# SPECIAL CORE ANALYSIS STUDY

FOR

A/S NORSKE SHELL EXPL. AND PRO.

WELL: 31/2-2, 31/2-3

CORE LABORATORIES UK LTD.

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Norway

September 1981

Attention: Mr Jolly

Subject: Special Core Analysis
Wells: 31/2-2, 31/2-3
File: UKSCAL 80087

Gentlemen,

In a telex dated 3rd November 1980, ref Foro 31109, from Mr Jolly of Norske Shell Exploration and Production, Core Laboratories were requested to perform a series of special core analysis measurements on samples from the subject wells. The results of these measurements are presented herein and serve to confirm previous preliminary data.

A total of nine full diameter samples from well 31/2-2 and six full diameter samples from well 31/2-3 were received for use in this study.

The samples were drilled using kerosene as the bit lubricant, due to the friable nature of the core a number of samples had to be mounted in thin metal sleeves. This prevented Amott wettability and electrical resistivity measurements being performed.

Cont'd.....

The samples were cleaned in cool solvents, dried in an humidity controlled oven and had air permeability and helium injection porosity measured. All samples are described with respect to depth and lithology on pages 1 and 2 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

Jon Roberts
Laboratory Manager

Water-Oil Relative Permeability Data (Page 31)

Three samples from well 31/2-2 and four samples from well 31/2-3 were scheduled to undergo this analysis.

The samples that had previously undergone gas-oil relative permeability measurements were restored under vacuum with the refined mineral oil, mounted in an hydraulic core holder and flushed with this oil to ensure the removal of any trapped gas. Effective permeability to the oil was then remeasured.

Sample number 1B from well 31/2-2 and samples numbered 10B, 11B and 15B from well 31/2-3 collapsed prior to water-oil relative permeability measurements.

The remaining three samples were flooded with simulated formation brine and incremental production of oil and water recorded against time. The floods were terminated at water-oil relative permeability ratios in excess of 100, and effective permeability to the brine was then measured.

Water-oil relative permeability data was calculated using a digital computer and the floods are summarised on page 31 and are presented in tabular form on pages 32 through 34 and in graphical form on pages 35 through 40.

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COMPANY: NORSKE SHELL EXPL AND PRO. FORMATION:

WELL: 31/2-3 COUNTRY: NORWAY

FIELD:

## IDENTIFICATION AND DESCRIPTION OF SAMPLES

| Sample Number | Depth Metres | Lithological Description |
|---|---|---|
| 10A | 1502.61 | SS, lt gy, m-cgr, pcmt, Fri, abd mic, arg mat, hzt fract. |
| 10B | 1502.66 | SS, lt gry, m-cgr, v.p. cmt, v fri, abd mic, arg mat, sample fractured |
| 11A | 1554.24 | As Above |
| 11B | 1554.29 | As Above |
| 12A | 1585.51 | SS, lt gry, m-vcgr, v.p. cmt, v fri, abd mic. |
| 12B | 1585.61 | As Above |
| 13A | 1602.98 | SS, gry, vf-fgr, mod cmt, fri, arg |
| 13B | 1603.03 | SS, gry, fgr, m-pcmt, fri, arg, mic, sample fractured |
| 14A | 1525.13 | As Above |
| 14B | 1525.18 | As Above |
| 15A | 1574.69 | As Above |
| 15B | 1574.74 | As Above. |

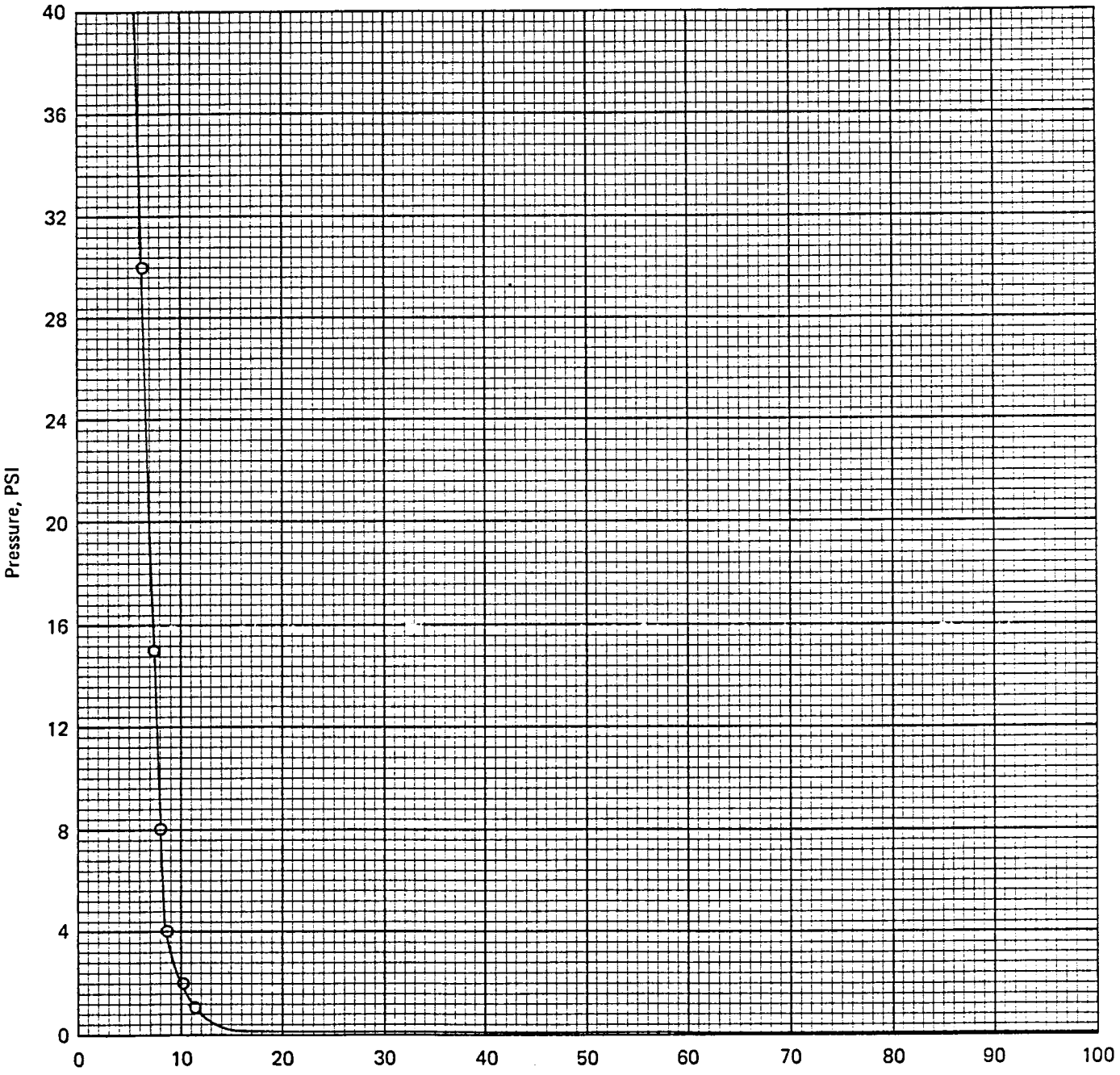
# AIR-BRINE CAPILLARY PRESSURE DATA

| Sample Number | Permeability Millidarcys | Porosity Per Cent | Brine Saturation, Per Cent Pore Space | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Pressure, PSI: 1 | 2 | 4 | 8 | 15 | 30 | 200 |
| | | | WELL: 31/2-2 | | | | | | |
| 7A | 18830 | 35.0 | 11.4 | 10.1 | 8.5 | 7.9 | 7.2 | 6.3 | 4.3 |
| 2A | 8440 | 30.8 | 79.5 | 66.9 | 44.1 | 25.3 | 21.1 | 15.8 | 10.6 |
| 6A | 6550 | 36.8 | 42.7 | 34.2 | 23.5 | 12.3 | 9.6 | 7.0 | 5.1 |
| 4A | 4460 | 40.3 | 71.6 | 50.1 | 30.6 | 17.6 | 13.5 | 11.4 | 6.8 |
| 1A | 1760 | 33.4 | 96.9 | 68.7 | 43.9 | 17.3 | 9.8 | 9.1 | 1.4 |
| 3A | 174 | 26.9 | 100 | 97.3 | 85.1 | 75.4 | 68.4 | 62.1 | 38.8 |
| | | | Well: 31/2-3 | | | | | | |
| 10A | 5150 | 36.6 | 58.7 | 31.0 | 24.0 | 19.7 | 18.1 | 17.3 | 17.2 |
| 12A | 4020 | 37.2 | 84.2 | 59.3 | 40.4 | 32.9 | 23.6 | 13.3 | 6.6 |
| 13A | 136 | 30.5 | 84.8 | 82.7 | 79.8 | 76.7 | 71.8 | 66.2 | 37.4 |

Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-2 Country NORWAY
Field

Sample Number: 7A

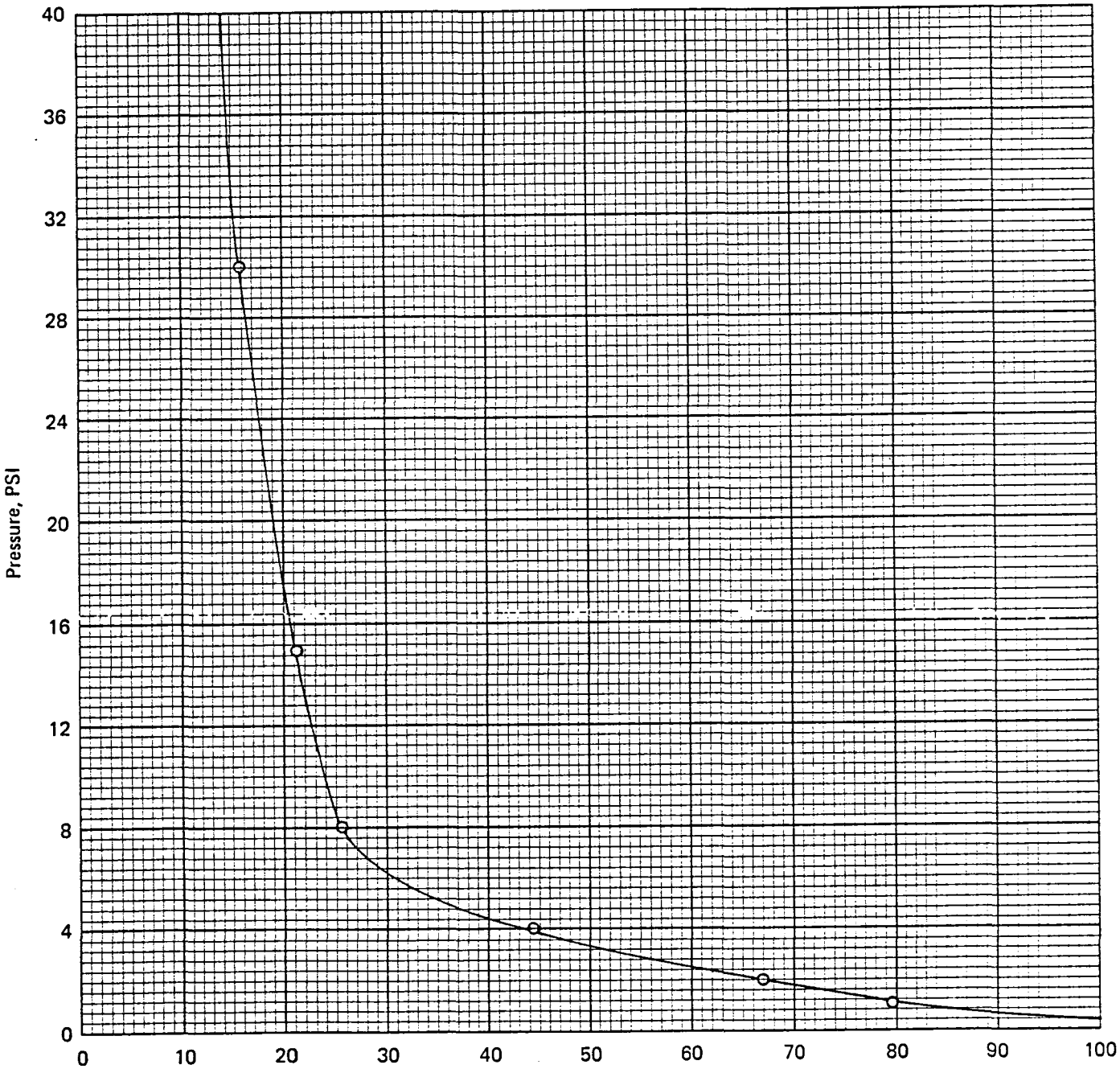
Air Permeability, MD: 18,830



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-2 Country NORWAY
Field

Sample Number: 2A

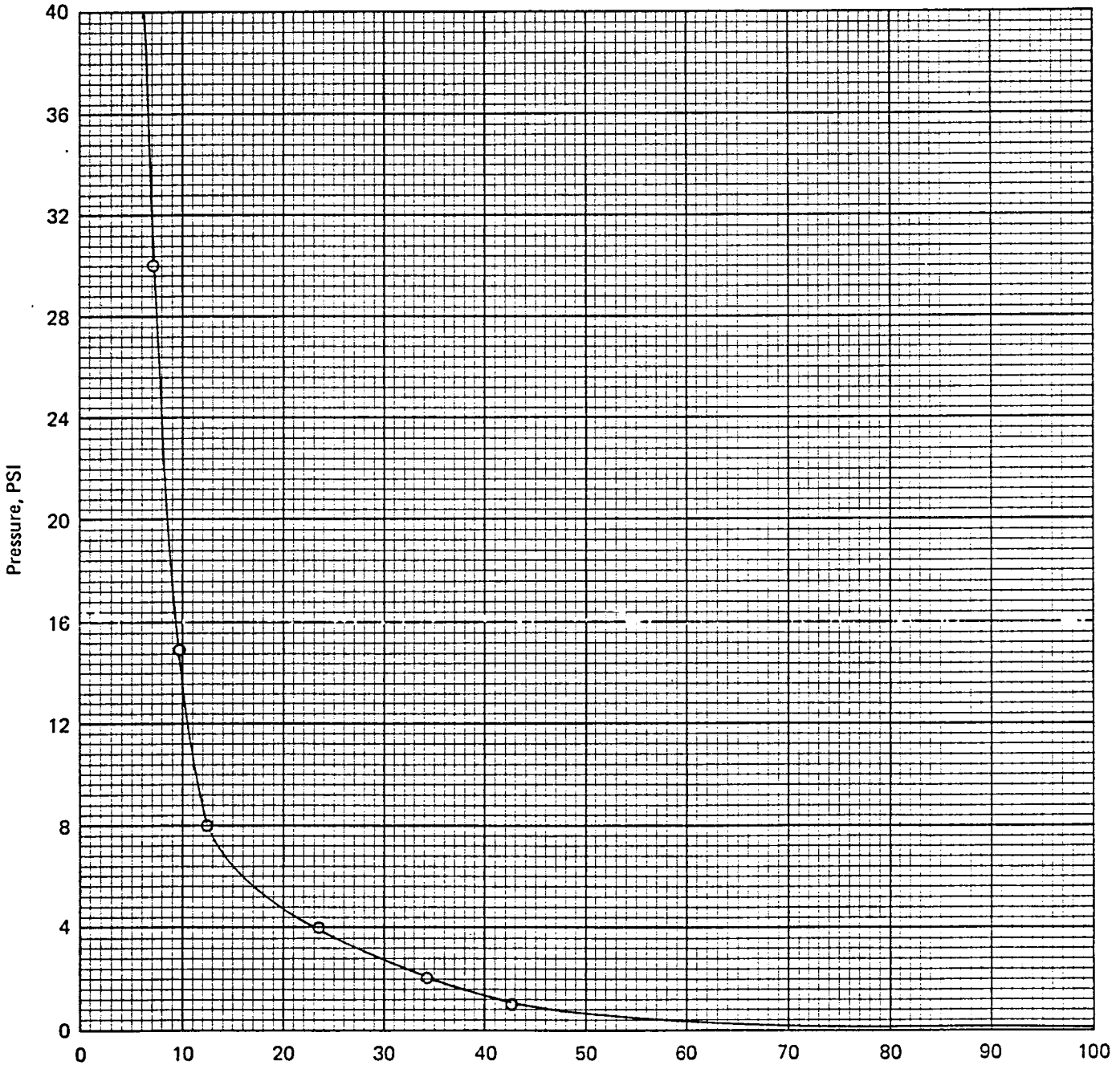
Air Permeability, MD: 8440



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-2 Country NORWAY
Field

Sample Number: 6A

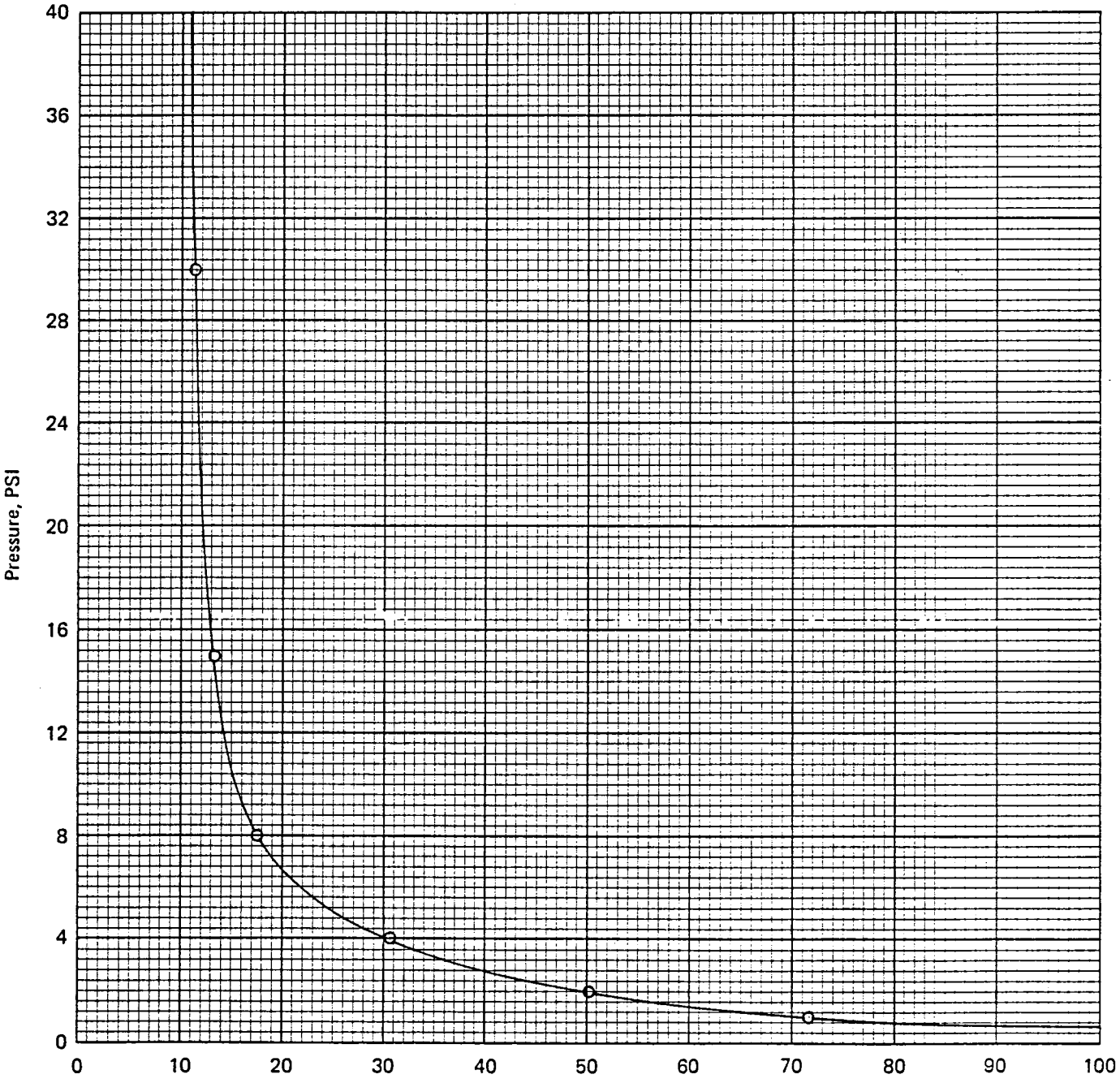
Air Permeability, MD: 6500



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-2 Country NORWAY
Field

Sample Number: 4A

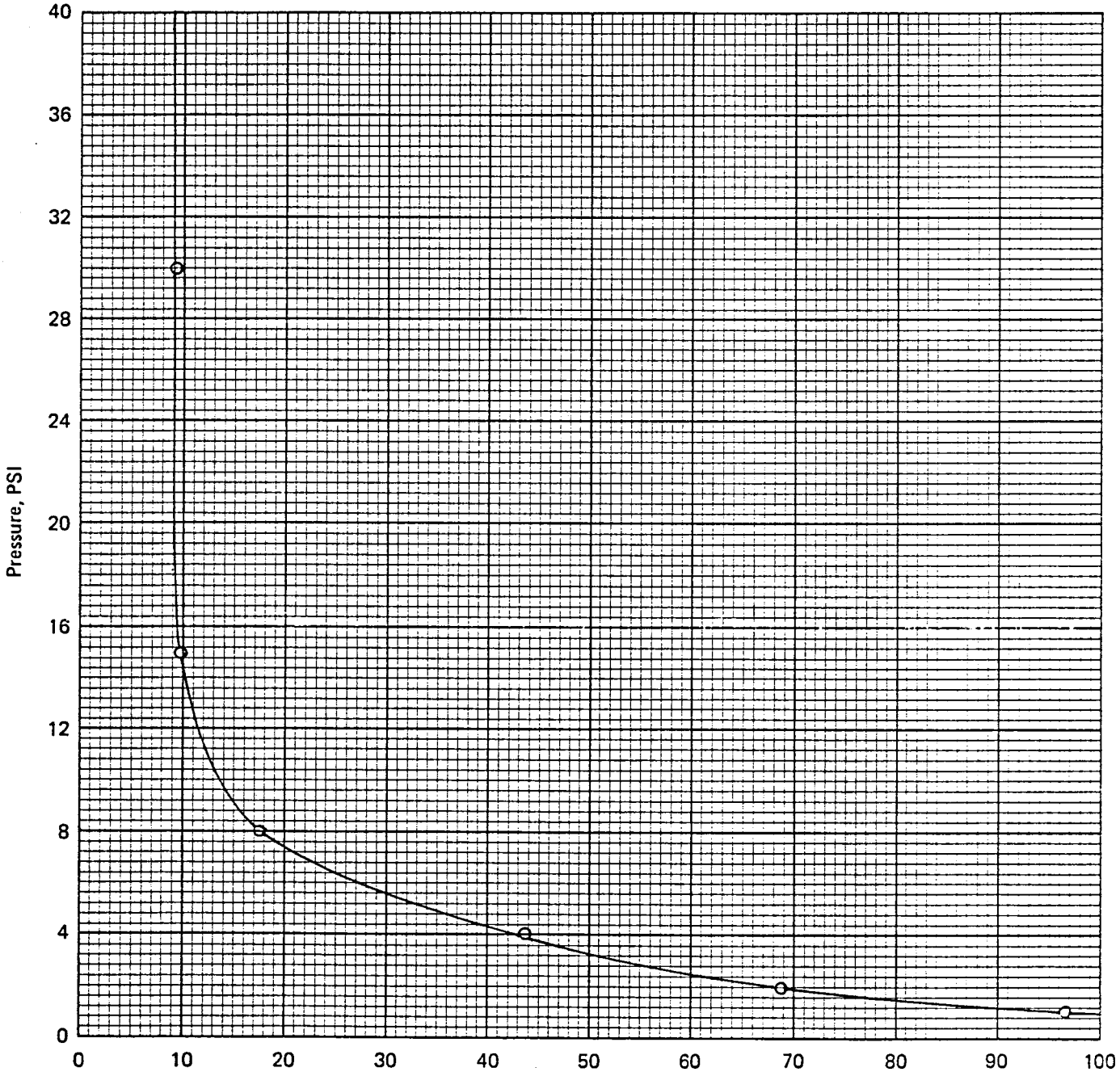
Air Permeability, MD: 4460



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-2 Country NORWAY
Field

Sample Number: 1A

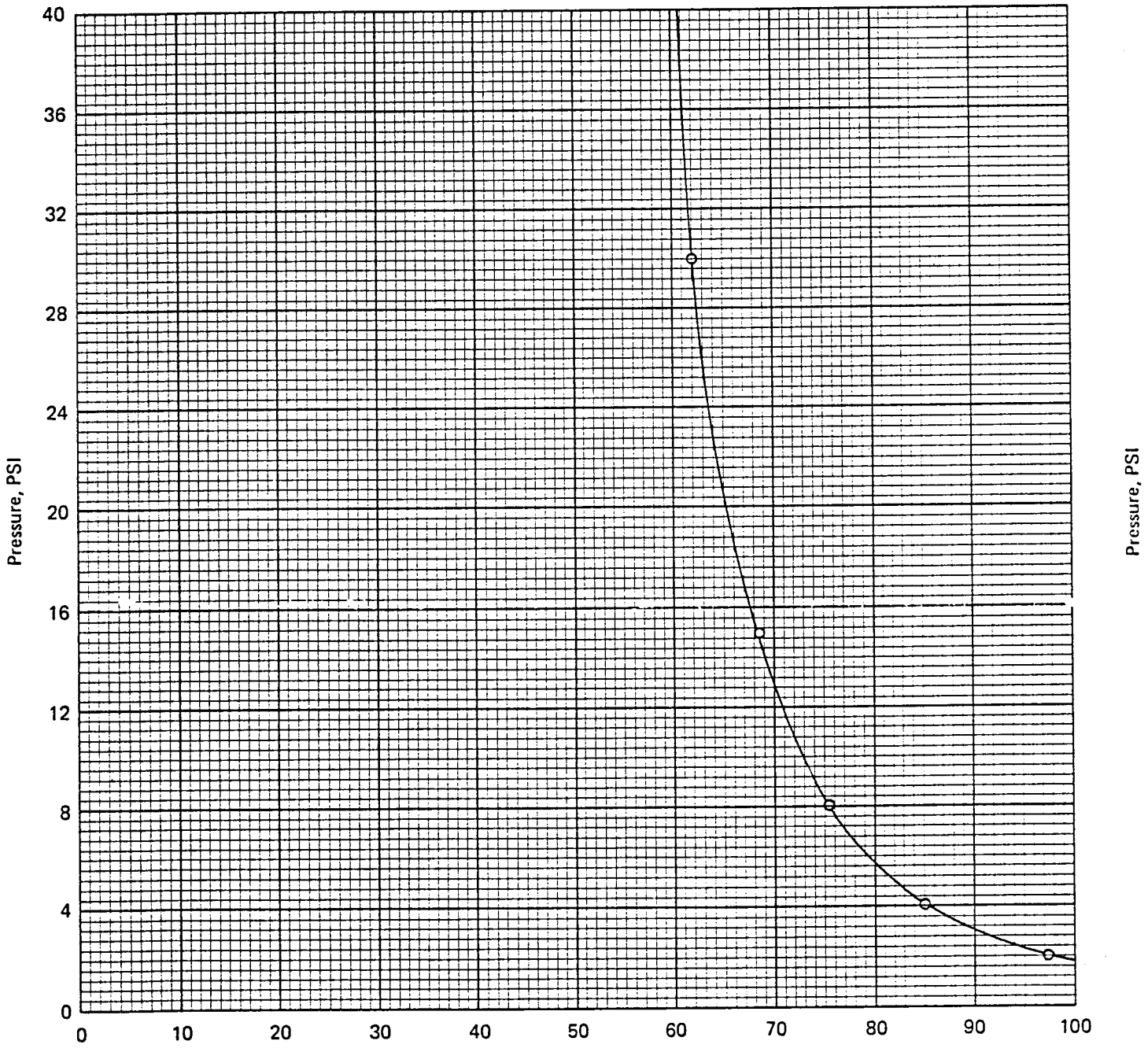
Air Permeability, MD: 1760



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-2 Country NORWAY
Field

Sample Number: 3A

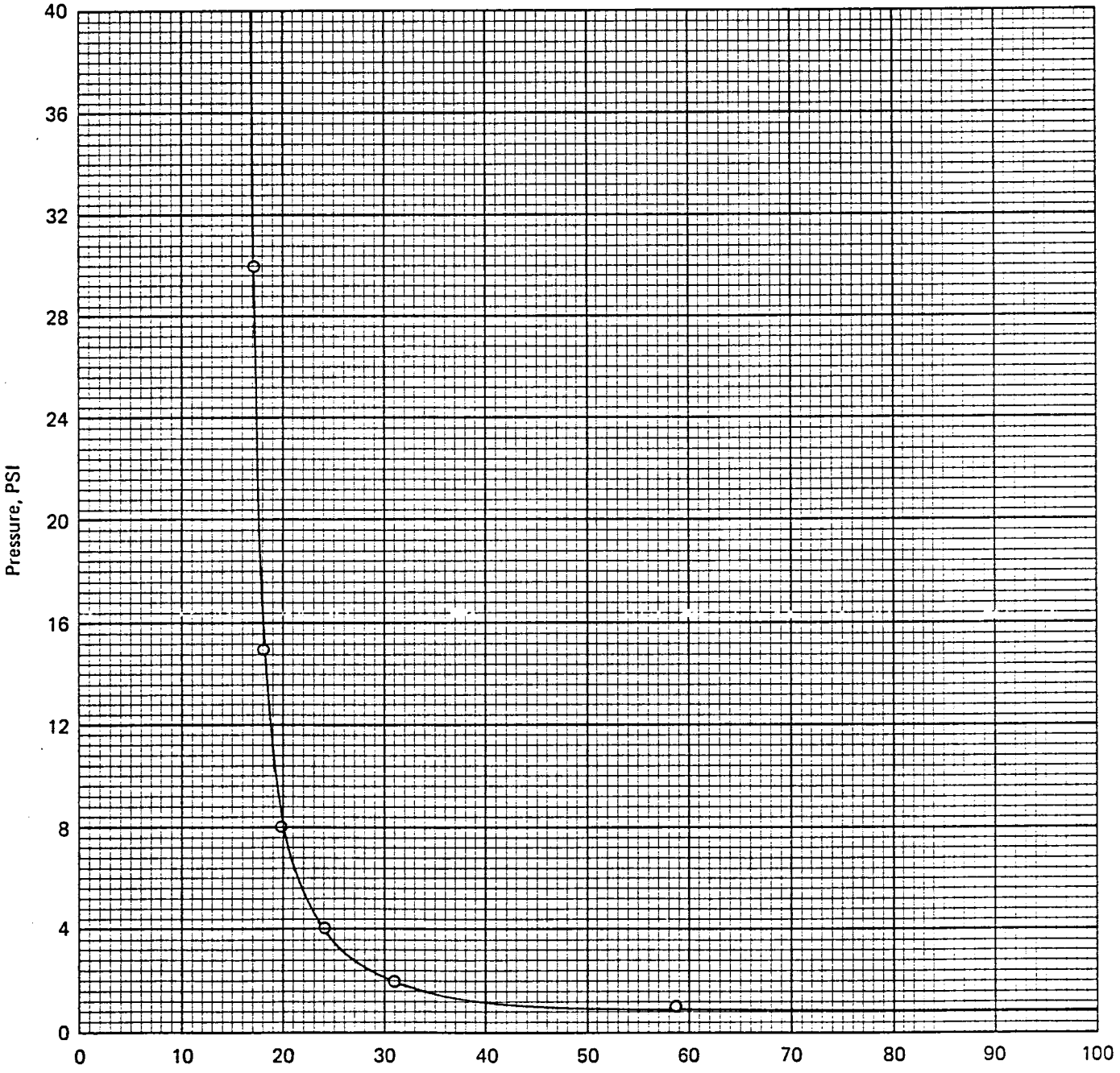
Air Permeability, MD: 174



