PN 3-60-63

CHEMICAL ENGINEERING GROUP
WATER ANALYSIS REPORT

To: T. O. Davis, File

Date Collected: 3-18, 19 Date Rec'd 3-21-60 Date Rep'd 3-23-60 Lab No. 15,901

Source of Sample Wellhead, Navajo B #1-W, HORSESHOE-GALLUP FLD., San Juan Co., New Mexico

CHEMICAL ANALYSIS

CONSTITUENTS	Mg Liter	CONSTITUENTS	Mg Liter	CONSTITUENTS	Mg Liter
1. Total Solids	7,615	6. Calcium	192	11. Sulfates	4,570
2. pH	7.9	7. Magnesium	32	12. Carbonates	0
3. Sp. Grav. 60 F.	1.006	8. Iron 4 as Fe (6.7 FeS)		13. H2S	0
4. Res. 68 F.		9. Chlorides	300	14. ~~Hydroxide~~ Ba	0
5. Sodium	2,215	10. Bicarbonates	305		
Pattern Code		A9A9AoAo:AoB5J5Ao			

INTERPRETATION

PROBLEM:

CONCLUSION:

REMARKS:

ATLANTIC COST $14.74

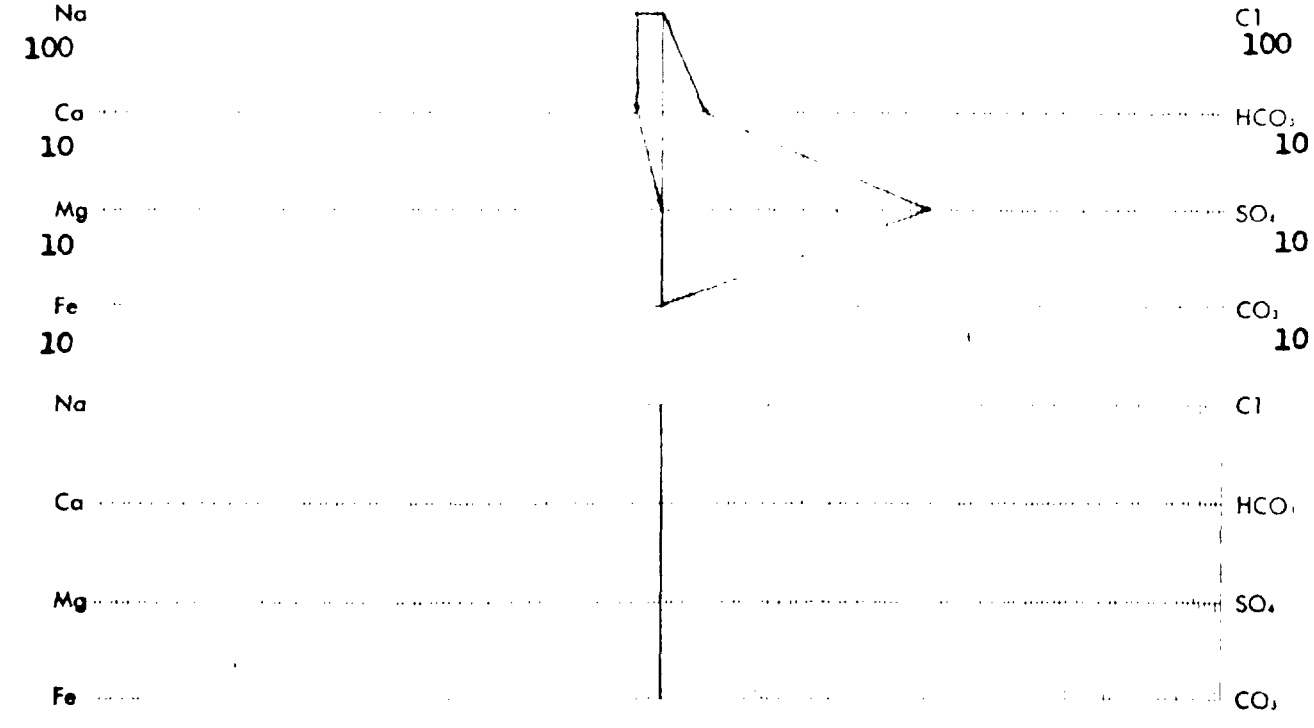
COMMERCIAL COST $ 28.00

AUTHORIZED BY T.O. Davis

CHARGE TO Navajo B #1-W

Approved by HENRY LEWELLING

Reported by MONTE KAPLAN



3B 543C

Exhibit D

Office of the State Engineer
Office Box 1079
Santa Fe, New Mexico

Gentlemen:

In compliance with the New Mexico Oil Conservation Commissions' Memorandum No. 5-58, dated January 31, 1958, The Atlantic Refining Company is furnishing the following information:

1. Copy of our application to waterflood the Atlantic Navajo and Navajo 'B' Leases in the Horseshoe-Gallup Oil Pool, San Juan County, New Mexico.

2. The water source will be the Atlantic Navajo 'B' No. 1-W well located in the Horseshoe-Gallup Field in the SW/4 of Section 19 - T31N - R16W, San Juan County, New Mexico, and other wells in the project area if necessary.

3. The water will be produced from the Morrison formation which occurs between 2106 feet and 2802 feet in the Atlantic Navajo 'B' No. 1-W.

4. A copy of a water analysis is enclosed.

ILLEGIBLE

LARGE FORMAT EXHIBIT HAS BEEN REMOVED AND IS LOCATED IN THE NEXT FILE

EXHIBIT "C"

DESCRIPTION OF CASING PROGRAM OF INJECTION WELLS

THE ATLANTIC REFINING COMPANY APPLICATION FOR AN ORDER

AUTHORIZING WATER INJECTION ON ITS NAVAJO AND NAVAJO "B" LEASES

Lease and Well Number	Surface Casing			Producing Casing			Well Locations All in T31N - R16W San Juan Co., N. Mex.	
	Size	Setting Depth	Cement Sacks	Size	Setting Depth	Cement Sacks	Unit	Section
Navajo 9	8 5/8	102.07	125	5 1/2	1446.72	135	B	30
16	8 5/8	100.90	115	5 1/2	1300.73	130	H	31
17	8 5/8	98.80	115	5 1/2	1286.00	130	B	31
22	8 5/8	98.97	115	5 1/2	1362.52	130	J	29
23	8 5/8	103.64	115	5 1/2	1379.01	130	F	29
24	8 5/8	95.70	115	4 1/2	1409.82	160	D	29
26	8 5/8	99.75	115	4 1/2	1347.09	190	B	29
28	8 5/8	94.26	115	4 1/2	1306.25	150	J	31
29	8 5/8	101.49	115	5 1/2	1366.00	130	F	31
Navajo "B" 1	8 5/8	102.06	115	5 1/2	1577.21	150	N	19
3	8 5/8	103.65	115	4 1/2	1446.21	180	P	19
4	8 5/8	97.47	115	4 1/2	1474.27	190	J	19
5	8 5/8	98.05	115	4 1/2	1487.72	195	F	19
7	8 5/8	98.03	115	4 1/2	1513.40	225	N	20
8	8 5/8	100.09	100	4 1/2	1588.24	150	L	20

OIL CONSERVATION COMMISSION
SANTA FE, NEW MEXICO

Date 6-2-60

CASE 1979 Hearing Date 6-1-60

My recommendations for an order in the above numbered cases are as follows:

1. Grant Atlantic request for a secondary recovery project in the Horseshoe Gallup oil Pool.

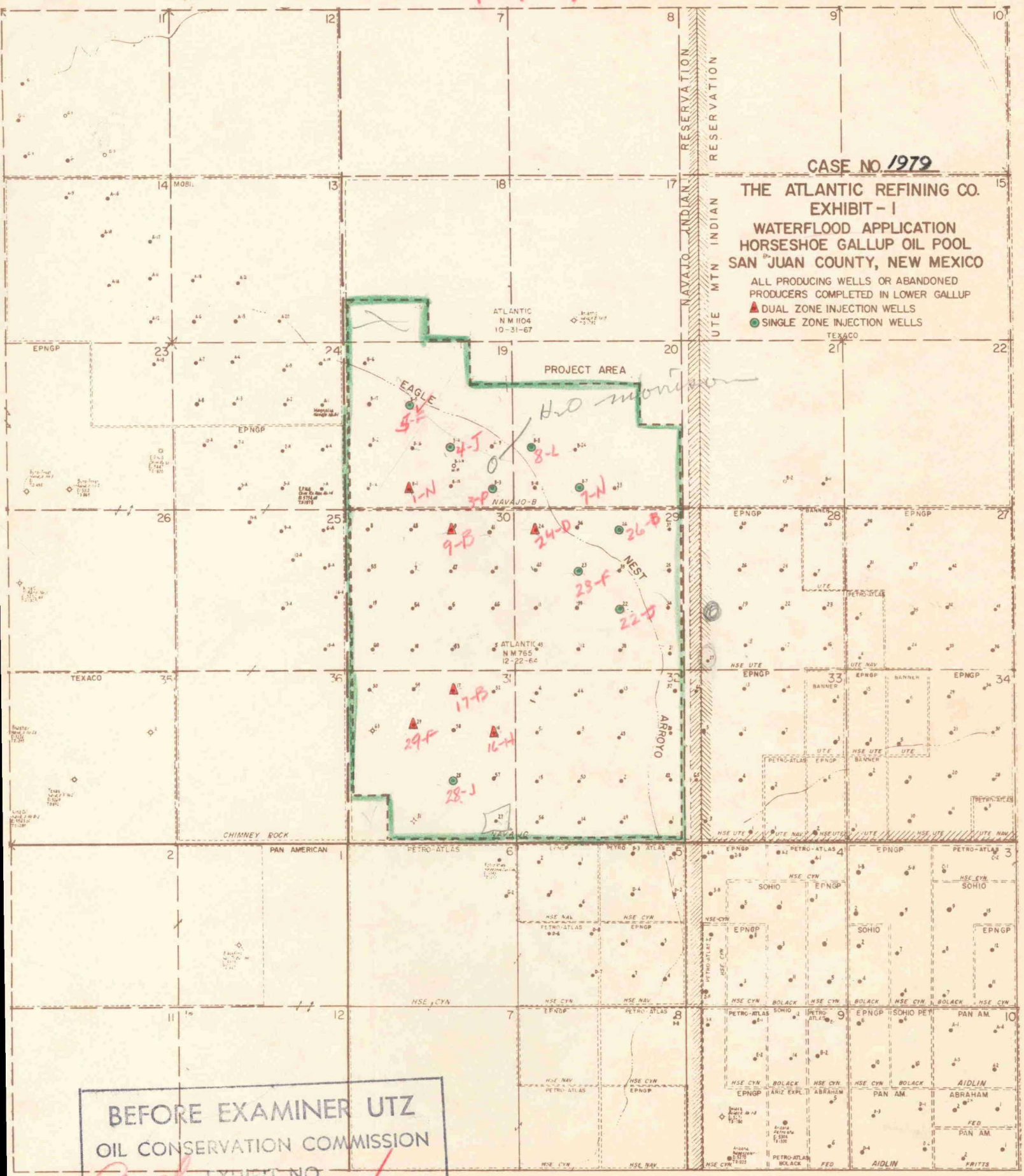
2. Unit area to consist:

31 N - 16 W
Sec. 18, S/2 SW/4
" 19, W/2, W/2 E/2, SE/4 NE/4, E/2 SE/4.
" 20, S/2, S/2 NW/4, SW/4 NE/4.
" 29, All
" 30, All
" 31, E/2, E/2 W/2, NW/4 SW/4, W/2 NW/4
" 32 All

Balance of Recommendation attached

E. S. Walker

T31N, R16W



BEFORE EXAMINER UTZ
OIL CONSERVATION COMMISSION
EXHIBIT NO. 1
CASE NO. 1979

Case No. 1979
The Atlantic Refining Co.
Exhibit No. 3

PROPOSED GAS EQUIVALENT CREDIT FOR WATER INJECTION

HORSESHOE-GALLUP OIL POOL, SAN JUAN COUNTY, NEW MEXICO

RULE 7. Credit for daily average net water injected into the Horseshoe-Gallup Oil Pool through any injection well located within the project area may be converted to its gas equivalent and applied to any well producing with a gas-oil ratio in excess of two thousand cubic feet of gas per barrel of oil. Total credit for net water injected in the project area shall be the gas equivalent volume of the daily average net water injected during a one-month period. The daily average gas equivalent of net water injected shall be computed in accordance with the following formula:

$$E_g = (V_{w\ inj} - V_{w\ prod}) \times 5.61 \times \frac{P_a}{15.025} \times \frac{520^\circ}{T} \times \frac{1}{Z}$$

where:

E_g = Average daily gas equivalent of net water injected, cubic feet

$V_{w\ inj}$ = Average daily volume of water injected, barrels

$V_{w\ prod}$ = Average daily volume of water produced, barrels

5.61 = Cubic foot equivalent of one barrel of water

P_a = Average reservoir pressure at mid-point of the pay-zones of the Horseshoe-Gallup Oil Pool in project area, psig + 12.05 as determined from most recent survey.

15.025 = Pressure base, psi

520° = Temperature base of 60°F expressed as absolute temperature

T_s = Reservoir temperature of 87°F expressed as absolute temperature

Z = Compressibility factor from analysis of Horseshoe-Gallup gas at average reservoir pressure, P_a, interpolated from compressibility tabulation below:

Reservoir Pressure	Z	Reservoir Pressure	Z
50	.9725	450	.7220
100	.9465	500	.6900
150	.9215	550	.6560
200	.8885	600	.6135
250	.8600	650	.5655
300	.8325	700	.5220
350	.8030	750	.4630
400	.7710	800	.3935

400,000 stock tank barrels per month can be maintained for about nine years. At that time, the oil productivity declines because of the increasing amounts of water being produced.

Water Source

The Dakota formation should provide an ample supply of water for waterflood purposes. Atlantic drilled the Navajo #45 well through the Dakota formation to a total depth of 2078 feet. The Dakota sand was topped at 1816 feet and extended to 2063 feet with a few shale breaks. Two cores were cut (1846 to 1896 and 1989 to 2039) and two drill stem tests were taken. From 61 feet of analyzed core, 44 feet had an average air permeability of 167 mds. Results of the two DST's are tabulated below:

Test No.	Depth From	Depth To	Flow Period	Shut-In Period	Recovery	Flow Pressures	Final Shut-in Pressure
1	1849	1896	90 min.	30 min.	1585' water	119-701	745
2	1992	2039	90 min.	30 min.	1762' water	299-806	809

Analysis of the water recovered in DST #1 showed 4,996 ppm. total solids with a pH of 7.0. The solids constituents were as follows:

Sodium	1578 ppm
Calcium	24 ppm
Magnesium	1 ppm
Iron	0 ppm
Barium	0 ppm
Chloride	284 ppm
Bicarbonate	625 ppm
Sulfate	2484 ppm
Carbonate	0 ppm
Hydroxide	0 ppm

The Dakota sands are expected to be well developed in all areas of the field so water source wells could be located where they would be most convenient.

HORSESHOE-GALLUP FIELD STUDY

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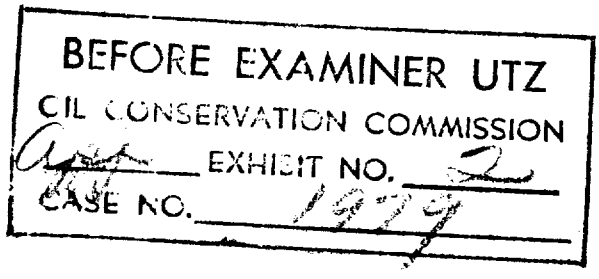
CASE No. 1979
THE ATLANTIC REFINING CO.
EXHIBIT No. 2

HORSESHOE GALLUP FIELD

SAN JUAN COUNTY, NEW MEXICO

WATERFLOOD STUDY
UPPER AND LOWER TOCITO



THE ATLANTIC REFINING COMPANY

HORSESHOE GALLUP FIELD

SAN JUAN COUNTY, NEW MEXICO

WATERFLOOD STUDY
UPPER AND LOWER TOCITO

THE ATLANTIC REFINING COMPANY

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SUMMARY

INTRODUCTION

Since early in the life of the Horseshoe-Gallup Field it has been apparent that the normal producing mechanism will be solution-gas drive and that some form of fluid injection would be needed to maintain producing rates and increase recovery. A review of various fluid injection processes indicated that water injection would be the best. Low pressure gas injection is inefficient and the low reservoir pressure and shallow producing depths preclude use of miscible fluid injection, including high pressure gas injection. Accordingly, this report assembles reservoir data on the field, predicts the primary recovery performance, and shows the gain that will result from pressure maintenance by water injection. The calculated performance of an average 80-acre five-spot flood pattern is shown.

In this study, the extreme northwest extension of the field (north of Section 15, T-31-N, R-17-W) was not included.

CONCLUSIONS

The following conclusions are drawn from this study:

1. Primary oil recovery will be small--being approximately 12.3% of the oil in-place or 95 barrels per acre-foot.
2. Primary producing rates are beginning to decline. The rate of decline will increase sharply by the end of 1960.
3. Waterflooding will increase ultimate recovery to 51% of the total oil in-place or to 392 barrels per acre-foot.
4. An adequate source of water for flooding is probably available from the Dakota formation.

RECOMMENDATIONS

1. Waterflood operations should be started immediately in the field.
2. The operators should work out a cooperative plan for location of injection and producing wells.

DISCUSSION

FIELD BACKGROUND

Location

The Horseshoe-Gallup Field is located in San Juan County, New Mexico, approximately twenty miles west and about eight miles north of the town of Farmington, New Mexico.

Discovery

The field was discovered June 22, 1957 by the Arizona Explorations, Inc., Horseshoe Canyon "B" #1 well located in the NW/4 NW/4, Section 3, Township 30 North, Range 16 West, San Juan County, New Mexico. This well was drilled to a total depth of 1780' and had an initial potential of 120 BPD of 42° gravity oil.

Geology

The Horseshoe-Gallup Field is located in the southwestern part of the San Juan Basin. The oil reservoir trends northwest and southeast and is a stratigraphic trap approximately thirteen miles long and up to three miles wide. The Lower Gallup sandstone formation ranges in depth from about 800 feet at its northwestern end to about 5200 feet at the southeastern end. A structure map contoured on the Gallup sandstone (except for the extreme northwest end of the field) is shown on Page 1 of the Tables and Figures Section of this report. Its productive interval is composed of two sand sections known as the Upper and Lower Tocito. These sands are shown on longitudinal cross section A-A', page 2. The trace of this cross section is shown on the structure map. The average net thickness of the combined Upper and Lower Tocito is 17.8 feet and the average porosity is 16.1%. The two sands are continuous, however, the Upper Tocito changes into a shale in the northwestern part of the field and is not present as a pay zone. On the other hand, the Lower Tocito is not as wide, laterally, as the Upper Tocito.

RESERVOIR PROPERTIES

Summary

The following table lists average reservoir properties of the Tocito zones in the Horseshoe-Gallup Field determined from available geological, core, and PVT data:

Porosity (%)	16.1
Permeability, [redacted] (md.) Liquid	82
Connate Water (%)	32.4
Initial Pressure (psig at +4175 datum)	215
Saturation Pressure (psig at +4175')	215
Reservoir Temperature (°F)	87
Area (developed acres)	10,200
Spacing (acres/well)	40
Number of wells (Aug. 1959)	234
Average Net Pay (Lower plus Upper Tocito) (ft.)	17.8
Original Oil in-place (bbls/ac.ft.)	770

Core Data

Analyses run on diamond cores taken in 45 wells were available. Thirty of these wells were on Atlantic's Navajo "A" and "B" leases. There were 398 core samples from the Upper Tocito whose permeability was 1 md. or greater. From the Lower Tocito, 345 samples had a permeability of 1 md. or greater. Four hundred and sixty-five Upper Tocito samples and 478 Lower Tocito samples had porosity values of 12% or greater.

The available core data were punched onto IBM cards for sorting, arranging in order of ascending permeability and porosity, and printing. Using permeabilities of 1 md., or above, graphs of air permeability versus per cent of total samples were constructed for the Upper and Lower Tocito, pages 9 and 10. These plots were

divided into five equal groups (based on number of samples) and average permeability determined for each group. With this average permeability and Atlantic's restored-state data, an average water saturation was determined for each of the five groups.

Porosity distribution curves (pages 13 and 14) were drawn in the same manner as the permeability distribution curves but using porosities of 12%, or above. The 12% porosity value corresponds approximately to 1 md. permeability. These plots were also divided into five equal groups based on number of samples and average porosity determined for each of the groups. With each group's respective average porosity and water saturation, an effective oil porosity was calculated for each group. This effective porosity versus per cent of total number of samples is shown on pages 15 and 16.

From the effective porosity distribution curves, the average effective oil porosity--porosity x (1 - connate water saturation)--of the Upper and Lower Tocito was determined to be 10.8% and 11.0%, respectively.

Fluid Properties

Atlantic obtained a bottom hole fluid sample from their Navajo #5 well on August 13, 1959. In order to obtain a sample representative of both the Upper and Lower Tocito zones, it was collected above the Upper zone at which point the pressure in the well bore was 150 pounds. The PVT study was run showing a 150# psi saturation pressure; however, to make this data compatible with actual reservoir conditions, the curves were extrapolated to 215 psi, the initial reservoir pressure. The formation volume factor, gas solubility, gas conversion factor, and oil viscosity versus pressure plots are shown as pages 5, 6, 7, and 8. The fluid properties are summarized on page 4.

Relative Permeability

Atlantic's Chemical Engineering Laboratory ran k_g/k_o curves on nine selected plugs from the Upper and Lower Tocito whose permeability corresponded to each of the five sample groups discussed in the Core Data Section. These curves were then

combined at equal flowing gas-oil ratios or at equal k_g/k_o's. The curves for the Upper and Lower Tocito were so similar that only one curve was drawn. The average k_g/k_o versus effective oil saturation curve is shown on page 18. Pages 19 through 27 are the individual k_g/k_o curves plotted versus oil saturation. Page 17 is a relative permeability data summary.

