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28-14-13W

FINAL REPORT

Relative Permeability Testing
Carter-Colliver #1 CO2 1 Well

(1 CO2-1)

28 - 14 - 13W
15 - 167 - 23179

Performed for:
Kansas Geological Survey
1930 Constant Avenue, Campus West
The University of Kansas
Lawrence, Kansas 66047-3726

July 11, 2001

Performed by:
Core Laboratories, Inc.
Advanced Technology Center
Rock Properties Laboratory
6316 Windfern
Houston, Texas 77040
File: HOU-010412

July 11, 2001

Kansas Geological Survey
1930 Constant Avenue, Campus West
The University of Kansas
Lawrence, Kansas 66047-3726

Attention: Mr. Allan Byrnes

Subject: Final Report
Relative Permeability Testing
Carter-Colliver #1 CO2 1 Well
File: HOU-010412

Mr. Byrnes:

A relative permeability study has been completed for the Kansas Geological Survey. The testing program was authorized by Mr. Allan Byrnes of the Kansas Geological Survey. Data was provided when the tests were completed.

Thank you for this opportunity to be of service. Please contact me if you have any questions on the report or data.

Regards,

Wade Williams
Lab Supervisor
Flow Studies
Houston Advanced Rock Properties Group

EXPERIMENTAL PROCEDURES
Unsteady-State Gas-Oil & Water-Oil Relative Permeability
Extracted-State Sample

1. The sample was cleaned by flushing with alternating slugs of toluene and methanol, and dried in a vacuum oven at 220° F. Basic properties were measured at 1500 psi.

2. The sample was pressure saturated with a synthetic formation brine.

3. The sample was then installed in a centrifuge in air-displacing-brine configuration and spun at an appropriate capillary pressure, 200 psi, to reach initial water saturation. The sample was unloaded from the centrifuge and loaded into a hydrostatic coreholder and 1500 psi overburden stress applied.

4. A laboratory oil of 1.65 cp was injected at a suitable constant rate until an equilibrium differential pressure was observed. Effective permeability to oil at irreducible water saturation was determined at two injection rates.

5. Humidifed nitrogen was injected at a suitable constant pressure, while collecting produced volumes and monitoring differential pressure and elapsed time, until a gas-oil ratio of 50 or greater was observed. Effective permeability to gas at residual oil saturation was determined at two injection pressures.

6. The sample was resaturated with the laboratory oil and permeability measured. The sample was now ready for the unsteady-state water-oil permeability test.

7. Synthetic formation brine was then injected at a suitable constant pressure, while collecting produced oil and water volumes and monitoring differential pressure and cumulative time, until a water-cut of 99.95 percent was achieved.

8. Effective permeability to brine at residual oil saturation was determined at two injection pressures. The sample was unloaded, weighed, and submitted to Dean-Stark extraction to determine residual fluid saturations.

9. Unsteady-state gas-oil relative permeability relationships are calculated by the method of Jones and Roszelle. Water-oil relative permeability relationships were calculated using the theory of Welge as expanded by Johnson, Bossler, and Naumann and refined by Jones and Roszelle.

BASIC PROPERTIES OF TEST SAMPLES

Confining Stress: 1500 psi

Kansas Geological Survey
Murfin Drilling Company
Carter-Colliver #1 CO2 I
Hall-Gurney Field

Russell, KS
File: HOU-010412

Sample Number	Depth, feet	Permeability to Air, millidarcys	Porosity, fraction	Grain Density, gm/cc
1	2893.30	141	0.275	2.70

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SUMMARY OF SAMPLE PARAMETERS

Kansas Geological Survey
Murfin Drilling Company
Carter-Colliver #1 CO2 I
Hall-Gurney Field

Russell, KS
File: HOU-010412

Sample Number	Depth, feet	Length, cm	Area, cm	Pore Volume, cc
1	2893.30	5.62	5.03	7.67

SUMMARY OF FLUID PARAMETERS

Kansas Geological Survey
Murfin Drilling Company
Carter-Colliver #1 CO2 I
Hall-Gurney Field

Russell, KS
File: HOU-010412

Fluid	Temperature, °F	Viscosity, centipoise	Density, gm/cc
Synthetic Formation Brine	70	1.148	1.066
Isopar Laboratory Oil	70	1.65	0.762
Humidified Nitrogen	70	0.020	-

