# TRANSACTIONS

OF THE

# AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS

(INCORPORATED)

## Volume 160

# PETROLEUM DEVELOPMENT AND TECHNOLOGY 1945

## PETROLEUM DIVISION

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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.

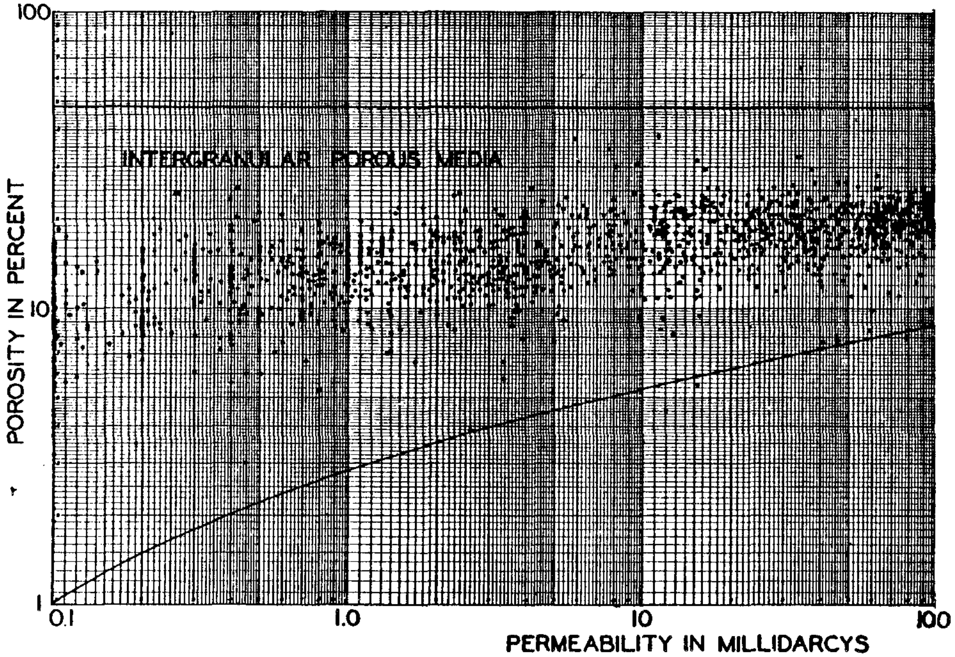



FIG. 1.—POROSITIES AND PERMEABILITIES OF

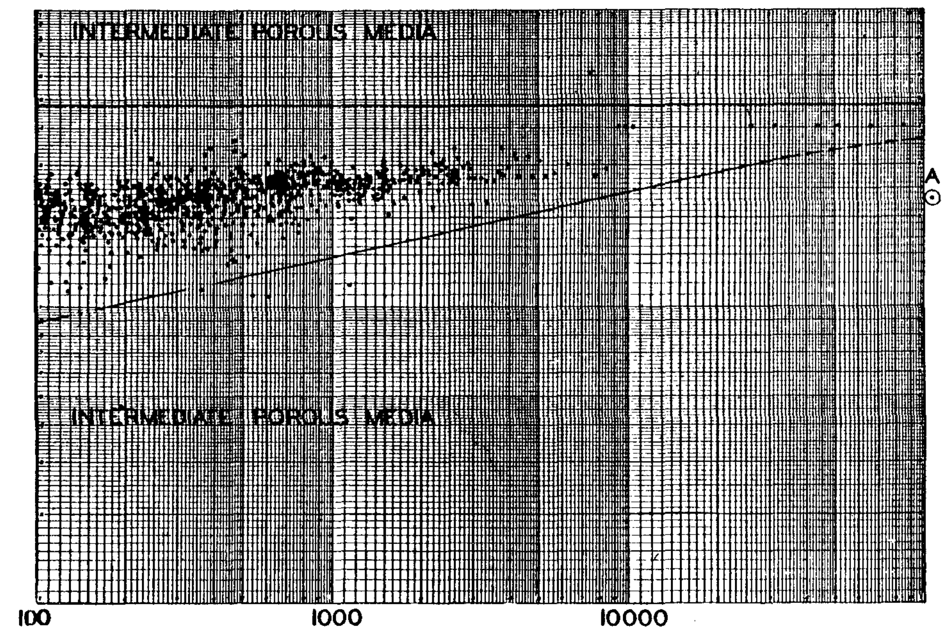
this was plainly impracticable except in a few cases,[7] hence only the latter type of data have been used.) Comparison reveals, however, that for uniform sandstones the two porosities are practically equal, and on this basis we have felt justified in including the data of Fancher, Lewis and Barnes,[3] 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.




