CORE LABORATORIES, INC.
Petroleum Reservoir Engineering
DALLAS, TEXAS
February 2, 1973

Phillips Petroleum Company Norway
P. O. Box 1766
Vika
Oslo 1, Norway

Attention: Mr. J. Tate Clark

Subject: Special Core Analysis Study
Torfelt Field
Norwegian Sector, North Sea
Our File Number: SCAL-72131

Gentlemen:

Presented in this report are the results of special core analysis measurements performed on samples of limestone formation recovered from the subject field. The cores used in this study are identified as to well and depth on page one and lithologically described on pages two and three.

Approval for the various special tests was received from Mr. J. Tate Clark under phase 8 of a letter dated December 21, 1971, authorizing a fracture study of cores recovered from the 2/4-8AX well. The laboratory testing was reconfirmed by a letter from Mr. R. M. Archambeault dated May 5, 1972.

The results of two air-brine capillary pressure tests, using restored-state procedures, are given on page four. These tests were performed to comply with the request to determine whether the presence of horizontal stylolites, particularly in vertical plugs, would act as capillary discontinuities. The results, however, are inconclusive since the brine saturation of the cores remained at 100 per cent throughout the pressure levels obtainable in the capillary pressure cell. Desaturation did not occur until the samples were centrifuged at high speed under air and, therefore, capillary pressure curves were not defined.

The measured brine saturations determined at an equivalent capillary pressure of 320 psi (air-brine system) from the centrifuge are average values. Due to "boundary effect", an inherent condition of the centrifuge-type displacement, the average saturation must be mathematically manipulated to yield valid data. Average values are higher in magnitude than the true saturation and can only be corrected for "boundary effect" when a series of desaturation points have been determined at increasing levels of capillary pressure. Restored-state procedures were not considered to be a desirable technique for the low permeability rock investigated in this study, and the mercury injection method was recommended for the remaining samples selected for capillary pressure testing.

Results of the mercury injection capillary pressure determinations are shown in tabular form on page five and in graphical form on pages 14 through 17. The measured capillary pressure-saturation relationships indicate the water contents in the reservoir would be relatively low only at rather significant heights above an oil-water contact. The wetting phase saturations were low in magnitude only at the elevated capillary pressure levels. For reasons discussed above, the wetting phase saturations at irreducible conditions for sample No.'s 1 and 2V are lower in magnitude than the values previously determined at high speed in the centrifuge (air-brine system).

Penetration of mercury into the sample pores did not occur until 300 to 500 psia, indicating high threshold pressures for these samples. The saturations, however, decreased in magnitude quite rapidly after exceeding the threshold pressure of the rock. Although somewhat erratic in the lower permeability and porosity range, the minimum wetting phase saturations correlate reasonably well with either permeability or porosity.

A summary of the data, determined in conjunction with the gas-drive tests, is given on page six. Gas-oil relative permeability characteristics are presented in tabular form on pages 7 through 11 and in graphical form on pages 18 through 27. In spite of the low permeabilities of the samples, the data indicate above average gas displacement characteristics. Further, the gas-drive performances are noted to be comparatively similar for the permeability and porosity range represented. The horizontal silt streaks present in sample No. 9V did not appear to inhibit the flow of fluid. Two additional samples designated for gas drives were not tested due to abnormally low permeabilities to air.

Permeability and porosity measurements performed as a function of overburden pressure are tabulated on pages 12 and 13, respectively. These data were obtained at two intermediate pressure levels and at a maximum effective overburden pressure of 5000 psi, which was requested for these tests. In general, the reductions in permeability and porosity with increasing overburden pressure are normal for limestone formation of the type investigated in this study. With the exception of samples 25 and 28, porosities decreased less than one porosity per cent at the maximum overburden pressure of 5000 psi. The excessive permeability reduction indicated for samples 17 and 27 is attributed to the presence of fractures and/or stylolites.

The special core analysis tests were performed on one-inch diameter cylindrical plugs which had been prepared prior to shipment to our Dallas laboratory. Specific tests were designated for each sample in the test instructions furnished for this study. The samples were thoroughly extracted, leached of all salt and dried. Porosities and air permeabilities were then measured. The air permeabilities given throughout the report have been corrected for Klinkenberg effect.

A simulated formation brine having a sodium chloride content of 118,000 parts per million was used as the saturating fluid in preparation for the restored-state capillary pressure tests and gas-oil relative permeability determinations. The brine-saturated samples selected for the gas-drive tests were centrifuged at high speed under air to establish irreducible connate water saturations. The pores thus voided by these capillary displacements were resaturated with a viscous refined mineral oil.

The restored samples were flushed with the refined oil to insure that the established water contents were immobile. Effective permeabilities to oil were then measured. During the oil flush, mobile water was produced from the samples further reducing their water contents. The resultant water saturations for the relative permeability samples are noted to be in agreement with the irreducible wetting phase saturations determined by mercury injection.

Upon completion of the gas displacements, gas-oil relative permeability characteristics were calculated from the laboratory production data using a digital computer.

We appreciate this opportunity to be of service.

Very truly yours,

Core Laboratories, Inc.

Rondal Uhl (RSB)

Rondal Uhl, Manager
Special Core Analysis

DKK:VJP:dl
15 cc. - Addressee

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File SCAL-72131

Company Phillips Petroleum Company Norway
Number of Wells One
Field Torfelt
Formation
County
State Norwegian Sector, North Sea

Identification of Samples

Sample Number	Company	Well	Depth, Feet
1	Phillips Petroleum Company Norway	2/4-8AX	10289
2V			10291
3			10278
4			10303
5V			10262
6			10148
7			10155
8			10133
9V			10265
10			10324
11			9933
12			10319
13			9920
14			10280
15			10333
16			9930
17			10524
18			10310
19			10400
20			10160
21			10373
22			10290
23			10357
24			10135
25			9885
26			10353
27			10408
28			10611
29			10615

V - Vertical plug

Lithological Description

Sample Number	Description
1	Ls, buff, v/fnly xln, fracs, sty
2V	Same as above
3	Ls, buff, v/fnly xln
4	Same as above
5V	Ls, buff, v/fnly xln, fracs, sty
6	Ls, buff, v/fnly xln, dns, closed frac
7	Ls, buff, v/fnly xln, dns
8	Ls, buff, v/fnly xln, dns, fracs, sty
9V	Ls, buff, v/fnly xln, silt strks
10	Ls, buff, v/fnly xln, dns
11	Ls, buff, v/fnly xln, chalky
12	Ls, buff, v/fnly xln, dns
13	Ls, buff, v/fnly xln, dns
14	Ls, buff, v/fnly xln, chalky
15	Same as above
16	Same as above
17	Ls, buff, v/fnly xln, chalky, frac, sty
18	Ls, buff, v/fnly xln, chalky
19	Same as above
20	Same as above
21	Same as above
22	Ls, buff, v/fnly xln, chalky, sty
23	Ls, buff, v/fnly xln, chalky, pyr
24	Ls, buff, v/fnly xln, tr pyr
25	Ls, buff, v/fnly xln
26	Ls, buff, v/fnly xln, sty
27	Ls, buff, v/fnly xln, closed fracs

Lithological Description

Sample Number	Description
28	Ls, buff, v/fnly xln
29	Ls, buff, v/fnly xln, silty

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Air-Brine Capillary Pressure Data

Sample Number	Permeability, Millidarcys	Porosity, Per Cent	Pressure, PSI: 1	2	4	8	15	35	320*
			Brine Saturation, Per Cent Pore Space						
1	4.3	26.2	100.0	100.0	100.0	100.0	100.0	100.0	25.8
2V	2.8	23.4	100.0	100.0	100.0	100.0	100.0	100.0	28.8

* Equivalent pressure from centrifuge (air-brine system).