SYNTHETIC FORMATION BRINE

Kansas Geological Survey
Murfin Drilling Company
Carter-Colliver #1 CO2 I
Hall-Gurney Field

Russell, KS
File: HOU-010412

Constituent		Concentration, g/l
Sodium Chloride	(NaCl)	76.557
Calcium Chloride	(CaCl2·2H2O)	22.564
Magnesium Chloride	(MgCl2·6H2O)	18.111
Sodium Sulfate	(Na2SO4)	0.080
Potassium Chloride	(KCl)	0.263
Sodium Bicarbonate	(NaHCO3)	0.063

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SUMMARY OF GAS - OIL RELATIVE PERMEABILITY TEST RESULTS

Net Confining Stress: 1500 psi
Temperature: 70° F.

Kansas Geological Survey
Murfin Drilling Company
Carter-Colliver #1 CO2 I
Hall-Gurney Field

Russell, KS
File: HOU-010412

Sample Number	Sample Depth, feet	Permeability to Air, millidarcys	Porosity, fraction	Initial Conditions		Terminal Conditions			Oil Recovery,	
				Water Saturation, fraction pore space	Effective Permeability to Oil, millidarcys	Oil Saturation, fraction pore space	Effective Permeability to Gas, millidarcys	Relative Permeability to Gas*, fraction	fraction pore space	fraction oil in place
1	2893.30	141	0.275	0.142	126	0.524	17.6	0.140	0.335	0.390

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

GAS - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample
Temperature: 70°F Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
Murfin Drilling Company	Sample Depth, feet:	2893.30
Carter-Colliver #1 CO2 I	Permeability to Air, md:	141
Hall-Gurney Field	Porosity, fraction:	0.275
Russell, KS	Initial Water Saturation, fraction:	0.142
File: HOU-010412	Effective Permeability to Oil at Swi, md:	126

Gas Saturation, fraction	Gas-Oil Relative Permeability Ratio	Relative Permeability to Gas*, fraction	Relative Permeability to Oil*, fraction
0.000	-	0.000	1.0000
0.064	0.162	0.012	0.0743
0.081	0.385	0.015	0.0392
0.104	1.30	0.022	0.0172
0.123	3.00	0.030	0.0099
0.134	5.31	0.039	0.0074
0.160	14.1	0.048	0.0034
0.179	29.8	0.058	0.0019
0.194	58.7	0.067	0.0011
0.203	68.2	0.083	0.0012
0.230	162.	0.097	0.0006
0.246	312.	0.102	0.0003
0.254	437.	0.108	0.0002
0.263	588.	0.115	0.0002
0.274	828.	0.123	0.0001
0.276	984.	0.132	0.0001
0.278	1137.	0.136	0.0001
0.286	1365.	0.139	0.0001
0.294	1796.	0.140	0.0001

