CORE LABORATORIES

ADVANCED ROCK PROPERTIES STUDY
L.S. HOYT NO. 100 WELL
GORDON SAND
WETZEL COUNTY, WEST VIRGINIA

FINAL REPORT

103-1685

Performed for:
PENNZOIL PRODUCTS COMPANY
P.O. BOX 26105
VIENNA, WEST VIRGINIA 26105

February 6, 1996

Performed by:
CORE LABORATORIES, INC.
Rock Properties Laboratory
Dallas Advanced Technology Center
1875 Monetary Drive
Carrollton, Texas 75006

File: DAL-95288

CORELAB

PETROLEUM SERVICES

February 6, 1996

Pennzoil Products Company
P.O. Box 5519
Vienna, W. Virginia 26105

Attention: Mr. Bill Toomey

Subject: Advanced Rock Properties Study
L.S. Hoyt No. 100 Well
Gordon Sand
Wetzel County
West Virginia
File: DAL-95288

Dear Mr. Toomey:

A laboratory study designed to determine relative permeability characteristics of core material from the subject site has been completed for Pennzoil Products Company. This study was authorized and test parameters provided by Mr. Bill Toomey of Pennzoil in a telephone conversation with Brian Stevens of Core Laboratories on November 1, 1995. Final results of two unsteady-state water-oil relative permeability tests on wettability-restored samples are presented herein.

Two whole core segments from specified intervals of the subject site were supplied by Core Laboratories-Oklahoma City (Core Analysis File: 57182-13832) for the current study. Degassed crude oil from the L.S. Hoyt No. 63 Well was received on November 13. A brine containing 200,000 ppm dissolved salt was utilized to simulate the formation brine as instructed (See Composition Page 1). An outline of test procedures is presented on Page ii. Basic properties data may be found on Page 3. Fluid and sample parameters are provided on Pages 2 and 4, respectively. A summary of test results appears on Page 5 followed by the tabular and graphic water-oil relative permeability data on Pages 6 through 11.

Waterflood oil recoveries for the two test samples were 54.8 and 52.0 percent pore space (66.4 and 64.8 percent oil in place) yielding terminal oil saturations of 27.7 and 28.3 percent pore space, respectively. Relative permeability characteristics were generally typical of the unsteady-state technique in uniform sandstone samples such as these. The terminal relative permeability to water values of 0.267 and 0.295 are considered to represent moderately to slightly water-wet characteristics. Thank you for this opportunity to be of service. Please contact us if you have any questions concerning the enclosed information.

Very truly yours,

Brian E. Stevens

Brian E. Stevens
Rock Properties Laboratory
Dallas Advanced Technology Center

PROJECT PARTICIPANTS

Water-Oil Relative Permeability	Leland J. Hibbard
Project Coordination Report Preparation	Brian E. Stevens
Final Review	Melanie F. Dunn

EXPERIMENTAL PROCEDURES

Sample Preparation

1. Two 1-1/2 inch diameter core plug samples were drilled from each of the specified intervals using 2% KCl as the coring fluid. The samples were labeled with the appropriate core analysis number followed by "A" and "B".

2. The samples were extracted of hydrocarbons with cool toluene, leached of salts with cool methanol, and dried to a constant weight in a humidity-controlled oven at 140°F.

3. Sample dimensions were measured using digital calipers. Grain volumes were measured using a matrix cup and grain densities calculated using the corresponding sample weight.

4. Reservoir net confining stress was calculated based on the sample depth and the expected average reservoir pressure during waterflood of 1000 psi.

5. Permeability to air, Klinkenberg permeability, pore volume, and helium porosity were measured on each sample using Core Laboratories' CMS-300 core measurement system at the routine stress of 800 psi as well as at the calculated net reservoir stress of 1220 psi.

6. One sample form each interval was selected for relative permeability testing.

Fluid Preparation

1. Simulated formation brine was prepared using deionized water and reagent grade chemicals. The brine was evacuated of air and filtered to 0.22 microns prior to use.

2. The supplied crude oil was dewatered and filtered to 0.22 microns. The oil was handled anaerobically during testing to minimize oxidation.

3. Viscosities of the reservoir fluids were determined at ambient temperature using a glass viscometer. Densities were measured using a pycnometer.

4. A laboratory oil having a viscosity of about 20 times greater than the simulated brine was prepared for the relative permeability tests.