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-3 Country NORWAY
Field

Sample Number: 10A

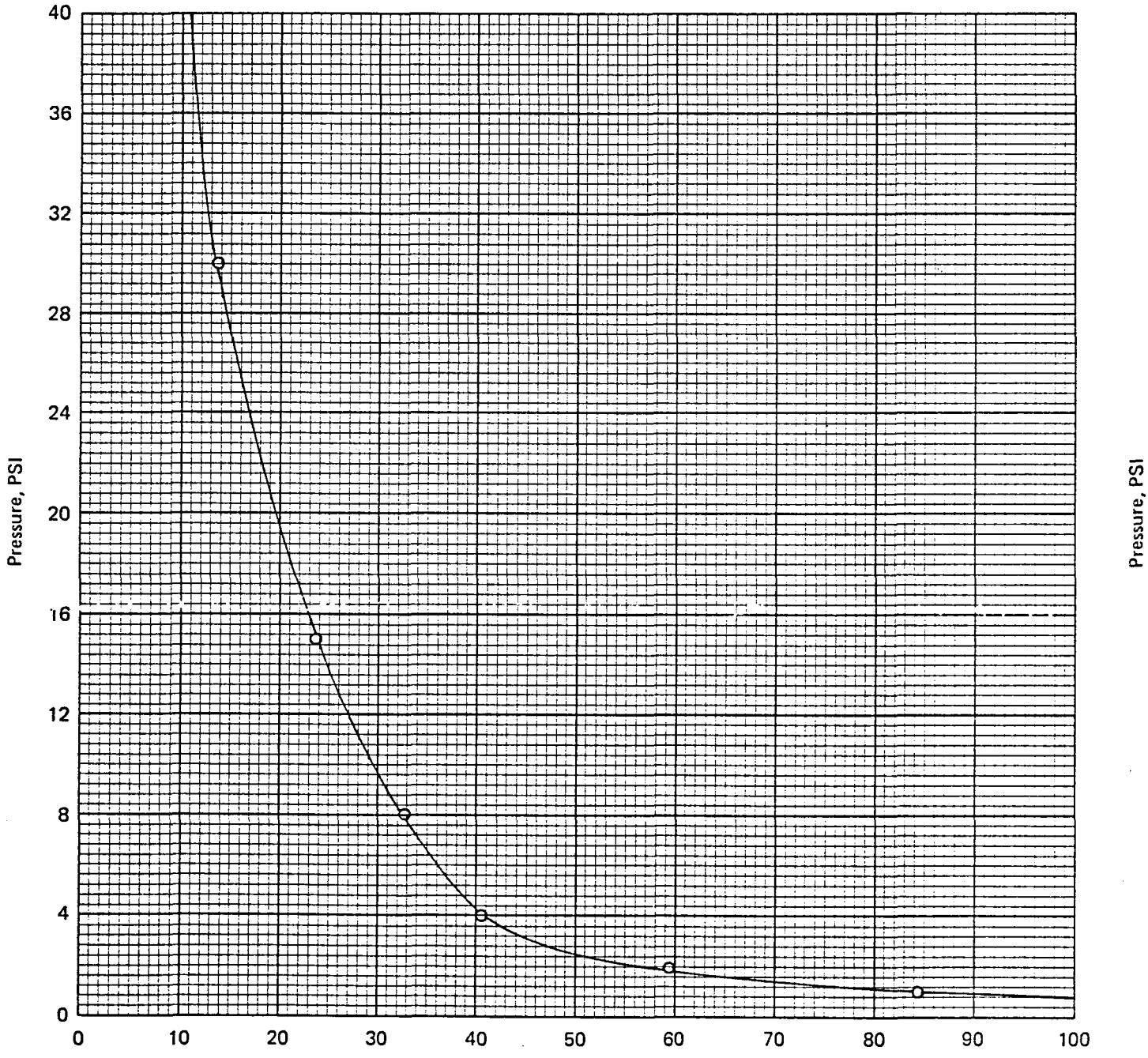
Air Permeability, MD: 5150



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-3 Country NORWAY
Field

Sample Number: 12A

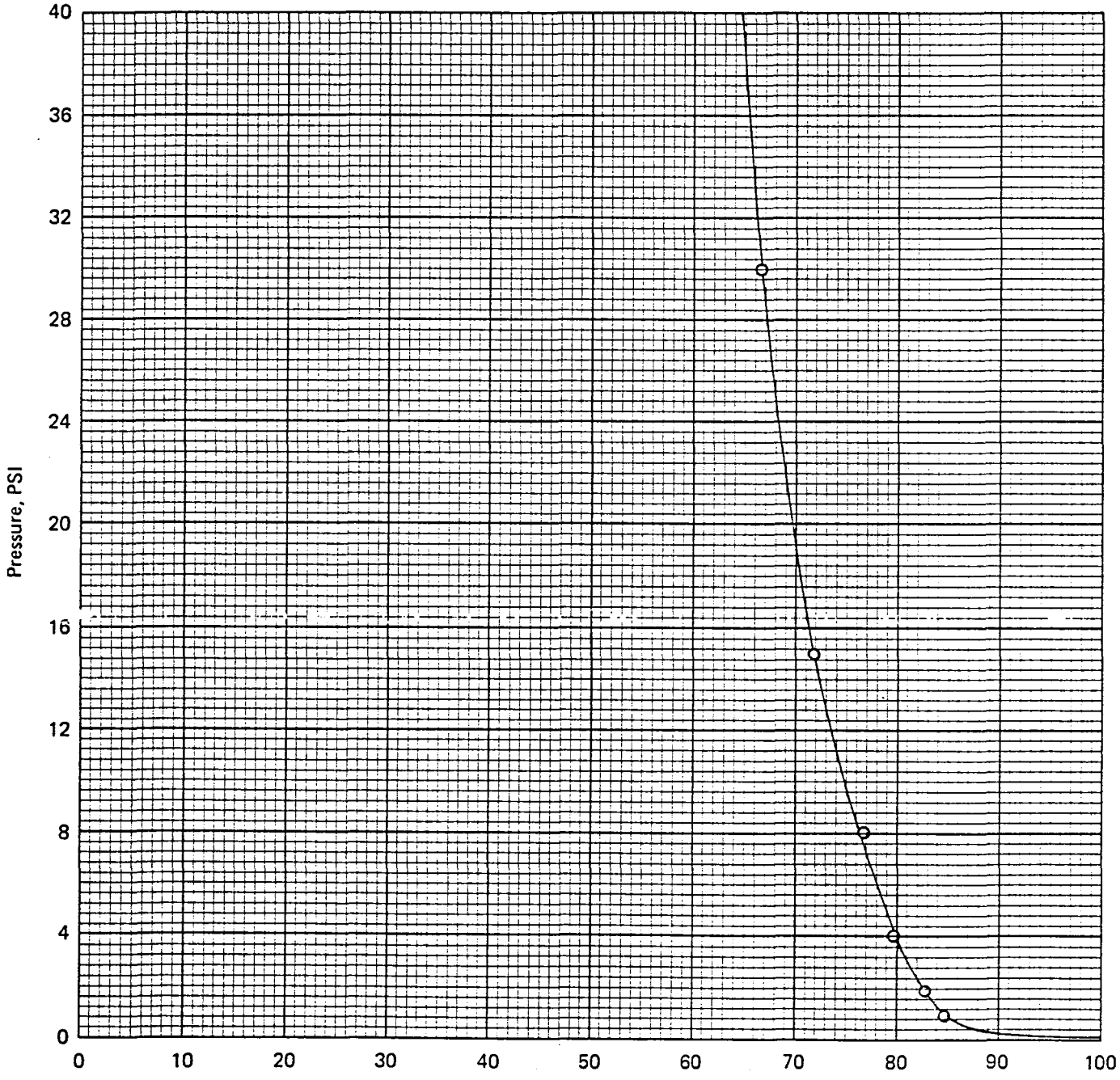
Air Permeability, MD: 4020



Company NORSKE SHELL EXPL. AND PROD. Formation
Well 31/2-3 Country NORWAY
Field

Sample Number: 13A

Air Permeability, MD: 136



# GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 1B

Air Permeability, Md: 7420

Oil Permeability with Initial Water Present, Md: 2970

Initial Water Saturation Per Cent Pore Space: 12.5

Porosity, Per Cent: 40.3

| Liquid Saturation Per Cent Pore Space | Gas-Oil Relative Permeability Ratio | Relative Permeability To Gas*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 100 | .000 | .000 | 1.000 |
| 90.9 | .260 | .122 | .470 |
| 88.5 | .570 | .151 | .265 |
| 86.5 | .886 | .173 | .196 |
| 81.9 | 2.07 | .222 | .107 |
| 78.3 | 4.19 | .260 | .062 |
