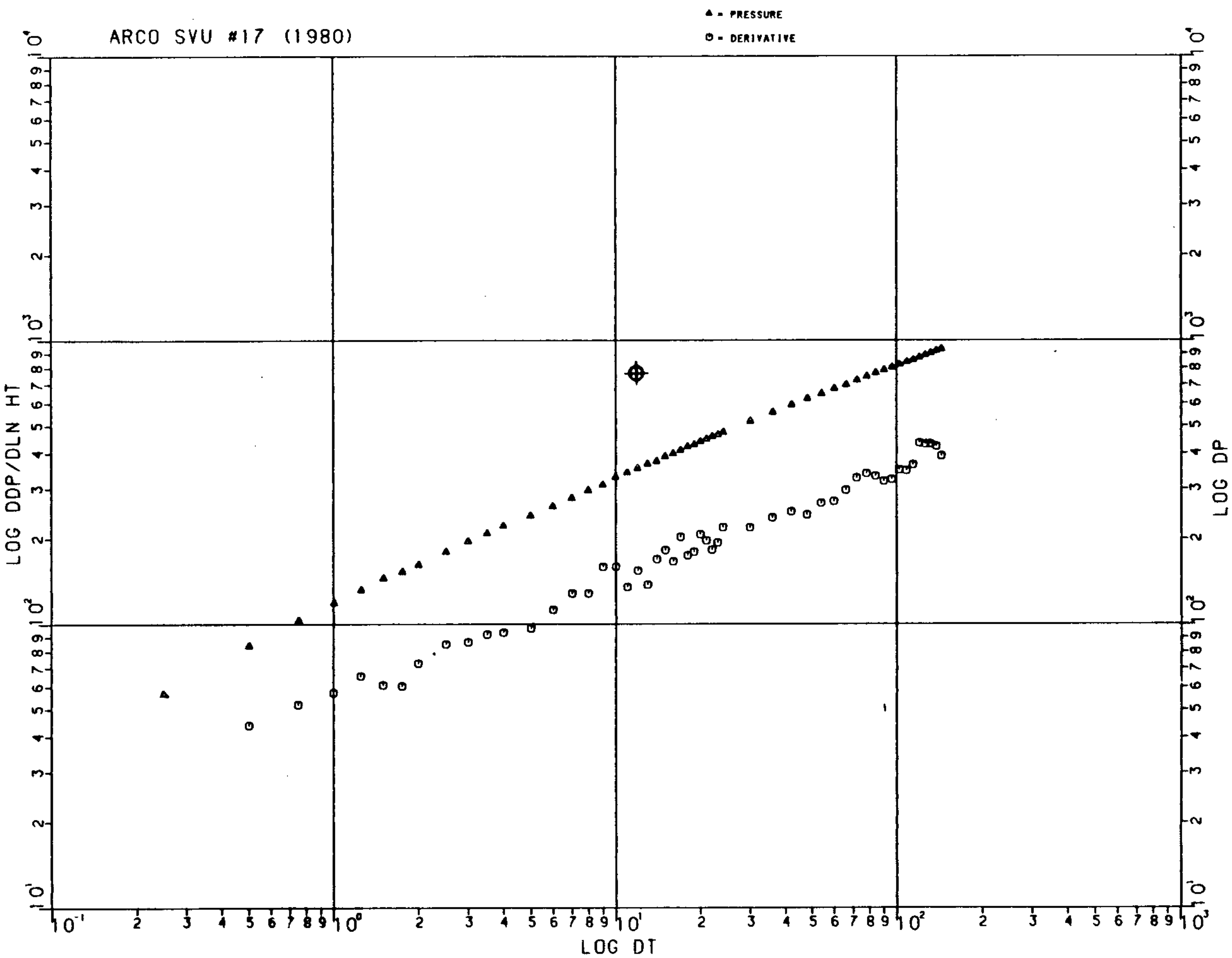
LOG DP
LOG DT



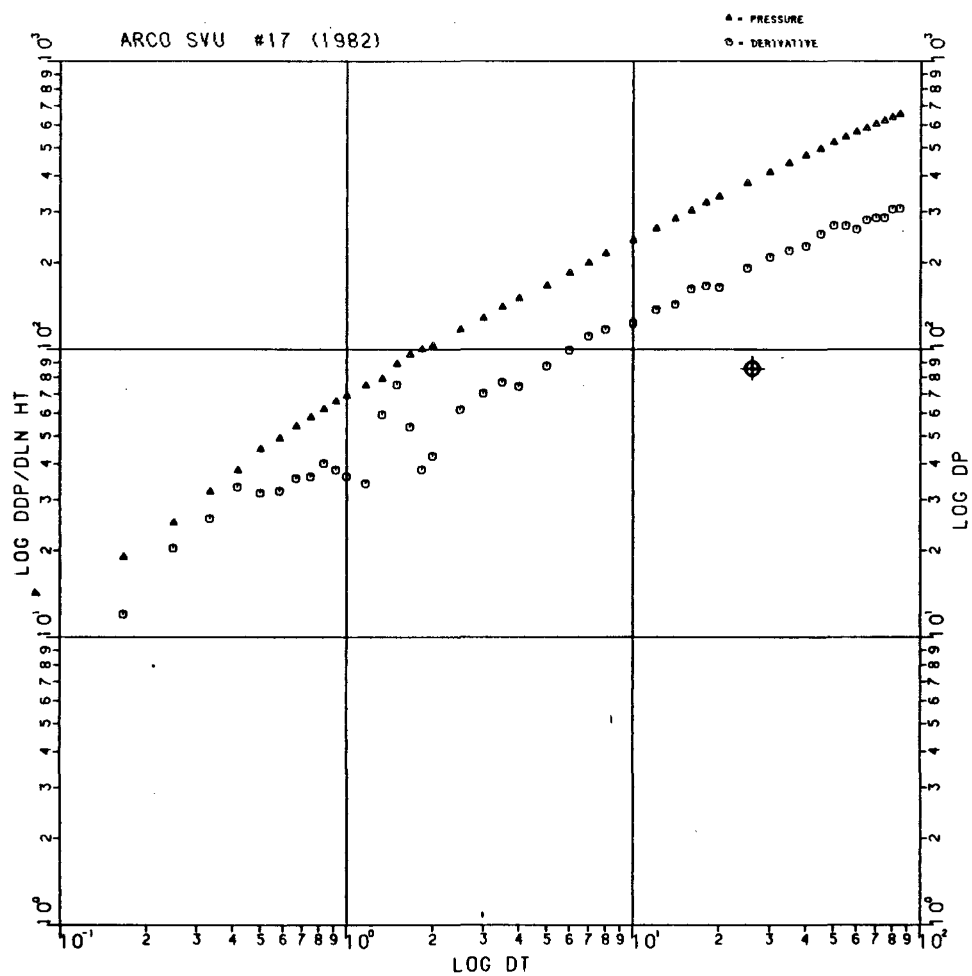
ARCO SVU #13 (1980)
▲ - PRESSURE
⊙ - DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT



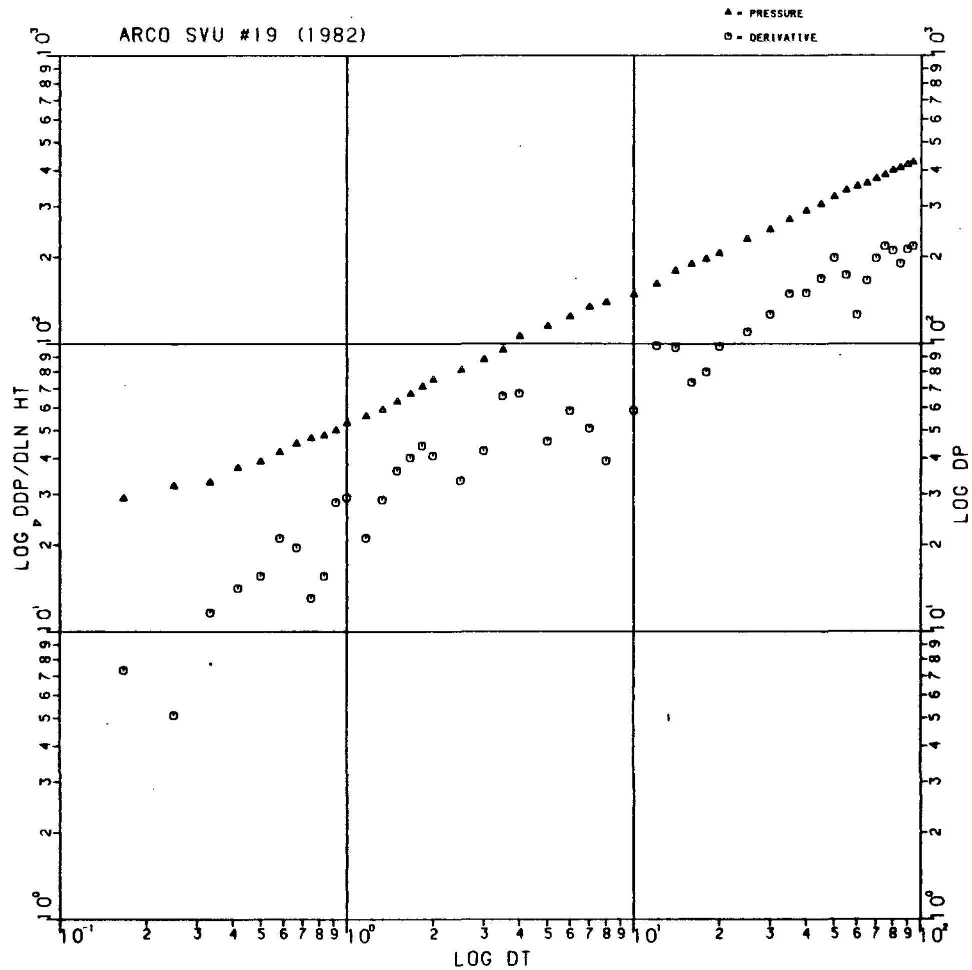
ARCO SVU #15 (1980)
▲ = PRESSURE
⊙ = DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT



ARCO SVU #17 (1980)
▲ = PRESSURE
⊙ = DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT

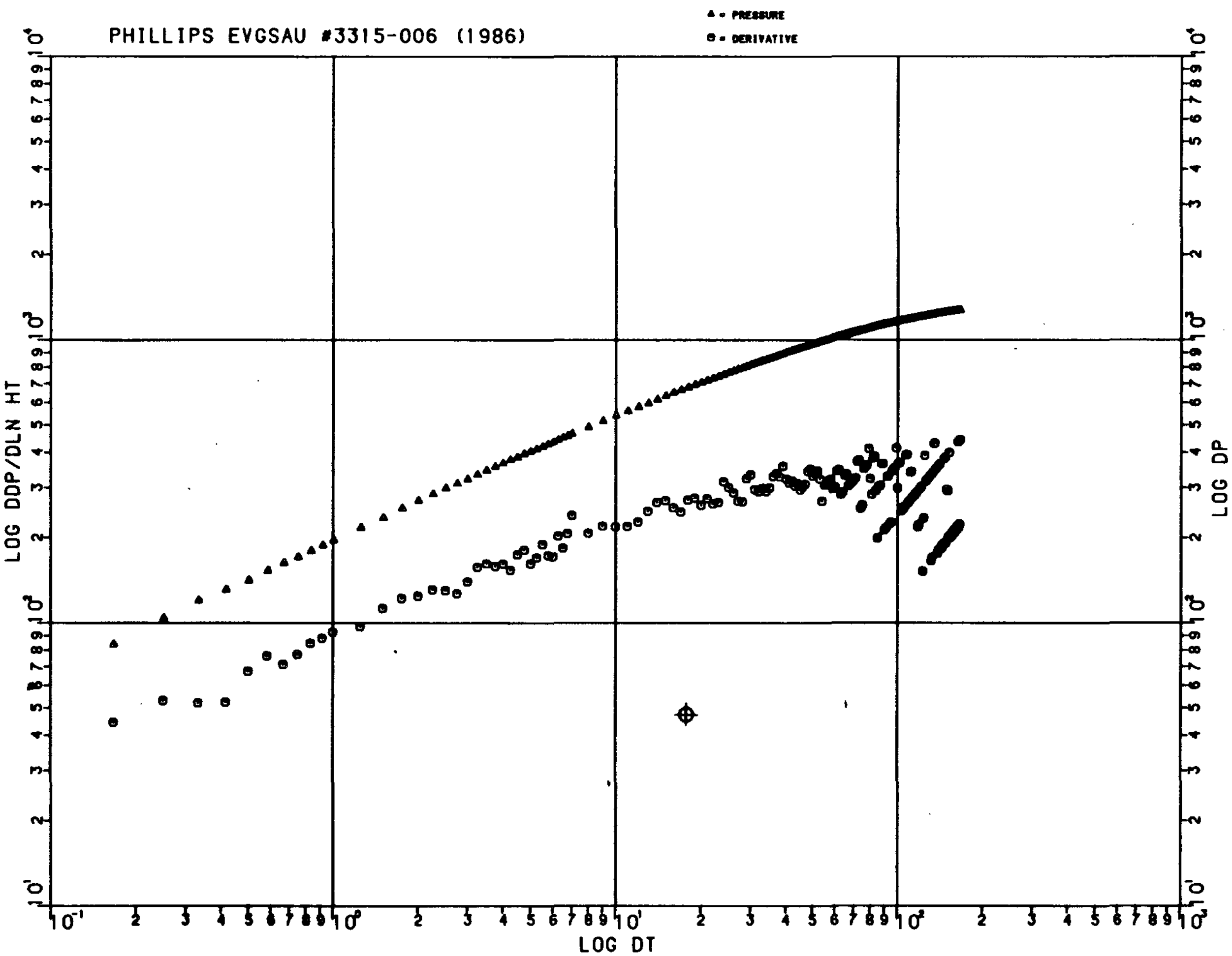


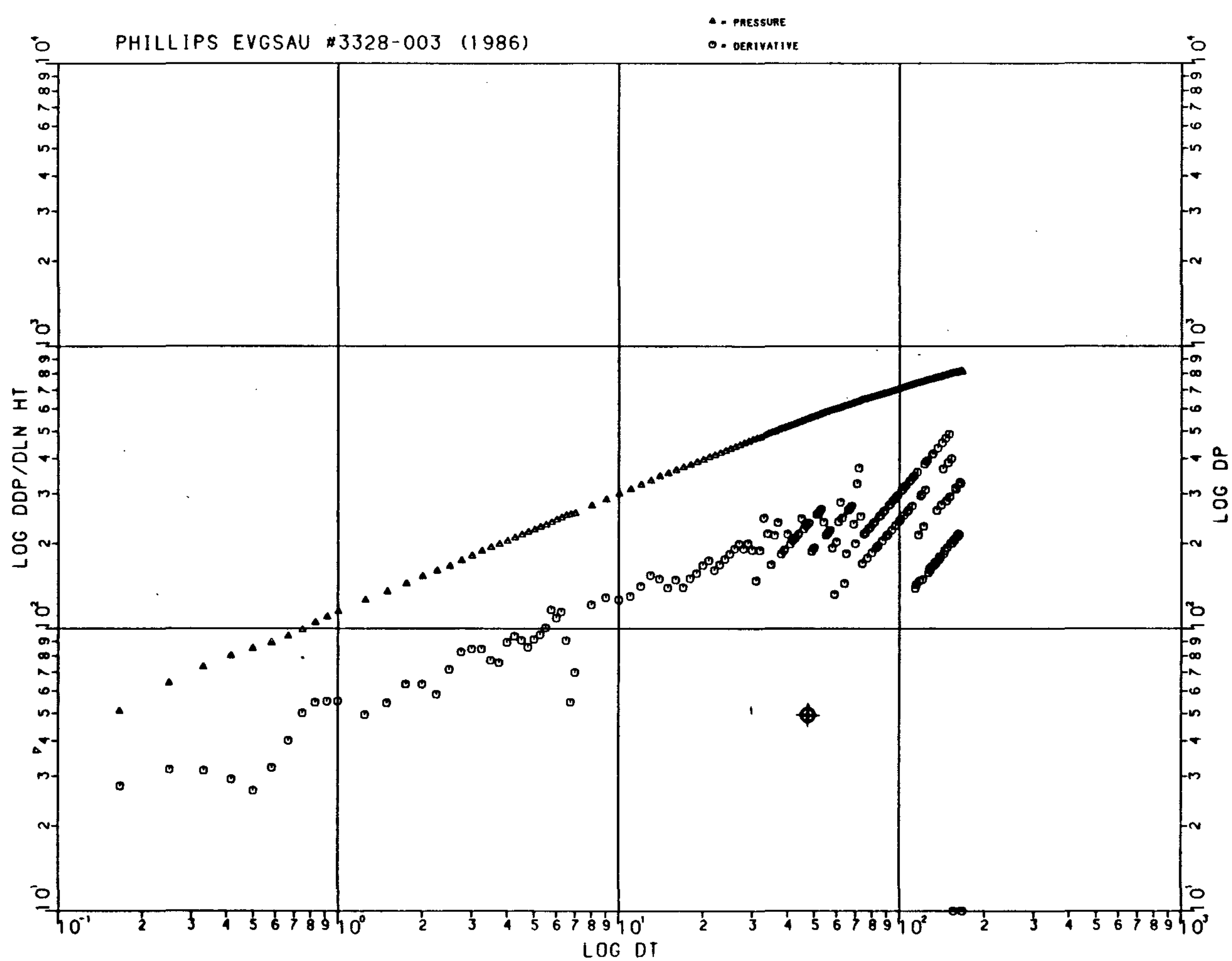
ARCO SVU #17 (1982)
▲ - PRESSURE
⊙ - DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT



ARCO SVU #19 (1982)
▲ = PRESSURE
⊙ = DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT

PHILLIPS EVGSAU #3315-006 (1986)

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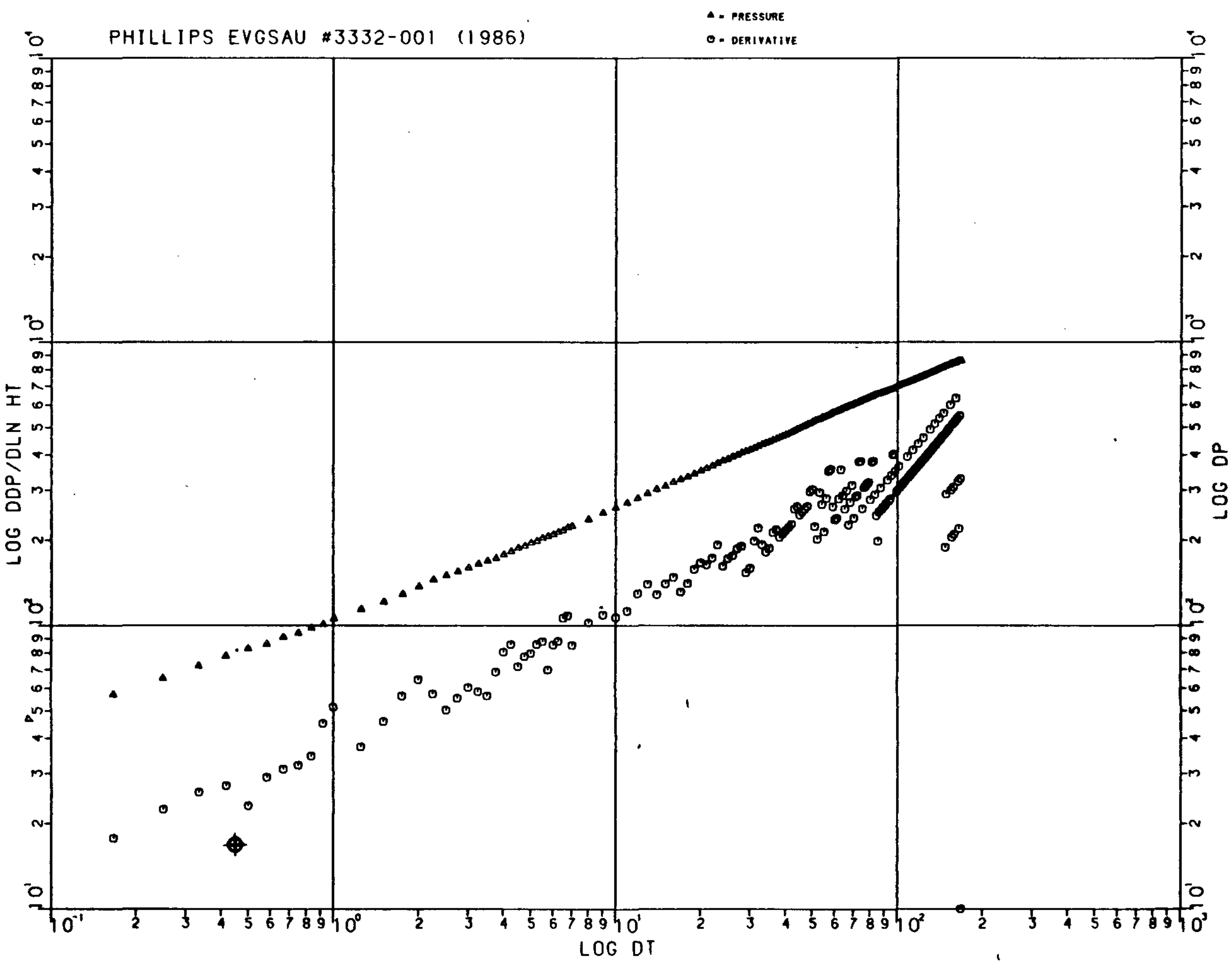

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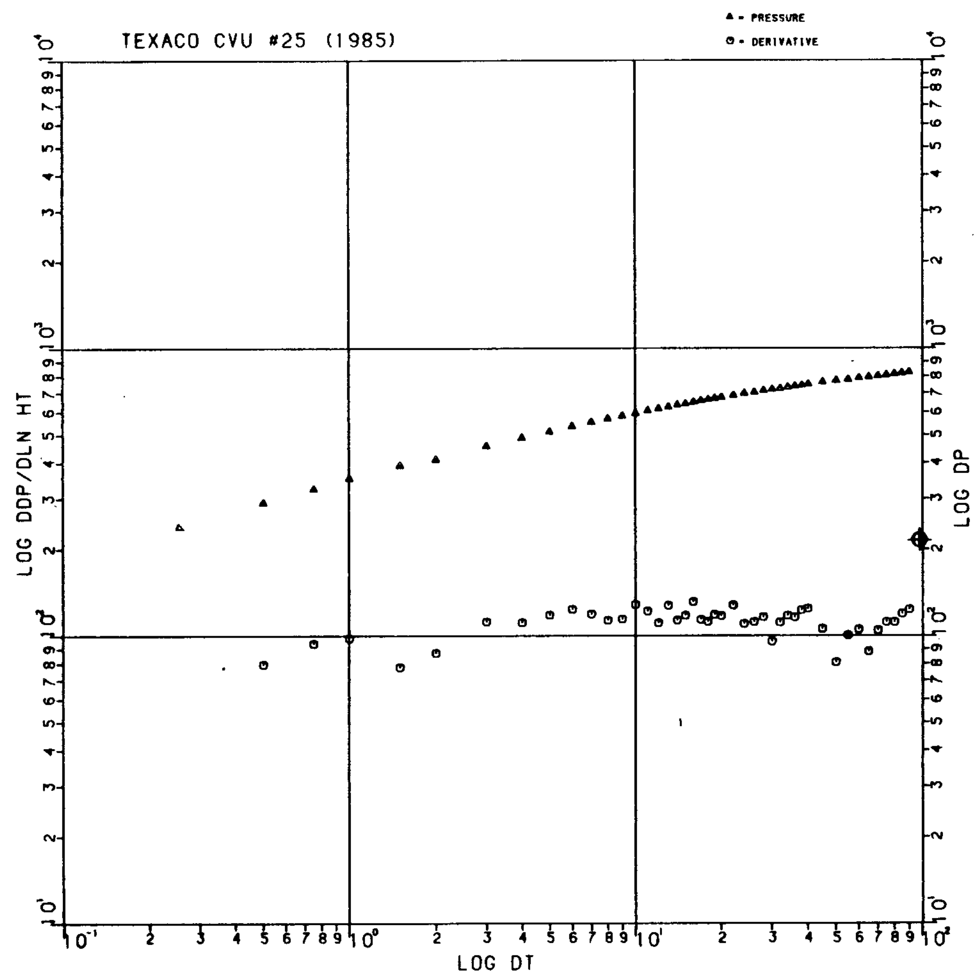
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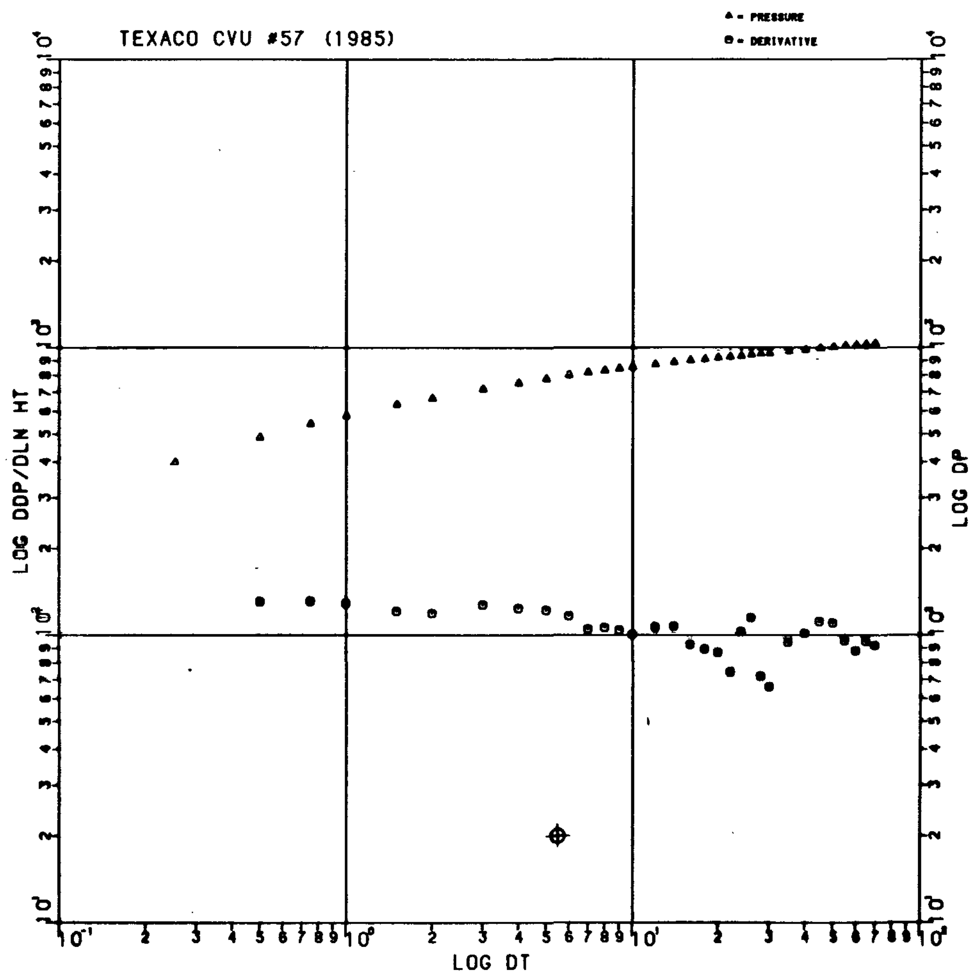