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Mercury Injection Capillary Pressure Data

Sample Number:	1	2V	3	4	5V	6	7	8
Permeability, Md.:	4.3	2.8	1.4	0.58	0.11	0.08	0.08	0.07
Porosity, Per Cent:	26.2	23.4	28.3	24.3	17.8	16.2	14.9	17.0
Injection Pressure, PSIA	Wetting Phase Saturation, Per Cent Pore Space							
3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
12	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
15	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
18	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
21	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
24	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
27	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
30	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
40	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
60	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
80	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
200	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
300	71.0	98.9	57.6	100.0	100.0	100.0	100.0	100.0
500	17.9	26.7	13.9	25.2	47.1	47.4	93.1	100.0
750	11.0	14.6	8.2	14.6	30.3	17.2	39.2	42.2
1000	8.6	11.1	6.1	11.2	22.6	11.1	22.8	27.4
1250	7.4	8.8	5.1	9.5	18.8	8.5	15.9	22.2
1500	6.1	7.7	4.8	8.6	16.5	7.2	14.0	19.1

Summary of Gas-Oil Relative Permeability Data

Sample Number	Permeability, Millidarcys: To Air	Permeability, Millidarcys: To Oil With Connate Water Present	Permeability, Millidarcys: To Gas at Kg/Ko of 100	Porosity, Per Cent	Connate Water Per Cent Pore Space	Oil in Place, Per Cent Pore Space	Oil Saturation, Per Cent Pore Space @ Kg/Ko of 1.0	Oil Saturation, Per Cent Pore Space @ Kg/Ko of 100	Oil Recovered, Per Cent Pore Space @ Kg/Ko of 1.0	Oil Recovered, Per Cent Pore Space @ Kg/Ko of 100
9V	1.1	0.58	0.25*	26.6	10.4	89.6	61.4	37.0*	28.2	52.6*
10	0.75	0.40	0.20*	25.7	9.6	90.4	54.8	29.3*	35.6	61.1*
11	0.54	0.26	0.14	32.6	13.8	86.2	49.2	25.3	37.0	60.9
12	0.40	0.22	0.10	21.5	16.2	83.8	55.6	30.0	28.2	53.8
13	0.38	0.19	0.11	29.6	15.0	85.0	55.0	32.3	30.0	52.7

* Extrapolated

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Gas-Oil Relative Permeability Data

Sample Number 9V

Air Permeability, Md. 1.1

Oil Permeability with Connate Water Present, Md. 0.58

Connate Water Saturation Per Cent Pore Space 10.4

Porosity, Per Cent 26.6

Liquid Saturation, Per Cent Pore Space	Gas-Oil Relative Permeability Ratio	Relative Permeability to Gas*, Fraction	Relative Permeability to Oil*, Fraction
96.5	.001	.0004	.389
95.2	.002	.0007	.349
93.9	.004	.001	.310
92.5	.006	.002	.274
90.7	.012	.003	.233
88.8	.022	.004	.197
86.6	.042	.007	.161
83.9	.082	.010	.126
80.9	.158	.015	.096
78.0	.296	.022	.074
74.7	.575	.031	.054
71.4	1.09	.043	.039
69.0	1.69	.052	.031
65.6	3.04	.067	.022
61.4	6.32	.088	.014
57.3	13.0	.113	.009
53.6	26.4	.143	.005
50.0	57.5	.188	.003
47.7	94.1	.223	.002

* Relative to air permeability.

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Gas-Oil Relative Permeability Data

Sample Number: 10
Air Permeability, Md.: 0.75
Oil Permeability with Connate Water Present, Md.: 0.40
Connate Water Saturation Per Cent Pore Space: 9.6
Porosity, Per Cent: 25.7

Liquid Saturation, Per Cent Pore Space	Gas-Oil Relative Permeability Ratio	Relative Permeability to Gas*, Fraction	Relative Permeability to Oil*, Fraction
97.1	.001	.0006	.461
95.3	.003	.0011	.421
93.7	.004	.0016	.390
91.9	.007	.0024	.355
89.7	.012	.004	.318
87.3	.022	.006	.279
84.4	.038	.009	.239
81.3	.069	.014	.200
77.6	.126	.020	.159
73.3	.238	.029	.121
68.8	.473	.041	.086
64.3	.964	055	.057
60.7	1.68	.069	.041
57.0	3.17	.088	.028
52.1	7.39	.118	.016
49.2	12.7	.140	.011
44.8	29.0	.180	.006
41.7	52.8	.220	.004
39.1	92.7	.264	.003

* Relative to air permeability.

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Gas-Oil Relative Permeability Data

Sample Number 11
Air Permeability, Md. 0.54
Oil Permeability with Connate Water Present, Md. 0.26
Connate Water Saturation Per Cent Pore Space 13.8
Porosity, Per Cent 32.6

Liquid Saturation, Per Cent Pore Space	Gas-Oil Relative Permeability Ratio	Relative Permeability to Gas*, Fraction	Relative Permeability to Oil*, Fraction
97.3	.0007	.0003	.429
94.8	.002	.0008	.383
93.1	.003	.0012	.355
91.4	.006	.0019	.328
89.1	.010	.003	.294
86.7	.019	.005	.261
84.2	.032	.007	.229
81.1	.057	.011	.196
77.6	.103	.017	.161
73.4	.195	.024	.125
69.7	.355	.035	.099
65.4	.699	.049	.070
62.1	1.19	.062	.052
58.0	2.29	.081	.035
53.9	4.47	.103	.023
48.7	11.2	.138	.012
44.6	25.5	.179	.007
42.1	42.8	.208	.005
35.1	235	.361	.002

* Relative to air permeability.

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Gas-Oil Relative Permeability Data

Sample Number 12
Air Permeability, Md. 0.40
Oil Permeability with Connate Water Present, Md. 0.22
Connate Water Saturation Per Cent Pore Space 16.2
Porosity, Per Cent 21.5

Liquid Saturation, Per Cent Pore Space	Gas-Oil Relative Permeability Ratio	Relative Permeability to Gas*, Fraction	Relative Permeability to Oil*, Fraction
98.7	.007	.003	.501
97.4	.013	.006	.455
96.3	.019	.008	.418
94.2	.034	.012	.359
90.4	.074	.021	.276
85.0	.173	.033	.192
79.0	.394	.050	.126
73.0	.858	.069	.080
68.4	1.60	.085	.053
63.1	3.64	.108	.030
59.5	6.83	.128	.019
55.4	14.5	.155	.011
51.5	32.2	.186	.006
49.0	54.3	.216	.004
42.5	260	.337	.001

* Relative to air permeability.

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Gas-Oil Relative Permeability Data

Sample Number 13
Air Permeability, Md. 0.38
Oil Permeability with Connate Water Present, Md. 0.19
Connate Water Saturation Per Cent Pore Space 15.0
Porosity, Per Cent 29.6

Liquid Saturation, Per Cent Pore Space	Gas-Oil Relative Permeability Ratio	Relative Permeability to Gas*, Fraction	Relative Permeability to Oil*, Fraction
97.8	.001	.0005	.443
96.4	.003	.0010	.410
94.9	.004	.0016	.378
93.4	.007	.0025	.349
91.5	.013	.004	.312
89.4	.023	.006	.275
87.0	.040	.009	.237
84.2	.071	.014	.199
81.1	.127	.020	.161
77.6	.237	.029	.123
74.0	.463	.041	.089
70.1	.922	.056	.061
67.1	1.58	.071	.045
63.8	2.97	.090	.030
60.4	5.83	.114	.020
56.7	12.0	.143	.012
53.2	25.6	.176	.007
49.8	55.9	.229	.004
45.2	183	.334	.002

* Relative to air permeability.

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Permeability Data

Sample Number	Effective Overburden Pressure, PSI 200	1000	3000	5000
	Air Permeability, Millidarcys			
14	1.9	1.8	1.6	1.5
15	1.3	1.3	1.2	1.2
16	1.3	1.2	1.1	1.1
17	1.0	0.08	0.03	0.02
18	1.0	1.0	0.94	0.94
19	0.39	0.37	0.37	0.36
20	0.22	0.22	0.21	0.21
21	0.21	0.19	0.19	0.17
22	0.21	0.21	0.20	0.20
23	0.12	0.11	0.11	0.10
24	0.11	0.10	0.10	0.10
25	0.10	0.10	0.08	0.07
26	0.05	0.05	0.05	0.05
27	0.04	0.02	0.01	<0.01
28	<0.01	*	*	*
29	<0.01	*	*	*

* Air permeability equipment prohibits accurate measurements below 0.01 md.