| 75.9 | 6.83 | .287 | .042 |
| 72.8 | 12.8 | .313 | .024 |
| 69.5 | 29.4 | .349 | .012 |
| 65.8 | 98.8 | .384 | .0040 |

* Relative to Oil Permeability

# GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 2B

Air Permeability, Md: 930

Oil Permeability with Initial Water Present, Md: 800

Initial Water Saturation Per Cent Pore Space: 18.6

Porosity, Per Cent: 39.4

| Liquid Saturation Per Cent Pore Space | Gas-Oil Relative Permeability Ratio | Relative Permeability To Gas*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 100 | .000 | .000 | 1.000 |
| 89.4 | .363 | .107 | .295 |
| 87.8 | .672 | .158 | .235 |
| 86.8 | .894 | .183 | .205 |
| 84.0 | 1.93 | .268 | .139 |
| 81.6 | 3.52 | .342 | .097 |
| 79.3 | 6.26 | .423 | .068 |
| 77.3 | 10.3 | .493 | .048 |
| 75.1 | 19.0 | .575 | .031 |
| 72.7 | 38.3 | .657 | .017 |

* Relative to Oil Permeability

## GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 10B

Air Permeability, Md: 8760

Oil Permeability with Initial Water Present, Md: 5360

Initial Water Saturation Per Cent Pore Space: 9.5

Porosity, Per Cent: 28.2

| Liquid Saturation Per Cent Pore Space | Gas-Oil Relative Permeability Ratio | Relative Permeability To Gas*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 100 | .000 | .000 | 1.000 |
| 98.8 | .072 | .066 | .910 |
| 97.6 | .093 | .071 | .763 |
| 94.7 | .149 | .078 | .522 |
| 92.9 | .202 | .085 | .420 |
| 90.8 | .281 | .091 | .324 |
| 86.5 | .538 | .106 | .196 |
| 81.8 | 1.16 | .124 | .101 |
| 78.3 | 2.28 | .138 | .057 |
| 75.1 | 4.93 | .149 | .029 |
| 71.9 | 13.3 | .165 | .012 |
| 69.1 | 86.4 | .178 | .0021 |

* Relative to Oil Permeability

# GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 12B

Air Permeability, Md: 1110

Oil Permeability with Initial Water Present, Md: 1060

Initial Water Saturation Per Cent Pore Space: 23.2

Porosity, Per Cent: 36.7

| Liquid Saturation Per Cent Pore Space | Gas-Oil Relative Permeability Ratio | Relative Permeability To Gas*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 100 | .000 | .000 | 1.000 |