ABOUT 2200 SAND AND SANDSTONE SPECIMENS.

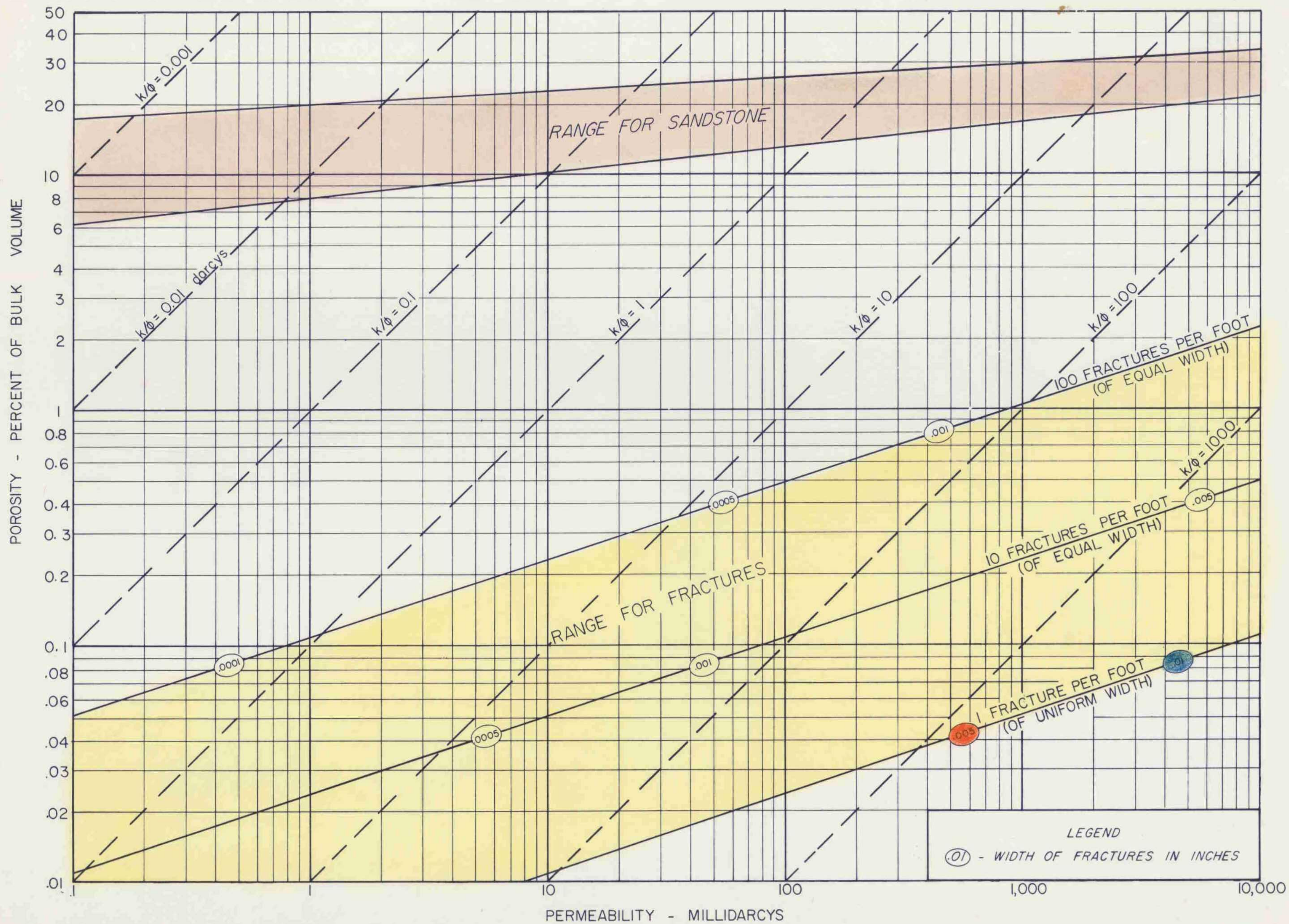
The upper boundary was taken to be the horizontal line, porosity equals 47.64 per cent—i.e., the maximum porosity of an ideal intergranular porous medium—on the assumption that by varying the size of

