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more strictly a lithologic factor than the effective porosity. (By the same token, it would have been preferable to use values of permeability calculated from lithologic rather than fluid dynamic data. However, cate, with sufficient accuracy for our purposes, the outline of the intergranular area in this region, and it was found that the uncorrected air data conformed to it satisfactorily.

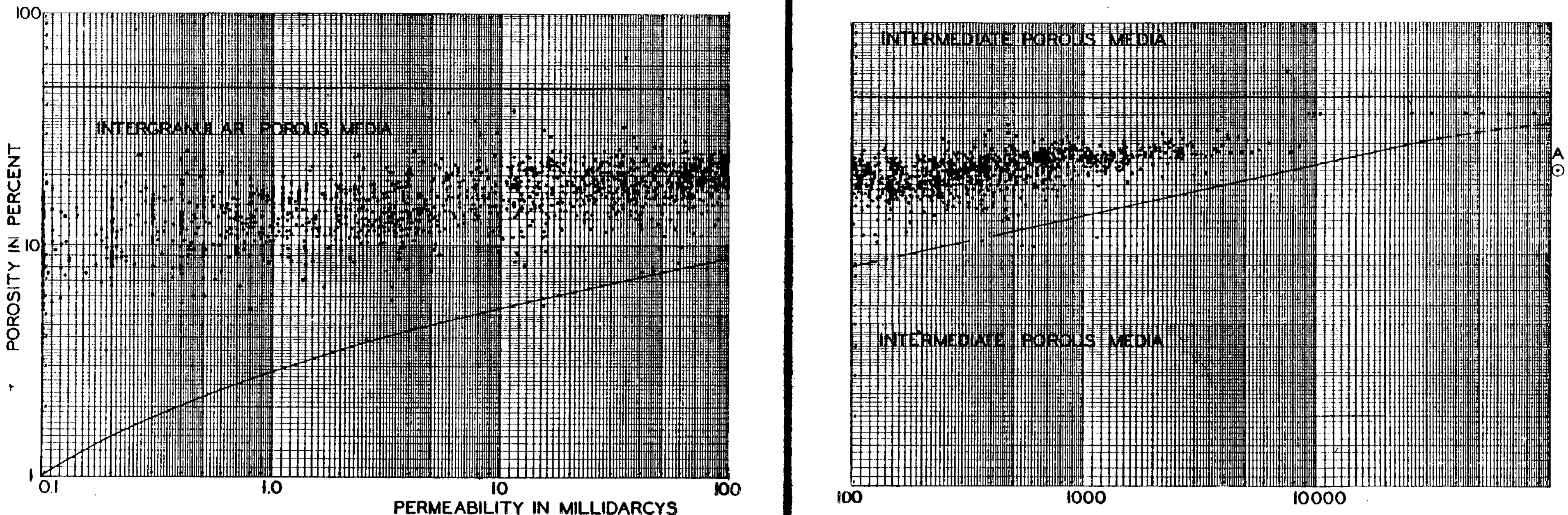


FIG. 1.—POROSITIES AND PERMEABILITIES OF ABOUT 2200 SAND AND SANDSTONE SPECIMENS.

this was plainly impracticable except in a few cases,[7] hence only the latter type of data have been used.) Comparison reveals, however, that for uniform sandstones the two porosities are practically equal, and on this basis we have felt justified in including the data of Fancher, Lewis and Barnes,[3] although, as will be brought out later, it appears probable that the effective porosity of a few of their samples was several units lower than the total porosity.

The majority of the permeability measurements were made with air as fluid, and, as far as we are aware, the mean air pressure in the samples was moderate during the tests. Although the air data below about 10 millidarcys may be considerably in error according to Klinkenberg's[8] work, enough liquid data were available to indicate, with sufficient accuracy for our purposes, the outline of the intergranular area in this region, and it was found that the uncorrected air data conformed to it satisfactorily.

It is clear that insufficient points are accumulated in Fig. 1 to outline definitely the intergranular area. The data are not so much lacking in number as in variety; that is, variety as regards the manner of evolution of the samples. For example, the reason for the thinning out of points in the region below 10 per cent porosity and to the left of the 10-md. ordinate probably is that points falling in that region represent conditions of intergranular void geometry that are comparatively rare in sandstones of natural origin; hence only a few would be present in a numerous assemblage of random data. Therefore, what has been obtained is the part of the general intergranular area that pertains to a certain class of intergranular porous media of natural origin; viz., the sandstones.

An attempt has been made to locate approximately the lower boundary of the general intergranular area for media composed of elementary units whose size range does not exceed that of the grains composing consolidated and unconsolidated sands. This was done by drawing the solid line through the loci of three points corresponding to samples containing fine cracks produced by laboratory handling, and, as it were, on the dividing line between intergranular and intermediate porous media; and a number of the data of Fancher, Lewis and Barnes[3] on Bradford, Wilcox, Johnson, 3rd Venango and Glade sandstones. It is possible that the deviations of the latter samples are caused by some inhomogeneity, especially in the 3rd Venango samples, since this sand is notoriously irregular; or they may reflect the difference between the effective and the absolute porosity of the samples, since, as already mentioned, the majority of our data represent absolute porosities while those of Fancher, Lewis and Barnes are effective porosities.* In all of these cases the addition of a few units of porosity would serve to place these points in accord with the remainder of the plot.

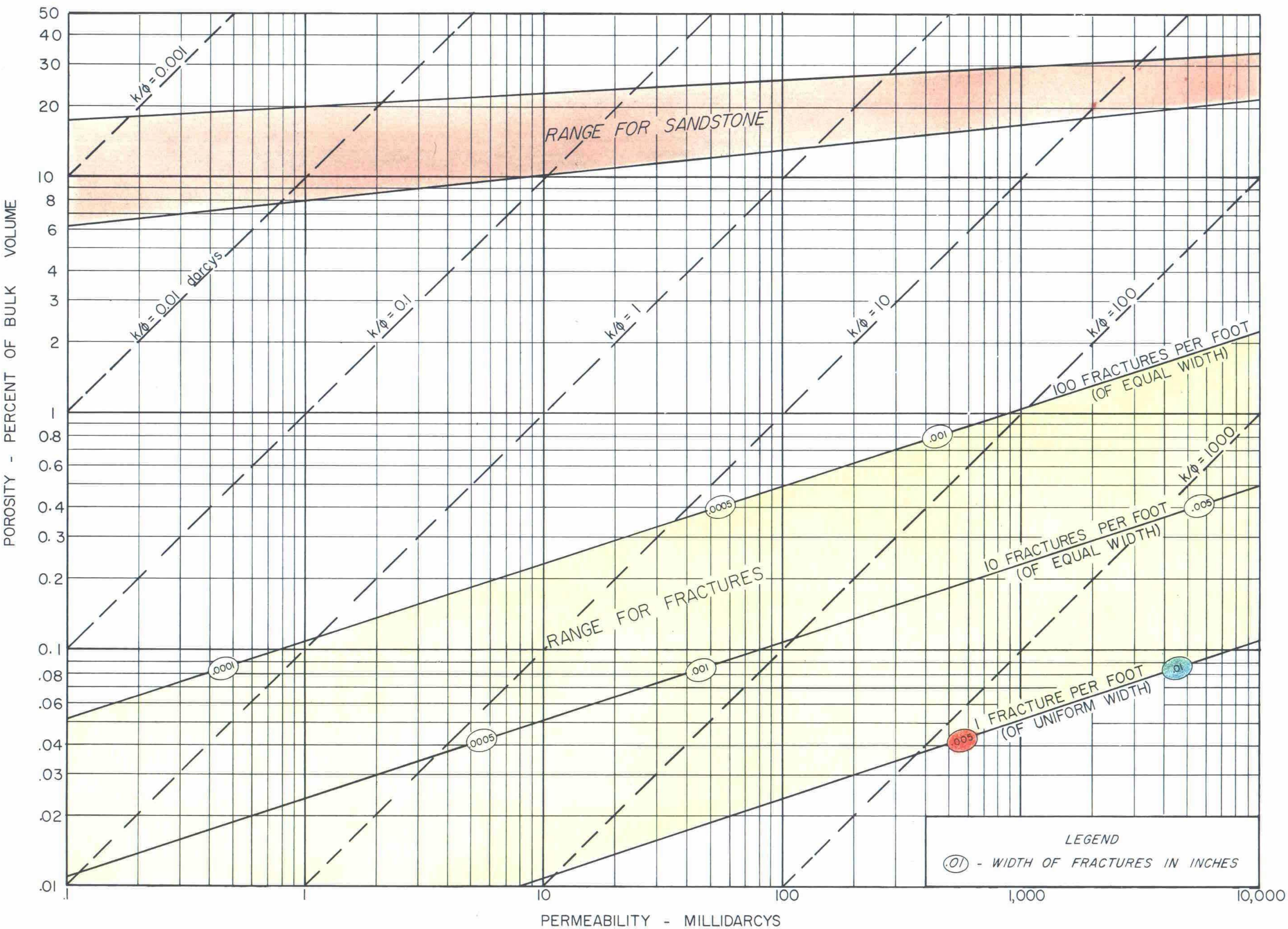
The upper boundary was taken to be the horizontal line, porosity equals 47.64 per cent—i.e., the maximum porosity of an ideal intergranular porous medium—on the assumption that by varying the size of

* To illustrate the magnitude of the differences that may exist between the porosity values derived by the two methods, we have selected and show below several data on two of these sands, from Table 5, page 119, of the paper cited.[3]

Sample No.	Sand	Field	Total Porosity, Per Cent	Effective Porosity, Per Cent
[illegible]	3rd Venango	[illegible]	[illegible]	[illegible]
[illegible]	3rd Venango	Pleasantville	[illegible]	[illegible]
37	Bradford	Kane	13.0	10.2
40	Bradford	Kane	16.4	14.4
41	Bradford	Kane	17.4	13.6

VALUES OF K/φ FOR SANDSTONE RESERVOIRS AND FOR FLOW SYSTEMS OF FRACTURES IN AN IMPERMEABLE MATRIX

FRACTURES PARALLEL TO DIRECTION OF FLOW



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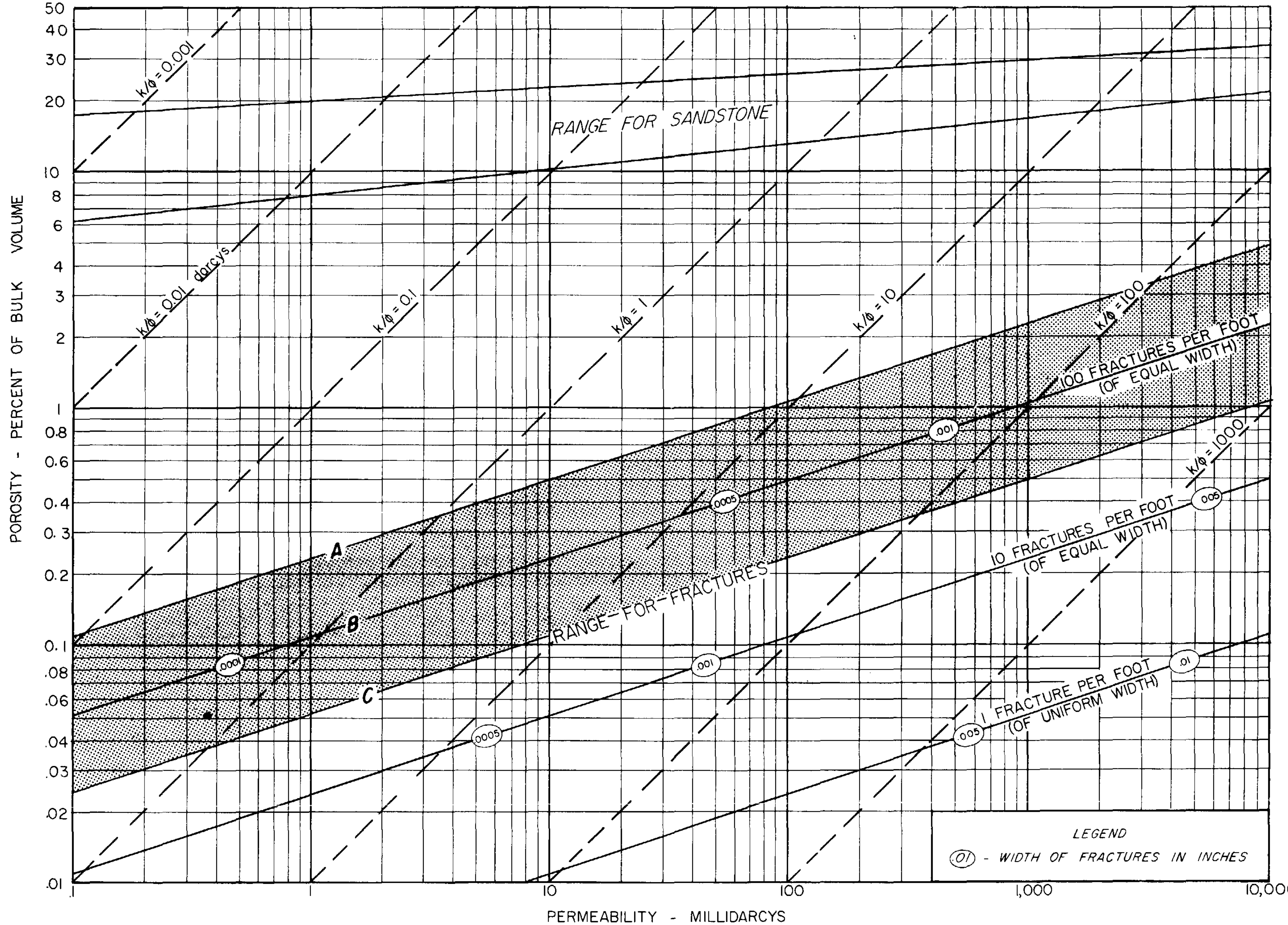
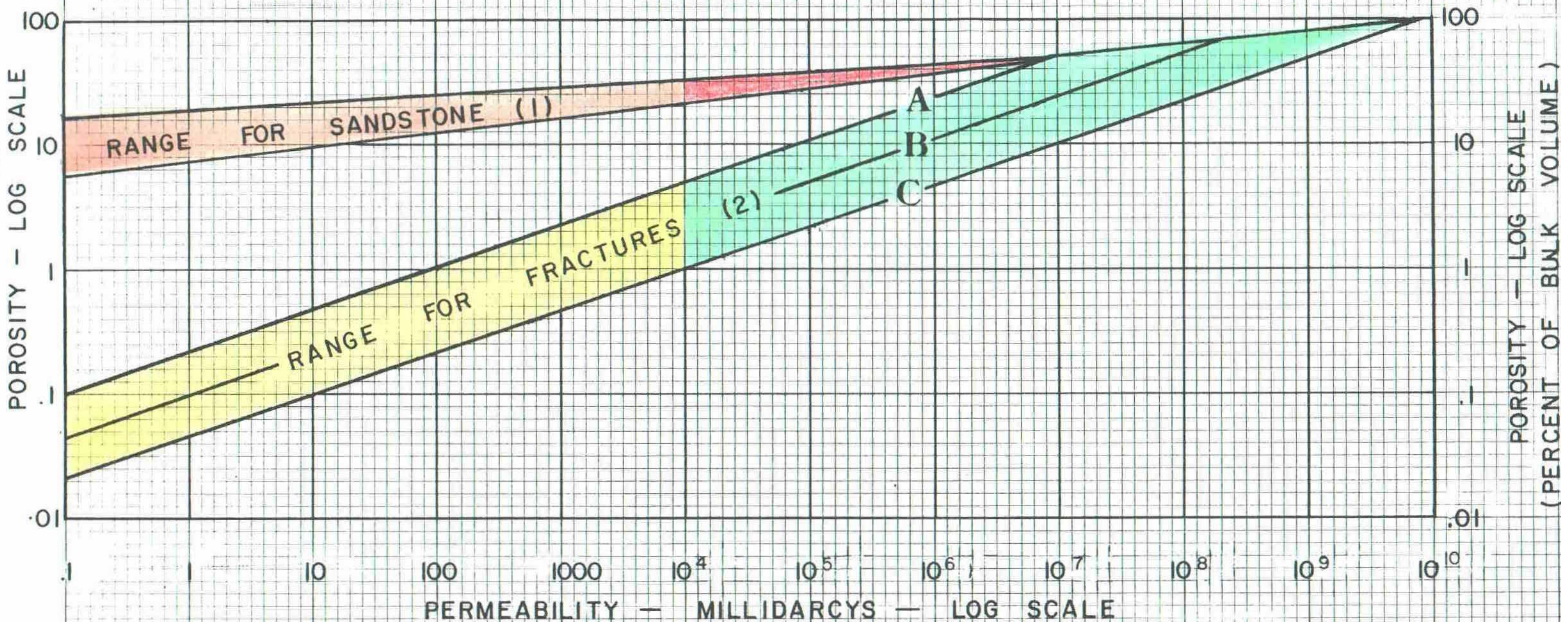


APPENDIX III FIGURE NO. III-4

COMPARISON OF RELATION OF POROSITY TO PERMEABILITY

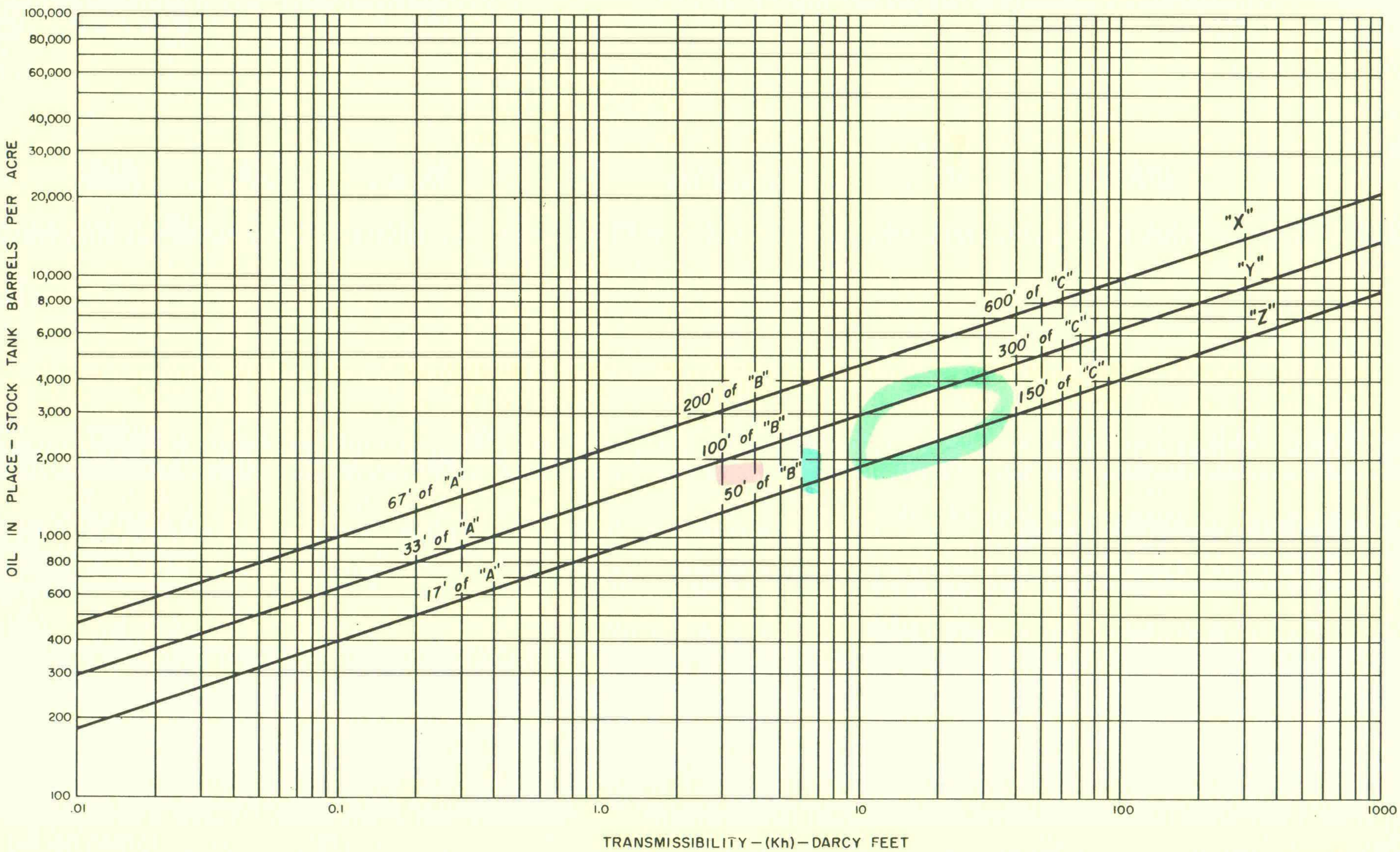


(1) FROM CORE SAMPLES (BULNES & FITTING: TRANS AIME 1945)

(2) ESTIMATED

6/86

RELATION OF OIL IN PLACE
TO
TRANSMISSIBILITY
FOR
POROSITY-PERMEABILITY RELATIONS
"A", "B" & "C"
AND FOR
RESERVOIR THICKNESSES SHOWN
F.V.F.=1.29



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APPENDIX III FIGURE NO. III-5

THE FLOW OF HOMOGENEOUS FLUIDS THROUGH POROUS MEDIA

BY

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Second Impression

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MUSKAT - FDHF

ity and is not limited by the value of r_0. For evidently in the limiting case when the well face has been completely plugged or mudded off, $k_i = 0$, and Q/Q_0 would become infinitely large.

7.8. The Effect of Acid Treatment in Highly Fractured Limestones.—That extended fractures in a limestone reservoir may play a significant role in the production from such reservoirs becomes fairly obvious when it is observed that a fracture of even a small width may have an effective permeability hundreds of times as great as that of the limestone proper. For a real fracture of width w may evidently be considered as equivalent to an open linear channel of equal width. Now for viscous-flow conditions the carrying capacity of such a linear channel per unit pressure gradient may be shown by the classical hydrodynamics to be given by

$$Q = w^3/12\mu, \tag{1}$$ [1]

where μ is the viscosity of the liquid. The equivalent permeability of the channel is, therefore,

$$k = \frac{w^2}{12} = \frac{10^8 w^2}{12} \text{ darcys,} \tag{2}$$

if w is expressed in centimeters. Hence a fracture of only 0.1 mm. width will have a permeability of 833 darcys, whereas the permeability of the limestone proper will usually be of the order of 0.01 darcy. In fact, the total fluid-carrying capacity of a complete radial system of radius 45 ft. consisting of a limestone of permeability 0.01 darcy can be carried by a *single* linear fracture 45 ft. long, of depth equal to that of the radial system, and of width 0.126 mm.

If acid is introduced into a well drilled into a limestone formation, it will evidently tend to flow rapidly into, and widen, any fractures leading into the well bore as well as reacting with the limestone immediately surrounding the bore. Hence, in view of the fact that the radial permeability increase about the well bore will have only a relatively small effect upon the production capacities, unless the affected region be initially abnormally tight, it becomes of interest to examine the effects to be expected owing to the widening of the fractures. While in practical cases these fractures will be of limited extent and the acid will not, in general,

[1] *Cf.* H. Lamb, "Hydrodynamics," 6th ed., p. 582, 1932.

PERMEABILITY & POROSITY OF FRACTURES
(C&H pg 283) (Muskat FoHF pg 425)

$K = (54 \times 10^6)(w^2)$ darcys (w inches)

Assume only permeability from fractures & that matrix has 0 permeability;

w (inches) (1)	Perm. of Fracture $(54\times10^6)(w)^2$ (darcys) (2)	Avg perm for 1 fracture per foot $(2)\times(w/12)$ darcys (3)	Porosity for 1 fracture per foot w/12 (4) FRACTION	FOR 10 FRACTURES per foot perm (darcys)	porosity FRACTION	FOR 100 FRACTURES/FOOT perm darcys	porosity FRACTION
.01	54×10^2	4.5	.00082	45	.0082	450	.082
.001	54	.0045	.000082	.045	.00082	.45	.0082
.005	1350	.56	*.00045	5.6	.0048	56	.048
.0001	.54	.0000045	*.0000082	.000045	.000082	.00045	.00082

Applied PETROLEUM RESERVOIR ENGINEERING

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and

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PRENTICE-HALL, INC.

Englewood Cliffs, N. J. *1959*

CRAFT + HAWKINS

fracture, both in centimeters, $(p_1 - p_2)$ is the pressure differential in dynes per square centimeter which exists between the ends of the fracture of length L centimeters, and μ is the fluid viscosity in *poises*. Equation (6.22) may be combined with Eq. (6.20) as in the previous section to obtain an expression for the permeability of a fracture as

$$k = 54 \times 10^6\, W^2 \text{ darcys } (W = \text{inches}) \tag{6.23}$$

The permeability of a fracture only 0.001 inch wide is 54 darcys or 54,000 md.

Fractures and solution channels account for economic production rates in many dolomite, limestone, and sandstone rocks, which could not be produced economically if such openings did not exist. Consider, for example, a rock of very low primary or matrix permeability, say 0.01 md, but which contains on the average a fracture 0.005 inch wide and one foot in lateral extent per square foot of rock. Assuming the fracture is in the direction in which flow is desired, the law of parallel flow, Eq. (6.17) will apply, and

$$k_{avg} = \frac{0.01[144 - (12 \times 0.005)] + (54 \times 10^6 \times 0.005^2)(12 \times 0.005)}{144}$$

$$= 0.562 \text{ darcy} = 562 \text{ md}$$

11. Radial Flow of Incompressible Fluid, Steady-State. Consider radial flow toward a vertical well bore of radius r_w in a horizontal stratum of uniform thickness and permeability, as shown in Fig. 6.16. If the fluid is

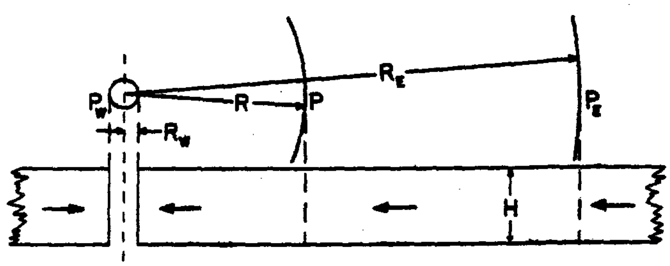


Fig. 6.16.

incompressible, the flow across any circumference is a constant. Let p_w be the pressure maintained in the well bore when the well is flowing q *reservoir* barrels per day and a pressure p_e is maintained at the external radius r_e. Let the pressure at any radius r be p. Then at this radius r,

$$v = \frac{q}{A} = \frac{q}{2\pi rh} = -1.127\,\frac{k}{\mu}\frac{dp}{dr}$$

where positive q is in the positive r direction. Separating variables and

Naturally Fractured Reservoirs

Roberto Aguilera

Petroleum Publishing Company
Tulsa, Oklahoma

and,

$$q = \int_0^{w_o} \frac{(p_1 - p_2)}{\mu L}\left(\frac{w_o^2}{8} - \frac{w^2}{2}\right) 2hdw \quad (1\text{-}32)$$

Integrating,

$$q = \frac{w_o \, A \, (p_1 - p_2)}{12\mu \, L} \quad (1\text{-}33)$$

The previous equation can be combined with Darcy's law (Eq. 1-18) to obtain a relationship for permeability as follows:

$$k = \frac{w_o^2 \, A\,(p_1 - p_2)}{12 \, \mu L} \times \frac{\mu \, L}{9.86 \times 10^{-9} \, A\,(p_1 - p_2)} \quad (1\text{-}34)$$

and,

$$k = 8.45 \times 10^6 \, w_o^2 \text{ darcys} \quad (1\text{-}35)$$

where w_o is in centimeters. If the fracture width (w_o) is in inches rather than in centimeters, the permeability is given by:

$$k = 54 \times 10^6 \, w_o^2 \text{ darcys} \quad (1\text{-}36)$$

Consequently, the permeability of a fracture 0.01 in. thick would be 5,400 darcys or 5,400,000 md. These extremely high values of permeability clearly indicate the importance of fractures on production of tight reservoirs which otherwise would be noncommercial.

Example 1-3. Calculate the average permeability of a rock which contains three fractures, each one 0.01 in. wide. Dimensions of the rock are 1 ft × 1 ft × 1 ft. Matrix permeability is 1 millidarcy.

$$K_{av} = \frac{0.001\,[144 - 3\,(12 \times 0.01)] + [(54 \times 10^6 \times 0.01^2)\,3\,(12 \times 0.01)]}{144}$$

$$K_{av} = 13.51 \text{ darcys} = 13{,}510 \text{ md}$$ = 4,500 md, for 1 fracture per foot

Migration and Accumulation

One reasonable explanation for petroleum migration and accumulation in fractured reservoirs is provided by the theory of dilatancy. The principle of this theory is explained with the use of Fig. 1-7, as in the case of earthquakes. Fig. 1-7A shows a fault under tectonic stresses. In Fig. 1-7B the stresses have built up sufficiently to fracture the rock.

Then, fluids start moving into the dilatant zone, due to the vacuum produced by the fractures. In Fig. 1-7C the fluids have already filled the

GENERAL DESCRIPTION

Although the majority of the industry's oil reservoirs that are fractured are those that comprise a rock with matrix porosity laced with fractures, the operators in the Boulder and Puerto Chiquito pools have recognized the producing reservoirs to be of fracture porosity only. (Reference Case No. 7980 before the New Mexico Oil Conservation Division, November 16, 1983, McHugh Exhibit No. 9, Section S.)

Performance of the wells in the Gavilan pool are showing the same characteristics. It is clear that Gavilan also produces from fracture porosity only.

The subject reservoirs are referred to as "fractured shale reservoirs" and occur in the Niobrara member of the Mancos shale formation. The lithology of the reservoir rock varies from shale to siltstone to sandy layers; and sometimes containing a high percentage of calcium or dolomite. (Reference is made to AAPG paper by W.W. London, 1972, "Dolomite in Flexure-Fractured Petroleum Reservoirs in New Mexico and Colorado": American Association Petroleum Geologist Bulletin, v. 56, p. 815-821.)

The rock property which is significant in the determination of oil in place is "effective hydrocarbon porosity". It is an elusive physical characteristic impossible to evaluate from currently available core and log data.

Effective hydrocarbon porosity can be approximated from the statistics of depleted pools given a reasonable estimate of the pool's areal size. As to reservoirs early in their production lives, the only reliable method of estimating effective hydrocarbon pore space is by interference testing. Conventional drawdown and buildup analyses are woefully inadequate for this purpose.

E

RESULTS OF INTERFERENCE TESTS EVIDENCE THE FACT THAT THE RESERVOIR PORE SPACE CONSISTS OF FRACTURE POROSITY ONLY WITH NO CONTRIBUTION FROM A "MATRIX" POROSITY.

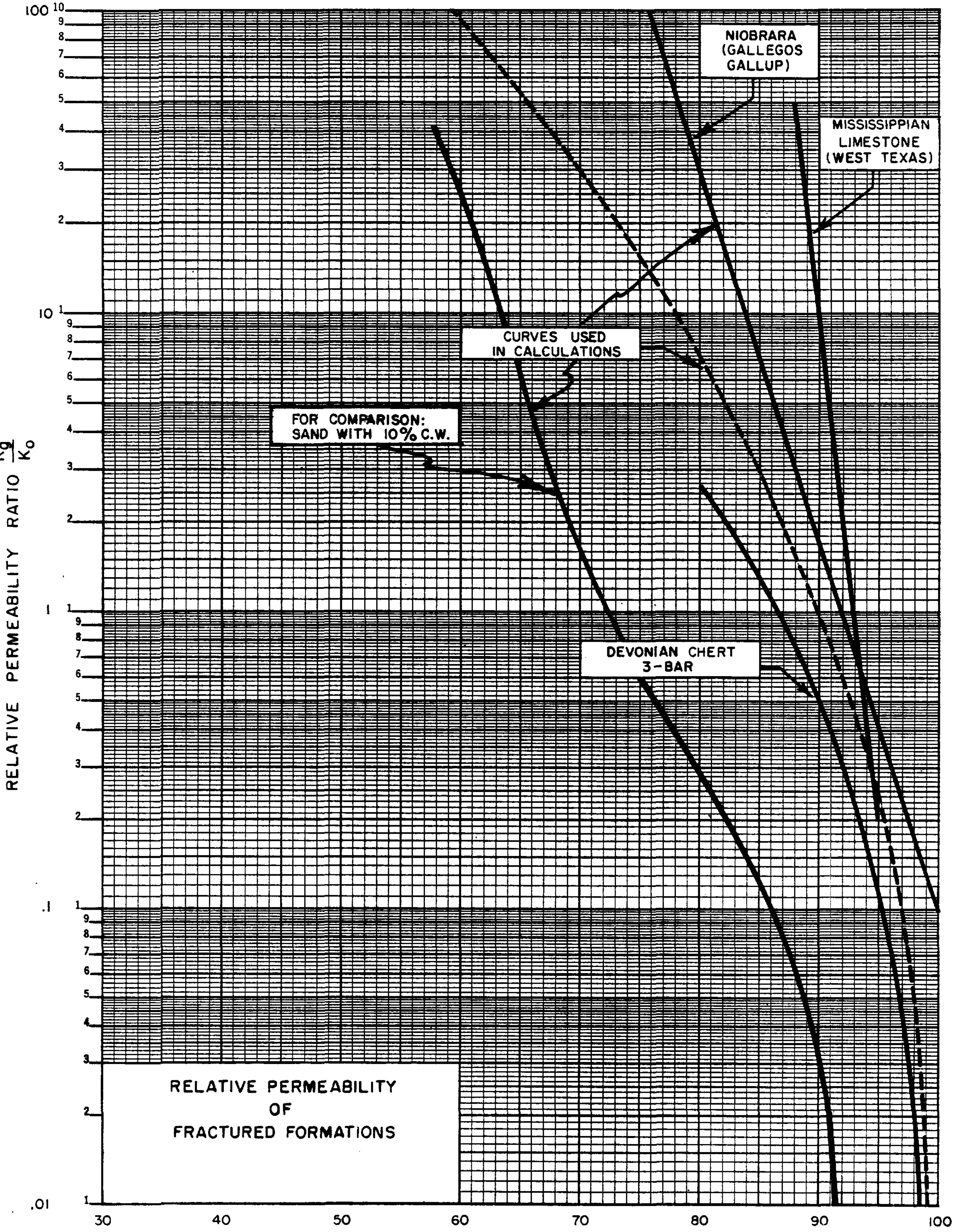
The information which shows beyond all doubt that the producing reservoir of the Canada Ojitos Unit is from fracture porosity is that shown by the 1965 and 1968 interference tests in which there was measured transmissibility on the order of 5 to 10 darcy feet with a volume of hydrocarbon pore space of about 2500 barrels per acre.

If the reservoir were one of matrix porosity, as a sand, this 2500 barrels per acre of hydrocarbon pore space could be contained in:

3 feet of producing reservoir with 10% porosity, or
2 feet of producing reservoir with 15% porosity.

