

Denne rapport
tilhører



L&U DOK. SENTER

L. NR. 30284290022

KODE Well 31/2-5 nr 30

Returneres etter bruk

MECHANICAL CORE ANALYSIS STUDY

FOR

WELL EXPLORATION & PRODUCTION

SPECIAL CORE ANALYSIS STUDY
FOR
A/S NORSKE SHELL EXPLORATION & PRODUCTION
Well: 31/2-5



CORE LABORATORIES UK LTD.

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P.O. Box 40,
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Norway

March 1982

Attention: Mr T. Tosus

Subject: Special Core Analysis Study
Well: 31/2-5
Area: North Sea, Norway
File: UKSCAL 311 81039

Gentlemen,

In a telex dated 25th February 1981, ref 2219 from Norske Shell Exploration and Production, Core Laboratories UK Limited was requested to perform the following special core analysis measurements on samples from the subject well.

1. Electrical Resistivity
2. Gas-Oil Relative Permeability
3. Water-Oil Relative Permeability
4. Steady-State Gas-Water Relative Permeability
5. Wettability (Amott-Harvey Method)

Items 2, 3, 4 and 5 were scheduled to be performed using fresh state samples. Three samples were scheduled for item 4, to be performed in our Dallas laboratory, however, due to the friable nature of the core these measurements were not possible.

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A/S Norske Shell Exploration and Production
Special Core Analysis Study
March 1982
Page Two

The results of the remaining analyses are presented herein as a final report and serve to confirm all the data which have previously been submitted in preliminary form. A table of contents immediately follow this letter, and the samples are described with respect to depth and lithology on page 1 of this report.

It has been a pleasure working with A/S Norske Shell Exploration and Production on this study. Should you have any questions please do not hesitate to contact us.

Yours faithfully,
CORE LABORATORIES UK LIMITED

A handwritten signature in black ink, appearing to read "Jon Roberts", written in a cursive style with a large flourish at the end.

Jon Roberts
Laboratory Manager,
Special Core Analysis

JCR/MBH/hsb

10 cc - Addressee

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Special Core Analysis Procedures

Sample Preparation

Nineteen, preserved, full diameter core samples, representing a depth range between 1536.30 and 1651.14 metres were recovered from the subject well and were shipped to our London laboratories for analysis.

From these core pieces, it was proposed that twenty-two one and a half inch diameter plug size samples should be drilled, using kerosene as the bit lubricant. However, due to the friable nature of the core a number of these samples were mounted in thin metal sleeves to maintain their coherence.

Five samples were scheduled to undergo wettability measurements, however the samples were too friable for this analysis in the unmounted state, and mounting these samples would preclude wettability measurements so no data is available.

As electrical resistivity measurements were requested, these samples were not mounted.

All samples scheduled for fresh-state measurements were stored under treated, degassed kerosene prior to analysis. The remaining samples, all scheduled for electrical resistivity measurements, were cleaned in cool solvents, firstly with xylene and then with methanol. Samples numbered 1A, 4A, 9A and 13A collapsed and could not undergo further analysis. The remaining samples were dried in a humidity controlled oven and had air permeability and helium injection porosity measured.

Formation Factor and Resistivity Index Data

Six samples were scheduled to undergo this analysis but samples numbered 1A, 4A, 9A and 13A had previously collapsed in cleaning.

The remaining clean, dry samples were evacuated and saturated under vacuum with a synthetic formation brine consisting of approximately 75,700 mg/l total dissolved solids. This brine was synthesised according to information supplied in a telex dated 24th March 1981 and a copy of this analysis is presented on page 2 of this report.

The remaining two samples numbered 3A and 19A were unsuitable for further analysis due to the friable nature of the samples, which resulted in excessive grain loss.

Gas-Oil Relative Permeability Data (Page 3)

Seven samples were scheduled to undergo this analysis.

The fresh state samples were each mounted in a hydraulic core holder and flushed with a refined mineral oil having a viscosity of approximately 20 centipoise at room conditions to ensure the removal of all mobile water and trapped gas. Effective permeability to this oil was then measured. Sample number 18B has an effective oil permeability below 0.08 millidarcies, which is the recommended minimum for floods.

Cont'd.....

Gas-oil relative permeability measurements were performed using humidified nitrogen as the displacing phase. Incremental volumes of oil and gas produced were recorded against time and the floods were terminated at gas-oil relative permeability ratios in excess of 30.

Following gas-oil relative permeability measurements, samples numbered 5B and 9B were restored under vacuum with the refined mineral oil prior to water-oil relative permeability measurements. The remaining samples were cleaned in a Dean-Stark type distillation apparatus, leached in methanol and dried in a humidity controlled oven. Air permeability and helium injection porosity were then measured and fluid saturations calculated using material balance equations.

Relative permeability data were calculated using a digital computer and results are presented in tabular form on pages 3 through 8 and in graphical form on pages 9 through 20.

Samples numbered 3B, 8B, 9B and 11B all show abnormal oil curves, this shape is usually indicative of channelling occurring during relative permeability measurements.

Water-Oil Relative Permeability Data (Page 21)

Six samples were scheduled to undergo this analysis.

Samples 5B and 9B which, following gas-oil relative permeability measurements, were restored under vacuum with a refined mineral oil, were each mounted in a hydraulic core holder and flushed with this oil to ensure the removal of any trapped gas. Effective permeability to this oil was then remeasured.

Four fresh state samples were each mounted in a hydraulic core holder and were flushed with the refined mineral oil to ensure the removal of all mobile water and trapped gas. Effective permeability to this oil was then measured. Samples numbered 17B and 19B have effective oil permeabilities below 0.08 millidarcies which is the recommended minimum for floods.

Water-oil relative permeability measurements were performed on the remaining samples using synthetic formation brine as the displacing phase. Incremental productions of oil and water produced were recorded against time and the floods were terminated at water-oil relative permeability ratios in excess of 100. Effective permeability to the brine was then measured.

The samples were then cleaned in a Dean-Stark type distillation apparatus, leached in methanol and were dried in a humidity controlled oven. Air permeability and helium injection porosity were measured and fluid saturations calculated using material balance equations.

Water-oil relative permeability data were calculated using a digital computer and results are summarised on page 21 and are presented in tabular form on pages 22 through 25 and in graphical form on pages 26 through 33.

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File: UKSCAL 311-81039

COMPANY: A/S NORSKE SHELL EXP. & PROD. FORMATION:
WELL: 31/2-5 COUNTRY: NORTH SEA
FIELD: STATE: NORWAY

IDENTIFICATION AND DESCRIPTION OF PLUG SAMPLES

Sample Number	Depth Metres	Lithological Description
3B	1553.29	Ss, lt gry, fgrn, uncons, abnt mica, w lim & cl grns.
5B	1565.29	Ss, lt gry, fgrn, uncons, abnt mica.
7B	1572.57	Ss, lt gry, fgr, semi-uncons, w/scat clac gns, poss shl frags.
8B	1576.07	Ss, lt gry/gn, mgrn, uncons, abnt mica.
9B	1597.72	As above.
10B	1602.65	As above.
11B	1605.45	Ss, lt gry w/yelsh och pchs (fe stn), mgrn, uncons, abnt mica.
16B	1629.79	Sltly/ss, lt olv gry/gn, fgrn, consol, w/scat calc gns poss shl frag, scat carb mat.
17B	1639.32	Sltst, lt olv gry/gn, f grn, consol, w/scat qtz & musc gr & scat calc mat.
18B	1644.08	Sltst, dk gry, f grn, consol, v/f qtz grns in vf cl mtrx.
19B	1651.14	Sltly/ss, lt gry, f grn, consol, w/scat carb mat.

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Water Analysis Data

Total Dissolved Solids: 75,700 mg/l
Specific Gravity: 1.056 @ 59°F
Resistivity, ohm-metres: 0.116 @ 59°F

<u>Constituents</u>	mg/l
Sodium	15,700
Calcium	12,000
Magnesium	370
Strontium	520
Barium	35
Iron	60
Chloride	47,000

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GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 3B

Initial Water Saturation
Per Cent Pore Space: 34.5

Air Permeability, Md: 3790

Porosity, Per Cent: 33.6

Oil Permeability with
Initial Water Present, Md: 2372

<u>Liquid Saturation Per Cent Pore Space</u>	<u>Gas-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Gas*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
100	0.000	0.000	0.000
96.9	0.079	0.035	0.438
94.3	0.144	0.047	0.325
92.4	0.216	0.057	0.266
87.2	0.558	0.087	0.155
84.3	0.924	0.105	0.114
81.2	1.62	0.129	0.080
78.5	2.62	0.152	0.058
76.0	4.17	0.182	0.044
73.3	6.56	0.219	0.033
66.5	21.2	0.286	0.014
65.0	29.2	0.318	0.011
63.1	39.1	0.336	0.0086

* Relative to Oil Permeability

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GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 5B

Initial Water Saturation
Per Cent Pore Space: 26.4

Air Permeability, Md: 1004

Oil Permeability with
Initial Water Present, Md: 821

Porosity, Per Cent: 43.4

<u>Liquid Saturation Per Cent Pore Space</u>	<u>Gas-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Gas*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
100	0.000	0.000	1.000
94.6	0.025	0.014	0.580
91.9	0.050	0.024	0.431
88.6	0.121	0.035	0.291
86.7	0.217	0.051	0.233
82.6	0.619	0.094	0.153
79.5	1.37	0.148	0.108
77.1	2.41	0.184	0.076
74.5	4.42	0.223	0.051
71.7	8.84	0.266	0.030
69.6	20.3	0.305	0.016
66.2	42.7	0.339	0.0080

* Relative to Oil Permeability

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GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 8B

Initial Water Saturation
Per Cent Pore Space: 20.6

Air Permeability, Md: 13846

Oil Permeability with
Initial Water Present, Md: 8273

Porosity, Per Cent: 40.1

<u>Liquid Saturation Per Cent Pore Space</u>	<u>Gas-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Gas*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
100	0.000	0.000	1.000
96.2	0.066	0.026	0.402
93.0	0.142	0.039	0.272
90.7	0.264	0.053	0.200
84.1	0.881	0.089	0.101
81.6	1.54	0.109	0.071
79.4	2.51	0.123	0.049
77.7	3.77	0.139	0.037
75.2	6.53	0.156	0.024
70.9	19.0	0.171	0.0090
68.4	43.4	0.182	0.0042

* Relative to Oil Permeability

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GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 9B

Initial Water Saturation
Per Cent Pore Space: 25.0

Air Permeability, Md: 7785

Oil Permeability with
Initial Water Present, Md: 4378

Porosity, Per Cent: 38.7

<u>Liquid Saturation Per Cent Pore Space</u>	<u>Gas-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Gas*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
100	0.000	0.000	1.000
97.2	0.152	0.054	0.354
96.0	0.215	0.064	0.298
94.9	0.274	0.072	0.263
91.9	0.548	0.085	0.156
87.8	1.61	0.117	0.073
86.2	2.37	0.131	0.055
84.0	3.92	0.150	0.038
80.7	10.3	0.174	0.017
79.3	24.5	0.202	0.0082
76.5	52.7	0.232	0.0044

* Relative to Oil Permeability

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GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 11B