5. Treated kerosene was utilized as a buffer fluid between the crude oil and laboratory oil injections.

Wettability Restoration

1. The selected samples were evacuated of air and pressure-saturated with the simulated brine.

2. The samples were spun in a high speed centrifuge to the specified target initial water saturation of 20 percent pore space.

3. The samples were briefly vacuumed under treated kerosene then flushed using 200 psi backpressure to fully saturate the samples.

4. Crude oil was injected to displace the resident oil and the samples aged under crude oil for a period of 30 days.

5. Crude oil was re-injected following the aging period and any additional water production recorded.

Water-Oil Relative Permeability

1. Each sample was loaded in a hydrostatic coreholder, a net confining pressure of 1220 psi applied, and treated kerosene injected to remove the crude oil.

2. The viscous laboratory oil then was injected to displace the previous oil and effective permeability to oil at initial water saturation determined.

3. A waterflood was performed by injecting the simulated brine at a constant rate of 4 ml/min until a water-cut of 99.95 percent or greater was achieved. Produced oil and water volumes and differential pressure as a function of time were recorded.

4. Effective permeability to brine at residual oil saturation was determined on each sample.

5. The samples were unloaded and residual fluid saturations verified by Dean-Stark toluene extraction.

6. Water-oil relative permeability relationships were calculated from the production data using the method of Johnson, Bossler, and Naumann and Jones-Roszelle.

SIMULATED FORMATION BRINE

Pennzoil Products Company

File: DAL-95288

Constituent		Concentration, ppm
Sodium Chloride	(NaCl)	180000.
Calcium Chloride	($CaCl_2$)	10000.
Magnesium Chloride	($MgCl_2$)	5000.
Potassium Chloride	(KCl)	5000.

SUMMARY OF FLUID PARAMETERS

Pennzoil Products Company

File: DAL-95288

Fluid	Temperature, °F	Viscosity, centipoise	Density, gm/cc
Simulated Formation Brine	68.	1.57	1.148
Laboratory Oil	68.	32.9	0.846
Degassed Crude Oil	68.	5.71	0.814

SUMMARY OF BASIC PROPERTIES

Pennzoil Products Company
L.S. Hoyt No. 100 Well
Gordon Sand

Wetzel County
West Virginia
File: DAL-95288

Sample Number	Depth, feet	Permeability, millidarcys				Porosity, fraction		Grain Density, gm/cc
		Klinkenberg		to Air				
		800 psi	1220 psi	800 psi	1220 psi	800 psi	1220 psi	
10A	3145.0	202.	200.	213.	211.	0.243	0.242	2.67
10B*	3145.3	214.	212.	226.	224.	0.254	0.253	2.67
16A	3151.1	172.	170.	182.	180.	0.253	0.252	2.67
16B*	3151.4	167.	164.	177.	174.	0.253	0.252	2.67

* Samples selected for testing

SUMMARY OF SAMPLE PARAMETERS

Pennzoil Products Company
L.S. Hoyt No. 100 Well
Gordon Sand

Wetzel County
West Virginia
File: DAL-95288

Sample Number	Depth, feet	Length, cm	Area, cm^2	Pore Volume,* cc
10B	3145.3	6.57	11.36	18.82
16B	3151.4	6.57	11.22	18.54

* 1220 psi confining stress

SUMMARY OF WATER-OIL RELATIVE PERMEABILITY

Unsteady-State Method Wettability-Restored Samples
Ambient Temperature Net Confining Stress: 1220 psi

Pennzoil Products Company
L.S. Hoyt No. 100 Well
Gordon Sand

Wetzel County
West Virginia
File: DAL-95288

Sample Number	Depth, feet	Permeability to Air, millidarcys	Porosity, fraction	Initial Conditions		Terminal Conditions			Oil Recovered	
				Water Saturation, fraction	Effective Permeability to Oil, millidarcys	Oil Saturation, fraction	Effective Permeability to Water, millidarcys	Relative Permeability to Water*, fraction	fraction pore space	fraction oil in place
10B	3145.3	224.	0.254	0.175	190.	0.277	50.7	0.267	0.548	0.664
16B	3151.4	174.	0.253	0.196	147.	0.284	43.3	0.295	0.520	0.647

* Relative to the effective permeability to oil at initial water saturation

WATER - OIL RELATIVE PERMEABILITY

Unsteady-State Method Wettability-Restored Sample
Ambient Temperature Net Confining Stress: 1220 psi