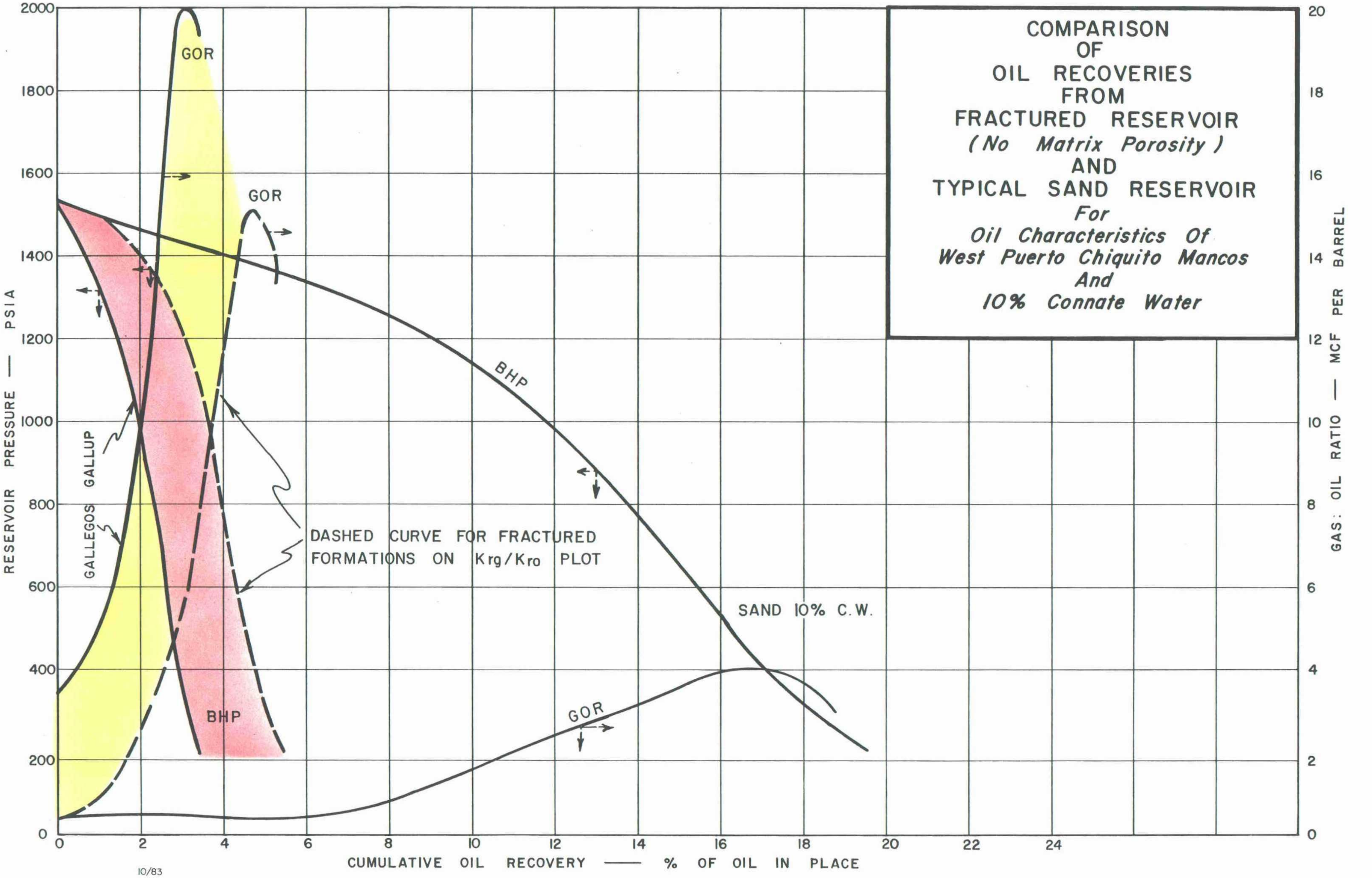
Typical sand reservoirs with matrix porosity show permeabilities for these porosities on the average of about 1 millidarcy and 10 millidarcies respectively. The resulting transmissibilities at 3 millidarcy feet and 20 millidarcy feet respectively is so much less than that actually measured as to preclude any possibility that the producing zone is a reservoir of typical sandstone matrix porosity since the measured transmissibility is 2000 to 3000 times that shown for a 10% porosity sand and 300 to 500 times that shown for a 15% porosity sand. (See schedule below.)

Characteristics of typical sand with matrix porosity				Actual Reservoir
Sand Thickness (Feet)	Porosity (Percent)	Permeability (md)	Resulting Transmiss-ibility (Kh) (md-feet)	Measured Transmiss-ibility (Kh) (md-feet)
3	10	1	3	5,000-10,000
2	15	10	20	5,000-10,000


NIOBRARA (GALLEGOS GALLUP)
MISSISSIPPIAN LIMESTONE (WEST TEXAS)
CURVES USED IN CALCULATIONS
FOR COMPARISON: SAND WITH 10% C.W.
DEVONIAN CHERT 3-BAR
RELATIVE PERMEABILITY OF FRACTURED FORMATIONS
RELATIVE PERMEABILITY RATIO $\frac{K_g}{K_o}$
TOTAL LIQUID SATURATION-PERCENT OF PORE SPACE
100
10
1
.1
.01
30
40
50
60
70
80
90
100

10/83

F


COMPARISON
OF
OIL RECOVERIES
FROM
FRACTURED RESERVOIR
(No Matrix Porosity)
AND
TYPICAL SAND RESERVOIR
For
Oil Characteristics Of
West Puerto Chiquito Mancos
And
10% Connate Water
RESERVOIR PRESSURE — PSIA
GAS: OIL RATIO — MCF PER BARREL
CUMULATIVE OIL RECOVERY — % OF OIL IN PLACE
GOR
GOR
GOR
BHP
BHP
GALLEGOS
GALLUP
DASHED CURVE FOR FRACTURED FORMATIONS ON Krg/Kro PLOT
SAND 10% C.W.
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0
2
4
6
8
10
12
14
16
18
20
22
24

10/83

COMPARISON
OF PRODUCTION RATES OF CANADA OJITOS UNIT WELLS
PRIOR TO DEVELOPMENT OF GAVILAN
WITH
DEPLETION RATES FOR GAVILAN
AND THAT PART OF WEST PUERTO CHIQUITO ADJOINING GAVILAN

		That part of West Puerto Chiquito pool in the Canada Ojitos Unit with well-developed fracture system and gravity drainage (one zone producing)	Gavilan and that part of West Puerto Chiquito pool adjoining Gavilan with well-developed fracture system and minimal gravity drainage (all zones producing)
1) Anticipated Recovery	(Barrels/Acre)	700*	300**
2) Production Rate	(BOPD/Well)	700	700
3) Depletion Rate	(Acres/Day)	1	2.3
4) Well Density	(Acres/Well)	2500	320
5) Well Density divided by Depletion Rate (Line 4 divided by Line 3)	(Days)	2500	140
6) Allowable if depleted at rate similar to Canada Ojitos Unit	(BOPD)	700	39

* Based on one zone at 2500 barrels oil per acre hydrocarbon pore space (± 2000 stock tank barrels per acre oil in place), 1/2 of which provides gravity drainage recovery at 55% of oil in place, and 1/2 of which provides combination gravity drainage and solution gas drive for 15% of oil in place.

** Based on all zones having estimated hydrocarbon pore space of 4500 barrels oi per acre (3300 stock tank barrels per acre oil in place) and 5.6% solution gas drive recovery of 180 BOPA and 120 BOPA of production above bubble point and some gravity drainage.

OPPOSITION ARGUMENTS IDENTIFIED AND REFUTED IN CASE NO. 8950 (FOR WEST PUERTO CHIQUITO) AND CASE NO. 8946 (FOR GAVILAN)

INTRODUCTION

Cases 8950 and 8946 are applications to establish gas-oil ratio limits for each pool of 1000 cubic feet per barrel and oil allowables of 200 barrels per day for 320 acre proration units and 400 barrels per day for 640 acre proration units (along with credit in determining effective gas-oil ratios for injected gas).

Opponents to the provisions of these applications have posed arguments which the applicants consider to be without merit.

Some of these opposition arguments are identified and refuted as described on the following pages of this section.

These arguments are:

Item 1: A change in allowables during development of a field is an improper regulation since it adversely impacts industry's plans made at an earlier time.

Item 2: Allowable change will cause economic hardship.

Item 3: Reduction in production rates from current levels, if undertaken, should be proportional to current rates of production.

H

OPPOSITION ARGUMENTS IDENTIFIED AND REFUTED IN CASE NO. 8950 (FOR WEST PUERTO CHIQUITO) AND CASE NO. 8946 (FOR GAVILAN)

(Reference: Page 1, Item 1)

ARGUMENT

A change in allowables during development of a field is an improper regulation since it adversely impacts industry's plans made at an earlier time.

ARGUMENT REFUTED

Any rule or regulation of the Oil Conservation Division is subject to change. The Oil Conservation Division is obliged to make changes in any of its rules or regulations whenever information is developed supporting such changes and this information is brought before the Commission in accordance with its rules.

Operators cannot be "guaranteed" that any given allowable will remain fixed throughout any particular time, or phase of development or depletion, in the life of a pool - including an operator's "payout period" for his development program.

The risk of a change in allowable is just one of the many risks that an operator assumes when he drills a well.

OPPOSITION ARGUMENTS IDENTIFIED AND REFUTED
IN CASE NO. 8950 (FOR WEST PUERTO CHIQUITO)
AND CASE NO. 8946 (FOR GAVILAN)

(Reference: Page 1, Item 2)

ARGUMENT

The allowable change will cause economic hardship.

ARGUMENT REFUTED

As noted in Item 1, Page 2, of this section, the owner of a well assumes many risks when he undertakes the drilling of a well, and some of them are factors affecting economics: just as the Oil Conservation Division cannot guarantee a fixed allowable, neither can it guarantee the stability of other economic factors, such as a fixed price for oil.

Those owners developing West Puerto Chiquito have, in the past, faced many economic adversities, including tier one category pricing (and windfall profits tax) for oil.

Initial development conditions in West Puerto Chiquito included a price for oil of $2.05 per barrel at the wellhead when drilling costs approximated $180,000 per well. Compared to today's drilling costs of approximately $500,000 per well, this would equate to an oil price of about $6.00 per barrel at the wellhead. So although current economic conditions are not favorable, they still are not as adverse as those under which the West Puerto Chiquito pool was initially developed.

(Reference: Page 1, Item 3)

ARGUMENT

Reduction, if any, from current level of production should be proportional, i.e., for a 50% overall pool production rate reduction, wells currently making 100 BOPD should be reduced to 50 BOPD and wells making 600 BOPD should be reduced to 300 BOPD.

ARGUMENT REFUTED

Implicit in this argument are two unwarranted assumptions:

A. That the existing allowable is a "proper" allowable.

B. That each well's share of the pool's recoverable oil is directly proportional to well productivity.

As to Item A above, and as shown earlier herein, the existing allowable is unreasonably high, given the anticipated average recovery from a 320 acre proration unit (absent pressure maintenance and gravity drainage), refuting this assumption. As to Item B above that a well's productivity is in direct proportion to the well's share of the pool's recoverable reserves, we note the following:

1. As shown earlier herein, hydrocarbon pore space is greater for those parts of the reservoir which have higher transmissibilities. The proportion, however, is not one to one; rather the hydrocarbon pore space can be expected to vary with transmissibility approximately as the cube root of the ratio of the transmissibilities of the two areas.

2. This variation in reservoir space throughout the pool can be described only on an area basis - not on an individual well basis.

3. Extensive testing in West Puerto Chiquito has shown that not only are individual well productivities not representative of area reservoir characteristics but information derived from pressure buildup tests, although yielding better information than well productivities, still does not show the area's reservoir characteristics. In this type of a reservoir, such information can be determined only through interference testing.

4. As a consequence of the above, it is a practical impossibility to relate well productivities to reservoir volume directly such that well productivity would be a proper parameter to use in determining allowables. We note, for example, that wells in West Puerto Chiquito have indicated productivities up to 10,000 to 20,000 barrels per well; and a 70% reduction thereof (the approximate reduction proposed in Cases 8950 and 8946) could still result in allowables of 3000 to 6000 BOPD per well - unreasonably high figures.

PROPOSED SPECIAL RULES AND REGULATIONS
FOR THE
B-M-G WEST PUERTO CHIQUITO MANCOS PRESSURE MAINTENANCE PROJECT

RULE 1. The project area of the B-M-G West Puerto Chiquito Mancos Pressure Maintenance Project, hereinafter referred to as the Project, shall comprise the Niobrara-Greenhorn participating area of the Canada Ojitos Unit as it may be expanded or contracted, lying within the West Puerto Chiquito Mancos oil pool, in Rio Arriba County, New Mexico, described as follow:

Township 26 North, Range 1 East
Section 19: All
Section 20: W/2
Section 29-32: All

Township 26 North, Range 1 West
Sections 1-36: All

Township 25 North, Range 1 East
Sections 5-8: All
Sections 17-20: All
Section 29: W/2
Sections 30-31: All

Township 25 North, Range 1 West
Sections 1-36: All

Townships 24 North, Range 1 East
Sections 6-7: All
Section 8: W/2
Section 17: W/2
Section 18: All
Section 19: N/2
Section 20: NW/4

Township 24 North, Range 1 West
Sections 1-15: All
Section 23: N/2
Section 24: N/2

RULE 2. The allowable for the Project shall be the sum of the allowables of the several wells within the project area, including those wells which are shut-in, curtailed, or used as injection wells. Allowables for all wells shall be determined in a manner hereinafter prescribed.

RULE 3. Allowables for injection wells may be transferred to producing wells within the project area, as may the allowables for producing wells which, in the interest of more efficient operation of the Project, are shut-in or curtailed because of high gas-oil ratio or are shut-in for any of the following reasons: pressure regulation, control of pattern or sweep efficiencies, or to observe changes in pressures or changes in characteristics of reservoir liquids or progress of sweep.

RULE 4. The allowable assigned to any well which is shut-in or which is curtailed in accordance with the provisions of Rule 3, which allowable is to be transferred to any well or wells in the project area or production, shall in no event be greater than its ability to produce during the test prescribed by Rule 6 below, or greater than the current top unit allowable for the pool during the month of transfer, whichever is less.

RULE 5. The allowable assigned to any injection well on a 640-acre proration unit shall be top unit allowable for the West Puerto Chiquito Mancos Oil Pool.

RULE 6. The allowable assigned to any well which is shut-in or curtailed in accordance with Rule 3, shall be determined by a 24-hour test at a stabilized rate of production, which shall be the final 24-hour period of a 72-hour test throughout which the well should be produced in the same manner and at a constant rate. The daily tolerance limitation set forth in Commission Rule 502 I (a) and the limiting gas-oil ratio (1000 to 1) for the West Puerto Chiquito Mancos Oil Pool shall be waived during such tests. The project operator shall notify all operators offsetting the well, as well as the Commission, of the exact time such tests are to be conducted. Tests may be witnessed by representatives of the offsetting operators and the Commission, if they so desire.

RULE 7. The allowable assigned to each producing well in the Project shall be equal to the well's ability to produce or to top unit allowable for the West Puerto Chiquito Mancos Oil Pool, whichever is less, provided that any producing well in the project area which directly or diagonally offsets a well outside the Canada Ojitos Unit Area producing from the same common source of supply shall not produce in excess of top unit allowable for the pool. Production of such well at a higher rate shall be authorized only after notice and hearing. Each producing well shall be subject to the limiting gas-oil ratio (1000 to 1) for the West Puerto Chiquito Mancos Oil Pool except that any well or wells within the project area producing with a gas-oil ratio in excess of 1000 cubic feet of gas per barrel of oil may be produced on a "net" gas-oil ratio basis, which net gas-oil ratio shall be determined by applying credit for daily average gas injected, if any, into the West Puerto Chiquito Mancos Oil Pool within the project area to such high gas-oil ratio well. The daily adjusted oil allowable for any well receiving gas injection credit shall be determined in accordance with the following formula:

$$A_{adj} = \frac{TUA \times F_a \times 1,000}{\frac{P_g - I_g}{P_o}}$$

where A_{adj} = the well's daily adjusted allowable.

TUA = top unit allowable for the pool.

F_a = the well's acreage factor (1.0 if one well on a 640 acre proration unit or 1/2 each if two wells on a 640 acre unit, and 1/2 for a well in a section along the Gavilan boundary which lies closer than 2310' from the Gavilan boundary).

P_g = average daily volume of gas produced by the well during the second preceding month, cubic feet.

I_g = the well's allocated share of the daily average gas injected during the preceding month, cubic feet.

P_o = average daily volume of oil produced by the well during the preceding month, barrels.

In no event shall the amount of injected gas being credited to a well be such as to cause the net gas-oil ratio, $\frac{P_g - I_g}{P_o}$ to be less than 1000 cubic feet of gas per barrel of oil produced.

RULE 8. Each month the project operator shall, within two weeks after the normal unit allowable for Northwest New Mexico has been established, submit to the Commission a Pressure Maintenance Project Operator's Report, on a form prescribed by the Commission, outlining thereon the data required, and requesting allowables for each of the several wells in the Project as well as the total Project allowable. The aforesaid Pressure Maintenance Project Operator's Report shall be filed in lieu of Form C-120 for the Project.

RULE 9. The Commission shall, upon review of the report and after any adjustments deemed necessary, calculate the allowable for each well in the Project for the next succeeding month in accordance with these rules. The sum of the allowables so calculated shall be assigned to the Project and may be produced from the wells in the Project in any proportion except that no well outside the Project producing from the same common source of supply shall produce in excess of top allowable for that particular proration unit. Allowables from other wells may not be transferred to such well.

RULE 10. The conversion of producing wells to injection, the drilling of additional wells for injection, and expansion of the project area shall be accomplished only after approval of the same by the Secretary-Director of the Commission. To obtain such approval, the project operator shall file proper application with the Commission, which application, if it seeks authorization to convert additional wells to injection or to drill additional injection wells, shall include the following:

(1) A plat showing the location of proposed injection well, all wells within the project area, and offset operators, locating wells which offset the project area.

(2) A schematic drawing of the proposed injection well which fully describes the casing, tubing, perforated interval, and depth showing that the injection of gas will be confined to the Niobrara member of the Mancos shale.

(3) A letter stating that all offset operators to the proposed injection well have been furnished a complete copy of the application and the data of notification.

The Secretary-Director may approve the proposed injection well if, within 20 days after receiving the application, no objection to the proposal is received. The Secretary-Director may grant immediate approval, provided waivers of objection are received from all offset operators.

Expansion or contraction of the project area shall be in accordance with Rule 1, but exceptions approved by the Secretary-Director of the Commission administratively when good cause is shown therefor.

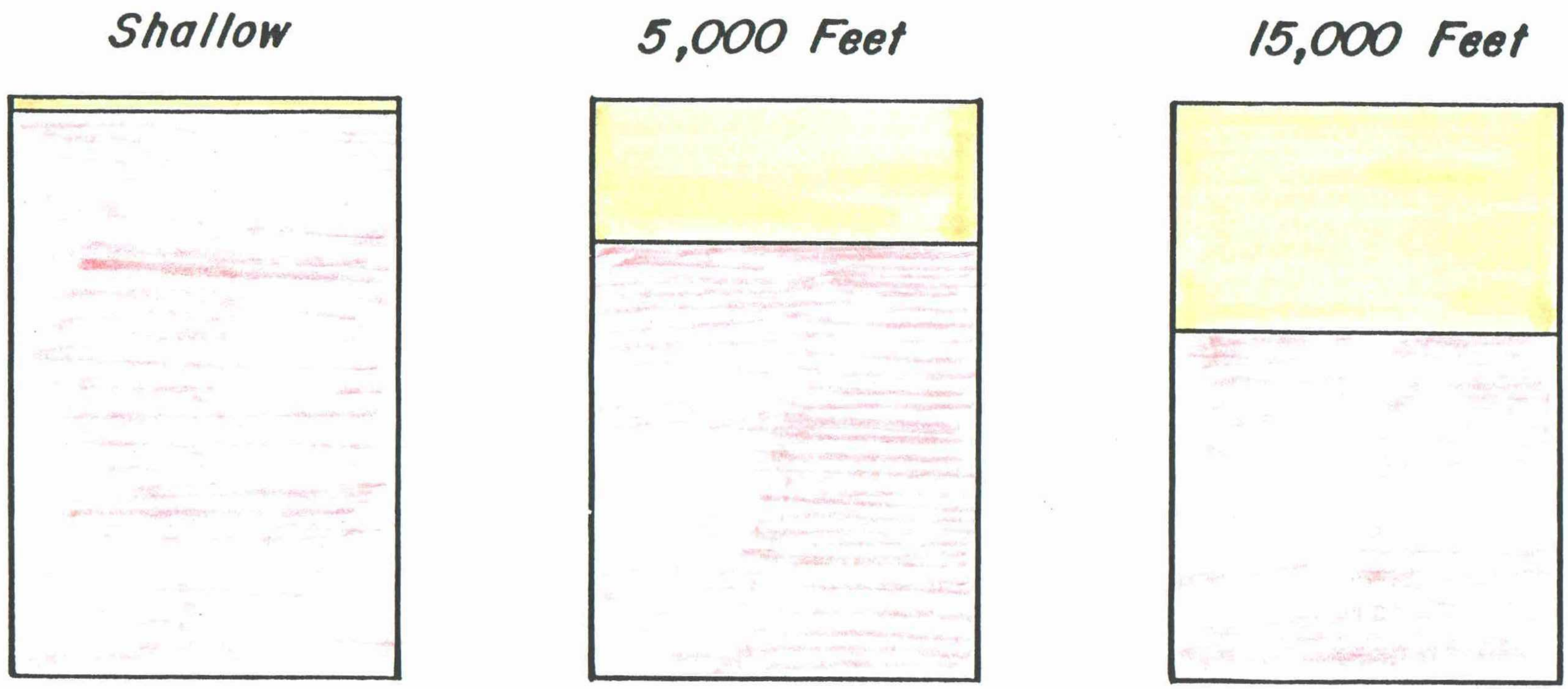
<u>RULE 11.</u> That the subject pressure maintenance project shall be governed by the provisions of Rules 701, 702 and 703 of the Commission Rules and Regulations insofar as said rules are not inconsistent with the rules prescribed by this order.

That allowables to all wells in the Canada Ojitos Unit Area but outside the limits of the B-M-G West Puerto Chiquito Mancos Pressure Maintenance Project Area as defined herein shall be assigned and produced in accordance with the applicable Commission Rules and Regulations.

That jurisdiction of this cause is retained for the entry of such further orders as the Commission may deem necessary.

KELLEY

RESERVOIR OIL NORMALLY HAS
A
SIGNIFICANT AMOUNT OF GAS DISSOLVED IN IT

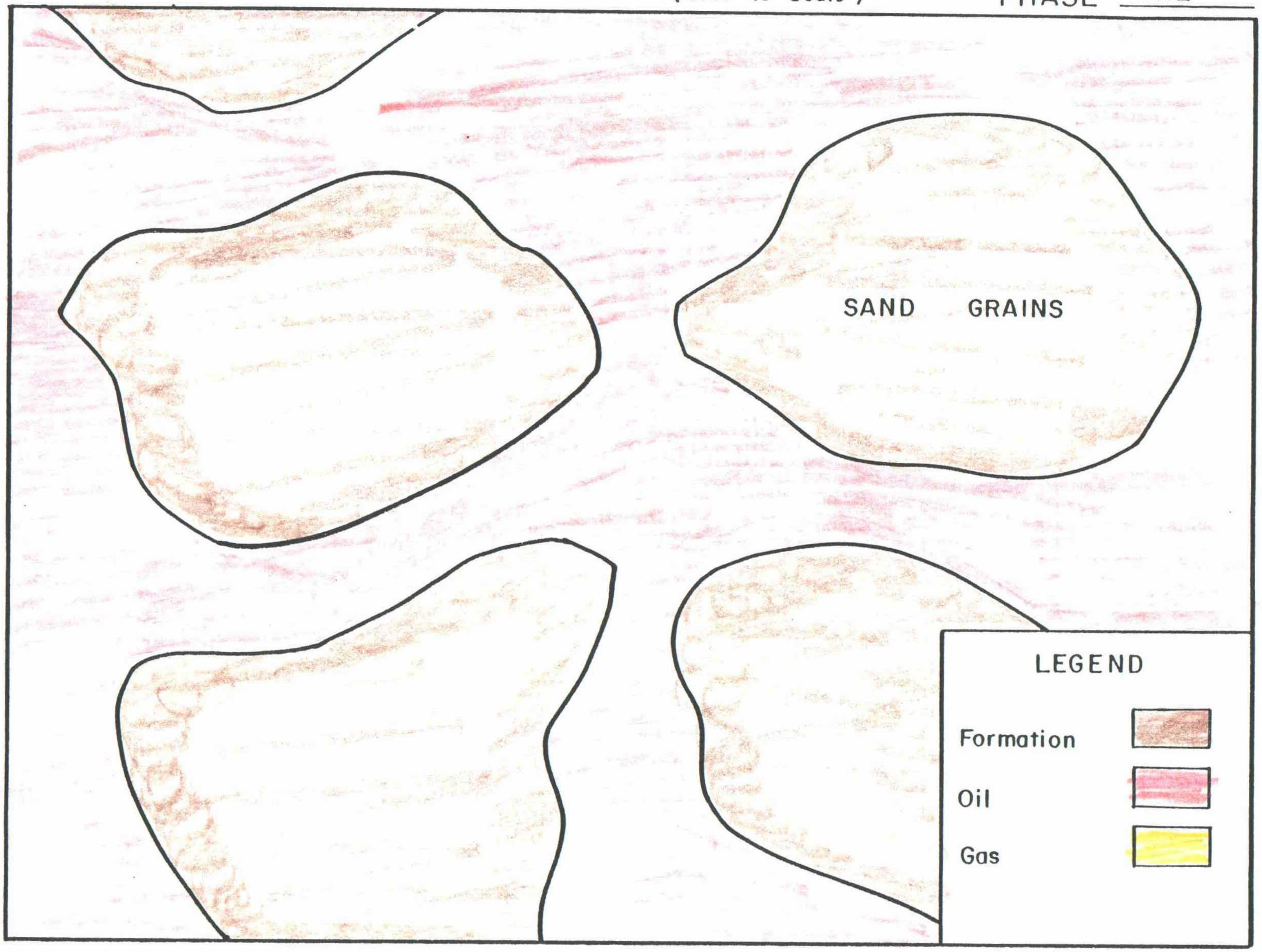


BEFORE THE
OIL CONSERVATION COMMISSION
Santa Fe, New Mexico
Case No. 8950 Exhibit No. 2
Submitted by BENSON-MONTIN-GREER
Hearing Date August 21, 1986

Ex. 2
Page 1

RELATIVE PERMEABILITY EXAMPLE — SANDSTONE RESERVOIR

(Not To Scale) PHASE ONE



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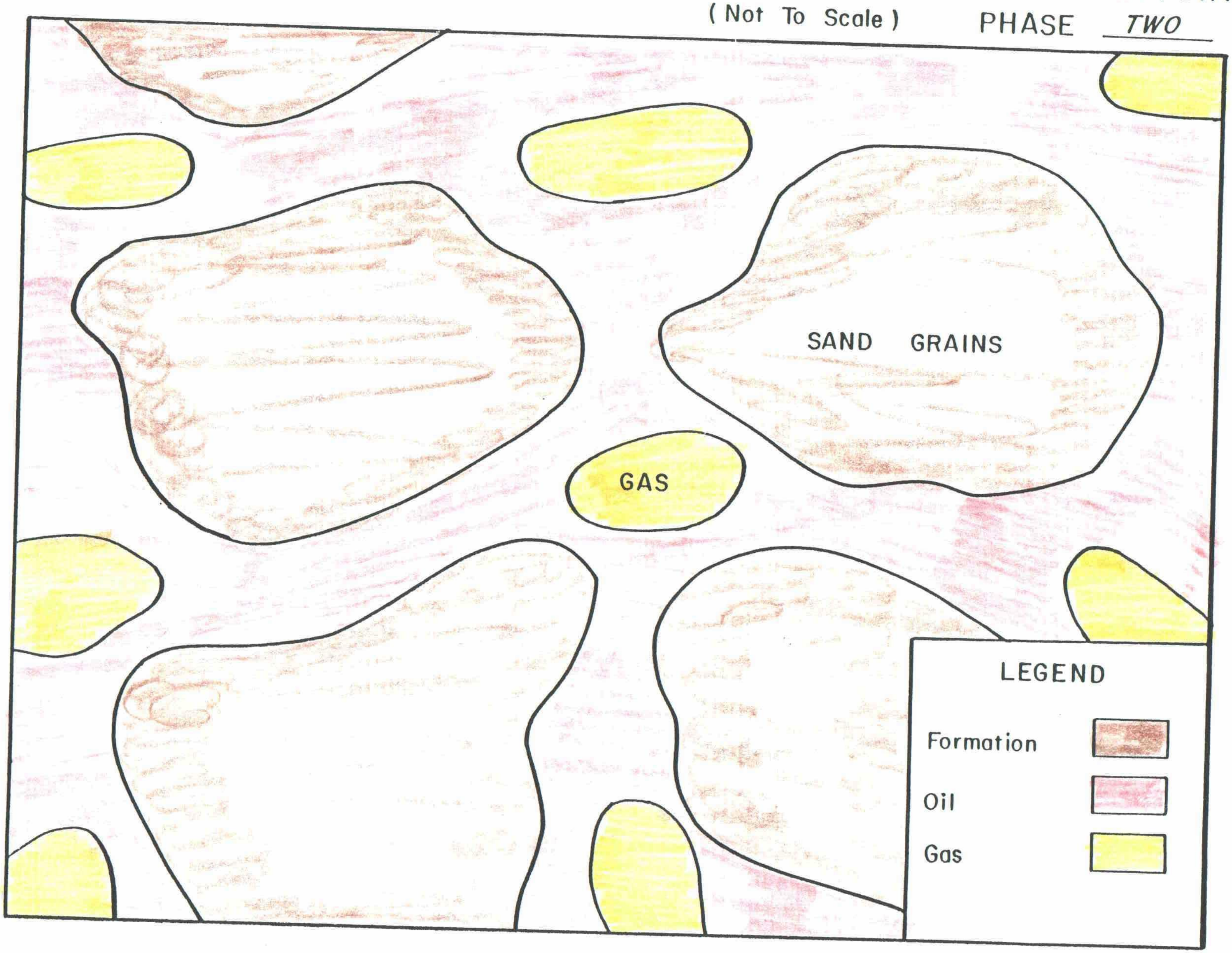
RELATIVE PERMEABILITY EXAMPLE — SANDSTONE RESERVOIR

(Not To Scale) PHASE TWO



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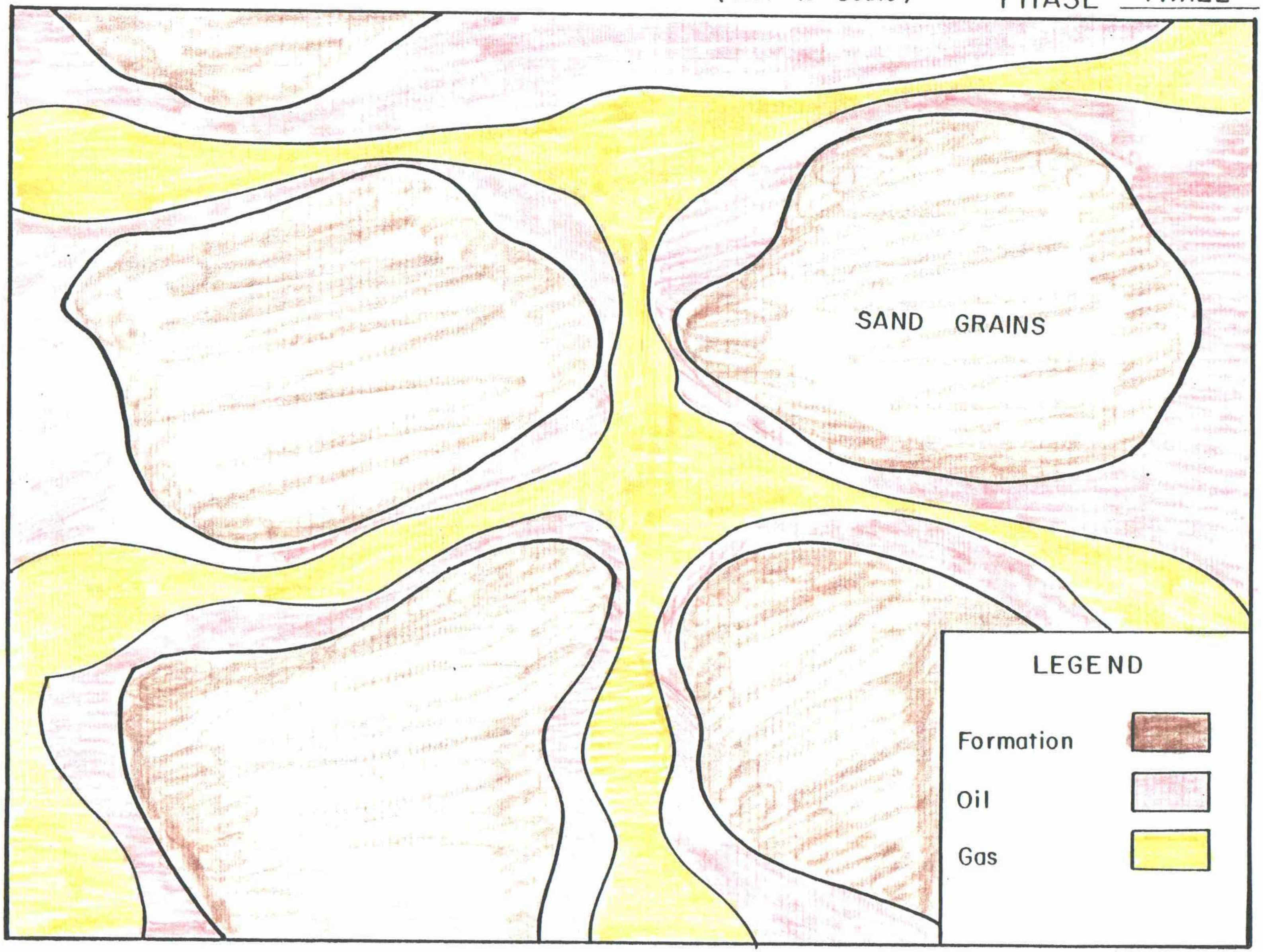
RELATIVE PERMEABILITY EXAMPLE — SANDSTONE RESERVOIR