| 94.5 | .082 | .038 | .464 |
| 92.7 | .154 | .053 | .345 |
| 90.8 | .277 | .070 | .255 |
| 87.3 | .693 | .106 | .154 |
| 85.0 | 1.15 | .124 | .108 |
| 80.0 | 3.76 | .164 | .044 |
| 77.7 | 6.81 | .184 | .027 |
| 74.8 | 15.6 | .203 | .013 |
| 71.9 | 49.5 | .223 | .0045 |

* Relative to Oil Permeability

# GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 15B

Air Permeability, Md: 19

Oil Permeability with Initial Water Present, Md: 8.1

Initial Water Saturation Per Cent Pore Space: 22.5

Porosity, Per Cent: 26.0

| Liquid Saturation Per Cent Pore Space | Gas-Oil Relative Permeability Ratio | Relative Permeability To Gas*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 100 | .000 | .000 | 1.000 |
| 89.9 | .260 | .063 | .243 |
| 89.0 | .357 | .076 | .213 |
| 87.2 | .686 | .096 | .140 |
| 86.6 | .815 | .103 | .127 |
| 85.4 | 1.15 | .117 | .102 |
| 83.3 | 2.05 | .136 | .067 |
| 82.2 | 2.79 | .151 | .054 |
| 79.9 | 8.36 | .174 | .021 |
| 75.8 | 37.8 | .204 | .0054 |