Initial Water Saturation

Air Permeability, Md: 13749

Per Cent Pore Space: 21.8

Oil Permeability with
Initial Water Present, Md: 12740

Porosity, Per Cent: 41.2

<u>Liquid Saturation Per Cent Pore Space</u>	<u>Gas-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Gas*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
100	0.000	0.000	1.000
96.1	0.148	0.031	0.207
93.6	0.243	0.040	0.162
92.5	0.302	0.043	0.142
90.3	0.457	0.048	0.105
87.9	0.746	0.053	0.071
85.3	1.31	0.059	0.045
83.0	2.08	0.062	0.030
79.9	4.77	0.065	0.014
77.4	10.7	0.068	0.0064
74.9	34.1	0.072	0.0021

* Relative to Oil Permeability

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GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 16B

Initial Water Saturation
Per Cent Pore Space: 40.0

Air Permeability, Md: 95

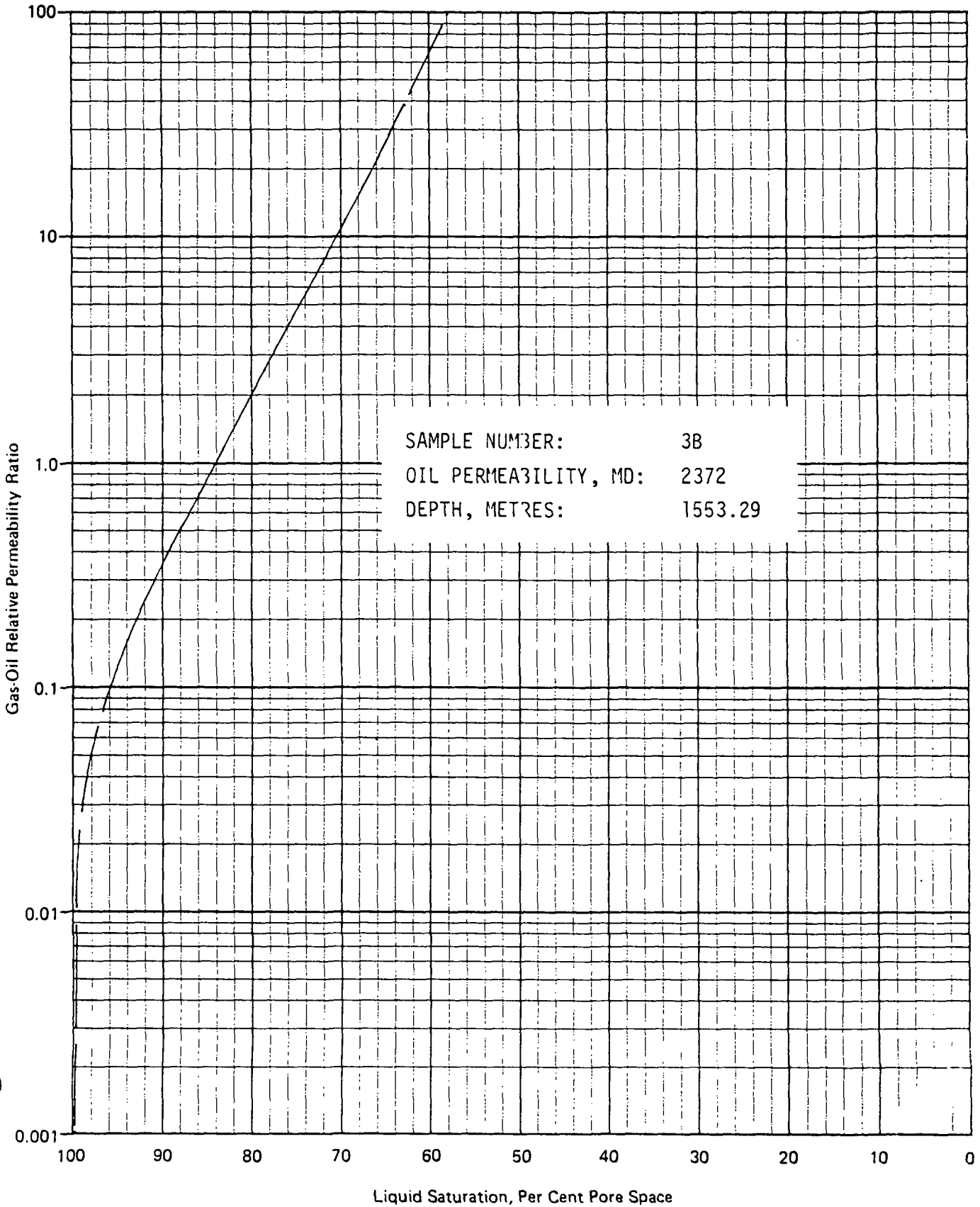
Oil Permeability with
Initial Water Present, Md: 46

Porosity, Per Cent: 26.1

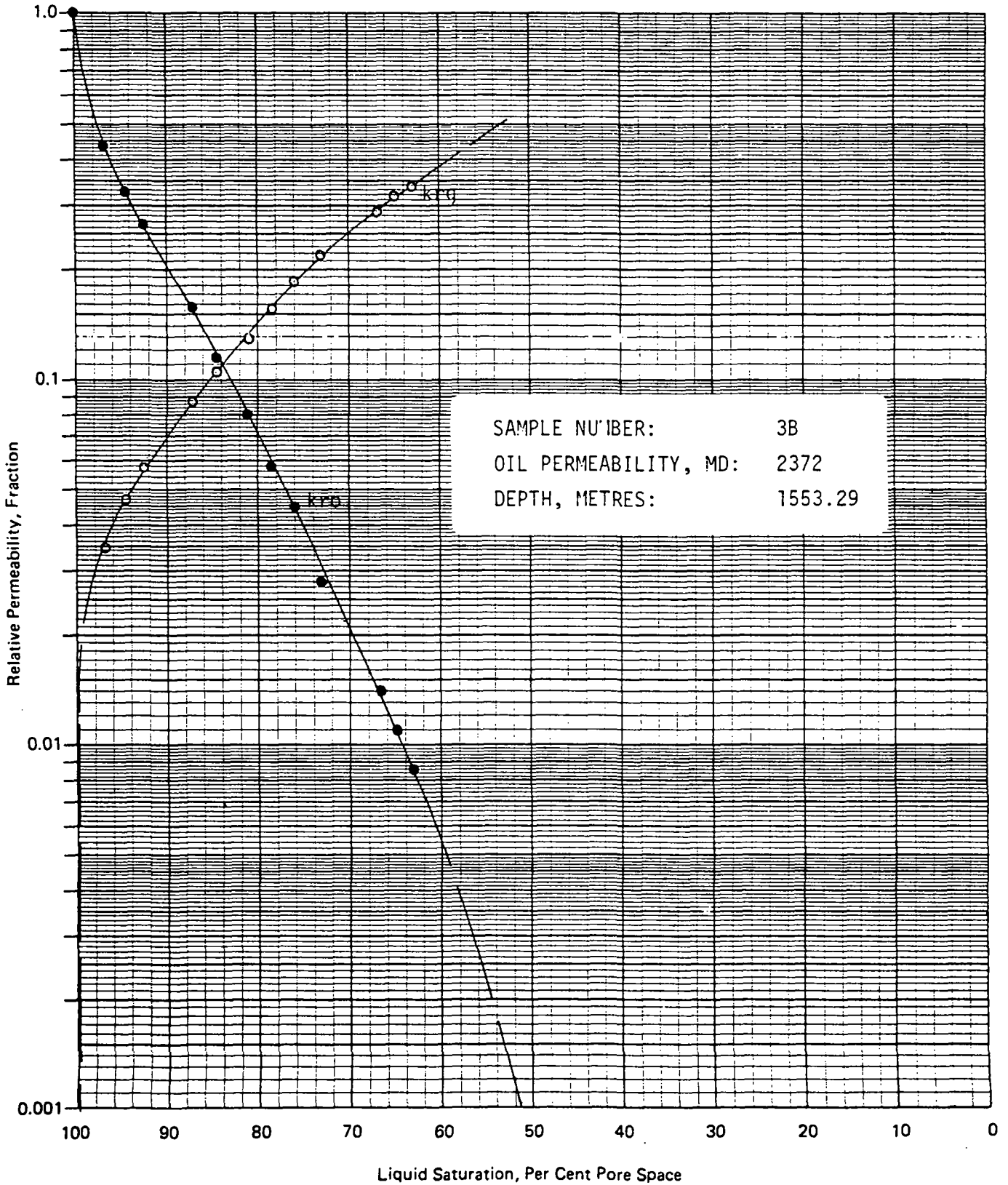
<u>Liquid Saturation Per Cent Pore Space</u>	<u>Gas-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Gas*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
100	0.000	0.000	1.000
94.3	0.071	0.030	0.425
93.2	0.140	0.052	0.369
92.4	0.212	0.073	0.343
91.0	0.352	0.102	0.289
89.6	0.615	0.129	0.209
87.1	1.56	0.201	0.129
85.7	2.55	0.243	0.095
84.4	4.05	0.293	0.072
82.8	7.03	0.362	0.051
81.0	13.4	0.442	0.033
76.8	51.7	0.627	0.012

* Relative to Oil Permeability

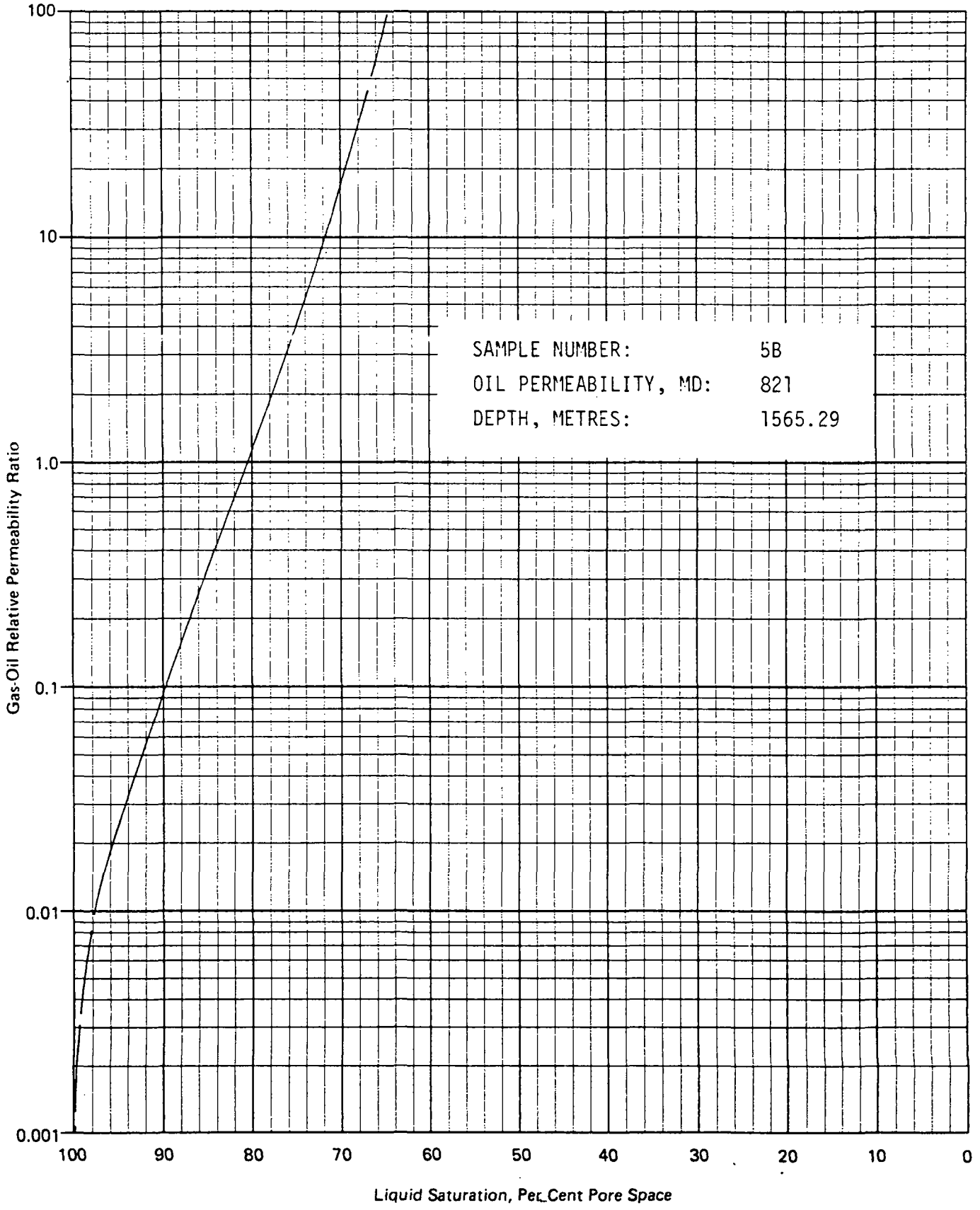
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