Porosity Data

Sample Number	Effective Overburden Pressure, PSI			
	200	1000	3000	5000
	Porosity, Per Cent			
14	30.4	30.4	30.1	30.1
15	27.3	26.8	26.8	26.8
16	36.4	36.4	36.1	35.7
17	10.0	9.8	9.7	9.6
18	27.8	27.6	27.4	27.0
19	23.2	23.1	22.8	22.8
20	19.6	19.6	19.4	19.4
21	11.1	11.0	10.8	10.7
22	18.9	18.8	18.8	18.8
23	17.2	16.9	16.8	16.8
24	16.4	16.2	16.0	15.9
25	26.4	26.2	25.7	25.3
26	14.3	14.2	14.1	14.1
27	16.5	16.5	16.5	16.5
28	6.5	6.4	6.3	5.3
29	1.1	1.1	1.0	0.9

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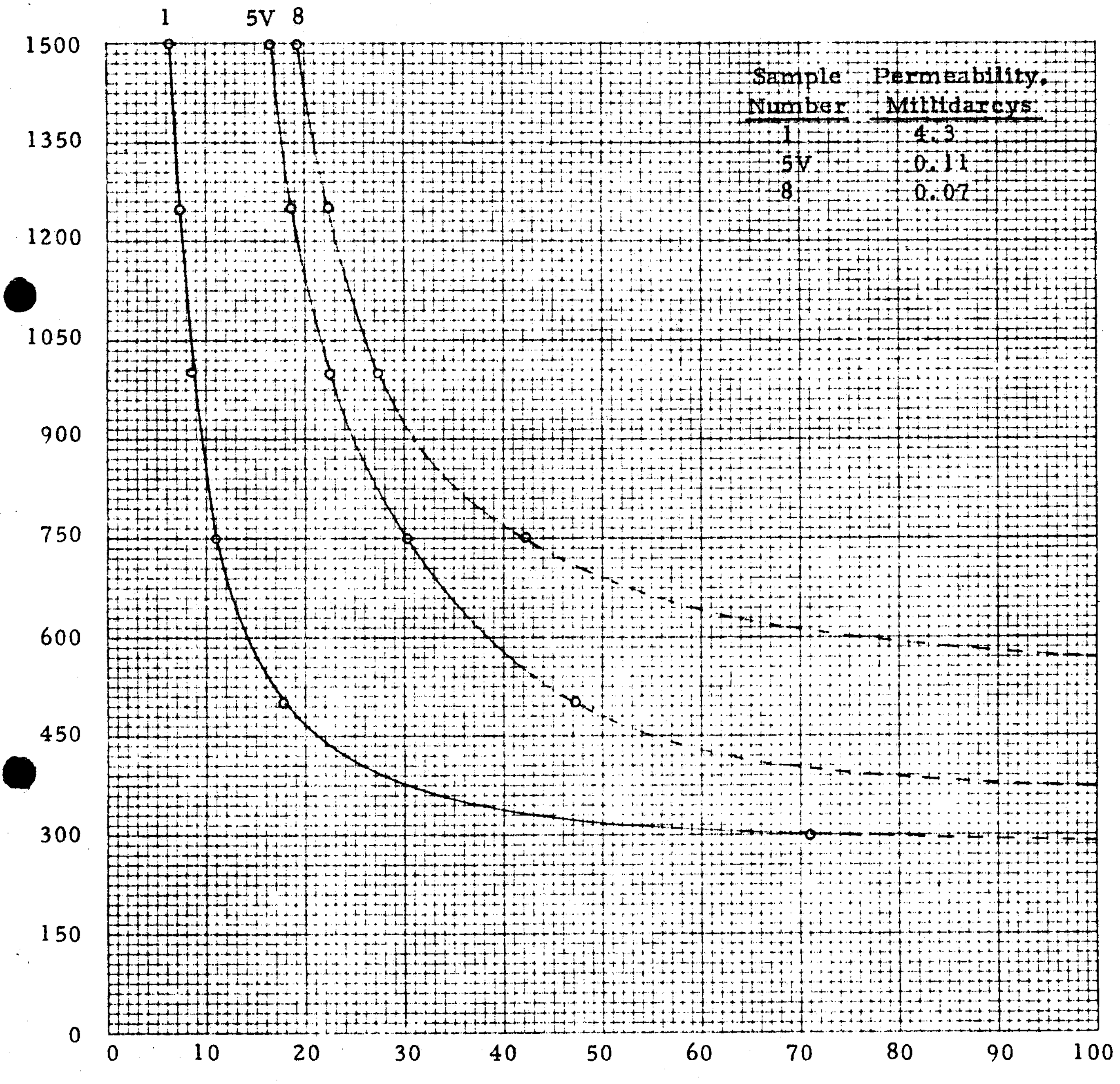
Company: Phillips Petroleum Company
Norway
Formation:
Well: 2/4-8AX
County:
Field: Torfelt
State: Norwegian Sector, North Sea



Wetting Phase Saturation, Per Cent Pore Space

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Phillips Petroleum Company

Company Norway
Well 2/4-8AX
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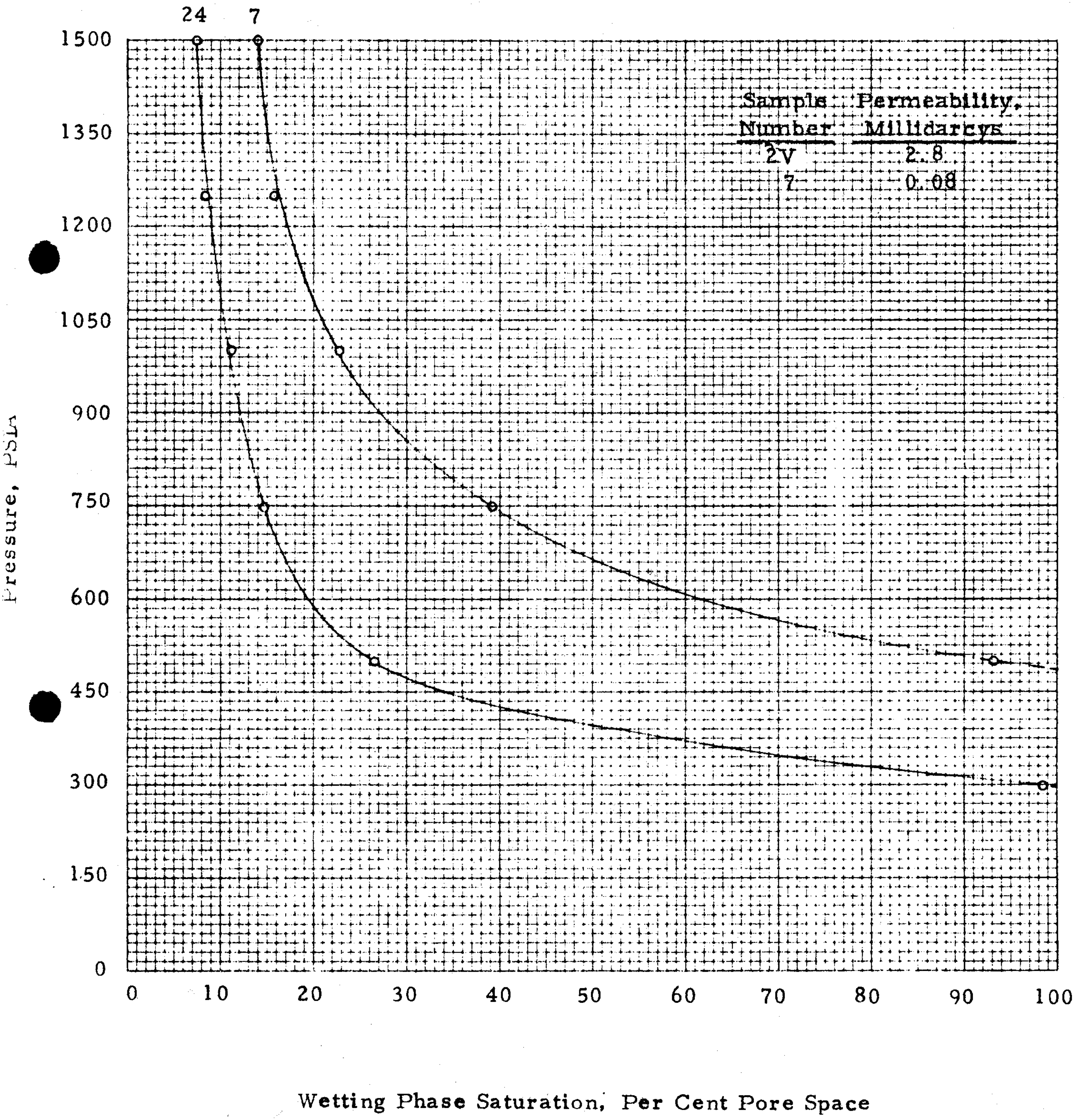