(Not To Scale) PHASE *THREE*



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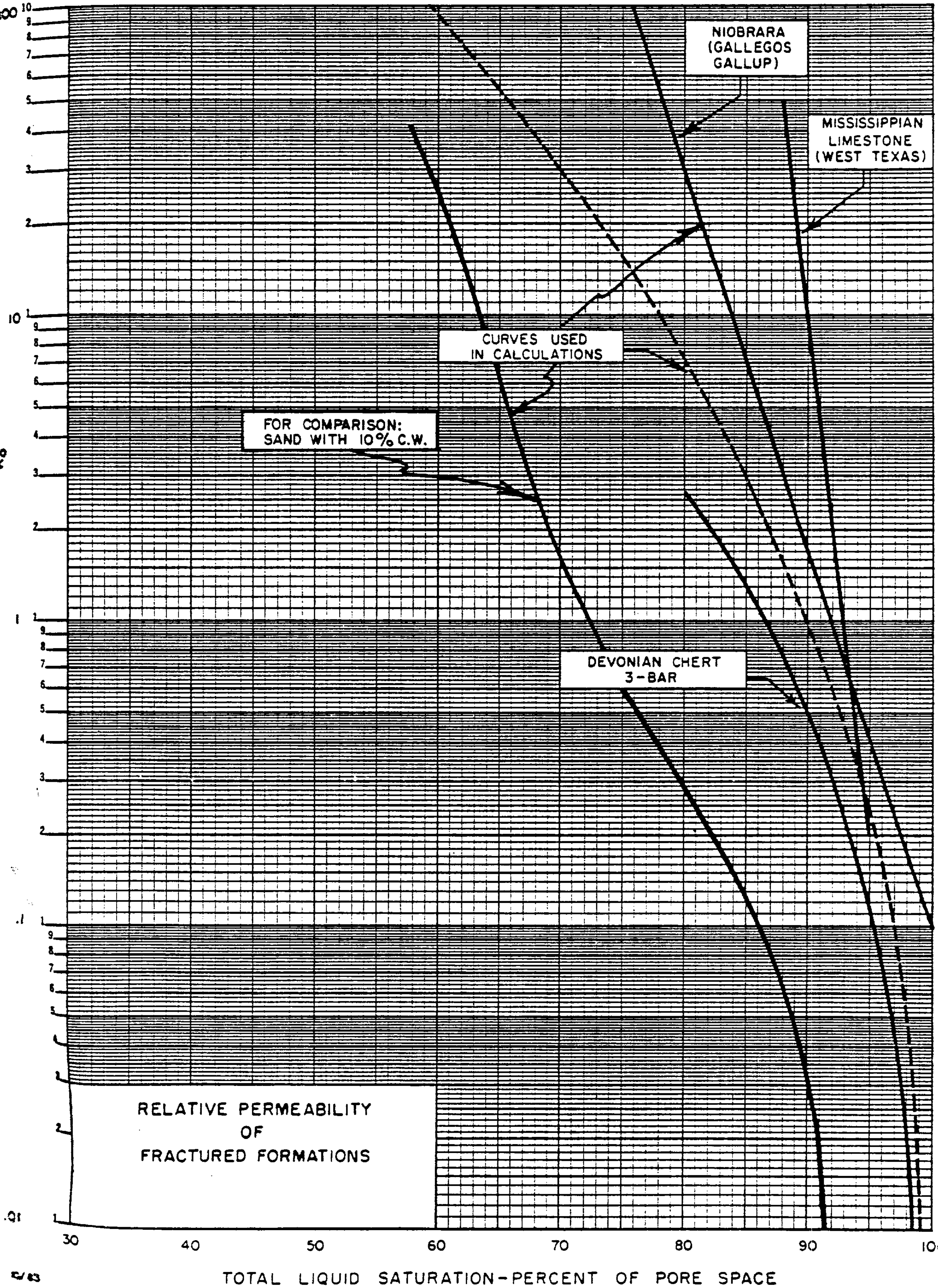
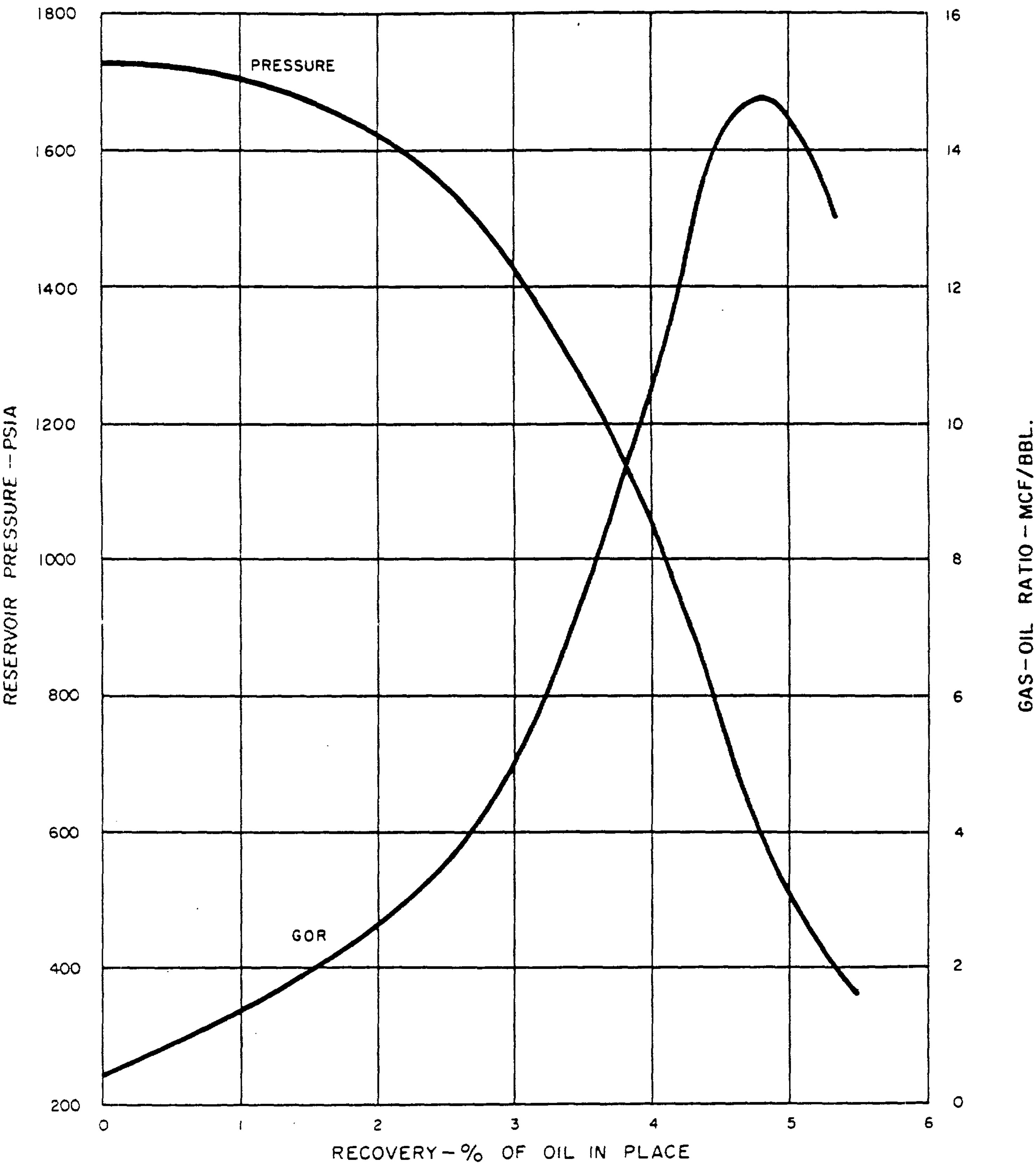

NIOBRARA (GALLEGOS GALLUP)
MISSISSIPPIAN LIMESTONE (WEST TEXAS)
CURVES USED IN CALCULATIONS
FOR COMPARISON: SAND WITH 10% C.W.
DEVONIAN CHERT 3-BAR
RELATIVE PERMEABILITY OF FRACTURED FORMATIONS
100
10
1
.1
.01
30
40
50
60
70
80
90
100
TOTAL LIQUID SATURATION-PERCENT OF PORE SPACE

SOLUTION GAS DRIVE
PRODUCTION HISTORY

FOR A FRACTURED RESERVOIR
WITH PVT DATA
SIMILAR TO GAVILAN

Ex. 2
Page 6



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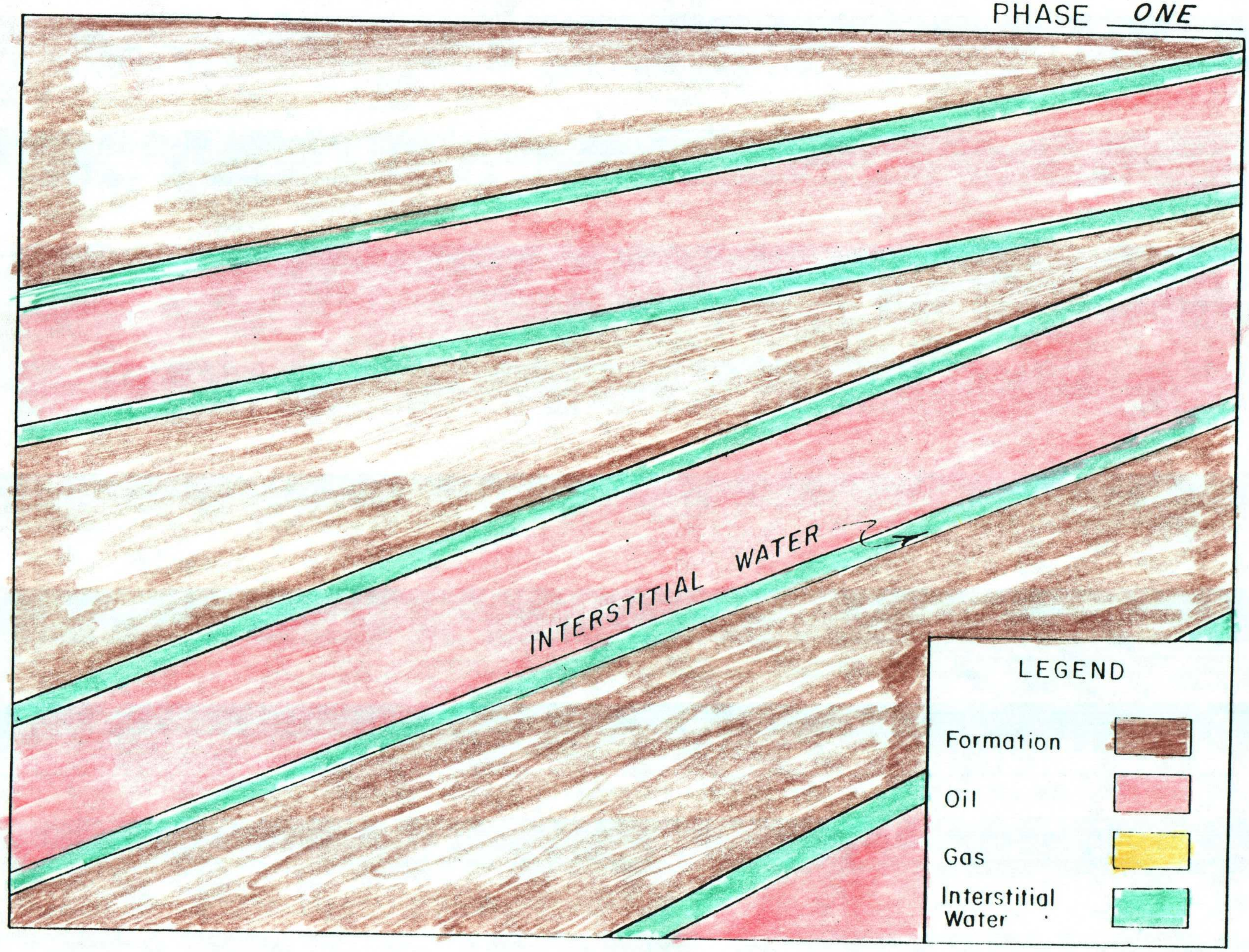
RELATIVE PERMEABILITY EXAMPLE
FRACTURED RESERVOIR — NO MATRIX POROSITY

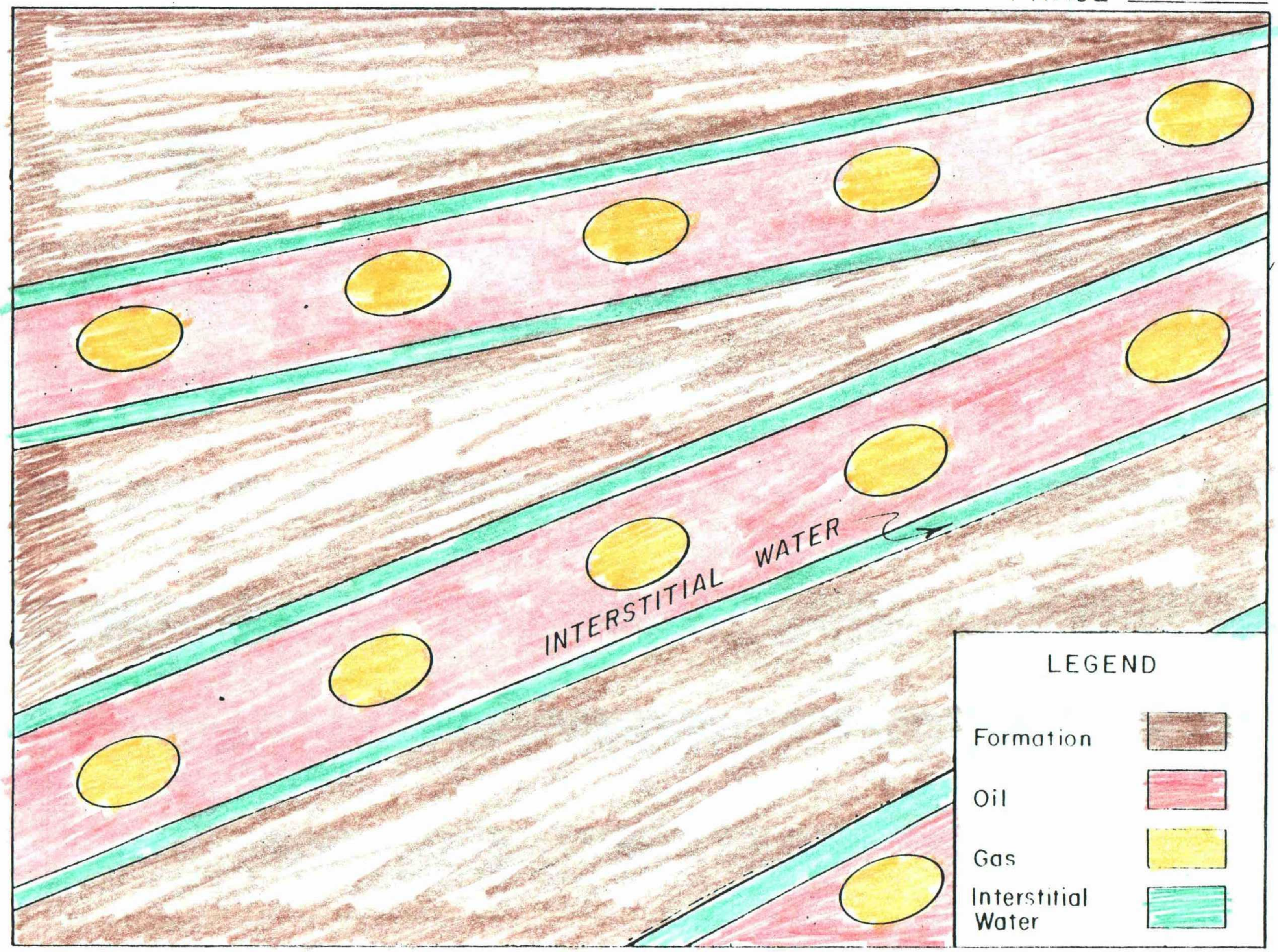
PHASE ONE



(Not To Scale)

RELATIVE PERMEABILITY EXAMPLE
FRACTURED RESERVOIR — NO MATRIX POROSITY

PHASE _TWO_



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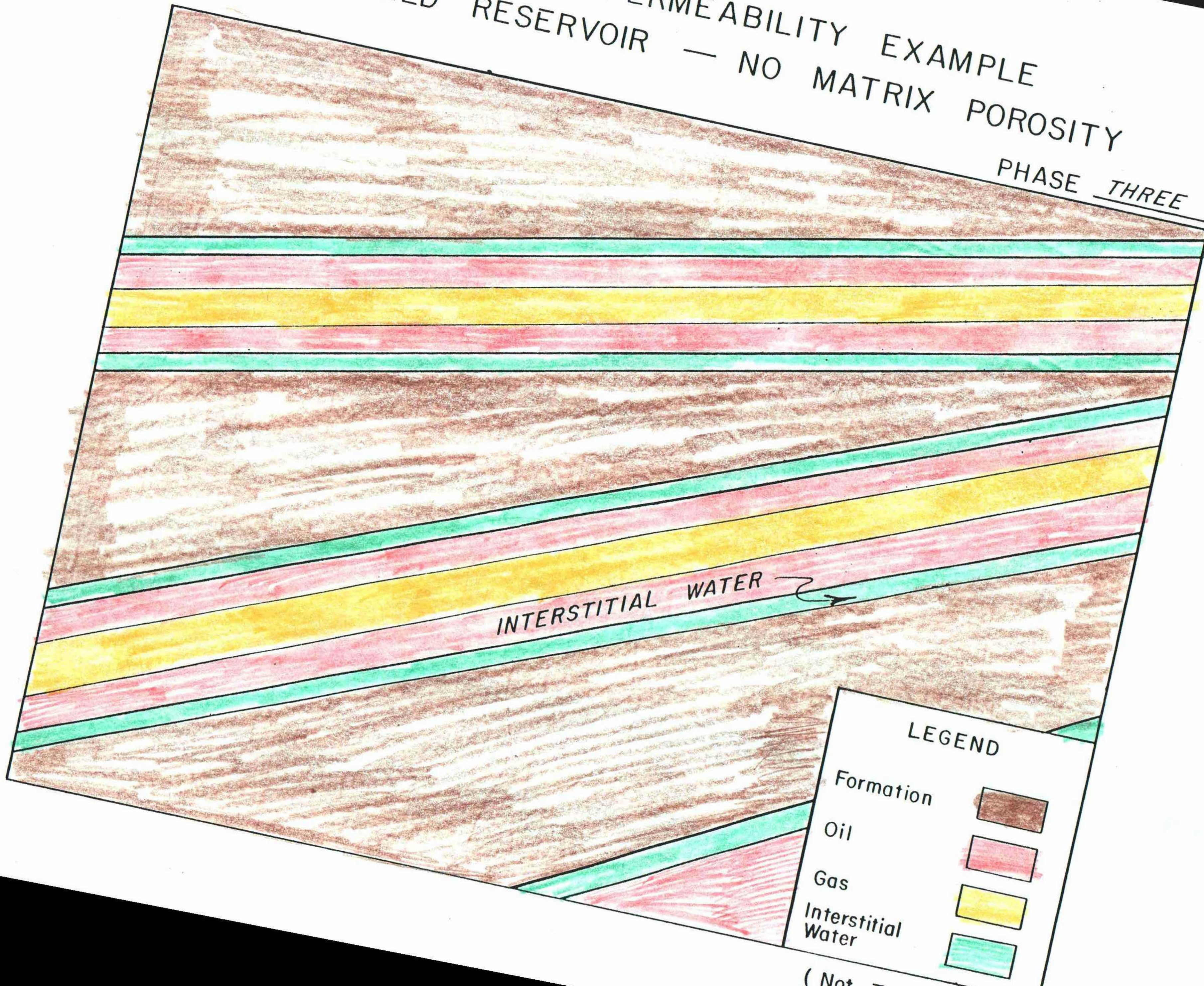
RELATIVE PERMEABILITY EXAMPLE
FRACTURED RESERVOIR — NO MATRIX POROSITY

PHASE THREE



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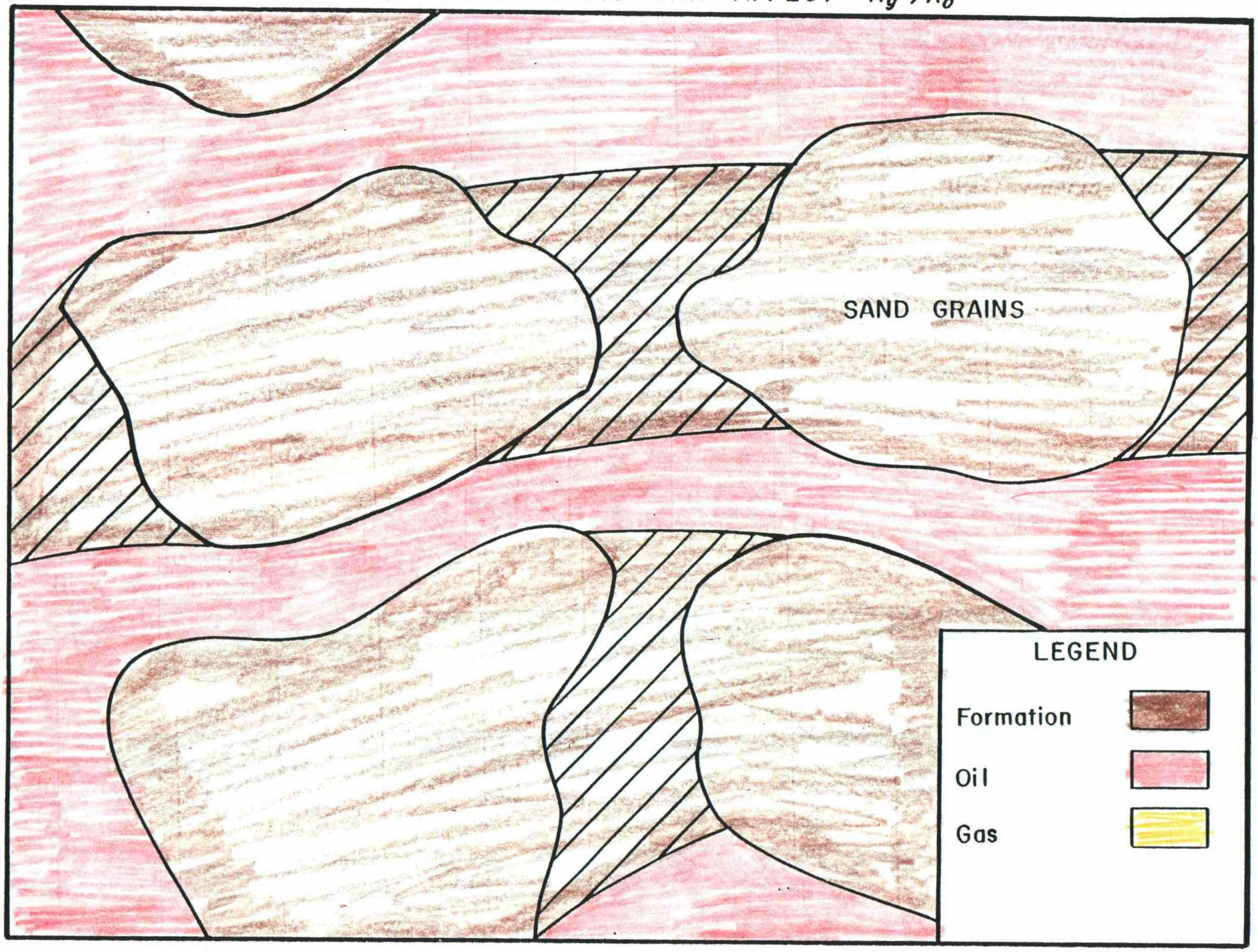
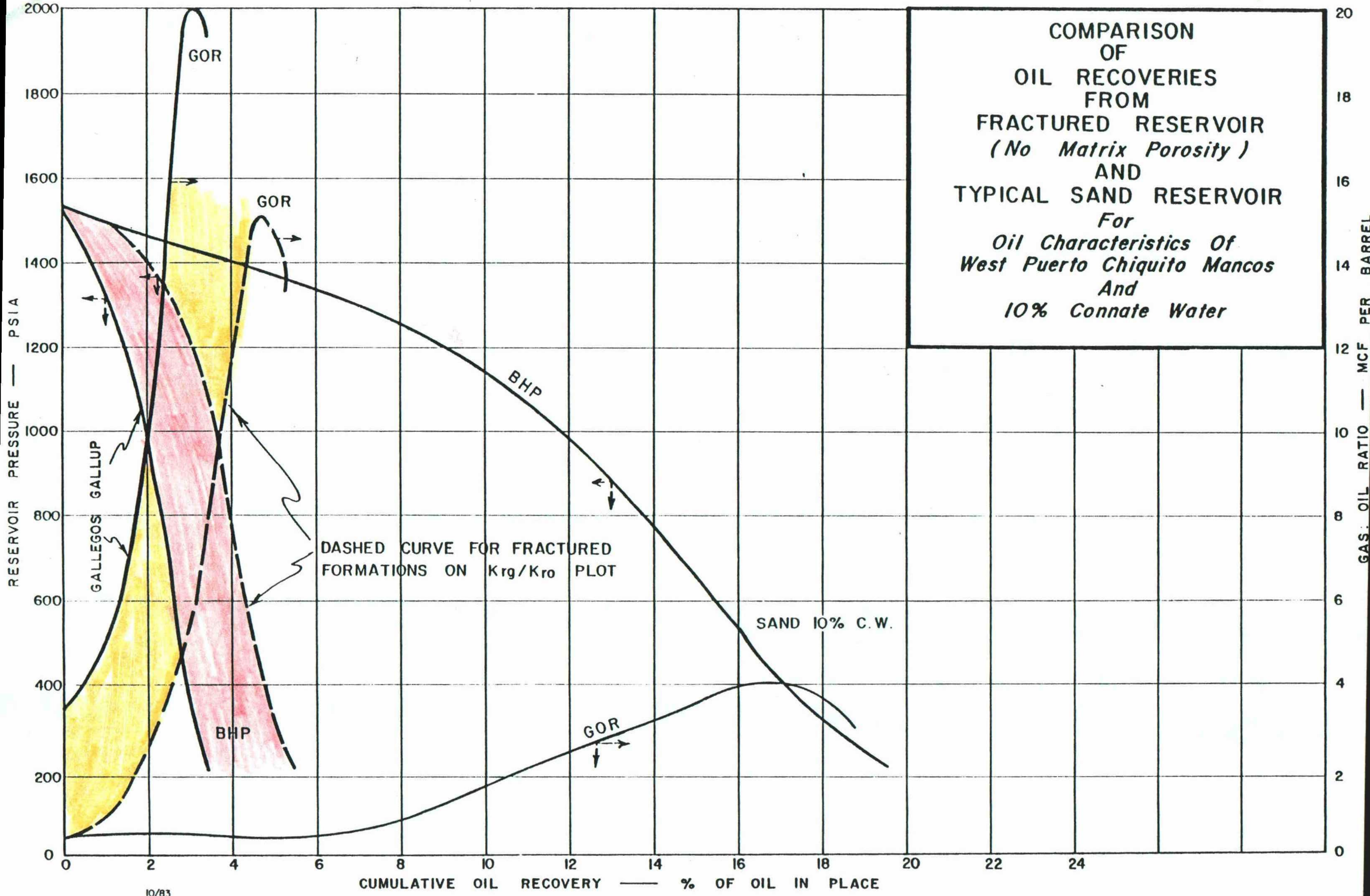
RELATIVE PERMEABILITY EXAMPLE — SANDSTONE RESERVOIR

"CEMENTING" OF SAND GRAINS CAN AFFECT K_g / K_o



(Not To Scale)

11/83 cs


COMPARISON
OF
OIL RECOVERIES
FROM
FRACTURED RESERVOIR
(No Matrix Porosity)
AND
TYPICAL SAND RESERVOIR
For
Oil Characteristics Of
West Puerto Chiquito Mancos
And
10% Connate Water
RESERVOIR PRESSURE — PSIA
GAS: OIL RATIO — MCF PER BARREL
CUMULATIVE OIL RECOVERY — % OF OIL IN PLACE
GOR
GOR
GOR
BHP
BHP
GALLEGOS
GALLUP
DASHED CURVE FOR FRACTURED FORMATIONS ON Krg/Kro PLOT
SAND 10% C.W.
10/83

OIL CONSERVATION DIVISION

MR. KELLY

BENSON-MONTIN-GREER DRILLING CORP.
EXHIBITS IN CASE NOS. 8946 & 8950
BEFORE THE OIL CONSERVATION DIVISION OF THE
NEW MEXICO DEPARTMENT OF ENERGY AND MINERALS

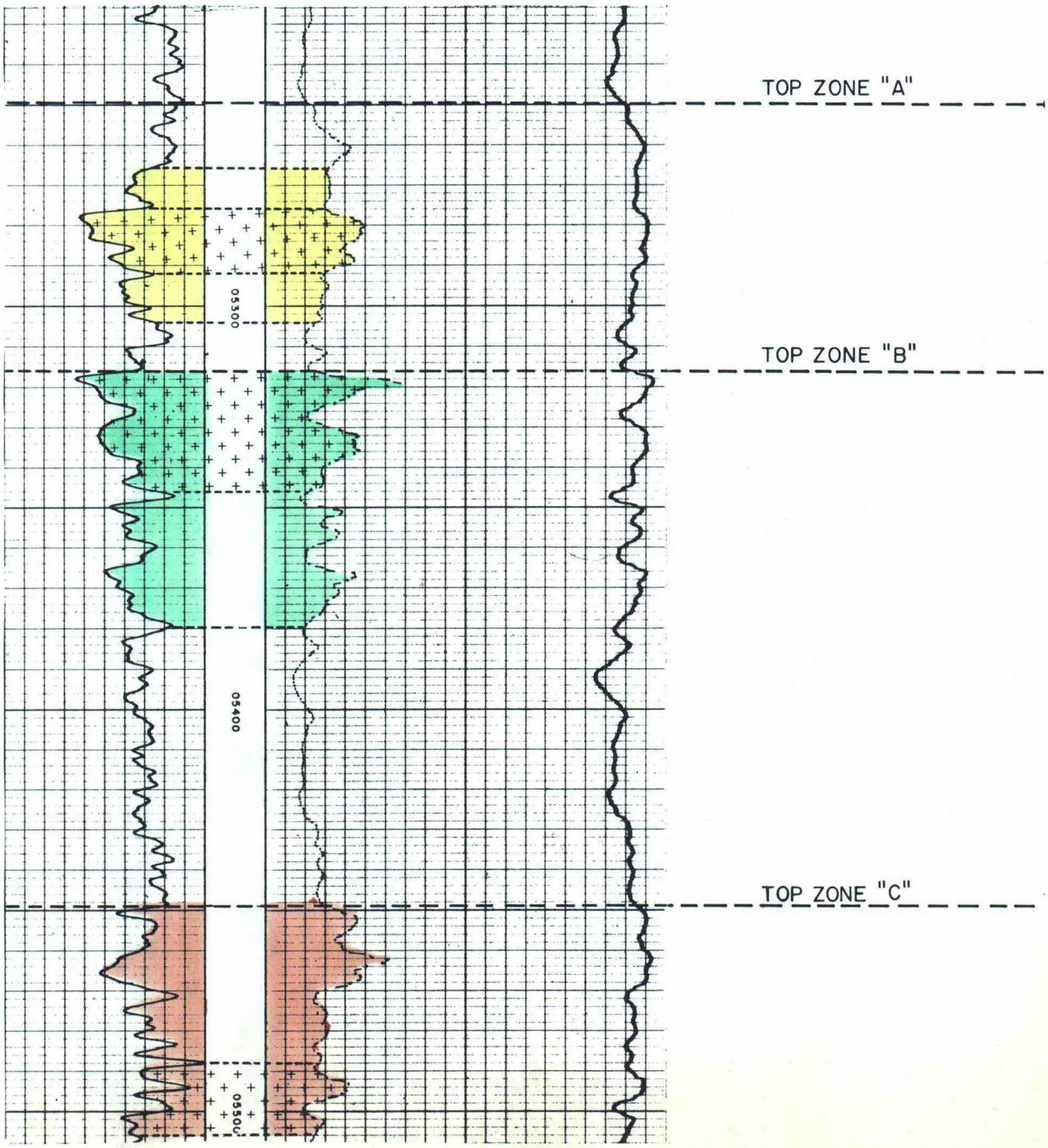
AUGUST 7, 1986

NMOCC/NMOCD Case No. 8950
Hearing Date 8/21/86
Benson-Montin-Greer
Exhibit No. 3

IDENTIFICATION OF MAIN PRODUCING ZONES
NORTHEAST PUERTO CHIQUITO
AND
SOUTHWEST PUERTO CHIQUITO

BENSON-MONTIN-GREER DRLG. CORP.

CAÑADA OJITOS UNIT NO. B-18



PHYSICAL PRINCIPLES OF OIL PRODUCTION

By MORRIS MUSKAT, Ph.D.
DIRECTOR OF PHYSICS DIVISION
GULF RESEARCH & DEVELOPMENT COMPANY

First Edition

NEW YORK TORONTO LONDON
McGRAW-HILL BOOK COMPANY, INC.
1949

where k_o is the permeability to oil, μ_o is the oil viscosity, $\Delta\gamma$ is the density difference between the oil and gas,[1] and θ is the dip angle. If h be the thickness of the oil zone normal to the direction of dip, the volume rate

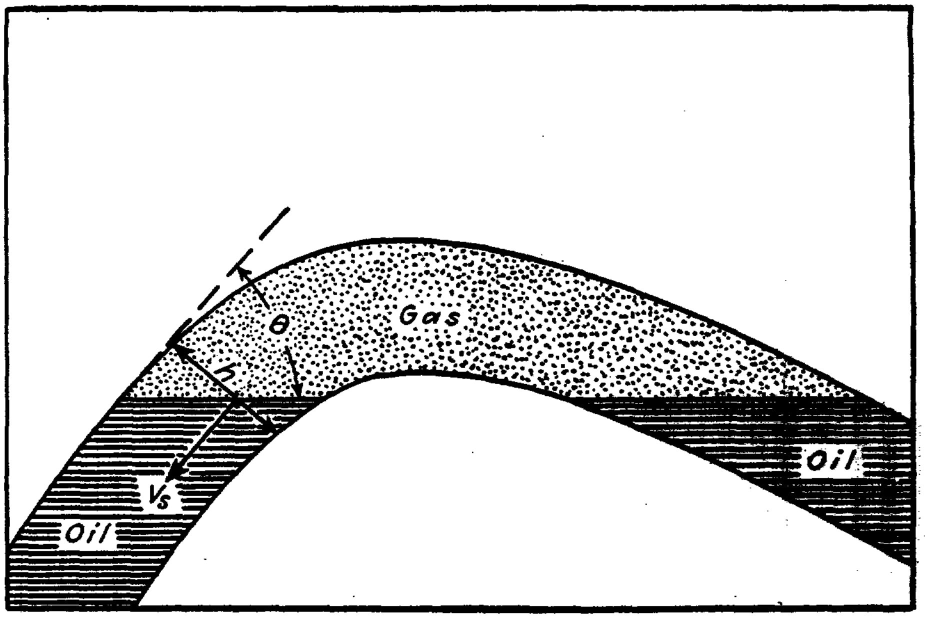


FIG. 10.39.

of oil downdip free-fall migration, in stock-tank measure, will be

$$Q_o = v_s h = \frac{k_o \Delta\gamma g h \sin\theta}{\mu_o \beta_o}, \tag{2}$$

per unit distance parallel to the strike, β_o being the formation-volume factor of the oil. The drainage per unit projected surface area of gas-oil contact is therefore

$$Q = \frac{k_o \Delta\gamma g \sin^2\theta}{\mu_o \beta_o} = 21.29 \frac{k_o \Delta\gamma \sin^2\theta}{\mu_o \beta_o} \text{ (bbl/day)/acre}, \tag{3}$$

where k_o is expressed in millidarcys and $\Delta\gamma$ as a specific gravity. The corresponding rate of vertical fall of the gas-oil-contact plane will be[2]

$$v_z = 2.744 \times 10^{-3} \frac{k_o \Delta\gamma \sin^2\theta}{\mu_o \bar{f}} \text{ ft/day}, \tag{4}$$

where $\bar{f}$ is the net porosity vacated by the oil drainage.