* 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 |
|---|---|---|---|---|
| 11 | 3rd Venango | Oil City | 7.5 | 4.8 |
| 25 | 3rd Venango | Pleasantville | 17.1 | 14.7 |
| 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

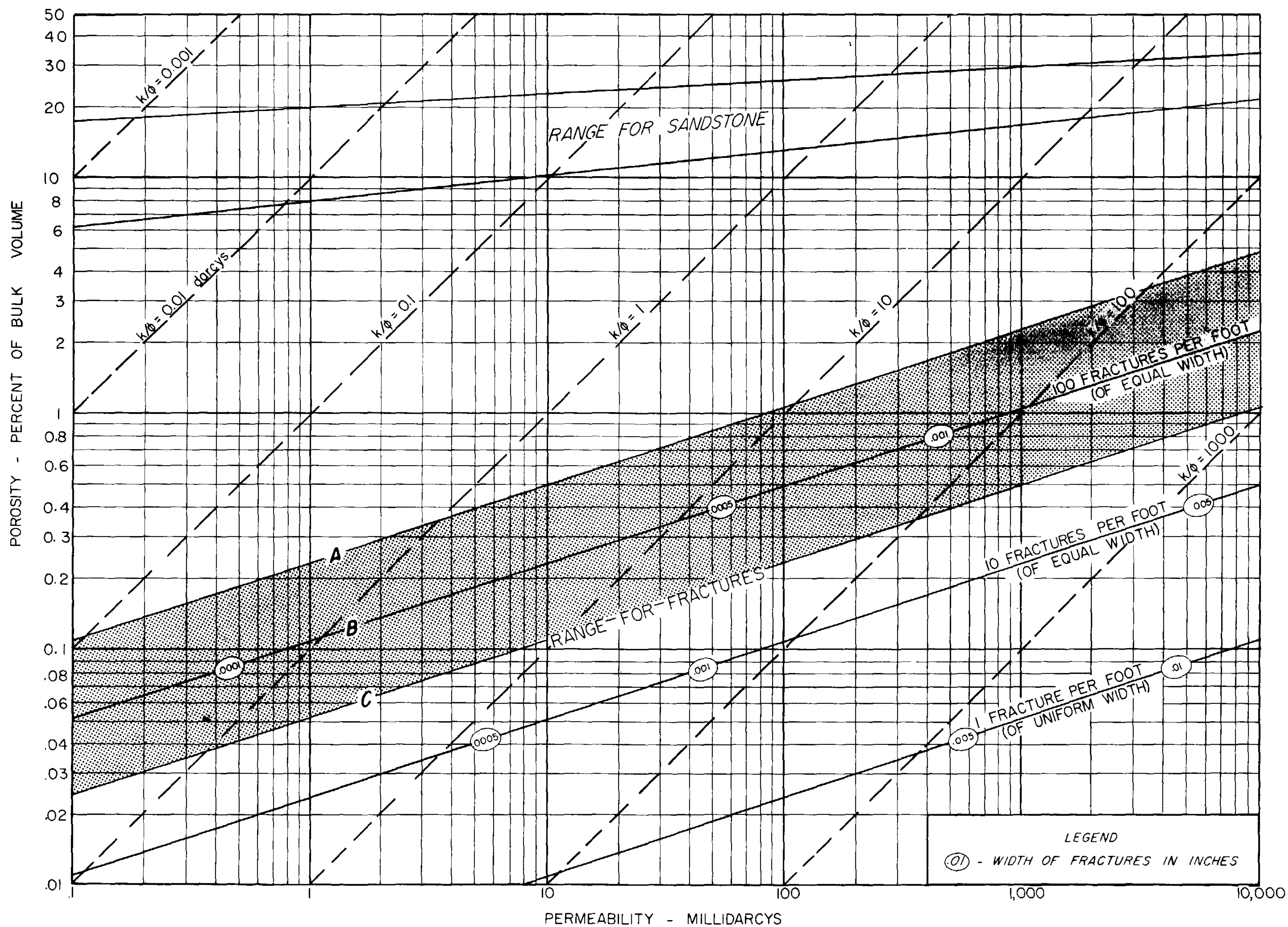
*FRACTURES PARALLEL TO DIRECTION OF FLOW*