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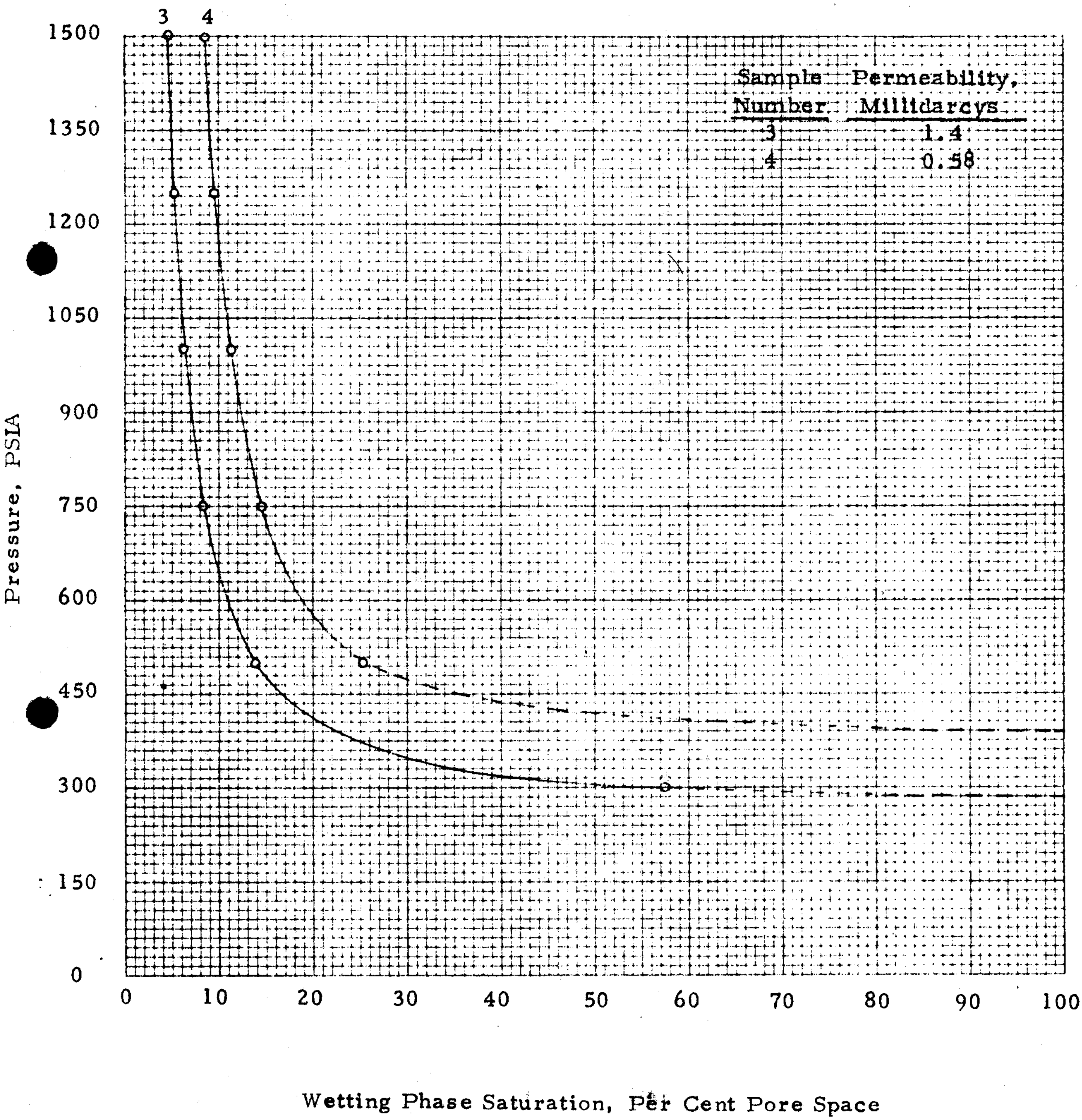

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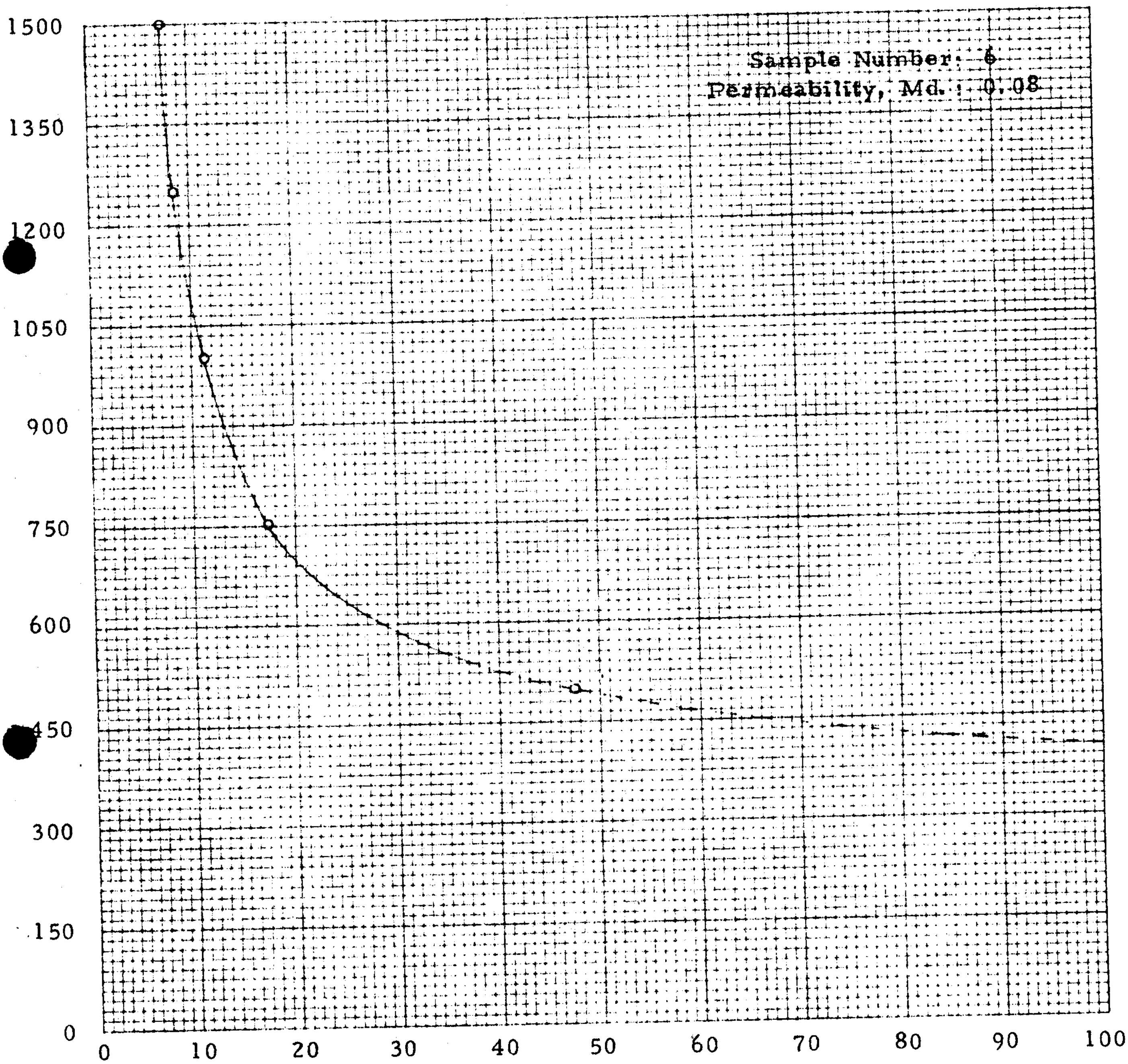