[1] If the gas phase is immobile and not continuous, there will be no buoyancy reaction on the oil due to the gas and $\Delta\gamma$ should be replaced by the oil density γ.

[2] In practice the gas-oil contact will not lie strictly in a plane because of permeability variations. Moreover, even if the permeability were uniform, the gas-oil contact would be a capillary transition zone rather than a sharp geometrical plane (cf. Sec. 7.9).

OIL RECOVERIES UNDER GRAVITY DRAINAGE DEPLETION AND PRESSURE MAINTENANCE AS DEPENDENT ON PHYSICAL RESERVOIR CHARACTERISTICS AND AS AFFECTED BY WELL SPACING

FRACTURED SHALE RESERVOIRS

NIOBRARA MEMBER OF THE
MANCOS SHALE FORMATION

WEST PUERTO CHIQUITO POOL
RIO ARRIBA COUNTY, NEW MEXICO

ALBERT R. GREER

DECEMBER, 1969

PART B - METHOD OF CALCULATING GRAVITY DRAINAGE RATES

Muskat (Reference No. 4) has shown the equation giving maximum possible gravity drainage rates. This equation , in terms of barrels per day per surface acre of gas-oil contact, is:

$$Q = \frac{21.29\ kd\ \sin^2 \theta}{\mu\ B} \qquad (VI - 2)$$

where Q = gravity drainage rate, barrels per day per surface acre of gas-oil contact

k = permeability to oil, md

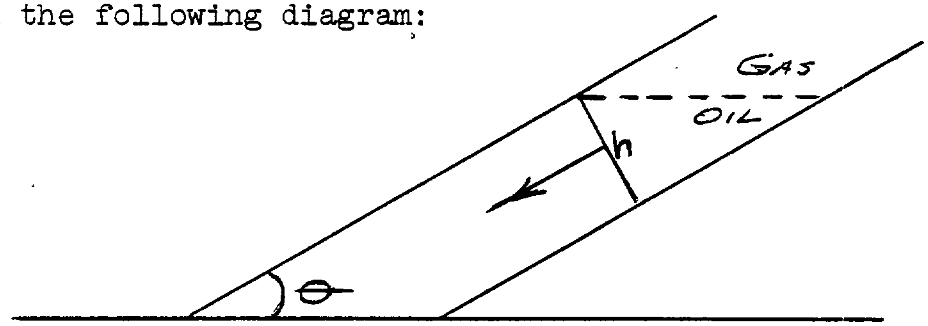
d = difference in specific gravities of oil and gas (water = 1.0)

μ = oil viscosity, cp

B = FVF of oil

θ = angle of dip of formation

The formation thickness and dip of the beds are shown schematically in the following diagram:



With reference to the above sketch, we may determine the surface area of gas-oil contact to be: (per linear mile along the strike)

$$\text{Area of contact} = \left(\frac{h}{\sin \theta}\right)\left(\frac{5,280}{43,560}\right) = .121\ \frac{h}{\sin \theta} \qquad (VI - 3)$$

Multiplying Equation VI-2 by Equation VI-3, and converting to darcys, yields: $\left(\frac{BOPD}{Acre} \times \frac{Acres}{mile} = \frac{BOPD}{mile}\right)$

$$Q = \frac{2{,}580\ h\ K\ d\ \sin\theta}{\mu\ B} \qquad \text{(VI - 4)}$$

where Q - gravity drainage rate in BOPD per linear mile of gas-oil contact along the strike

which is an equation useful to us, as we now have the gravity drainage rate in terms of properties we can determine directly from well tests (transmissibility) or other readily available sources. As stated in Part II of the text, this formula is used to calculate the gravity drainage rates shown on Figure 5.

TRANSACTIONS

OF THE

American Institute of Mining and Metallurgical Engineers

(INCORPORATED)

Volume 179

PETROLEUM DEVELOPMENT AND TECHNOLOGY 1949

PETROLEUM BRANCH

PAPERS AND DISCUSSIONS PRESENTED AT MEETINGS HELD AT LOS ANGELES, OCT. 23–24, 1947; DENVER, SEPT. 28–OCT. 2, 1947; TULSA, OCT. 8–10, 1947; NEW YORK, FEB. 15–19, 1948; DALLAS, OCT. 4–6, 1948; AND LOS ANGELES, OCT. 14–15, 1948; ALSO SEVERAL NOT PRESENTED AT ANY MEETING.

PUBLISHED BY THE INSTITUTE
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29 WEST 39TH STREET
NEW YORK 18, N. Y.

TRANSACTIONS
AIME 1949
VOL 179

CHAPTER IV. *Research Engineering*

Lance Creek Sundance Reservoir Performance—a Unitized Pressure-maintenance Project

BY LINCOLN F. ELKINS,* R. W. FRENCH† AND WAYNE E. GLENN,‡ MEMBERS AIME

(Denver and Tulsa Meetings, September–October 1947)

ABSTRACT

THE Lance Creek Sundance reservoir provides a case history of 10 years performance of a reservoir in which unit operation has permitted effective utilization of gravity drainage augmented by primary pressure control with injection of gas into top structural wells. Detailed performance of the reservoir is presented by means of maps of well status, reservoir pressure, individual well recovery, etc., and by pool-performance charts. Analysis of reservoir performance indicates only minor water encroachment, so that gravity, injected gas, and expansion of gas are the main oil-expulsive agents.

A simplified theory of regional drainage of oil from upstructure location to downstructure location due to gravity is presented and checked by means of comparison of "reservoir" permeability and "well" permeability from the pool performance. Good order of magnitude agreement was obtained.

Individual well performance and overall reservoir performance indicate possibility that maintenance of pressure makes ineffective those parts of the reservoir in which permeability is too low to permit effective drainage of oil by action of gravity. Oil from these parts can be recovered only when pressure is reduced locally by selective withdrawal or when overall reservoir pressure is finally reduced.

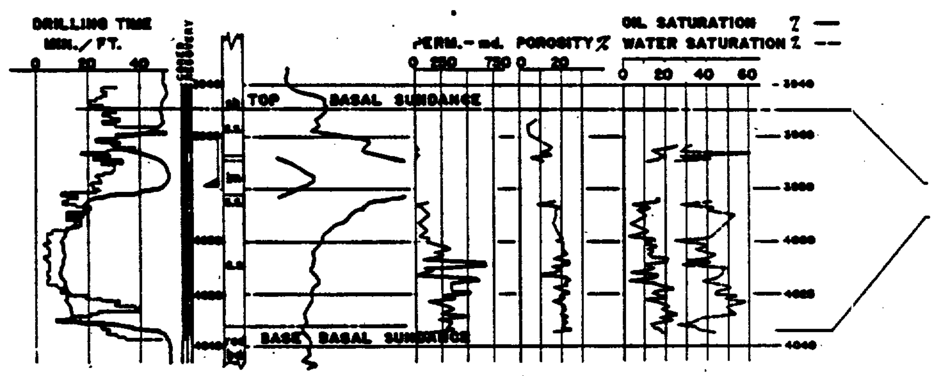

FIG 1—COLUMNAR SECTION AND COMPOSITE LOG, LANCE CREEK FIELD.

INTRODUCTION

The Lance Creek oil field, Townships 35 and 36N, Range 65W, Niobrara County, Wyoming, was discovered in October 1918, when Ohio Well No. State 1 was

Manuscript received at the office of the Institute Sept. 7, 1947. Issued as TP 2401 in PETROLEUM TECHNOLOGY, July 1948.

* Continental Oil Co., Ponca City, Okla.; present address The Standard Oil Co. (Ohio), Oklahoma City, Okla.
† The Standard Oil Co. (Ohio), Oklahoma City, Okla.
‡ Continental Oil Co., Ponca City, Okla.

separation of oil and gas. In an underground petroleum reservoir, this is partly offset by capillary forces, which primarily control ultimate segregation, and frictional or viscosity effects, which primarily control rate of segregation. Gravity segregation can be minimized by production of upstructure wells at high gas-oil ratios; it can be made quite effective by unit operation with countercurrent flow of oil and gas; and it can be made most effective with sufficient gas injection upstructure to fill the space voided by downdip drainage of oil. Gravity drainage cannot be increased—according to the popular misconception—by "piston-like" action of high-pressure gas in a gas cap. Gas pressure can force oil to flow downdip at a rate faster than gravity drainage, but gas will flow also in accordance with effective permeabilities of the rock to gas and to oil and in accordance with potential gradients in each of gas and oil phases. Overall efficiency in terms of gas-oil ratios will be better than gas injection into a similar flat reservoir, but it will not be the same as true gravity drainage in which no gas but solution gas is produced.

Making only the one basic assumption of applicability of Darcy's law of fluid flow in porous media and using measurable physical characteristics of the reservoir rock and fluids, it is possible to calculate with reasonable accuracy the *maximum* rate at which oil can drain by gravity from upstructure to downstructure regions. Certain features of the operation of the reservoir can reduce the rate of drainage, but at least the maximum rate has practical significance in determining whether a reservoir can be exploited at a desired rate by the gravity drainage method.

Darcy's law for downdip flow of oil (essentially two-dimensional flow in the "curved" plane of the reservoir formation) may be expressed as:

$$Q_o = 1.127\,\frac{K_o H L}{U_o FVF}\left(\frac{dP}{dD} - d_o \sin\alpha\right) \quad [1]$$

Where

- Q_o = rate of oil flow, bbl tank oil per day.
- K_o = effective permeability to oil, darcys.
- H = thickness of formation exposed to flow, ft.
- L = length of formation exposed to flow (measured along strike or structure contour).
- U_o = viscosity of oil, centipoise.
- FVF = formation volume factor of oil.
- P = pressure in oil phase, psi.
- D = distance along dip of formation, ft.
- d_o = density gradient of oil, psi per foot.
- $\sin\alpha$ = sine of dip angle.
- 1.127 = factor to convert darcys to barrels, feet, pounds per square inch, and day system of units.

Since maximum gravity drainage will occur in presence of static gas, and since pressure at each point in the reservoir will be the same in gas and oil phases except for a small difference in capillary pressure, the downdip pressure gradient in the gas-oil region may be calculated from the gas density gradient and will be given by the formula:

$$\frac{dP}{dD} = d_g \sin\alpha \quad [2]$$

where

d_g = density gradient of gas, psi per foot.

Combining this with Eq 1 gives:

$$Q_o = 1.127\,K_o H_o \frac{(d_o - d_g)}{U_o FVF} L \sin\alpha \quad [3]$$

for *maximum* gravity drainage. Since reservoirs are not perfectly symmetrical and fluid withdrawals are not uniformly distributed, the gas-oil contact will advance faster downdip in some areas than in others. Since the tendency exists for oil to seek a common level, there will be a lateral component of flow to compensate for the unequal advance, and the actual flow path will exceed the shortest downdip path and thus decrease the net downdip

FOR 1 MILE
* if use sp. gty (Water=1), with density .4335 #/in²/ft
$Q_o = (1.127\,Kh \times .4335(S_o - S_g) \times 5280 \sin\alpha) \div \mu\,(FVF)$
$= (2580\,Kh(S_o - S_g)\sin\alpha) \div \mu\,(FVF)$

GRAVITY DRAINAGE RATES
WEST PUERTO CHIQUITO

FOR CONDITIONS OF:
OIL DENSITY 44.9#/cubic foot
GAS DENSITY 5.35#/cubic foot
OIL VISCOSITY .62 centipoises

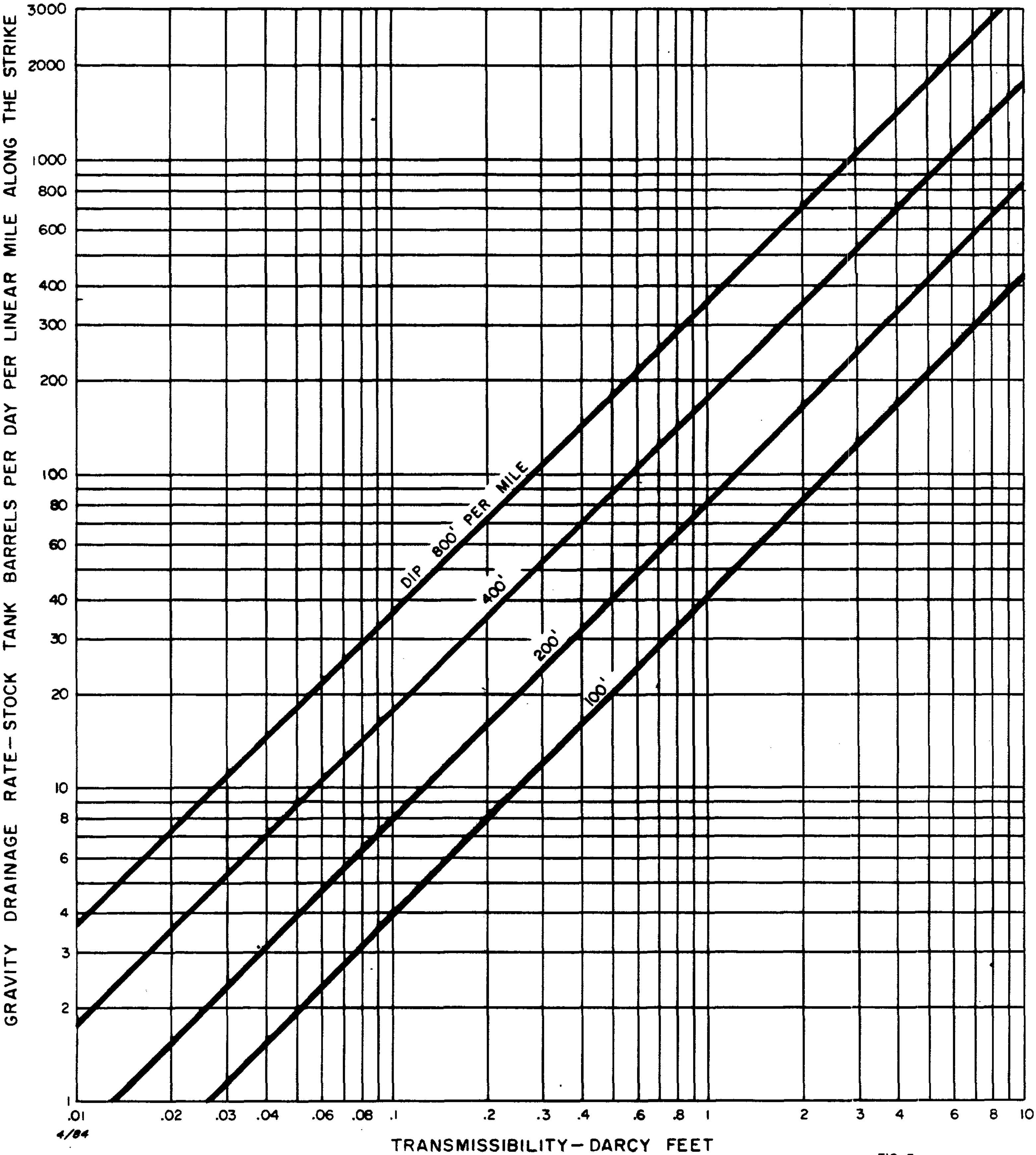

FIG. 5

COMPARISON OF GRAVITY DRAINAGE RATES FOR RESERVOIR WITH FRACTURE POROSITY WITH RESERVOIR WITH MATRIX (SAND) POROSITY

Reservoir section 1 mile wide by 3 miles down dip
Formation dip 100 feet per mile (assume vertical permeability = 0)

	Sand Reservoir	Fracture Reservoir
Transmissibility (darcy feet)	10	10
Thickness	20	?
Porosity (H.C.), percent	20	?
Permeability, horizontal (millidarcies)	500	?
Oil-in-place, STB/acre	31000	3000
Oil-in-place 3 square mile section (Mbbl)	60000	5800
Solution gas drive recovery Percent oil-in-place	± 20	± 6
Barrels/acre	6000	200
Barrels for 3 square mile section (Mbbls)	11500	380
Gravity drainage recovery At 1/2 of maximum of 55% of oil in place (bbls/acre)	8500	800
Barrels for 3 square mile section (Mbbls)	16000	1500
Gravity drainage rate BOPD/linear mile along strike	200	200
Years at gravity drainage rate to reach equivalent solution gas drive recovery	157	5.2
Years at gravity drainage rate to obtain gravity drainage reserves	220	21

OIL CONSERVATION DIVISION

MR. KELLY

BENSON-MONTIN-GREER DRILLING CORP.
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BEFORE THE OIL CONSERVATION DIVISION OF THE
NEW MEXICO DEPARTMENT OF ENERGY AND MINERALS

AUGUST 7, 1986

NMOCC/NMOCD Case No. 8950
Hearing Date 8/21/86
Benson-Montin-Greer
Exhibit No. 4

IMPACT ON STATE REVENUE FROM TAXES BY REDUCING ALLOWABLES ON GAVILAN PRODUCTION

The Chairman has asked for information describing the impact of reduced allowables on state revenue.

In this respect, the following pertinent statistics respecting discount rates were obtained from the State Treasurer's Office during the week ending August 15, 1986.

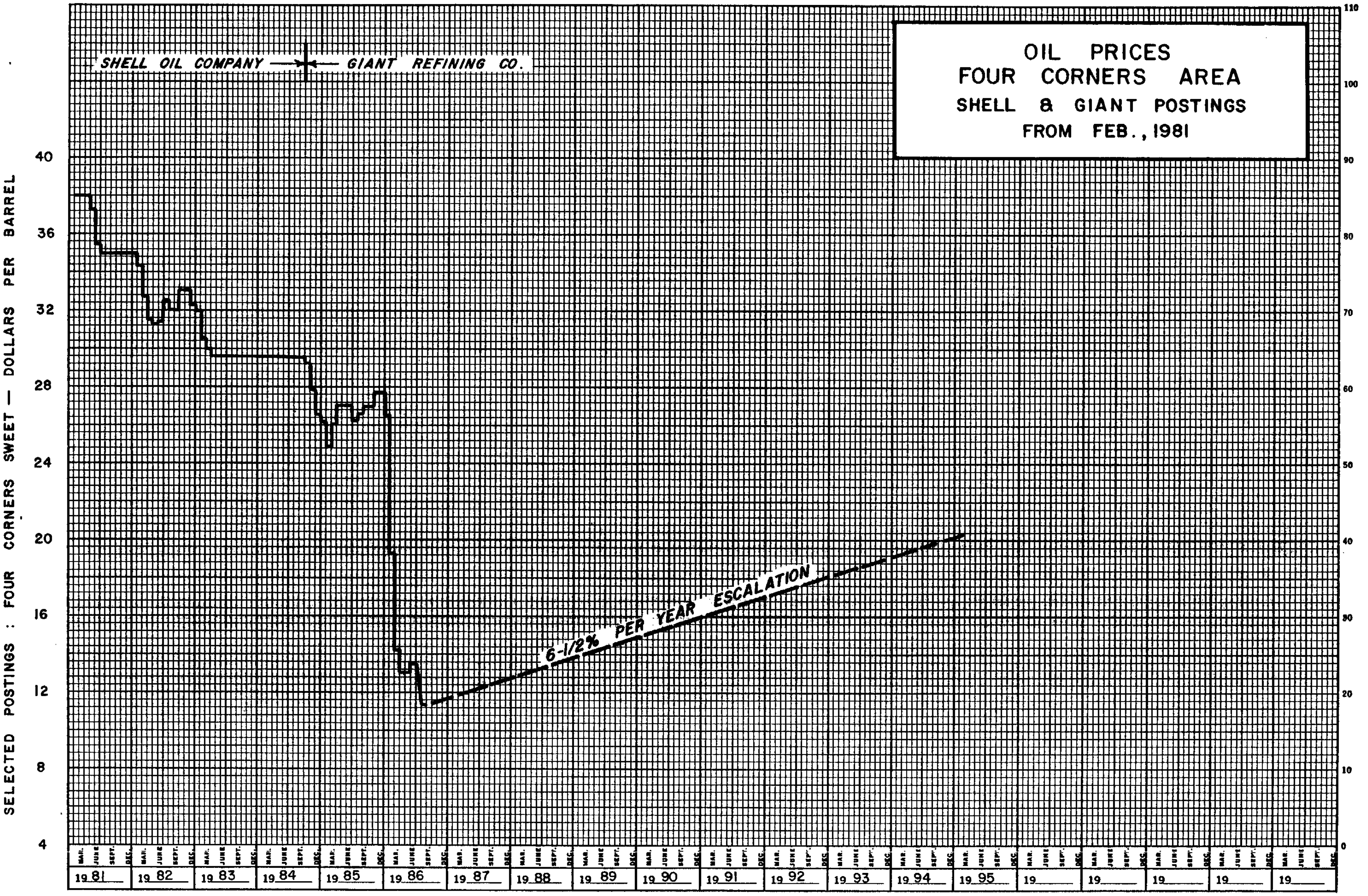
1. Current short term earnings:
   Excess funds on deposit in banks and overnight deposits were averaging 6.1% to 6.25%. Approximately $184 million of these kinds of funds were on deposit during this time.

2. Longer term interest earnings:
   CD's for one year were 6.01%; for 182 days, 5.75%. $256 million were earning interest at these rates.

3. Cost of money for funds borrowed:
   The following percentages were given for about $80 million of severance tax bonds sold in July:
   6%, 7.2%, 7.5%, 6.7%, 6.9% and 5.75%, for an overall arithmetic average of about 6.5%.

Accordingly, for the following analyses, a discount rate of 6.5% per annum has been used.

A


OIL PRICES
FOUR CORNERS AREA
SHELL & GIANT POSTINGS
FROM FEB., 1981
SHELL OIL COMPANY
GIANT REFINING CO.
6-1/2% PER YEAR ESCALATION
SELECTED POSTINGS : FOUR CORNERS SWEET — DOLLARS PER BARREL
40
36
32
28
24
20
16
12
8
4
110
100
90
80
70
60
50
40
30
20
10
0
MAR. JUNE SEPT. DEC.
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
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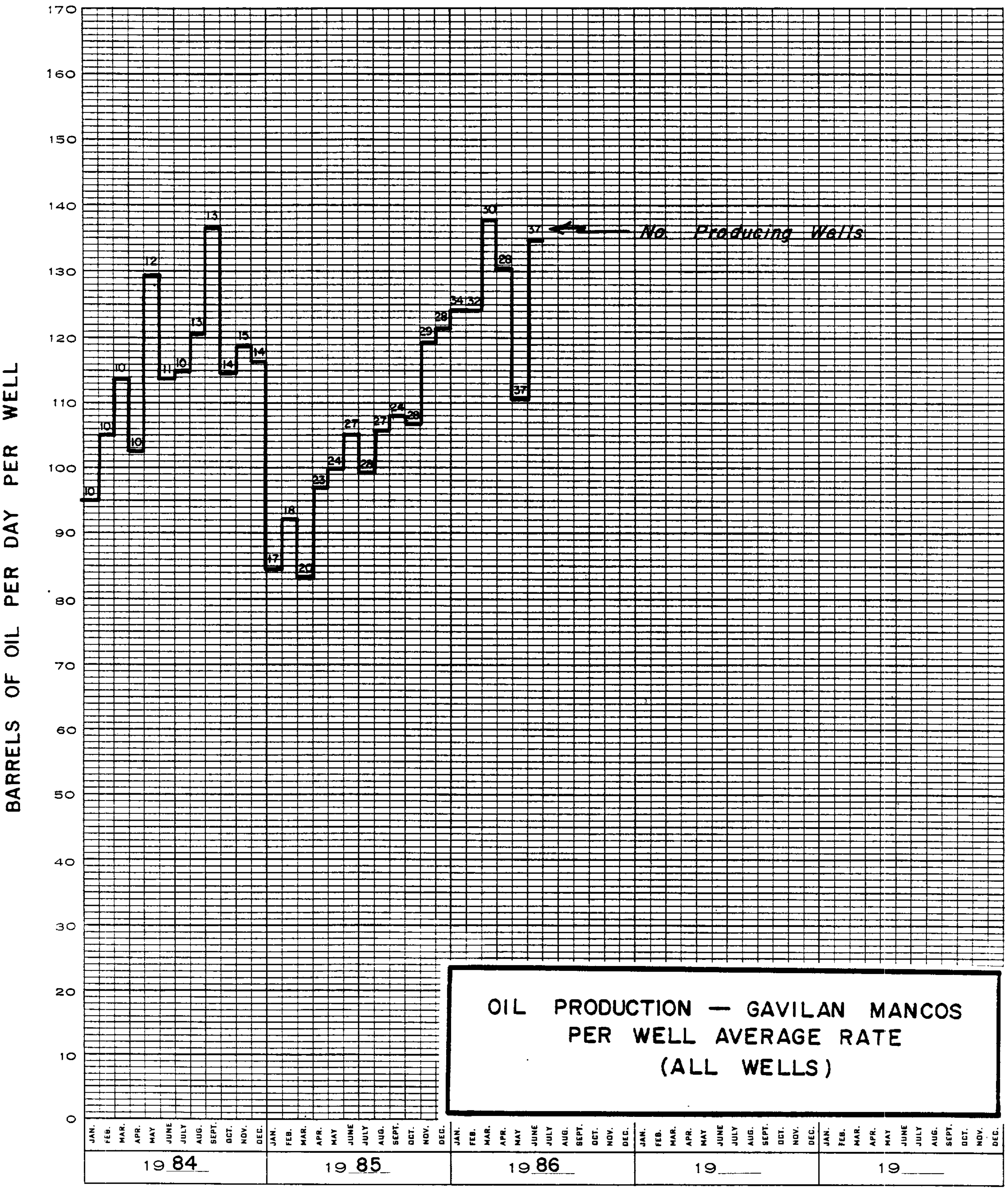
8-86



BARRELS OF OIL PER DAY PER WELL
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
No. Producing Wells
10
10
10
10
12
11
10
13
13
14
15
14
17
18
20
23
24
27
28
27
24
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37
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
1984
1985
1986
19
19
OIL PRODUCTION — GAVILAN MANCOS
PER WELL AVERAGE RATE
(ALL WELLS)

8-86

COMPARISON OF PRESENT WORTH OF NEW MEXICO'S FUTURE REVENUE FROM PRODUCTION TAXES FOR CONDITIONS OF HIGH PRODUCTION RATE VERSUS CONDITIONS OF LOW PRODUCTION RATE FOR CONSTANT PRICE OF OIL

ASSUMPTIONS FOR HIGH PRODUCTION RATE:

1. Pool instantly and completely developed on 320-acre spacing.
2. Pool-wide average per-well initial production rate will be the same as now (± 130 BOPD for all wells)
   and
   With all spacing units drilled, producing mechanism will be solution gas drive with recoveries of ± 200 BOPA, or average of 64,000 barrels for 320-acre spaced wells.
3. Economic limit, 3 BOPD/well.
4. Production decline rate 72.43%/year.
5. Discounted present worth of future income is 59,000 barrels/well average.

ASSUMPTIONS FOR LOW PRODUCTION RATE:

1. Additional wells drilled will be only those necessary for efficient drainage.
2. Pool-wide per well average initial production rate will be 37-1/2 BOPD.
3. Economic limit same as for first example, 3 BOPD. Production decline rate is 5%/year.
4. Ultimate recovery increased by about 10% (to 71,000 barrels/well).
5. Discounted present worth of future income is 59,000 barrels/well average (same as first example).

ASSUMPTIONS FOR BOTH EXAMPLES:

1. Oil price is constant throughout.
2. Discount rate is 6.5% per annum, compounded monthly, 30.4 day month.

COMPARISON
OF
PRESENT WORTH
OF
NEW MEXICO'S FUTURE REVENUE
FROM PRODUCTION TAXES
FOR
CONDITIONS OF HIGH PRODUCTION RATE
VERSUS
CONDITIONS OF LOW PRODUCTION RATE
FOR
CONSTANT PRICE OF OIL

	EXAMPLE I	EXAMPLE II
Initial Production Rate (BOPD)	130	37.5
Production Decline Rate, Percent/Year	72.43	5.00
Producing Life (Years)	5.2	6.0
Ultimate Recovery (Barrels)	64,000	71,000
Discounted Ultimate Recovery (@ 6.5%/Year), Barrels	59,000	59,000

STATISTICS FOR WELL WITH INITIAL PRODUCTION RATE OF 130 BOPD

		Undiscounted		Discounted		
Year	Month	Production for Month (Bbls)	Cumulative Production (Bbls)	Factor	Production for Month (Bbls)	Cumulative Production (Bbls)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	1	3837	3837	.9946	3816	3816
	2	3612	7449	.9893	3573	7390
	3	3401	10850	.9834	3346	10736
	4	3201	14051	.9786	3133	13868
	5	3014	17065	.9734	2934	16802
	6	2837	19903	.9681	2747	19549
	7	2671	22574	.9629	2572	22122
	8	2515	25089	.9577	2408	24530
	9	2367	27456	.9525	2255	26785
	10	2229	29685	.9474	2112	28897
	11	2098	31783	.9423	1977	30874
	12	1975	33759	.9372	1851	32725
1	1	1860	35618	.9322	1734	24459
	2	1751	37369	.9272	1623	36082
	3	1648	39017	.9222	1520	37602
	4	1552	40569	.9172	1423	39025
	5	1461	42030	.9123	1333	40358
	6	1375	43405	.9073	1248	41605
	7	1295	44700	.9025	1168	42774
	8	1219	45918	.8976	1094	43868
	9	1147	47066	.8928	1024	44892
	10	1080	48146	.8879	959	45851
	11	1017	49163	.8832	898	46750
	12	957	50120	.8784	841	47591
2	1	901	51022	.8737	787	48378
	2	849	51870	.8690	737	49115
	3	799	52669	.8643	690	49806
	4	752	53421	.8596	646	50452
	5	708	54129	.8550	605	51057
	6	666	54796	.8504	567	51624
	7	627	55423	.8458	531	52155
	8	591	56014	.8413	497	52652
	9	556	56570	.8367	465	53117
	10	524	57094	.8322	436	53553
	11	493	57586	.8277	408	53961
	12	464	58050	.8233	382	54343
3	1	437	58487	.8188	358	54701
	2	411	58898	.8144	335	55036
	3	387	59286	.8100	314	55349
	4	364	59650	.8057	294	55643
	5	343	59993	.8013	275	55918
	6	323	60316	.7970	258	56175
	7	304	60620	.7927	241	56416
	8	286	60907	.7884	226	56642
	9	270	61176	.7842	211	56853
	10	254	61430	.7800	198	57051
	11	239	61669	.7758	185	57237
	12	225	61894	.7716	174	57410
4	1	212	62105	.7674	163	57573
	2	199	62305	.7633	152	57725
	3	188	62492	.7592	143	57867
	4	177	62669	.7551	133	58001
	5	166	62835	.7510	125	58126
	6	156	62992	.7470	117	58243
	7	147	63139	.7430	110	58352
	8	139	63278	.7390	103	58455
	9	131	63409	.7350	96	58551
	10	123	63532	.7310	90	58640
	11	116	63648	.7271	84	58725
	12	109	63757	.7232	79	58804
5	1	103	63859	.7193	74	58877
	2	97	63956	.7154	69	58946
	3	91	64047	.7115	65	59011

STATISTICS FOR WELL WITH INITIAL PRODUCTION RATE OF 130 BOPD

PAGE 2

From figures on previous page weighted average discount rate: 59011/64000 = .9220.