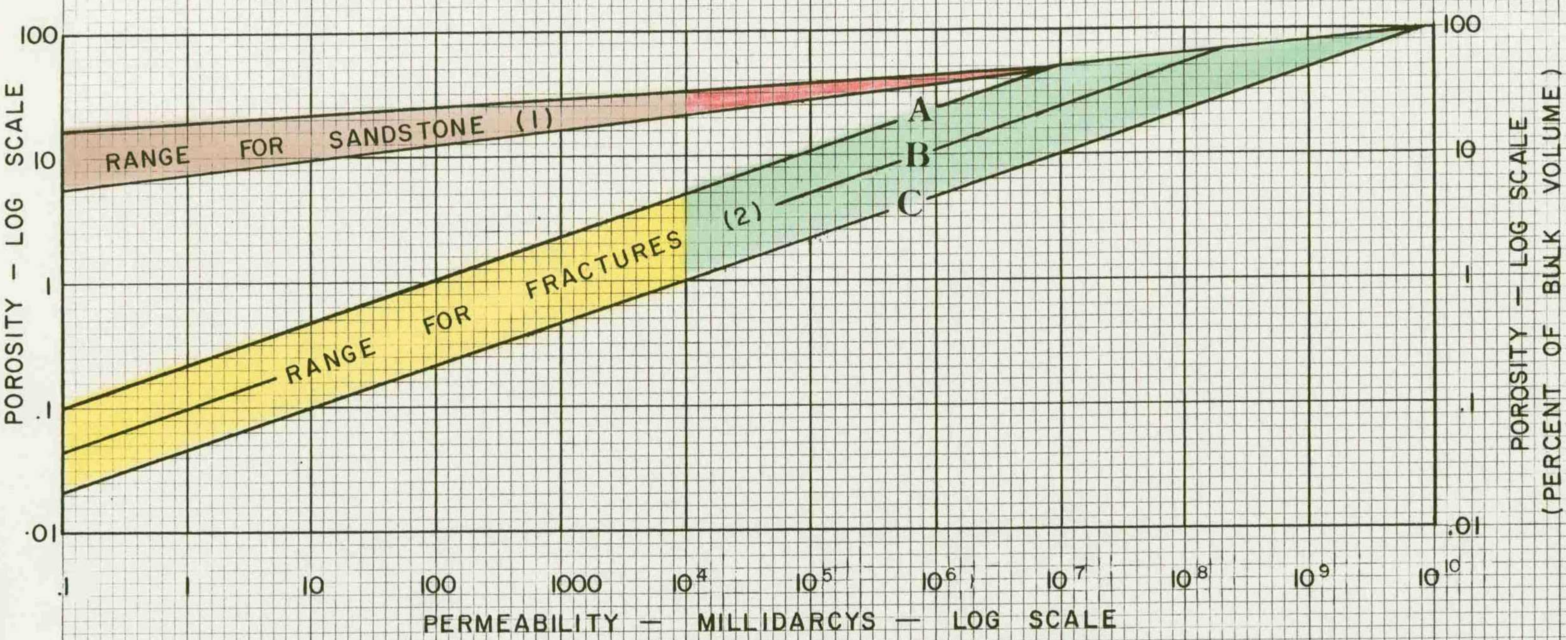

APPENDIX III FIGURE NO. III-3

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

*FRACTURES PARALLEL TO DIRECTION OF FLOW*



# COMPARISON OF RELATION OF POROSITY TO PERMEABILITY



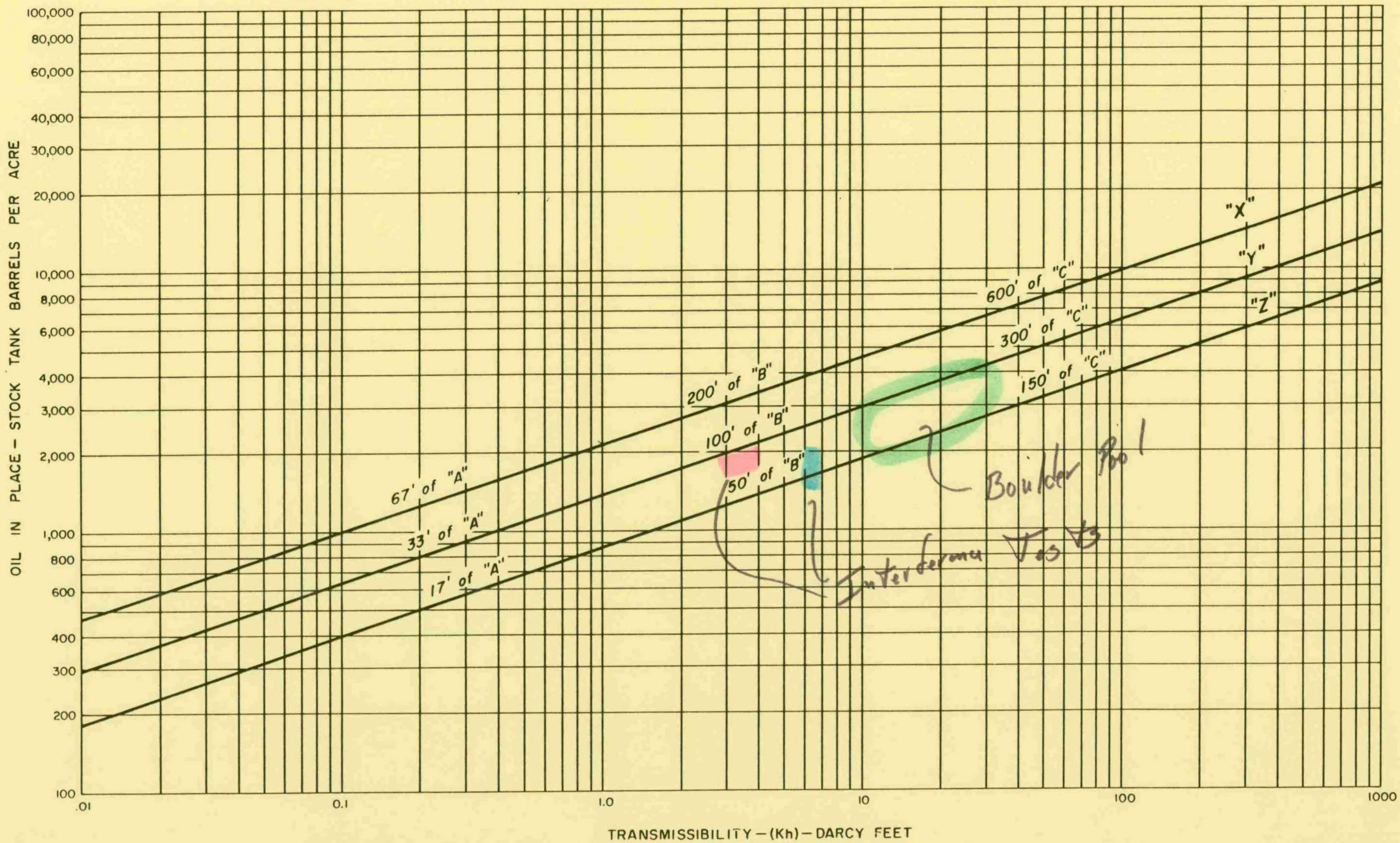

(1) FROM CORE SAMPLES (BULNES & FITTING TRANS AIME 1945)

(2) ESTIMATED

K+E 10 X 10 TO THE INCH • 10 X 15 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 47 0700

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




FILE: 13 A

APPENDIX III FIGURE NO. III-5

# THE FLOW OF HOMOGENEOUS FLUIDS THROUGH POROUS MEDIA


BY

M. MUSKAT, PH.D.

*Chief of Physics Division, Gulf Research & Development Company*

WITH AN INTRODUCTORY CHAPTER BY

R. D. WYCKOFF, B.S. IN E.E.