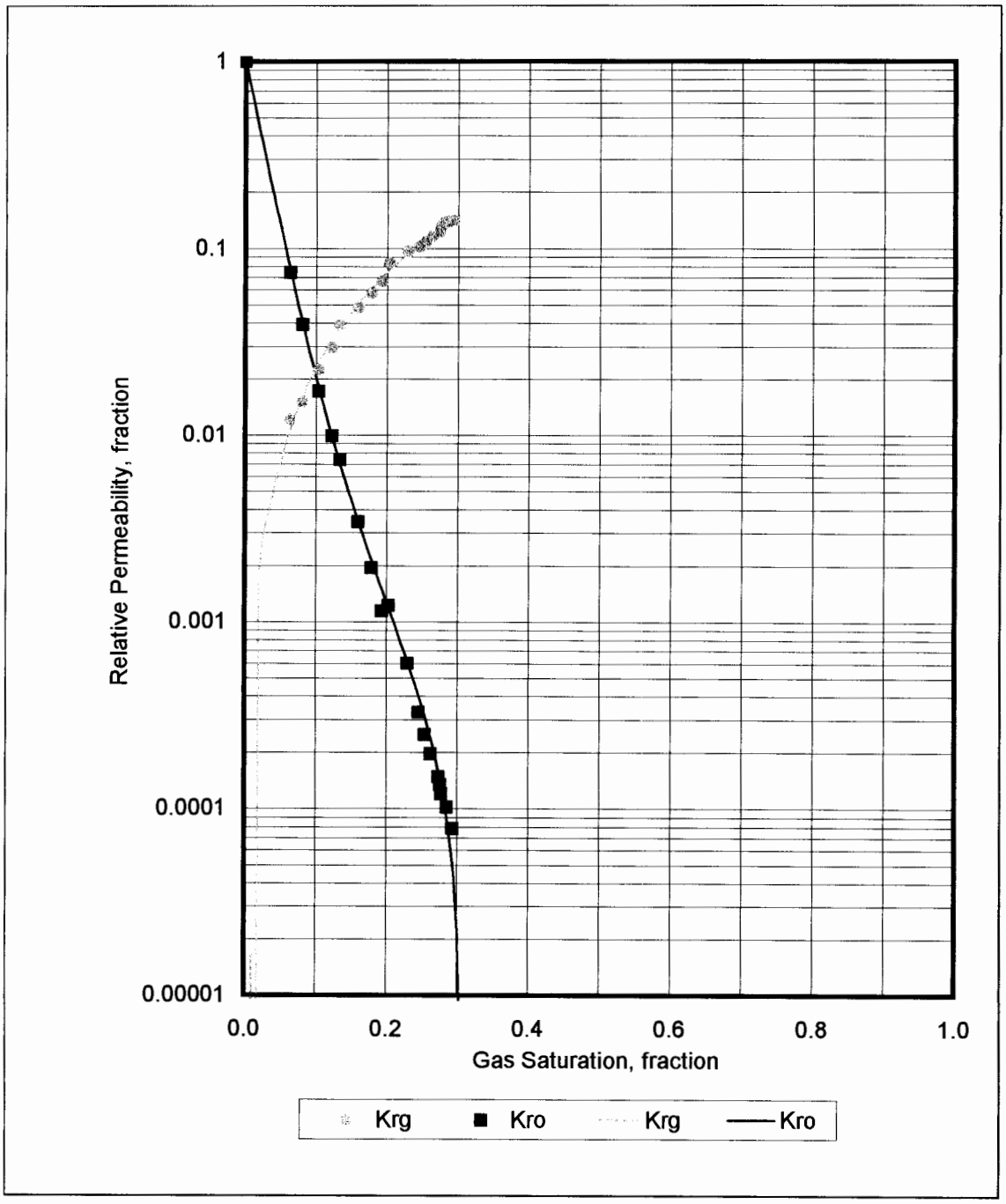
* Relative to the effective permeability to oil at initial water saturation

GAS - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample

Temperature: 70°F Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
Murfin Drilling Company	Sample Depth, feet:	2893.3
Carter-Colliver #1 CO2 I	Permeability to Air, md:	141
Hall-Gurney Field	Porosity, fraction:	0.275
Russell, KS	Initial Water Saturation, fraction:	0.142
File: HOU-010412	Effective Permeability to Oil at Swi, md:	126.0