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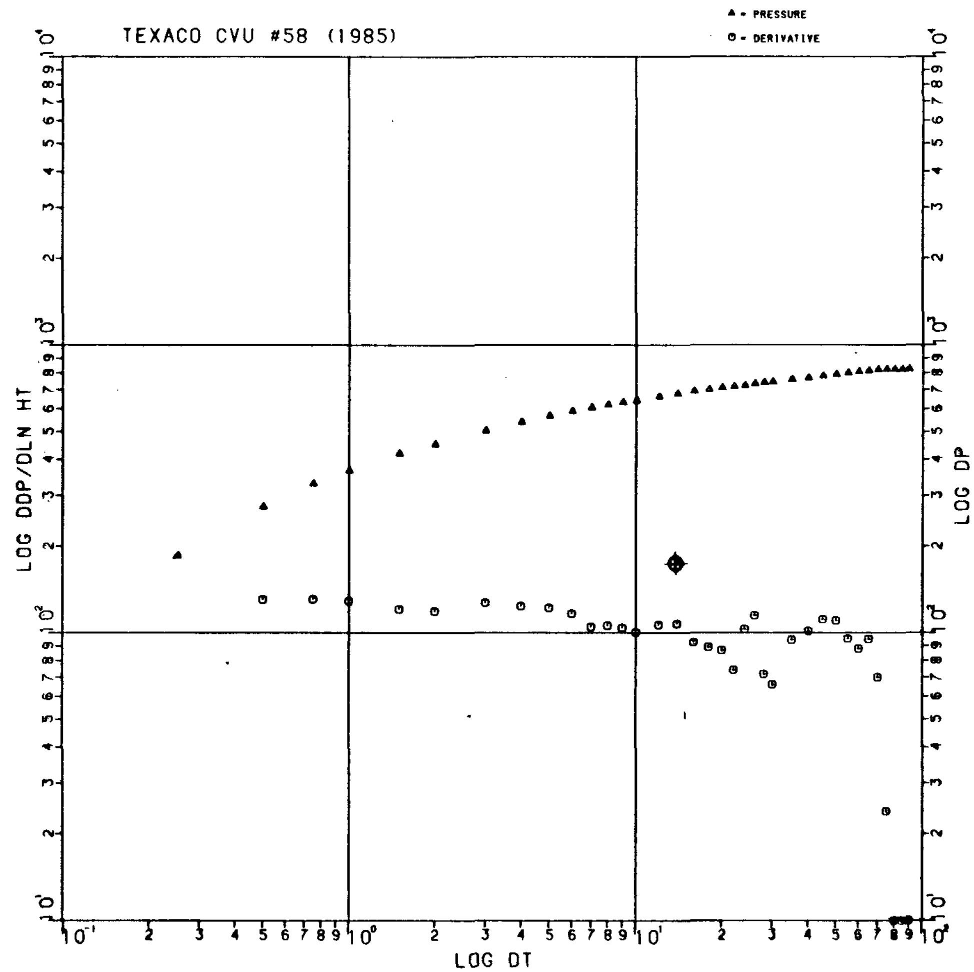

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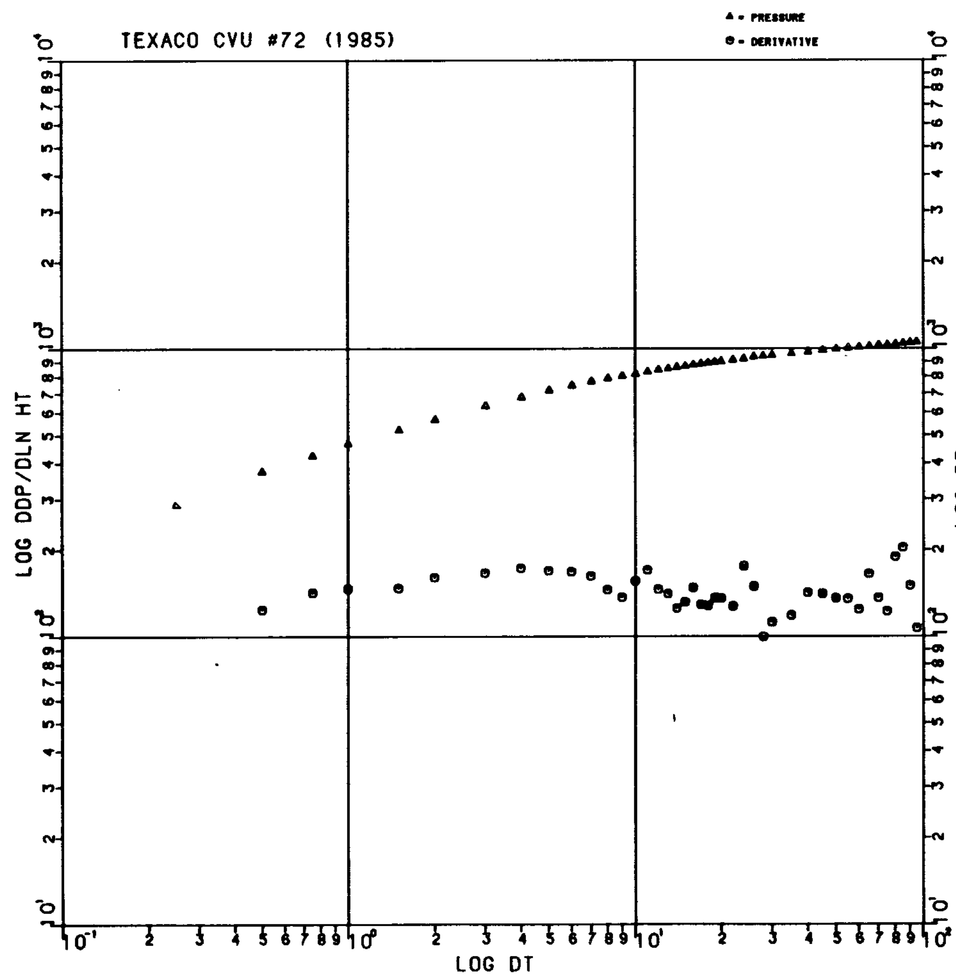

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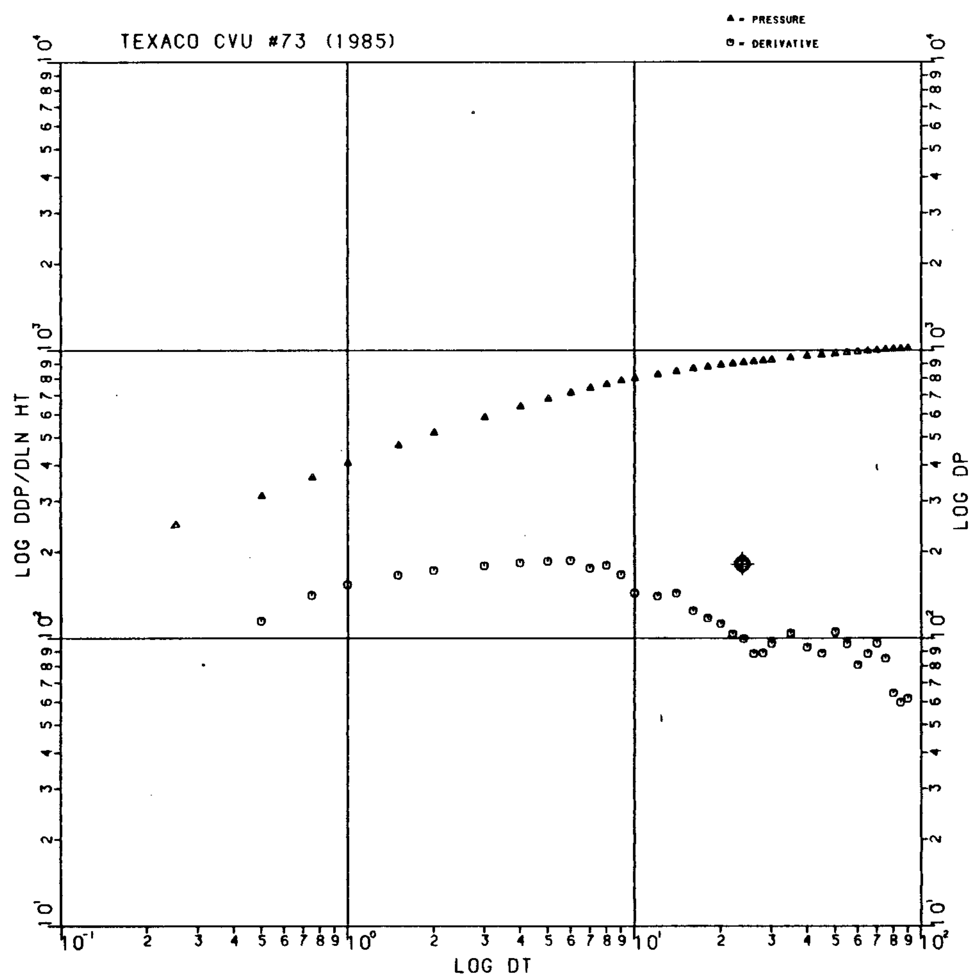
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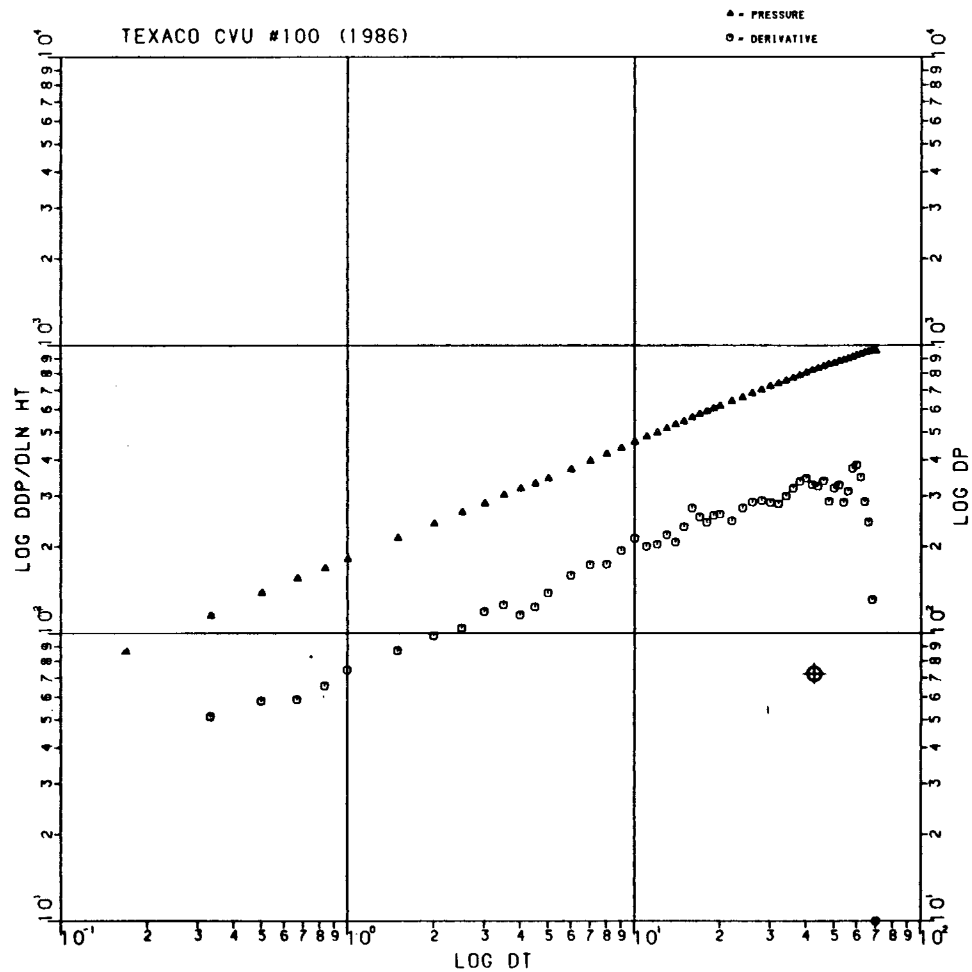
LOG DT