PRIMARY PERFORMANCE

Since the field is limited around practically all its perimeter by lack of porous producing formation, solution gas drive will be the predominant producing mechanism. No water-oil contact has yet been found and, if one exists, it will not contribute to recovery in any significant degree. With the average relative permeability curve and the PVT data previously described, a solution gas drive performance calculation was run using the IBM 650 computer. The results of this calculation are shown on page 29. Under natural depletion, 12.3% of the initial oil in-place will be recovered to a 35 psig reservoir abandonment pressure, which corresponds to an economic limit of about 3 BOPD. This results in 95 barrels per acre-foot recovery by primary means out of 770 barrels per acre-foot originally in place.

Productivity index decline calculations were also run on the IBM 650 computer, the results of which are shown on page 31. Using these P.I. decline results, the field's future producing rates were predicted and are shown on page 30. This curve shows that the rate will decline slowly until late in 1960, after which the rate will drop rapidly.

Past performance of the Horseshoe-Gallup oil pool is shown on page 32. Development drilling is nearly complete with the limits of the pool almost completely defined.

WATERFLOOD PERFORMANCE

Approach

Examination of the core properties previously discussed shows a wide variation in permeabilities and porosities in the Upper and Lower Tocito sands which will cause the waterflood front to advance in a non-uniform manner. In order to calculate quantitatively the advance of the flood front, we have treated the reservoir as a system of parallel, separate, uniform layers each of which have different permeabilities, porosities, and residual oil values. The procedure involves the following steps:

(1) The core properties (permeability and porosity) were arranged in ascending order as shown on pages 9, 10, 13, and 14.

(2) The reservoir was arbitrarily divided into five layers of uniform thickness. Core properties were assigned to these layers according to the per cent incidence shown on the above mentioned figures.

(3) Performances based on the core properties were calculated and averaged to obtain an average performance of each layer.

(4) The total reservoir performance was determined by summing the average behavior of individual layer performances.

Several assumptions were made to facilitate this calculation. These are that (1) the reservoir is repressured and is operating under a constant pressure drop from injection wells to producing wells, (2) there is no cross-flow between layers, and (3) there is no flow of oil behind the waterflood front in any of the layers. The last assumption is consistent with laboratory observations of waterflood performance of water wet reservoirs. Based on the laboratory flooding tests of fresh cores taken from the Horseshoe-Gallup Field, it was concluded that the reservoir is water wet. Page 28 presents the results of the fresh core waterfloods.

Flood Pattern

The choice of the flooding pattern is dependent on several factors. These are (1) the mobility ratio (this is the mobility of the water divided by the mobility of the oil), (2) the permeability of the reservoir, (3) field oil rate (capacity or allowable control). From the fluid and rock properties, a mobility ratio equal to one was calculated. This means that both water and oil have the same ease of movement in the reservoir. As a result, one injection well can supply enough water to support one producing well. This situation describes a five-spot development.

The second factor which must be examined in choosing a pattern is the permeability of the formation. The higher the permeability, the higher will be the total number of barrels of water that can be injected per day and the higher will be the resulting oil rate. The five-spot pattern gives the maximum throughput rate for a one to one mobility ratio situation. This leads into the third consideration which is the oil rate.

If the Horseshoe-Gallup Field were to be produced at capacity, the optimum pattern to support that rate would be the five-spot. However, in view of the probable restriction of the field oil rate below capacity, a variation from the five-spot pattern can be used in flooding the field. In the center areas of the field where injection capacities are high, fewer injection wells are needed to support the oil rate. In this area a nine-spot pattern (three producing wells per one injection well) or a peripheral type pattern might be used. The edges of the field have lower permeabilities and thicknesses and, here, a five-spot pattern is required to support the oil rate.

Throughput Rate

Throughput rate can be defined as a steady state total rate (oil plus water) which can be produced from a particular well pattern by imposing a given pressure drop. In magnitude, it is equal to the pressure drop across the system divided

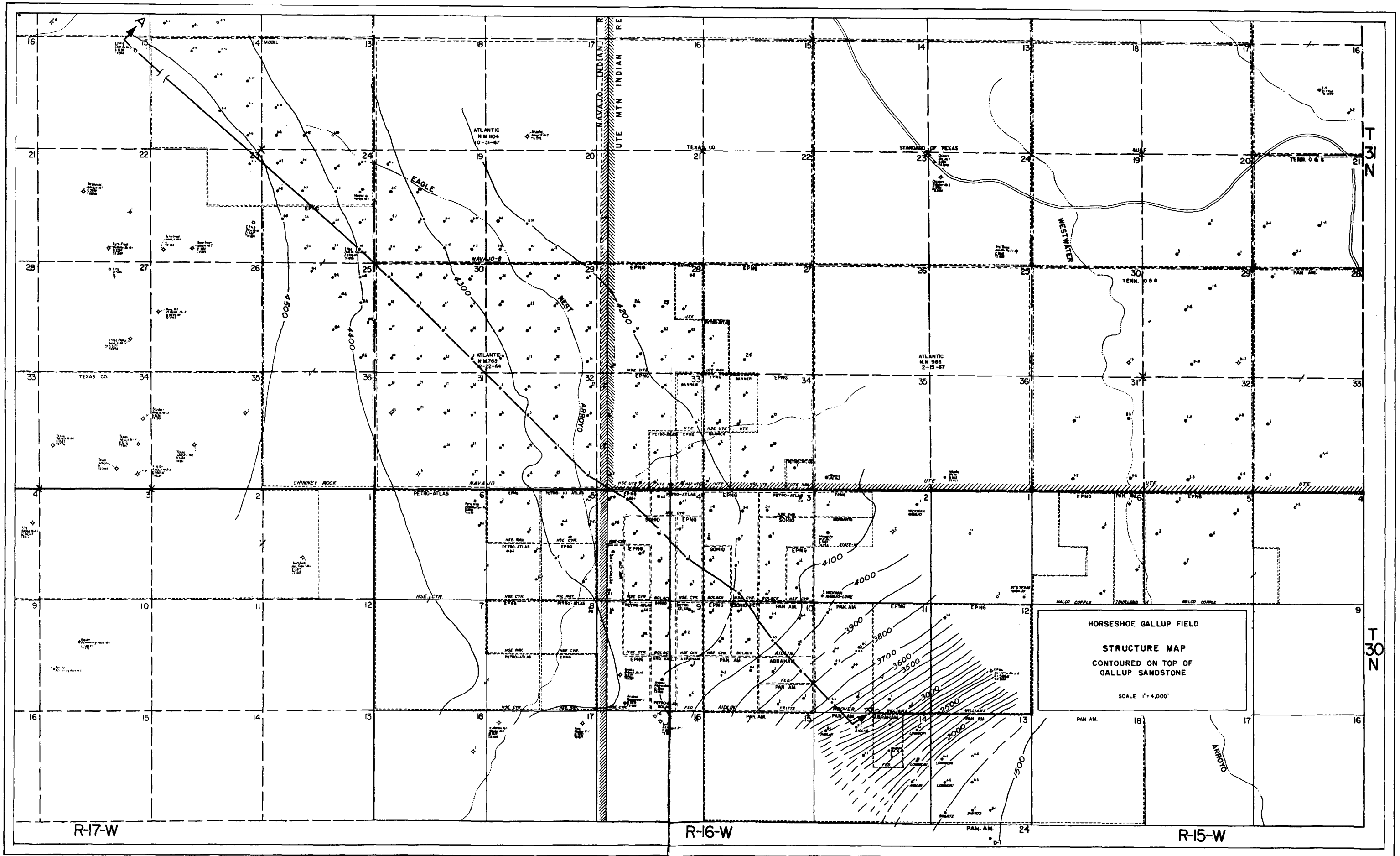
by the total resistance of the system. To determine the maximum capacity rate, a pressure drop of 1180 psi was used based on the assumptions of 1200 psi bottom hole injection pressure (less than formation breakdown) and 20 psi bottom hole producing pressure. Since the mobility of the water is equal to the mobility of the oil, the throughput rate is constant after fill-up. The steady state throughput rate after fill-up was calculated by the use of an equation for the five-spot developed by Morris Muskat.

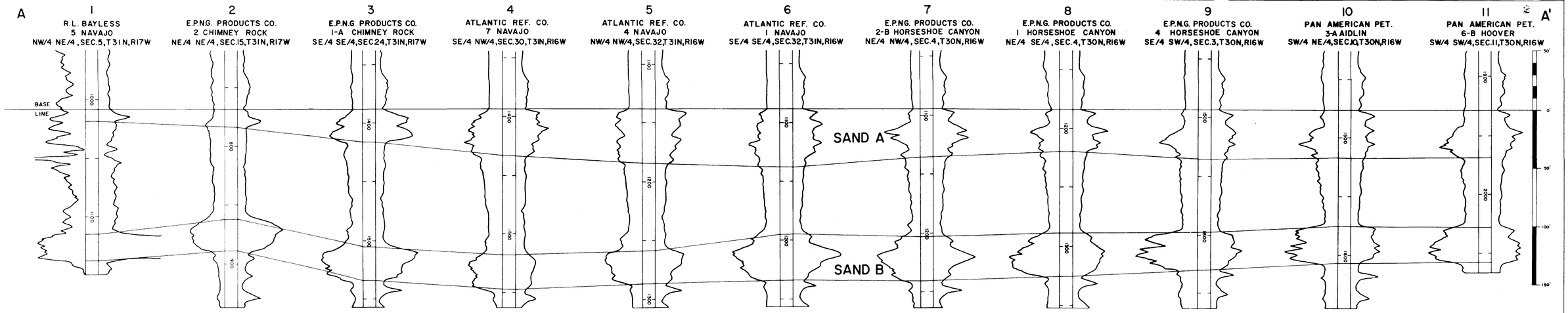
Typical Performance

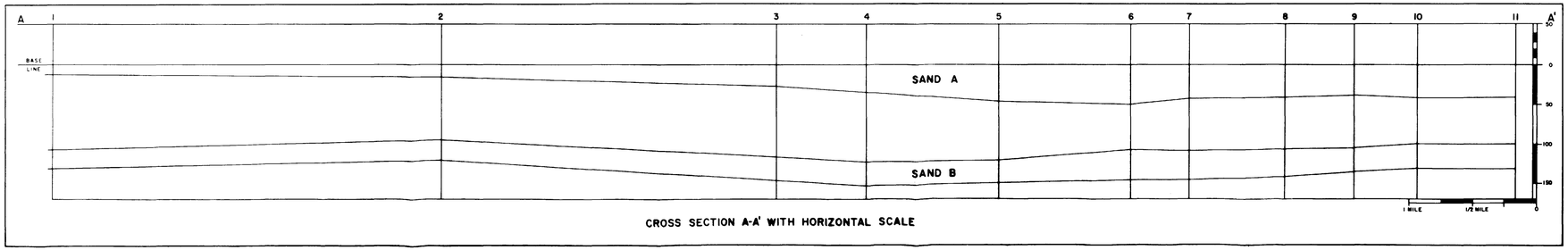
To obtain the over-all performance, the volumes injected and produced were added at a given time to produce the over-all performance. Page 33 shows the performance of a typical five-spot area. The over-all properties of this five-spot are the same as those listed under the section entitled "Reservoir Properties - Summary." The graph on page 33 shows that the typical 80-acre five-spot will produce about 490,000 stock tank barrels of oil in 15 years. In order to produce this amount of oil, 2.3 million barrels of water must be injected, and 1.6 million barrels of water will be produced.

The waterflood results are summarized on page 32. On an acre-foot basis, primary recovery is estimated to be 95 bbl/acre-foot. The total recovery estimated from primary plus waterflood is 392 bbls/acre-foot which amounts to 51% of the initial oil in-place.

Page 30 shows the results of the five-spot flooding performance (which gives approximately the same results as using five-spots in combination with nine-spots) applied to the field as a whole compared to the primary field performance. As shown, the increase in oil rate to 400,000 barrels per month occurs rapidly. By starting the waterflood early in the field life, there is little gas space to fill up (the initial gas saturation is estimated to be 4.8 per cent of the pore volume when flooding operations begin). Our calculations show that the rate of about


NAVAJO INDIAN RE
UTE MTN INDIAN
EAGLE
WEST
ARROYO
WESTWATER
CHIMNEY ROCK
NAVAJO
HSE. CYN.
ATLANTIC N M 1104 10-31-67
ATLANTIC N.M. 765 12-22-64
ATLANTIC N.M. 986 2-15-67
TEXAS CO.
MOBIL
STANDARD OF TEXAS
GULF
TENN. G & E
EPNG
SOHIO
PETRO-ATLAS
PAN AM.
UTE
BARNES
ABRAHAM
AIDLIN
HORSESHOE GALLUP FIELD
STRUCTURE MAP
CONTOURED ON TOP OF GALLUP SANDSTONE
SCALE 1"= 4,000'
4500
4400
4300
4200
4100
4000
3900
3800
3700
3600
3500
3000
2500
2000
1500
T 31 N
T 30 N
R-17-W
R-16-W
R-15-W





CROSS SECTION A-A' WITH HORIZONTAL SCALE

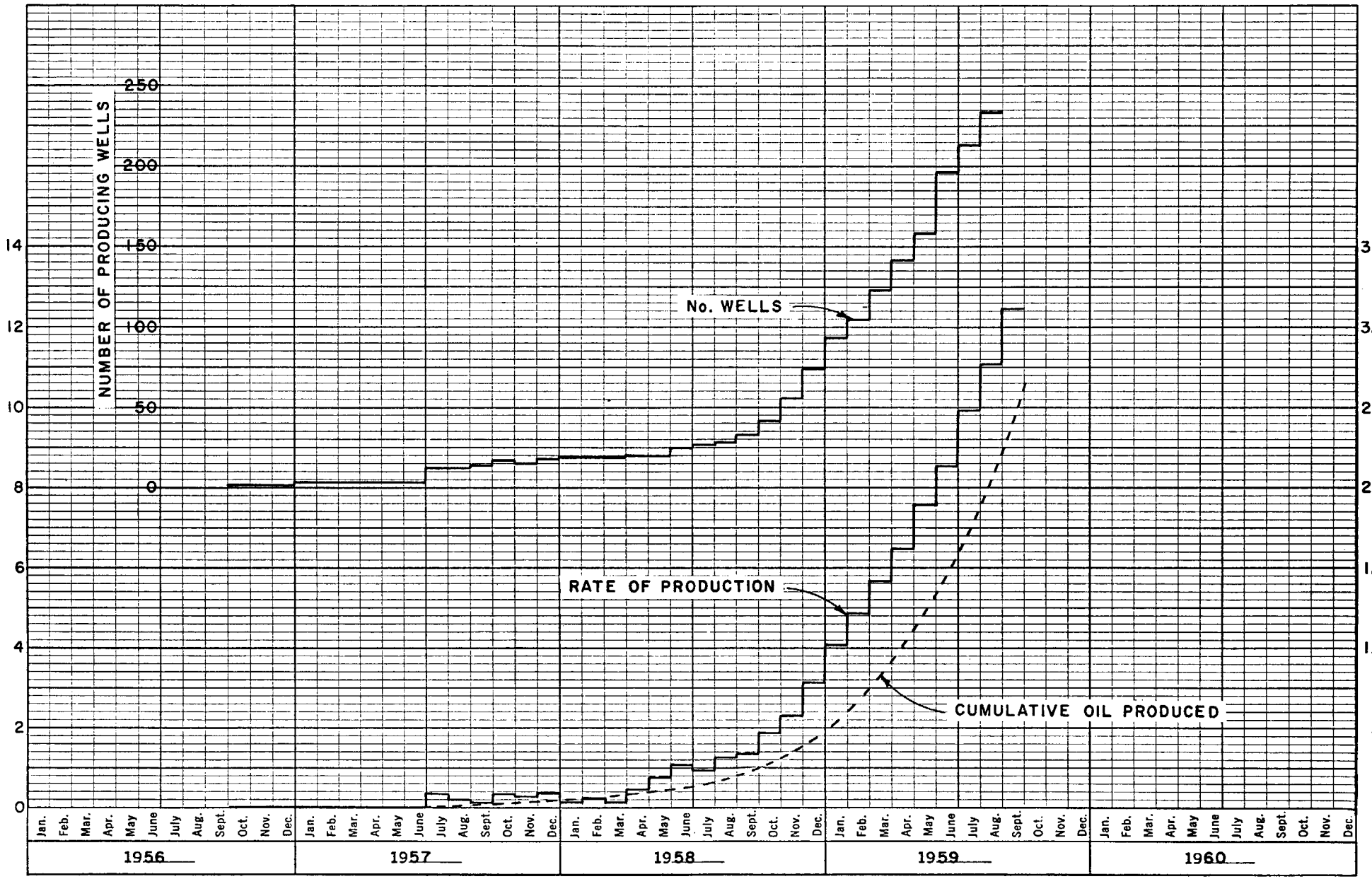
LONGITUDINAL CROSS-SECTION A–A'

(REPRODUCED FROM EL PASO EXHIBIT NO. 5, CASE NO. 1596, PRESENTED TO N.M.O.C.C. FEB. 4, 1959)

HORSESHOE GALLUP FIELD

SAN JUAN COUNTY, NEW MEXICO

PERFORMANCE HISTORY
HORSESHOE GALLUP OIL FIELD
UPPER AND LOWER TOCITO



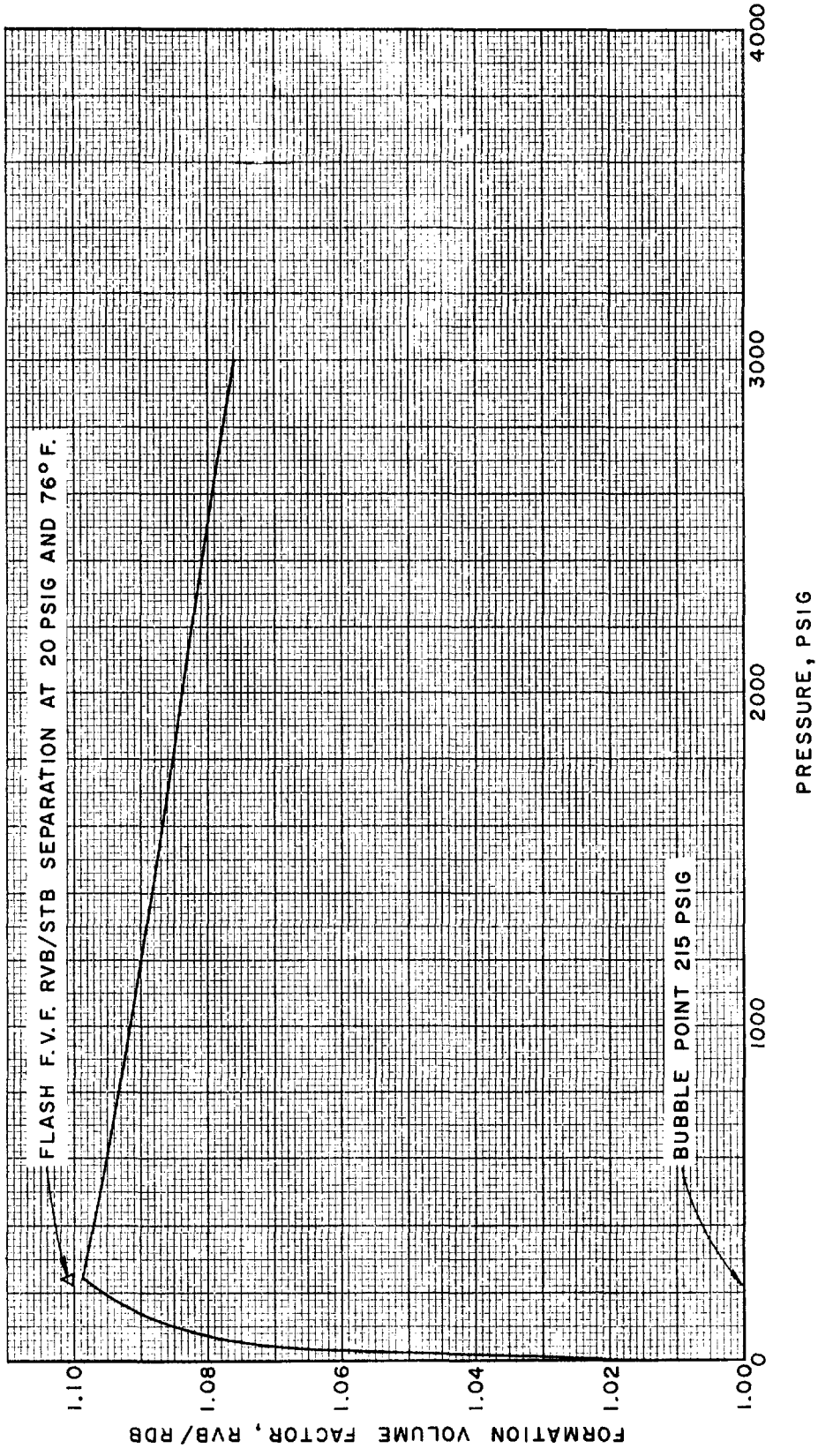
HORSESHOE-GALLUP FIELD

SUMMARY OF FLUID PROPERTIES

Original Reservoir Pressure	215 psig at +4175 datum
Saturation Pressure	215 psig at + 4175 datum
Reservoir Temperature	87 °F
Solution Gas-Oil Ratio	147 SCF/STB
Formation Volume Factor at 215 psig	1.10 rvb/STB
Crude Oil Gravity at 60 °F	42 °API
Oil Viscosity at 215 psig and 87 °F	1.63 cp.
Water Viscosity at 87 °F	0.88 cp.
Oil Compressibility at 87 °F	7×10^{-6} vol/vol/psi slightly above bubble point
	4.6×10^{-3} vol/vol/psi slightly below bubble point