Compare with weighted average continuous discount rate of 6.5%

$$\bar{D}cp = \frac{(dt)\ (e^{dt} - e^{-tj})}{(dt + tj)\ (e^{dt} - 1)}$$

d = 72.43% per year
t = 5.2 years
j = 6.5%

$\bar{D}cp = .9239$

STATISTICS FOR WELL WITH INITIAL PRODUCTION RATE OF 37-1/2 BOPD

Year	Month	Undiscounted Production for Month (Bbls)	Undiscounted Cumulative Production (Bbls)	Discounted Factor	Discounted Production for Month (Bbls)	Discounted Cumulative Production (Bbls)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	1	1138	1138	.9946	1132	1132
	2	1134	2272	.9893	1121	2253
	3	1129	3401	.9839	1111	3364
	4	1124	4525	.9786	1100	4464
	5	1119	5644	.9734	1090	5554
	6	1115	6759	.9681	1079	6633
	7	1110	7869	.9629	1069	7702
	8	1106	8975	.9577	1059	8761
	9	1101	10076	.9525	1049	9809
	10	1096	11172	.9474	1039	10848
	11	1092	12264	.9423	1029	11877
	12	1087	13351	.9372	1019	12896
1	1	1083	14434	.9322	1009	13905
	2	1078	15512	.9272	1000	14905
	3	1074	16586	.9222	990	15895
	4	1069	17655	.9172	981	16876
	5	1065	18720	.9123	971	17847
	6	1060	19780	.9073	962	18809
	7	1056	20836	.9025	953	19762
	8	1052	21888	.8976	944	20706
	9	1047	22935	.8928	935	21641
	10	1043	23978	.8880	926	22567
	11	1039	25017	.8832	917	23485
	12	1034	26051	.8784	908	24393
2	1	1030	27081	.8737	900	25293
	2	1026	28106	.8690	891	26184
	3	1021	29128	.8643	883	27067
	4	1017	30145	.8596	874	27941
	5	1013	31158	.8550	866	28807
	6	1009	32166	.8504	858	29665
	7	1005	33171	.8458	850	30515
	8	1000	34171	.8413	842	31356
	9	996	35167	.8367	834	32190
	10	992	36159	.8322	826	33015
	11	988	37147	.8277	818	33833
	12	984	38131	.8233	810	34643
3	1	980	39111	.8188	802	35445
	2	976	40087	.8144	795	36240
	3	972	41058	.8100	787	37027
	4	968	42026	.8057	780	37806
	5	964	42989	.8013	772	38578
	6	960	43949	.7970	765	39343
	7	956	44904	.7927	757	40101
	8	952	45856	.7885	750	40851
	9	948	46803	.7842	743	41594
	10	944	47747	.7800	736	42330
	11	940	48687	.7758	729	43059
	12	936	49622	.7714	722	43781
4	1	932	50555	.7674	715	44496
	2	928	51482	.7633	708	45205
	3	924	52407	.7592	702	45907
	4	920	53327	.7551	695	46601
	5	917	54243	.7510	688	47289
	6	913	55156	.7470	682	47971
	7	909	56065	.7430	675	48646
	8	905	56970	.7390	669	49315
	9	901	57872	.7350	662	49978
	10	898	58769	.7310	656	50634
	11	894	59663	.7271	650	51284
	12	890	60553	.7232	644	51928
5	1	886	61440	.7193	638	52565
	2	883	62323	.7154	632	53197
	3	879	63202	.7115	626	53822

STATISTICS FOR WELL WITH INITIAL PRODUCTION RATE OF 37-1/2 BOPD
PAGE 2

Year	Month	Undiscounted Production for Month (Bbls)	Undiscounted Cumulative Production (Bbls)	Discounted Factor	Discounted Production for Month (Bbls)	Discounted Cumulative Production (Bbls)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
5	4	875	64077	.7077	620	54442
	5	872	64949	.7039	614	55056
	6	868	65817	.7001	608	55663
	7	865	66682	.6963	602	56265
	8	861	67543	.6926	596	56862
	9	857	68400	.6888	591	57452
	10	854	69254	.6851	585	58037
	11	850	70104	.6814	579	58617
	12	847	70951	.6778	574	59191

STATISTICS FOR WELL WITH INITIAL PRODUCTION RATE OF 37-1/2 BOPD

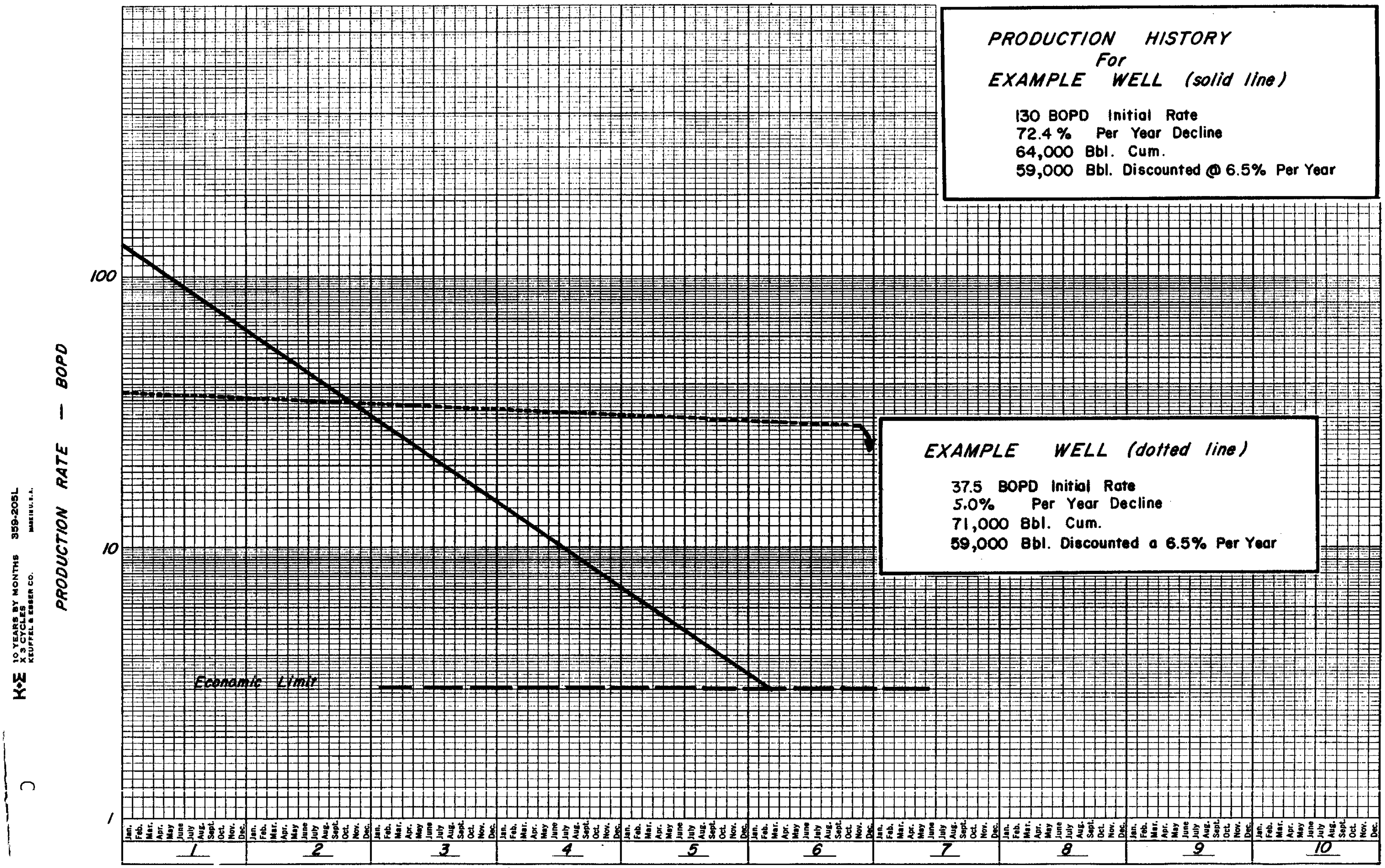
From figures on previous page weighted average discount rate: 59191/70951 = .8343.

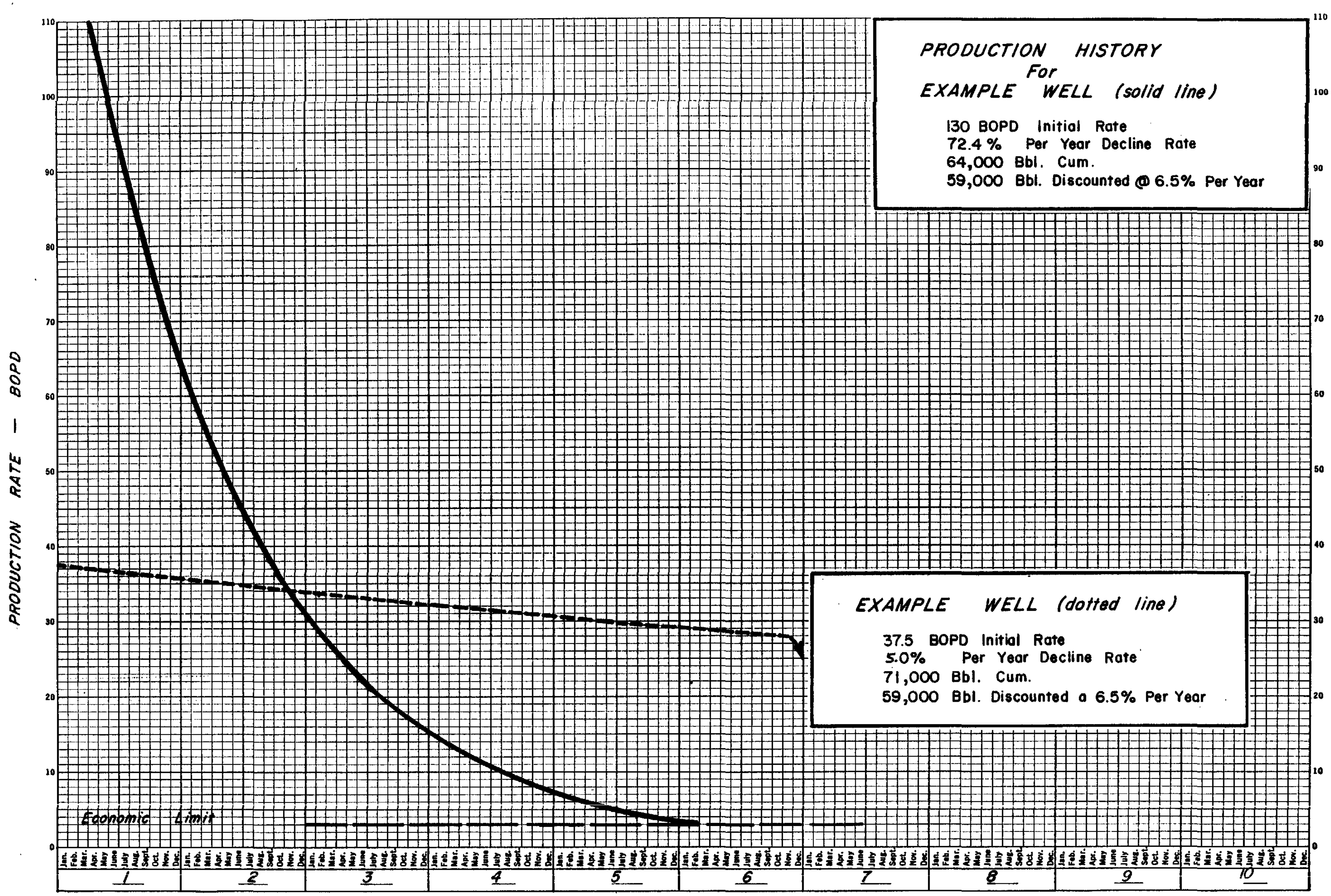
Compare with weighted average continuous discount rate of 6.5%

$$\bar{D}cp = \frac{(dt)\ (e^{dt} - e^{-tj})}{(dt + tj)\ (e^{dt} - 1)}$$

d = 5.00% per year
t = 6.0 years
j = 6.5%

$\bar{D}cp$ = .8361


PRODUCTION HISTORY
For
EXAMPLE WELL (solid line)
130 BOPD Initial Rate
72.4 % Per Year Decline
64,000 Bbl. Cum.
59,000 Bbl. Discounted @ 6.5% Per Year
EXAMPLE WELL (dotted line)
37.5 BOPD Initial Rate
5.0% Per Year Decline
71,000 Bbl. Cum.
59,000 Bbl. Discounted a 6.5% Per Year
Economic Limit
PRODUCTION RATE — BOPD
100
10
1
1
2
3
4
5
6
7
8
9
10
K+E 10 YEARS BY MONTHS X 3 CYCLES KEUFFEL & ESSER CO. 359-205L



K+E 10 YEARS BY MONTHS X 110 DIVISIONS 359-200L
KEUFFEL & ESSER CO. MADE IN U.S.A.

8-86

GAVILAN MANCOS PRODUCTION STATISTICS
FOR ALL WELLS

Date	Total Monthly Pool Oil Production	No. Wells	Production Per Well Per Month	BOPD Per Well
1984				
Jan 1-31	29,443	10	2,944	95.0
Feb 1-28	29,380	10	2,938	104.9
March 1-31	35,279	10	3,528	113.8
April 1-30	30,826	10	3,083	102.8
May 1-31	48,106	12	4,009	129.3
June 1-30	37,533	11	3,412	113.7
July 1-31	35,510	10	3,551	114.5
Aug 1-31	48,575	13	3,737	120.5
Sept 1-30	53,177	13	4,091	136.4
Oct 1-31	49,721	14	3,552	114.6
Nov 1-30	53,276	15	3,552	118.4
Dec 1-31	50,573	14	3,612	116.5
1985				
Jan 1-31	44,587	17	2,623	84.6
Feb 1-28	46,407	18	2,578	92.1
March 1-31	51,713	20	2,586	83.4
April 1-30	66,736	23	2,902	96.7
May 1-31	73,684	24	3,071	99.0
June 1-30	85,109	27	3,152	105.1
July 1-31	86,256	28	3,081	99.4
Aug 1-31	88,588	27	3,281	105.8
Sept 1-30	77,586	24	3,233	107.8
Oct 1-31	92,791	28	3,314	106.9
Nov 1-30	103,754	29	3,578	119.3
Dec 1-31	105,578	28	3,771	121.6
1986				
Jan 1-31	131,058	34	3,855	124.3
Feb 1-28	111,329	32	3,479	124.3
March 1-31	127,946	30	4,265	137.6
April 1-30	109,478	28	3,910	130.3
May 1-31	126,731	37	3,425	110.5
June 1-30	149,517	37	4,041	134.7

D

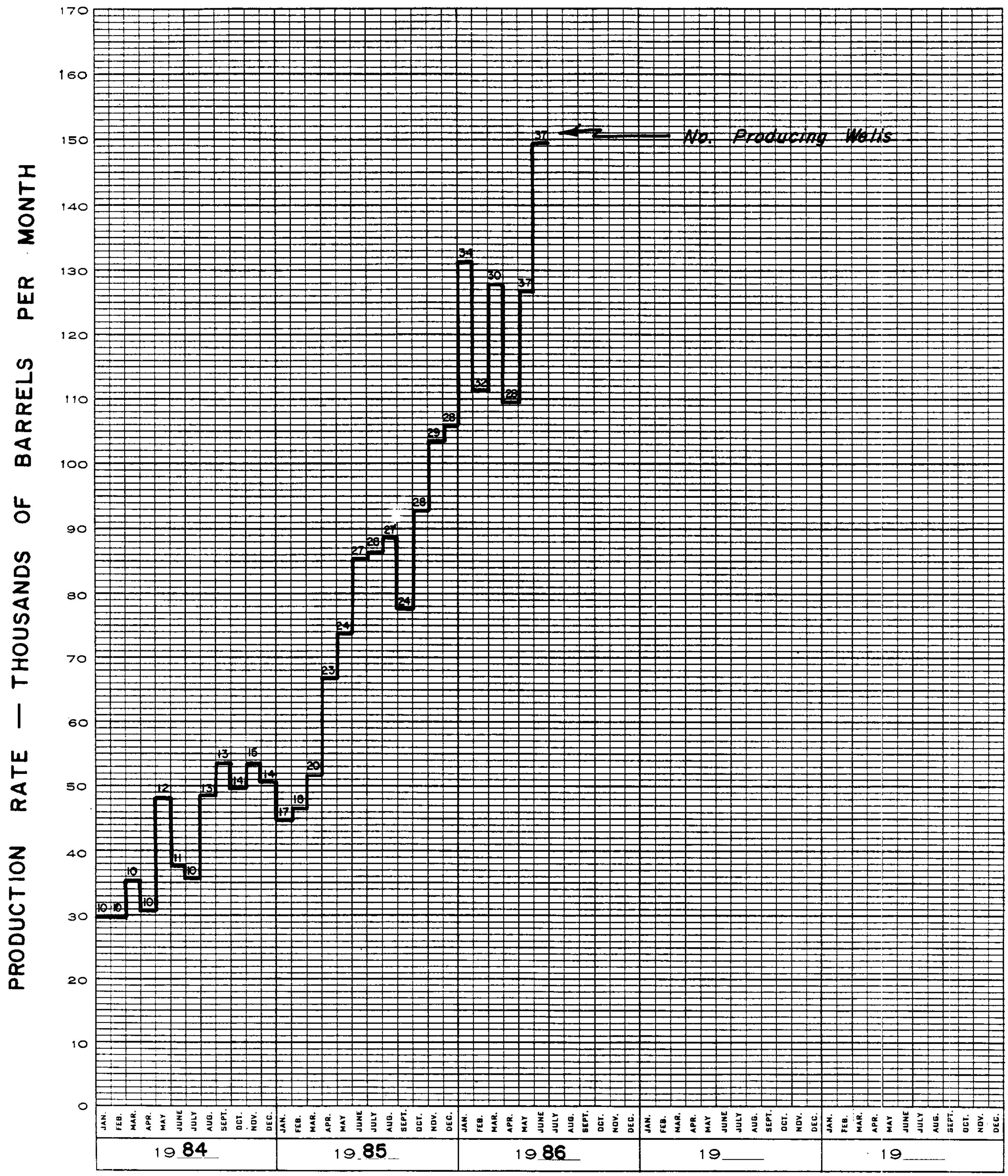
GAVILAN MANCOS PRODUCTION STATISTICS
(ALL WELLS AND ALL WELLS LESS THOSE WITH GREATER THAN 300 BOPD)

	Total Production All Wells				Production Less That for Wells Over 300 BOPD				
Date	Total Monthly Pool Oil Production	No. Wells	Production Per Well Per Month	BOPD Per Well	Production of Wells (No. of Wells)	Total Monthly Pool Oil Production	No. Wells	Production Per Well Per Month	BOPD Per Well
1984									
Jan 1-31	29,443	10	2,944	95.0	-0-		10		95.0
Feb 1-28	29,380	10	2,938	104.9	-0-		10		104.9
March 1-31	35,279	10	3,528	113.8	9,701 (1)	25,578	9	2,842	91.7
April 1-30	30,826	10	3,083	102.8	-0-		10		102.8
May 1-31	48,106	12	4,009	129.3	12,159 (1)	35,947	11	3,268	105.4
June 1-30	37,533	11	3,412	113.7	9,967 (1)	27,566	10	2,757	91.9
July 1-31	35,510	10	3,551	114.5	-0-		10		114.5
Aug 1-31	48,575	13	3,737	120.5	-0-		13		120.5
Sept 1-30	53,177	13	4,091	136.4	23,317 (2)	29,860	11	2,715	90.5
Oct 1-31	49,721	14	3,552	114.6	-0-		14		114.6
Nov 1-30	53,276	15	3,552	118.4	35,180 (3)	18,096	12	1,508	50.3
Dec 1-31	50,573	14	3,612	116.5	11,024 (1)	39,549	13	3,042	98.1
1985									
Jan 1-31	44,587	17	2,623	84.6	12,072 (1)	32,515	15	2,168	69.9
Feb 1-28	46,407	18	2,578	92.1	22,979 (2)	23,428	16	1,464	52.3
March 1-31	51,713	20	2,586	83.4	13,098 (1)	38,615	19	2,032	65.6
April 1-30	66,736	23	2,902	96.7	14,349 (1)	52,387	22	2,381	79.4
May 1-31	73,684	24	3,071	99.0	15,652 (1)	58,032	23	2,523	81.4
June 1-30	85,109	27	3,152	105.1	28,077 (2)	57,032	25	2,281	76.0
July 1-31	86,256	28	3,081	99.4	25,623 (2)	60,633	26	2,332	75.2
Aug 1-31	88,588	27	3,281	105.8	25,821 (2)	62,767	25	2,511	81.0
Sept 1-30	77,586	24	3,233	107.8	23,454 (2)	54,132	22	2,461	82.0
Oct 1-31	92,791	28	3,314	106.9	26,544 (2)	66,247	26	2,548	82.2
Nov 1-30	103,754	29	3,578	119.3	41,853 (3)	61,901	27	2,293	76.4
Dec 1-31	105,578	28	3,771	121.6	39,107 (3)	66,471	25	2,659	85.8
1986									
Jan 1-31	131,058	34	3,855	124.3	64,142 (5)	66,916	29	2,307	74.4
Feb 1-28	111,329	32	3,479	124.3	45,463 (4)	65,866	28	2,352	84.0
March 1-31	127,946	30	4,265	137.6	46,769 (4)	1,177	26	3,122	100.7
April 1-30	109,478	28	3,910	130.3	25,496 (2)	83,982	26	3,230	107.7
May 1-31	126,731	37	3,425	110.5	64,043 (5)	62,688	32	1,959	63.2
June 1-30	149,517	37	4,041	134.7	73,161 (5)	76,356	32	2,386	79.5

GAVILAN MANCOS PRODUCTION STATISTICS
(ALL WELLS AND ALL WELLS LESS THOSE WITH LESS THAN 25 BOPD)

	Total Production All Wells				Production Less That for Wells Under 25 BOPD				
Date	Total Monthly Pool Oil Production	No. Wells	Production Per Well Per Month	BOPD Per Well	Production of Wells (No. of Wells)	Total Monthly Pool Oil Production	No. Wells	Production Per Well Per Month	BOPD Per Well
1984									
Jan 1-31	29,443	10	2,944	95.0	-0-		10		95.0
Feb 1-28	29,380	10	2,938	104.9	-0-		10		104.9
March 1-31	35,279	10	3,528	113.8	764 (1)	34,515	9	3,835	123.7
April 1-30	30,826	10	3,083	102.8	-0-		10		102.8
May 1-31	48,106	12	4,009	129.3	-0-		12		129.3
June 1-30	37,533	11	3,412	113.7	991 (2)	36,542	9	4,060	135.3
July 1-31	35,510	10	3,551	114.5	507 (1)	35,003	9	3,889	125.5
Aug 1-31	48,575	13	3,737	120.5	537 (1)	48,038	12	4,003	129.1
Sept 1-30	53,177	13	4,091	136.4	648 (1)	52,529	12	4,377	145.9
Oct 1-31	49,721	14	3,552	114.6	680 (2)	49,041	12	4,087	131.8
Nov 1-30	53,276	15	3,552	118.4	1,441 (3)	51,835	12	4,320	144.0
Dec 1-31	50,573	14	3,612	116.5	851 (3)	49,722	11	4,520	145.8
1985									
Jan 1-31	44,587	17	2,623	84.6	2,290 (6)	42,297	11	3,845	124.0
Feb 1-28	46,407	18	2,578	92.1	1,053 (5)	45,354	13	3,489	124.6
March 1-31	51,713	20	2,586	83.4	2,181 (8)	49,532	12	4,128	133.2
April 1-30	66,736	23	2,902	96.7	1,889 (5)	64,847	18	3,603	120.1
May 1-31	73,684	24	3,071	99.0	2,506 (8)	71,178	16	4,449	143.5
June 1-30	85,109	27	3,152	105.1	2,436 (8)	82,673	19	4,351	145.0
July 1-31	86,256	28	3,081	99.4	2,167 (7)	84,089	21	4,004	129.2
Aug 1-31	88,588	27	3,281	105.8	2,024 (7)	86,564	20	4,328	139.6
Sept 1-30	77,586	24	3,233	107.8	1,656 (6)	75,930	18	4,218	140.6
Oct 1-31	92,791	28	3,314	106.9	2,566 (7)	90,225	21	4,296	138.6
Nov 1-30	103,754	29	3,578	119.3	1,746 (6)	102,008	23	4,435	147.8
Dec 1-31	105,578	28	3,771	121.6	2,521 (6)	103,057	22	4,684	151.1
1986									
Jan 1-31	131,058	34	3,855	124.3	3,887 (12)	127,171	22	5,781	186.5
Feb 1-28	111,329	32	3,479	124.3	1,966 (10)	109,363	22	4,971	177.5
March 1-31	127,946	30	4,265	137.6	2,320 (9)	125,626	21	5,982	193.0
April 1-30	109,478	28	3,910	130.3	1,635 (8)	107,843	20	5,392	179.7
May 1-31	126,731	37	3,425	110.5	4,041 (12)	122,690	25	4,908	158.3
June 1-30	149,517	37	4,041	134.7	1,992 (9)	147,525	28	5,269	175.6

TOTAL MONTHLY
GAVILAN MANCOS POOL
OIL PRODUCTION



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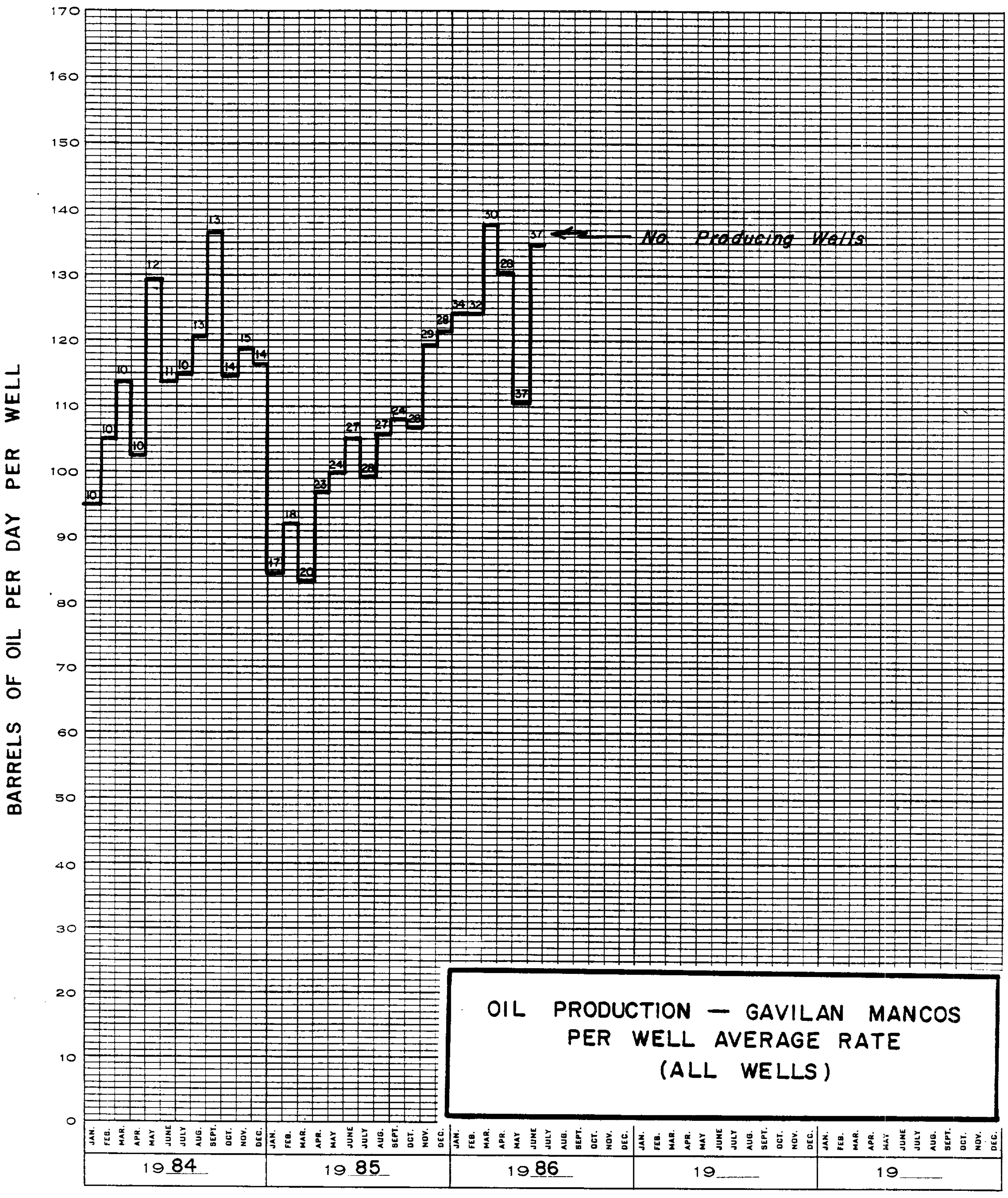
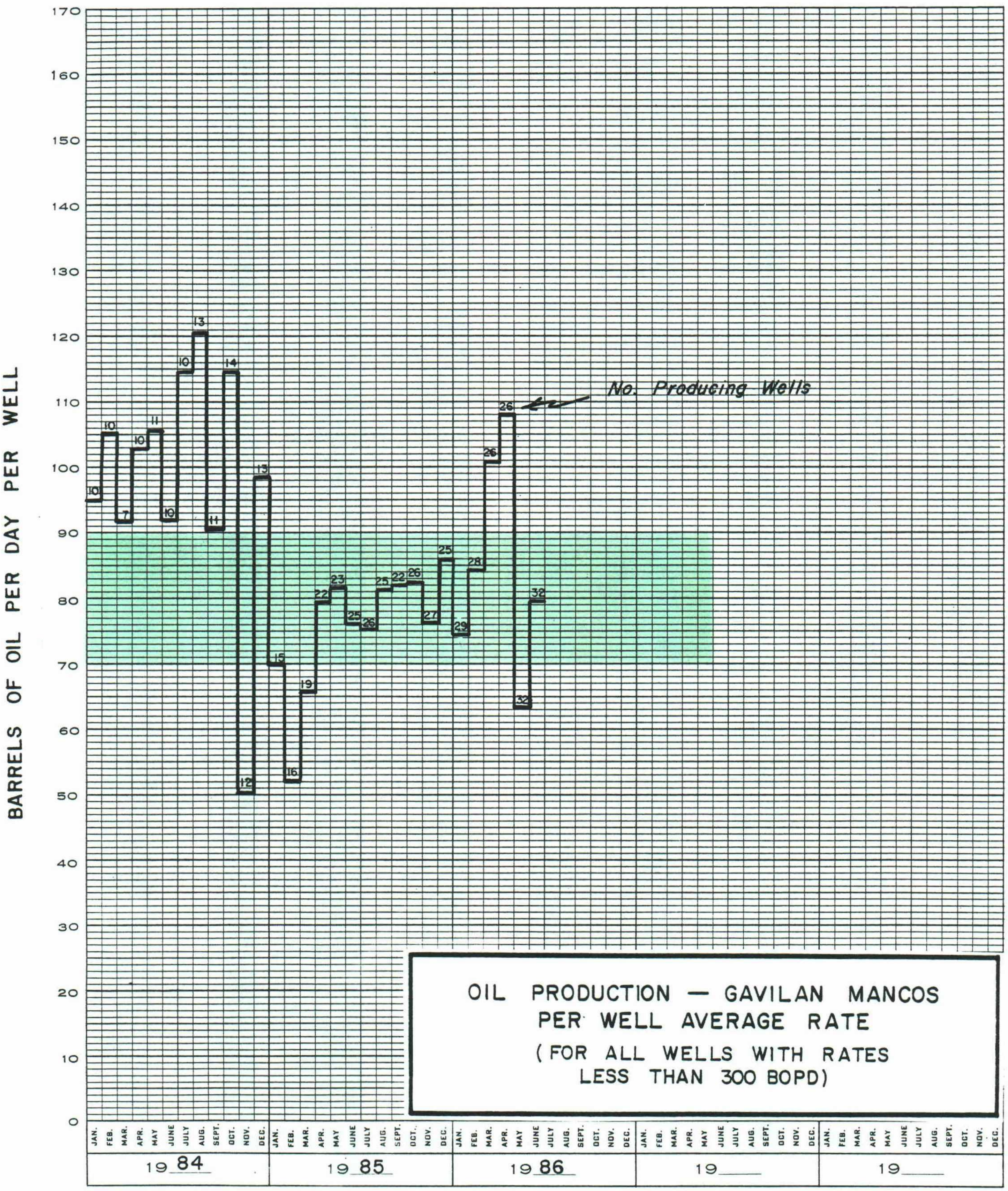


BARRELS OF OIL PER DAY PER WELL
No. Producing Wells
OIL PRODUCTION — GAVILAN MANCOS
PER WELL AVERAGE RATE
(ALL WELLS)
1984
1985
1986

8-86


BARRELS OF OIL PER DAY PER WELL
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
No. Producing Wells
10
10
7
10
11
10
10
13
11
14
12
13
15
16
19
22
23
25
26
25
22
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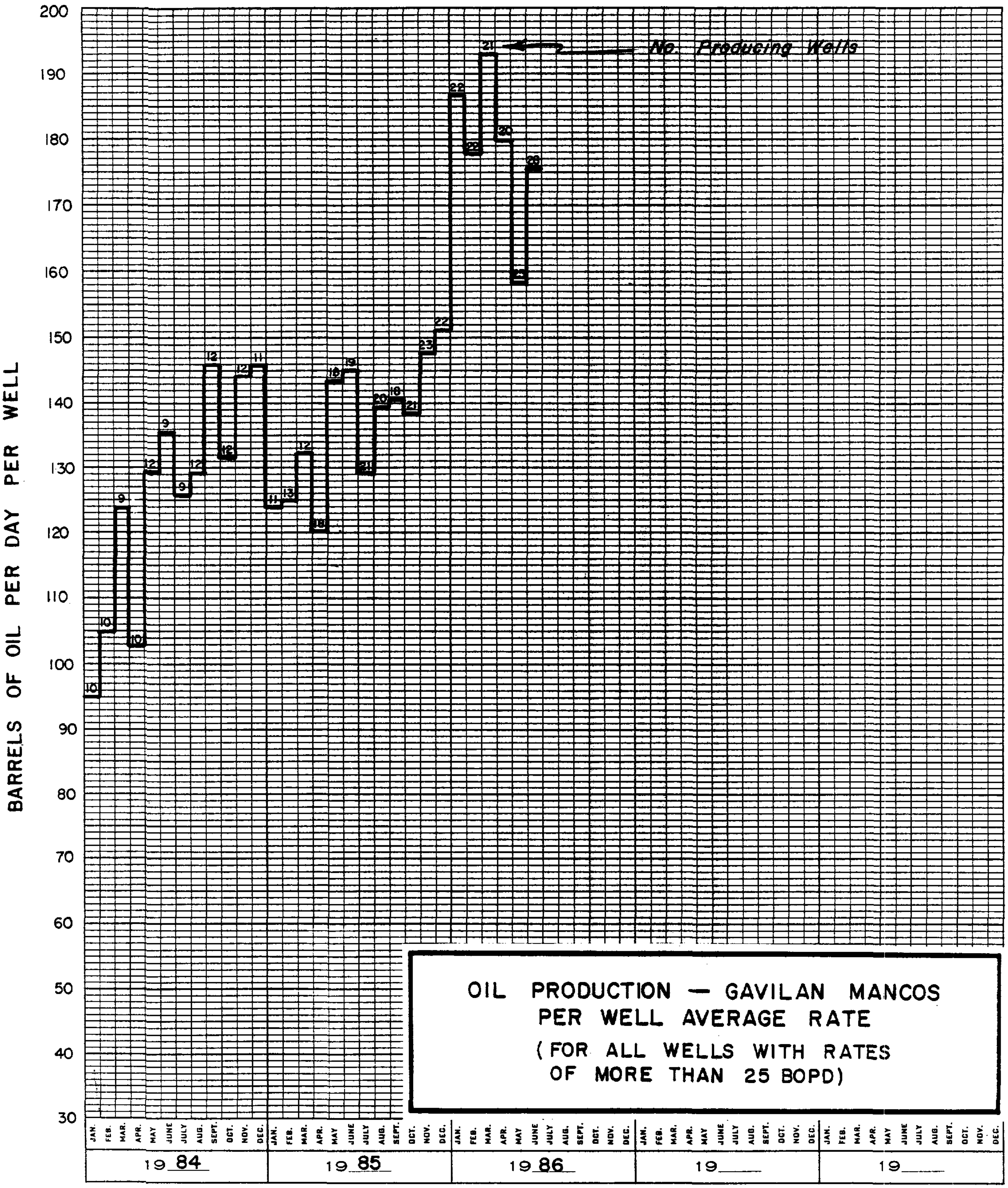
32
32
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
19 84
19 85
19 86
19
19
OIL PRODUCTION — GAVILAN MANCOS
PER WELL AVERAGE RATE
(FOR ALL WELLS WITH RATES
LESS THAN 300 BOPD)

8-86



OIL PRODUCTION — GAVILAN MANCOS
PER WELL AVERAGE RATE
(FOR ALL WELLS WITH RATES
OF MORE THAN 25 BOPD)