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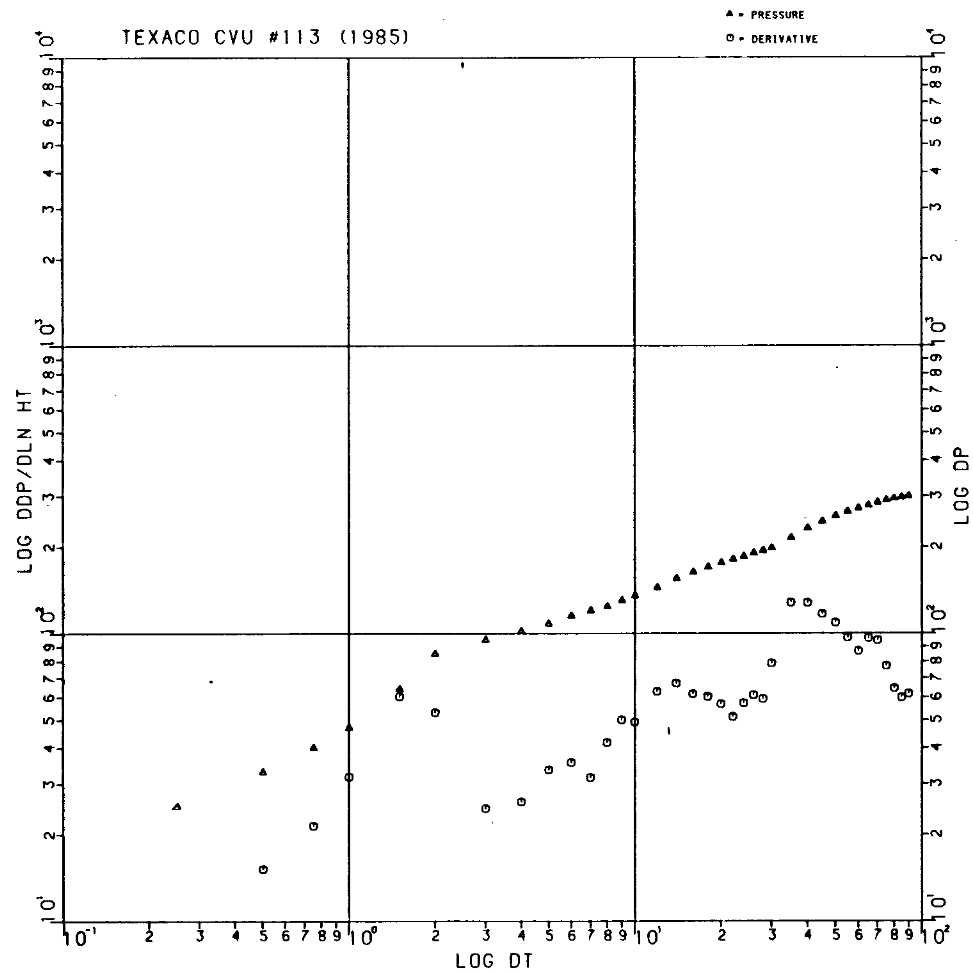

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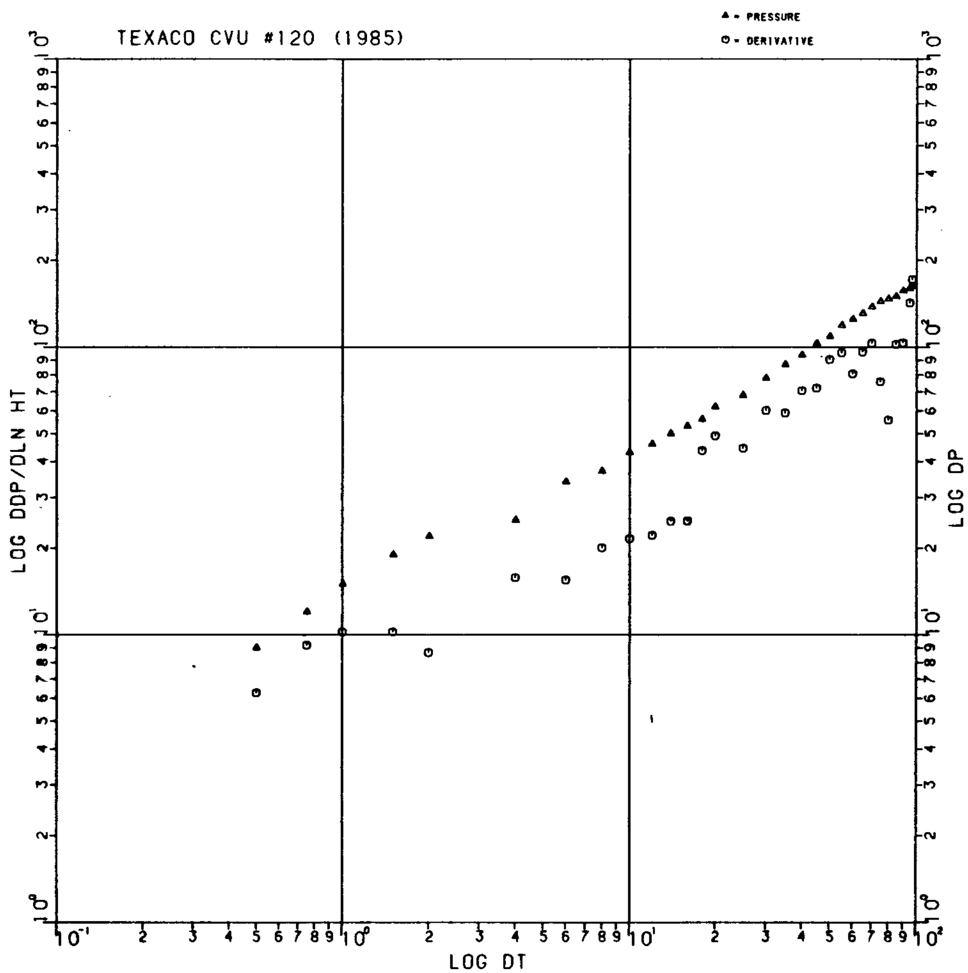

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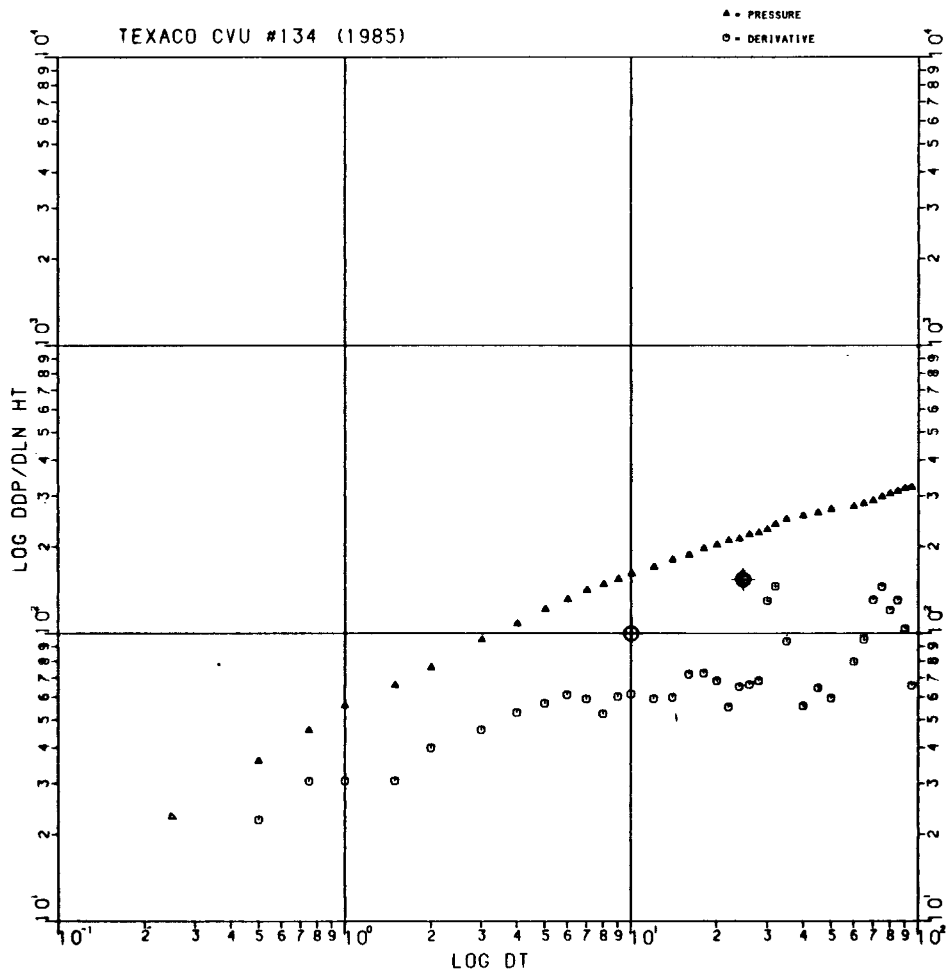

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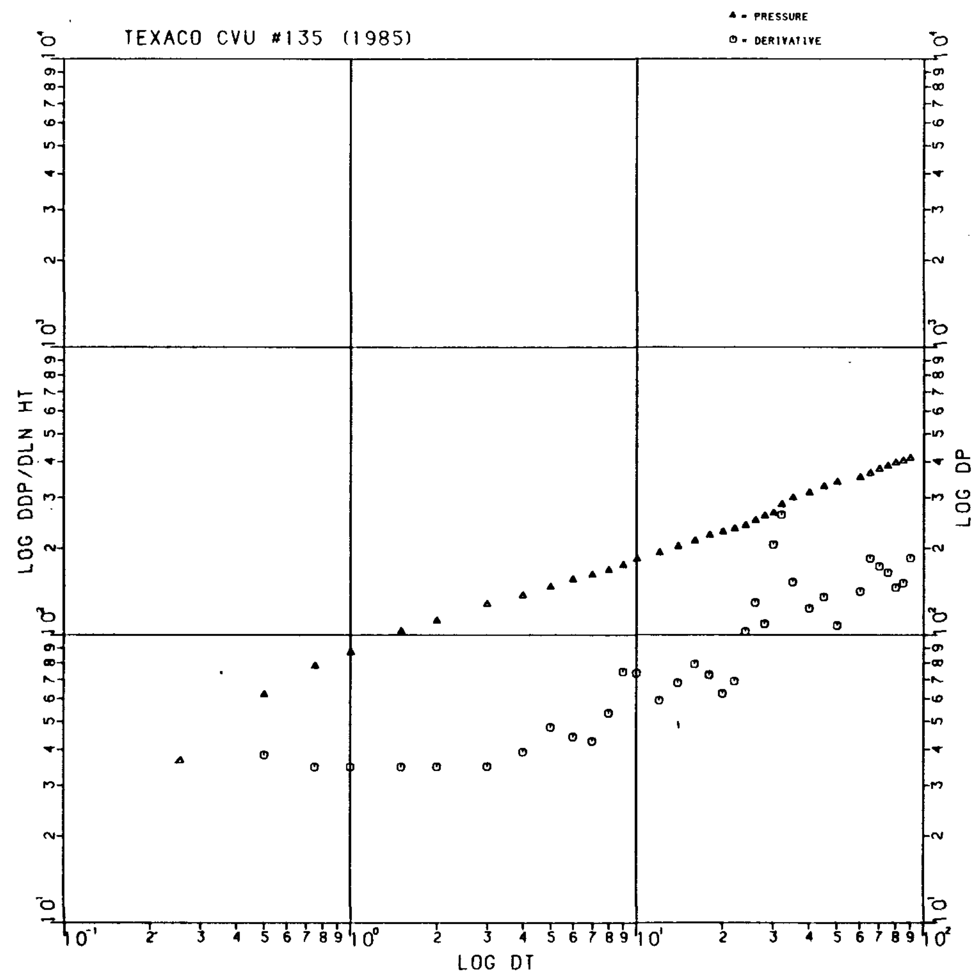