*Formerly Chief of Physics Division, now Staff Geophysicist (Houston, Texas), Gulf Research & Development Company*



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1937

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 $\mu$ 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 FOHK pg 425)

$$K = (54 \times 10^6)(w^2) \text{ darcys} \quad (w: \text{inches})$$

Assume only permeability is 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) | FOR 10 FRACTURES per foot porosity FRACTION | FOR 100 FRACTURES/FOOT perm darcys | FOR 100 FRACTURES/FOOT porosity FRACTION |
|---|---|---|---|---|---|---|---|
| .01 | $54\times10^2$ | 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


B. C. CRAFT

*and*

M. F. HAWKINS

***Petroleum Engineering Department***
***Louisiana State University***



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 $\mu$ 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

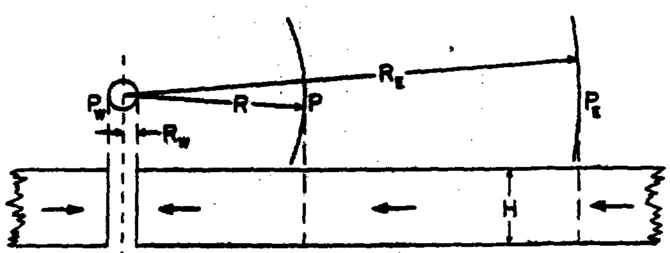



**Fig. 6.16.**

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,

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

Integrating,

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

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

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

and,

$$k = 8.45 \times 10^6\ w_o^2\ darcys \tag{1-35}$$

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

$$k = 54 \times 10^6\ w_o^2\ darcys \tag{1-36}$$

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.

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

$$K_{av} = 13.51\ darcys = 13,510\ md$$ = 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.