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GAS - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample
Temperature: 70°F Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
Murfin Drilling Company	Sample Depth, feet:	2893.3
Carter-Colliver #1 CO2 I	Permeability to Air, md:	141
Hall-Gurney Field	Porosity, fraction:	0.275
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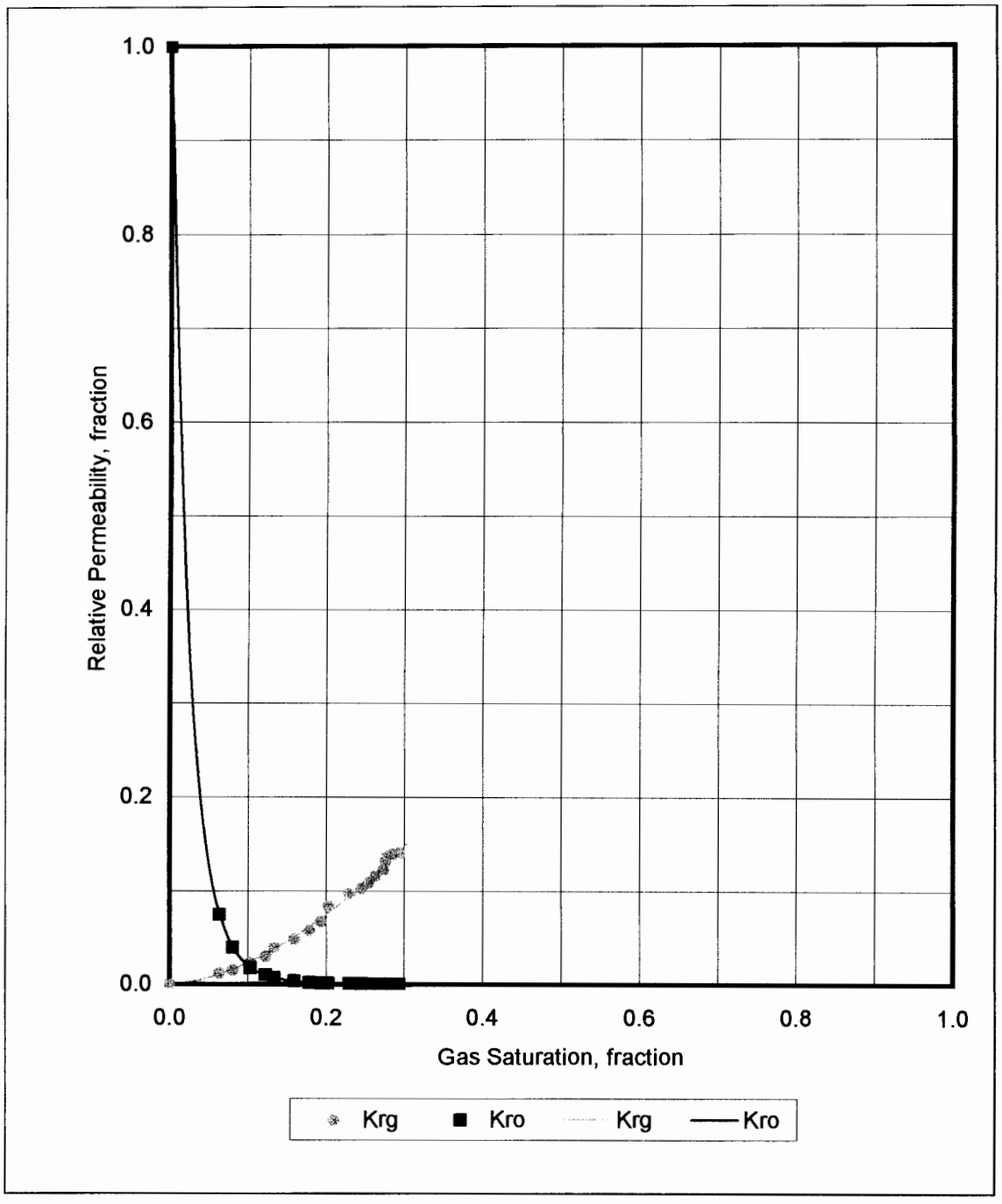

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GAS - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample