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⊙ - DERIVATIVE
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LOG DP
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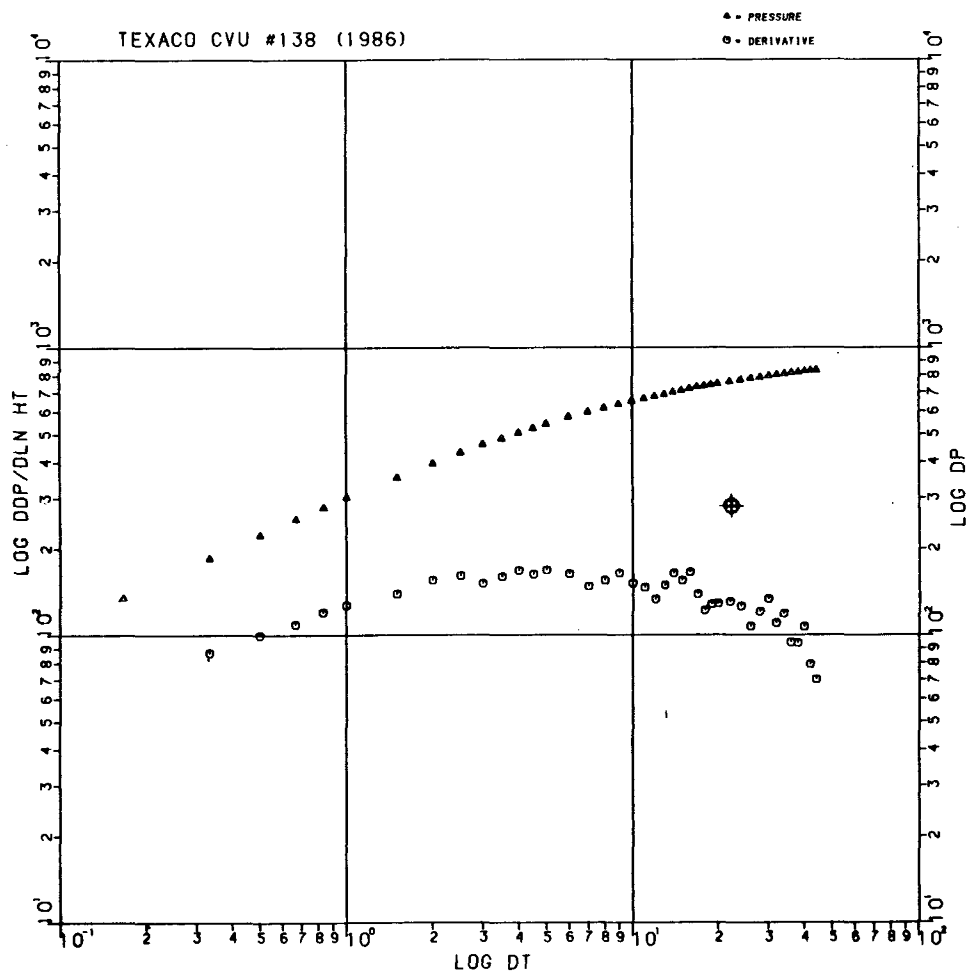
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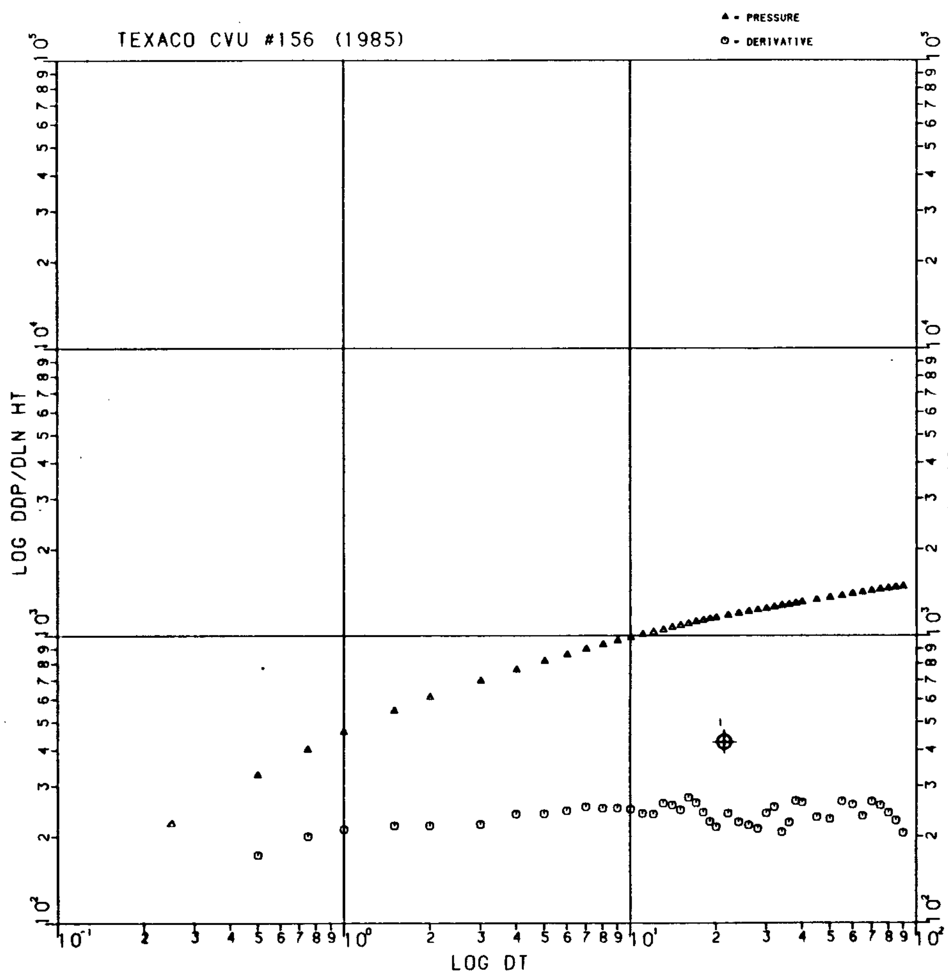
LOG DP
LOG DT



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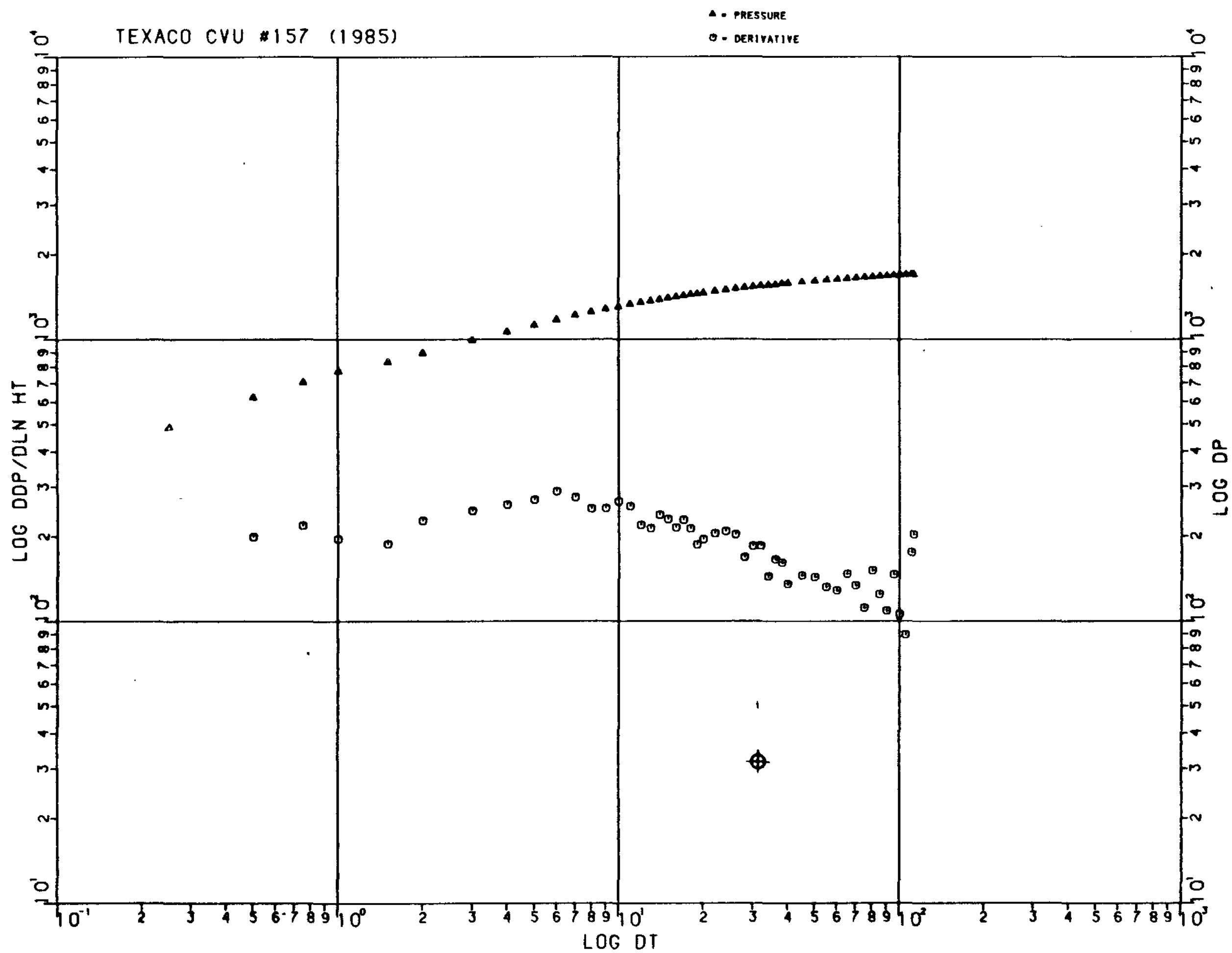
LOG DP
LOG DT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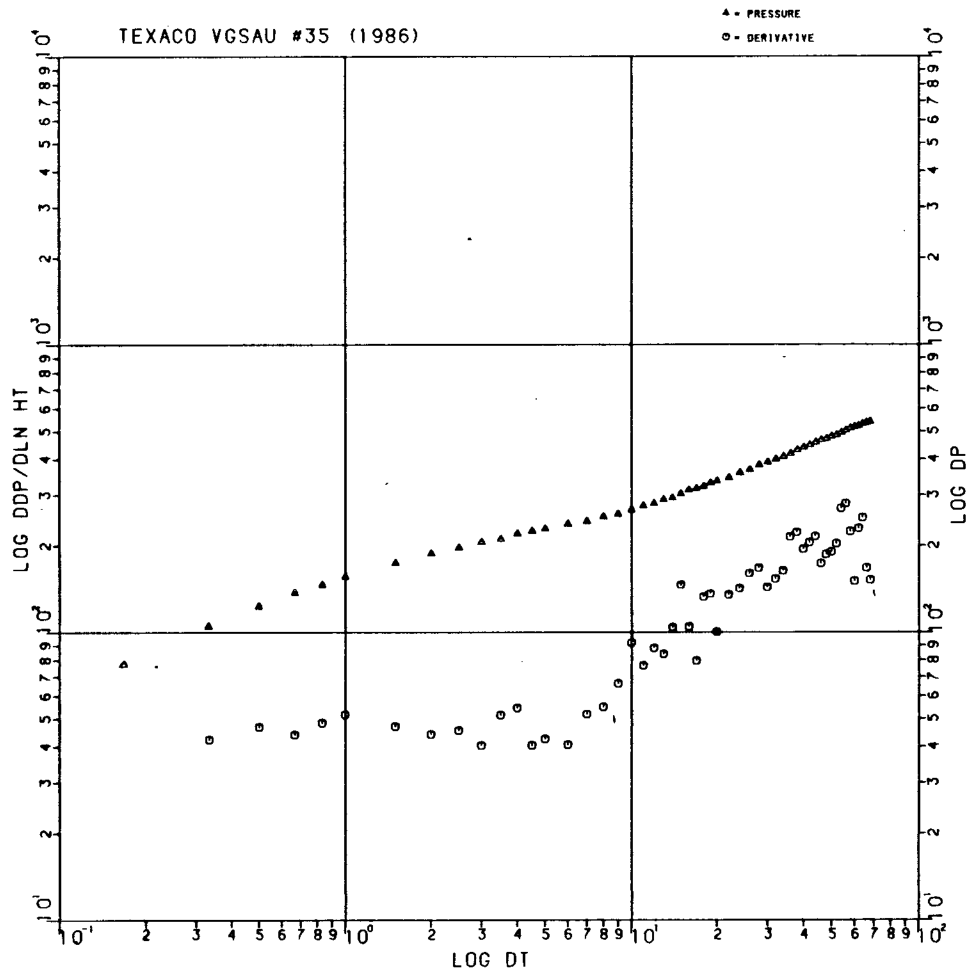
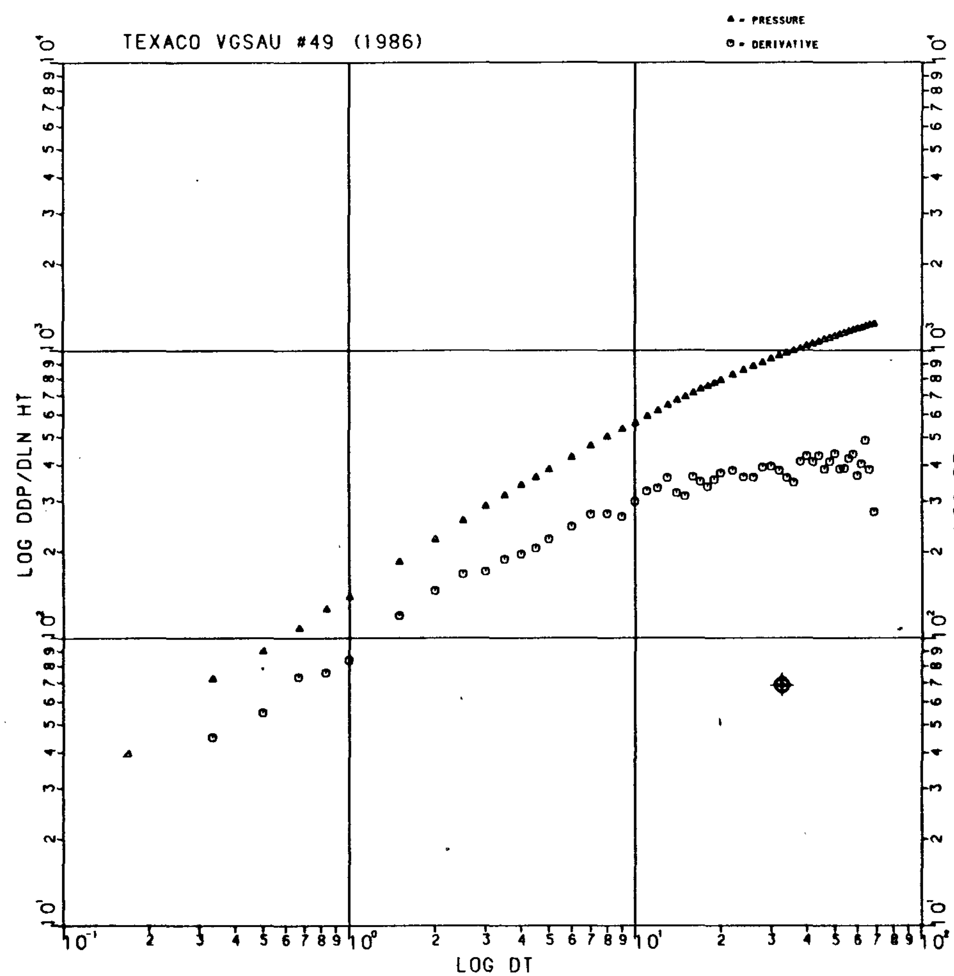
⊖ - DERIVATIVE
LOG DDP/DLN HT
LOG DP
LOG DT