Wetting Phase Saturation, Per Cent Pore Space

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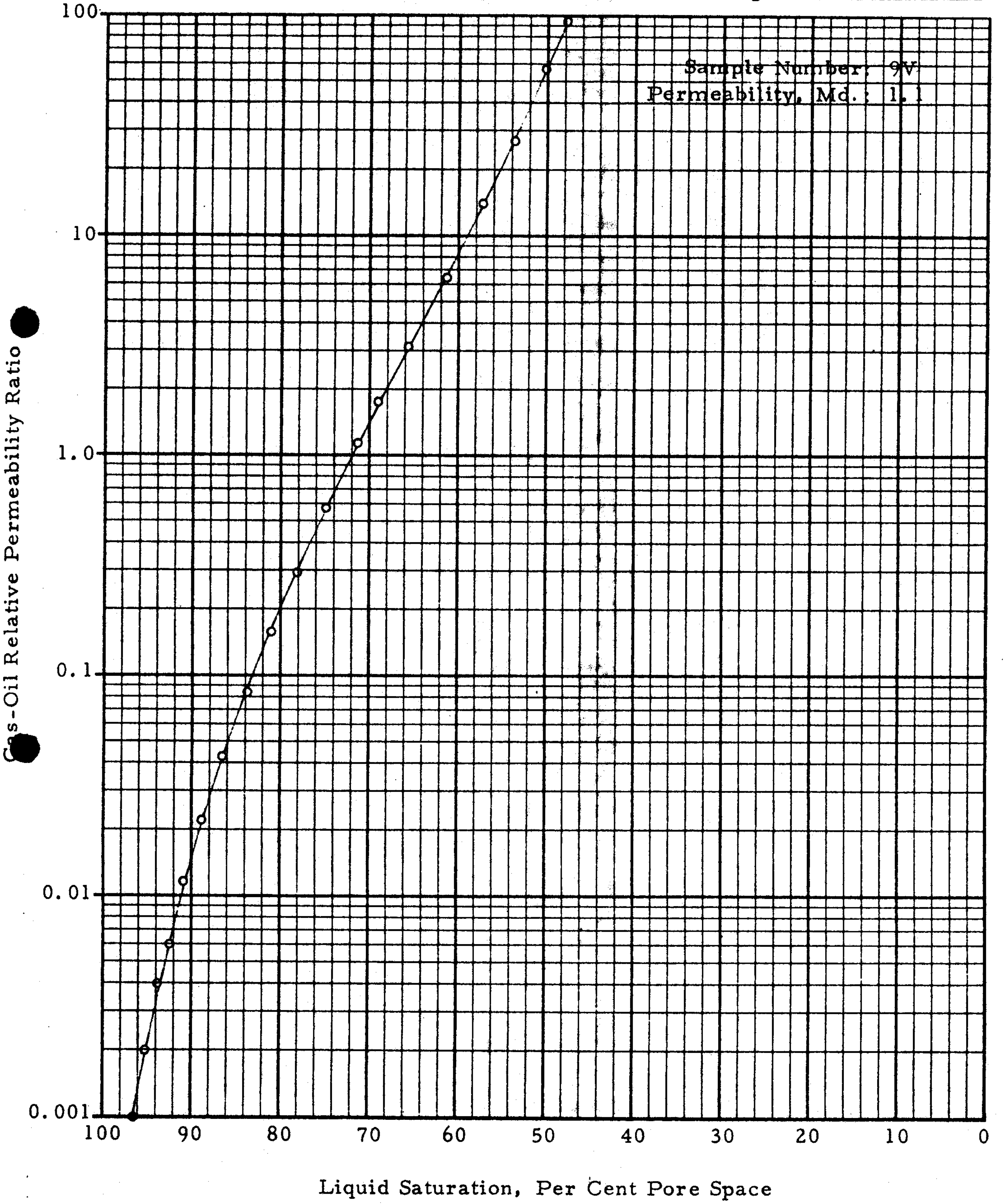

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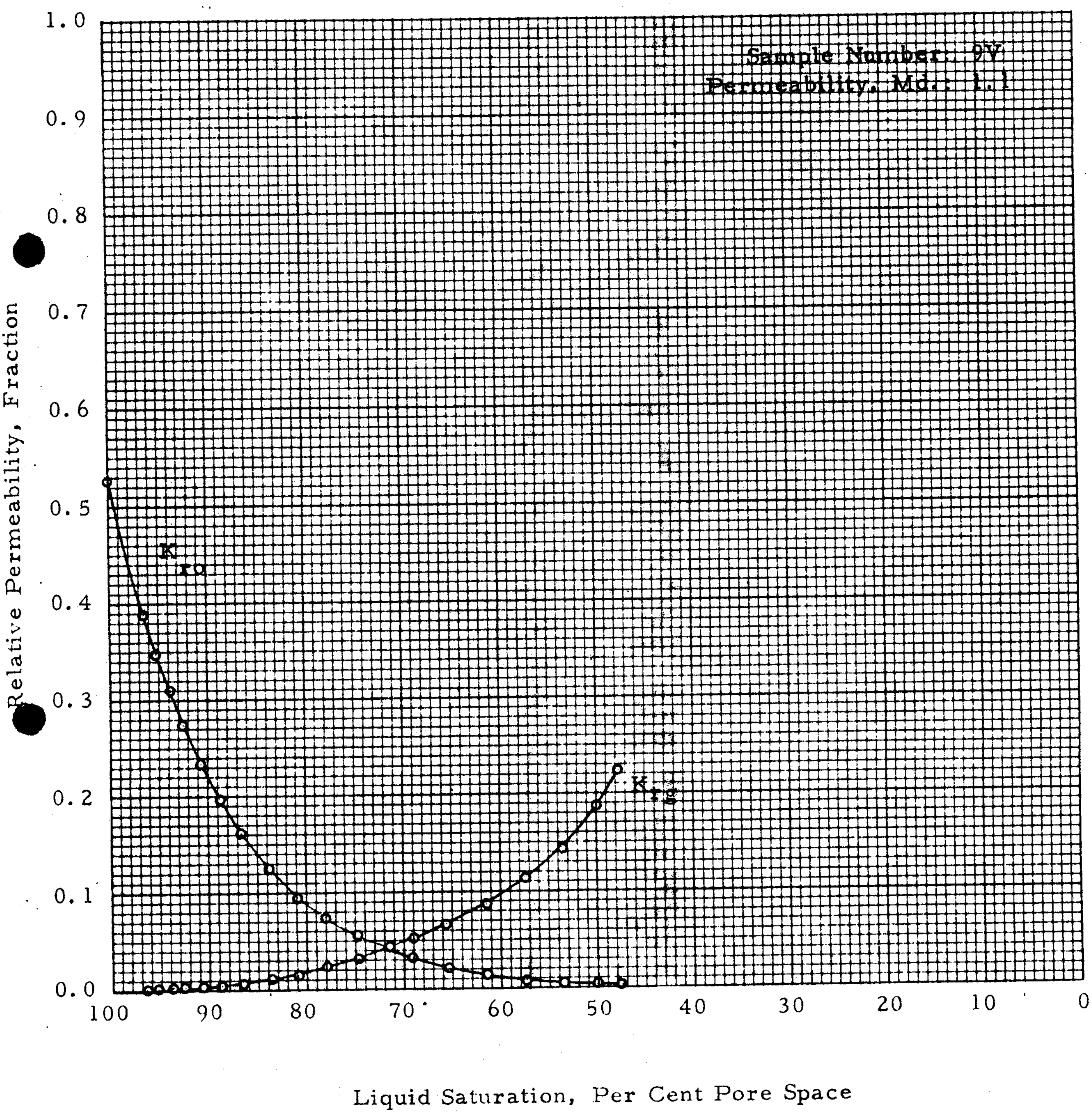
Phillips Petroleum Company

Company	Norway	Formation	
Well	2/4-8AX	County	
Field	Torfelt	State	Norwegian Sector, North Sea