Temperature: 70°F Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
Murfin Drilling Company	Sample Depth, feet:	2893.3
Carter-Colliver #1 CO2 I	Permeability to Air, md:	141
Hall-Gurney Field	Porosity, fraction:	0.275
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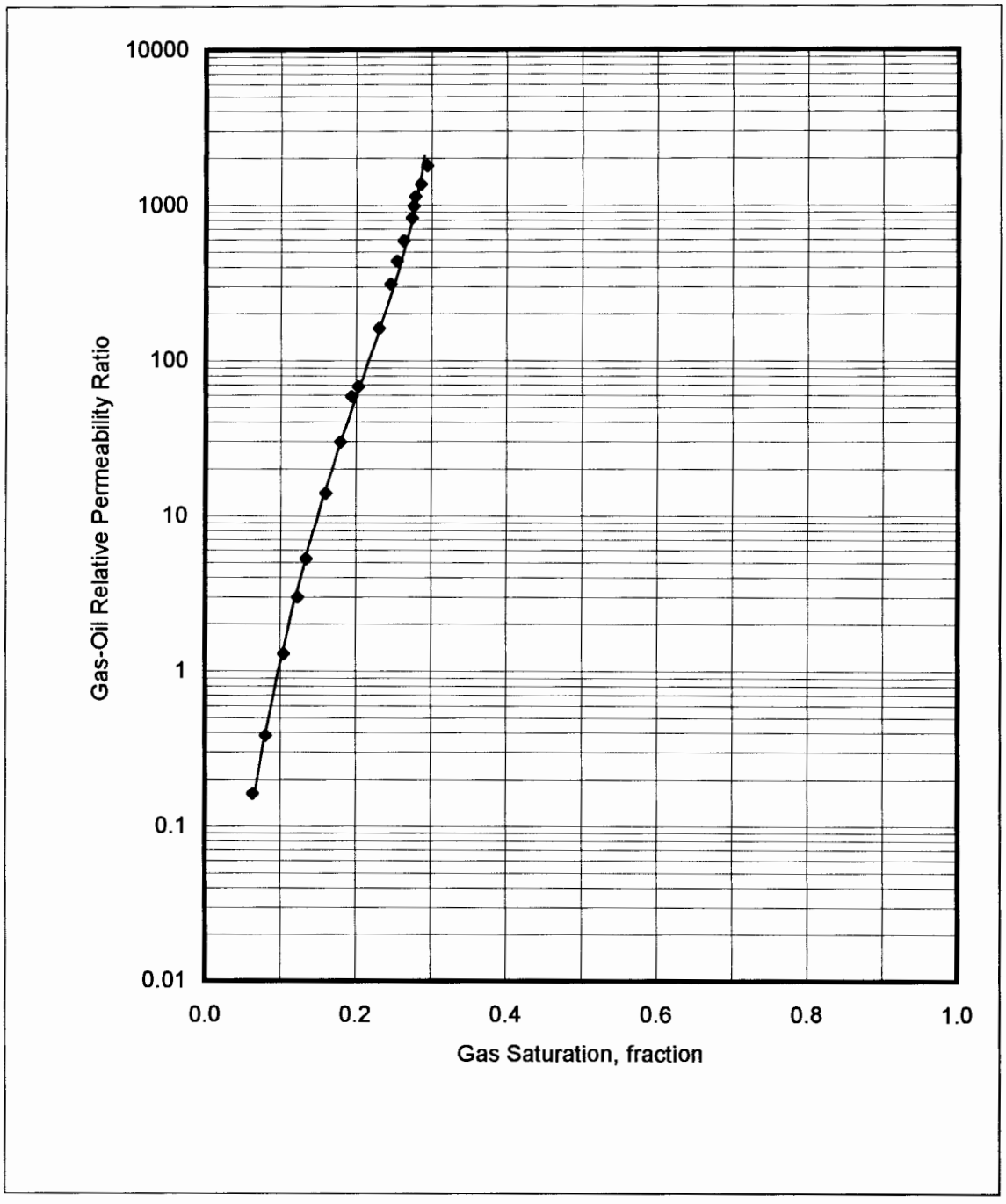

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SUMMARY OF WATER-OIL RELATIVE PERMEABILITY TEST RESULTS

Net Confining Stress: 1500 psi
Temperature: 70° F.

Kansas Geological Survey
Murfin Drilling Company
Carter-Colliver #1 CO2 I
Hall-Gurney Field

Russell, KS
File: HOU-010412

Sample Number	Depth, feet	Permeability to Air, millidarcys	Porosity, fraction	Initial Conditions		Terminal Conditions			Oil Recovery,	
				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
1	2893.30	141	0.275	0.142	134	0.444	54.7	0.408	0.414	0.483

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

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WATER - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample
Temperature: 70° F. Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
Murfin Drilling Company	Sample Depth, feet:	2893.30
Carter-Colliver #1 CO2 I	Permeability to Air, md:	141
Hall-Gurney Field	Porosity, fraction:	0.275
Russell, KS	Initial Water Saturation, fraction:	0.142
File: HOU-010412	Effective Permeability to Oil at Swi, md:	134

Water Saturation, fraction	Water-Oil Relative Permeability Ratio	Relative Permeability to Water*, fraction	Relative Permeability to Oil*, fraction
0.142	-	0.000	1.000
0.186	0.147	0.071	0.484
0.217	0.398	0.091	0.230
0.326	7.83	0.168	0.021
0.365	21.0	0.205	0.010
0.388	35.2	0.231	0.007
0.416	66.3	0.248	0.004
0.444	122.	0.285	0.002
0.473	235.	0.326	0.001
0.497	420.	0.338	0.001
0.518	652.	0.371	0.001
0.542	2555.	0.396	0.000
0.556		0.408	