TEXACO VGSAU #35 (1986)

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LOG DDP/DLN HT
LOG DP
LOG DT

VACUUM FIELD WATERFLOW COMMITTEE

TEXACO STATUS REPORT

Surface inspections, annulus and bradenhead surveys have been completed on all injection wells operated by Texaco. This represents a total of 153 wells as seen on the field map. All valves were visible and open. Twenty-four hour shut-in pressures were recorded. Wells exhibiting bradenhead and/or annular pressures were subsequently reopened with pressures dissipating in less than 5 minutes. No wells indicated communication between the evaportie section and annular spaces.

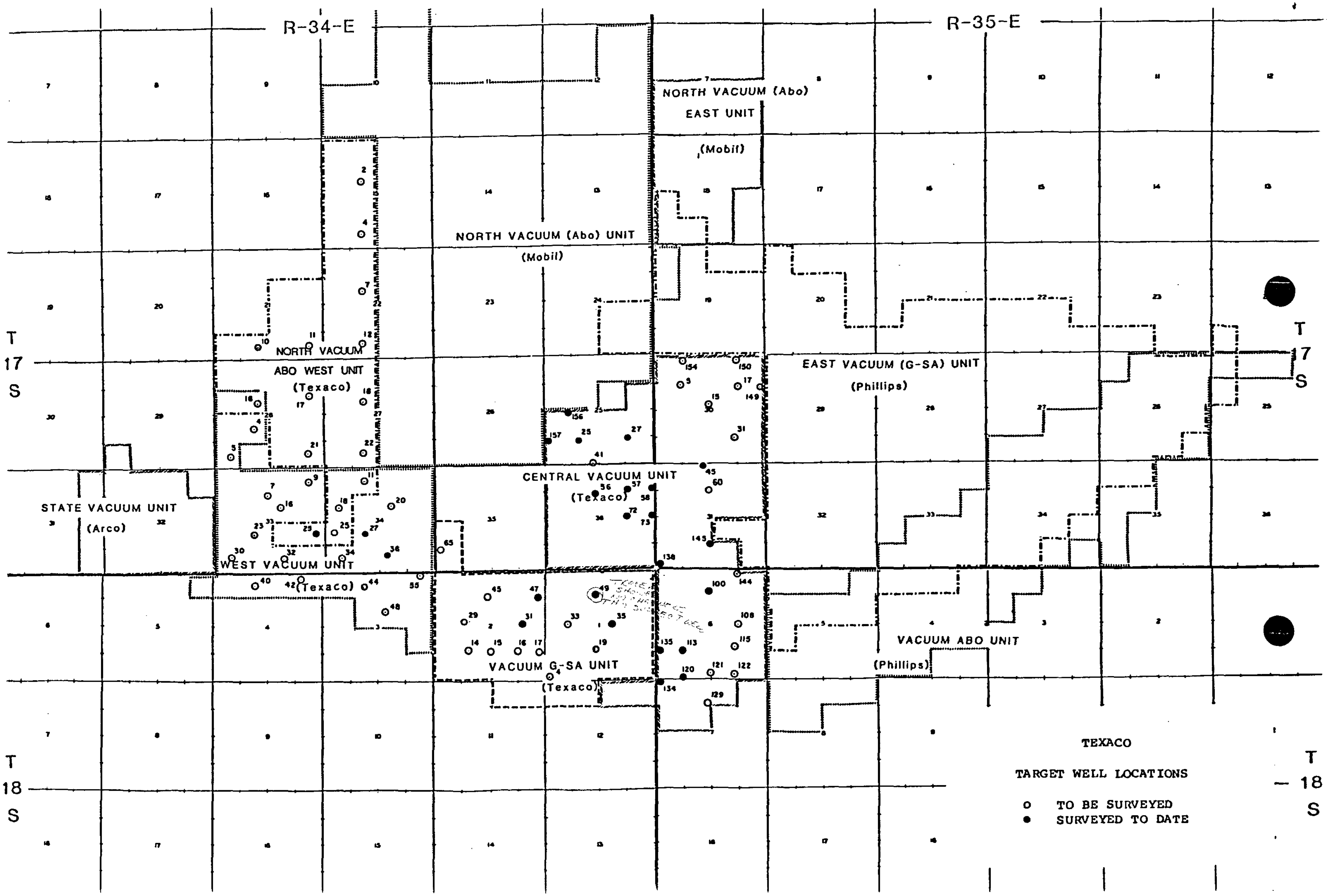
Texaco supports the Geological Committee's recommendation not to flow water from the evaporite section. Wells for the purpose of monitoring pressure in the salt section have been recommended as seen on the field map. AFE's for recompleting these wells are being processed along with other associated cost estimates.

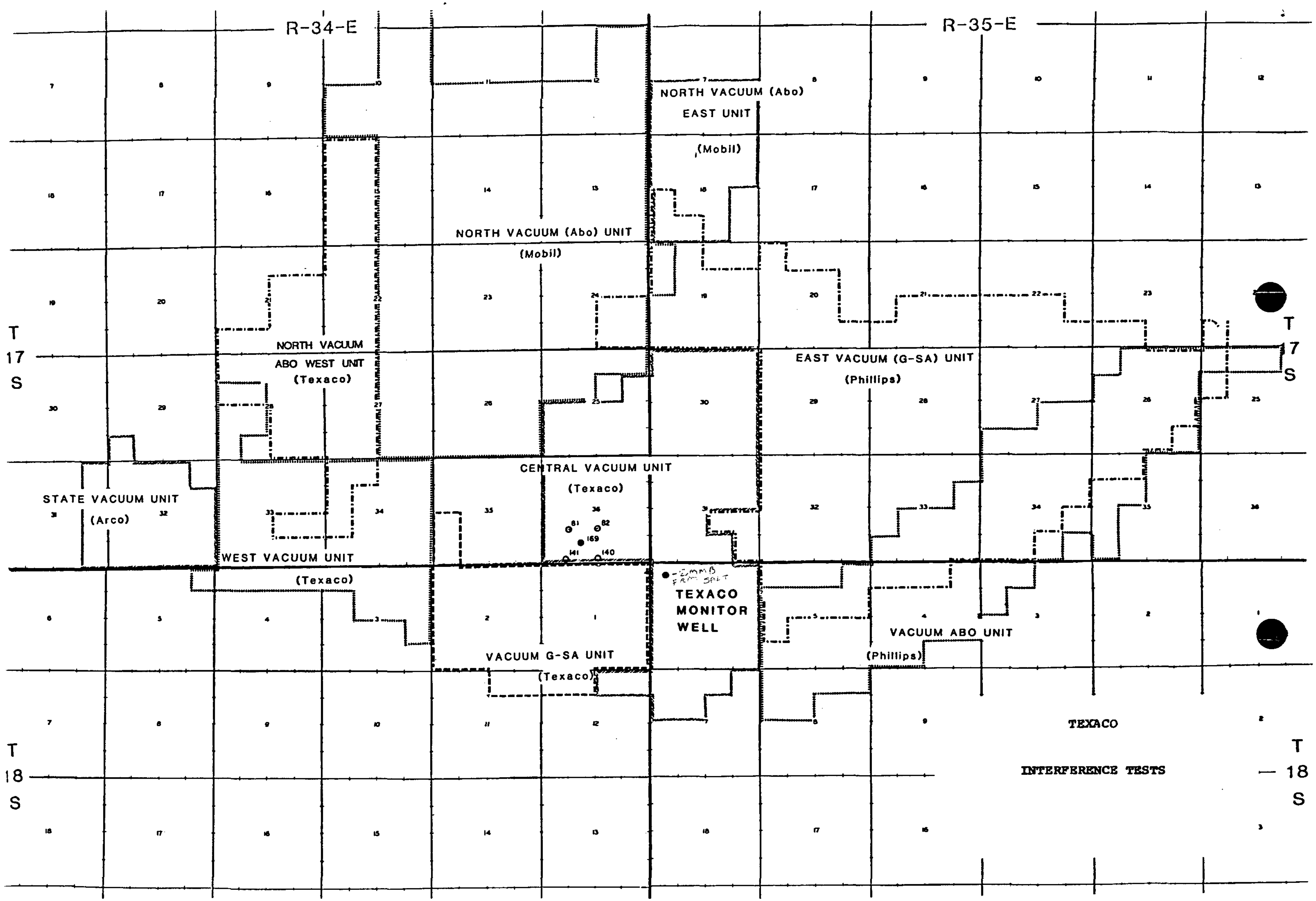
Texaco recently completed drilling Central Vacuum Unit Well No. 169. Interference tests were run between this well and the Central Vacuum Unit monitor well and also the four surrounding San Andres injection wells. A map showing these relative locations is attached. This replacement well encountered significant flows in the salt section with no pressure response detected in any of the test wells. Isotopic and hydrocarbon analysis' are being run on various water samples collected from this well. Tests are also being run to detect the presence of polymer or carbon dioxide as a tracer element.

Texaco has identified 78 injection wells meeting criteria to be on the target well list. A map of these locations is attached. Several wells targeted have injection pressures below the 900 psi limit set by the committee. Texaco added these wells to the list due to large injection volumes. Currently, 24 wells have been surveyed by one or more of the methods recommended by the technical committee. Radioactive tracer surveys have been run on 8 wells, pressure falloffs have been run on 11 wells and 5 wells have had both of these surveys run on them.

Three wells have been identified as suspect due to large storage volumes. Texaco plans to further investigate these wells by the various other methods adopted by the technical committee. Once results from these various methods have been compared, the remaining wells will be surveyed accordingly.

Beg flow @ 1854' fr. new mon well 167 2000 BWPH
+ 6 minor flows
Never HC (water) in flows


R-34-E
R-35-E
T 17 S
T 18 S
NORTH VACUUM (Abo) EAST UNIT
(Mobil)
NORTH VACUUM (Abo) UNIT
(Mobil)
NORTH VACUUM ABO WEST UNIT
(Texaco)
EAST VACUUM (G-SA) UNIT
(Phillips)
STATE VACUUM UNIT
(Arco)
CENTRAL VACUUM UNIT
(Texaco)
WEST VACUUM UNIT
(Texaco)
VACUUM G-SA UNIT
(Texaco)
VACUUM ABO UNIT
(Phillips)
TEXACO
TARGET WELL LOCATIONS
o TO BE SURVEYED
● SURVEYED TO DATE