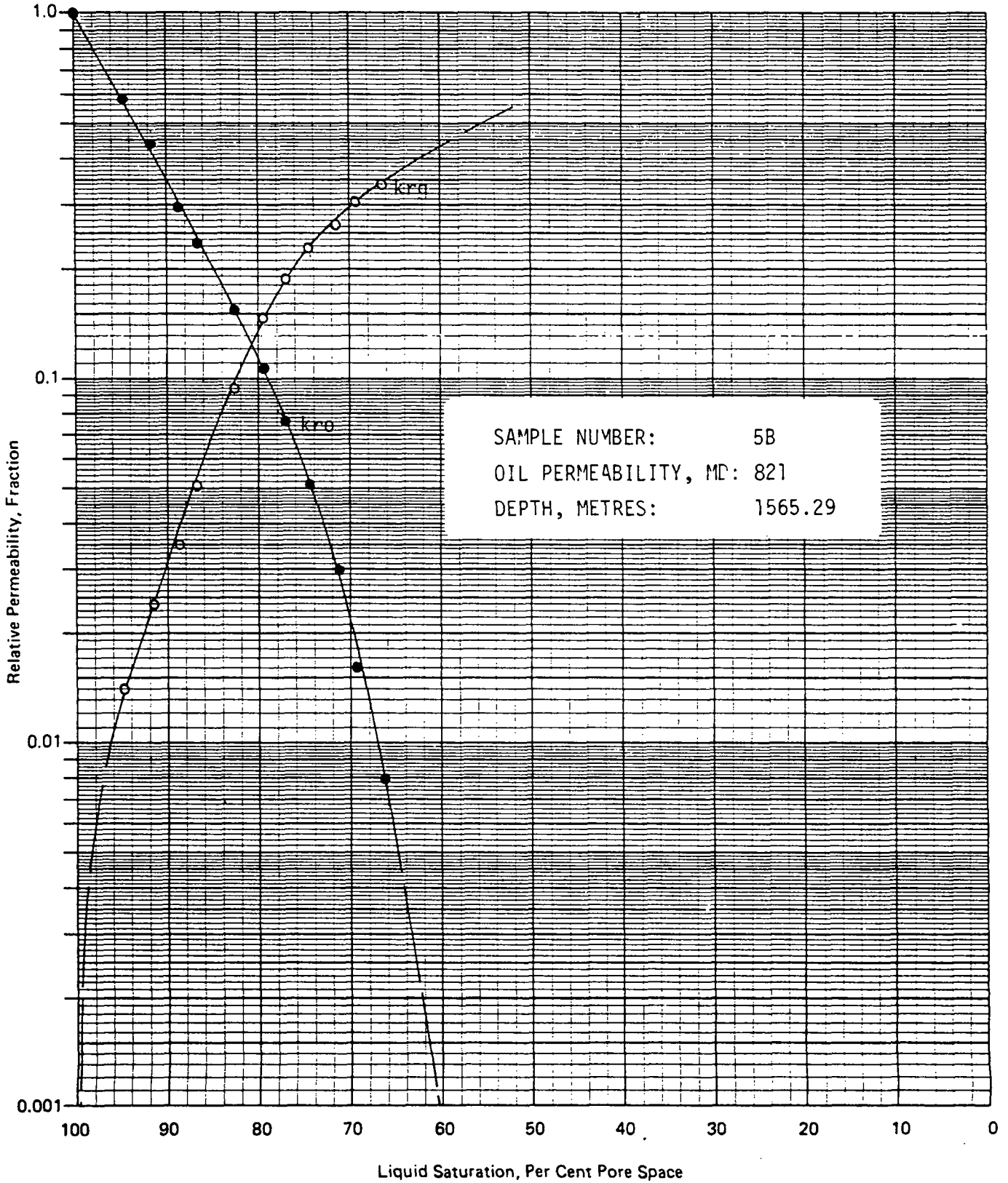
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 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



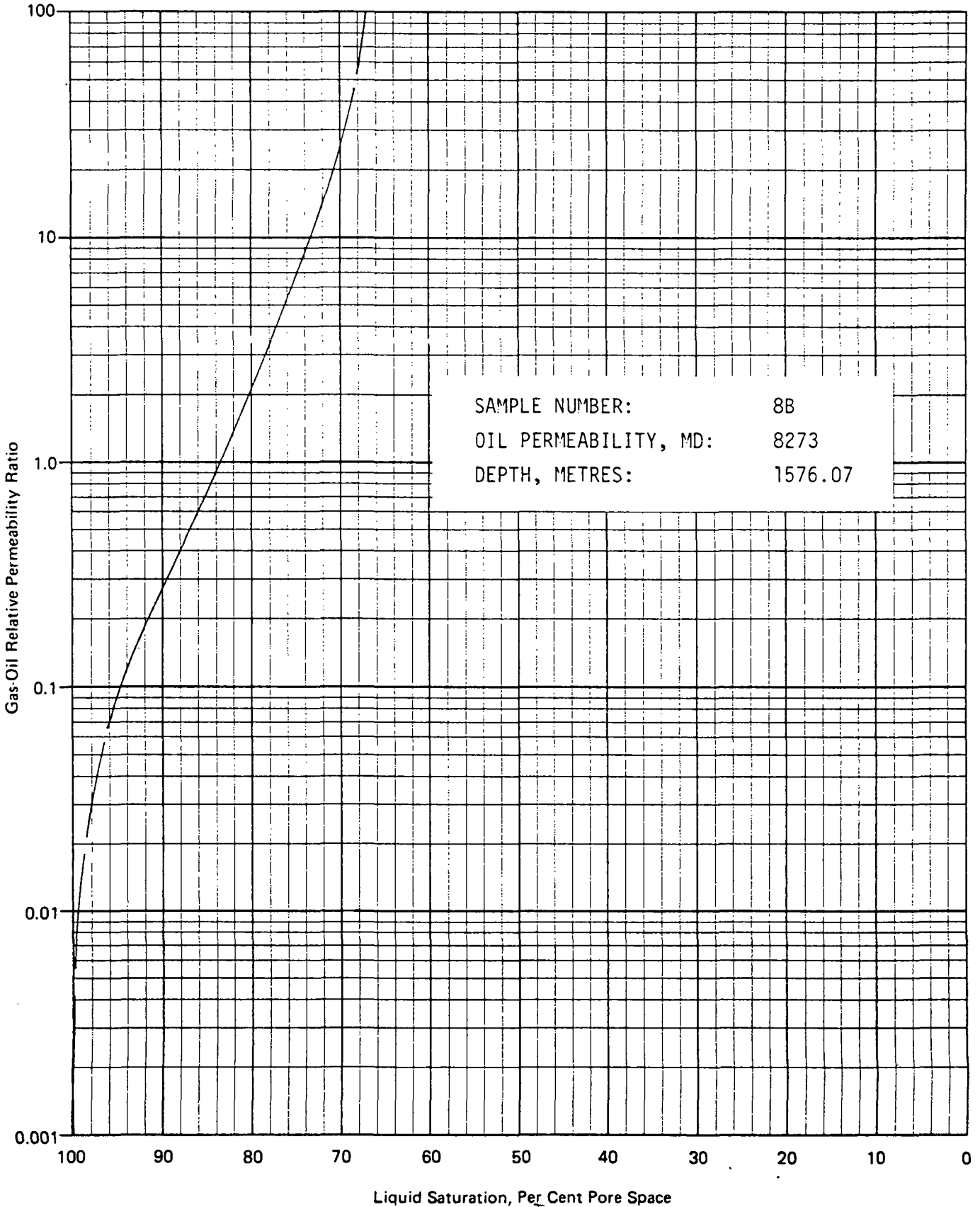
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



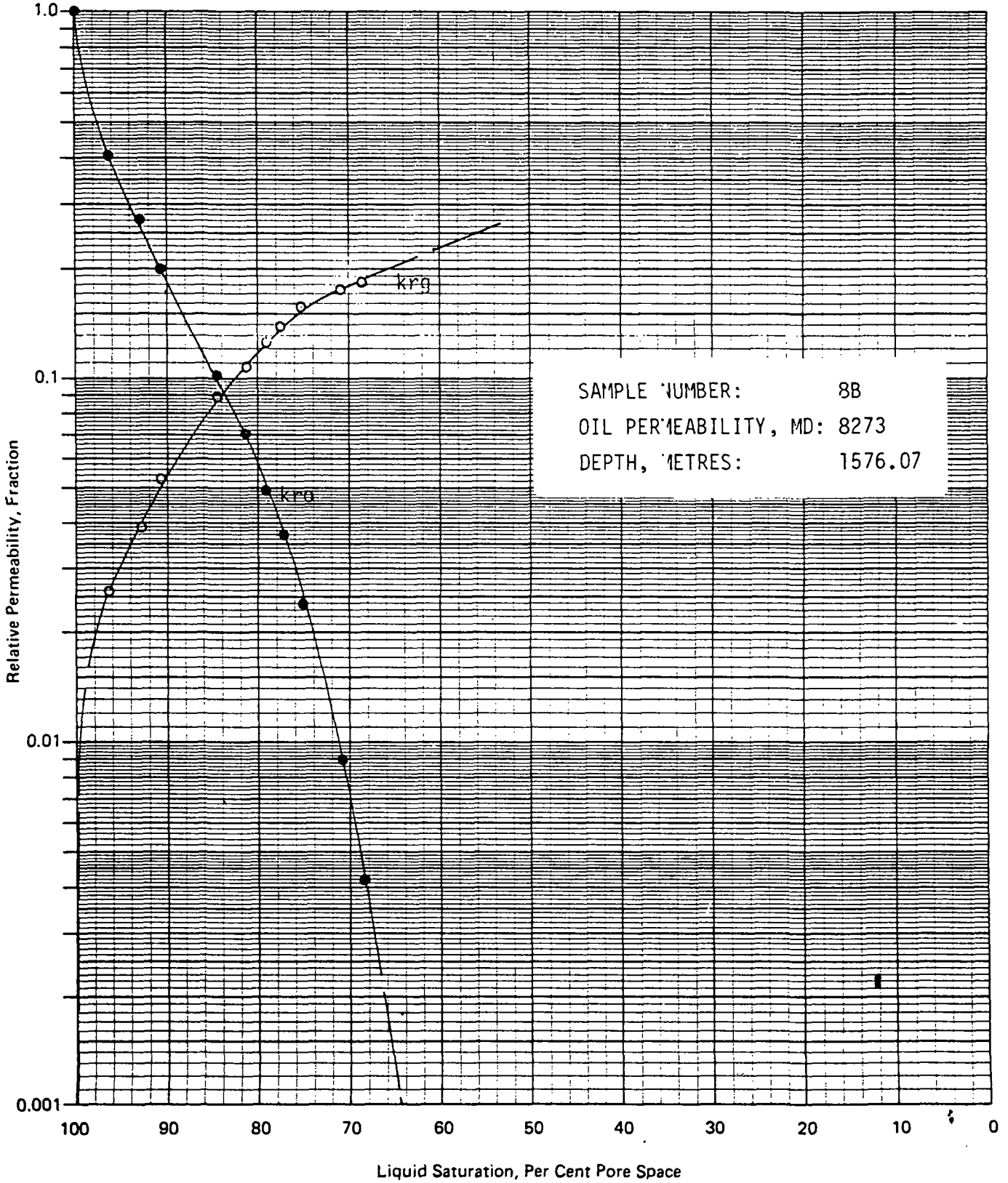
Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