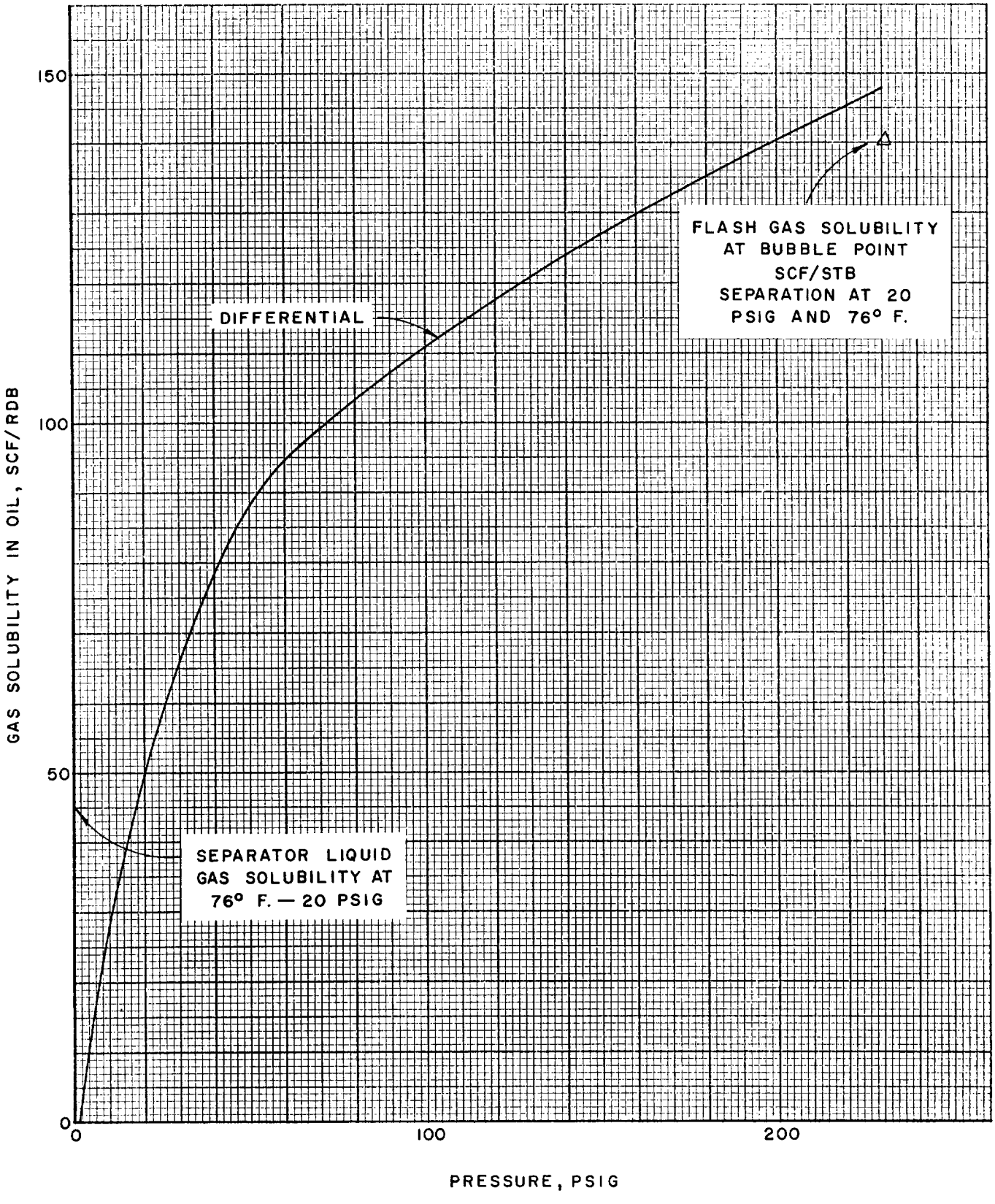
FORMATION VOLUME FACTORS

NAVAJO Nº 5 WELL
GALLUP SAND
HORSESHOE – GALLUP FIELD
SAN JUAN COUNTY, NEW MEXICO



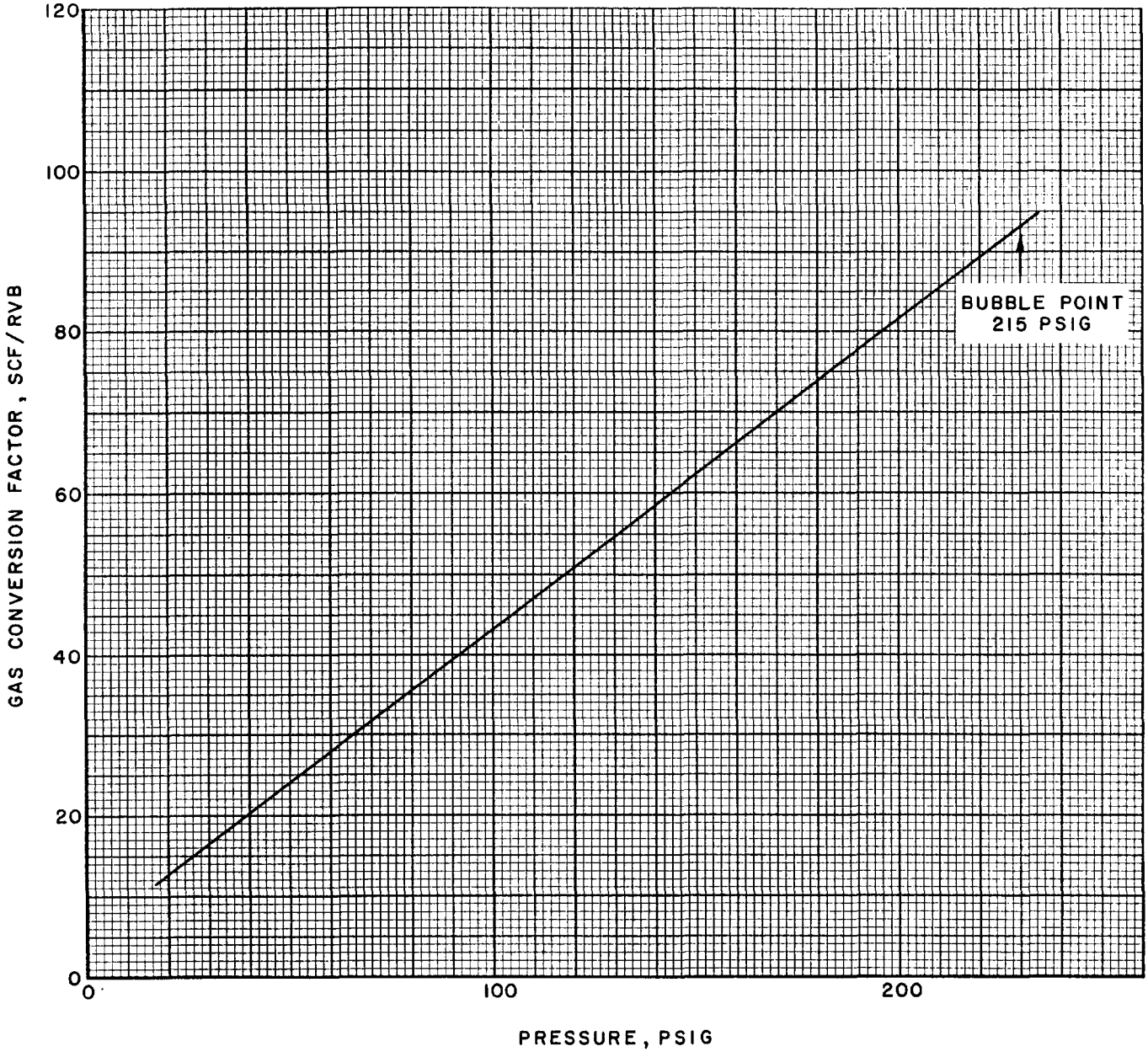
TOTAL SOLUTION GAS SOLUBILITIES AND GAS SOLUBILITY IN SEPARATOR LIQUID

NAVAJO Nº 5 WELL
GALLUP SAND
HORSESHOE — GALLUP FIELD
SAN JUAN COUNTY, NEW MEXICO



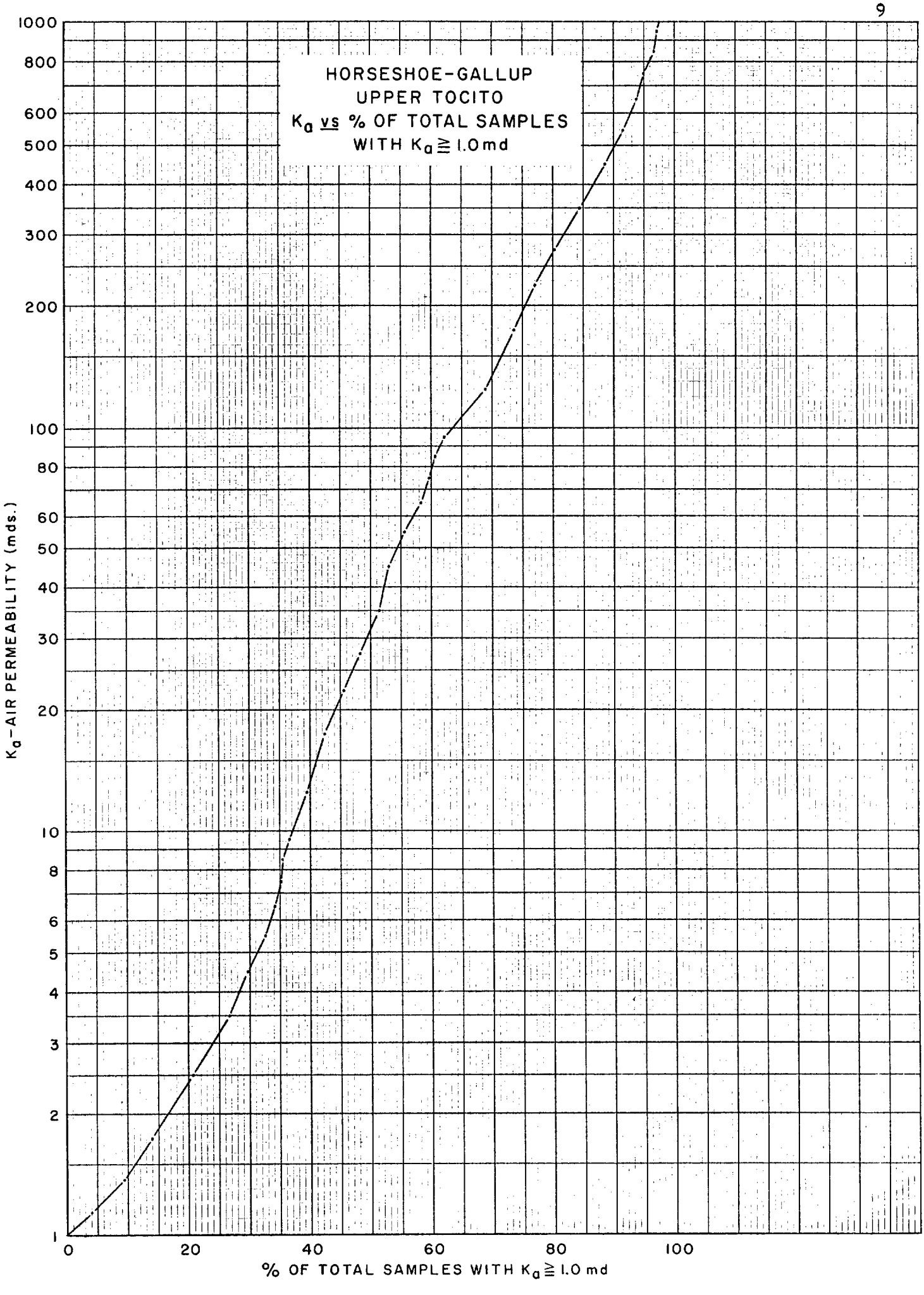
GAS CONVERSION FACTOR

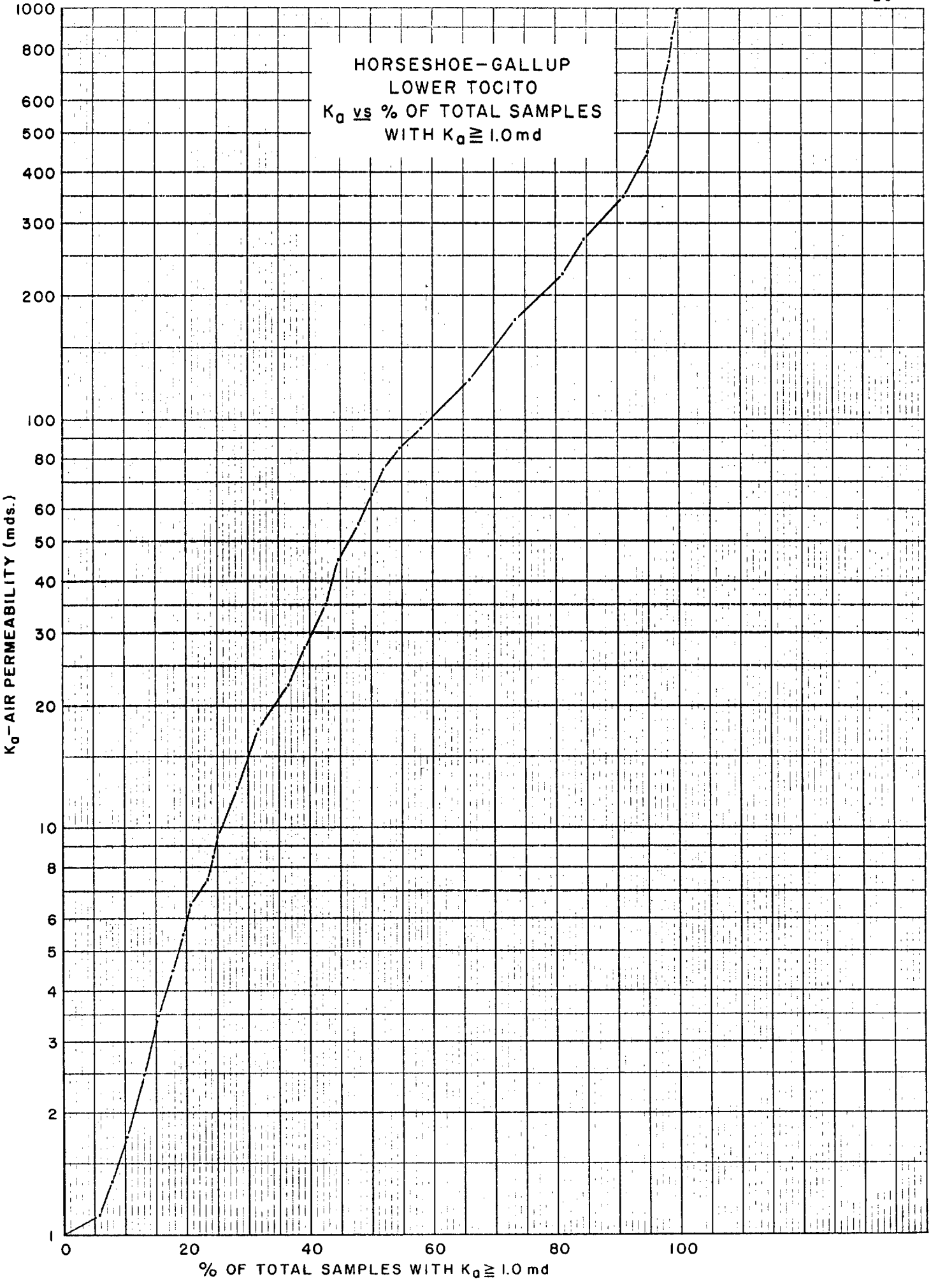
NAVAJO Nº 5 WELL
GALLUP SAND
HORSESHOE – GALLUP FIELD
SAN JUAN COUNTY, NEW MEXICO