R-34-E
R-35-E
T 17 S
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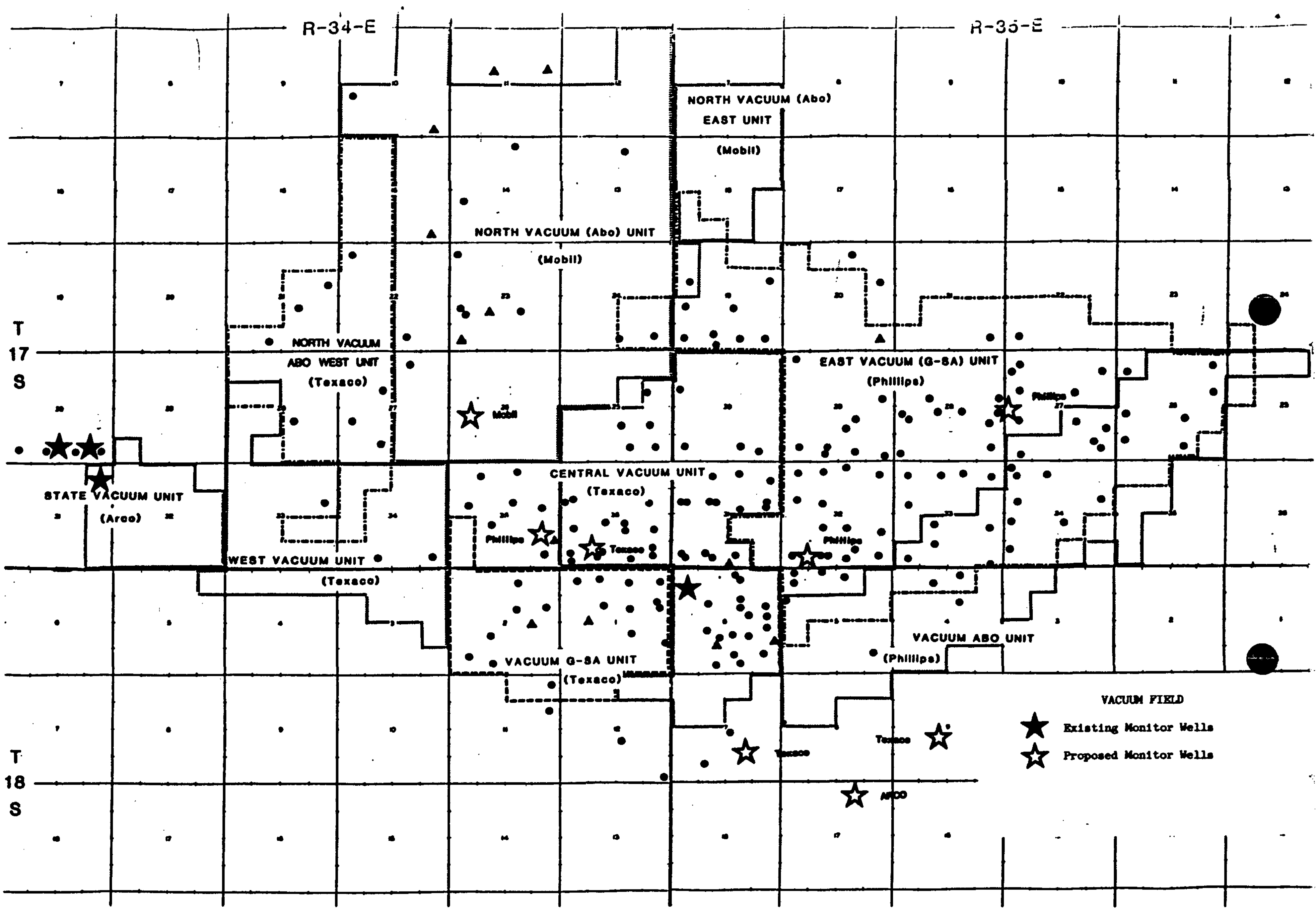
NORTH VACUUM (Abo) EAST UNIT
(Mobil)
NORTH VACUUM (Abo) UNIT
(Mobil)
NORTH VACUUM ABO WEST UNIT
(Texaco)
EAST VACUUM (G-SA) UNIT
(Phillips)
STATE VACUUM UNIT
(Arco)
CENTRAL VACUUM UNIT
(Texaco)
WEST VACUUM UNIT
(Texaco)
TEXACO MONITOR WELL
VACUUM ABO UNIT
(Phillips)
VACUUM G-SA UNIT
(Texaco)
61
82
169
141
140
TEXACO
INTERFERENCE TESTS


R-34-E
R-35-E
T 17 S
T 18 S
NORTH VACUUM (Abo) EAST UNIT
(Mobil)
NORTH VACUUM (Abo) UNIT
(Mobil)
NORTH VACUUM ABO WEST UNIT
(Texaco)
EAST VACUUM (G-SA) UNIT
(Phillips)
CENTRAL VACUUM UNIT
(Texaco)
STATE VACUUM UNIT
(Arco)
WEST VACUUM UNIT
(Texaco)
VACUUM G-SA UNIT
(Texaco)
VACUUM ABO UNIT
(Phillips)
Mobil
Phillips
Texaco
ARCO
VACUUM FIELD
Existing Monitor Wells
Proposed Monitor Wells

VACUUM FIELD WATERFLOW COMMITTEE

Report to Management Committee
Phillips Petroleum Company
November 6, 1986

Phillips' Accomplishments To Date

As the Vacuum Field Waterflow Committee was being formed, Phillips was completing two wells, Lea #18 and Lea #32, in the western portion of the field as monitor wells. These wells flowed for a short time (total production was approximately 60,000 bbls.) and were subsequently shut in. They have been used as pressure monitors since.

Early in the work of the Technical Committee, a Phillips geochemist suggested geochemical and isotopic work on injected and produced waters in the field. As a result, approximately 35 water samples were collected by the operators in the field and sent to Phillips. Phillips then supervised the lab work (Some was done in our own labs.). The results were compiled and analyzed by the Phillips geochemist. His report was approved by the Technical Committee and submitted to the Management Committee, and ultimately to the NMOCD.

Pressure buildup tests run on the Central Vacuum Unit monitor well by Texaco were submitted to and analyzed by Phillips' pressure transient experts. From the storage volume calculated from these tests and in conjunction with the geochemist, tracer tests were designed for possible use in the field. Radioactive and non-radioactive chemical tracers that could be used in these tests were researched and recommended by Phillips. Several pressure transient tests were also designed. These include interference tests between possible sources of the waterflow problem and monitor well(s), as well as between existing and possible future monitor wells. These recommendations and designs have been approved by the Technical Committee and included in their reports. They have also been presented to the NMOCD.

Recently, injection well pressure falloff tests have been suggested as a possible way to identify an abnormally high storage volumes in the vicinity of injection wells. Phillips' pressure transient experts have received three tests on Phillips operated wells, as well as twenty-five more from other operators in the field. Their analysis is presently under way.

At the request of the Management Committee, bradenhead and annular pressure surveys were run on all injectors in the field. Tests were run on 121 wells operated by Phillips (EVGSAU 101 wells, VAU 10, Hale 6, Mable 2, and Lea 2). During these tests, surface casing was checked to ensure that any external valves or piping were free and open to the surface.

In order to outline a good logging plan for the committee, Phillips R&S personnel researched and made a recommendation on available logging tools that might be able to locate very small volume fluid movement behind casing in the injection wells. That recommendation was included in the most recent Technical Committee report. Their most highly recommended tool was a "scintillation" tracer survey. Phillips has run 56 of these surveys, in conjunction with temperature surveys, in the last year (EVGSAU 48 wells, Hale 8, and Mable 2).

Phillips' geologist has picked tops for the Rustler, Salado, and Cowden Anhydrite formations and the base of the Salado formation from wells in EVGSAU to be used by the geologic committee in constructing contour maps. Initial contacts were made with a consultant knowledgeable in evaporite dissolution who will meet with the technical committees.

Phillips has also obtained a legal opinion concerning the completion of monitor wells outside the unitized interval. Such completion would have to have the approval of the leaseholder.

## Phillips' Proposed Work

Phillips proposes to run approximately three thru-tubing nuclear logs by year end. These are such logs as Schlumberger's TDT and Dresser-Titan's PDK. We would also like to run Texaco's thru-casing nuclear tool in one of the Hale-CVU injectors.

All injection wells with surface injection pressures greater than or equal to 900 psi will have falloff tests run to check for abnormally high storage volumes.

Other work shall depend upon the results of these tests.

Phillips will also construct computer maps of the field. These maps will show wells that have been tracer surveyed, the bradenhead survey results, BHP in the San Andres, and San Andres parting pressure data.

November 5, 1986

Vacuum Field Waterflow
Technical Committee

RE: TEXACO RESPONSE TO MANAGEMENT COMMITTEE CHARGES

Surface inspections, annulus and bradenhead surveys have been completed on all injection wells operated by Texaco. All valves were visible and open. Twenty-four hour shut-in pressures were recorded. Wells exhibiting bradenhead and/or annular pressures were subsequently reopened with pressures dissipating in less than 5 minutes. No wells indicated communication between the salt section and annular spaces.

Charge No. 1 - Monitor Wells

Texaco is proposing the following wells be recompleted as monitor wells should conditions dictate:

| | |
|---|---|
| Central Vacuum Unit No. 91 | 660' FSL, 1980' FWL, 36-17-34 |
| State AP No. 2 | 2310' FSL, 1650' FWL, 9-18-35 |
| State AN No. 6 | 990' FSL, 2310' FEL, 7-18-35 |

AFE's for recompletion are being prepared along with associated costs to produce a monitor well.

Charge No. 2 - Pressure Testing and Tracers

Texaco is in the process of drilling Central Vacuum Unit Well No. 169 which is replacement for Central Vacuum Unit Well No. 91. A pressure recorder has been installed on the Central Vacuum Unit Monitor Well No. 1 for interference testing should a significant waterflow be encountered in the replacement well. Bottom hole electronic quartz pressure gauges have been installed in the four injection wells offsetting the replacement well to detect any pressure pulse in the San Andres created by flowing the salt section. No information has been gained as of yet.

Charge No. 3 - Well Survey Program

Injection profiles and falloffs have been run on the following wells as noted. None of the profiles indicated channeling. Falloff data is still being analyzed. Conventional analysis of storage volume has been hampered by lack of early time data. Methods involving type curve analysis are being evaluated for validity. The falloffs utilizing electronic gauges will also provide early time data critical for evaluating storage. This will present an opportunity to verify type curve analysis by conventional analysis.

DCC:jss

# WELL SURVEY PROGRAM

Central Vacuum Unit

| | |
|---|---|
| *** | 25 |
| * | 27 |
| * | 45 |
| * | 56 |
| *** | 57 |
| *** | 58 |
| *** | 72 |
| *** | 73 |
| ** | 100 |
| *** | 113 |
| *** | 120 |
| *** | 134 |
| *** | 135 |
| ** | 138 |
| ** | 145 |
| *** | 156 |
| *** | 157 |

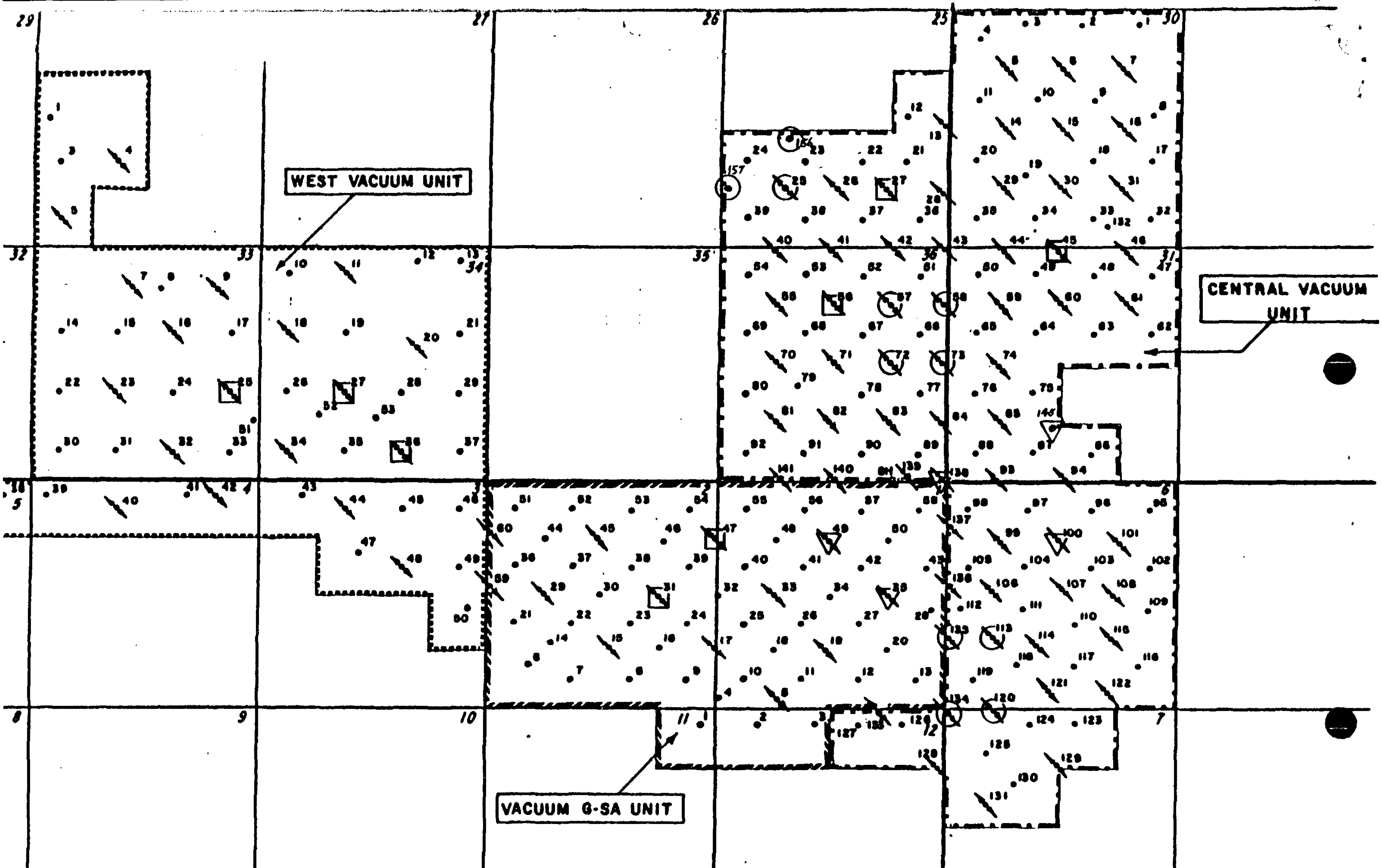
Vacuum Grayburg San Andres Unit

| | |
|---|---|
| * | 31 |
| ** | 35 |
| * | 47 |
| ** | 49 |

West Vacuum Unit

| | |
|---|---|
| * | 25 |
| * | 27 |
| * | 36 |

*     Injection Profiles.
**    Injection Profiles and Pressure Falloff Tests.
***   Pressure Falloff Tests.