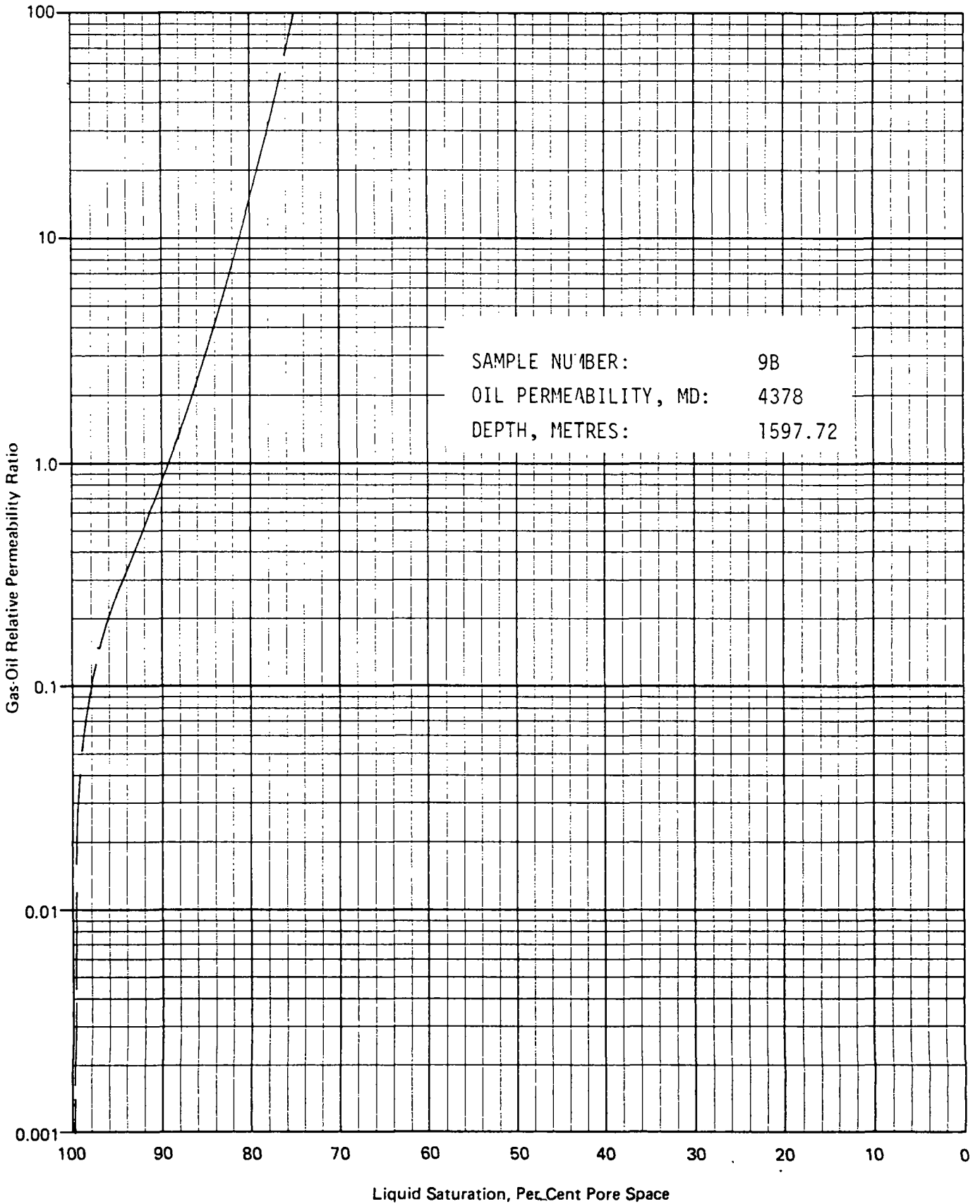
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



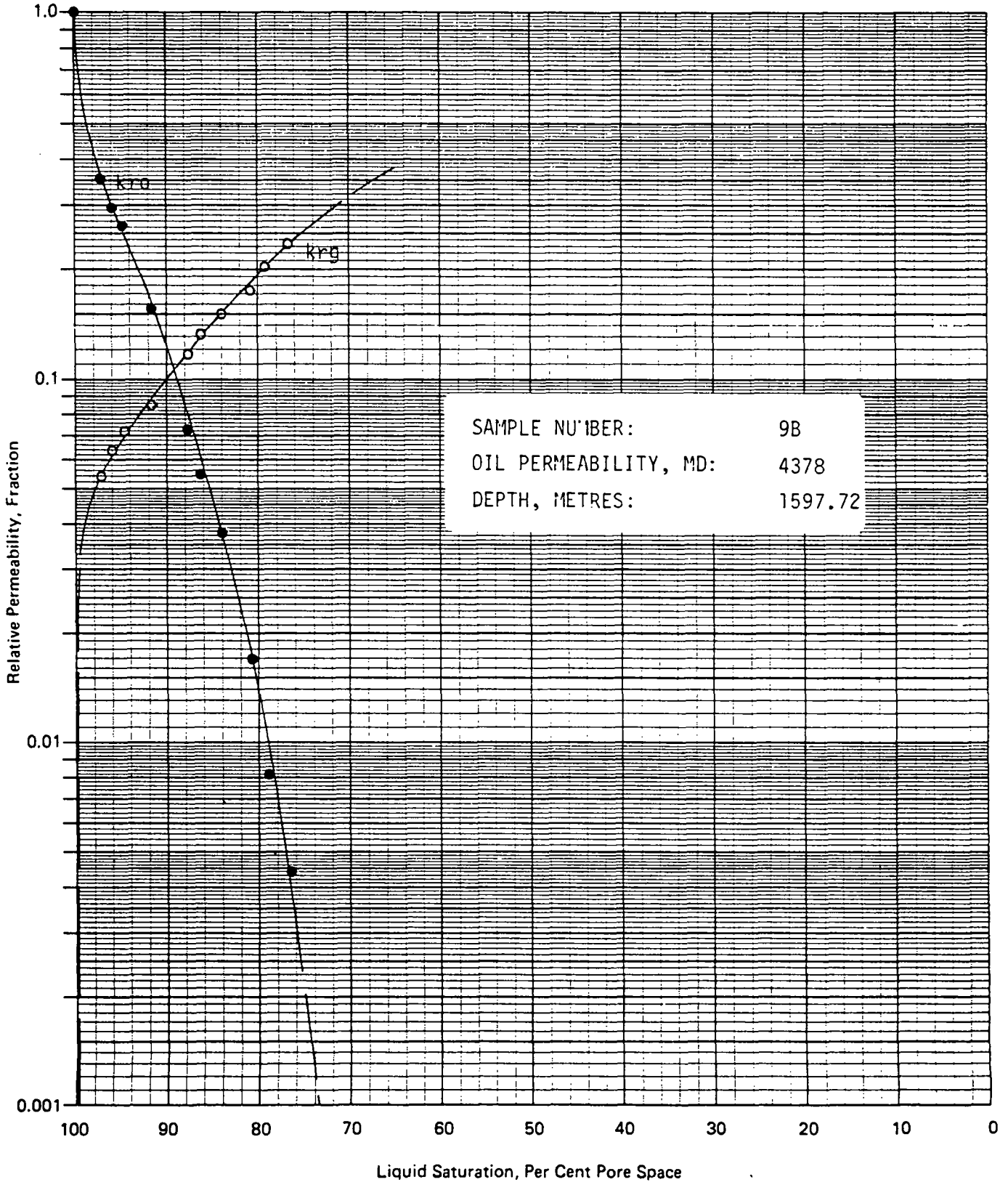
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