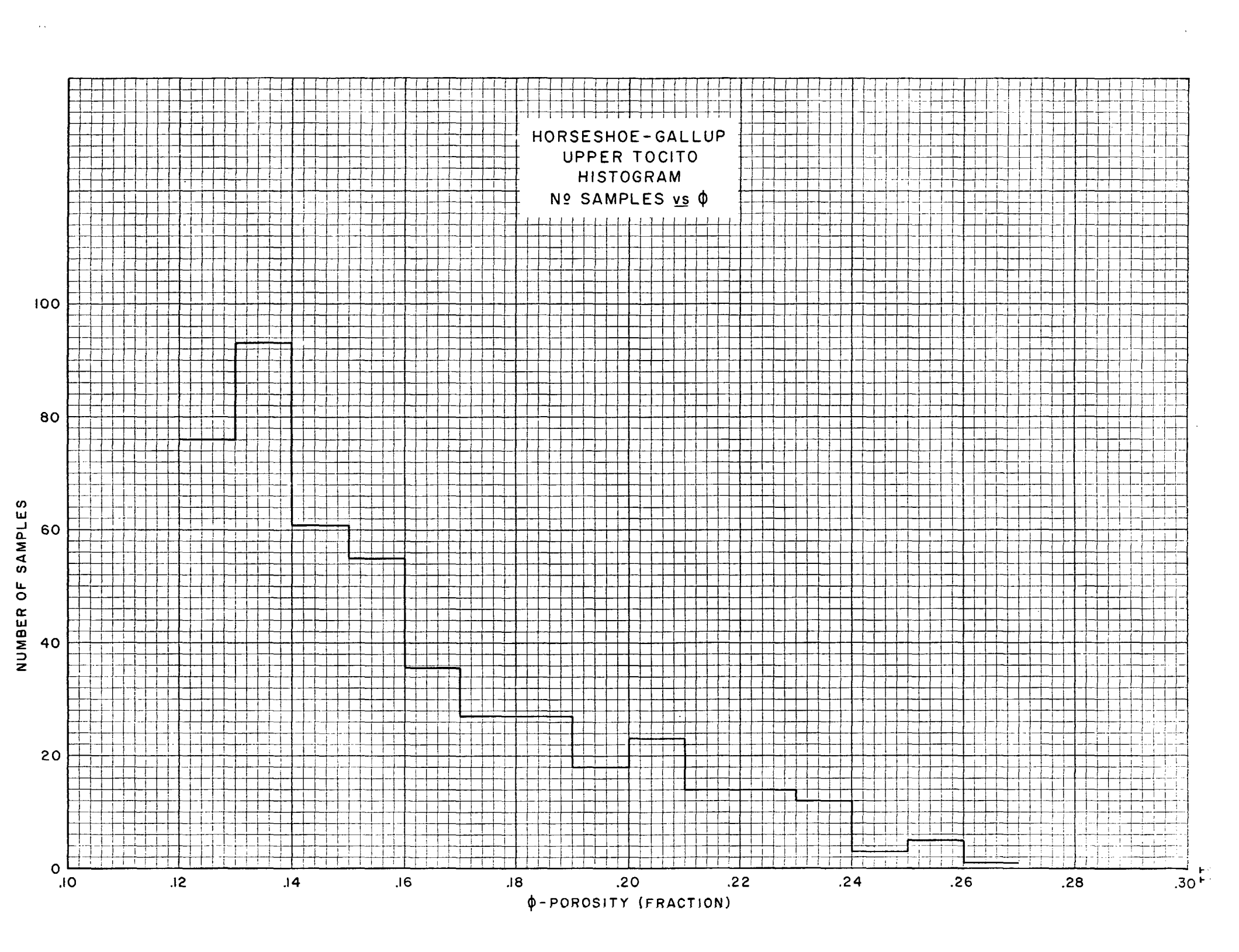


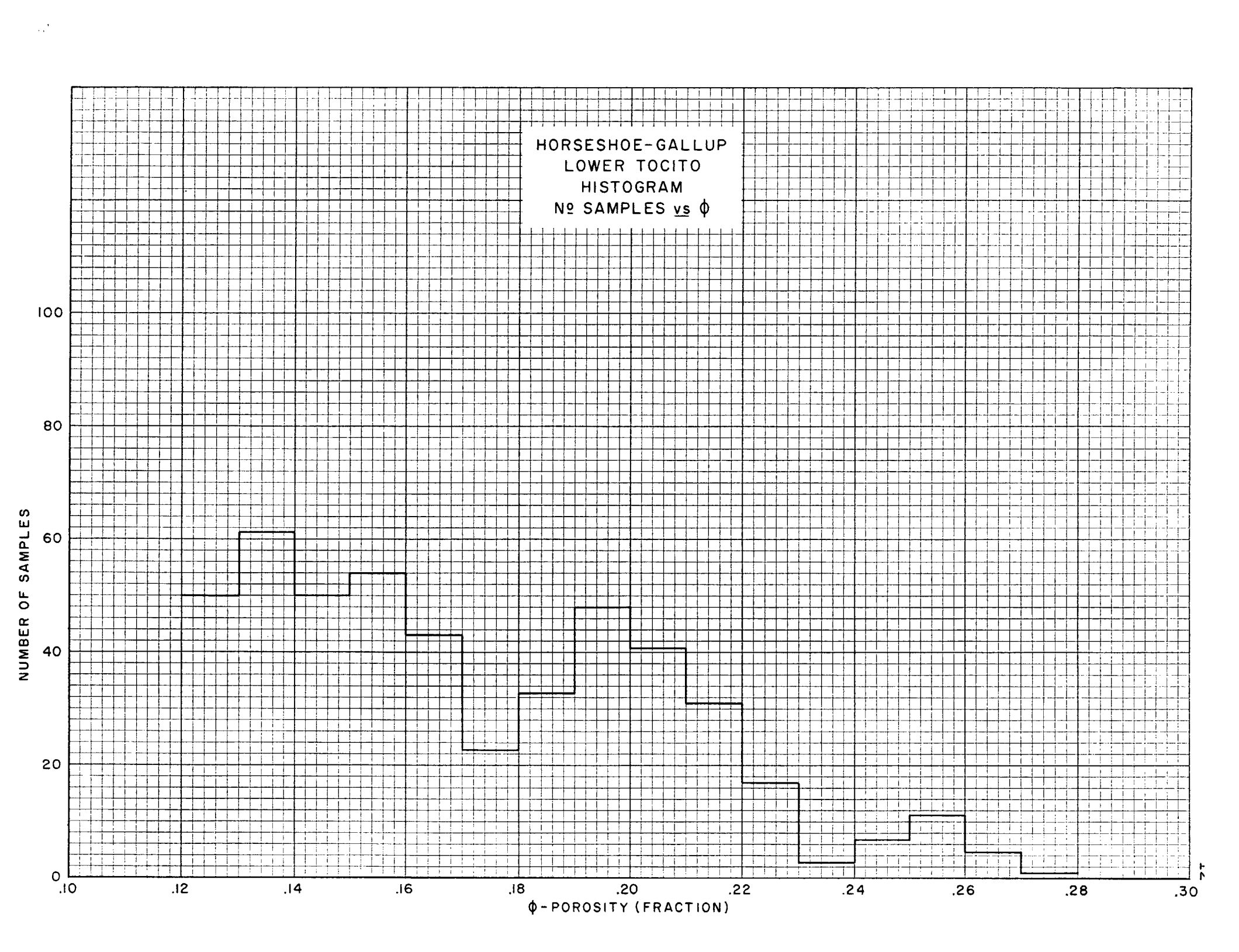
OIL VISCOSITY

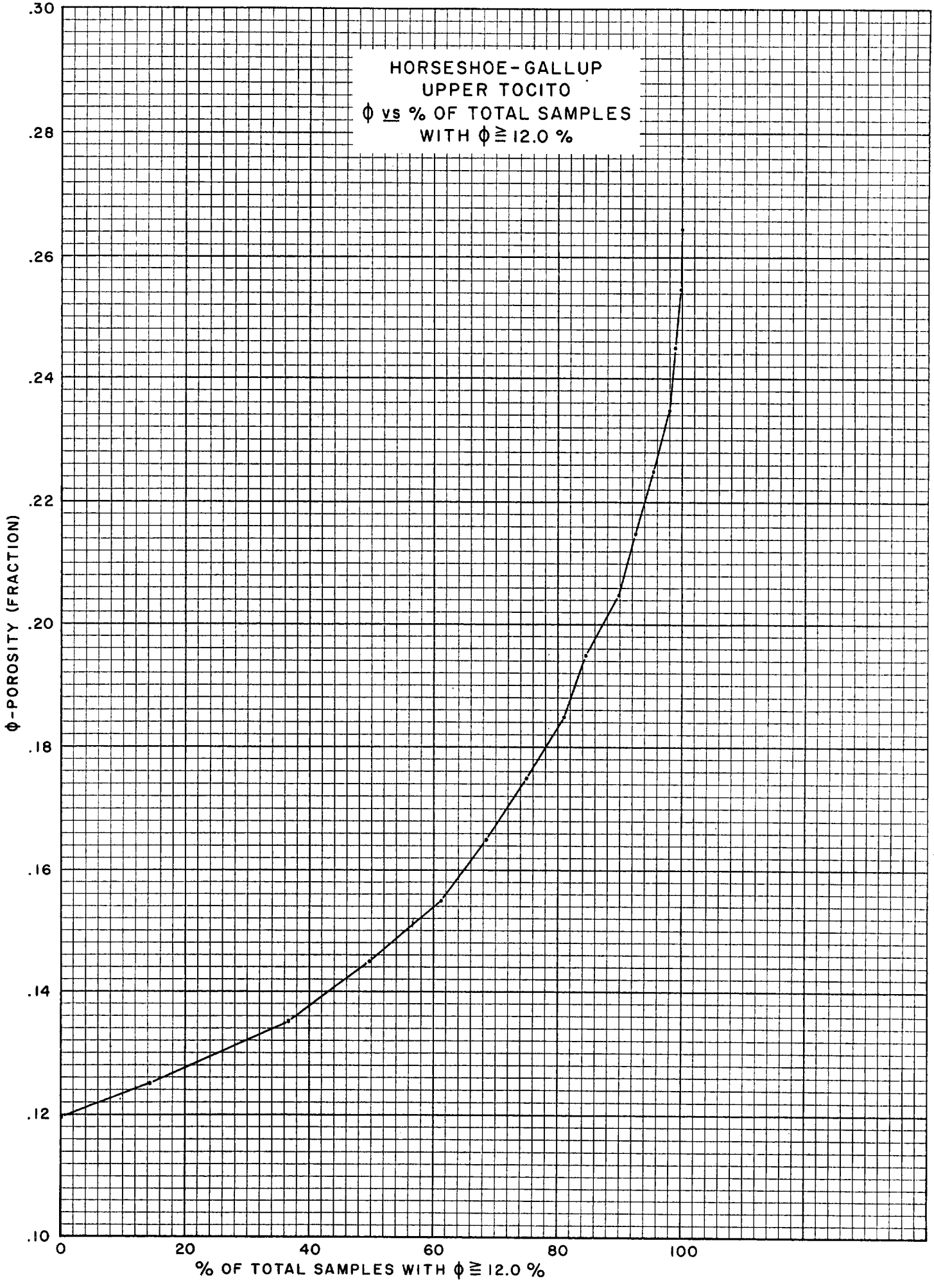
NAVAJO Nº 5 WELL
GALLUP SAND
HORSESHOE – GALLUP FIELD
SAN JUAN COUNTY, NEW MEXICO

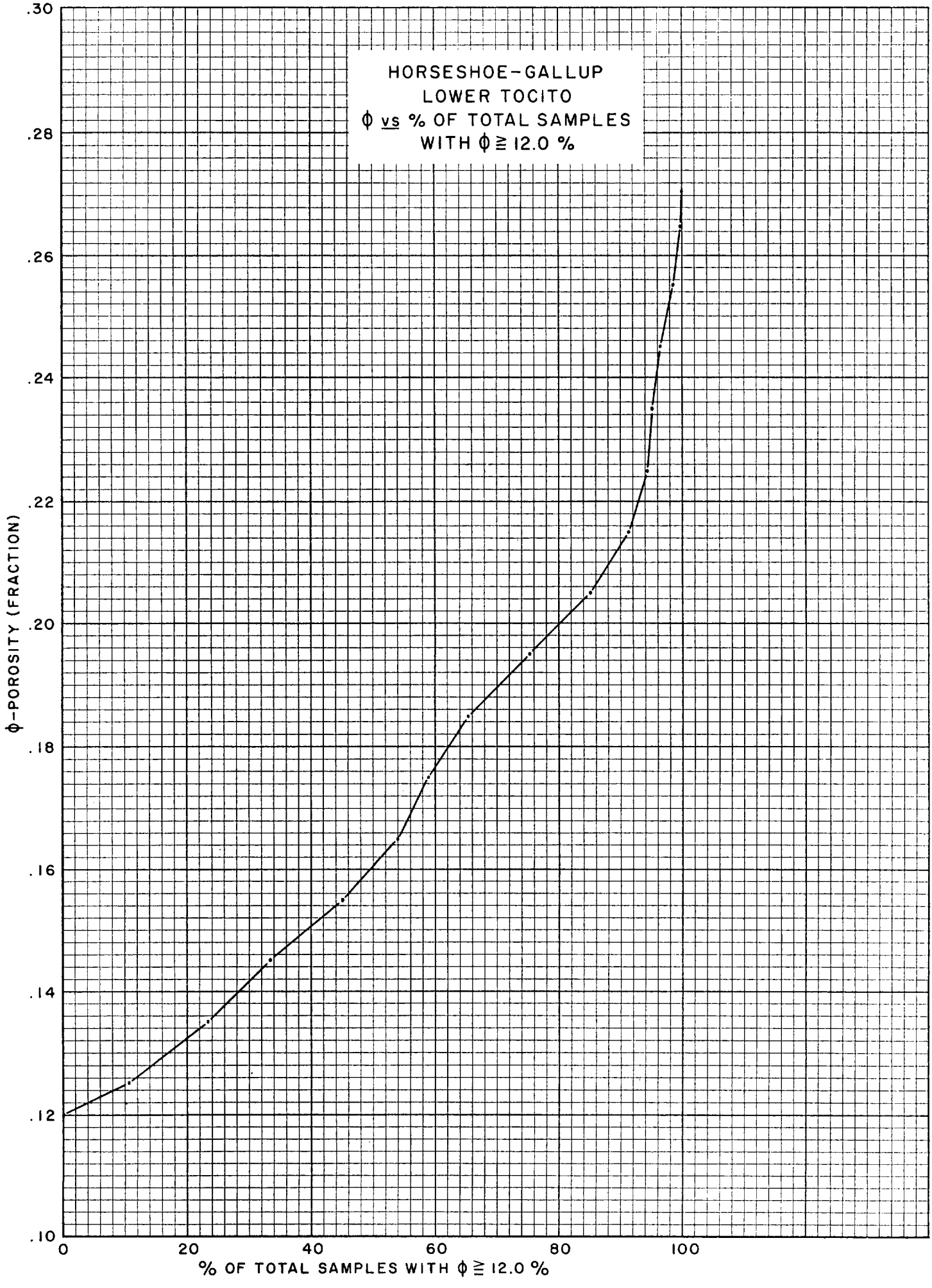

HORSESHOE-GALLUP
UPPER TOCITO
K_a vs % OF TOTAL SAMPLES
WITH $K_a \geqq 1.0$ md
K_a-AIR PERMEABILITY (mds.)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0
20
40
60
80
100
% OF TOTAL SAMPLES WITH $K_a \geqq 1.0$ md

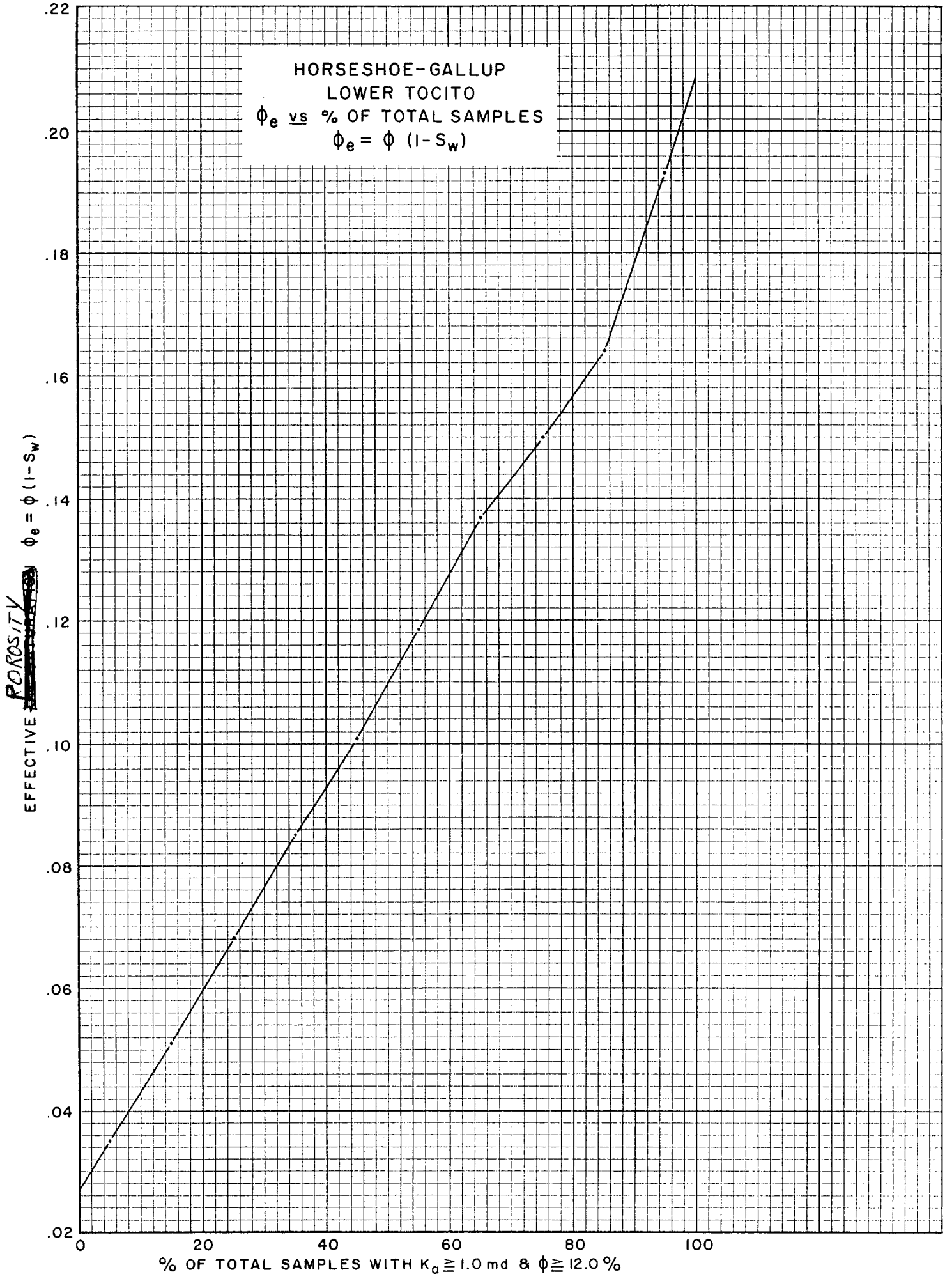

HORSESHOE-GALLUP
LOWER TOCITO
K_a vs % OF TOTAL SAMPLES
WITH $K_a \geq 1.0$ md
K_a-AIR PERMEABILITY (mds.)
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
0
20
40
60
80
100
% OF TOTAL SAMPLES WITH $K_a \geq 1.0$ md

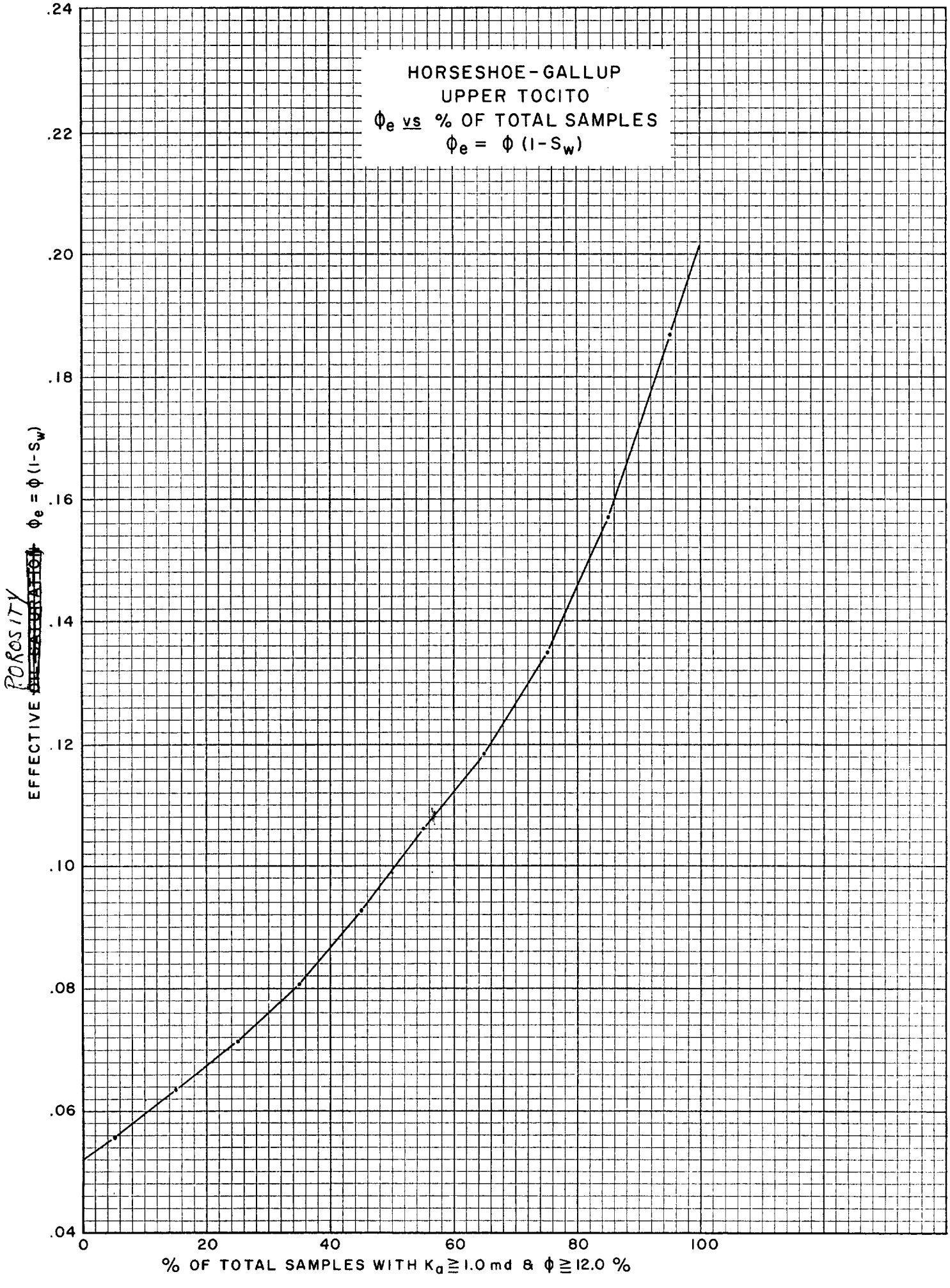

HORSESHOE-GALLUP
UPPER TOCITO
HISTOGRAM
Nº SAMPLES vs ϕ
NUMBER OF SAMPLES
0
20
40
60
80
100
.10
.12
.14
.16
.18
.20
.22
.24
.26
.28
.30
ϕ-POROSITY (FRACTION)


HORSESHOE-GALLUP
LOWER TOCITO
HISTOGRAM
Nº SAMPLES vs ϕ
NUMBER OF SAMPLES
0
20
40
60
80
100
.10
.12
.14
.16
.18
.20
.22
.24
.26
.28
.30
ϕ - POROSITY (FRACTION)


HORSESHOE-GALLUP
UPPER TOCITO
φ vs % OF TOTAL SAMPLES
WITH φ ≧ 12.0 %
φ-POROSITY (FRACTION)
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
0
20
40
60
80
100
% OF TOTAL SAMPLES WITH φ ≧ 12.0 %


HORSESHOE-GALLUP
LOWER TOCITO
φ vs % OF TOTAL SAMPLES
WITH φ ≧ 12.0 %
φ-POROSITY (FRACTION)
.30
.28
.26
.24
.22
.20
.18
.16
.14
.12
.10
0
20
40
60
80
100
% OF TOTAL SAMPLES WITH φ ≧ 12.0 %


HORSESHOE-GALLUP
LOWER TOCITO
ϕ_e vs % OF TOTAL SAMPLES
$\phi_e = \phi\ (1-S_w)$
EFFECTIVE POROSITY $\phi_e = \phi\ (1-S_w)$
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
.02
0
20
40
60
80
100
% OF TOTAL SAMPLES WITH $K_a \geqq 1.0$ md & $\phi \geqq 12.0\%$


HORSESHOE-GALLUP
UPPER TOCITO
ϕ_e vs % OF TOTAL SAMPLES
$\phi_e = \phi (1-S_w)$
EFFECTIVE POROSITY $\phi_e = \phi(1-S_w)$
.24
.22
.20
.18
.16
.14
.12
.10
.08
.06
.04
0
20
40
60
80
100
% OF TOTAL SAMPLES WITH $K_a \geqq 1.0$ md & $\phi \geqq 12.0$ %

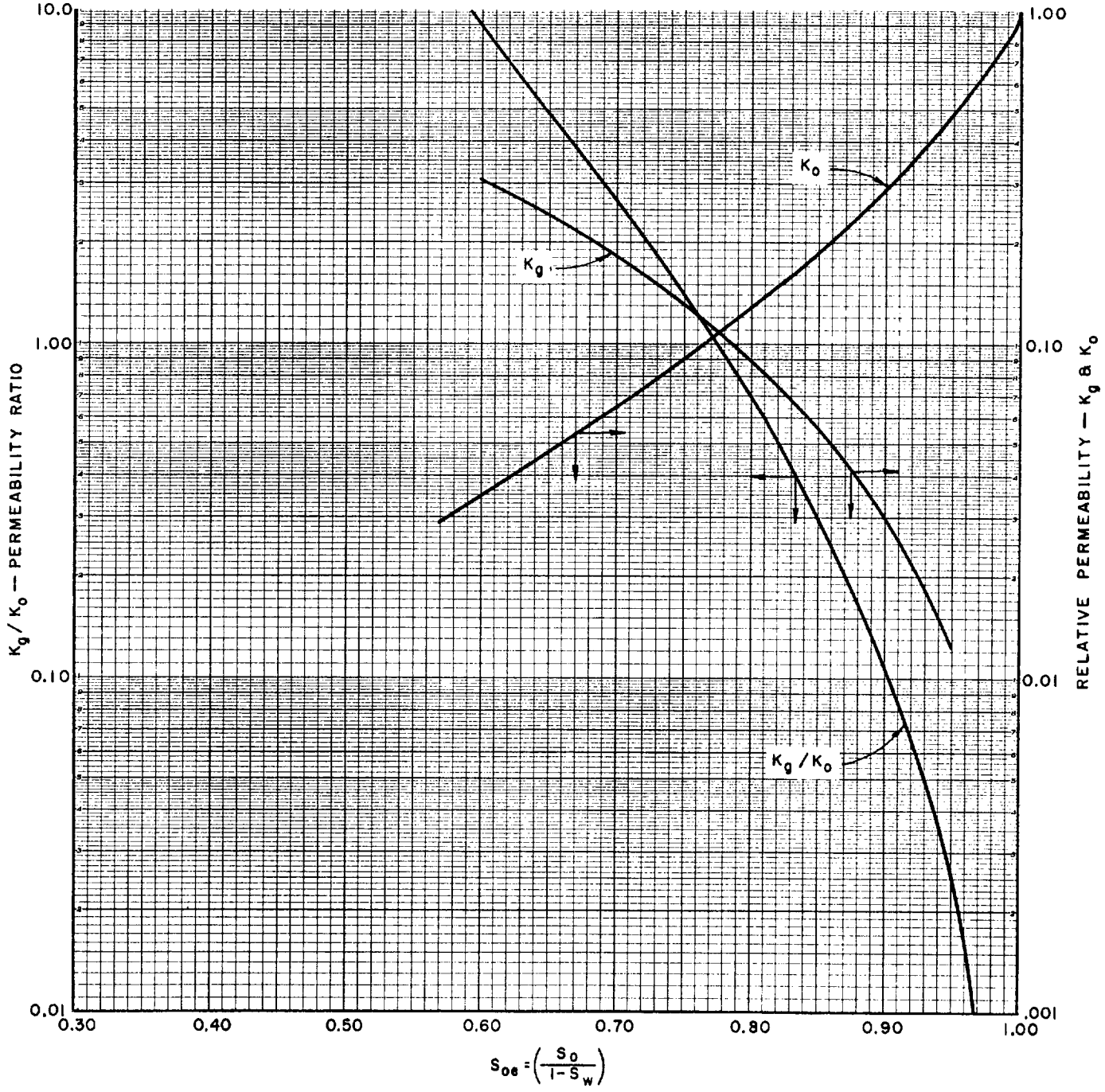
CHEMICAL ENGINEERING GROUP
RELATIVE PERMEABILITY LABORATORY
DATA SUMMARY

STUDY NO. F59-10
DATE: September 18, 1959

SUBJECT: Gas-Oil Relative Permeability
FIELD: Horseshoe-Gallup COUNTY: San Juan STATE: New Mexico