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

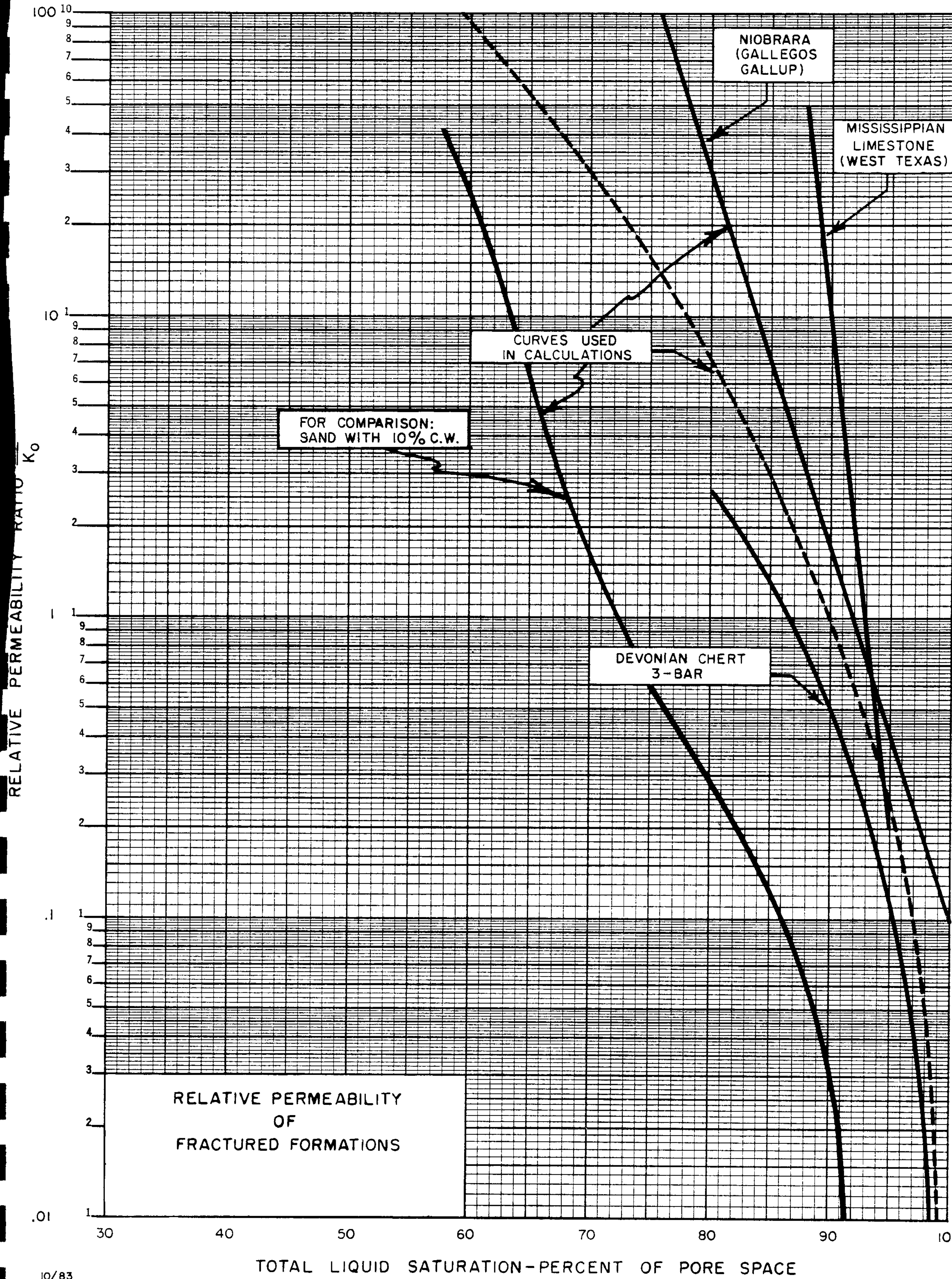
The information which shows beyond all doubt that the producing reservoir of the Canada Ojitos Unit is from fracture porosity is that shown by the 1965 and 1968 interference tests in which there was measured transmissibility on the order of 5 to 10 darcy feet with a volume of hydrocarbon pore space of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