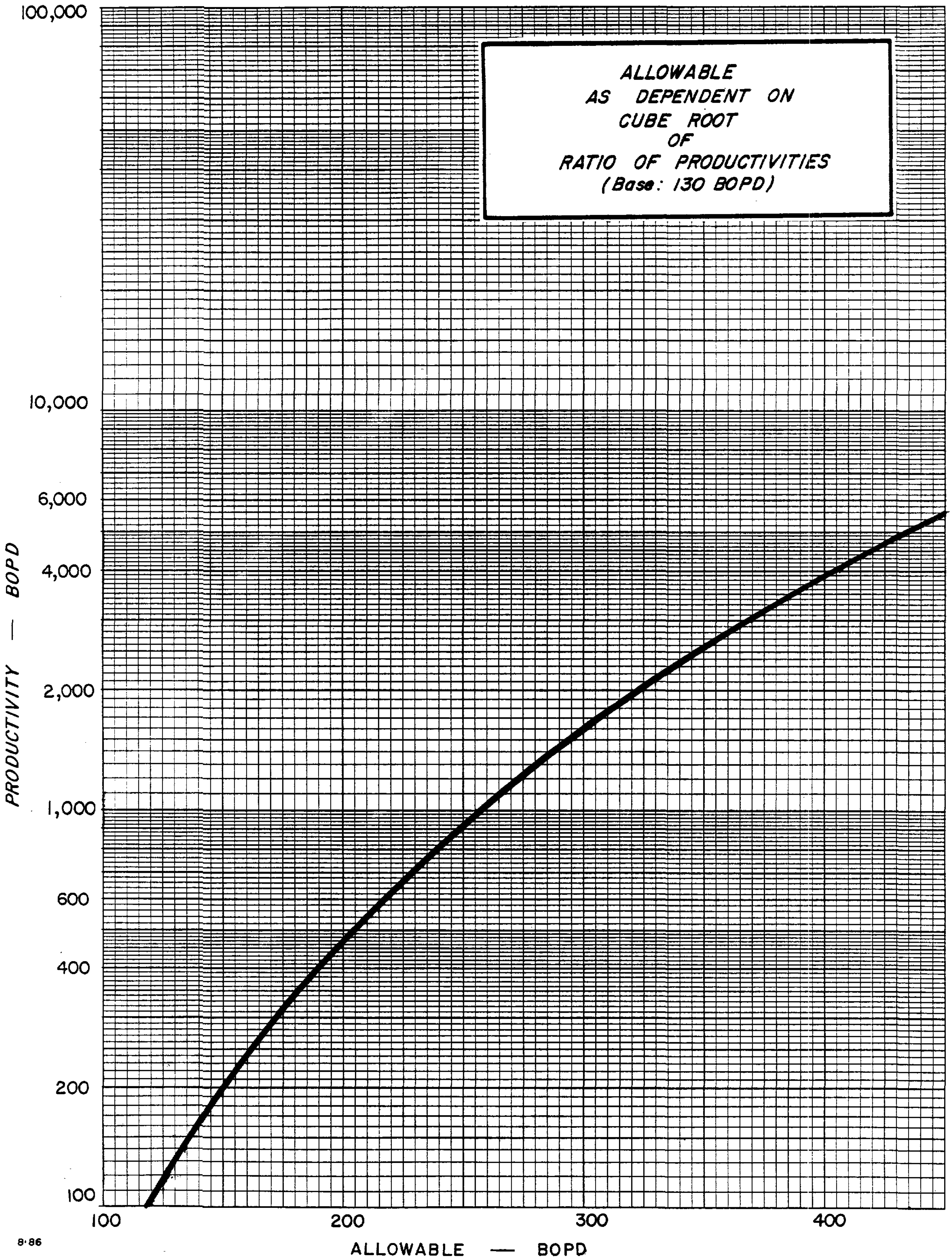
COMPARISON OF ALLOWABLES OF 200 BOPD AND 700 BOPD WITH ALLOWABLE BASED ON RATIO OF CUBE ROOT OF PRODUCTIVITIES*

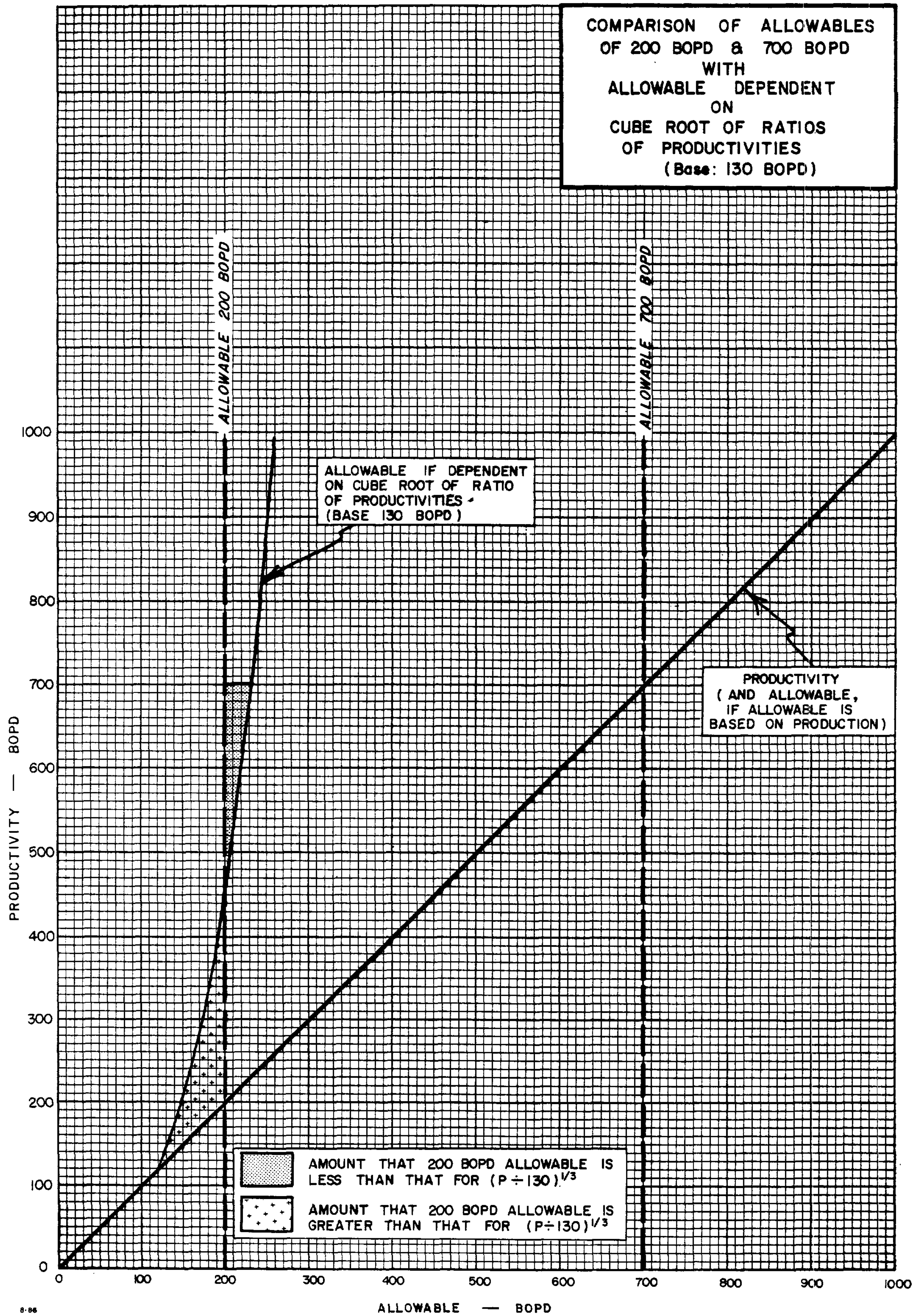
Productivity (BOPD) (1)	Allowable if based on cube root of ratio of productivities* (2)	200 or Productivity Less Col 2 (BOPD) ** (3)	Productivity Less Col 2 (4)
50	95	-	-
100	119	-	-
130	130	0	0
150	136	14	14
200	150	50	50
300	172	28	128
400	189	11	211
500	204	(4)	296
600	216	(16)	384
700	228	(28)	472
1000	257	(57)	743
10000	553	(353)	9447

* Base: 130 BOPD: allowable = (productivity, BOPD divided by 130) raised to 1/3 power.

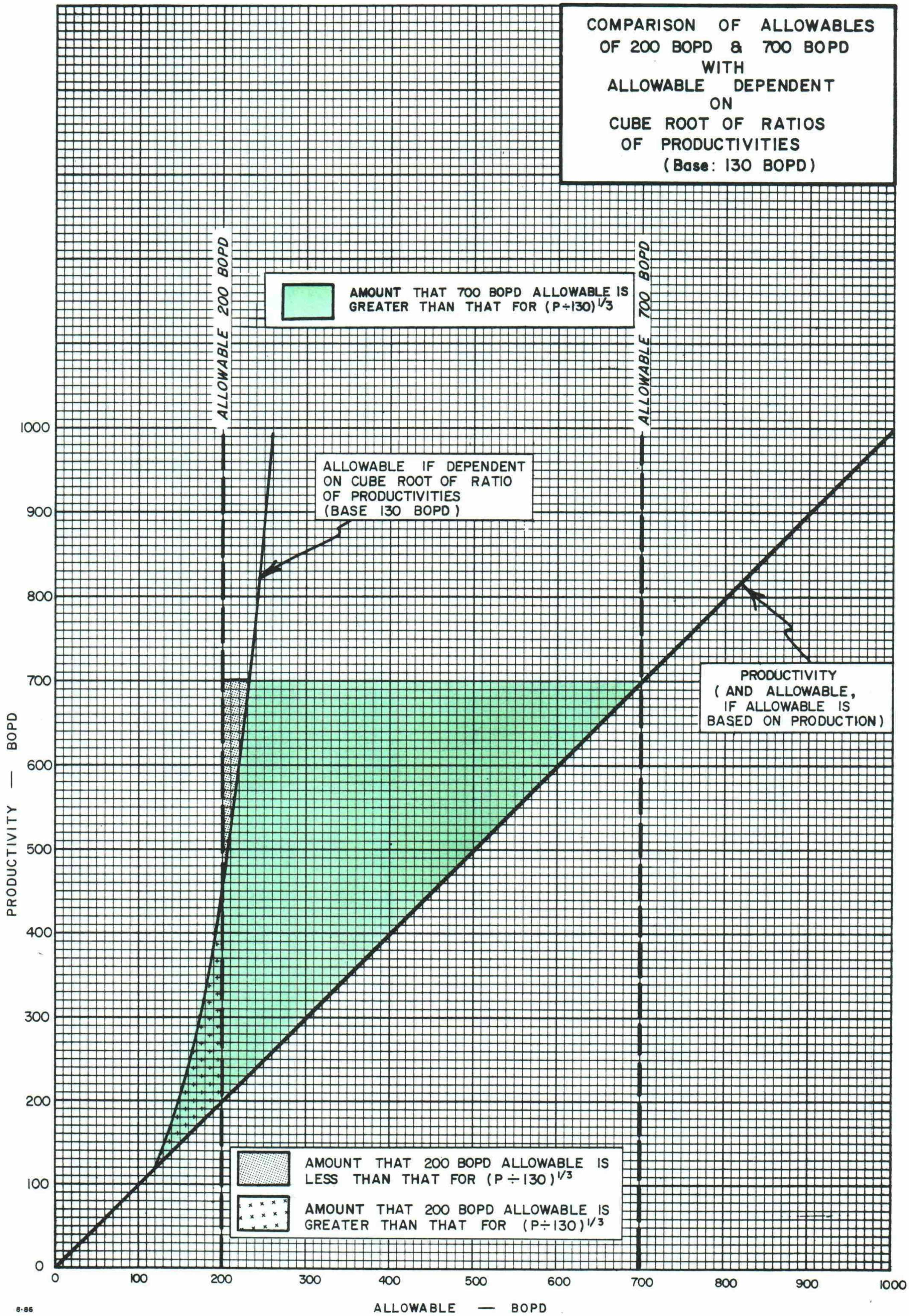
** Col. 3 is 200 BOPD or productivity (whichever is less) minus Col. 2.

E


ALLOWABLE
AS DEPENDENT ON
CUBE ROOT
OF
RATIO OF PRODUCTIVITIES
(Base: 130 BOPD)
100,000
10,000
6,000
4,000
2,000
1,000
600
400
200
100
PRODUCTIVITY — BOPD
100
200
300
400
ALLOWABLE — BOPD
8-86



COMPARISON OF ALLOWABLES OF 200 BOPD & 700 BOPD WITH ALLOWABLE DEPENDENT ON CUBE ROOT OF RATIOS OF PRODUCTIVITIES (Base: 130 BOPD)
ALLOWABLE 200 BOPD
ALLOWABLE 700 BOPD
ALLOWABLE IF DEPENDENT ON CUBE ROOT OF RATIO OF PRODUCTIVITIES (BASE 130 BOPD)
PRODUCTIVITY (AND ALLOWABLE, IF ALLOWABLE IS BASED ON PRODUCTION)
AMOUNT THAT 200 BOPD ALLOWABLE IS LESS THAN THAT FOR (P÷130)^1/3
AMOUNT THAT 200 BOPD ALLOWABLE IS GREATER THAN THAT FOR (P÷130)^1/3
PRODUCTIVITY — BOPD
ALLOWABLE — BOPD
0
100
200
300
400
500
600
700
800
900
1000
8-86



COMPARISON OF ALLOWABLES OF 200 BOPD & 700 BOPD WITH ALLOWABLE DEPENDENT ON CUBE ROOT OF RATIOS OF PRODUCTIVITIES (Base: 130 BOPD)
ALLOWABLE 200 BOPD
ALLOWABLE 700 BOPD
AMOUNT THAT 700 BOPD ALLOWABLE IS GREATER THAN THAT FOR (P÷130)^1/3
ALLOWABLE IF DEPENDENT ON CUBE ROOT OF RATIO OF PRODUCTIVITIES (BASE 130 BOPD)
PRODUCTIVITY (AND ALLOWABLE, IF ALLOWABLE IS BASED ON PRODUCTION)
AMOUNT THAT 200 BOPD ALLOWABLE IS LESS THAN THAT FOR (P÷130)^1/3
AMOUNT THAT 200 BOPD ALLOWABLE IS GREATER THAN THAT FOR (P÷130)^1/3
PRODUCTIVITY — BOPD
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
500
600
700
800
900
1000
ALLOWABLE — BOPD

8-86

P 307 895 617

Amoco Production Co.
Post Office Box 800
Denver, Colorado 80201

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Amoco Production Co.
Post Office Box 800
Denver, Colorado 80201

4. Type of Service: ☐ Registered ☒ Certified ☐ Express Mail ☐ Insured ☐ COD

Article Number: P307895617

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X [signature]

7. Date of Delivery 7-8-86

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

BEFORE THE OIL CONSERVATION COMMISSION

Case No. 8950 5

Submitted by Benson-Montin-Greer

Hearing Date 8/7/86

P 307 895 618

Dugan Production Co.
Post Office Box 208
Farmington, NM 87499

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ **Show to whom, date and address of delivery.**
2. ☐ **Restricted Delivery.**

3. **Article Addressed to:**

Dugan Production Co.
Post Office Box 208
Farmington, NM 87499

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307 895 618

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X Staci Adams

6. Signature – Agent
X

7. Date of Delivery 7-3-86

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 619

Kenai Oil & Gas, Inc.
1675 Larimer, Suite 500
Denver, Colorado 80202

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Kenai Oil & Gas, Inc.
1675 Larimer, Suite 500
Denver, Colorado 80202

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307895619

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X Malissa Pierce

7. Date of Delivery
7-7-86

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 620

Cotton Petroleum Co.
750 Ptarmigan Place
3773 Cherry Creek North
Denver, Colorado 80209

4-1-86 CV

PS Form 3811, July 1983 447-845

● **SENDER: Complete items 1, 2, 3 and 4.**

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Cotton Petroleum Co.
750 Ptarmigan Place
3773 Cherry Creek North
Denver, Colorado 80209

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307895620

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X Jeanne M. Tanzmann

6. Signature – Agent
X

7. Date of Delivery
7/7/86

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 621

A. G. Hill
5000 Thanksgiving Tower
Dallas, Texas 75201

7-1-86 cv

PS Form 3811, July 1983 447-845

DOMESTIC RETURN RECEIPT

● **SENDER: Complete items 1, 2, 3 and 4.**

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ **Show to whom, date and address of delivery.**
2. ☐ **Restricted Delivery.**

3. Article Addressed to:

A. G. Hill
5000 Thanksgiving Tower
Dallas, Texas 75201

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307895621

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X B. Dewp

7. Date of Delivery JUL 7 1986

8. Addressee's Address *(ONLY if requested and fee paid)*

P 307 895 622

Mobil Producing Texas
Post Office Box 633
Midland, Texas 79702

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Mobil Producing Texas
Post Office Box 633
Midland, Texas 79702

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307895622

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X [signature]

7. Date of Delivery

JUL 1986

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 623

Monsanto Oil Company
5051 Westheimer, Suite 1300
Houston, Texas 77056

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Monsanto Oil Company
5051 Westheimer, Suite 1300
Houston, Texas 77056

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307 895 623

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X Jerry Thomas

7. Date of Delivery
7-8-86

8. Addressee's Address (ONLY if requested and fee paid)

DOMESTIC RETURN RECEIPT

CAMPBELL & BLACK, P.A.
LAWYERS
POST OFFICE BOX 2208
SANTA FE, NEW MEXICO 87504-2208

P 307 895 624

RETURN RECEIPT REQUESTED

Oscar Abraham

525 Central, N.E.

Albuquerque, New Mexico 87102

ABR 25 210708N1 07

RETURN TO
NO FORWARDING ORD
UNABLE TO

CLAIM CHECK
782514

☐ HOLD

JUL 14 1986

1ST NOTICE

2ND NOTICE

RETURN

Detached from
PS Form 3849-A
Oct. 1980

P 307 895 624

Oscar Abraham
525 Central, N.E.
Albuquerque, New Mexico 87102

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Oscar Abraham
525 Central, N.E.
Albuquerque, New Mexico 87102

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307 895 624

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X

7. Date of Delivery

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

307 895 625

Reading & Bates Pet. Co.
3200 Mid-Continent Tower
Tulsa, Oklahoma 74103

7-1-86 CV

PS Form 3811, July 1983 447-845

● **SENDER:** Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Reading & Bates Pet. Co.
3200 Mid-Continent Tower
Tulsa, Oklahoma 74103

4. Type of Service:	Article Number
☐ Registered ☒ Certified ☐ Express Mail ☐ Insured ☐ COD	P307 895 625

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X [signature]

6. Signature – Agent
X

7. Date of Delivery
7-7-86

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

. ..7 895 626

Southern Union Exploration
Suite 1800, Renaissance Twr.
1201 Elm Street
Dallas, Texas 75270

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Southern Union Exploration
Suite 1800, Renaissance Twr.
1201 Elm Street
Dallas, Texas 75270

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P 307 895 626

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X R. Johnson

7. Date of Delivery
JUL 7 1986

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

CAMPBELL & BLACK, P.A.
LAWYERS
POST OFFICE BOX 2208
SANTA FE, NEW MEXICO 87504-2208

NOT DELIVERABLE AS ADDRESSED
UNABLE TO FORWARD

LYN 90 0607LRN1 07/07/86

RETURN TO SENDER
NO FORWARDING ORDER ON FILE
UNABLE TO FORWARD

Lynco Oil Corp.

5290 DTC Parkway

Englewood, Colorado 80111

P 307 895 627

RETURN RECEIPT REQUESTED

P 307 895 627

Lynco Oil Corp.
5290 DTC Parkway
Englewood, Colorado 80111

4-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Lynco Oil Corp.
5290 DTC Parkway
Englewood, Colorado 80111

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307 895 627

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X

7. Date of Delivery

8. Addressee's Address (ONLY if requested and fee paid)

NOT DELIVERABLE AS ADDRESSED UNABLE TO FORWARD

RETURNED TO SENDER

DOMESTIC RETURN RECEIPT

P 307 895 628

Shar-Alan Oil Corp.
4101 E. Louisiana Ave.
Denver, Colorado 80222

7-1-86 CV

PS Form 3811, July 1983 447-845

DOMESTIC RETURN RECE

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Shar-Alan Oil Corp.
4101 E. Louisiana Ave.
Denver, Colorado 80222

4. Type of Service:

☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail

Article Number
P307 895 628

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X

7. Date of Delivery

8. Addressee's Address *(ONLY if requested and fee paid)*

P 307 895 629

Billie S. Werntz
606 Loma Linda Pl., S.E.
Albuquerque, NM 87108

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Billie S. Werntz
606 Loma Linda Pl., S.E.
Albuquerque, NM 87108

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307 895 629

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X [signature]

6. Signature – Agent
X

7. Date of Delivery
7/5/[illegible]

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 630

Jicarilla Apache Tribe
Post Office Box 507
Dulce, New Mexico 87528

4-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Jicarilla Apache Tribe
Post Office Box 507
Dulce, New Mexico 87528

4. Type of Service:

☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail

Article Number: P307 895 630

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X [signature]

7. Date of Delivery
7/7/86

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 631

Hon. Jim Baca
Commissioner/Public Lands
P. O. Box 1148
Santa Fe, NM 87504

7-1-86 CV

PS Form 3811, July 1983 447-845

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.
3. Article Addressed to:

Hon. Jim Baca
Commissioner/Public Lands
P. O. Box 1148
Santa Fe, NM 87504

4. Type of Service:

☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail

Article Number: P307 895 631

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X

7. Date of Delivery

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 632

Bureau of Land Management
Post Office Box 6770
Albuquerque, NM 87107

7-1-86 CW

PS Form 3811, July 1983 447-845

● **SENDER: Complete items 1, 2, 3 and 4.**

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☐ Show to whom, date and address of delivery.
2. ☐ Restricted Delivery.

3. Article Addressed to:

Bureau of Land Management
Post Office Box 6770
Albuquerque, NM 87107

4. Type of Service:	Article Number
☐ Registered ☐ Insured ☒ Certified ☐ COD ☐ Express Mail	P307 895 632

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X B. Tatum

7. Date of Delivery

8. Addressee's Address *(ONLY if requested and fee paid)*

DOMESTIC RETURN RECEIPT

P 307 895 633

Northwest Pipeline Corp.
295 Chipeta Way
Salt Lake City, Utah 84108

.22

.75

.60

1.57

7/3/86

PS Form 3811, July 1983 447-845

DOMESTIC RETURN RECEIPT

SENDER: Complete items 1, 2, 3 and 4.

Put your address in the "RETURN TO" space on the reverse side. Failure to do this will prevent this card from being returned to you. The return receipt fee will provide you the name of the person delivered to and the date of delivery. For additional fees the following services are available. Consult postmaster for fees and check box(es) for service(s) requested.

1. ☒ Show to whom, date and address of delivery.

2. ☐ Restricted Delivery.

3. Article Addressed to:

Northwest Pipeline Corp.
295 Chipeta Way
Salt Lake City, Utah 84108

4. Type of Service:

☐ Registered ☐ Insured
☒ Certified ☐ COD
☐ Express Mail

Article Number: P 307 895 633

Always obtain signature of addressee or agent and DATE DELIVERED.

5. Signature – Addressee
X

6. Signature – Agent
X

7. Date of Delivery
7-7-86

8. Addressee's Address *(ONLY if requested and fee paid)*

SALT LAKE CITY, UT FOOTHILL STA
JUL 7 1986
USPS

CAMPBELL & BLACK, P.A.
LAWYERS

JACK M. CAMPBELL
BRUCE D. BLACK
MICHAEL B. CAMPBELL
WILLIAM F. CARR
BRADFORD C. BERGE
J. SCOTT HALL
PETER N. IVES
JOHN H. BEMIS

GUADALUPE PLACE
SUITE 1 - 110 NORTH GUADALUPE
POST OFFICE BOX 2208
SANTA FE, NEW MEXICO 87504-2208
TELEPHONE: (505) 988-4421
TELECOPIER (505) 983-6043

July 1, 1986

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Amoco Production Company
Post Office Box 800
Denver, Colorado 80201

Re: Application of Benson-Montin-Greer Drilling Corp. for Amendment of Division Order No. R-3401, Rio Arriba County, New Mexico.

Dear Sirs:

This letter is to advise you of the application of Benson-Montin-Greer Drilling Corp. for amendment of New Mexico Oil Conservation Division Order No. R-3401. In this case, Benson-Montin-Greer is seeking the amendment of the Special Rules and Regulations promulgated for the West Puerto Chiquito-Mancos Oil Pool which include provisions for a gas-oil ratio of 2000 to 1. In this case, Benson-Montin-Greer seeks amendment of that Order to provide for a special gas-oil ratio of 1000 to 1 and the establishment of a production limitation factor of 400 barrels of oil per day for each 640-acre spacing unit in the pool.

This application has been set for hearing before the Oil Conservation Division on July 23, 1986. You are not required to attend this hearing, but as an interest owner in this area you may appear and present testimony. Failure to appear at that time and become a party of record will preclude you from challenging the matter at a later date.

Very truly yours,

William F. Carr /cv

William F. Carr

WFC/cv

OIL CONSERVATION DIVISION

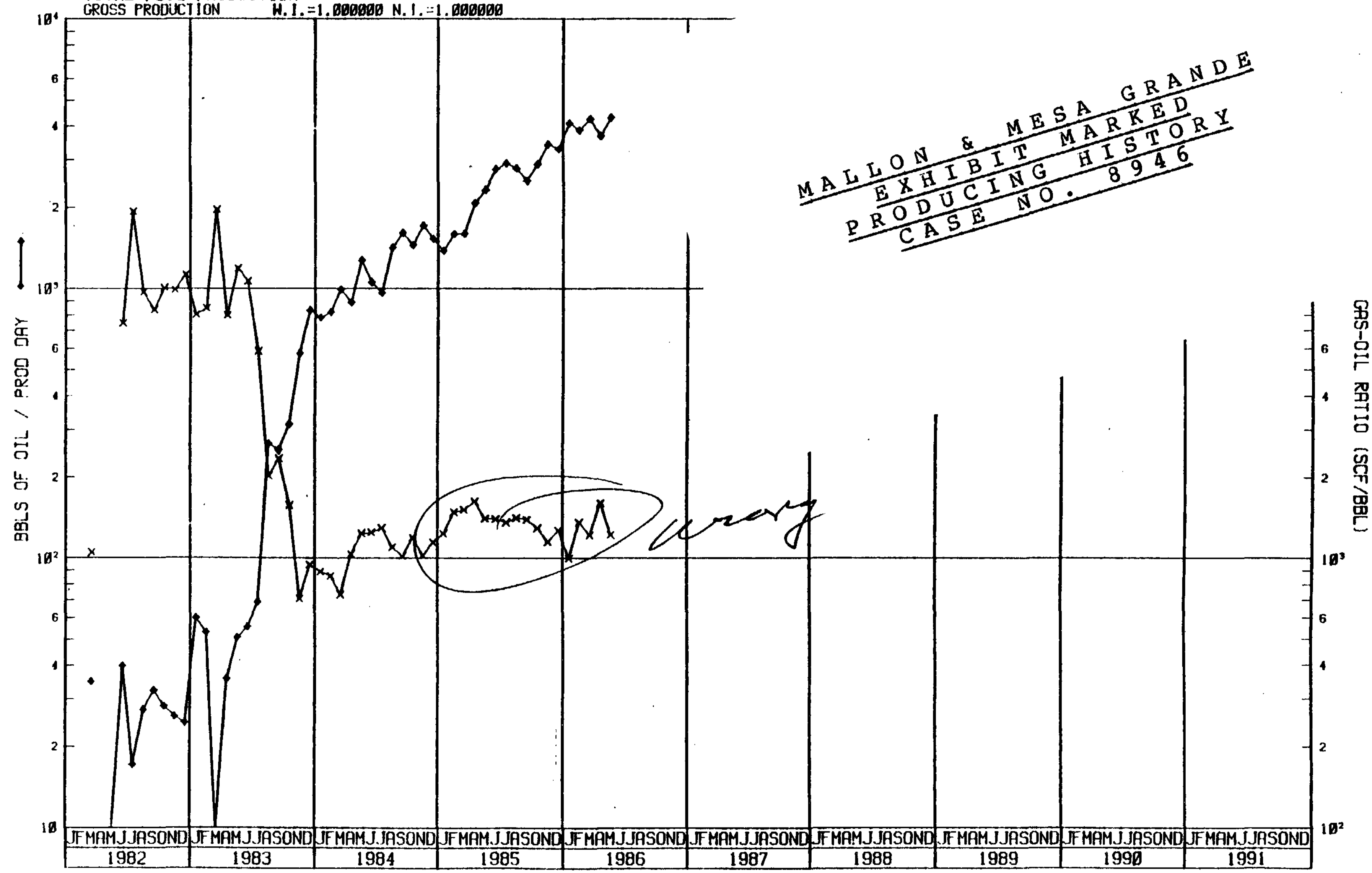
MR. STAMETS

BENSON-MONTIN-GREER DRILLING CORP.
EXHIBITS IN CASE NOS. 8946 & 8950
BEFORE THE OIL CONSERVATION DIVISION OF THE
NEW MEXICO DEPARTMENT OF ENERGY AND MINERALS

AUGUST 7, 1986

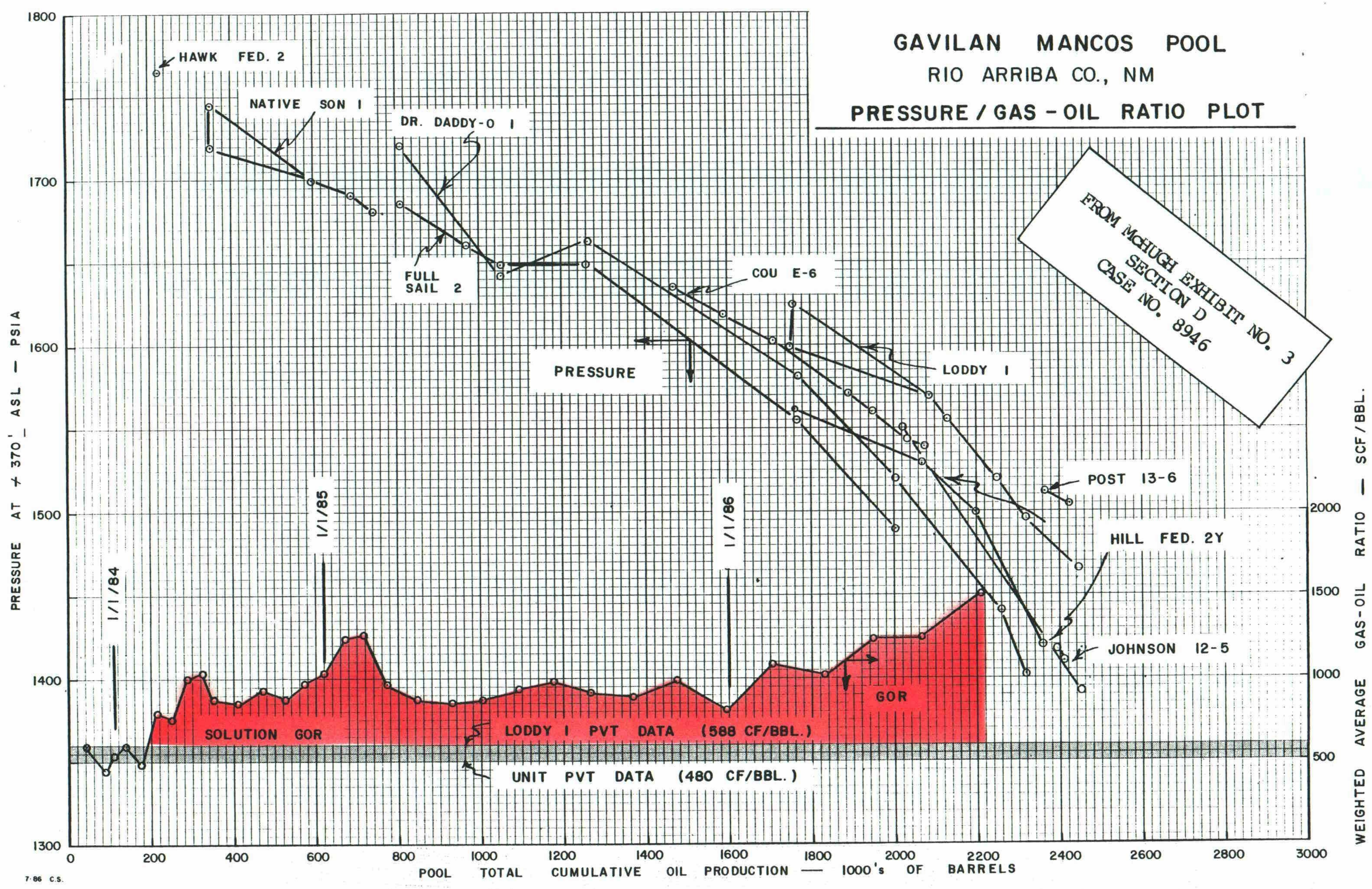
NMOCC/NMOCD Case No. 8950
Hearing Date 8/21/86
Benson-Montin-Greer
Exhibit No. 6