* Relative to Oil Permeability

# GAS-OIL RELATIVE PERMEABILITY DATA

Sample Number: 11B

Air Permeability, Md: 32

Oil Permeability with Initial Water Present, Md: 6.5

Initial Water Saturation Per Cent Pore Space: 29.3

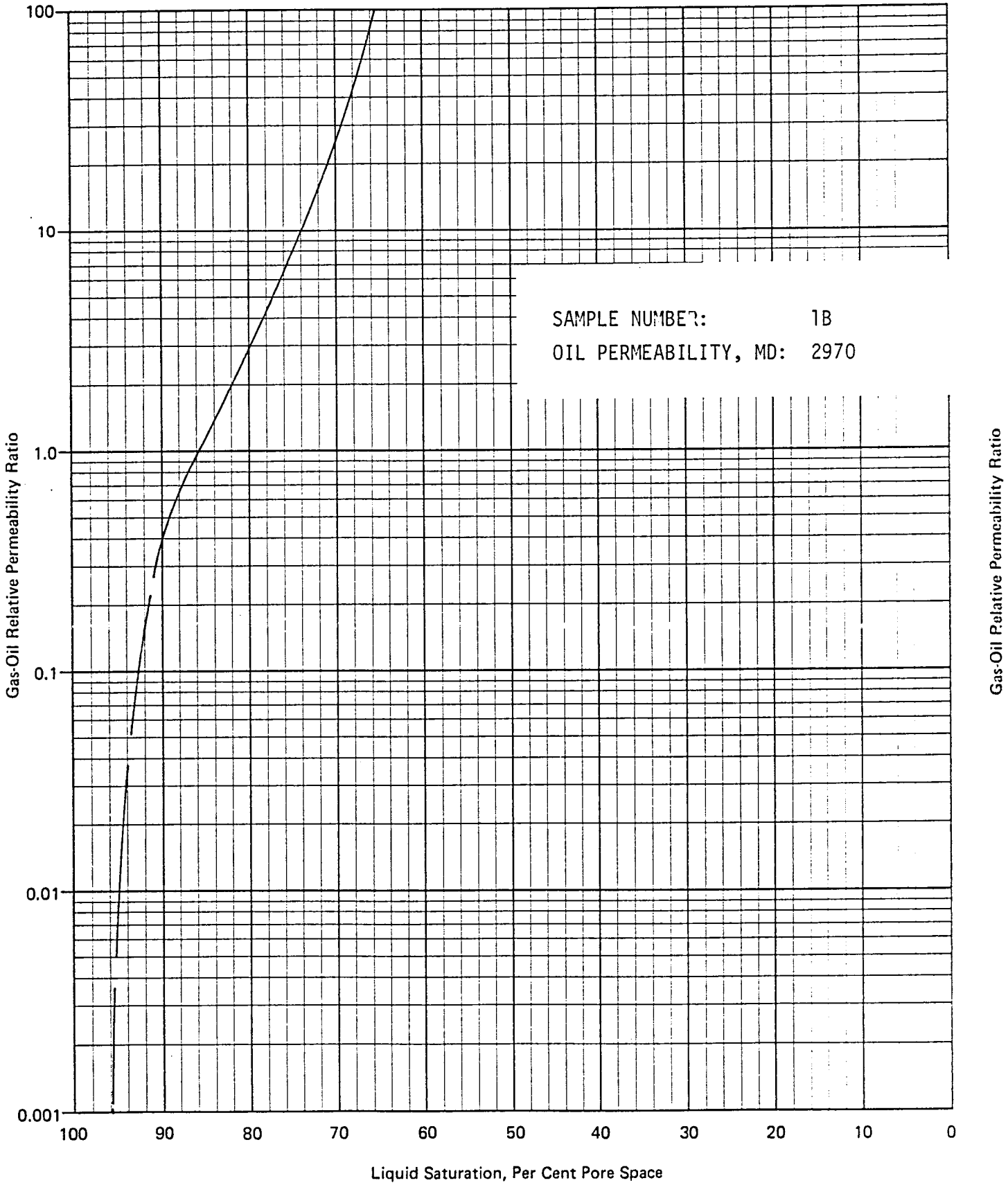
Porosity, Per Cent: 33.5

| Liquid Saturation Per Cent Pore Space | Gas-Oil Relative Permeability Ratio | Relative Permeability To Gas*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 100 | .000 | .000 | 1.000 |
| 96.6 | .031 | .024 | .780 |
| 95.7 | .051 | .036 | .700 |
| 94.5 | .081 | .049 | .614 |
| 93.6 | .122 | .065 | .530 |
| 91.5 | .303 | .123 | .407 |
| 89.0 | .798 | .211 | .264 |
| 87.8 | 1.13 | .251 | .223 |
| 84.9 | 2.67 | .371 | .139 |
| 82.3 | 5.18 | .435 | .084 |
| 79.6 | 11.4 | .512 | .045 |
| 77.1 | 26.9 | .608 | .023 |
| 75.1 | 57.3 | .699 | .012 |

* Relative to Oil Permeability

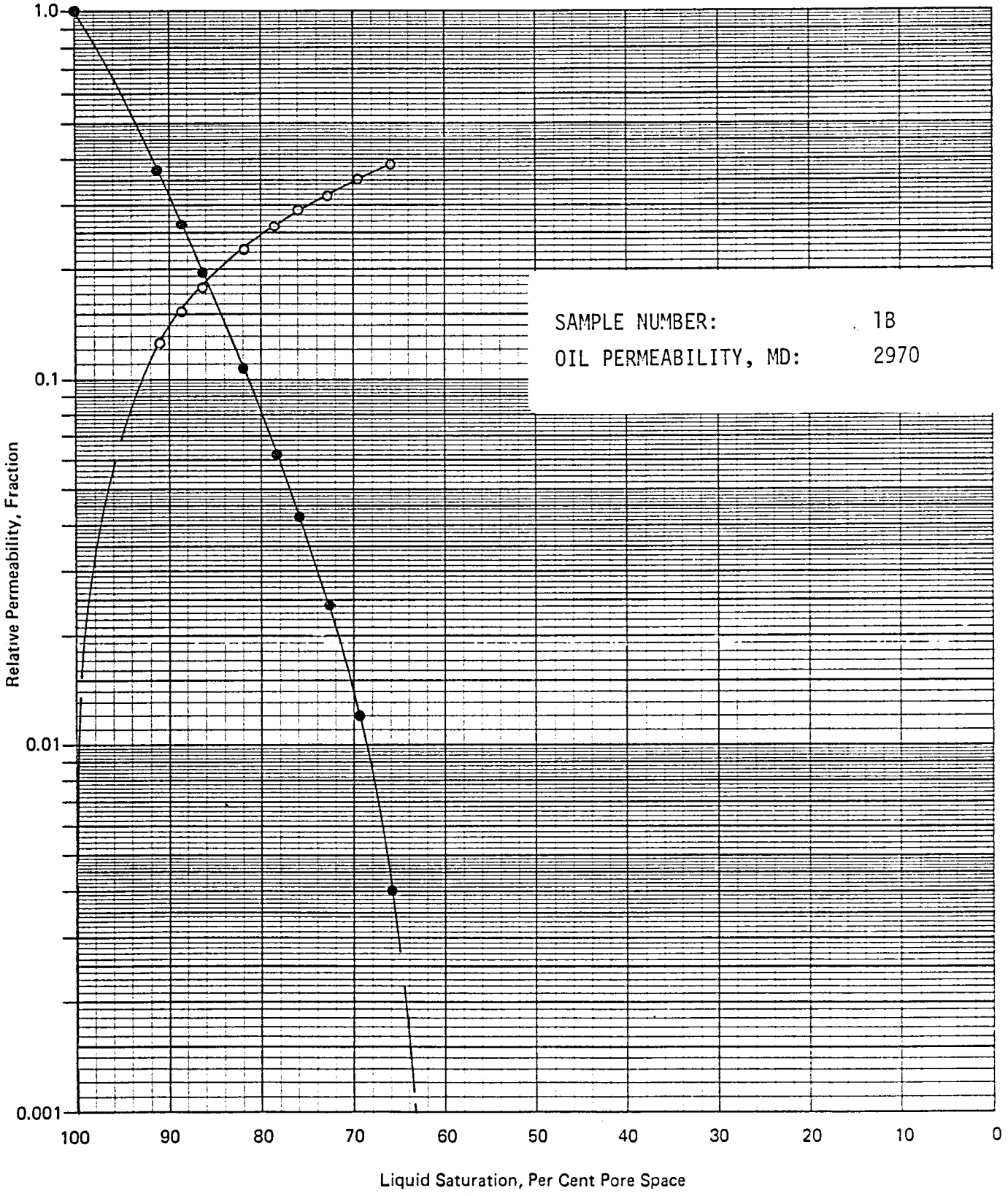
Company NORSKE SHELL EXPL. & PROD
Well 31/2-2
Field