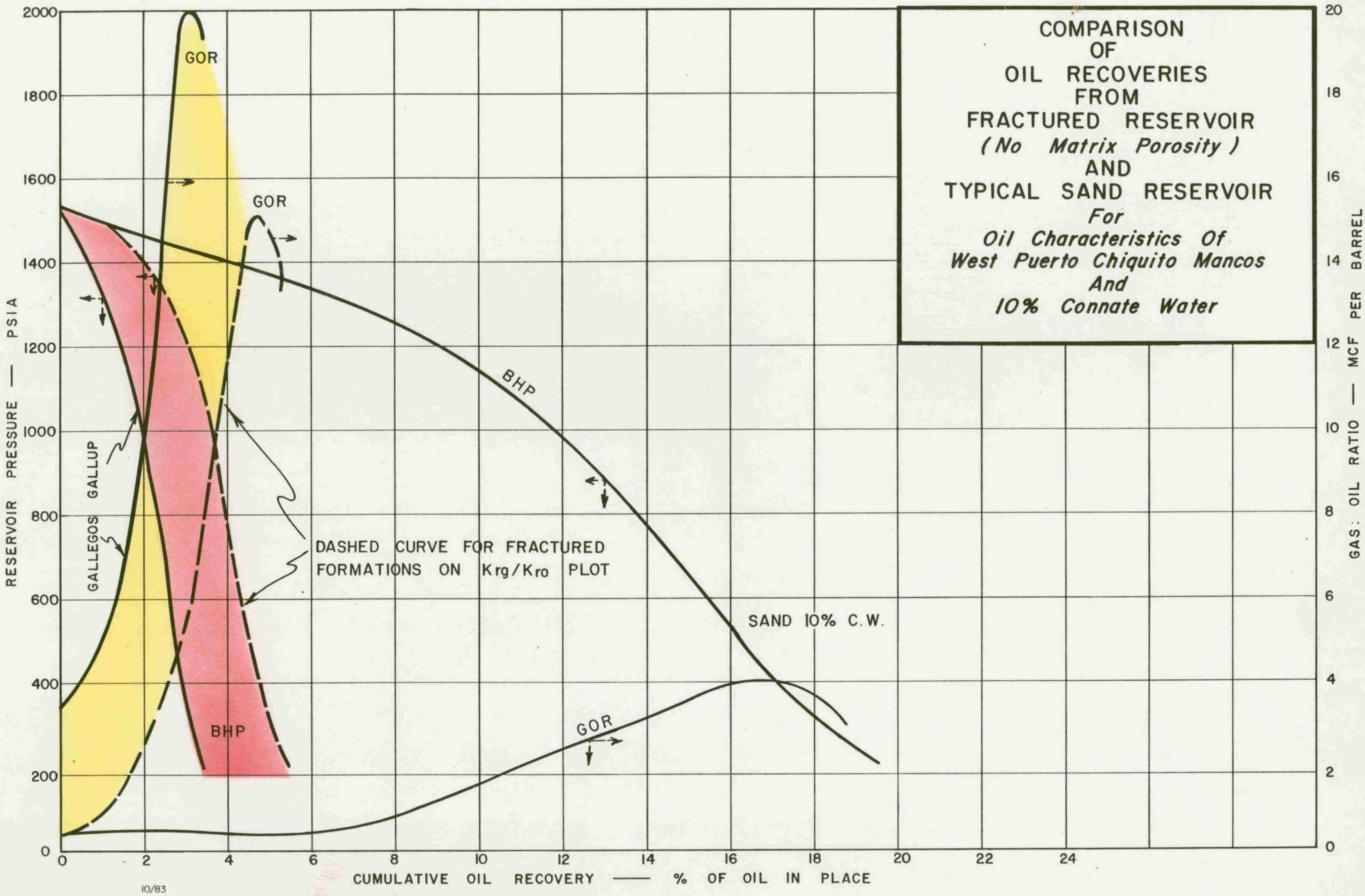
Typical sand reservoirs with matrix porosity show permeabilities for these porosities on the average of about 1 millidarcy and 10 millidarcies respectively. The resulting transmissibilities at 3 millidarcy feet and 20 millidarcy feet respectively is so much less than that actually measured as to preclude 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 |




RELATIVE PERMEABILITY OF FRACTURED FORMATIONS

10/83


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
2000
1800
1600
1400
1200
1000
800
600
400
200
0
20
18
16
14
12
10
8
6
4
2
0
2
4
6
8
10
12
14
16
18
20
22
24
GOR
GOR
BHP
GALLUP
GALLEGOS
DASHED CURVE FOR FRACTURED
FORMATIONS ON Krg/Kro PLOT
BHP
SAND 10% C.W.
GOR

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.

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.

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


(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:

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

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.

RULE 11. 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.