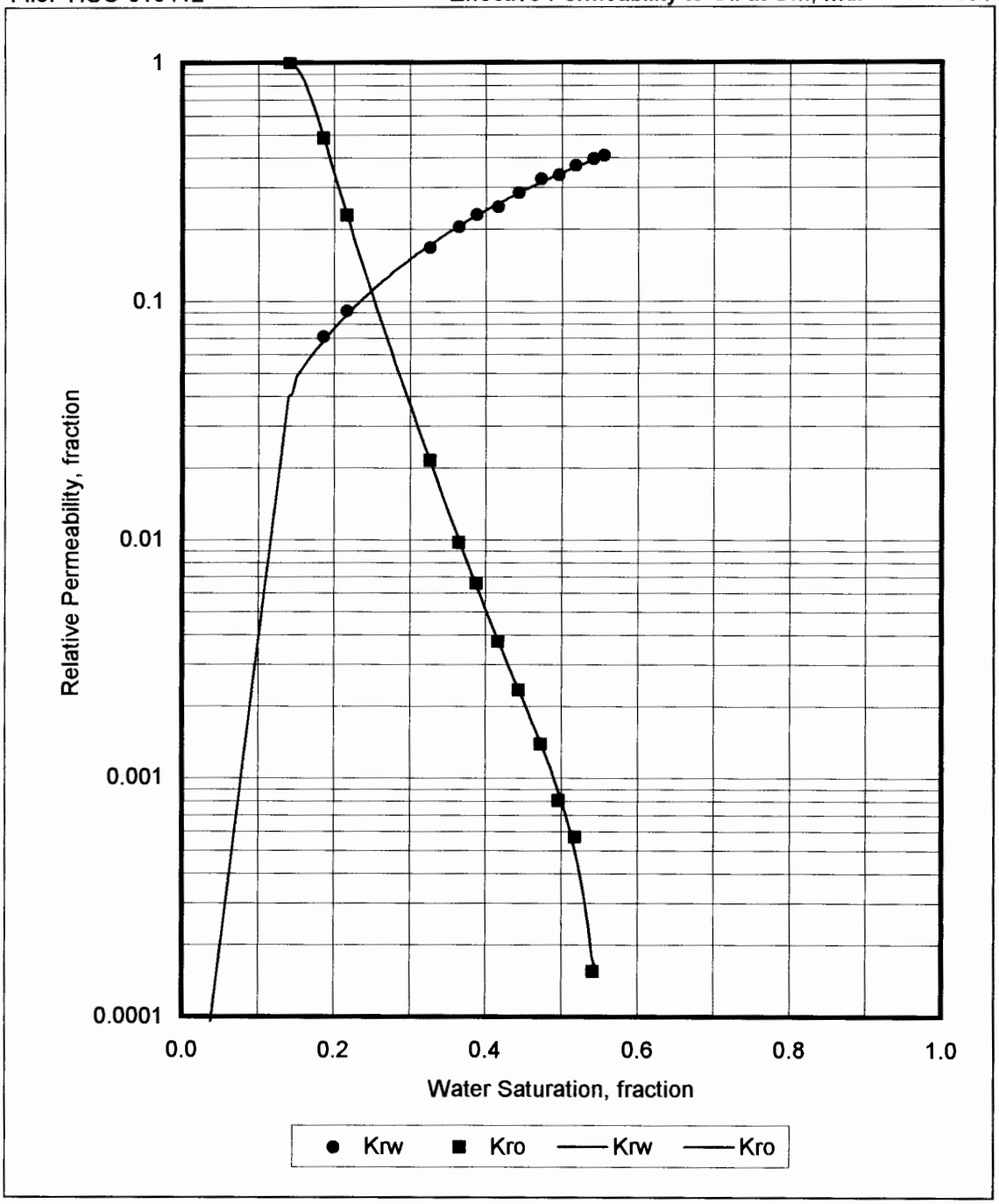
*Relative to the effective permeability to oil at intial water saturation