Phillips Petroleum Company
Company Norway
Well 2/4-8AX
Field Torfelt

Formation
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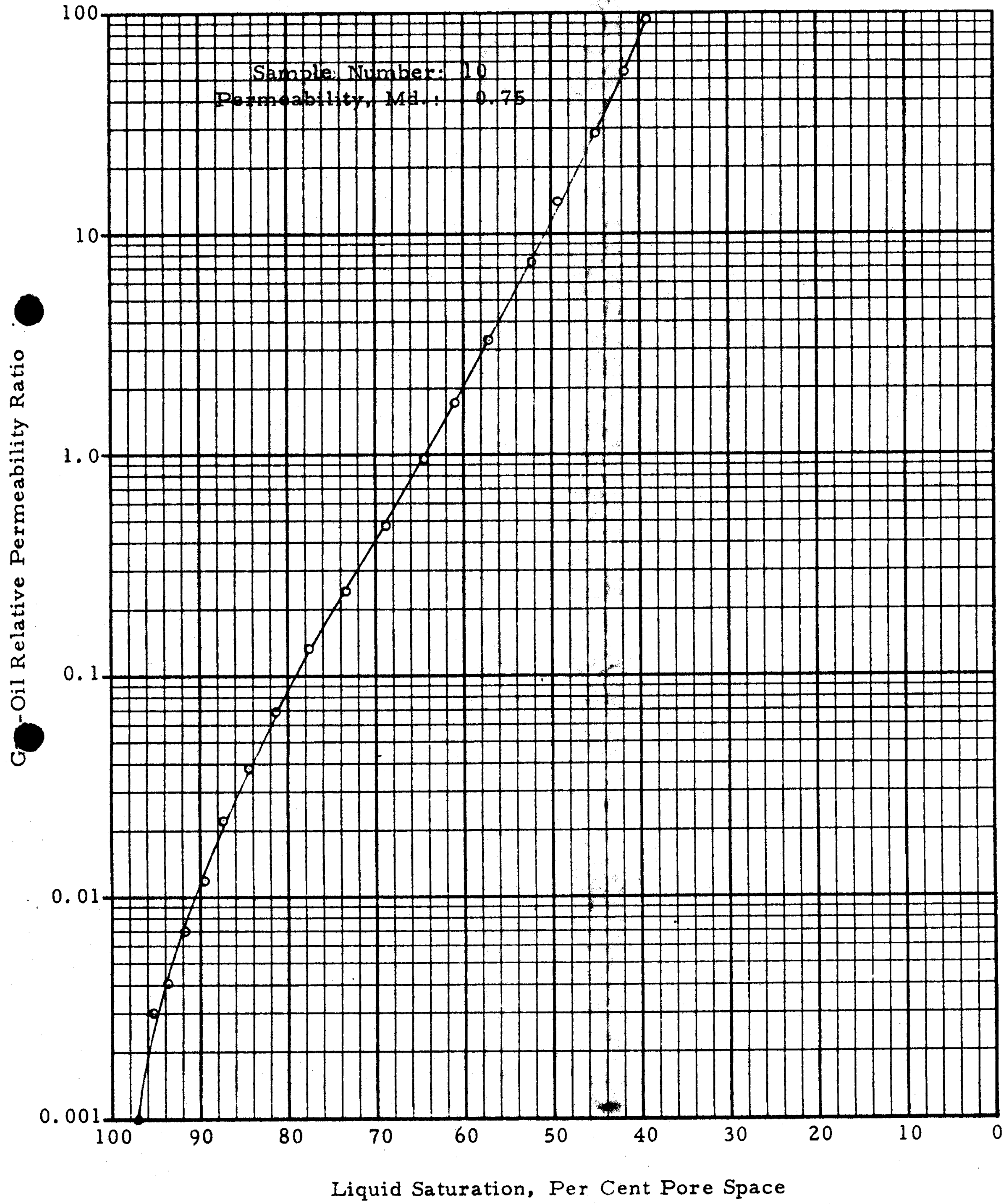

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County:
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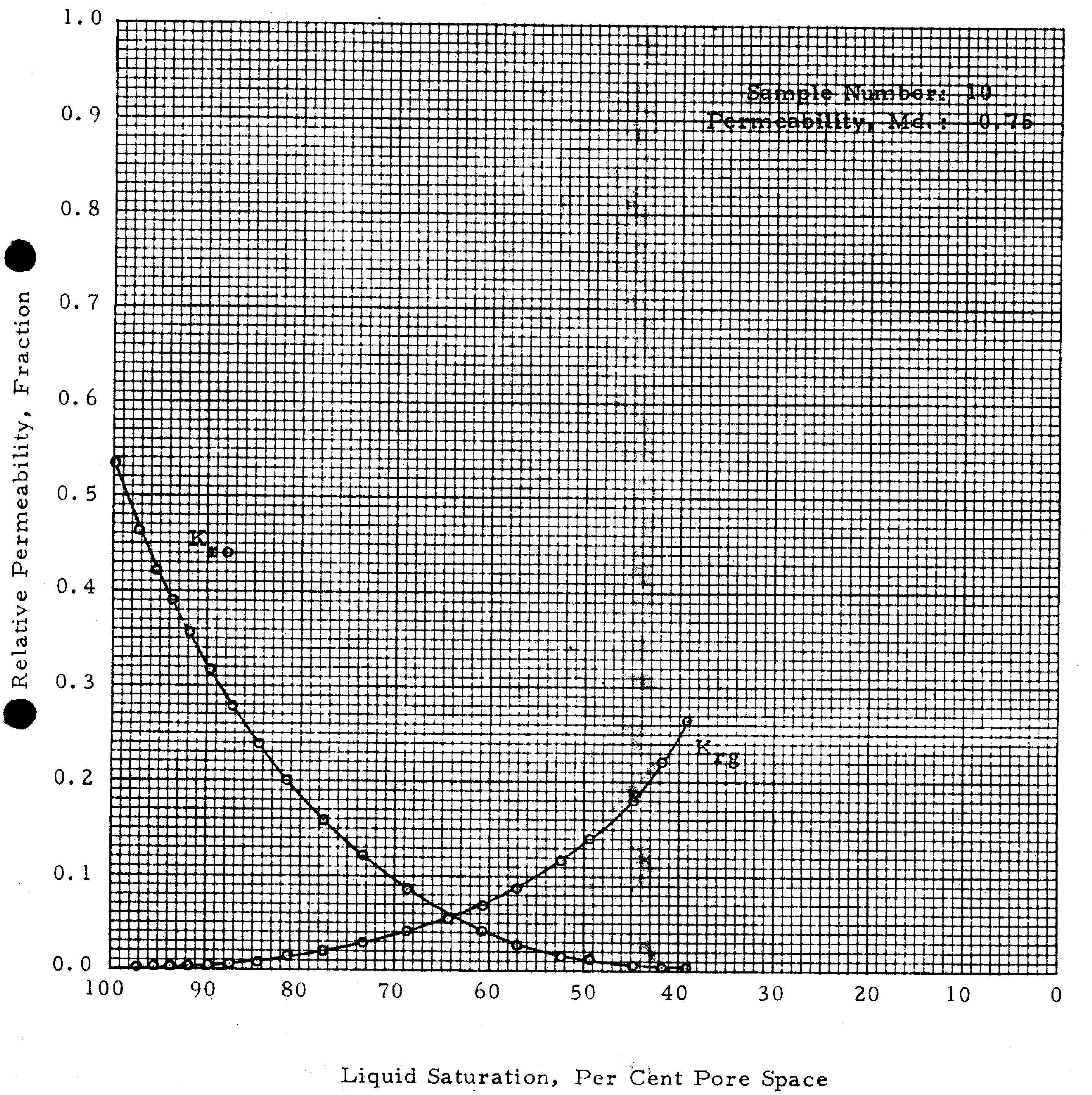

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Well 2/4-8AX
Field Torfelt
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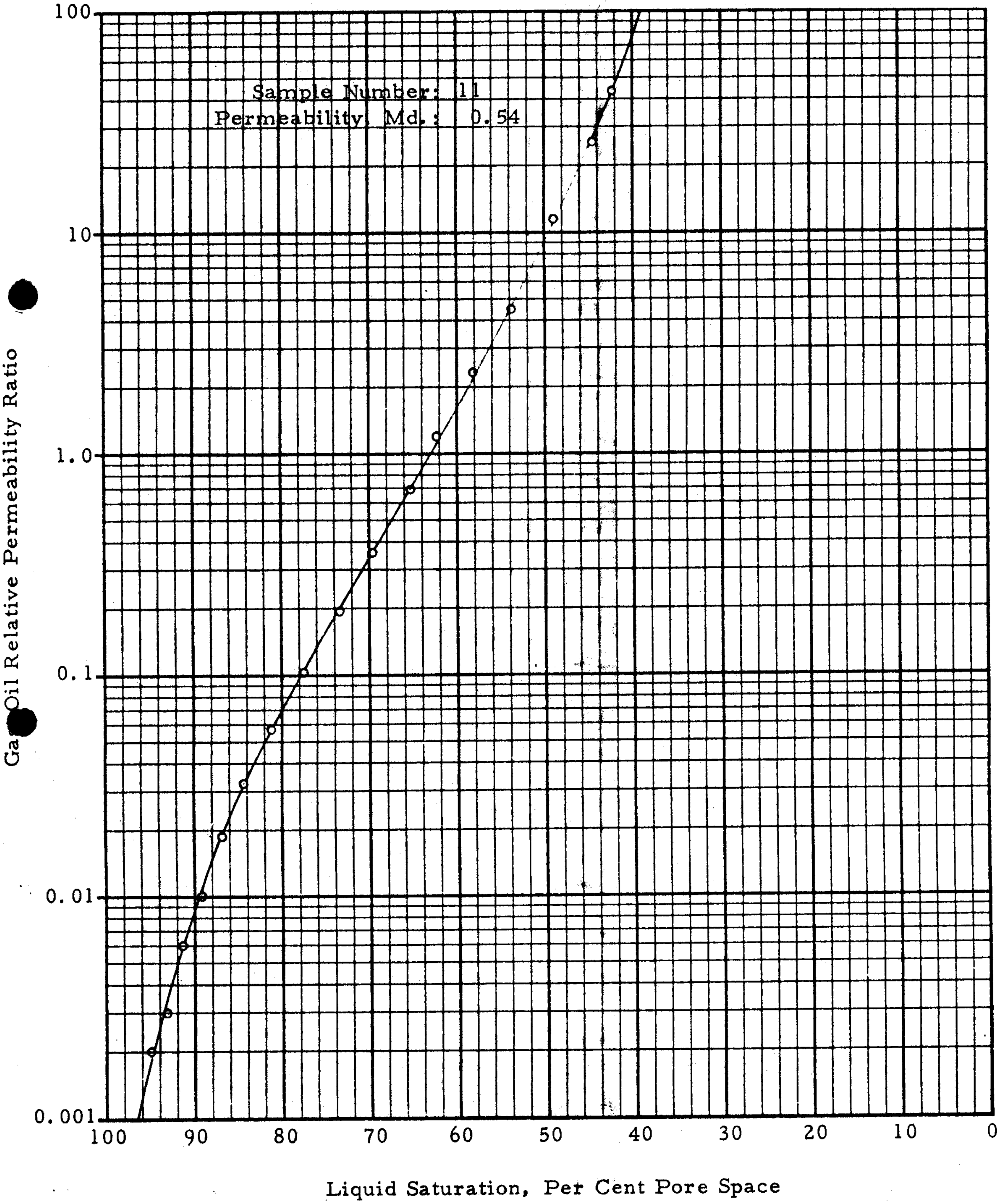