GAVILAN MANCOS POOL, RIO ARRIBA COUNTY, NEW MEXICO
TOTAL POOL PRODUCTION
GROSS PRODUCTION W.I.=1.000000 N.I.=1.000000

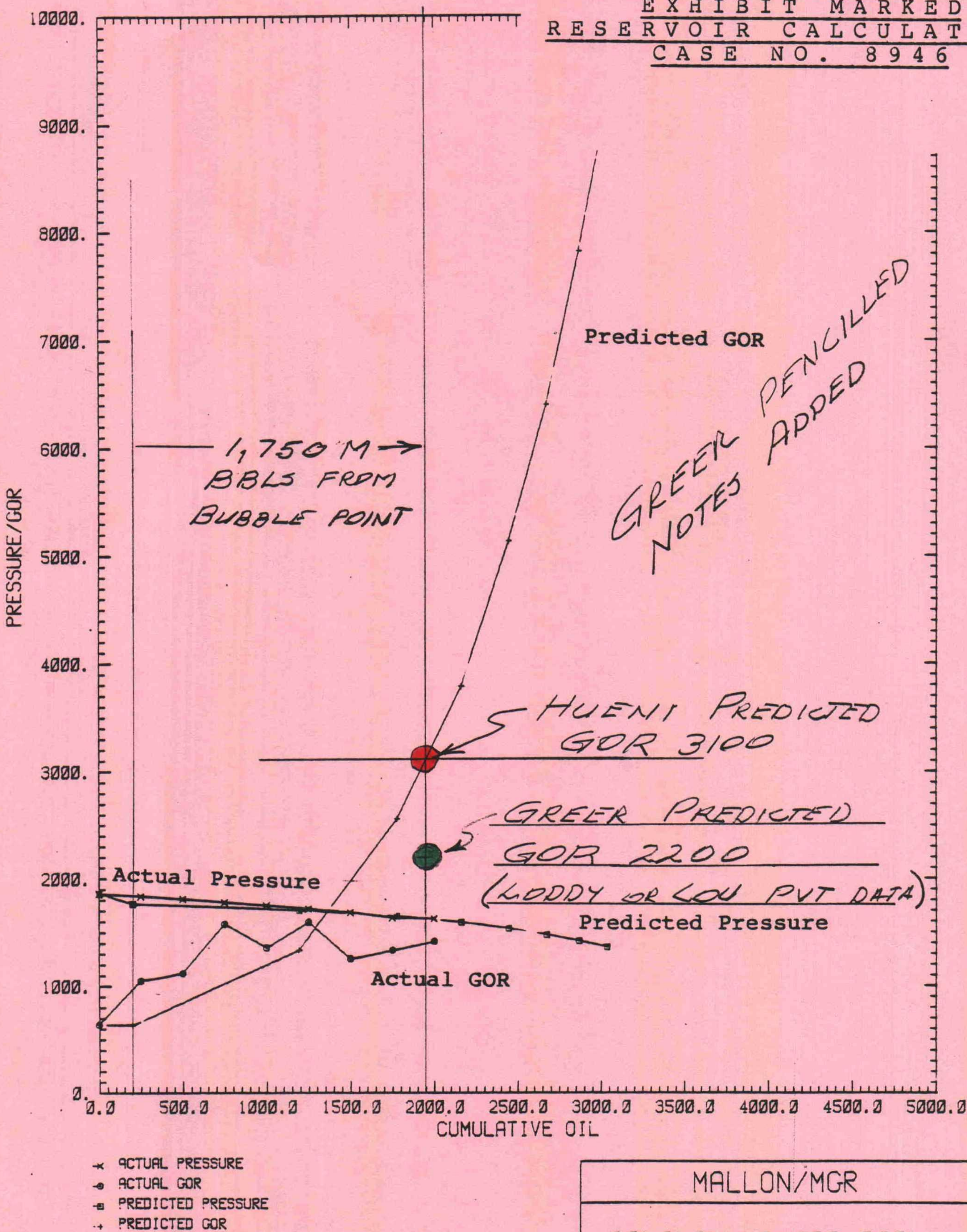


	Pool Total		Sum of #1 GAU & GAU-HOW		Pool Total less #1 GAU & GAV-HOW		
	OIL	GAS	OIL	GAS	OIL	GAS	WTED AVG GOR
1983							
Aug	6924	18,643	3030	15,119	3894	3524	905
Sept	8205	17,956	3254	11,560	4951	6396	1292
Oct	10,112	15,568	447	3,888	9,665	11,680	1209
Nov	21,375	12,761	171	1329	21,204	11,432	539
Dec	31,627	25,247	2477	10,970	29,150	14,277	490
1984							
Jan	29,446	22,374	2707	8640	26,741	13,734	514
F	29,380	20,990	2613	6452	26,767	14,538	543
M	35,279	23,521	2849	7526	32,430	15,995	493
A	30826	29,178	2886	7006	27,940	22,172	794
M	48,106	52,385	4778	19,879	43,328	32,506	750
Ju	37,533	43,143	2837	8,212	34,696	34,931	1007
Jul	35,510	40,491	2648	6,519	32,862	33,972	1034
Aug	48,575	50,402	2533	10,243	46,042	40,159	872
Sep	53,177	55,346	2,223	11,791	50,954	43,355	851
Oct	49,721	56,561	2,263	11,742	47,458	44,819	944
Nov	53,276	56,226	2,385	11,354	50,891	44,872	882
Dec	50,573	57,046	2,489	10,298	48,084	46,748	972

	Pool Total		Sum of GAV #1 & GAV. HOW		Pool Total less #1 GAV. & #1 GAV-HOW		
	oil	gas	oil	gas	oil	gas	GOR
1985							
JAN	44,587	54,837	1268	9,593	43,319	45,244	1044
FEB	46,407	68,213	1551	11,506	44,856	56,707	1264
MAR	51,713	77,356	1894	13,183	49,819	64,173	1289
AP	66,736	103,132	5321	43,219	61,415	59,913	976
MAY	73,684	102,362	7922	43,770	65,762	58,592	891
Ju	85,109	123,428	8,547	57,843	76,562	65,585	857
July	86,256	118,877	8260	51,920	77,996	66,957	859
Aug	88,588	124,740	7273	49,058	81,315	75,682	931
Sept	77,586	107,418	6190	37,131	71,396	70,287	985
Oct	92,791	120,078	6749	41,308	86,042	78,770	916
Nov	103,754	120,043	5545	31,768	98,209	88,075	897
Dec	105,578	131,884	6837	34,169	98,741	97,715	990
1986							
JAN	131,058	135,508	7193	35,840	123,865	99,668	805
FEB	111,329	149,845	5802	34,799	105,527	115,046	1090
MARCH	127,946	160,868	6319	38,384	121,627	122,484	1007
AP	109,478	174,136	3842	38,252	105,636	135,884	1286
MAY	126,731	165,278	2644	10,841	124,087	154,437	1245
JUN	163,093	258,723	4775	20,105	158,318	238,618	1507


GAVILAN MANCOS POOL
RIO ARRIBA CO., NM
PRESSURE / GAS - OIL RATIO PLOT
FROM McHUGH EXHIBIT NO. 3
SECTION D
CASE NO. 8946
HAWK FED. 2
NATIVE SON I
DR. DADDY-O I
FULL SAIL 2
COU E-6
PRESSURE
LODDY I
POST 13-6
HILL FED. 2Y
JOHNSON 12-5
1/1/84
1/1/85
1/1/86
SOLUTION GOR
LODDY I PVT DATA (588 CF/BBL.)
UNIT PVT DATA (480 CF/BBL.)
GOR
PRESSURE AT + 370' ASL — PSIA
WEIGHTED AVERAGE GAS-OIL RATIO — SCF/BBL.
POOL TOTAL CUMULATIVE OIL PRODUCTION — 1000's OF BARRELS
7-86 C.S.

MALLON & MESA GRANDE
EXHIBIT MARKED
RESERVOIR CALCULATIONS
CASE NO. 8946



MALLON/MGR

GAVILON MANCOS POOL

ACTUAL VS SOLUTION GAS DRIVE RECOVERY

SCALE: NTS	DATE: 05-AUG-86
SOURCE:	DRAWING NO.

Jerry R. Bergeson & Associates Inc.

RESERVOIR FLUID STUDY

for

Jerome P. McHugh and Associates

Lottie No. 1 Well
Lindrith Unit Field
Sandoval County, New Mexico
File Number: ARFL-860042

A

CORE LABORATORIES, INC.

Reservoir Fluid Analysis

File ARFL-860042

Company	Jerome P. McHugh and Associates	Date Sampled	February 26, 1986
Well	Lottie No. 1	County	Sandoval
Field	Lindrith Unit	State	New Mexico

FORMATION CHARACTERISTICS

Formation Name	Gallup Mancos
Date First Well Completed	
Original Reservoir Pressure	PSIG @ Ft.
Original Produced Gas/Oil Ratio	SCF/Bbl
Production Rate	Bbl/Day
Separator Pressure and Temperature	PSIG °F.
Oil Gravity at 60°F.	°API
Datum	Ft. Subsea
Original Gas Cap	

WELL CHARACTERISTICS

Elevation	7155 GL Ft.
Total Depth	PD 8130 TD 8175 Ft.
Producing Interval	6822-7122 Ft.
Tubing Size and Depth	2 7/8 In. to 7148 Ft.
Productivity Index	Bbl/D/PSI @ Bbl/Day
Last Reservoir Pressure	1648 PSIG @ 6994 Ft.
Date	February 26, 1986
Reservoir Temperature	170 °F. @ 6994 Ft.
Status of Well	Shut in since September 10, 1985
Pressure Gauge	Amerada
Normal Production Rate	Bbl/Day
Gas/Oil Ratio	SCF/Bbl
Separator Pressure and Temperature	PSIG, °F.
Base Pressure	PSIA
Well Making Water	% Cut

SAMPLING CONDITIONS

Sampled at	6994 Ft.
Status of Well	Shut in
Gas/Oil Ratio	SCF/Bbl
Separator Pressure and Temperature	PSIG, °F.
Tubing Pressure	354 PSIG
Casing Pressure	1312 PSIG
Sampled by	Tefteller, Inc.
Type Sampler	Wofford

REMARKS:

SUMMARY OF SAMPLES RECEIVED IN LABORATORY

Subsurface Fluid Samples

Cylinder Number	Laboratory Bubble Point Pressure: Pressure, PSIG	Laboratory Bubble Point Pressure: Temperature, °F.
SS-2049*	1135	72
SS-708	1132	72

* Selected for use in reservoir fluid study.

CORE LABORATORIES, INC.
Reservoir Fluid Analysis

File ARFL-860042
Well Lottie No. 1

HYDROCARBON ANALYSIS OF RESERVOIR FLUID SAMPLE

Component	Mol Percent	Weight Percent	Density, Gm/Cc @ 60°F.	°API @ 60°F.	Molecular Weight
Hydrogen Sulfide	0.00	0.00			
Carbon Dioxide	0.00	0.00			
Nitrogen	0.08	0.02			
Methane	24.58	3.64			
Ethane	8.79	2.44			
Propane	7.77	3.17			
iso-Butane	1.42	0.77			
n-Butane	4.66	2.50			
iso-Pentane	2.05	1.37			
n-Pentane	2.61	1.74			
Hexanes	3.72	2.88			
Heptanes plus	44.32	81.47	0.8335	38.1	199
	100.00	100.00			

VOLUMETRIC DATA OF RESERVOIR FLUID SAMPLE

Saturation pressure (bubble point pressure) = 1482 PSIG @ 170°F.

Specific volume at saturation pressure = 0.02291 ft ^{3}/lb @ 170°F. *

Thermal expansion @ 5000 PSIG = 1.05109 V @ 170°F./V @ 75°F.

Compressibility @ 170°F.:

From 5000 PSIG to 4000 PSIG = 8.82 x 10^{-6} V/V/PSI

From 4000 PSIG to 3000 PSIG = 9.92 x 10^{-6} V/V/PSI

From 3000 PSIG to 2000 PSIG = 11.09 x 10^{-6} V/V/PSI

From 2000 PSIG to 1482 PSIG = 12.41 x 10^{-6} V/V/PSI

Cou

* DENSITY FOR ADJUSTING PRESSURES TO DATUM:

.02291 ft ^{3}/# → 43.649 #/ft ^{3}

$$\frac{43.649\ \#/ft^3}{144\ in^2/ft^2} = .303\ \#/in^2 \text{ per ft}$$

PRESSURE-VOLUME RELATIONS AT 170°F.
(Constant Composition Expansion)

Pressure, PSIG	Relative Volume(1)	Y Function(2)
5000	0.9642	
4500	0.9683	
4000	0.9728	
3500	0.9776	
3000	0.9826	
2500	0.9878	
2000	0.9936	
1800	0.9960	
1700	0.9973	
1648(3)	0.9979	
1600	0.9985	
1500	0.9998	
1482(4)	1.0000	
1462	1.0058	
1444	1.0112	
1430	1.0157	
1395	1.0269	
1340	1.0465	2.255
1242	1.0882	2.166
1096	1.1671	2.079
936	1.2932	1.958
793	1.4575	1.864
673	1.6631	1.773
522	2.0745	1.664
396	2.6922	1.561
288	3.6447	1.490

(1) Relative Volume: V/Vsat is barrels at indicated pressure per barrel at saturation pressure.

(2) Y Function = $\frac{(Psat-P)}{(Pabs)(V/Vsat-1)}$

(3) Reservoir Pressure

(4) Bubble Point Pressure

DIFFERENTIAL VAPORIZATION AT 170°F.

Pressure, PSIG	Solution Gas/Oil Ratio(1)	Relative Oil Volume(2)	Relative Total Volume(3)	Oil Density, Gm/Cc	Deviation Factor, Z	Gas Formation Volume Factor(4)	Incremental Gas Gravity
1482	588	1.380	1.380	0.6991			
1300	537	1.358	1.465	0.7045	0.852	0.01179	0.711
1100	480	1.333	1.605	0.7113	0.865	0.01412	0.721
900	423	1.307	1.824	0.7160	0.878	0.01747	0.731
700	365	1.281	2.184	0.7252	0.896	0.02281	0.757
500	305	1.253	2.881	0.7327	0.914	0.03231	0.794
300	241	1.222	4.576	0.7411	0.939	0.05426	0.888
153	184	1.192	8.692	0.7489	0.962	0.10424	1.032
90	142	1.166	14.566	0.7558	0.973	0.16868	1.231
0	0	1.055		0.7769			1.921
	at 60°F. =	1.000					

Gravity of Residual Oil = 40.9°API @ 60°F.

(1) Cubic feet of gas at 15.025 psia and 60°F. per barrel of residual oil at 60°F.

(2) Barrels of oil at indicated pressure and temperature per barrel of residual oil at 60°F.

(3) Barrels of oil plus liberated gas at indicated pressure and temperature per barrel of residual oil at 60°F.

(4) Cubic feet of gas at indicated pressure and temperature per cubic foot at 15.025 psia and 60°F.

VISCOSITY DATA AT 170°F.

Pressure, PSIG	Oil Viscosity, Centipoise	Calculated Gas Viscosity, Centipoise	Oil/Gas Viscosity Ratio
5000	0.69		
4000	0.64		
3000	0.59		
2000	0.55		
1648 (1)	0.53		
1482 (2)	0.52		
1300	0.54	0.0150	36.0
1100	0.59	0.0144	41.0
900	0.65	0.0139	46.8
700	0.77	0.0133	57.9
500	0.92	0.0128	71.9
300	1.08	0.0120	90.0
153	1.21	0.0112	108.0
90	1.27	0.0105	120.9
0	1.33		

(1) Reservoir Pressure

(2) Bubble Point Pressure

CORE LABORATORIES, INC.

Reservoir Fluid Analysis

File ARFL-860042
Well Lottie No. 1

SEPARATOR TESTS OF RESERVOIR FLUID SAMPLE

Separator Pressure, PSIG	Temp., °F.	Gas/Oil Ratio (1)	Gas/Oil Ratio (2)	Tank Oil Gravity, °API @ 60°F.	Formation Volume Factor (3)	Separator Volume Factor (4)	Gas Gravity
50	100	427	447			1.046	0.881*
to							
0	70	51	51	42.7	1.305	1.004	1.275
			498				
100	100	366	393			1.074	0.829*
to							
0	70	94	95	42.9	1.298	1.006	1.326
			488				
125	100	344	374			1.087	0.812*
to							
0	70	115	116	42.9	1.299	1.005	1.330
			490				
150	100	325	357			1.099	0.794*
to							
0	70	133	134	42.9	1.300	1.005	1.330
			491				

(1) Gas/Oil Ratio in cubic feet of gas at 15.025 psia and 60°F. per barrel of oil at indicated pressure and temperature.

(2) Gas/Oil Ratio in cubic feet of gas at 15.025 psia and 60°F. per barrel of stock tank oil at 60°F.

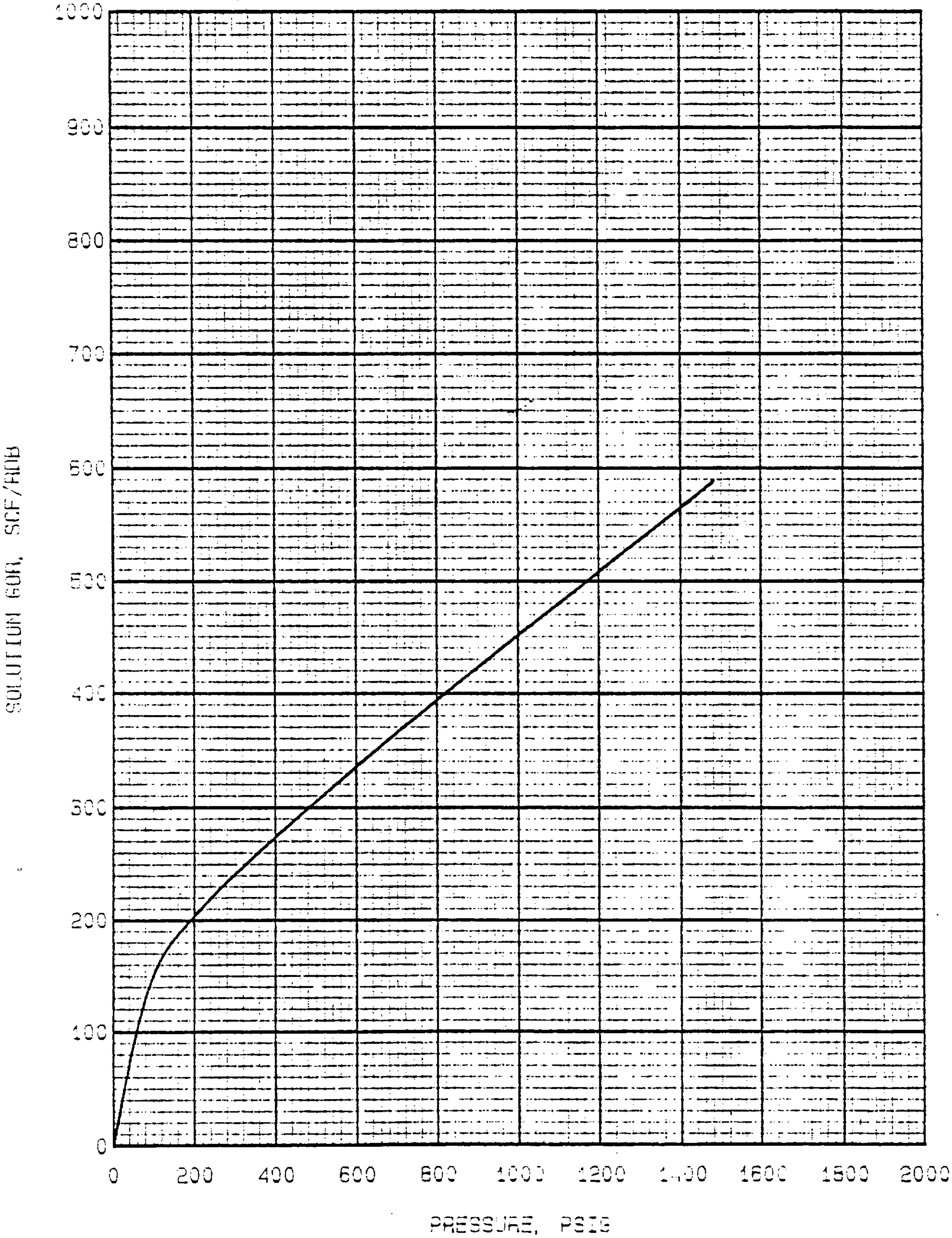
(3) Formation Volume Factor is barrels of saturated oil at 1482 psig and 170°F. per barrel of stock tank oil at 60°F.

(4) Separator Volume Factor is barrels of oil at indicated pressure and temperature per barrel of stock tank oil at 60°F.

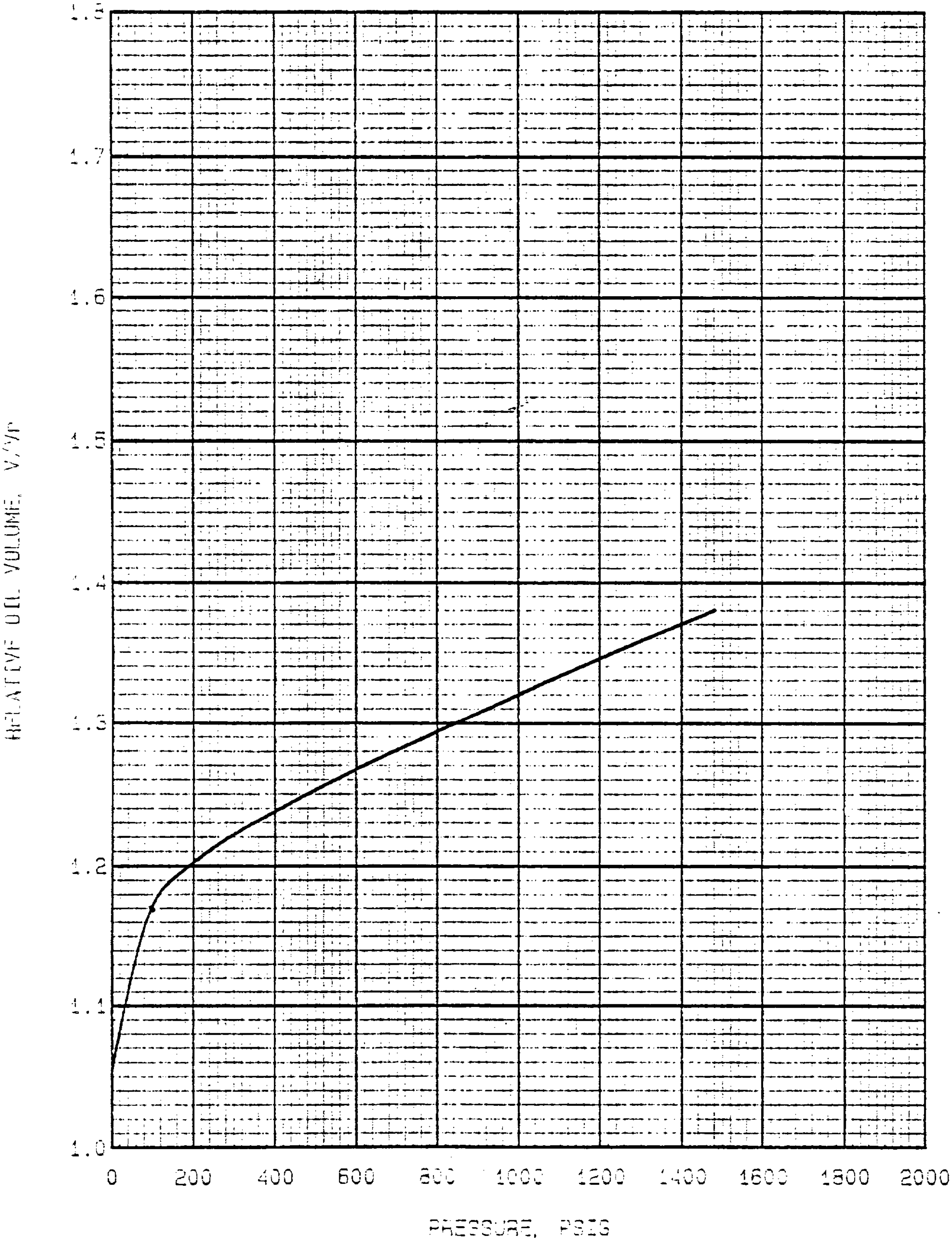
HYDROCARBON ANALYSES OF SEPARATOR GAS SAMPLES

Component	50 PSIG, 100°F. Mol Percent	50 PSIG, 100°F. GPM	100 PSIG, 100°F. Mol Percent	100 PSIG, 100°F. GPM	125 PSIG, 100°F. Mol Percent	125 PSIG, 100°F. GPM	150 PSIG, 100°F. Mol Percent	150 PSIG, 100°F. GPM
Hydrogen Sulfide	0.00		0.00		0.00		0.00	
Carbon Dioxide	0.00		0.00		0.00		0.00	
Nitrogen	0.20		0.22		0.23		0.27	
Methane	62.33		66.63		68.39		69.92	
Ethane	18.57	5.065	17.97	4.902	17.58	4.795	17.14	4.675
Propane	11.60	3.260	9.81	2.757	9.04	2.541	8.38	2.355
iso-Butane	1.38	0.461	1.09	0.364	0.95	0.317	0.86	0.287
n-Butane	3.45	1.110	2.57	0.827	2.30	0.740	2.07	0.666
iso-Pentane	0.75	0.280	0.54	0.202	0.48	0.179	0.44	0.164
n-Pentane	0.71	0.262	0.50	0.185	0.45	0.166	0.41	0.151
Hexanes	0.46	0.182	0.33	0.131	0.30	0.119	0.27	0.107
Heptanes plus	0.55	0.236	0.34	0.147	0.28	0.121	0.24	0.104
	100.00	10.856	100.00	9.515	100.00	8.978	100.00	8.509
Gas gravity (Air = 1.000):	0.881		0.829		0.812		0.794	
Gross heating value (BTU per cubic foot of dry gas at 15.025 psia and 60°F.):	1549		1465		1438		1410	

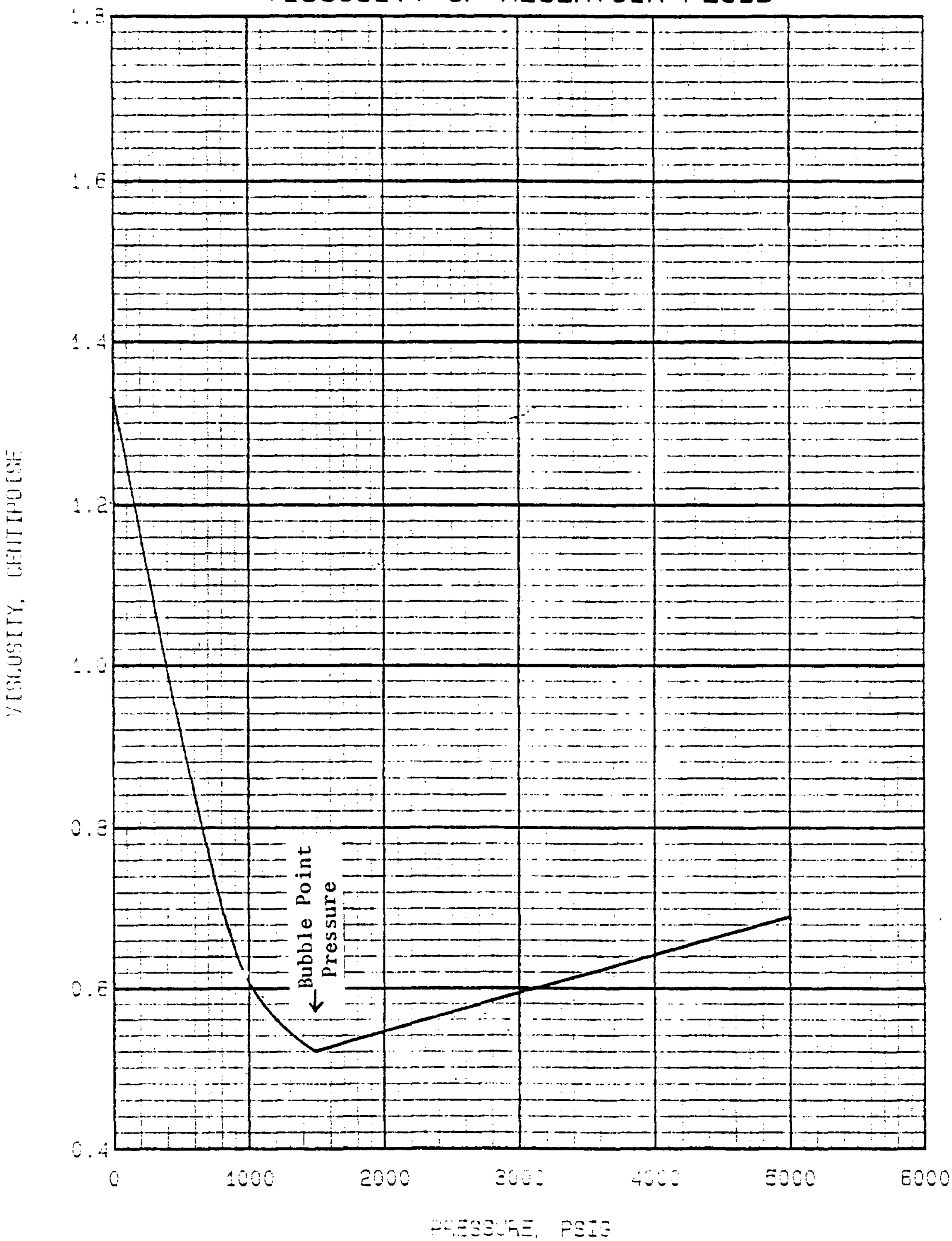
SOLUTION GAS/OIL RATIO DURING DIFFERENTIAL VAPORIZATION

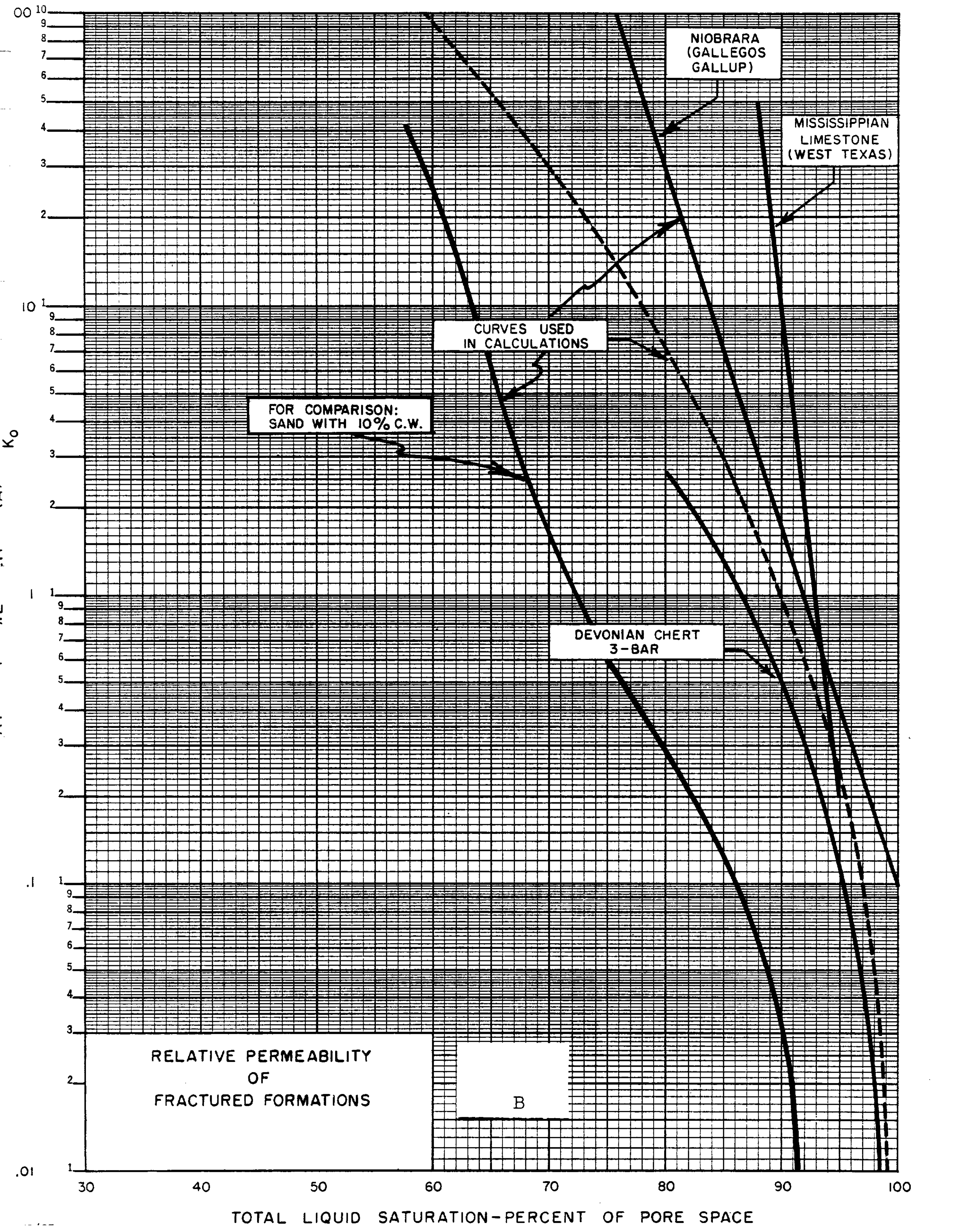


RELATIVE OIL VOLUME DURING DIFFERENTIAL VAPORIZATION

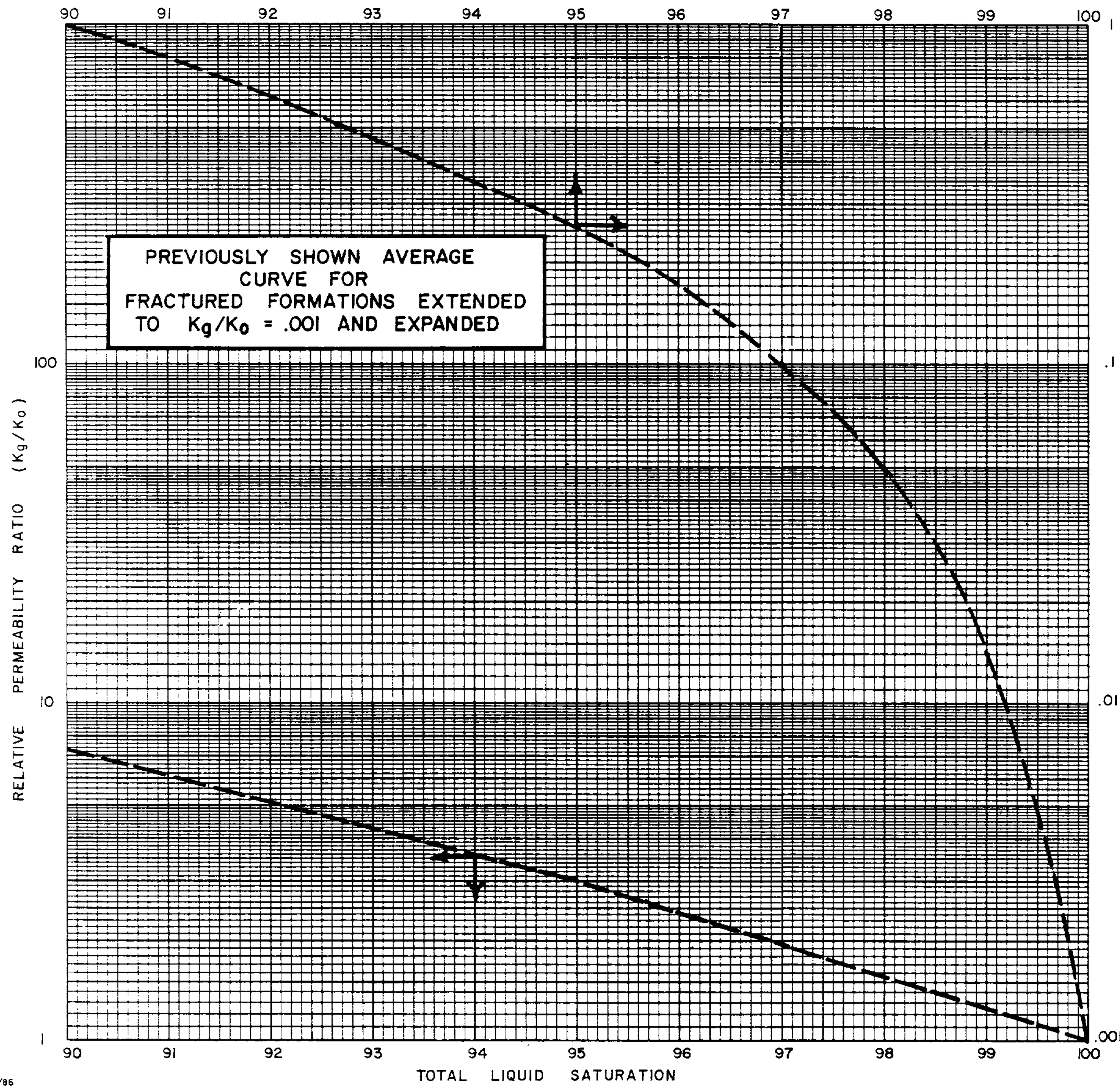


VISCOSITY OF RESERVOIR FLUID





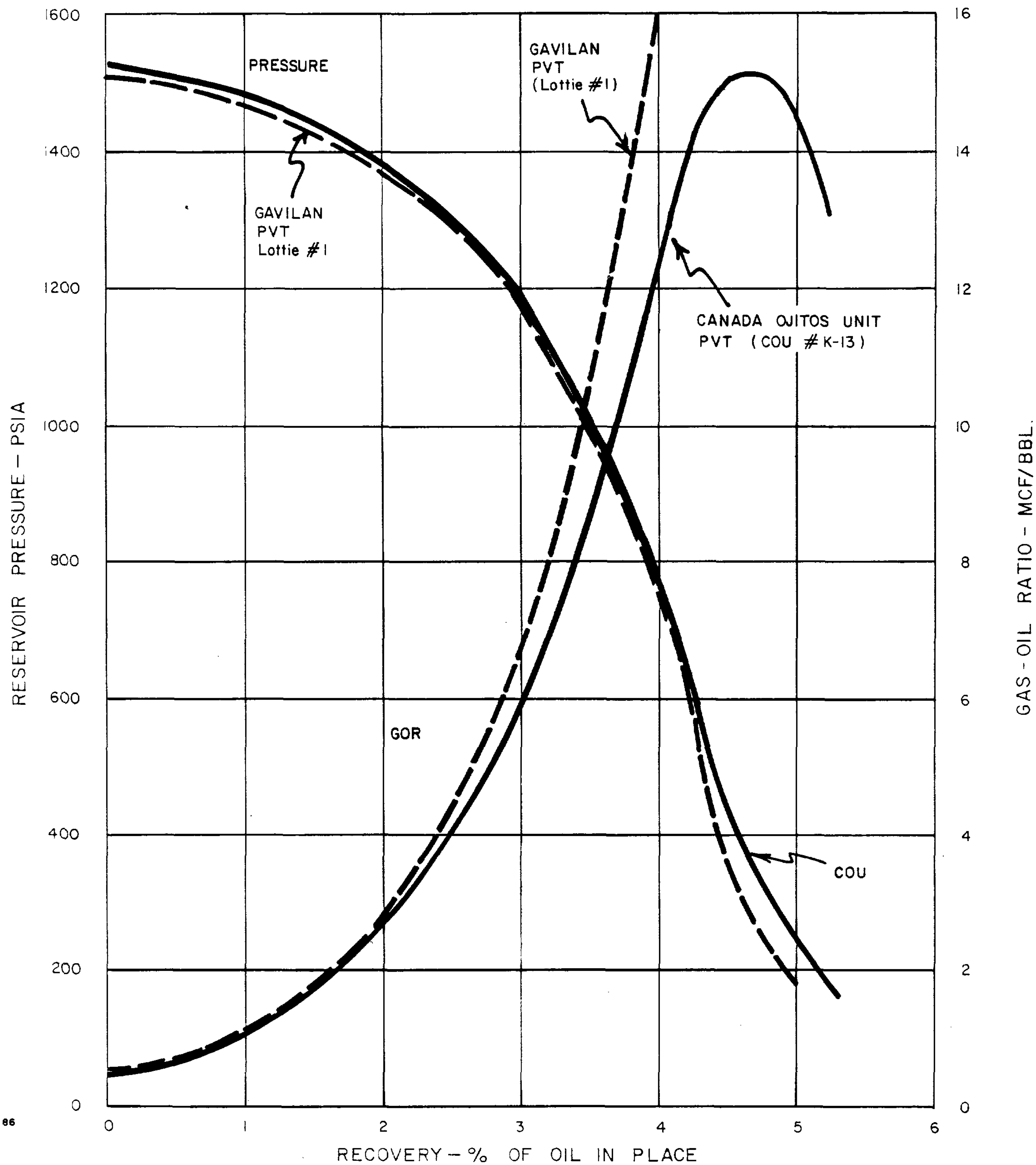
NIOBRARA (GALLEGOS GALLUP)
MISSISSIPPIAN LIMESTONE (WEST TEXAS)
CURVES USED IN CALCULATIONS
FOR COMPARISON: SAND WITH 10% C.W.
DEVONIAN CHERT 3-BAR
RELATIVE PERMEABILITY OF FRACTURED FORMATIONS
B
K_o
TOTAL LIQUID SATURATION—PERCENT OF PORE SPACE
30
40
50
60
70
80
90
100
.01
.1
1
10