Pennzoil Products Company	Sample Number:	10B
L.S. Hoyt No. 100 Well	Sample Depth, feet:	3145.3
Gordon Sand	Permeability to Air, md:	224
Wetzel County	Porosity, fraction:	0.254
West Virginia	Initial Water Saturation, fraction:	0.175
File: DAL-95288	Effective Permeability to Oil at Swi, md:	190

Water Saturation, fraction	Water-Oil Relative Permeability Ratio	Relative Permeability to Water*, fraction	Relative Permeability to Oil*, fraction
0.175	0.000	0.0000	1.000
0.216	0.011	0.0092	0.870
0.283	0.040	0.027	0.677
0.337	0.082	0.044	0.538
0.393	0.157	0.064	0.410
0.439	0.272	0.084	0.309
0.493	0.537	0.110	0.205
0.539	1.06	0.135	0.127
0.585	2.35	0.164	0.070
0.625	4.94	0.193	0.039
0.672	13.7	0.230	0.017
0.704	48.0	0.254	0.0053
0.723		0.267	

* Relative to the effective permeability to oil at initial water saturation

WATER-OIL RELATIVE PERMEABILITY

Unsteady-State Method Wettability-Restored Sample

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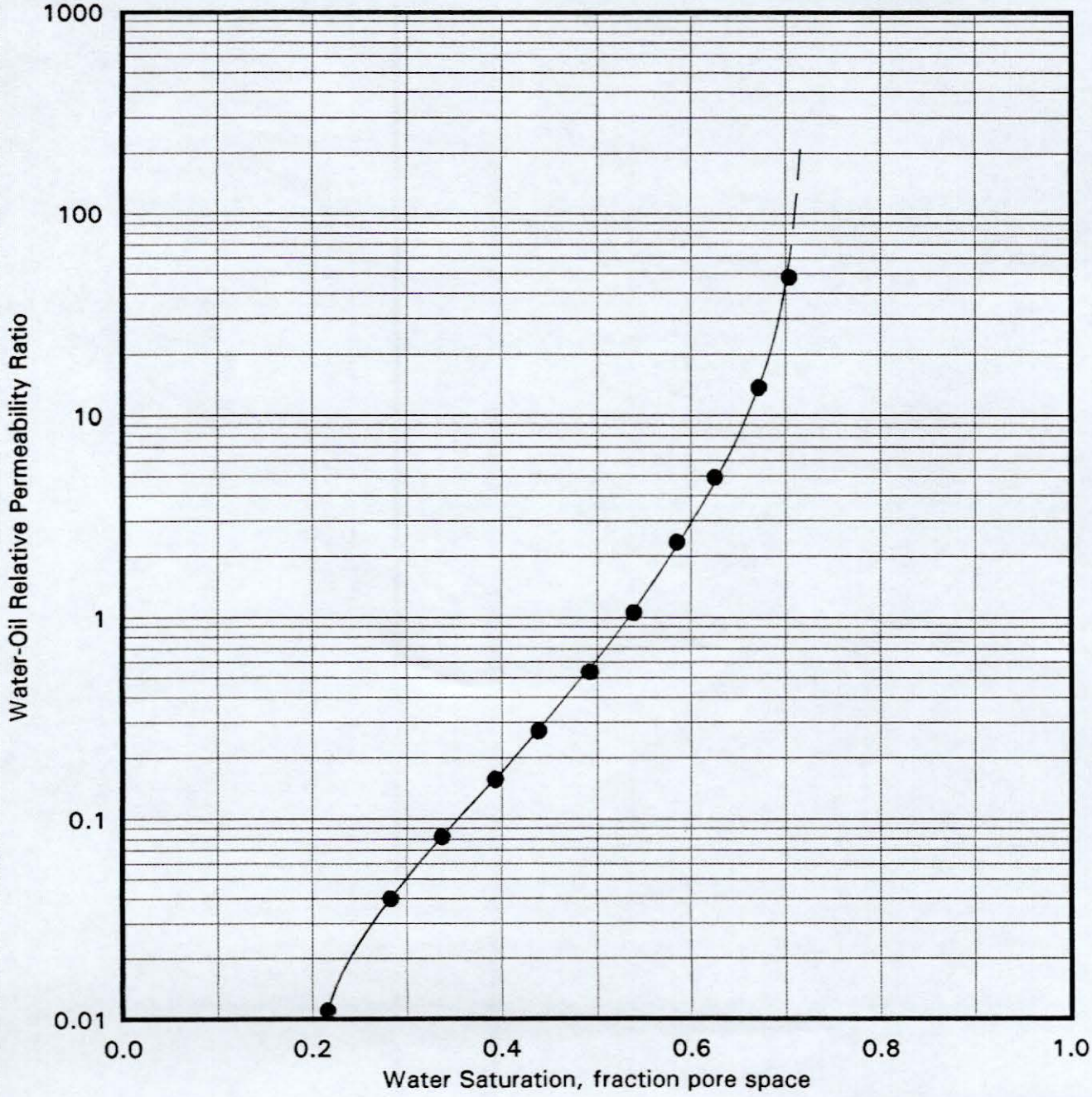