WATER - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample

Temperature: 70° F. Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
Murfin Drilling Company	Sample Depth, feet:	2893.3
Carter-Colliver #1 CO2 I	Permeability to Air, md:	141
Hall-Gurney Field	Porosity, fraction:	0.275
Russell, KS	Initial Water Saturation, fraction:	0.142
File: HOU-010412	Effective Permeability to Oil at Swi, md:	134



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WATER - OIL RELATIVE PERMEABILITY

Unsteady-State Method Restored-State Sample
Temperature: 70° F. Net Confining Stress: 1500 psi

Kansas Geological Survey	Sample Number:	1
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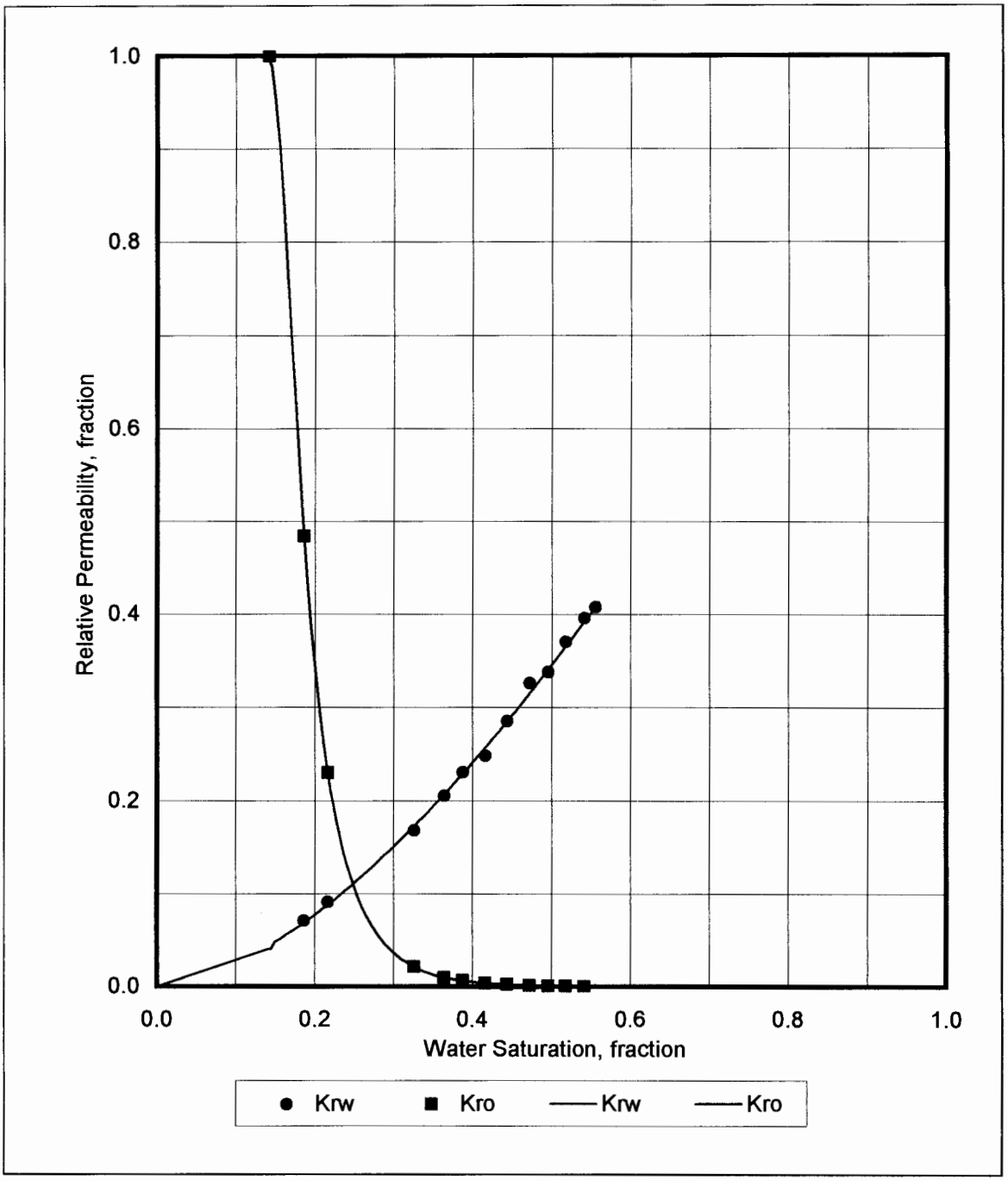