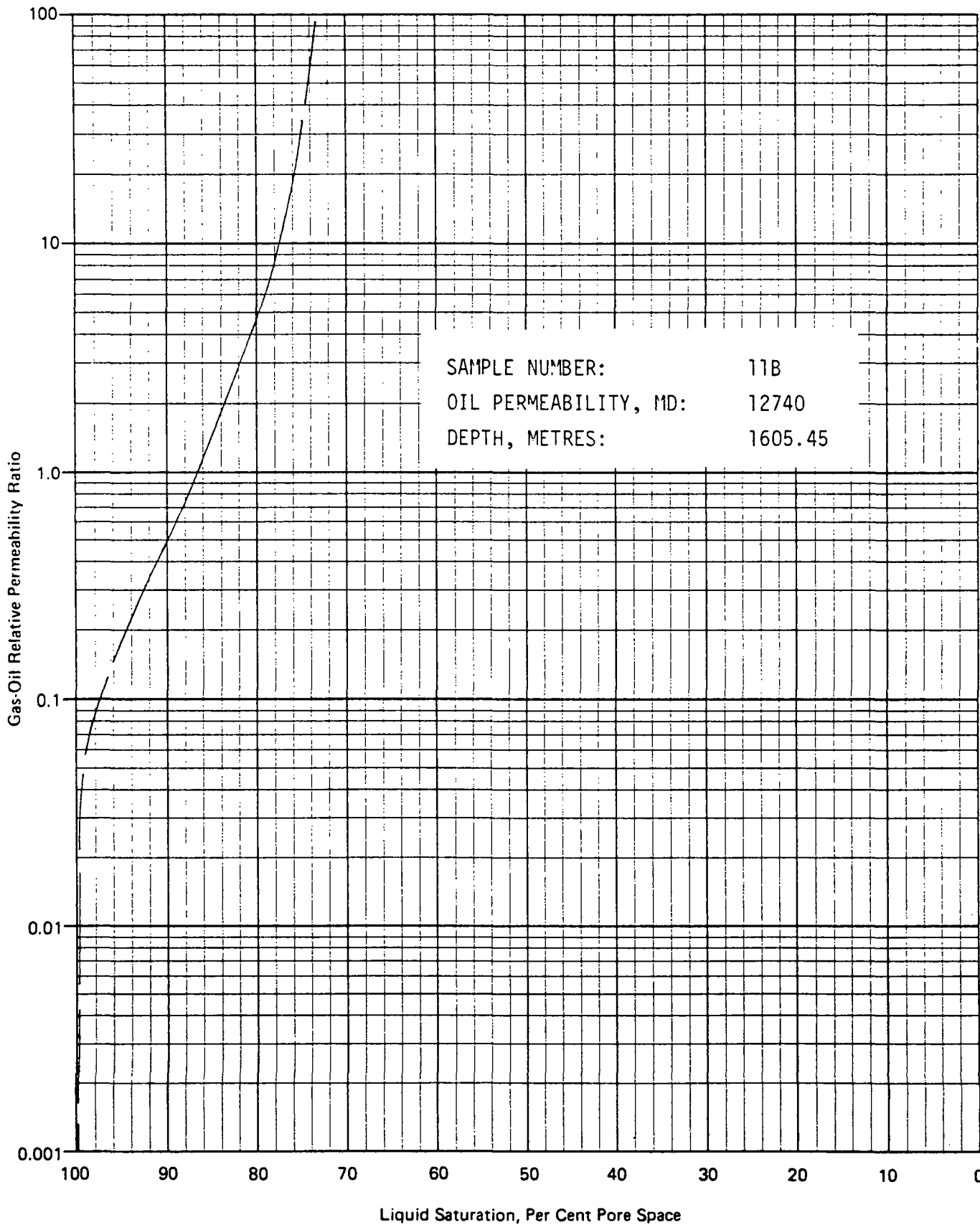
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY

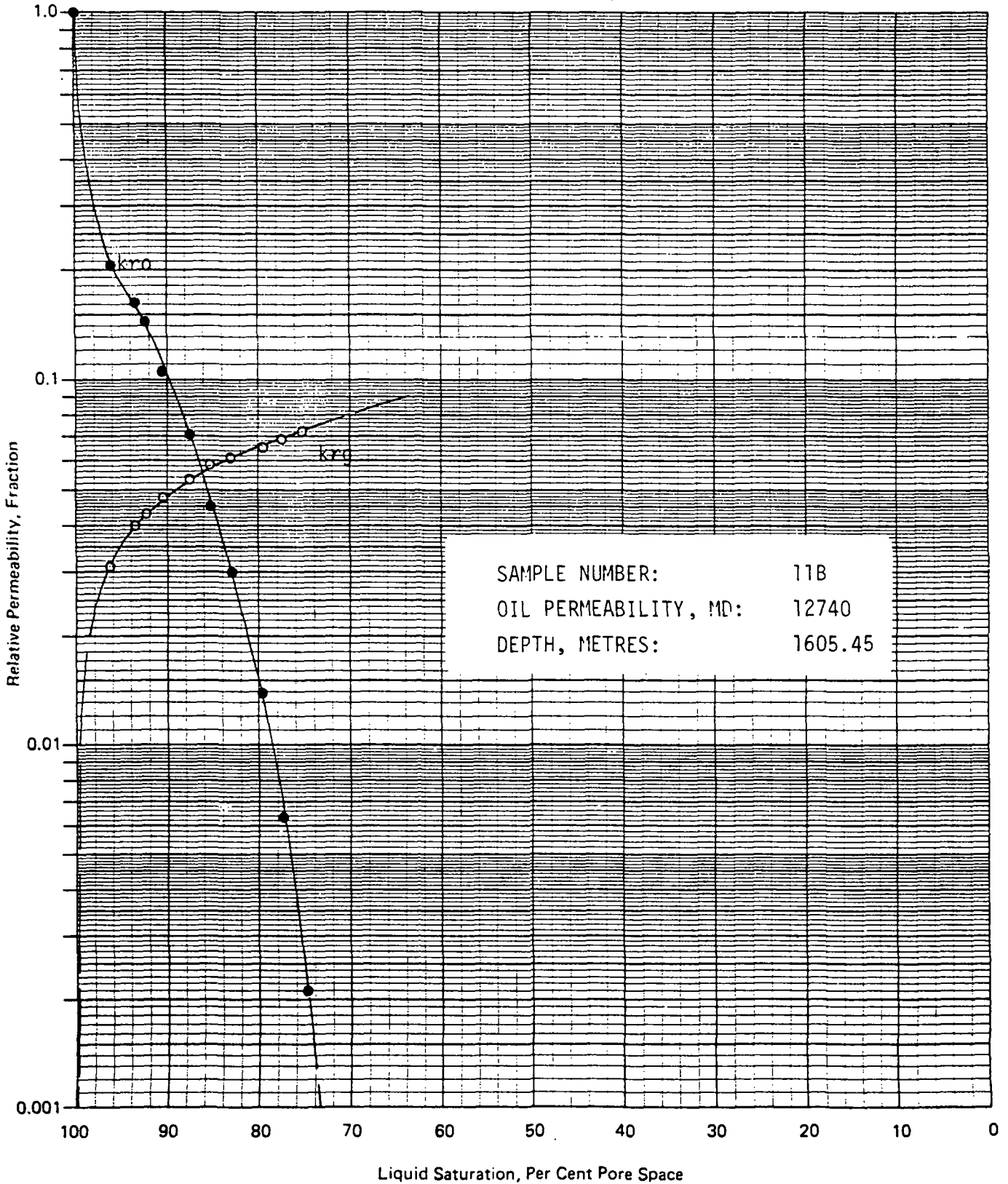


Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY

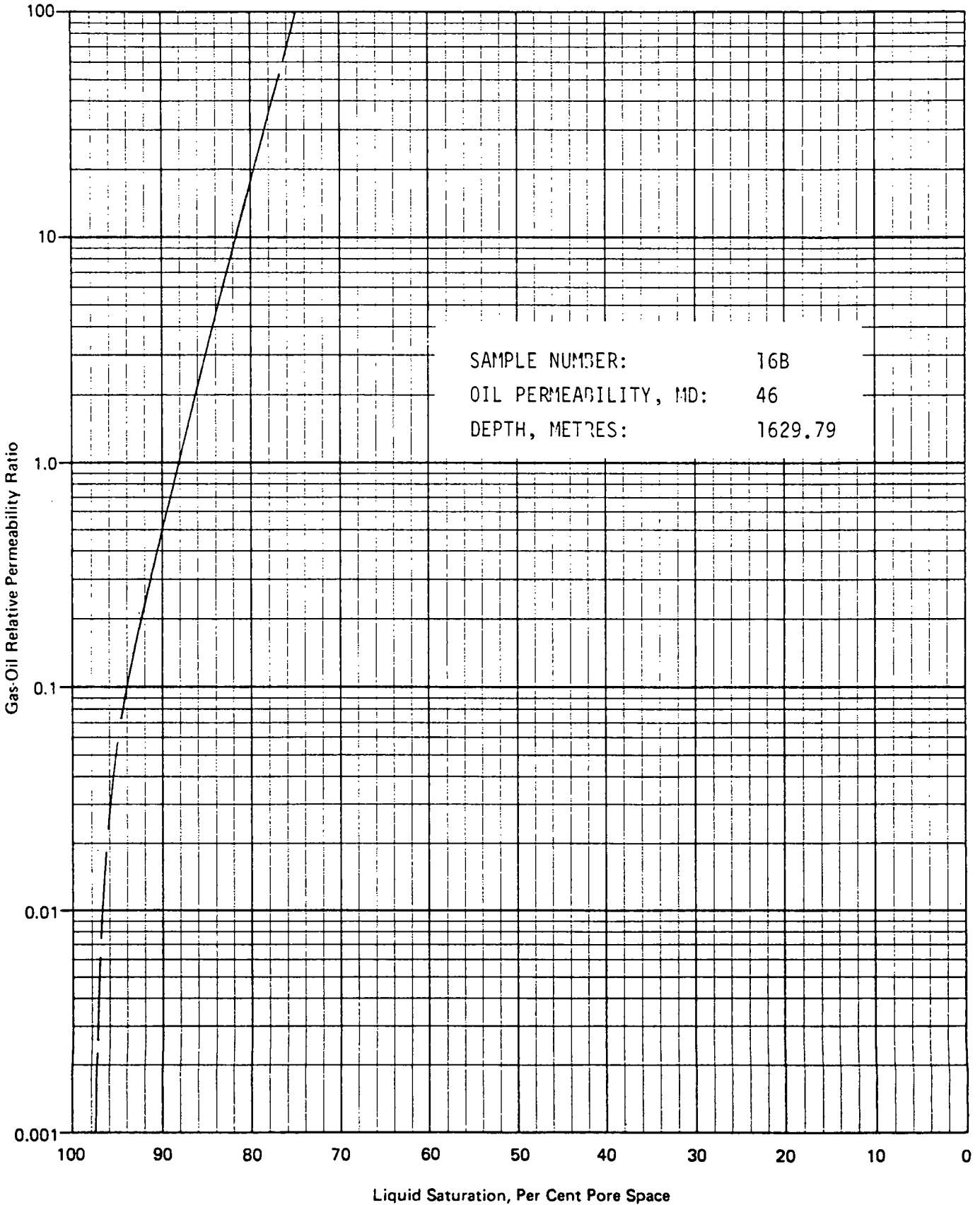


Gas-Oil Relative Permeability Ratio

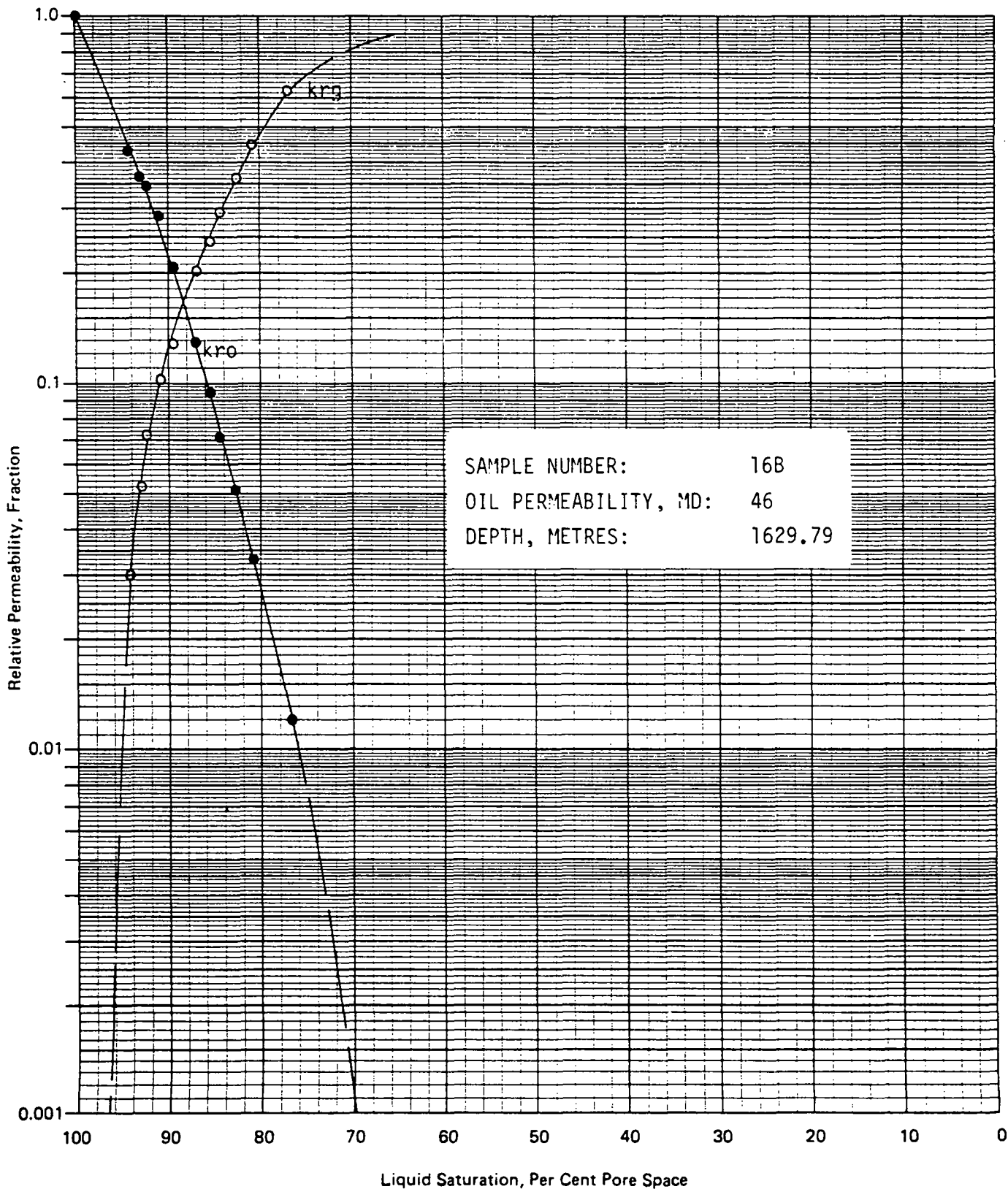
Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



SUMMARY OF WATERFLOOD TEST RESULTS

Sample Number	Air Permeability Millidarcys	Porosity Per Cent	Initial Conditions			Terminal Conditions			Oil Recovered	
			Water Saturation Per Cent	Oil Permeability Millidarcys	Oil Saturation Per Cent	Water Permeability Millidarcys	Per Cent Pore Space	Per Cent Pore Space	Oil in Place	
5B	1004	43.4	26.4	821	29.7	244	43.9	59.7		
7B	4167	36.5	25.2	3292	40.5	984	34.3	45.9		
9B	7785	38.7	25.0	4378	32.3	2671	42.7	56.9		
10B	7238	39.2	32.3	6556	25.2	2111	42.5	63.1		
17B	3.0	17.3	22.6	0.04	-	-	-	-		
18B	1.3	28.1	22.0	0.01	-	-	-	-		
19B	3.2	18.4	25.1	0.01	-	-	-	-		

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WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 5B

Initial Water Saturation
Per Cent Pore Space: 26.4

Air Permeability, Md: 1004

Oil Permeability with
Initial Water Present, Md: 821

Porosity, Per Cent: 43.4

<u>Water Saturation Per Cent Pore Space</u>	<u>Water-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Water*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
26.4	0.000	0.000	1.000
40.5	0.089	0.036	0.402
43.5	0.130	0.045	0.345
47.5	0.232	0.056	0.240
52.3	0.528	0.078	0.148
55.6	1.13	0.097	0.086
58.6	2.64	0.117	0.044
61.0	5.74	0.147	0.026
63.6	14.4	0.177	0.012
66.6	48.5	0.227	0.0047
67.7	81.7	0.239	0.0029
68.2	111	0.250	0.0023
70.3	-	0.297	0.0000

* Relative to Oil Permeability

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WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 7B

Initial Water Saturation
Per Cent Pore Space: 25.2

Air Permeability, Md: 4167

Oil Permeability with
Initial Water Present, Md: 3292

Porosity, Per Cent: 36.5

<u>Water Saturation Per Cent Pore Space</u>	<u>Water-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Water*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
25.2	0.000	0.000	1.000
36.1	0.127	0.029	0.230
39.7	0.250	0.039	0.156
43.5	0.560	0.053	0.095
46.0	1.15	0.077	0.067
49.6	2.66	0.112	0.042
52.7	7.75	0.155	0.020
53.9	14.8	0.190	0.013
55.1	27.2	0.223	0.0082
56.2	44.6	0.263	0.0059
57.5	72.9	0.277	0.0038
58.1	141.	0.297	0.0021
59.5	-	0.299	0.0000

* Relative to Oil Permeability

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WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 9B

Initial Water Saturation
Per Cent Pore Space: 25.0

Air Permeability, Md: 7785

Oil Permeability with
Initial Water Present, Md: 4378

Porosity, Per Cent: 38.7

<u>Water Saturation Per Cent Pore Space</u>	<u>Water-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Water*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
25.0	0.000	0.000	1.000
38.3	0.325	0.129	0.398
41.8	0.572	0.183	0.321
44.6	0.922	0.233	0.253
47.6	1.61	0.295	0.183
50.5	2.90	0.372	0.128
53.3	5.07	0.445	0.087
57.3	12.8	0.510	0.039
59.8	22.5	0.558	0.025
62.9	51.8	0.584	0.011
65.5	144	0.599	0.0042
67.7	-	0.610	0.0000

* Relative to Oil Permeability

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WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 10B

Initial Water Saturation
Per Cent Pore Space: 32.3

Air Permeability, Md: 7238

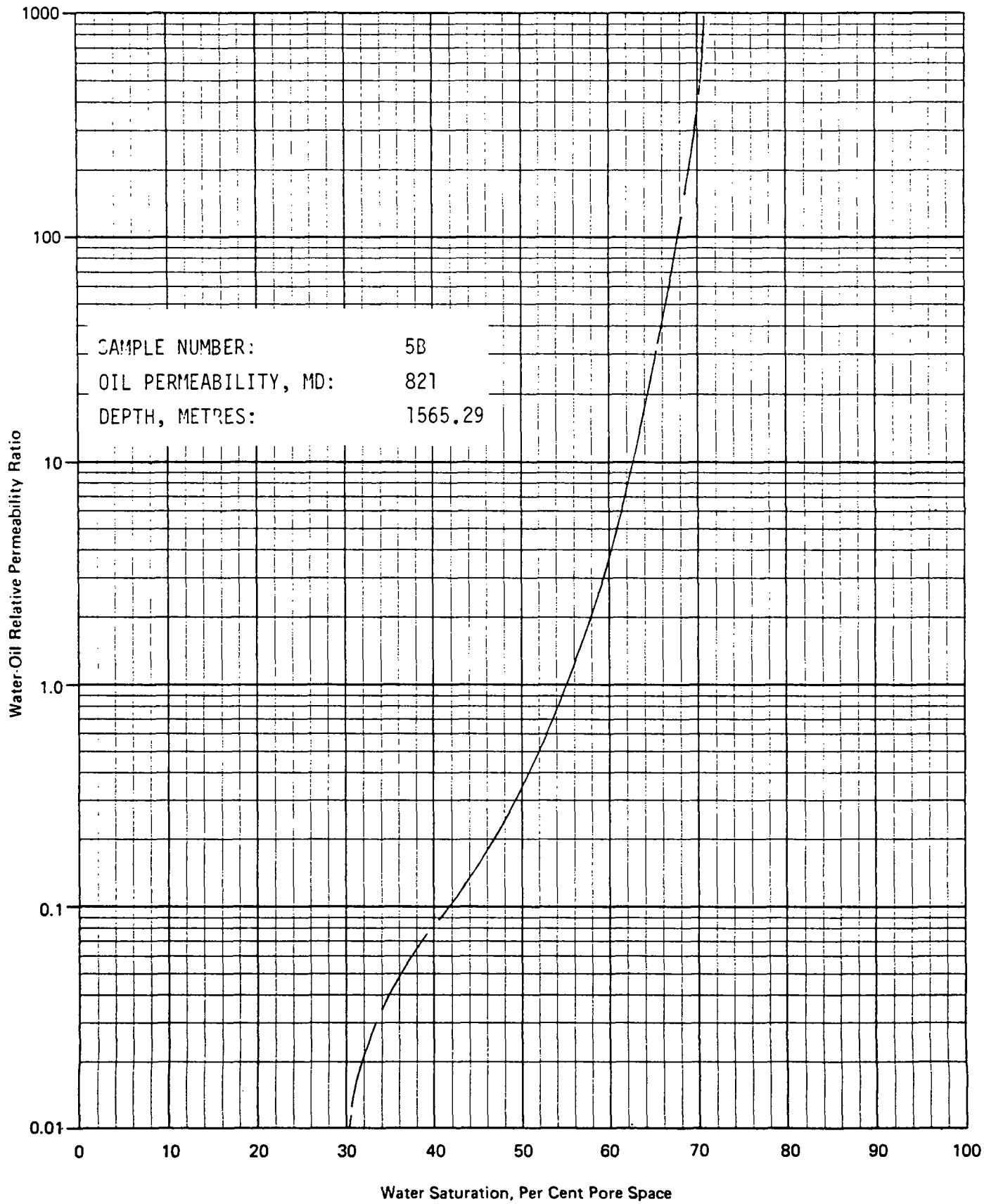
Oil Permeability with
Initial Water Present, Md: 6556