Phillips Petroleum Company
Company Norway
Well 2/4-8AX
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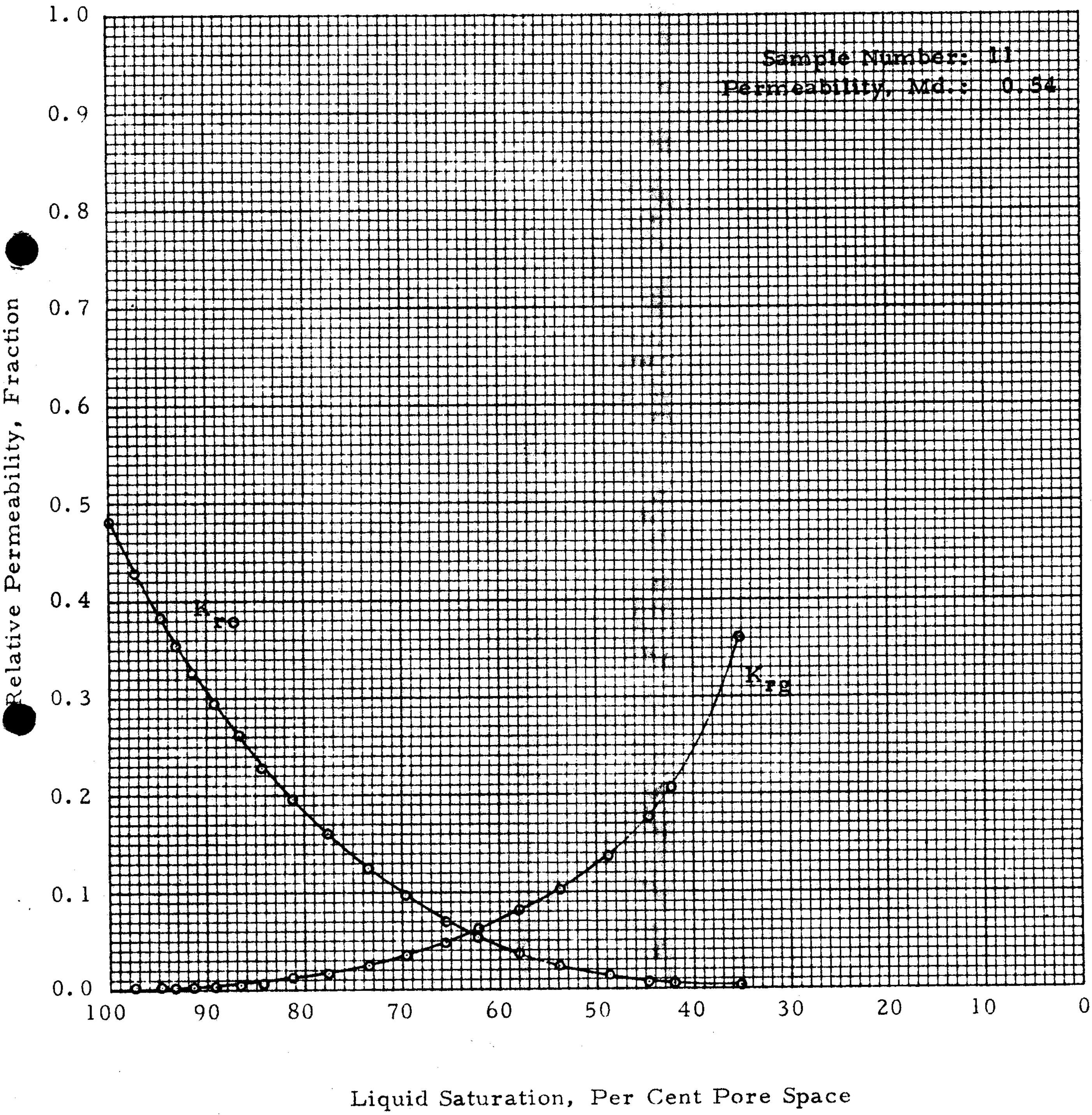