□ INJECTION PROFILES

▽ INJECTION PROFILES AND PRESSURE FALLOFF TESTS

○ PRESSURE FALLOFF TESTS

0 3000' 6000'

CRC 4-10-78
Rev. 2-6-80

TEXACO Inc.

VACUUM GRAYBURG SAN ANDRES POOL
LEA COUNTY, NEW MEXICO

# Mobil Producing Texas & New Mexico Inc.

November 04, 1986

P O BOX 633
MIDLAND, TEXAS 79702

William J. Mueller
Phillips Petroleum Company
4001 Penbrook Street
Odessa, Texas 79762

SALADO WATERFLOW STUDY
MOBIL'S PLAN OF ACTION
SAN ANDRES AND ABO WATERFLOODS
VACUUM FIELD

Dear Mr. Mueller:

Attached is a copy of Mobil's proposed plan of action to be incorporated into the overall Committee plan for presentation to the NMOCD, as well as a timetable for accomplishing the work. Some of the work is proposed for 1986 with some carry over into 1987. We are proposing diagnostic work on injection wells in both the San Andres and Abo waterfloods.

Briefly, we propose the following:

San Andres

1) Run radioactive tracer/temperature surveys in 14 injection wells (8-1986, 6-1987)

2) Run step rate tests in 4 injection wells to determine fracture pressure in this reservoir.

3) Recomplete one TA well to the Salado Section for use as a pressure monitoring well.

A:M630869A.TLH

Abo

1) Run radioactive tracer/temperature surveys in 20 injection wells (6-1986, 14-1987).

The plan of action is currently being routed for approval by our management and work is scheduled to start by November 15, 1986.

Very truly yours,

M E Sweeney

M. E. Sweeney
Environmental and Regulatory Manager

TLHill/hjw

Attachments

xc: J. D. Ramey

A:M630869A.TLH

# VACUUM SALADO WATERFLOW STUDY

## PROPOSED WORK SCHEDULE FOR 1986

| BRIDGES STATE | NOVEMBER 1986 WK 3 | NOVEMBER 1986 WK 4 | DECEMBER 1986 WK 1 | DECEMBER 1986 WK 2 | DECEMBER 1986 WK 3 | DECEMBER 1986 WK 4 |
|---|---|---|---|---|---|---|
| 2 WIW | | | | A,C | | |
| 3 WIW | | A,C | | | | |
| 6 WIW | | | | A,C | | |
| 7 WIW | | A,B,C | | | | |
| 20 WIW | A,C | | | | | |
| 21 WIW | A,C | | | | | |
| 24 WIW | A,C,B | | | | | |
| 30 WIW | A,B,C | | | | | |
| 31 WIW | SINKER BAR RUN | | | A,C | | |
| 37 WIW | | A,C | | | | |
| 43 WIW | | A,C | | | | |
| 167 WIW | | | A,C | | | |
| **STATE J** | | | | | | |
| 1 WIW | | | A,C | | | |
| 4 WIW | | | A,B,C | | | |
| **NVAU** | | | | | | |
| 117 WIW | | | | | A | |
| 118 WIW | | | | | A | |
| 140 WIW | | | | | A | |
| 148 WIW | | | | | | A |
| 157 WIW | | | | | | A |
| 202 WIW | | | | | | A |

**KEY TO THE PROPOSED WORK SCHEDULE**

A = TRACER/TEMPERATURE/SPINNER LOG

B = STEP RATE TEST

C = PULL AND CLEAN WELL TO ALLOW THE RUNNING OF TESTS A AND B

# VACUUM SALADO WATERFLOW STUDY

## PROPOSED WORK SCHEDULE FOR 1987

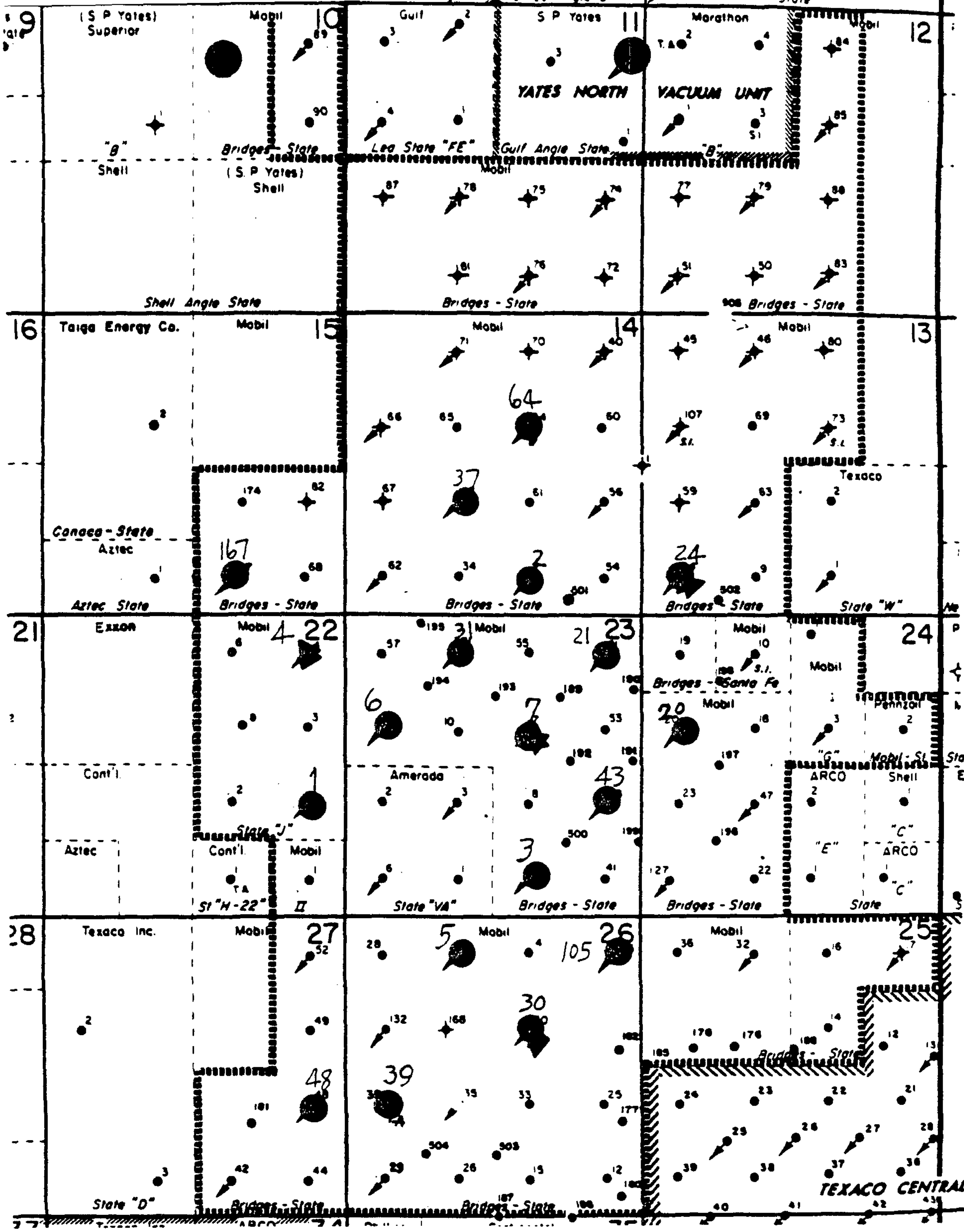
| | JANUARY 1987 | | | | | FEBRUARY 1987 | |
|---|---|---|---|---|---|---|---|
| NVAU | | WK 1 | WK 2 | WK 3 | WK 4 | WK 1 | WK 2 |
| 109 WIW | | A | | | | | |
| 119 WIW | | A | | | | | |
| 124 WIW | | A | | | | | |
| 147 WIW | | A | | | | | |
| 150 WIW | | | A | | | | |
| 159 WIW | | | A | | | | |
| 207 WIW | | | A | | | | |
| 212 WIW | ↕ SINKER BAR RUN | | A | | | | |
| 216 WIW | | | | A | | | |
| 171 WIW | | | | A | | | |
| 208 WIW | | | | A | | | |
| NVAEU | | | | | | | |
| 3 WIW | | | | A | | | |
| 4 WIW | | | | | A | | |
| 7 WIW | | | | | A | | |
| BRIDGES STATE 39 MONITOR WELL | | | | | DRILL OUT AND COMPLETE WELL IN THE SALT SECTION | | |

**KEY TO THE PROPOSED WORK SCHEDULE**

A = TRACER/TEMPERATURE/SPINNER LOG

B = STEP RATE TEST

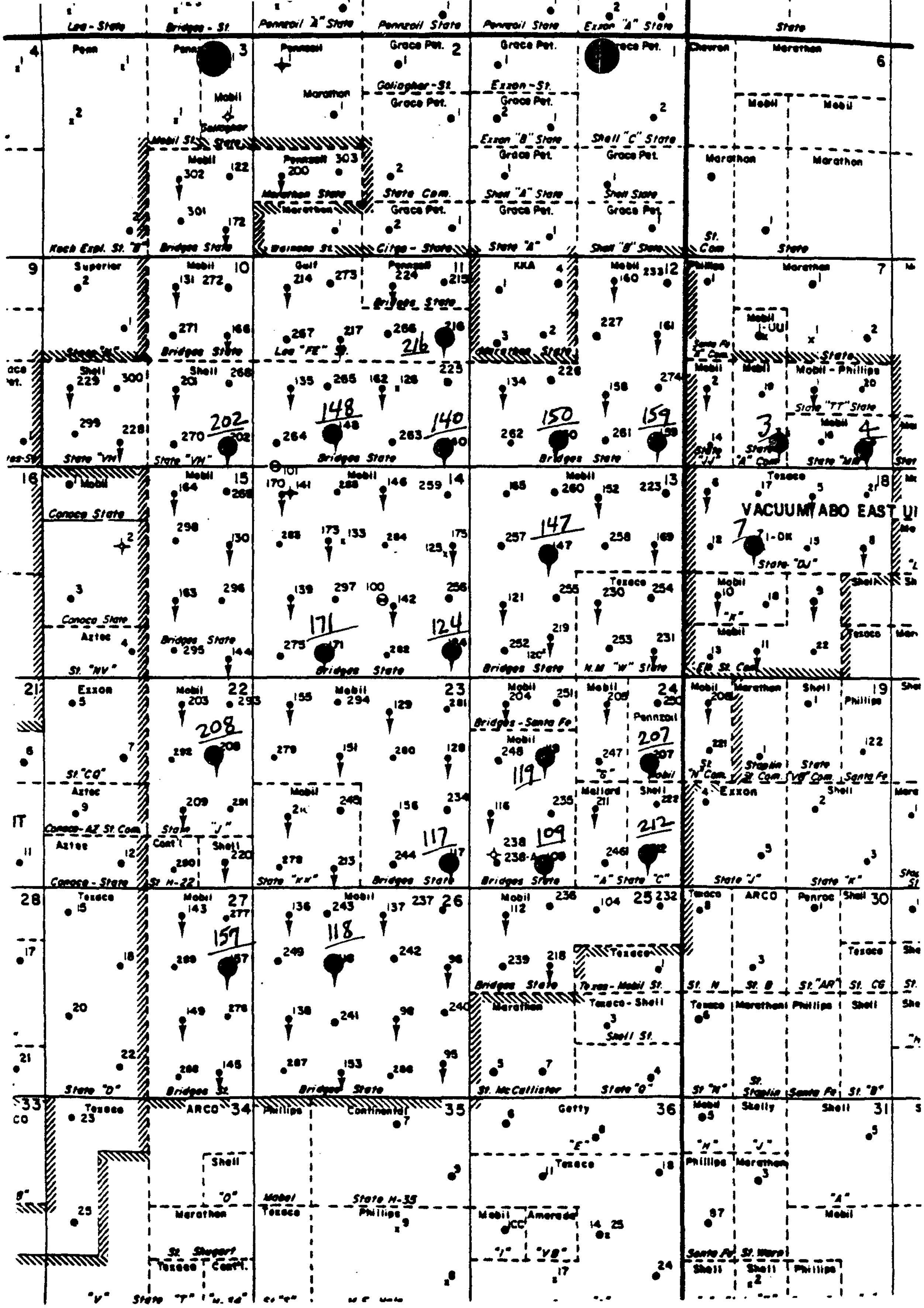
C = PULL AND CLEAN WELL TO ALLOW THE RUNNING OF TESTS A AND B




- TRACER/TEMP/SPINNER SURVEY
- STEP RATE TEST
- PRESS MONITORING WELL IN SALT SECTION

**MOBIL**

BRIDGES STATE LEASE
SAN ANDRES WATERFLOOD
(VACUUM FIELD)




ABO WELLS FOR TRACER / TEMP. SURVEY

MOBIL
NVAU
NVAEU