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WATER-OIL RELATIVE PERMEABILITY

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Ambient Temperature Net Confining Stress: 1220 psi

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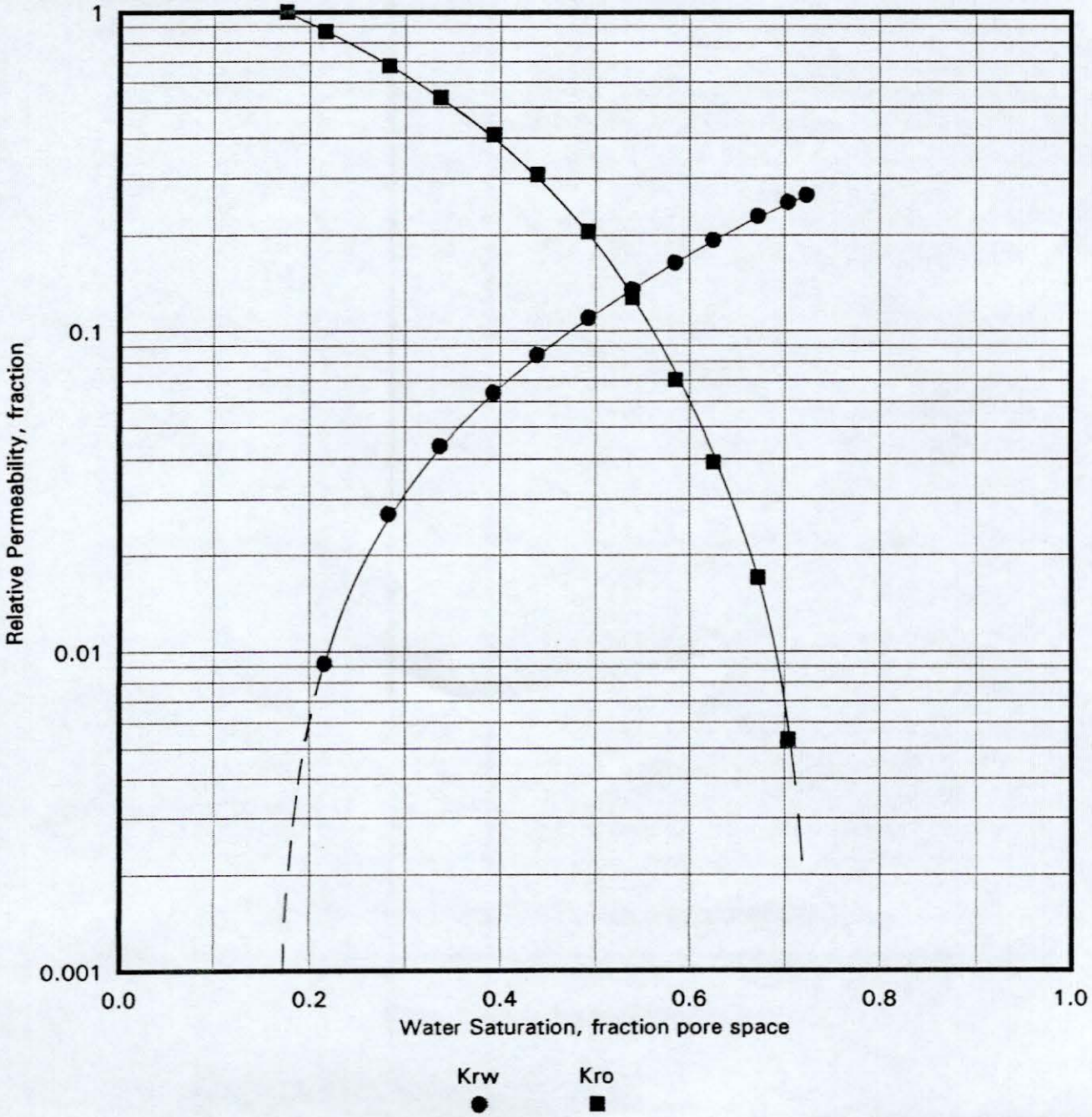