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Company: Phillips Petroleum Company Norway
Well: 2/4-8AX
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County:
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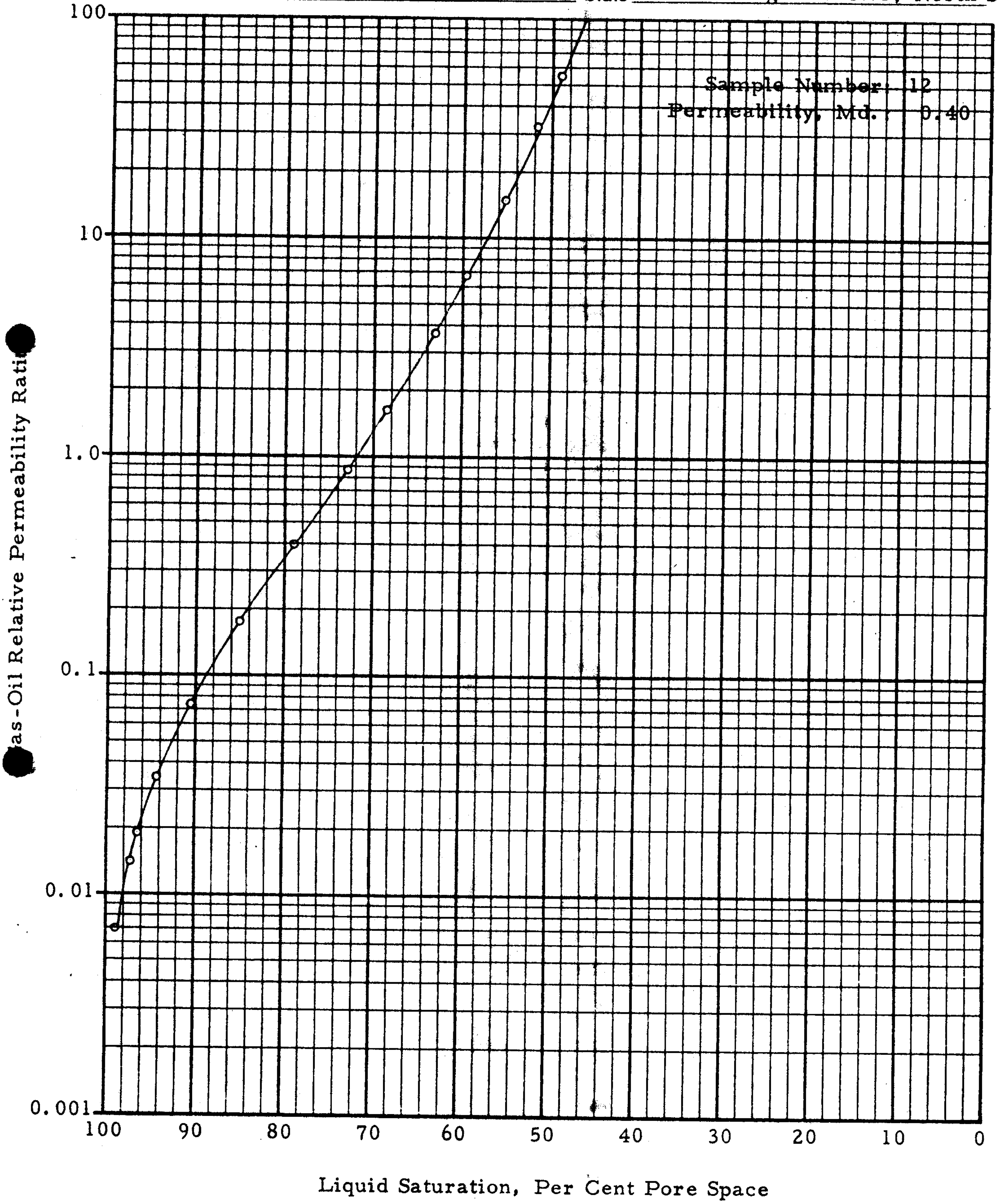
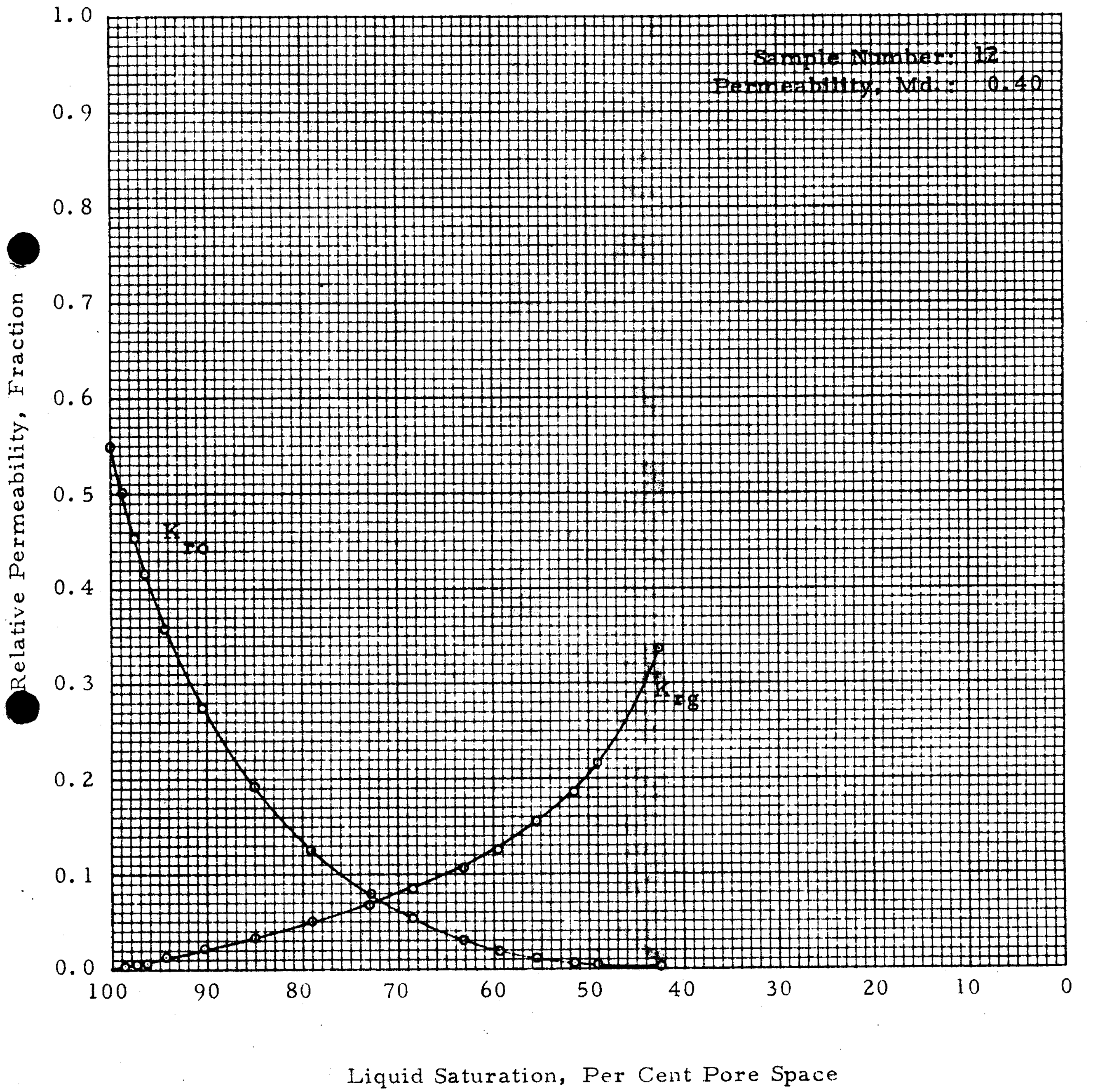


Company Phillips Petroleum Company Norway
Well 2/4-8AX
Field Torfelt
Formation
County
State Norwegian Sector, North Sea



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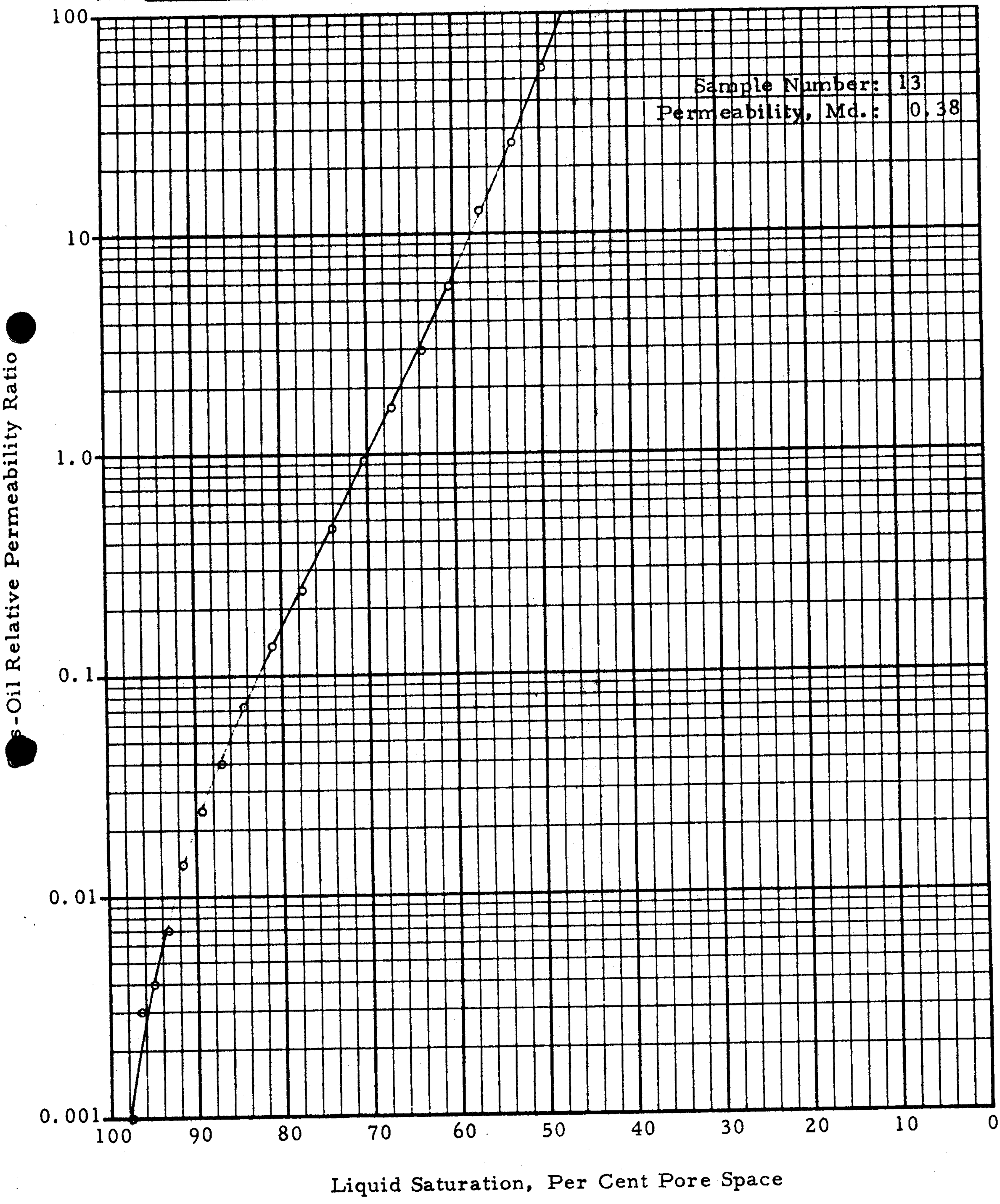

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