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WATER - OIL RELATIVE PERMEABILITY

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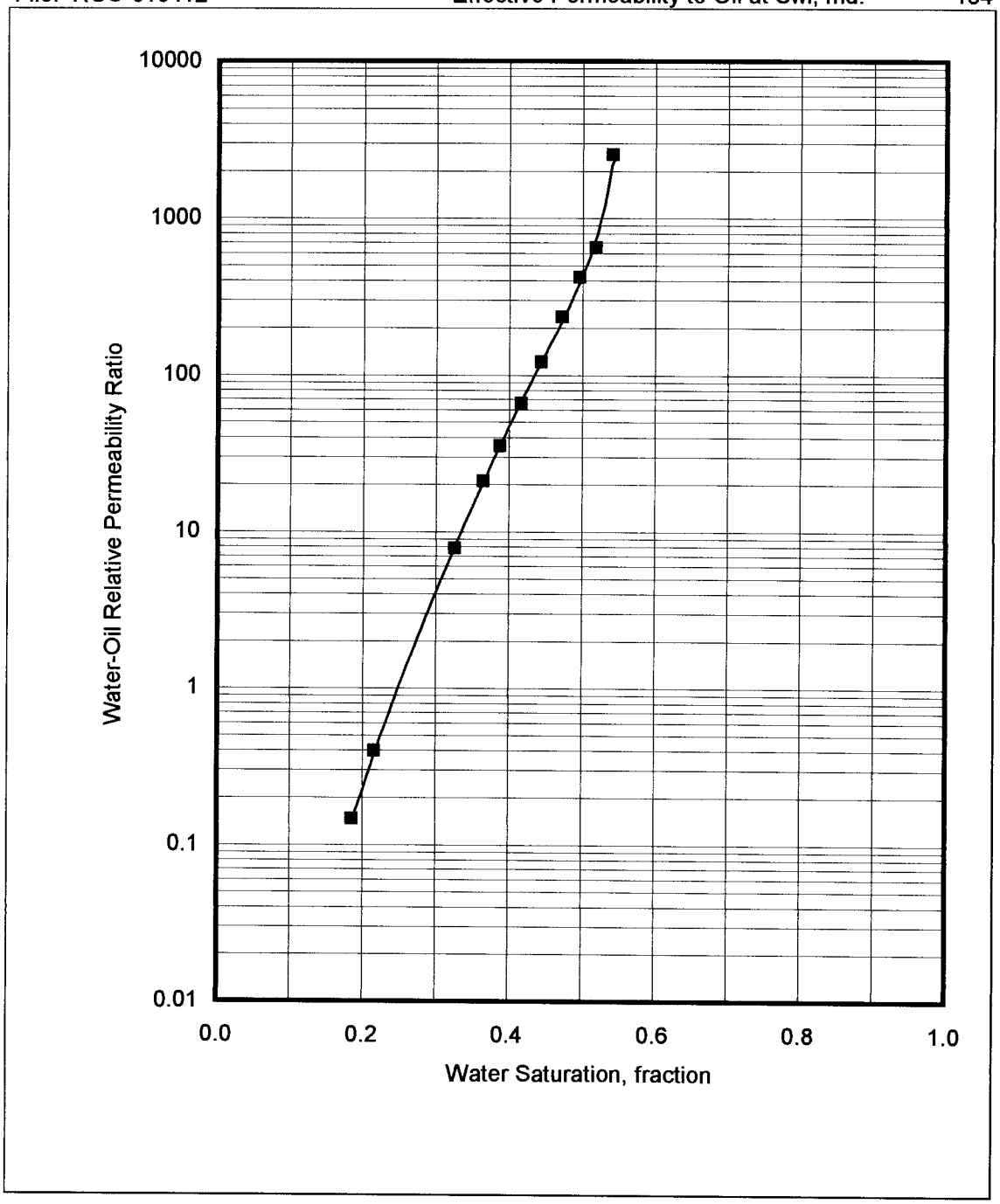

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