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WATER - OIL RELATIVE PERMEABILITY

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Water Saturation, fraction	Water-Oil Relative Permeability Ratio	Relative Permeability to Water*, fraction	Relative Permeability to Oil*, fraction
0.196	0.000	0.0000	1.000
0.243	0.010	0.0090	0.885
0.312	0.038	0.026	0.690
0.378	0.102	0.051	0.505
0.431	0.203	0.074	0.364
0.472	0.364	0.096	0.264
0.518	0.740	0.125	0.169
0.556	1.43	0.149	0.104
0.590	2.87	0.175	0.061
0.619	5.34	0.200	0.037
0.660	14.1	0.239	0.017
0.692	38.3	0.268	0.0070
0.716		0.295	

* Relative to the effective permeability to oil at initial water saturation

WATER-OIL RELATIVE PERMEABILITY

Unsteady-State Method Wettability-Restored Sample

Ambient Temperature Net Confining Stress: 1220 psi

Pennzoil Products Company	Sample Number:	16B
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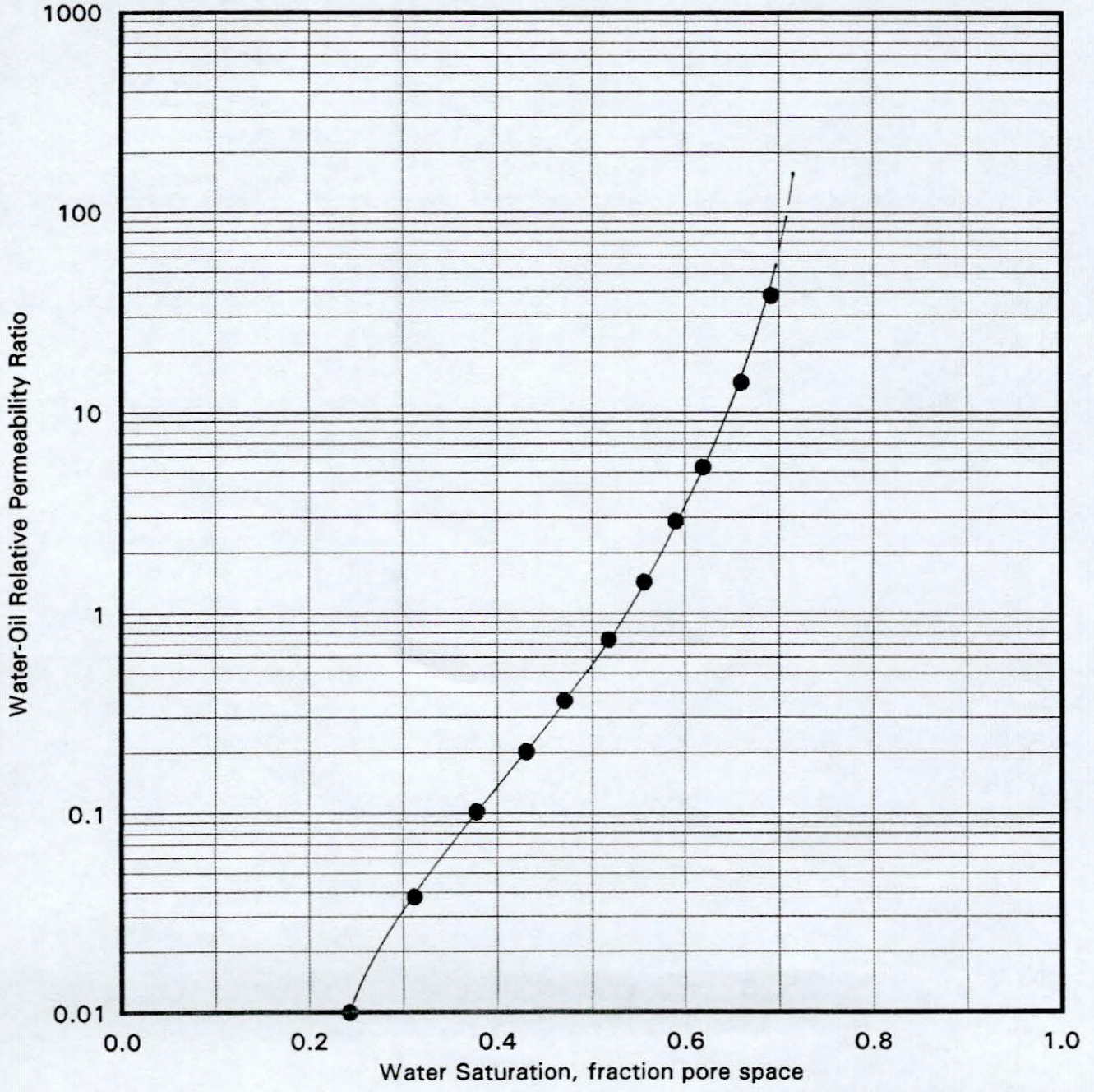