Porosity, Per Cent: 39.2

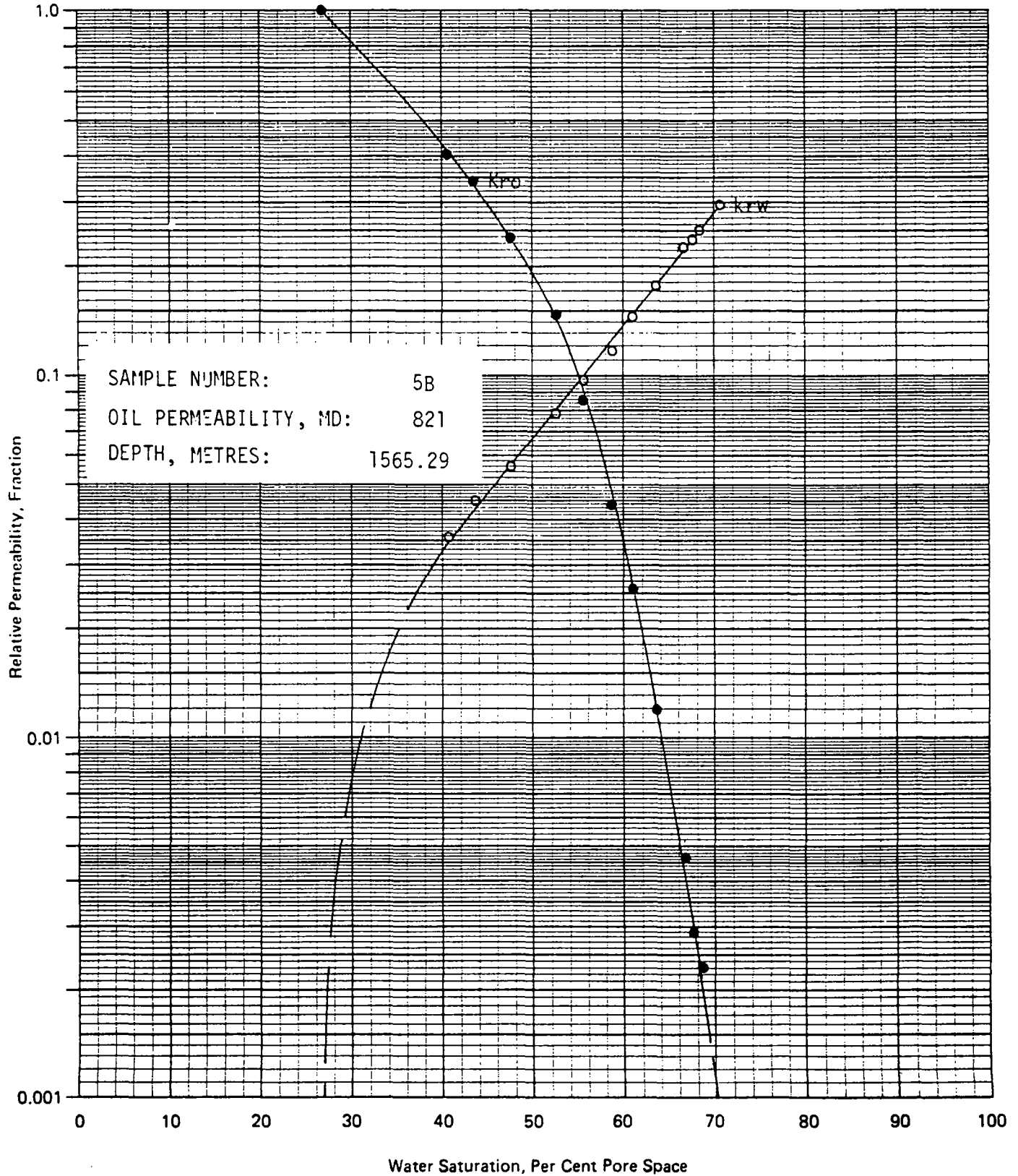
<u>Water Saturation Per Cent Pore Space</u>	<u>Water-Oil Relative Permeability Ratio</u>	<u>Relative Permeability To Water*, Fraction</u>	<u>Relative Permeability To Oil*, Fraction</u>
32.3	0.000	0.000	1.000
53.1	0.252	0.039	0.154
56.0	0.425	0.048	0.112
58.7	0.769	0.059	0.076
61.4	1.48	0.077	0.052
65.0	4.07	0.116	0.028
67.1	8.28	0.149	0.018
69.4	20.3	0.192	0.0094
71.4	50.9	0.245	0.0048
72.4	96.9	0.277	0.0029
73.2	171	0.301	0.0018
74.8	-	0.322	0.0000

* Relative to Oil Permeability

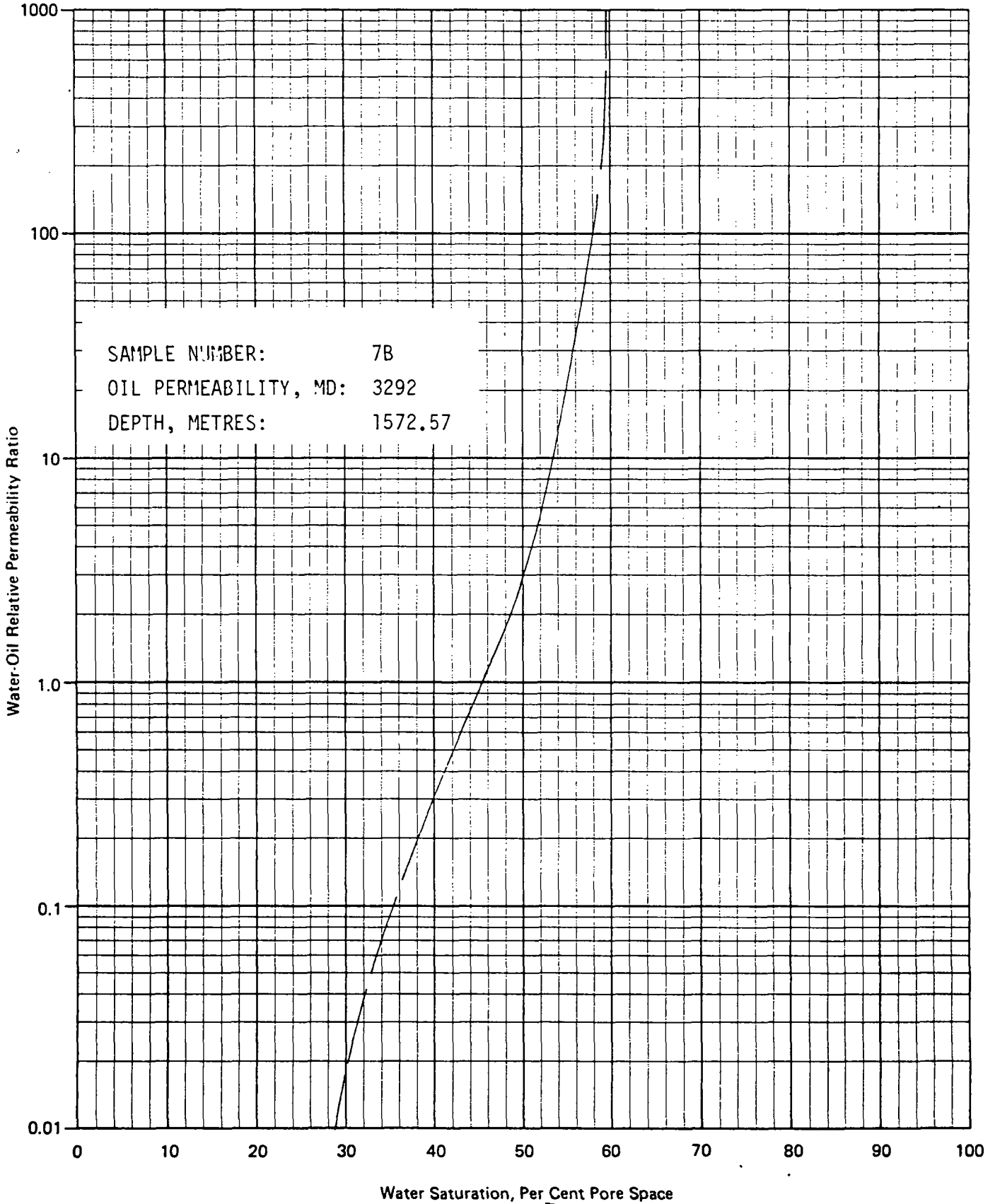
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



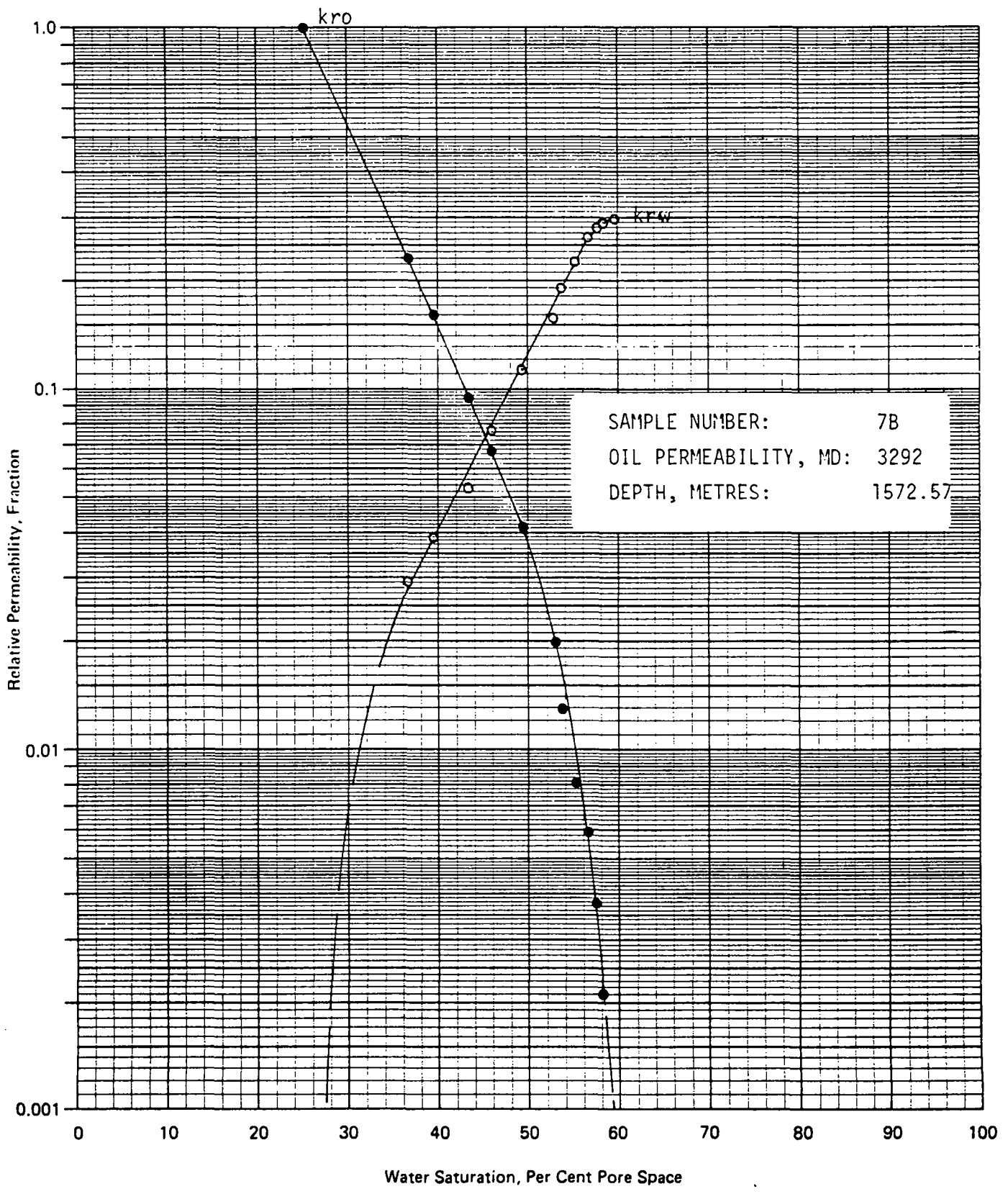
Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