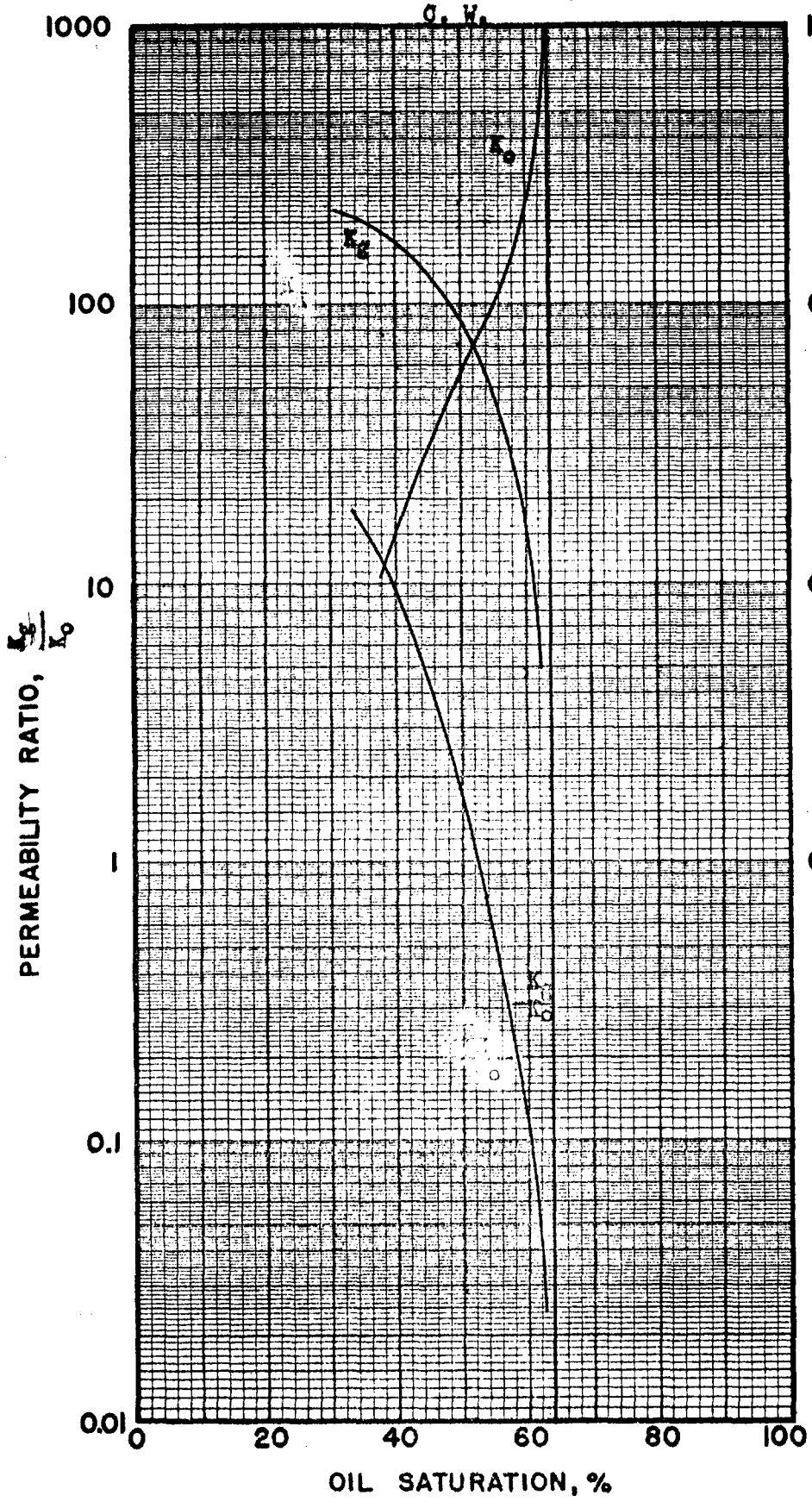
Formation and Well	Depth, Ft.	Permeability, Md. To Air	Permeability, Md. To Oil at Connate Water	Porosity, %	Interstitial Water %, After Displacement By Oil at 200 Psi
UPPER TOCITO					
Navajo #B-3	1295-96	15.0	10.3	9.4	36.7
Navajo #1	1111-12	57.5	33.5	11.6	22.3
Navajo #5	1178-79	296	251	17.2	21.9
Navajo #1	1117-18	725	641	18.9	25.5
LOWER TOCITO					
Navajo #1	1227-28	5.3	1.8	13.9	55.5
Navajo #1	1225-26	28.7	19.8	18.2	42.7
Navajo #1	1205-06	71.3	44.9	17.6	39.6
Navajo #1	1208-09	223	183	20.1	24.0
Navajo #1	1214-15	365	324	21.8	26.5

HORSESHOE GALLUP AVERAGE
RELATIVE PERMEABILITY CURVE
UPPER AND LOWER TOCITO



THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



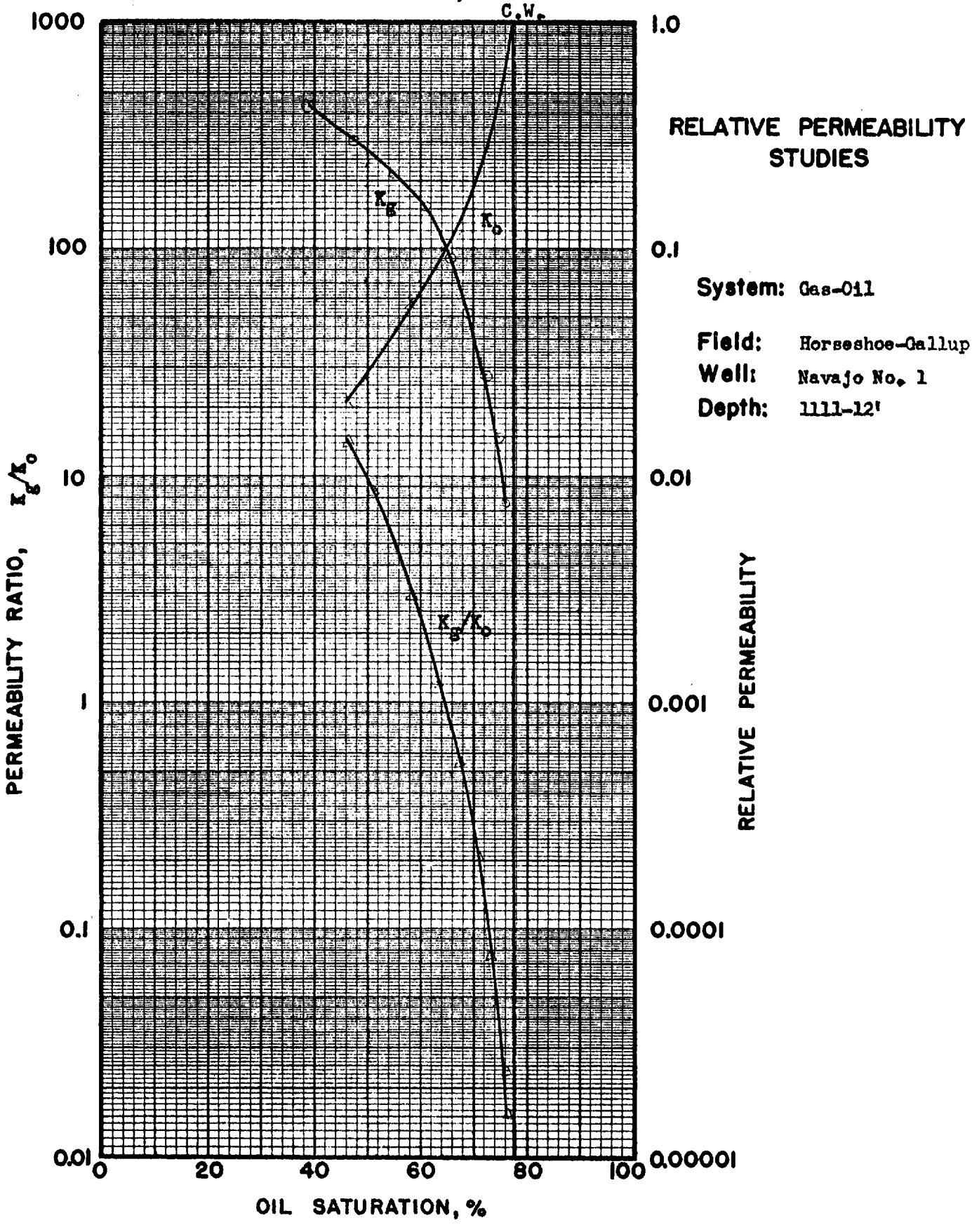
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. B-3
Depth: 1295-96

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



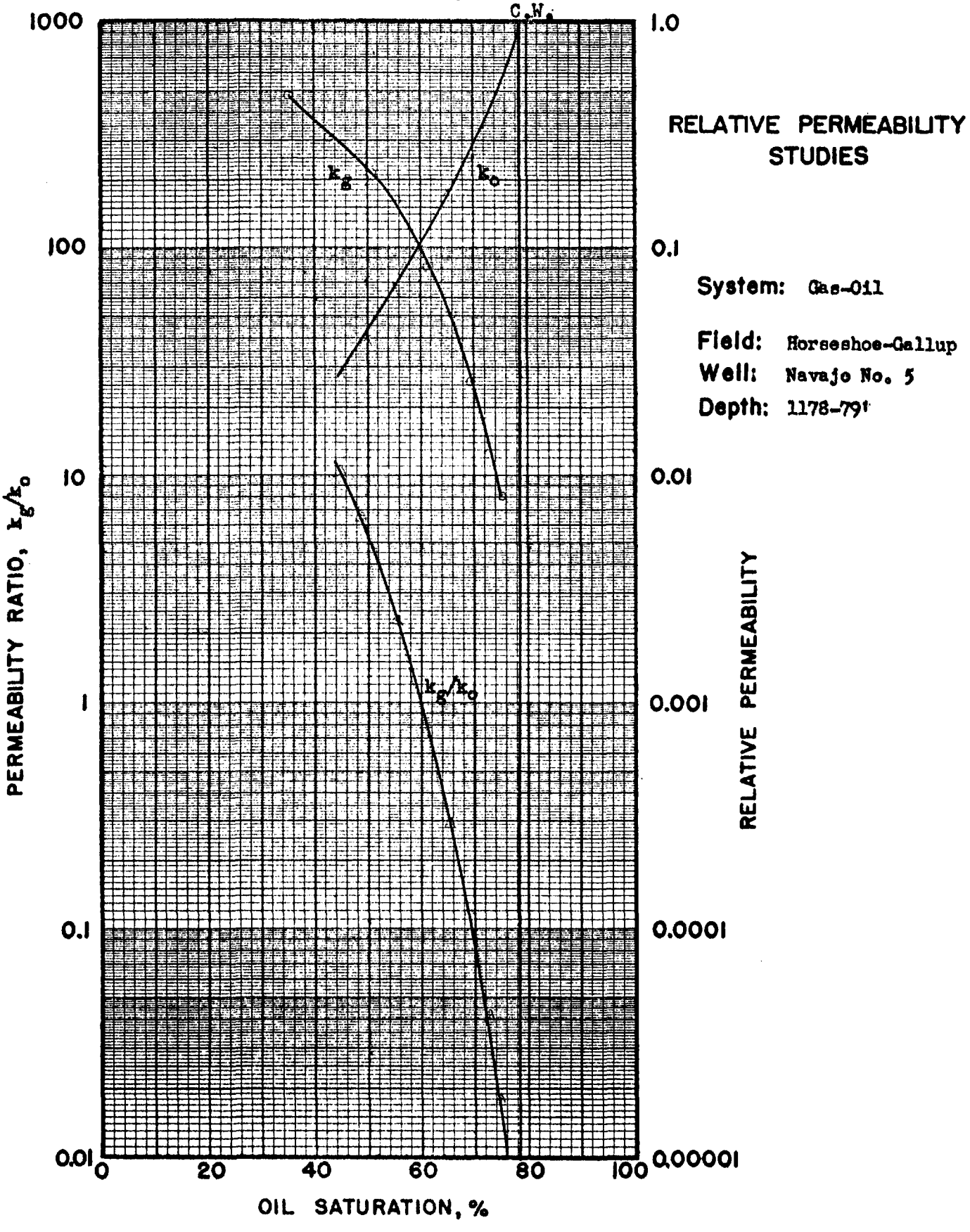
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1111-12'

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



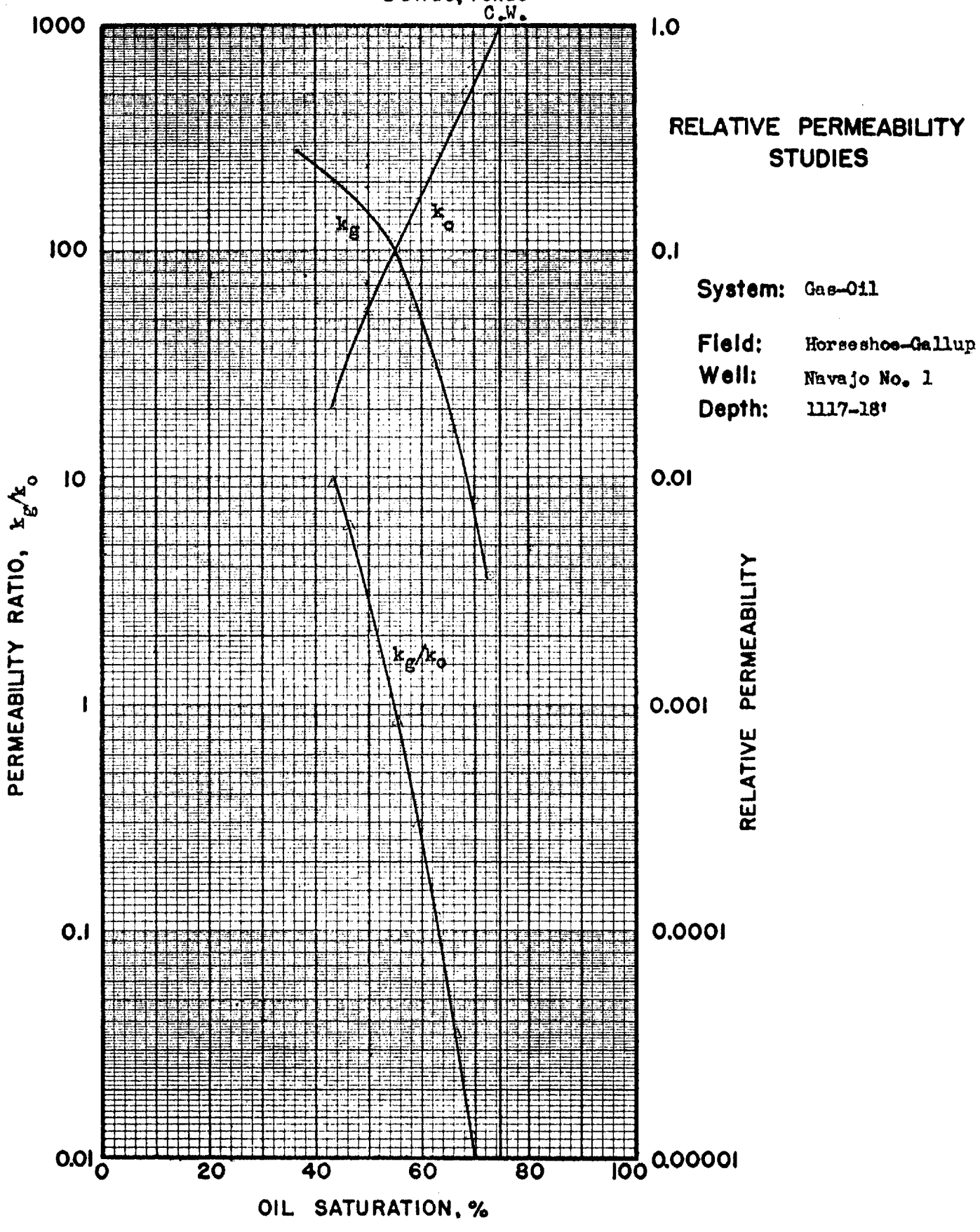
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 5
Depth: 1178-79'

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



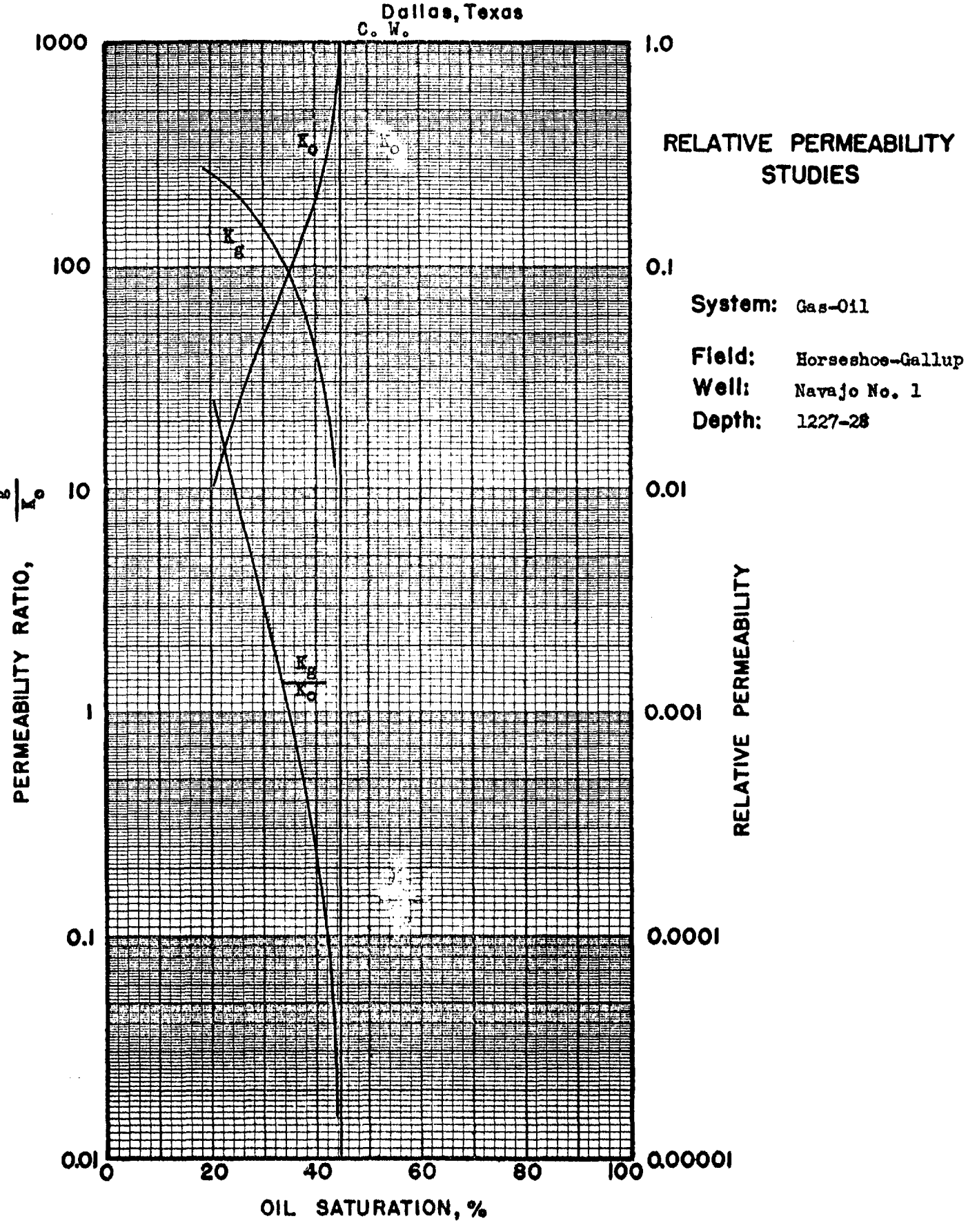
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1117-18'