PREVIOUSLY SHOWN AVERAGE CURVE FOR FRACTURED FORMATIONS EXTENDED TO Kg/Ko = .001 AND EXPANDED
90
91
92
93
94
95
96
97
98
99
100
1
100
.1
10
.01
1
.001
RELATIVE PERMEABILITY RATIO (Kg/Ko)
RELATIVE PERMEABILITY RATIO (Kg/Ko)
TOTAL LIQUID SATURATION

8/86

CALCULATED SOLUTION GAS DRIVE
PRODUCTION HISTORIES
For
FRACTURED FORMATIONS (CURVE "A")
AND
PVT DATA FOR WEST PUERTO CHIQUITO (COU K-13)
AND GAVILAN (LOTTIE #1)



8-86

CORE LABORATORIES, INC.

Reservoir Fluid Analysis

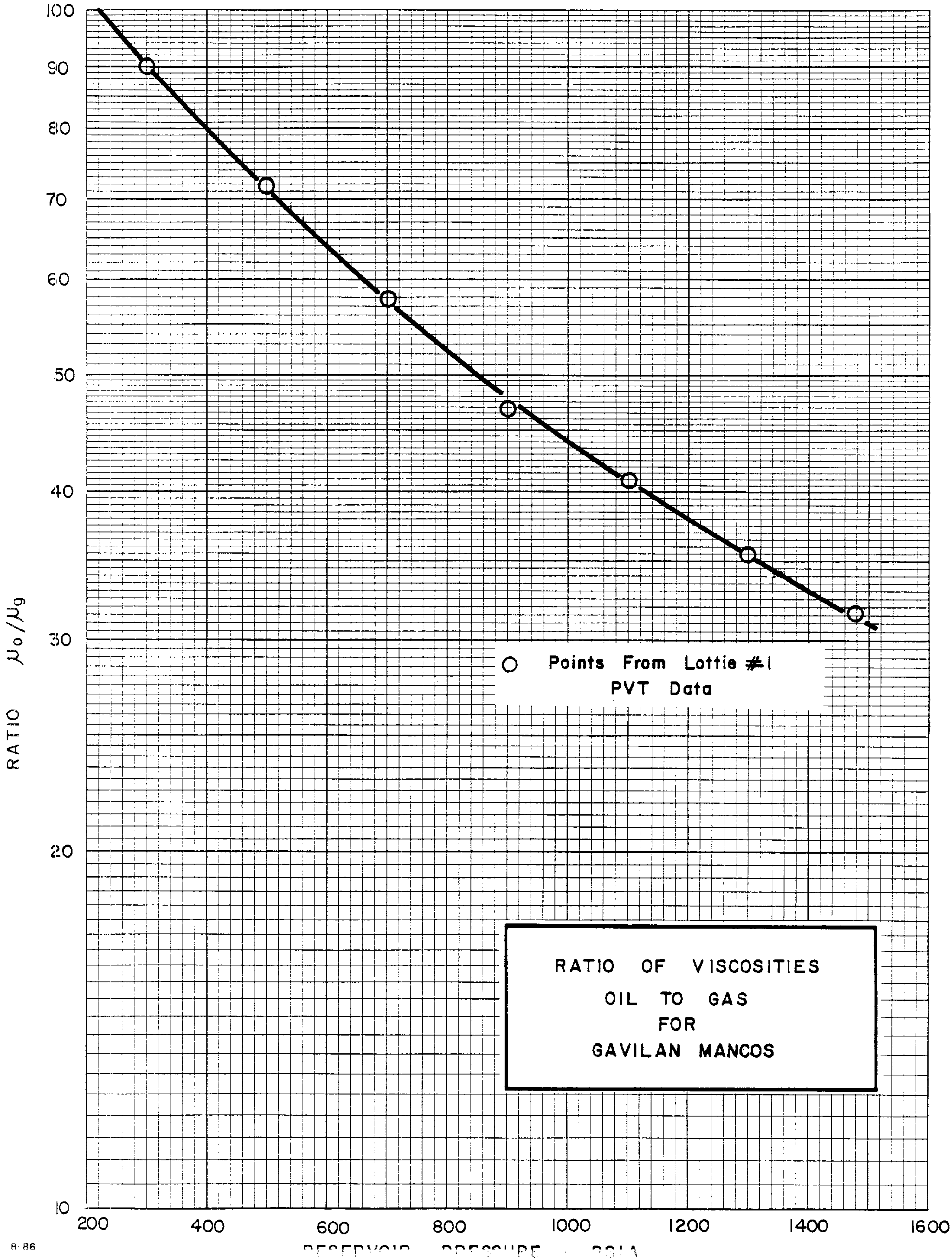
File ARFL-860042
Well Lottie No. 1

VISCOSITY DATA AT 170°F.

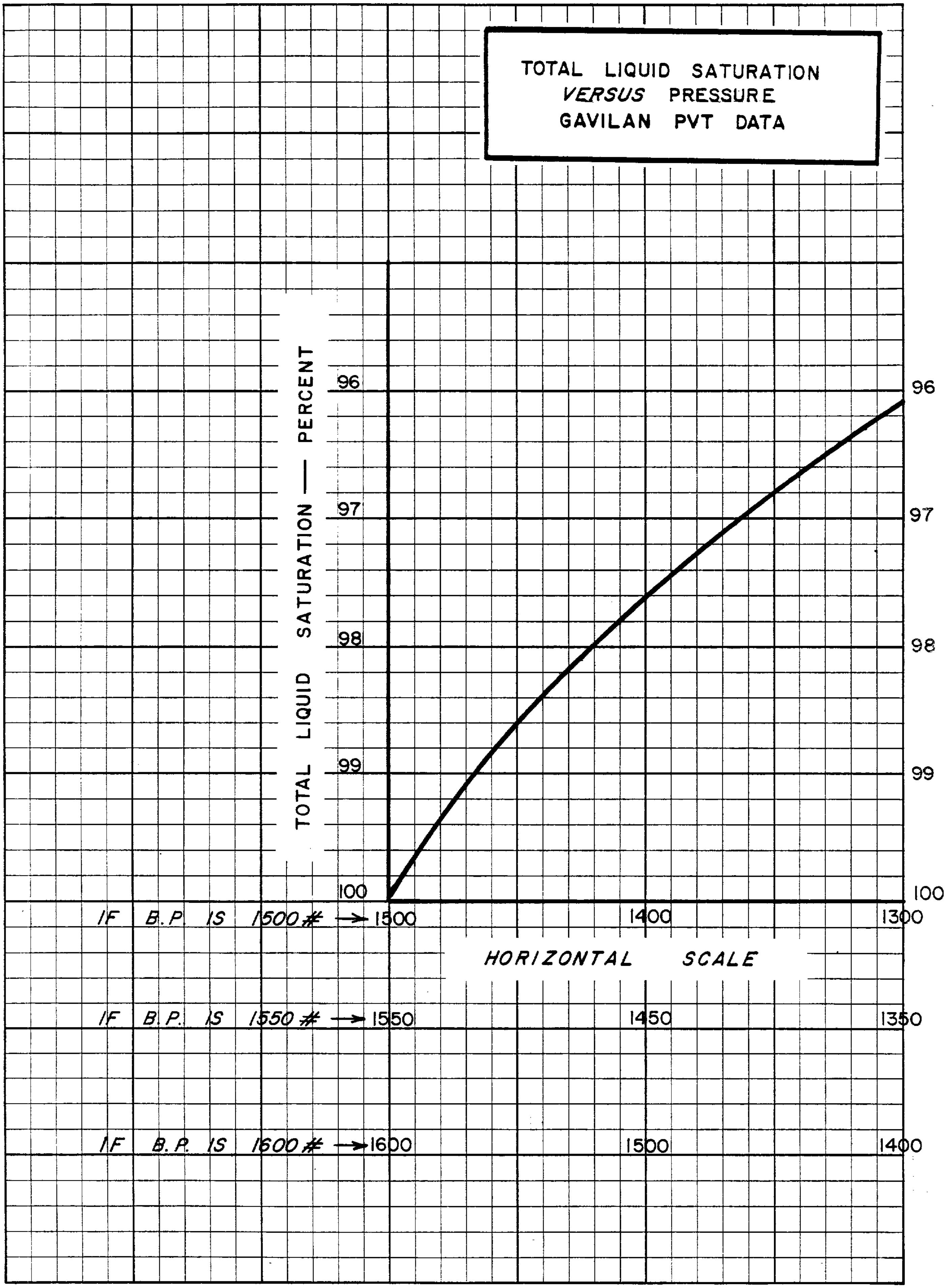
Pressure, PSIG	Oil Viscosity, Centipoise	Calculated Gas Viscosity, Centipoise	Oil/Gas Viscosity Ratio	
5000	0.69			
4000	0.64			
3000	0.59			
2000	0.55			
1648 (1)	0.53			
1482 (2)	0.52	.0156	33.3	est
1300	0.54	0.0150	36.0	
1100	0.59	0.0144	41.0	
900	0.65	0.0139	46.8	
700	0.77	0.0133	57.9	
500	0.92	0.0128	71.9	
300	1.08	0.0120	90.0	
153	1.21	0.0112	108.0	
90	1.27	0.0105	120.9	
0	1.33			

(1) Reservoir Pressure

(2) Bubble Point Pressure


RATIO OF VISCOSITIES
OIL TO GAS
FOR
GAVILAN MANCOS
Points From Lottie #1
PVT Data
RATIO μ_o/μ_g
100
90
80
70
60
50
40
30
20
10
200
400
600
800
1000
1200
1400
1600

8-86


TOTAL LIQUID SATURATION
VERSUS PRESSURE
GAVILAN PVT DATA
TOTAL LIQUID SATURATION — PERCENT
96
97
98
99
100
IF B.P. IS 1500# → 1500
1400
1300
HORIZONTAL SCALE
IF B.P. IS 1550# → 1550
1450
1350
IF B.P. IS 1600# → 1600
1500
1400

8-36

RELATIVE PERMEABILITY RATIOS ESTIMATED FROM FIELD DATA

McHUGH NATIVE SON #2

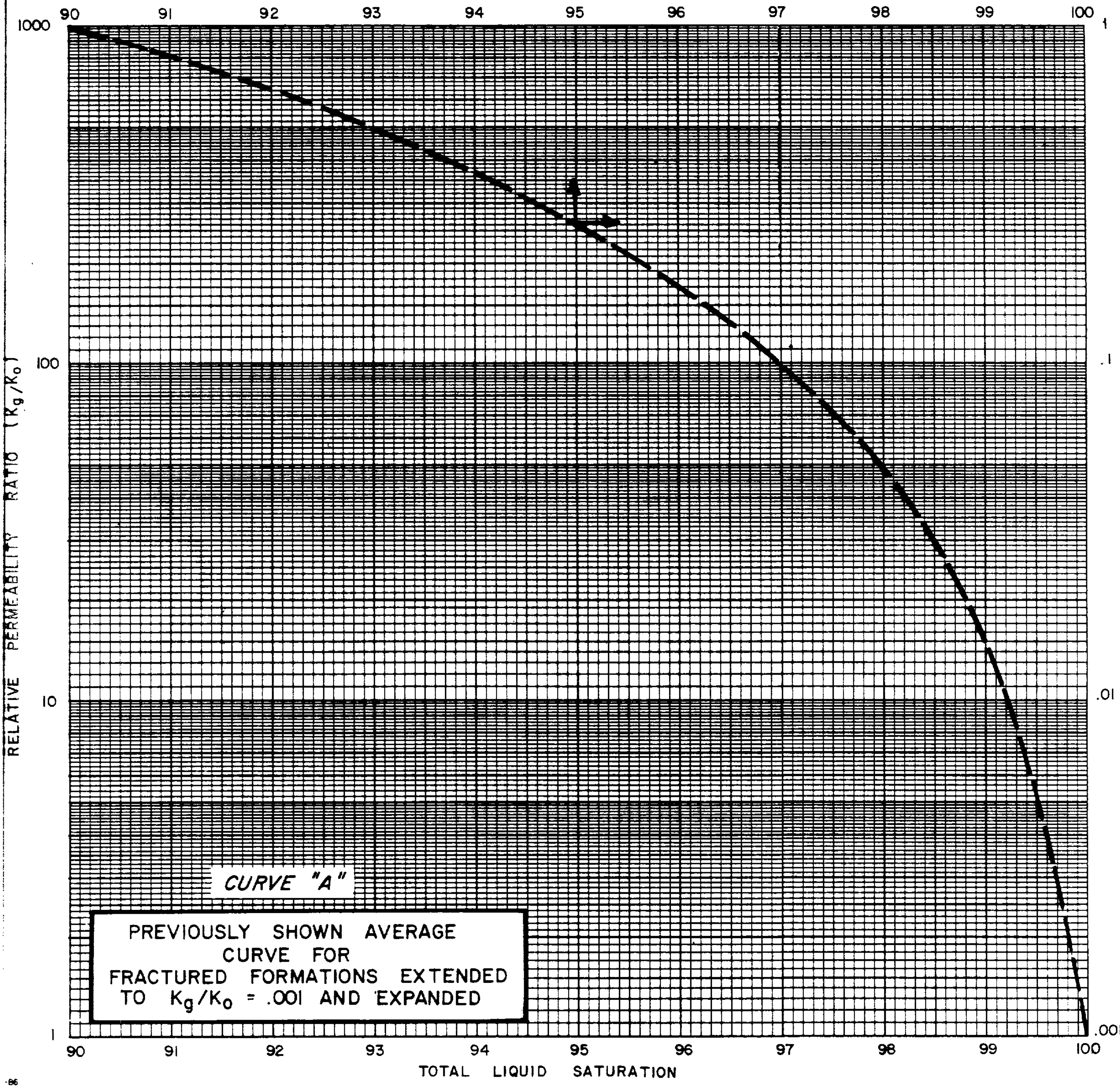
Top A Zone	+485
(Top A Zone Δ P from +370)	-65#
(Base C Zone from +370)	+35#

Month	Dec. 1985	Feb. 1986	April 1986	June 1986
Pressures:				
Est. Datum	1575	1540	1500	1450
Est. Top A Zone	1510	1475	1435	1385
Est. Bottom C Zone	1610	1575	1535	1485
Average P	1560	1525	1485	1435
GOR	1447	1934	2259	2835
Rs	580	580	570	560
$\mu o/\mu g$	30	31	32	33
Bg (SCF/bbl)	584	571	556	537
Bo	1.38	1.38	1.38	1.38
Kg/Ko*	.036	.055	.069	.093
Total liquid saturation for B.P. = 1500#	100	99.2-100	98.3-100	97.4-99.5
Total liquid saturation for B.P. = 1550#	98.8-100	98.1-100	97.4-99.5	96.6-98.3
Total liquid saturation for B.P. = 1600#	97.8-100	97.2-99.2	96.6-98.1	95.9-97.4

$$* \ Kg/Ko = \left(\frac{R - Rs}{BoBg}\right)\left(\frac{\mu g}{\mu o}\right)$$

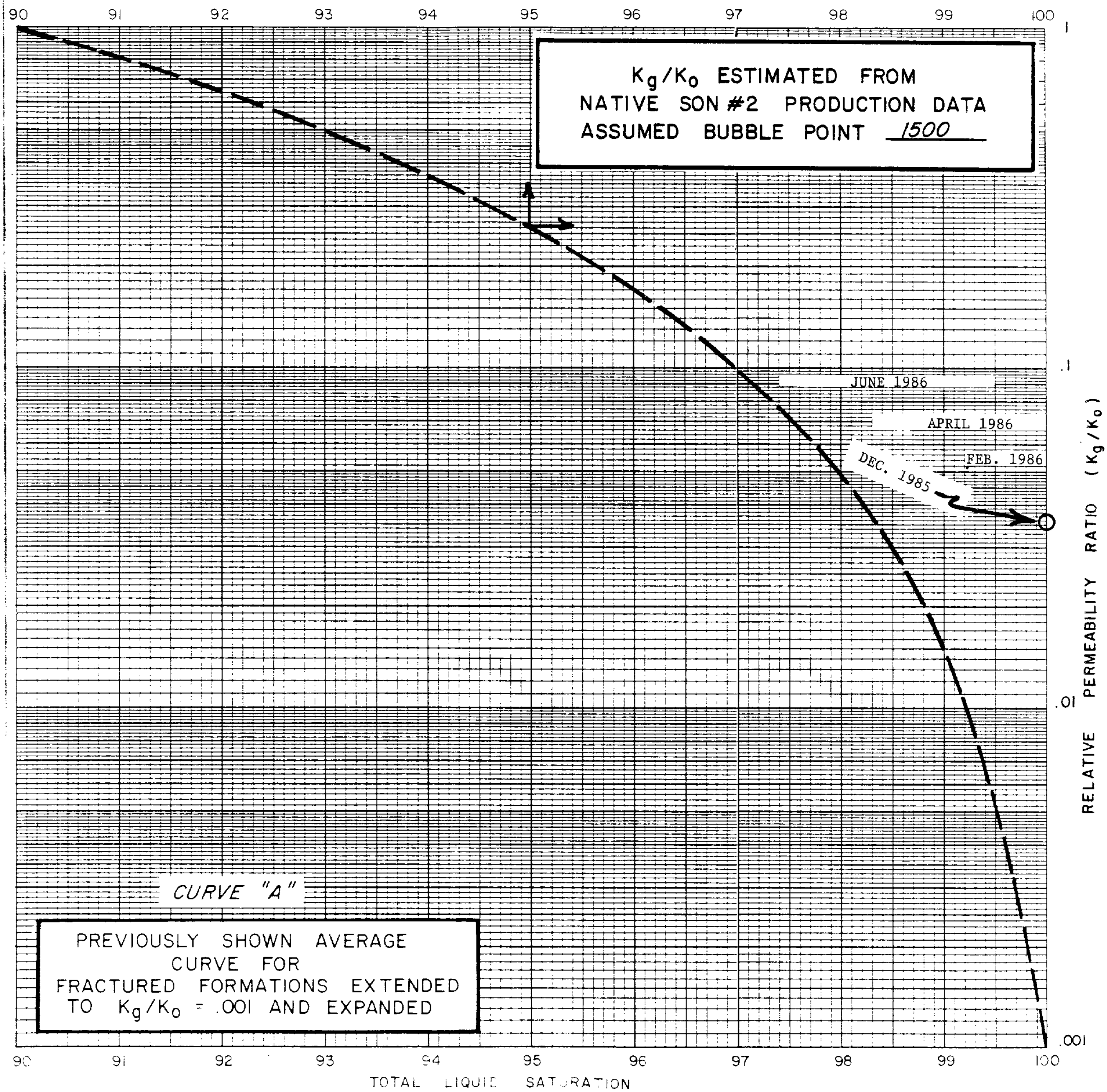
R = Produced GOR, cf/bbl
Rs = Gas in Solution, cf/bbl
Bo = Oil FVF, reservoir bbl/stock tank bbl
Bg = Gas FVF, SCF/bbl
ug/uo = Ratio of Gas to Oil Viscosities

D

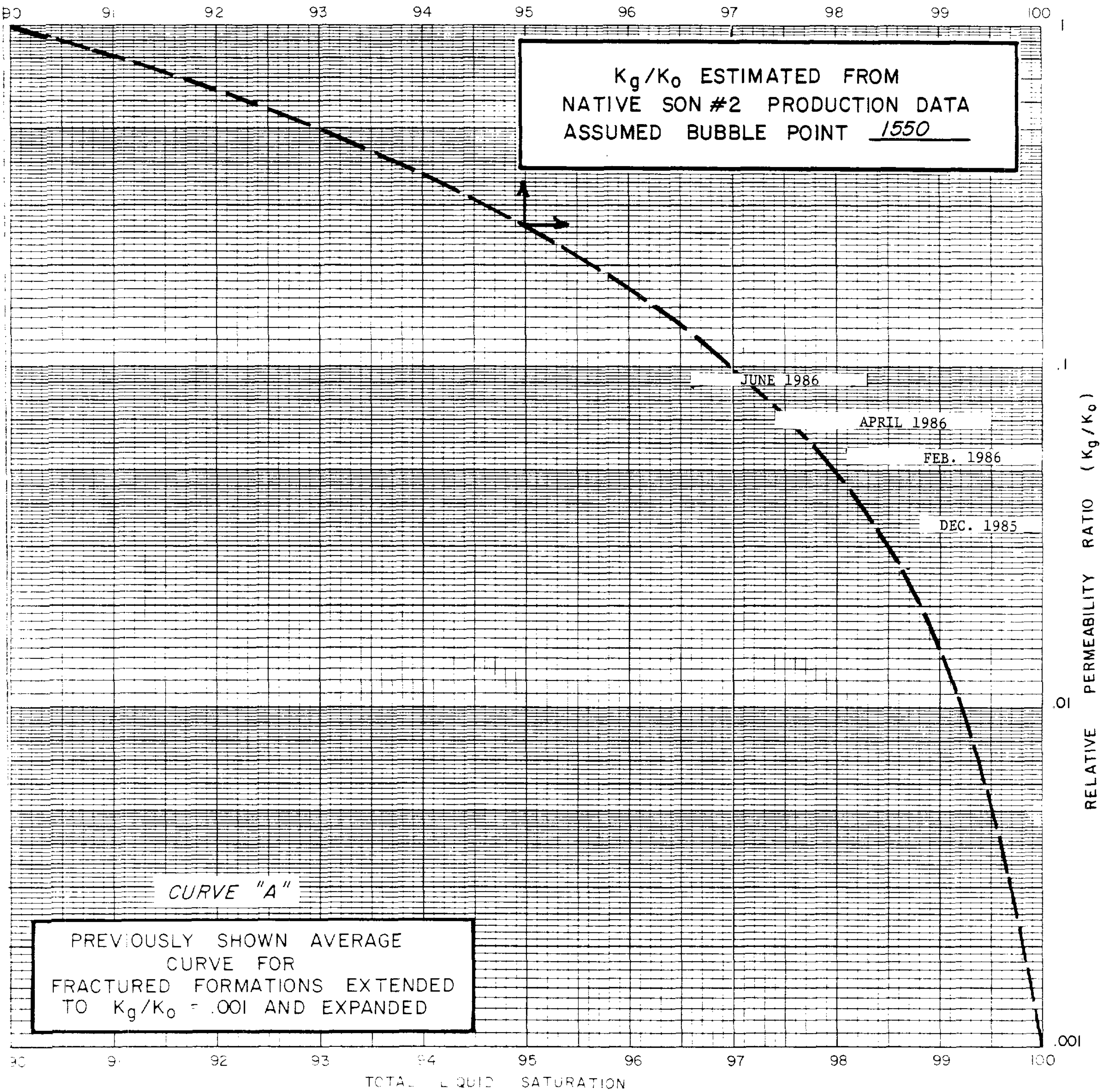


90 91 92 93 94 95 96 97 98 99 100
1000
100
10
1
1
.1
.01
.001
RELATIVE PERMEABILITY RATIO (Kg/Ko)
CURVE "A"
PREVIOUSLY SHOWN AVERAGE CURVE FOR FRACTURED FORMATIONS EXTENDED TO Kg/Ko = .001 AND EXPANDED
TOTAL LIQUID SATURATION

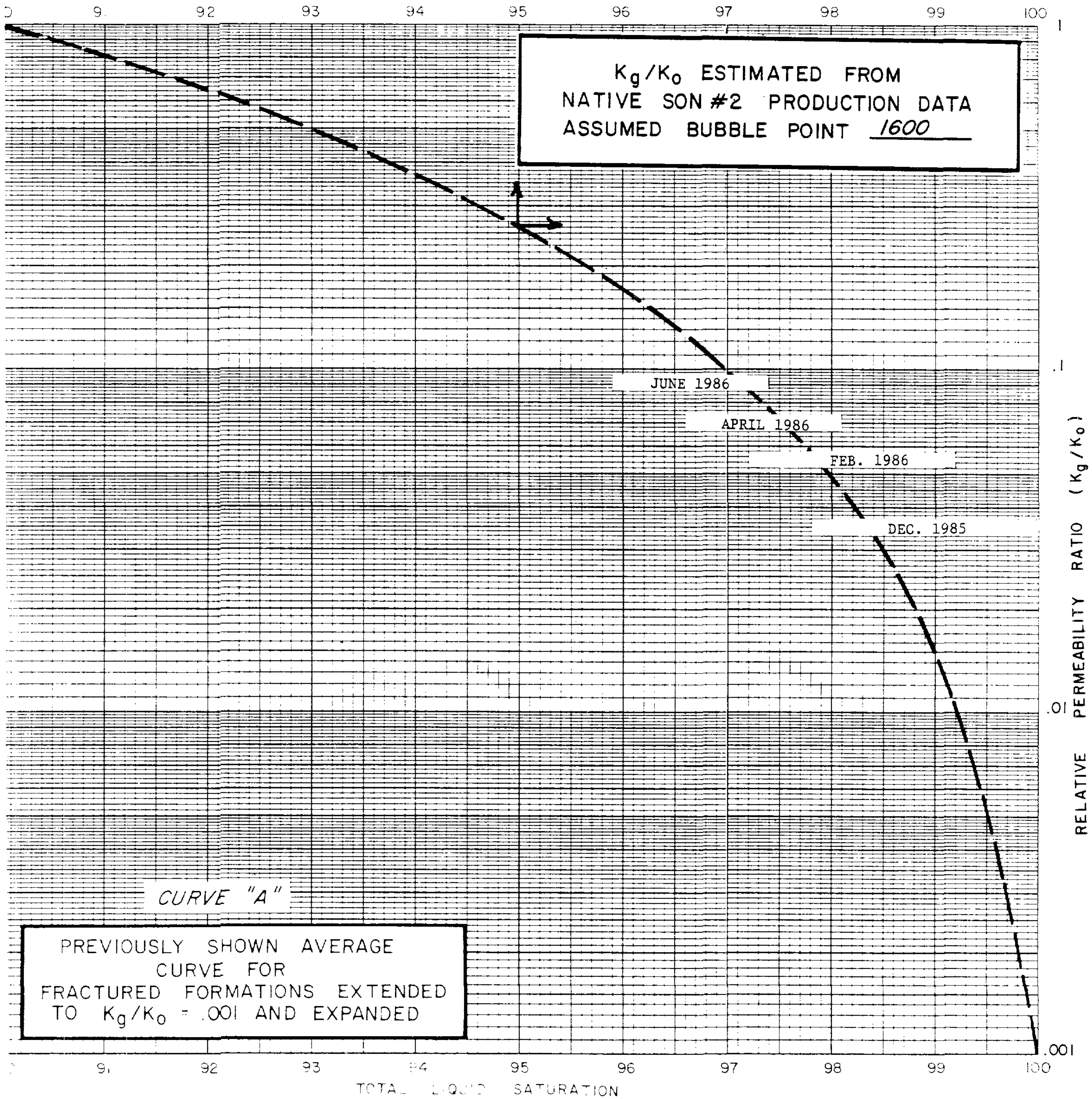
-86



90
91
92
93
94
95
96
97
98
99
100
1
.1
.01
.001
K_g/K_o ESTIMATED FROM
NATIVE SON #2 PRODUCTION DATA
ASSUMED BUBBLE POINT 1500
JUNE 1986
APRIL 1986
FEB. 1986
DEC. 1985
RELATIVE PERMEABILITY RATIO (K_g/K_o)
CURVE "A"
PREVIOUSLY SHOWN AVERAGE
CURVE FOR
FRACTURED FORMATIONS EXTENDED
TO K_g/K_o = .001 AND EXPANDED
TOTAL LIQUID SATURATION



K_g/K_o ESTIMATED FROM
NATIVE SON #2 PRODUCTION DATA
ASSUMED BUBBLE POINT 1550
JUNE 1986
APRIL 1986
FEB. 1986
DEC. 1985
CURVE "A"
PREVIOUSLY SHOWN AVERAGE CURVE FOR FRACTURED FORMATIONS EXTENDED TO K_g/K_o = .001 AND EXPANDED
1
.1
.01
.001
RELATIVE PERMEABILITY RATIO (K_g/K_o)
90
91
92
93
94
95
96
97
98
99
100
TOTAL LIQUID SATURATION



K_g/K_o ESTIMATED FROM
NATIVE SON #2 PRODUCTION DATA
ASSUMED BUBBLE POINT 1600
JUNE 1986
APRIL 1986
FEB. 1986
DEC. 1985
CURVE "A"
PREVIOUSLY SHOWN AVERAGE CURVE FOR FRACTURED FORMATIONS EXTENDED TO K_g/K_o = .001 AND EXPANDED
RELATIVE PERMEABILITY RATIO (K_g/K_o)
1
.1
.01
.001
92
93
94
95
96
97
98
99
100
TOTAL LIQUID SATURATION

Fluid Properties

Fluid property information was available for three wells:

1. McHugh, Loddy #1
2. McHugh, Native Son #3
3. BMG, Canado Ojitos Unit #12-11

After correcting the fluid property information to a common set of separator conditions, the Loddy #1 and COU #12-11 samples agreed quite closely both with respect to bubble point pressure (1482 psig and 1519 psig respectively) and trend in oil formation volume factor. It was concluded that the Native Son #3 sample was therefore not representative. The remaining samples were both taken after significant production from their respective pools and it could not be determined if the lab reported bubble point pressure reflected true reservoir conditions or if some gas evolution had occurred prior to sampling. Evidence that a higher bubble point existed initially in the reservoir is found in the absence of initial solution gas-oil ratios early in the life of the pool indicating an early pressure decline below the original bubble point pressure. Consequently, the lab reported data was corrected to an assumed bubble point pressure of 1770 psia which is the original pressure at the top of the Niobrara "A" section of the Gavilan Howard #1 which was found to be oil bearing. The fluid properties contained in the attached tables and plots reflect this extrapolation to the higher bubble point pressure. It should be noted that the adjusted initial dissolved gas-oil ratio for the Loddy #1 (which was the final sample selected) amounted to 646 cubic feet per barrel and agreed quite closely with the initial producing gas-oil ratio of the Rucker Lake #2 which was approximately 650 cubic feet per barrel for several months.