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WATER-OIL RELATIVE PERMEABILITY

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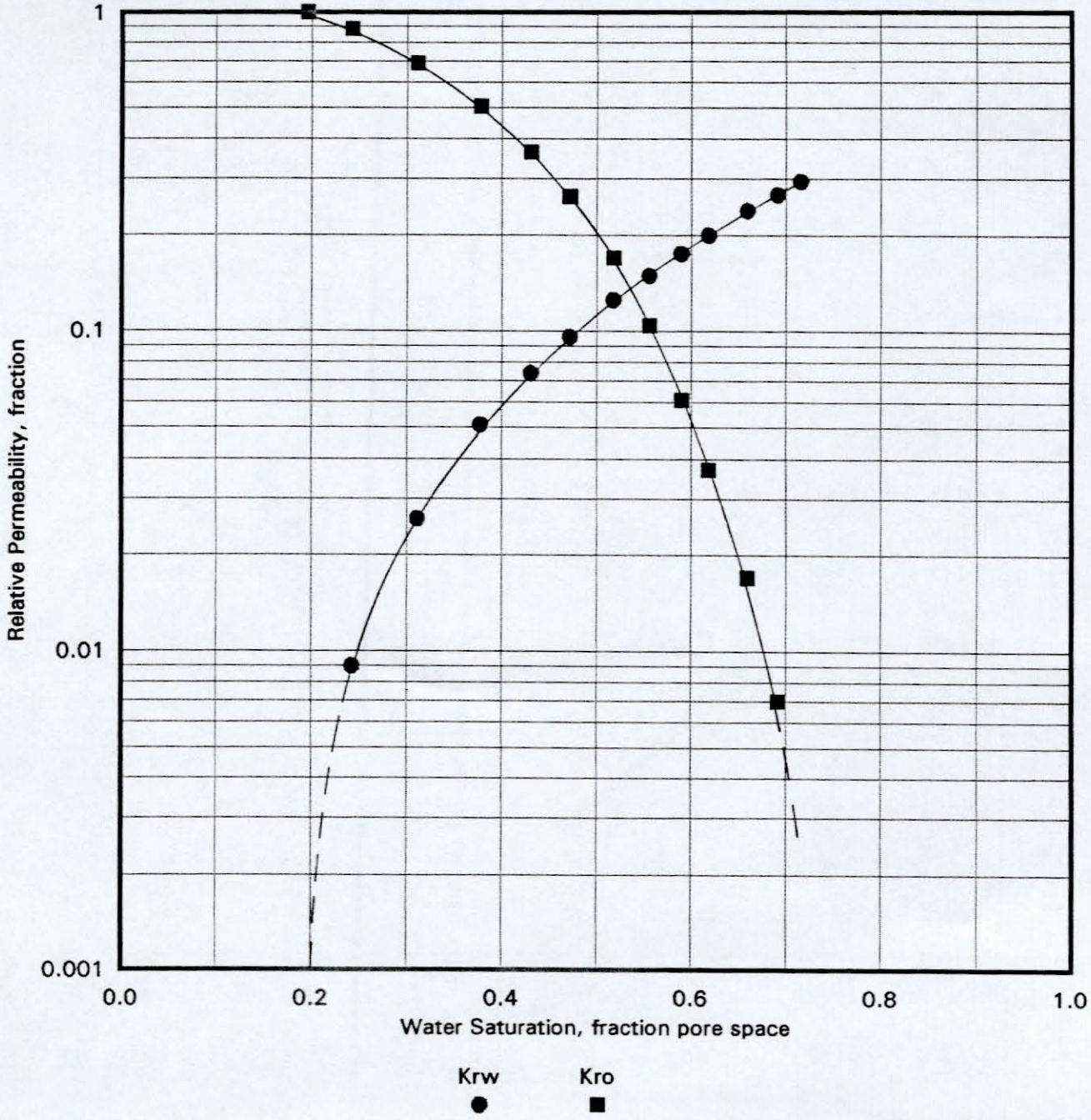

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