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



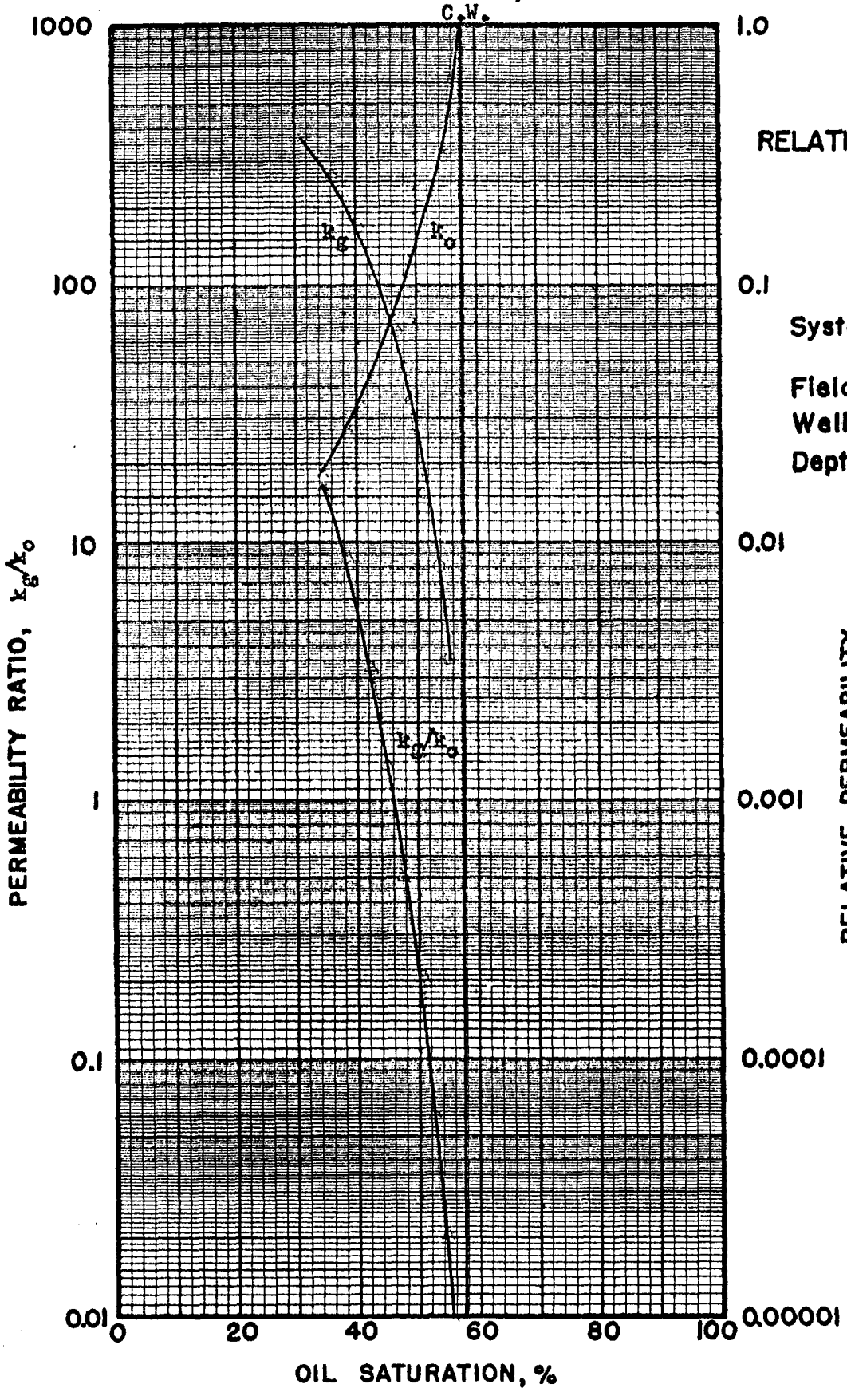
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1227-28

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



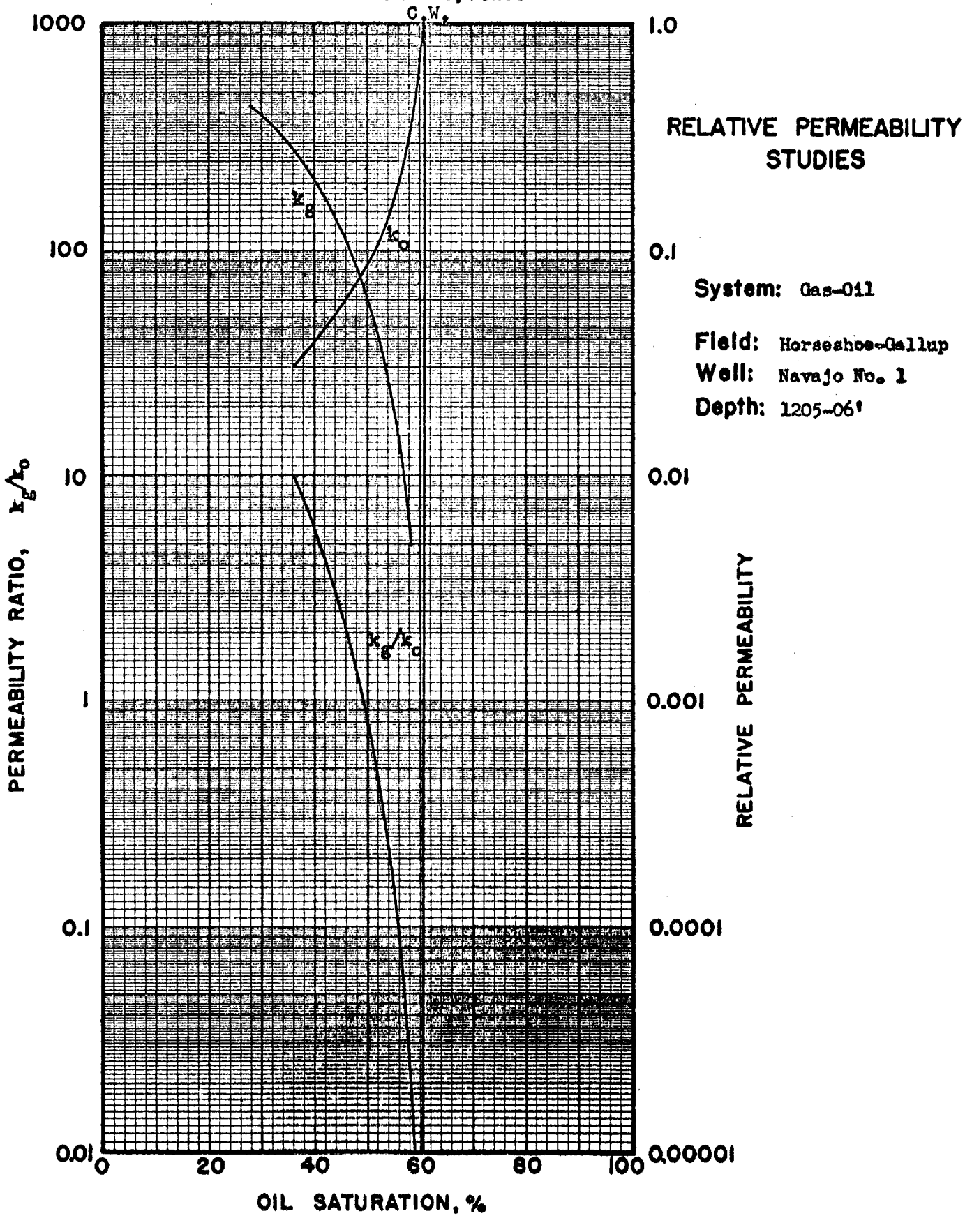
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1225-26'

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



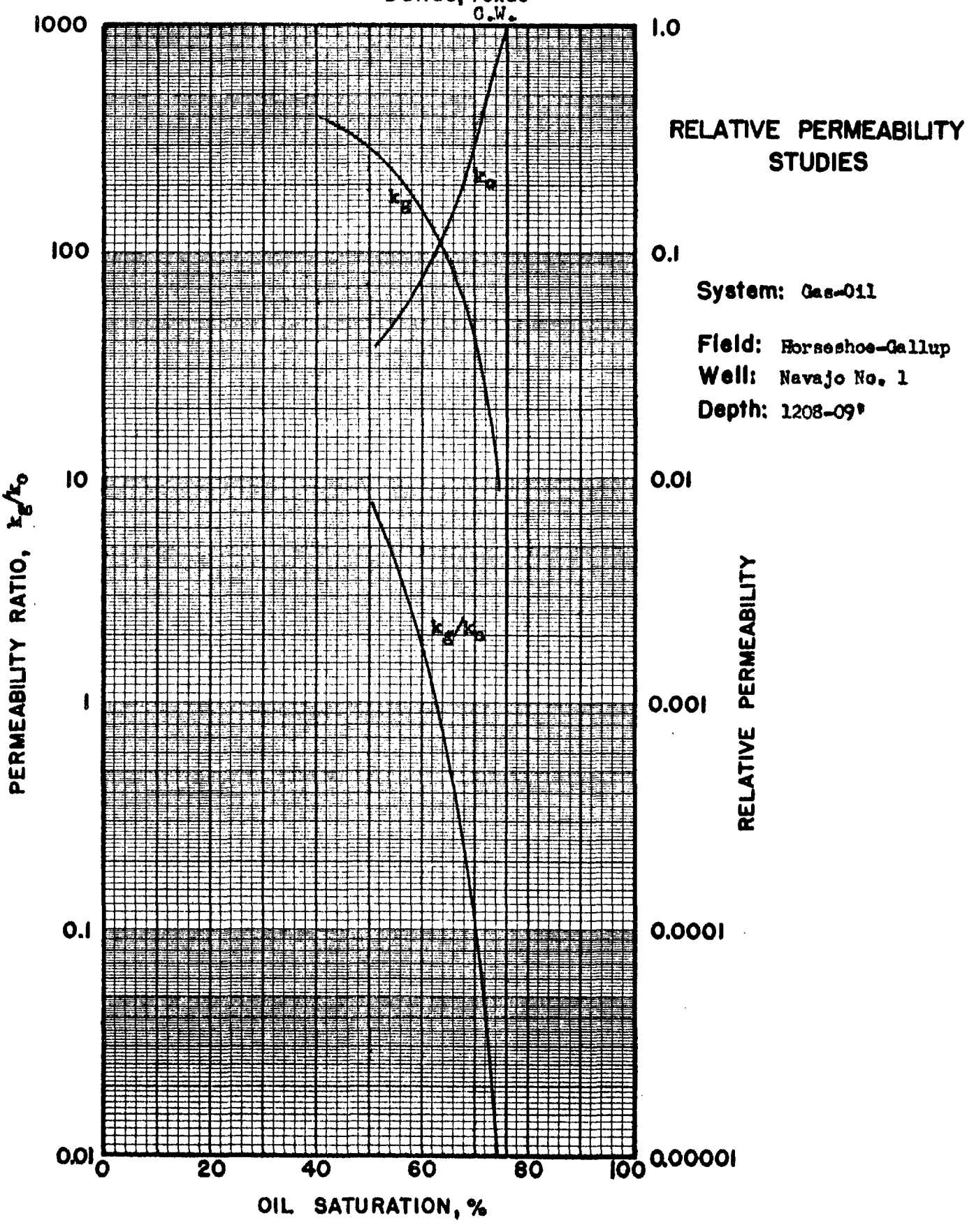
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1205-06'

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



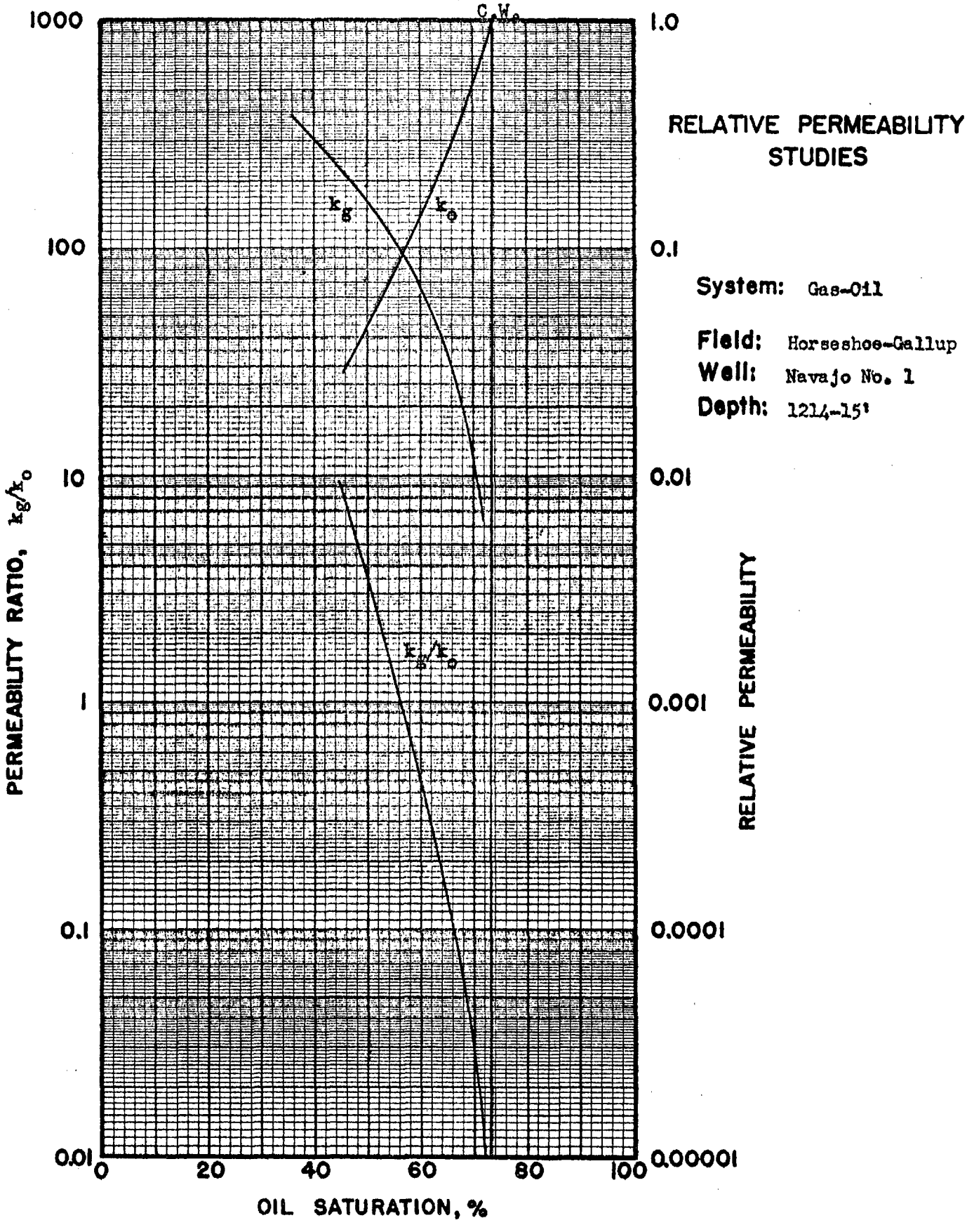
RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1208-09'

THE ATLANTIC REFINING COMPANY

PETROLEUM ENGINEERING SECTION
CHEMICAL ENGINEERING GROUP
Dallas, Texas



RELATIVE PERMEABILITY STUDIES

System: Gas-Oil

Field: Horseshoe-Gallup
Well: Navajo No. 1
Depth: 1214-15'

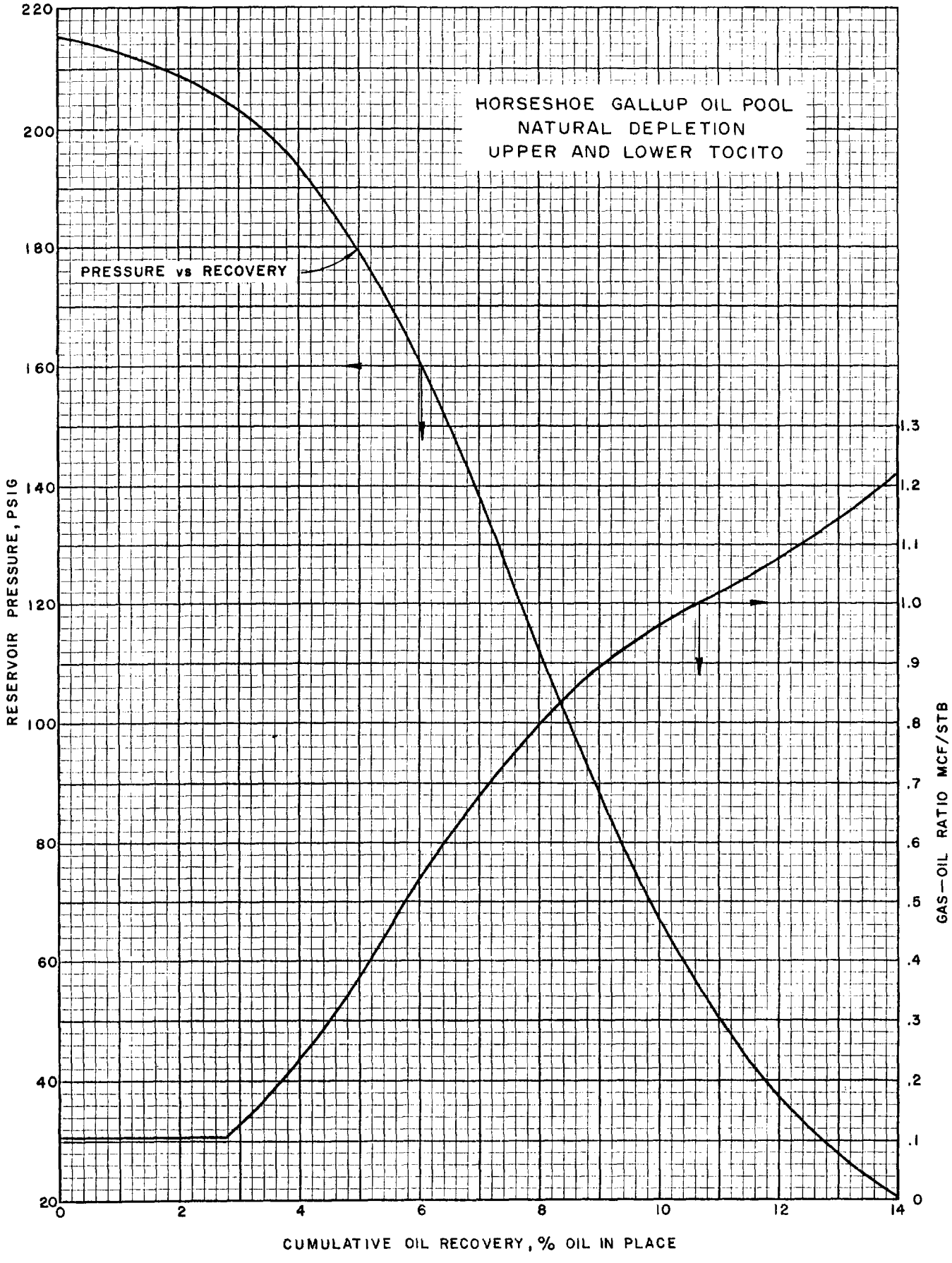
CHEMICAL ENGINEERING GROUP
RESTORED STATE LABORATORY
DATA SUMMARY

SUBJECT: Fresh Core Waterflood Results

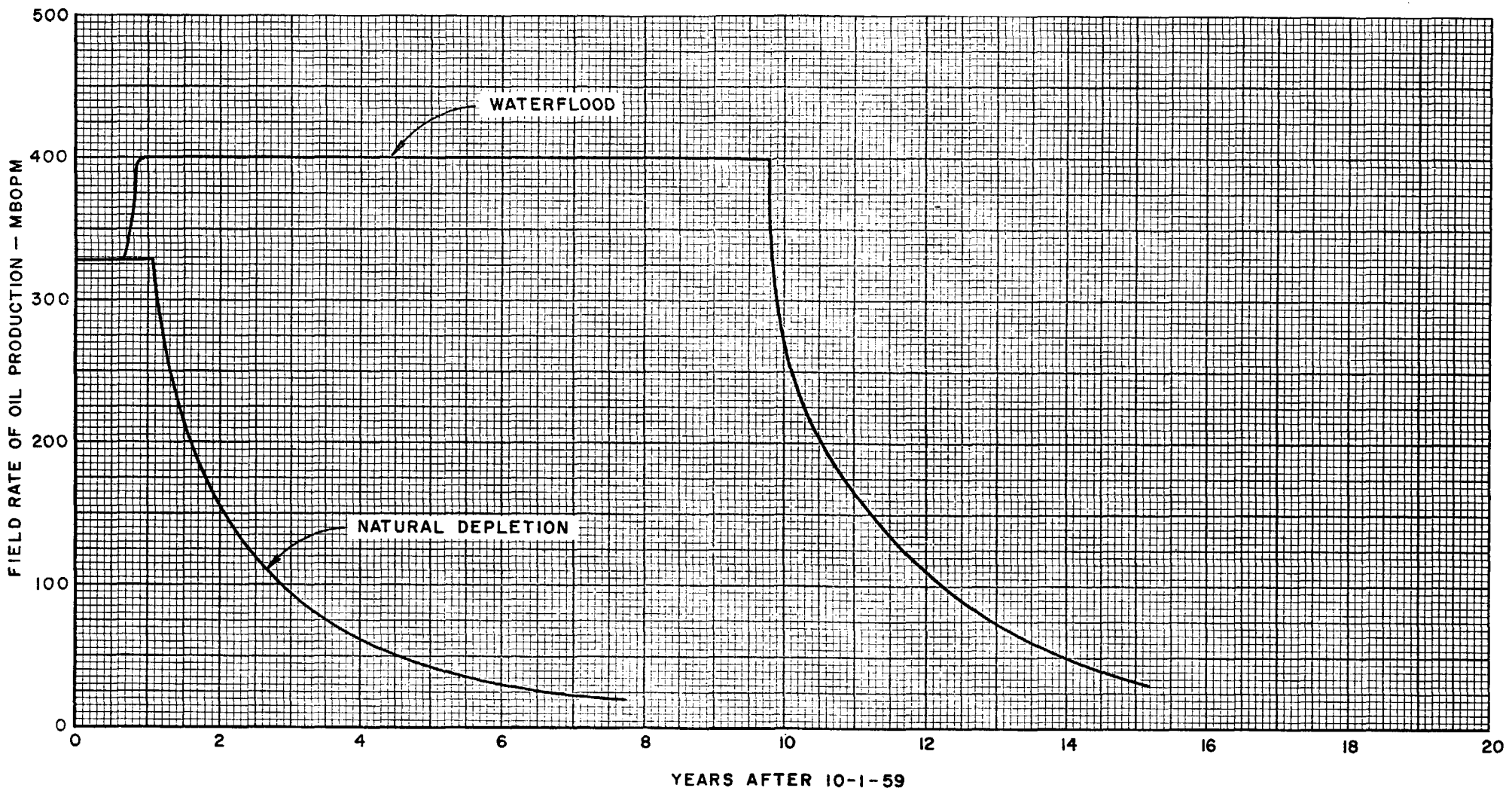
WELL: Navajo #5 STATE: New Mexico
FIELD: Horseshoe Gallup COUNTY: San Juan FORMATION: Tocito (Gallup)