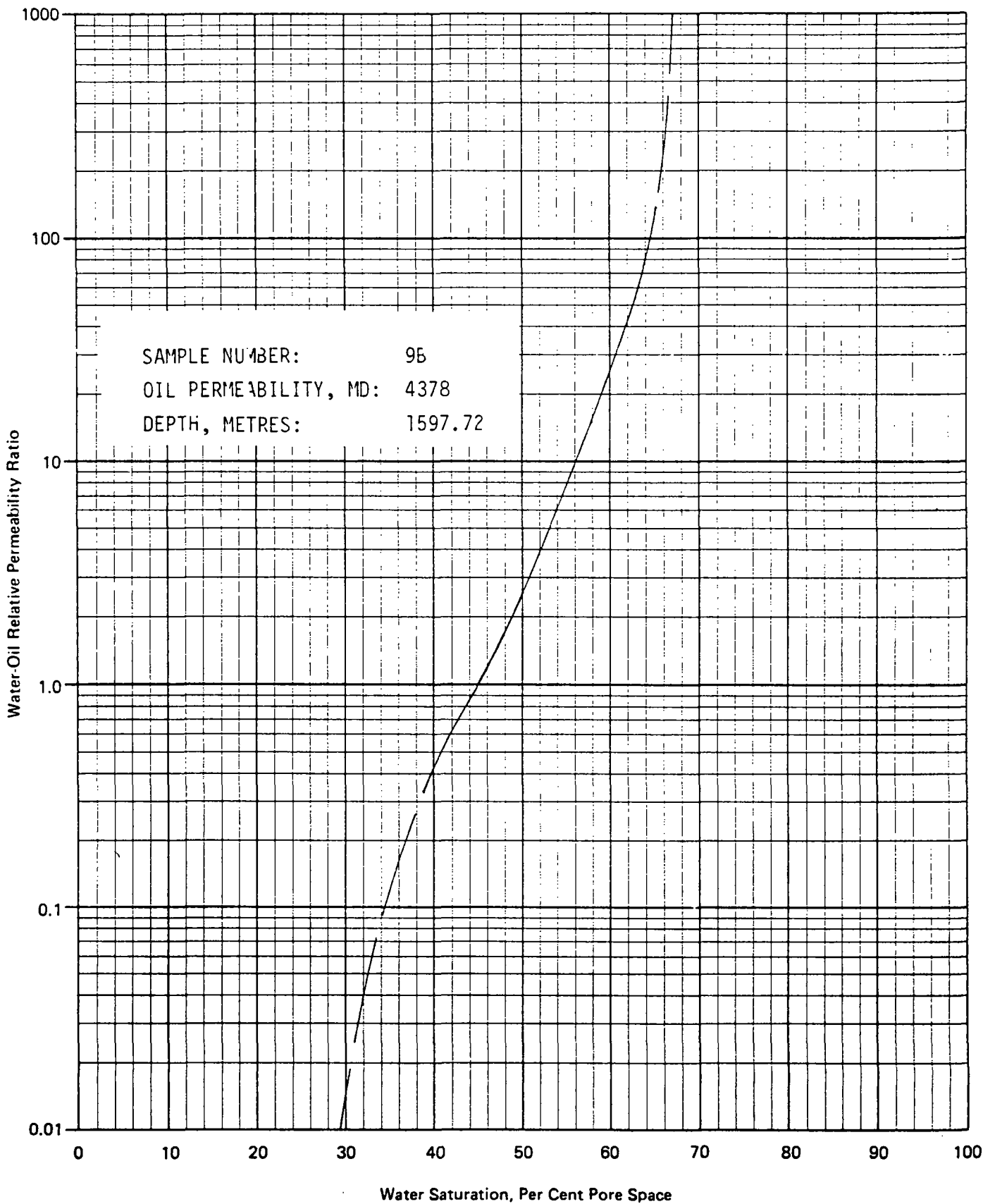
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



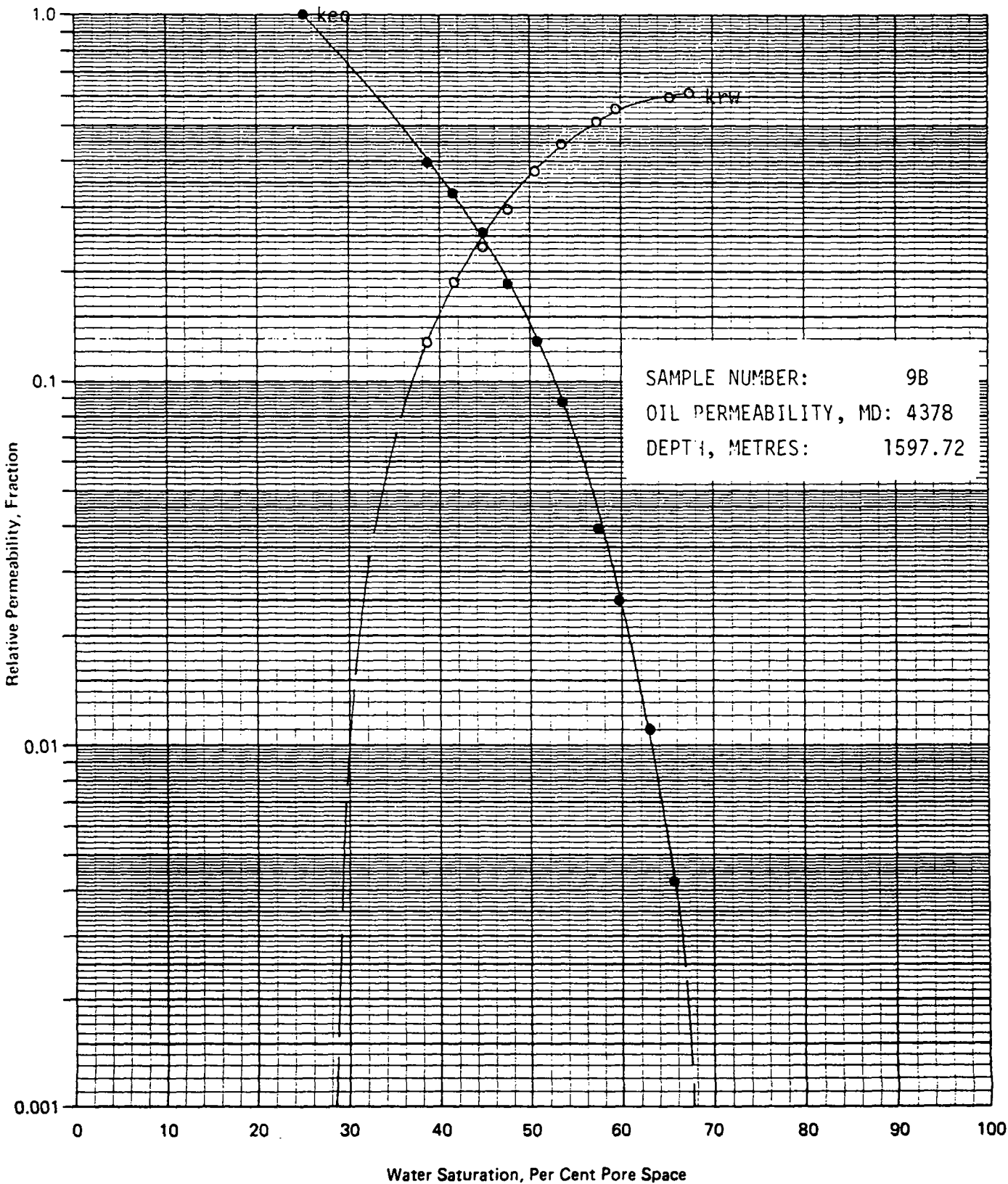
Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



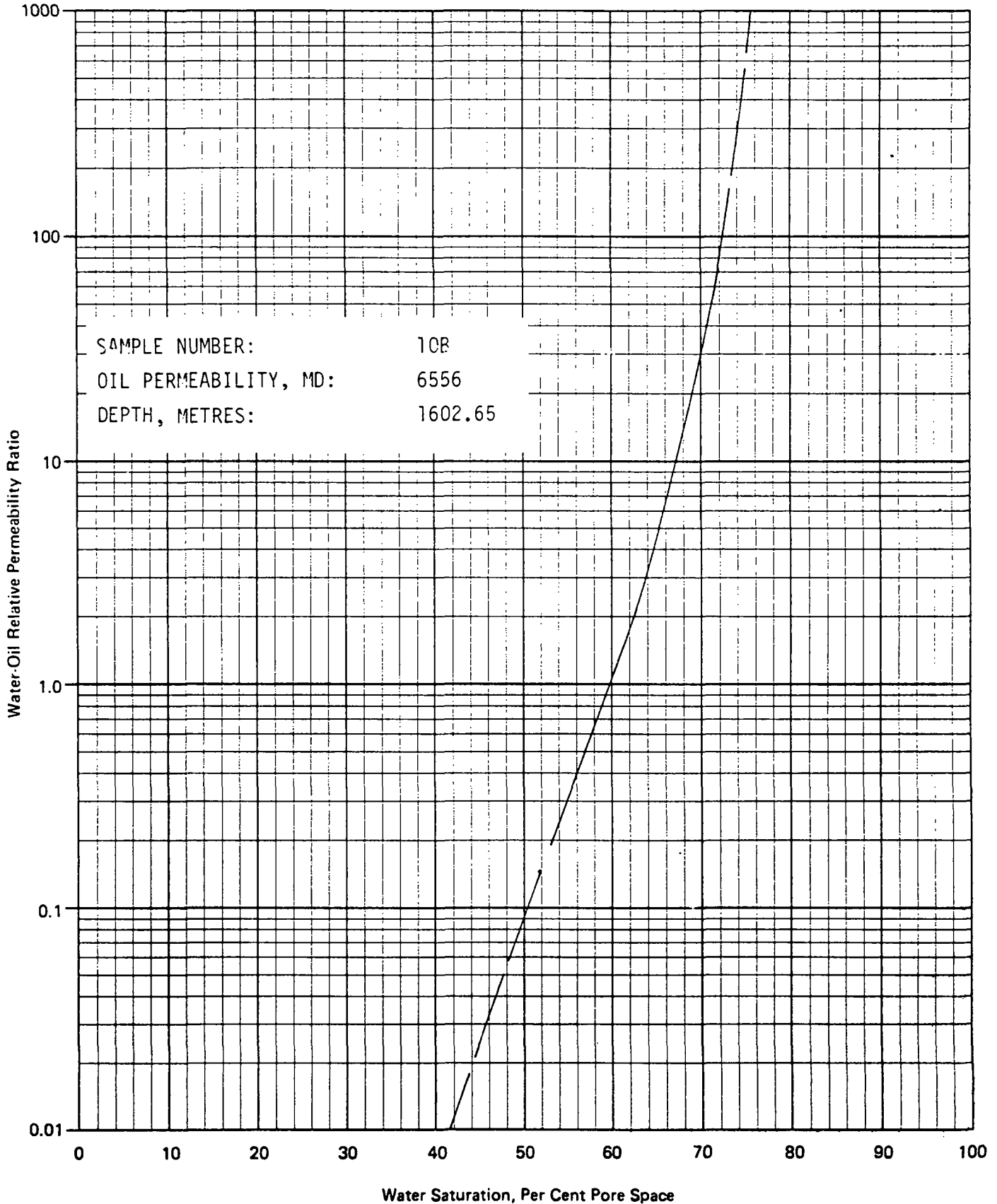
Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY



Company A/S NORSKE SHELL EXP & PROD Formation _____
Well 31/2-5 Country NORTH SEA
Field _____ NORWAY



Water-Oil Relative Permeability Ratio

Company A/S NORSKE SHELL EXP & PROD Formation _____
 Well 31/2-5 Country NORTH SEA
 Field _____ NORWAY