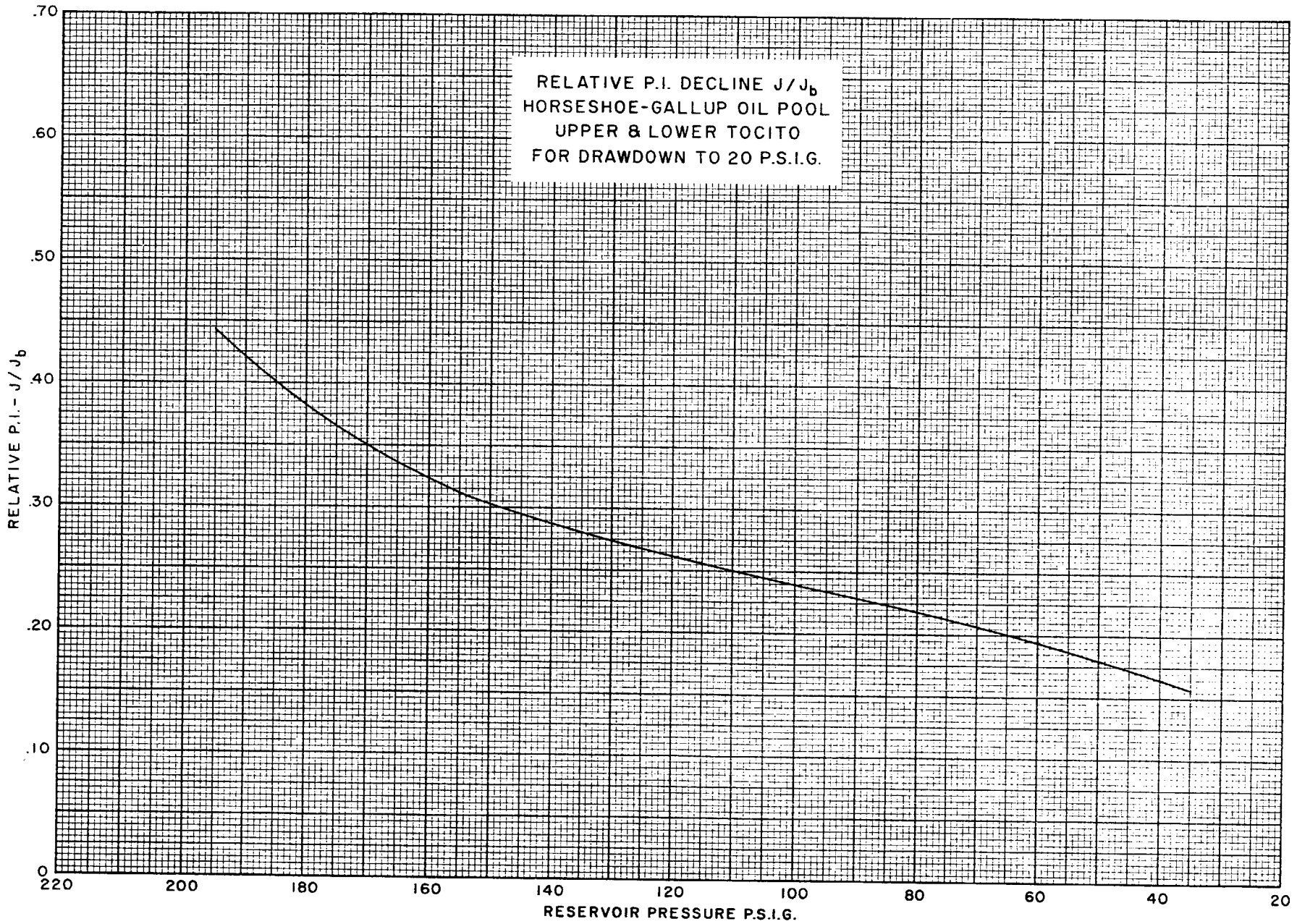
Depth, Ft.	Permeability, md. To Air	To Oil at C.W.	To Brine at R.O.	Porosity, %	Interstitial Water %, After Centrifuge with Oil at 200 psi	Residual Oil to Waterflood % P. V.
Upper Tocito						
1165-66	4.6	2.3	.21	11.3	18.4	51.3
1177-78	1128	795	221	17.9	31.5	22.2
1177-78	287	210	72.3	14.2	40.7	29.7
1195-96	1.1	.33	.02	7.1	26.1	52.2
Lower Tocito						
1282-83	50.8	30.1	14.2	18.5	35.2	26.7
1291-92	87.2	47.5	29.3	20.3	31.7	25.1
1297-98	228	119	66.1	21.0	31.3	18.9
1301	260	163	70.3	22.9	36.4	20.7
1281-82	159	98.3	45.7	20.2	16.1	31.6
1286	133	75.5	34.1	21.0	26.7	23.5
1290-91	170	109	56.1	20.8	25.2	27.9
1296-97	147	76.3	44.2	18.0	34.3	26.5
1302	190	105	50.4	19.9	29.4	23.2

$\gamma_w / \gamma_o = 1.86$


HORSESHOE GALLUP OIL POOL
NATURAL DEPLETION
UPPER AND LOWER TOCITO
PRESSURE vs RECOVERY
RESERVOIR PRESSURE, PSIG
GAS—OIL RATIO MCF/STB
CUMULATIVE OIL RECOVERY, % OIL IN PLACE
220
200
180
160
140
120
100
80
60
40
20
0
2
4
6
8
10
12
14
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0

FIELD OIL RATE vs TIME
FUTURE PRIMARY AND SECONDARY
HORSESHOE GALLUP OIL POOL
UPPER AND LOWER TOCITO




RELATIVE P.I. DECLINE J/Jb
HORSESHOE-GALLUP OIL POOL
UPPER & LOWER TOCITO
FOR DRAWDOWN TO 20 P.S.I.G.
RELATIVE P.I. - J/Jb
.70
.60
.50
.40
.30
.20
.10
0
220
200
180
160
140
120
100
80
60
40
20
RESERVOIR PRESSURE P.S.I.G.

PERFORMANCE SUMMARY

Primary

Estimated Primary Recovery % OIP	12.3%
Primary Recovery, bbl/acre-ft.	95
Estimated Primary Recovery to Start of Waterflood, bbl/acre-ft.	46

Secondary

Average Residual Oil	27.7% of pore volume
Estimated Gas Saturation at Start of Flood	4.8% of pore volume
Conformance Factor	88%
Added Oil Recovery by Waterflood, bbl/acre-ft.	297

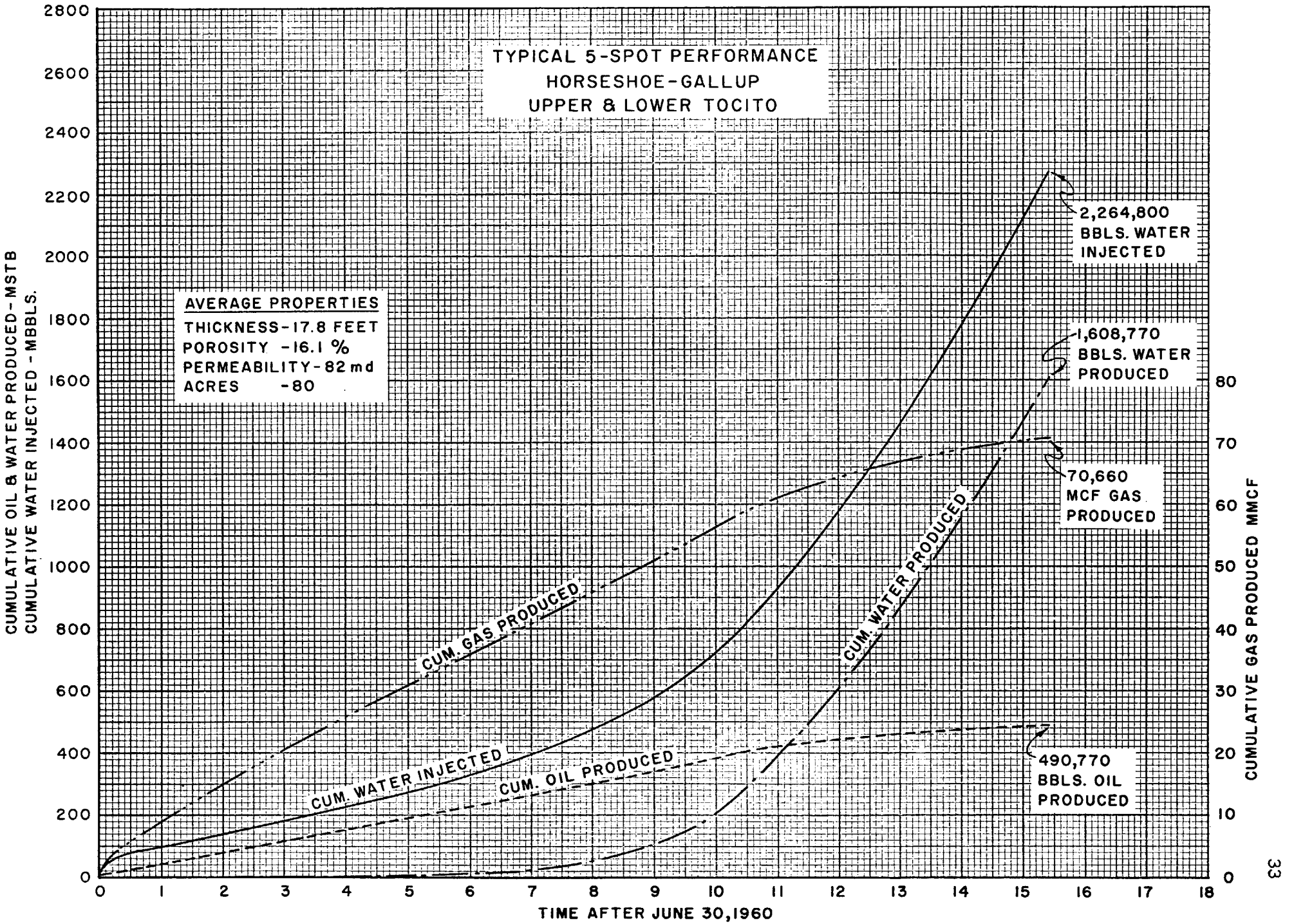

TYPICAL 5-SPOT PERFORMANCE
HORSESHOE-GALLUP
UPPER & LOWER TOCITO
AVERAGE PROPERTIES
THICKNESS-17.8 FEET
POROSITY -16.1 %
PERMEABILITY-82 md
ACRES -80
2,264,800 BBLS. WATER INJECTED
1,608,770 BBLS. WATER PRODUCED
70,660 MCF GAS PRODUCED
490,770 BBLS. OIL PRODUCED
CUM. GAS PRODUCED
CUM. WATER PRODUCED
CUM. WATER INJECTED
CUM. OIL PRODUCED
CUMULATIVE OIL & WATER PRODUCED-MSTB
CUMULATIVE WATER INJECTED-MBBLS.
CUMULATIVE GAS PRODUCED MMCF
TIME AFTER JUNE 30,1960
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
0
10
20
30
40
50
60
70
80
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Exhibit B

LOG NO. 21628 S

Distributed by Petroleum Information

P.I.

DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #9 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C NW NE
30 31N 16W

San Juan, New Mexico

F.C. - 1979

LOG NO 21628 S
30 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO #9
FIELD HORSESHOE GALLUP
LOCATION SEC. 30-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Other Surveys: NONE

Location of Well: 660' FR N/L 1980' FR E/L SEC. 30-31N-16W

Elevation: K.B. 5545' D.F. 5544' or G.L. 5539'

COUNTY SAN JUAN, N.M.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO #9
COMPANY ATLANTIC REFINING COMPANY

Log Depths Measured From	KB		Ft. above
RUN No.	ONE		
Date	11-5-58		
First Reading	1450		
Last Reading	1000		
Feet Measured	450		
Csg. Schlum.	--		
Csg. Driller	102		
Depth Reached	1453		
Bottom Driller	1453		
Mud Nat.	GEL CHEM		
Dens. — Visc.	9.1 — 50		
" Mud Resist.	2.7 @ 75 °F	@ °F	@ °F
" Res. BHT	1.9 @ 85 °F	@ °F	@ °F
pH	8.5		
" Wtr. Loss	4.6 @ CC 30 min °F	@ CC 30 min °F	@ CC 30 min °F
" Rmf	-- @	@	@
Bit Size	7 7/8"		
Spacer	3'		
Opr. Rig Time	1 HR		
Truck No.	2517FARM		
Recorded By	MATTHEWS		
Witness	JESSUP		

FOLD HERE

REMARKS VLC No.:
VLS No.:
VLP No.:
MUD FROM FLOW LINE
CD USED

Velocity (feet per second) = 1,000,000 / Interval Transit Time (microseconds per foot)

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	INTERVAL TRANSIT TIME microseconds per foot ← Increases Span: 3 Ft.; 2 Receivers
— 10 MV +	L.R. 1000'	106 86 66
		146 126 106
	1000	

Exhibit B

P.I.
DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

LOG NO. 22891 S — Distributed by Petroleum Information

COMPANY Atlantic Refining Company

WELL #29 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 1724 S/N 2067 E/W

SE NW 31 31N 16W

San Juan, New Mexico

LOG NO 22891 S

31 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION

Sonic Log

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO # 29
FIELD HORSESHOE GALLUP
LOCATION SEC. 31-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Other Surveys: NONE

Location of Well: 1724' FR N/L, 2067' FR W/L, SEC. 31-31N-16W

Elevation: K.B.: 5561, D.F.:, or G.L.: 5554

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO # 29
COMPANY ATLANTIC REFINING COMPANY

Log Depths Measured From	KB	-7 Ft. above	GL
RUN No.	ONE		
Date	2-10-59		
First Reading	1366		
Last Reading	1000		
Feet Measured	366		
Csg. Schlum.	--		
Csg. Driller	100		
Depth Reached	1370		
Bottom Driller	1370		
Mud Net.	GEL		
Dens. — Visc.	8.9 - 39	—	—
Mud Resist.	1.6 @ 72 °F	@ °F	@ °F
" Res. BHT	1.4 @ 84 °F	@ °F	@ °F
" pH	-- @	@	@
" Wtr. Loss	-- CC 30 min	CC 30 min	CC 30 min
" Rmf	1.3 @ 84 °F	@ °F	@ °F
Bit Size	7 7/8"		
Spans:			
3'	1000 To TD	To	To
1'	1000 To TD	To	To
Opr. Rig Time	1 HR.		
Truck No.	1559 FAPM.		
Recorded By	DILLI		
Witness	MR. SHEETS		

FOLD HERE

REMARKS
VLC No.: 77A
VLS No.: 99A
VLP No.: 59A

Velocity (feet per second) = 1,000,000 / Interval Transit Time (microseconds per foot)

SPONTANEOUS-POTENTIAL millivolts

— 10 MV +

DEPTHS

INTERVAL TRANSIT TIME
microseconds per foot
Increases
Span: 3 Ft.; 2 Receivers

2"-100'
L.R. 1000

106 86 66

Exhibit B

LOG NO. 22895 IE — Distributed by Petroleum Information

P.I.
DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #23 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 2080 S/N 1980 E/W

SE NW 29 31N 16W

San Juan, New Mexico

LOG NO 22895 IE

29 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO # 23
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO # 23
FIELD HORSESHOE GALLUP
LOCATION SEC. 29-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Location of Well: 2080' FR N/L, 1980' FR W/L, SEC. 29-31N-16W
Other Surveys: SL
Elevation: D.F. ____ K.B. ____ or G.L. 5432
FILING No. ____

RUN No.	ONE
Date	2-15-59
First Reading	1323
Last Reading	104
Feet Measured	1269
Csg. Schlum.	104
Csg. Driller	110
Depth Reached	1329
Bottom Driller	1330
Depth Datum	KB
Mud Nat.	OIL EMUL.
Dens. Visc.	8.8 62
Mud Resist.	1.7 @ 70 °F
" Res. BHT	1.4 @ 83 °F
Rmf	-- @ °F
Rmc	@ °F
" pH	@ °F
" Wtr. Loss	-- CC 30 min.
Bit Size	7 7/8"
Spcs.—AM	16"
MN	
IND.	40"
Opr. Rig Time	1 HR.
Truck No.	2517 FARM
Recorded By	KIMBALL
Witness	

FOLD HERE

REMARKS C.D. USED ; S.O. = 1 1/2"

Cartridge No. IRC-208C
Panel No. IRP-2608
Sonde No. IRS-121C

SPONTANEOUS-POTENTIAL millivolts

$-\left|\frac{10}{MV}\right|+$

DEPTHS

CONDUCTIVITY millimhos/m = $\frac{1000}{\text{ohms. m}^2/\text{m}}$

2"-100'

INDUCTION
400 200 0
600 400

L.R. 104'

RESISTIVITY -ohms. m²/m

16" NORMAL
0 100
0 1000
0 1000

Exhibit B

LOG NO.	24706 IE

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DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

CO. Atlantic Refining Company

WELL #8-B Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 1924 N/S 576 E/W NW SW 20 31N 16W

San Juan, New Mexico

LOG NO 24706 IE
20 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION

HOUSTON, TEXAS

Induction Electrical Log

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO # B-8
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO # B-8
FIELD HORSESHOE GALLUP
LOCATION SEC. 20-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Other Surveys: SL

Location of Well: 1980' [illegible] 660' [illegible] W/ SEC. 20-31N-16W [illegible]

Elevation: D.F. K.B. or G.L. 5545

FILING No.

RUN No.	ONE				
Date	6-12-59				
First Reading	1542				
Last Reading	109				
Feet Measured	1433				
Csg. Schlum.	109				
Csg. Driller	110				
Depth Reached	1548				
Bottom Driller	1550				
Depth Datum	KB				
Mud Nat.	OIL EMUL				
Dens. / Visc.	8.9 40				
Mud Resist.	1.6 @ 85 °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	1.6 @ 85 °F	@ °F	@ °F	@ °F	@ °F
Rmf	1.4 @ 85 °F	@ °F	@ °F	@ °F	@ °F
Rmc	-- @ °F	@ °F	@ °F	@ °F	@ °F
" pH	-- @ °F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	-- CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"				
Spcgs.—AM	16"				
MN					
IND.	40"				
Opr. Rig Time	2 HRS.				
Truck No.	2515FARN				
Recorded By	KIMBALL				
Witness	MR. SHEETS				

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REMARKS C.D. USED ; S.O. = 1½"

Cartridge No. 155C
Panel No. 41B
Sonde No. 200E

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
− 10 MV +	2"–100'	INDUCTION 400 200 0
	L.R. 109'	RESISTIVITY -ohms. m²/m
		16" NORMAL 0 100
		0 1000
		INDUCTION 0 100
		0 1000

Exhibit B

LOG NO. 23016 IE

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DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #1-B Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 601 N/S 2002 E/W
SE SW 19 31N 16W
San Juan, New Mexico

LOG NO 23016 IE
19 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO B-1
COMPANY ATLANTIC REFG. CO.

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO B-1
FIELD HORSESHOE GALLUP
LOCATION SEC. 19-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Location of Well: 601' FR S/L 2002' FR W/L SEC. 19-31N-16W
Other Surveys: SL
Elevation: D.F.: 5682 or G.L.: 5675
FILING No.

RUN No.	ONE			
Date	2-20-59			
First Reading	1563			
Last Reading	102			
Feet Measured	1461			
Csg. Schlum.				
Csg. Driller	102			
Depth Reached	1569			
Bottom Driller	1570			
Depth Datum	KB			
Mud Nat.	GEL OIL			
Dens. | Visc.	9.1 | 42			
Mud Resist.	1.7 @ 70°F	@ °F	@ °F	@ °F
" Res. BHT	1.45 @ 85°F	@ °F	@ °F	@ °F
Rmf	1.2 @ 85°F	@ °F	@ °F	@ °F
Rmc	-- @ °F	@ °F	@ °F	@ °F
pH	9 @ °F	@ °F	@ °F	@ °F
Wtr. Loss	5 CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"			
Spcs.—AM	16"			
MN	27'2"			
IND.	40"			
Opr. Rig Time	3 3/4 HR.			
Truck No.	2516 FARM.			
Recorded By	HAMILTON			
Witness	MR. SHEETS			

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REMARKS C.D. USED S.O.- 1½"

Cartridge No. C-88
Panel No. B179
Sonde No. C214

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
10 MV	2"-100'	INDUCTION 380 — 180 — 0
		RESISTIVITY -ohms. m²/m
	L.R. 102'	16" NORMAL 0 — 100
		INDUCTION 0 — 100
	1000	

EXHIBIT B

LOG NO. 22436 IE — Distributed by Petroleum Information

P.I.
DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #28 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 1949 N/S 1980 W/E

31 31N 16W

San Juan, New Mexico

LOG NO 22436 IE

31 31N 16W

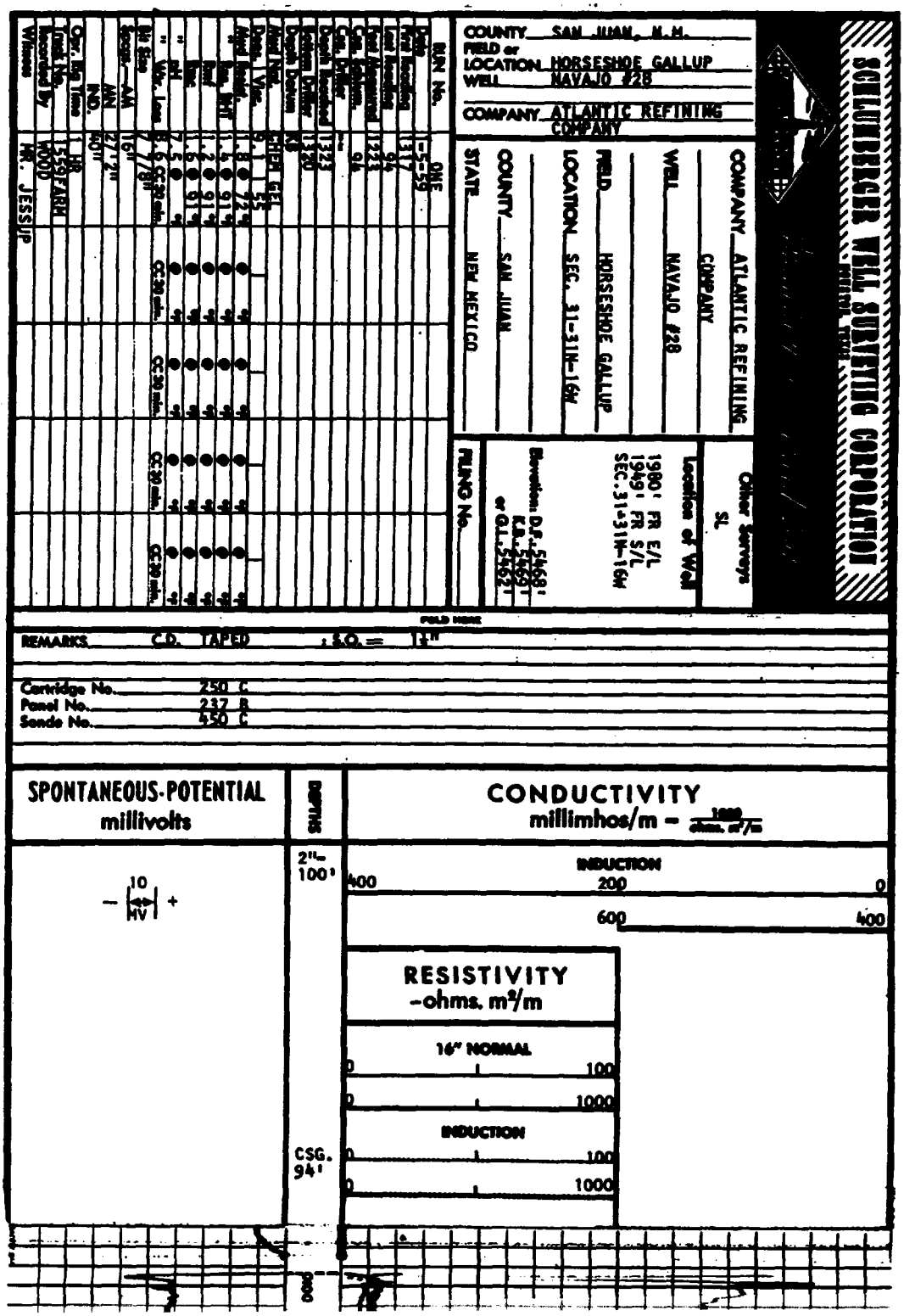

Exhibit B

LOG NO. 23100 IE

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BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #24 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C NW NW

29 31N 16W

San Juan, New Mexico

LOG NO 23100 IE 29 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO # 24
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO # 24
FIELD HORSESHOE GALLUP
LOCATION SEC. 29-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Other Surveys SL

Location of Well
660' FR N/L
660' FR W/L
SEC. 29-31N-16W

Elevation: D.F. ___ K.B. 5485 or G.L. ___

FILING No. ___

RUN No.	ONE				
Date	2-25-59				
First Reading	1415				
Last Reading	97				
Feet Measured	1318				
Csg. Schlum.	97				
Csg. Driller	95				
Depth Reached	1421				
Bottom Driller	1420				
Depth Datum	KB				
Mud Nat.	OIL EMUL				
Dens. | Visc.	8.8 | 42				
Mud Resist.	3.0 @ 60 °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	2.1 @ 84 °F	@ °F	@ °F	@ °F	@ °F
Rmf	-- @ °F	@ °F	@ °F	@ °F	@ °F
Rmc	-- @ °F	@ °F	@ °F	@ °F	@ °F
" pH	-- @ °F	@ °F	@ °F	@ °F	@ °F
" Wtr. Loss	-- CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"				
Spcgs.—AM	16"				
IND.	40"				
Opr. Rig Time	1 HR.				
Truck No.	2517 FARM.				
Recorded By	KIMBALL				
Witness	MR. SHEETS				

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REMARKS C.D. USED : S.O.- 1½"

Cartridge No. 208C
Panel No. 2608
Sonde No. 121C

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000/ohms. m²/m
− |10 MV| +	2"-100'	INDUCTION 400 — 200 — 0
	L.R. 97'	RESISTIVITY -ohms. m²/m: 16" NORMAL 0 — 100; 0 — 1000; INDUCTION 0 — 100; 0 — 1000

Exhibit B

LOG NO. 23763 IE

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DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

CO. Atlantic Refining Company

WELL #26 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C NW NE
29 31N 16W

San Juan, New Mexico

LOG NO 23763 IE
29 31N 16W

P.I. COMPLETION INFORMATION

SAN JUAN CO.
ATLANTIC REFINING #26 NAVAJO, c nw ne 29-31n-16w, 660 s/n 1980 w/e. HORSESHOE CANYON (F)
Contr: Banner. NMB-1A. 31n-16w
Spud 3-8-59. Csg: 8-5/8" @ 100 w/115; 4½" @ 1347 w/190. El: 5488 Gr. Log Tops: Upper Tocito 1294, Sanostee 1434. 1447 TD, PB 1334. Perf 1296-1312; sd oil fract. Comp 3-12-59.
IPF 102 BOPD. Prod Zone: Tocito, 1296-1312.

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO #26
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO #26
FIELD HORSESHOE GALLUP
LOCATION SEC. 29-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Location of Well: 660' FR N/L 1980' FR E/L SEC. 29-31N-16W
Other Surveys: SL
Elevation: D.F. 5495 K.B. 5495 or G.L.
FILING No.

RUN No.	ONE			
Date	3-11-59			
First Reading	1441			
Last Reading	100			
Feet Measured	1341			
Csg. Schlum.	100			
Csg. Driller	105			
Depth Reached	1447			
Bottom Driller	1445			
Depth Datum	KB			
Mud Nat.	OIL EMUL			
Dens. / Visc.	8.9 / 46			
Mud Resist.	1.25@ 68°F			
Res. BHT	.96@ 84°F			
Rmf	.72@ 84°F			
Rmc	-- @ --			
pH	-- @ --			
Wtr. Loss	CC 30 min.			
Bit Size	7 7/8"			
Spcgs.—AM	16"			
MN	27' 2"			
IND.	40"			
Opr. Rig Time	1 HR.			
Truck No.	2516 (ANM.			
Recorded By	HARTLION			
Witness	MR. [illegible]			

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REMARKS C.D. USED ; S.O. = 1½"

Cartridge No. CBO
Panel No. B179
Sonde No. C214

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
0 MV	2"-100'	INDUCTION 400 200 0 / 600 400
		RESISTIVITY 200

Exhibit B

LOG NO. 22112 S

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DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #22 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C NW SE 29 31N 16W

San Juan, New Mexico

LOG NO 22112 S
29 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION

COUNTY SAN JUAN, N.M.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO #22
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO #22
FIELD HORSESHOE GALLUP
LOCATION SEC. 29-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Other Surveys: NONE

Location of Well: 1980' FR S/L 1980' FR E/L SEC. 29-31N-16W

Elevation: K.B. 5512' D.F. G.L. 5505'

Log Depths Measured From	KB		1 Ft. above	DF
RUN No.	ONE			
Date	12-8-58			
First Reading	1345			
Last Reading	1000			
Feet Measured	345			
Csg. Schlum.	--			
Csg. Driller	102			
Depth Reached	1348			
Bottom Driller	1347			
Mud Net.	OIL EMUL			
Dens.	--			
Visc.	40			
Mud Resist.	-- @ °F	@ °F	@ °F	@ °F
Res. BHT	1.8 @ 69 °F	@ °F	@ °F	@ °F
pH	-- @ °F	@ °F	@ °F	@ °F
Wtr. Loss	-- CC 30 min	CC 30 min	CC 30 min	CC 30 min
Rmf	0.52 @ 83 °F	@ °F	@ °F	@ °F
Bit Size	7 7/8"			
Spacing	3'			
	Yo YO	Yo Yo	Yo Yo	Yo Yo
Opr. Rig Time	1 HR			
Truck No.	1588FARM			
Recorded By	PARSLOW			
Witness	JESSUP & SARTAIN			

REMARKS
VLC No.: A-60
VLS No.: A-77
VLP No.: A-59
MUD FROM MUD PIT

Velocity (feet per second) = 1,000,000 / Interval Transit Time (microseconds per foot)

SPONTANEOUS-POTENTIAL millivolts

$-\frac{10}{MV}+$

DEPTHS

INTERVAL TRANSIT TIME
microseconds per foot
Increases
Span: 3 Ft.; 2 Receivers

2"=100'

106 86 66

L.R. 1000'

1000

Exhibit B

LOG NO. 23322 IE

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DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #4-B Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C NW SE
19 31N 16W

San Juan, New Mexico

LOG NO 23322 IE
19 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO B-4
FIELD HORSESHOE GALLUP
LOCATION SEC. 19-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Location of Well: 1980' FR S/L, 1980' FR E/L, SEC. 19-31N-16W
Other Surveys: SL
Elevation: D.F. 5542, K.B. ____, or G.L. 5535
FILING No. ____

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO B-4
COMPANY ATLANTIC REFINING COMPANY

RUN No.	ONE			
Date	3-15-59			
First Reading	1456			
Last Reading	97			
Feet Measured	1359			
Csg. Schlum.	97			
Csg. Driller	97			
Depth Reached	1462			
Bottom Driller	1462			
Depth Datum	DF			
Mud Nat.	GEL-CHEM-OIL			
Dens. Visc.	8.9 45			
Mud Resist.	1.8 @ 60°F	@ °F	@ °F	@ °F
" Res. BHT	1.2 @ 86°F	@ °F	@ °F	@ °F
Rmf	.8 @ 86°F	@ °F	@ °F	@ °F
Rmc	1.5 @ 86°F	@ °F	@ °F	@ °F
pH	--			
Wtr. Loss	-- CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"			
Spcs.—AM	16"			
MN				
IND.	40"			
Opr. Rig Time	1			
Truck No.	1588 FARM			
Recorded By	HANDLEY			
Witness	MR. FLEI			

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REMARKS C.D. USED ; S.O. = 1½" MUD FROM FLOW LINE

Cartridge No. C-182
Panel No. B-138
Sonde No. C-215

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000/ohms. m²/m
− 10 MV +	2"-100'	INDUCTION 400 200 0 / 600 400
	L.R. 97'	RESISTIVITY -ohms. m²/m 16" NORMAL 0 100 / 0 1000 INDUCTION 0 100 / 0 1000
	1000	

Exhibit B

LOG NO. 23491 IE — Distributed by Petroleum Information

P.I.
DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

CO. Atlantic Refining Company

WELL #5-B Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 1980 S/N 2023 E/W

SE NW 19 31N 16W

San Juan, New Mexico

LOG NO 23491 IE

19 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO B-5
FIELD HORSESHOE GALLUP
LOCATION SEC. 19-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

COUNTY SAN JUAN, NEW MEX.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO B-5
COMPANY ATLANTIC REFINING COMPANY

RUN No.	ONE			
Date	3-20-59			
First Reading	1467			
Last Reading	102			
Feet Measured	1365			
Csg. Schlum.	102			
Csg. Driller	102			
Depth Reached	1473			
Bottom Driller	1470			
Depth Datum	KB			
Mud Nat.	CHEM. GEL.			
Dens. | Visc.	8.8 | 45			
Mud Resist.	2.5@ 66 °F	@ °F	@ °F	@ °F
" Res. BHT	1.8@ 92 °F	@ °F	@ °F	@ °F
Rmf	1.5@ 93 °F	@ °F	@ °F	@ °F
Rmc	1.7@ 93 °F	@ °F	@ °F	@ °F
pH				
Wtr. Loss	6 cc 30 min.	cc 30 min.	cc 30 min.	cc 30 min.
Bit Size	7 7/8"			
Spcs.—AM	16"			
MN	27'2"			
IND.	40"			
Opr. Rig Time	1 IIR.			
Truck No.	1559. FARM.			
Recorded By	WOOD			
Witness	MR. SHEETS			

Other Surveys: NONE

Location of Well: 1980' FR N/L 2023' FR W/L SEC. 19-31N-16W

Elevation: D.F. 5558 K.B. 5551 or G.L. 5551

FILING No.

FOLD HERE

REMARKS C.D. TAPED ; S.O. =

Cartridge No. 250C
Panel No. 237B
Sonde No. 450C

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
− 10 MV +	2"-100'	INDUCTION 400 — 200 — 0
		RESISTIVITY -ohms. m²/m 16" NORMAL 0 — 100 0 — 1000 INDUCTION

Exhibit B

LOG NO. 23485 IE — Distributed by Petroleum Information

P.I.
DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

CO. Atlantic Refining Company

WELL #7-B Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C SE SW 20 31N 16W

San Juan, New Mexico

LOG NO 23485 IE

20 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, N.M.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO B #7
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO B #7
FIELD HORSESHOE GALLUP
LOCATION SEC. 20-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

660' FR S L
1980' FR W/L
SEC. 20-31N-16W

Other Services: NONE

Elevation: D.F. 5482'
K.B. 5482'
or G.L. 5472'

FILING No.

RUN No.	ONE	
Date	3-26-59	
First Reading	1576	
Last Reading	98	
Feet Measured	1478	
Csg. Schlum.	98	
Csg. Driller	100	
Depth Reached	1582	
Bottom Driller	1582	
Depth Datum	KB	
Mud Nat.	GEL	
Dens. | Visc.	8.8 | 40	
Mud Resist.	2.0 @ 72°	
Res. BHT	1.6 @ 87°	
Rmf	-- @ °	
Rmc	@ °	
pH	9.2 @	
Wtr. Loss	6 CC 30 min.	
Bit Size	7 7/8"	
Spcg.—AM	16"	
MN		
IND.	40"	
Opr. Rig Time	1 HR	
Truck No.	2515 FARM	
Recorded By	JULIUS	
Witness	MR. [illegible]	

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REMARKS C.D. USED ; S.O. = 1½"

Cartridge No. 155C
Panel No. 41 F
Sonde No. 164C

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
— 10 MV +	2"-100'	INDUCTION 400 — 200 — 0
		600 — 400
		RESISTIVITY -ohms. m²/m
		16" NORMAL 0 — 100
		0 — 1000
		INDUCTION

Exhibit B

LOG NO. 22435 IE

Distributed by Petroleum Information

P.I.

DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #17 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) 660 S/N 1980 W/E

31 31N 16W

San Juan, New Mexico

LOG NO 22435 IE

31 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION

COUNTY SAN JUAN, N.M.
FIELD or LOCATION HORSESHOE CANYON
WELL NAVAJO #17
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO #17
FIELD HORSESHOE CANYON
LOCATION SEC. 31-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Location of Well: 660' FR N/L 1980' FR E/L SEC. 31-31N-16W
Other Surveys: SL
Elevation: D.F. 5457' K.B. 5450' or G.L. 5450'
FILING No.

Run No.	ONE				
Date	12-31-58				
First Reading	1304				
Last Reading	97				
Feet Measured	1207				
Csg. Schlum.	97				
Csg. Driller	97				
Depth Reached	1310				
Bottom Driller	1310				
Depth Datum	KB				
Mud Nat.	GEL OIL				
Dens. Visc.	8.9 45				
Mud Resis.	1.8@ 74°				
" Res. MST	1.6@ 85°				
Rmf	1.2@ 85°				
" Rmc	-- @ -°	@ -°	@ -°	@ -°	@ -°
" pH	8.4 @	@	@	@	@
" Wtr. Loss	6 cc/30 min.	cc/30 min.	cc/30 min.	cc/30 min.	cc/30 min.
Bit Size	2 7/8"				
Scale—AM	16"				
MN					
IND.	40"				
Opr. Rig Time	1 HR				
Truck No.	1555/FARM				
Recorded by	HAMILTON				
Witness	MR. SHEETS & MR. BAKER				

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REMARKS C.D. USED ; S.O. = 1½"

Cartridge No. C 250
Panel No. C 237
Sonde No. C 450

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m – 1000/ohms. m²/m
– 10 HV +	2"= 100'	INDUCTION 400 200 0 / 600 400
		RESISTIVITY -ohms. m²/m
		16" NORMAL 0 100 / 0 1000
	CSG. 97'	INDUCTION 0 100 / 0 1000
	1000	

Exhibit B

LOG NO. 21838 IE

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DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #16 Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C SE NE
31 31N 16W

San Juan, New Mexico

LOG NO 21838 IE
31 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, N.M.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO # 16
COMPANY ATLANTIC REFG. COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO # 16
FIELD HORSESHOE GALLUP
LOCATION SEC. 31-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Location of Well: 1980' FR N/L, 660' FR E/L, SEC. 31-31N-16W
Other Surveys: SL
Elevation: D.F.: 5432, K.B.: 5432, G.L.: 5425
FILING No.

RUN No.	ONE			
Date	11-20-58			
First Reading	1304			
Last Reading	1207			
Feet Measured	97			
Csg. Schlum.	--			
Csg. Driller	97			
Depth Reached	1310			
Bottom Driller	1310			
Depth Datum	KB			
Mud Nat.	GEL			
Dens. | Visc.	9.6 | 46			
Mud Resist.	2 @ 64 °F			
" Res. BHT	1.66 @ 83 °F			
Rmf	1.66 @ 83 °F			
Rmc	-- @ -- °F			
" pH	--			
Wtr. Loss	= CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"			
Spcg.—AM	16"			
IND.	40"			
Opr. Rig Time	1559 FARM			
Truck No.	162 HBS			
Recorded By	DILLI			
Witness	CUMELLA			

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REMARKS MUD FROM FLOW LINE

Cartridge No. 250
Panel No. 237
Sonde No. 450

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
− 10 MV +	L.R. 1207	INDUCTION 400 200 0
		600 400
	2"-100'	RESISTIVITY -ohms. m²/m
		16" NORMAL 0 100
		0 1000
		INDUCTION 0 100
		0 1000
	1000	

Exhibit B

LOG NO. 23223 IE — Distributed by Petroleum Information

P.I.
DENVER · CASPER
BILLINGS · BISMARCK
LOS ANGELES

COMPANY Atlantic Refining Company

WELL #3-B Navajo

FIELD Horseshoe Canyon

LOC (P.I.) C SE SE

19 31N 16W

San Juan, New Mexico

LOG NO 23223 IE
19 31N 16W

SCHLUMBERGER WELL SURVEYING CORPORATION
HOUSTON, TEXAS

Induction-Electrical Log

COUNTY SAN JUAN, N.M.
FIELD or LOCATION HORSESHOE GALLUP
WELL NAVAJO B #3
COMPANY ATLANTIC REFINING COMPANY

COMPANY ATLANTIC REFINING COMPANY
WELL NAVAJO B #3
FIELD HORSESHOE GALLUP
LOCATION SEC. 14-31N-16W
COUNTY SAN JUAN
STATE NEW MEXICO

Other Surveys NONE

Location of Well
660' FR S/L
660' FR E/L
SEC. 14-31N-16W

Elevation: D.F.:
K.B.: 5512'
or G.L.: 5505'

FILING No.

RUN No.	ONE				
Date	3-7-59				
First Reading	1441				
Last Reading	105				
Feet Measured	1336				
Csg. Schlum.	105				
Csg. Driller	105				
Depth Reached	1447				
Bottom Driller	1450				
Depth Datum	KB				
Mud Nat.	OIL EMUL.				
Dens. | Visc.	8.8 | 42	|	|	|	|
Mud Resist.	2.2 @ 58 °F	@ °F	@ °F	@ °F	@ °F
" Res. BHT	1.5 @ 84 °F	@ °F	@ °F	@ °F	@ °F
Rmf	@ °F	@ °F	@ °F	@ °F	@ °F
Rmc	@ °F	@ °F	@ °F	@ °F	@ °F
pH	@ °F	@ °F	@ °F	@ °F	@ °F
Wtr. Loss	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.	CC 30 min.
Bit Size	7 7/8"				
Spcgs.—AM	16"				
MN					
IND.	40"				
Opr. Rig Time	1 HR.				
Truck No.	2515 FARM				
Recorded By	DILLY				
Witness	MR. SHEETS				

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REMARKS C.D. USED ; S.O. = 1½"

Cartridge No.
Panel No.
Sonde No. C-214

SPONTANEOUS-POTENTIAL millivolts	DEPTHS	CONDUCTIVITY millimhos/m = 1000 / ohms. m²/m
10 — MV +	2"-100'	INDUCTION 400 200 0
		RESISTIVITY -ohms. m²/m
		16" NORMAL 0 100; 0 1000
		INDUCTION 0 100; 0 1000
	CSG. 105'