Formation
Country NORWAY



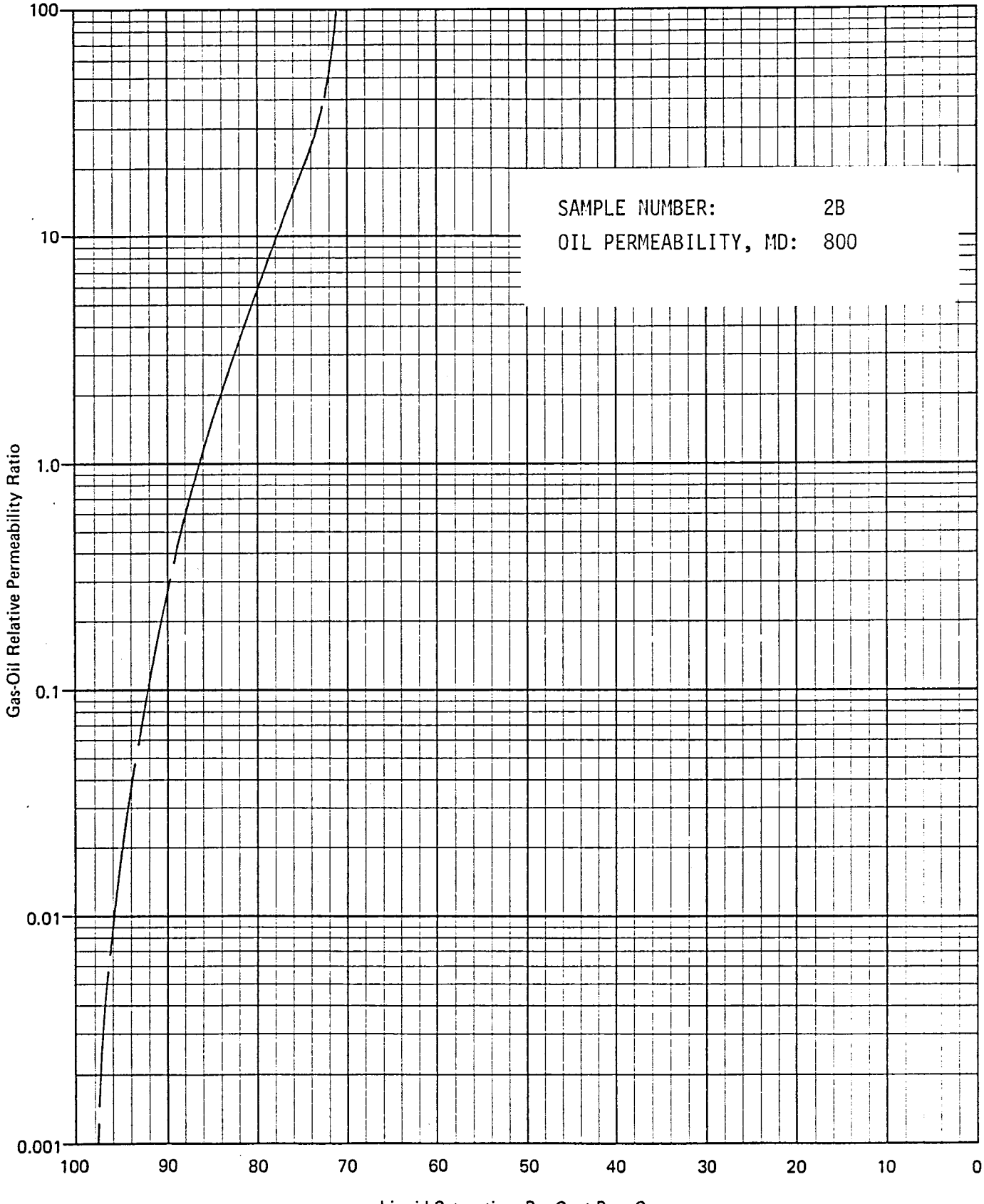
Company NORSKE SHELL EXPL. & PROD
Well 31/2-2
Field

Formation
Country NORWAY



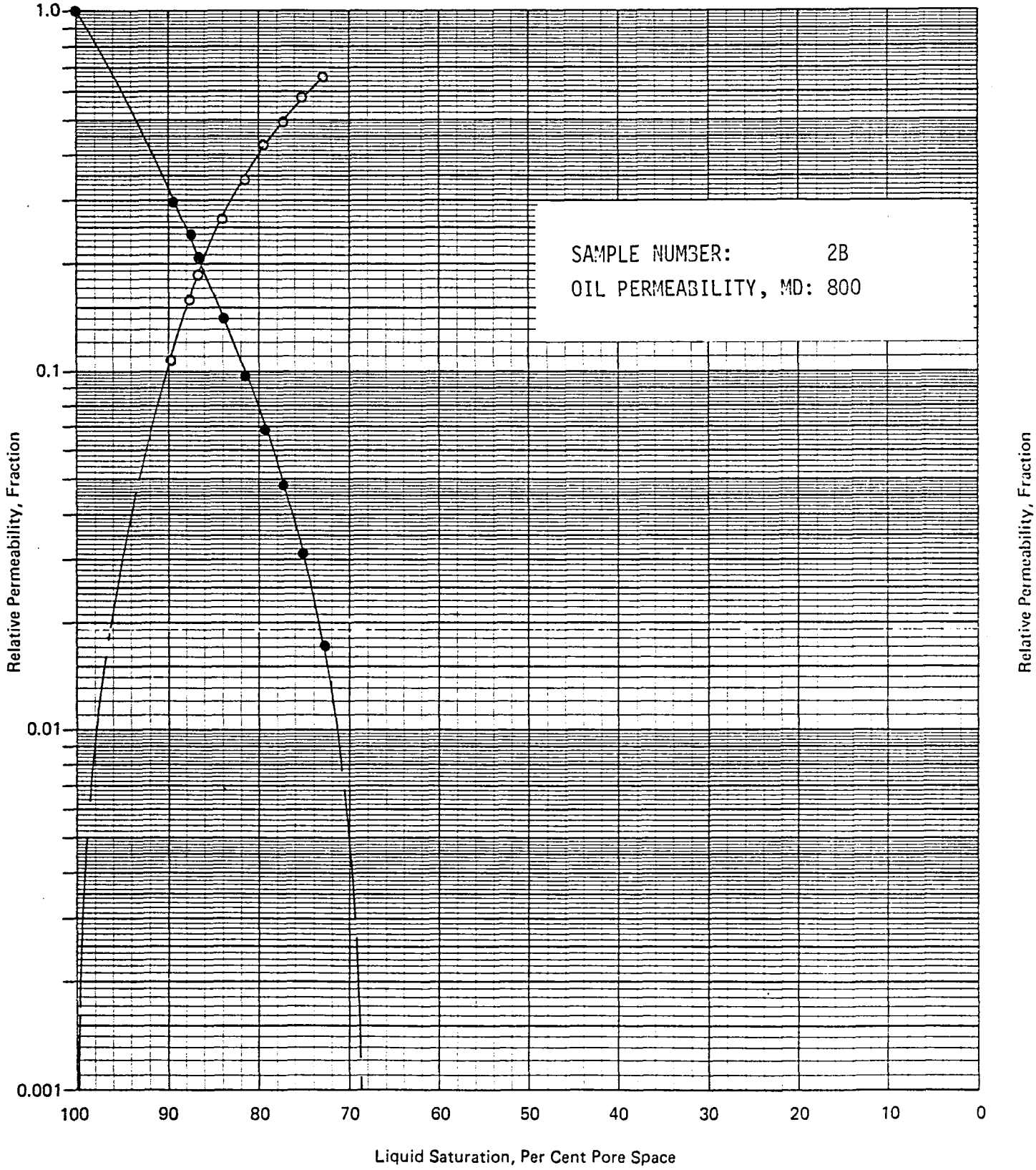
Company NORSKE SHELL EXPL. & PROD
Well 31/2-2
Field

Formation
Country NORWAY



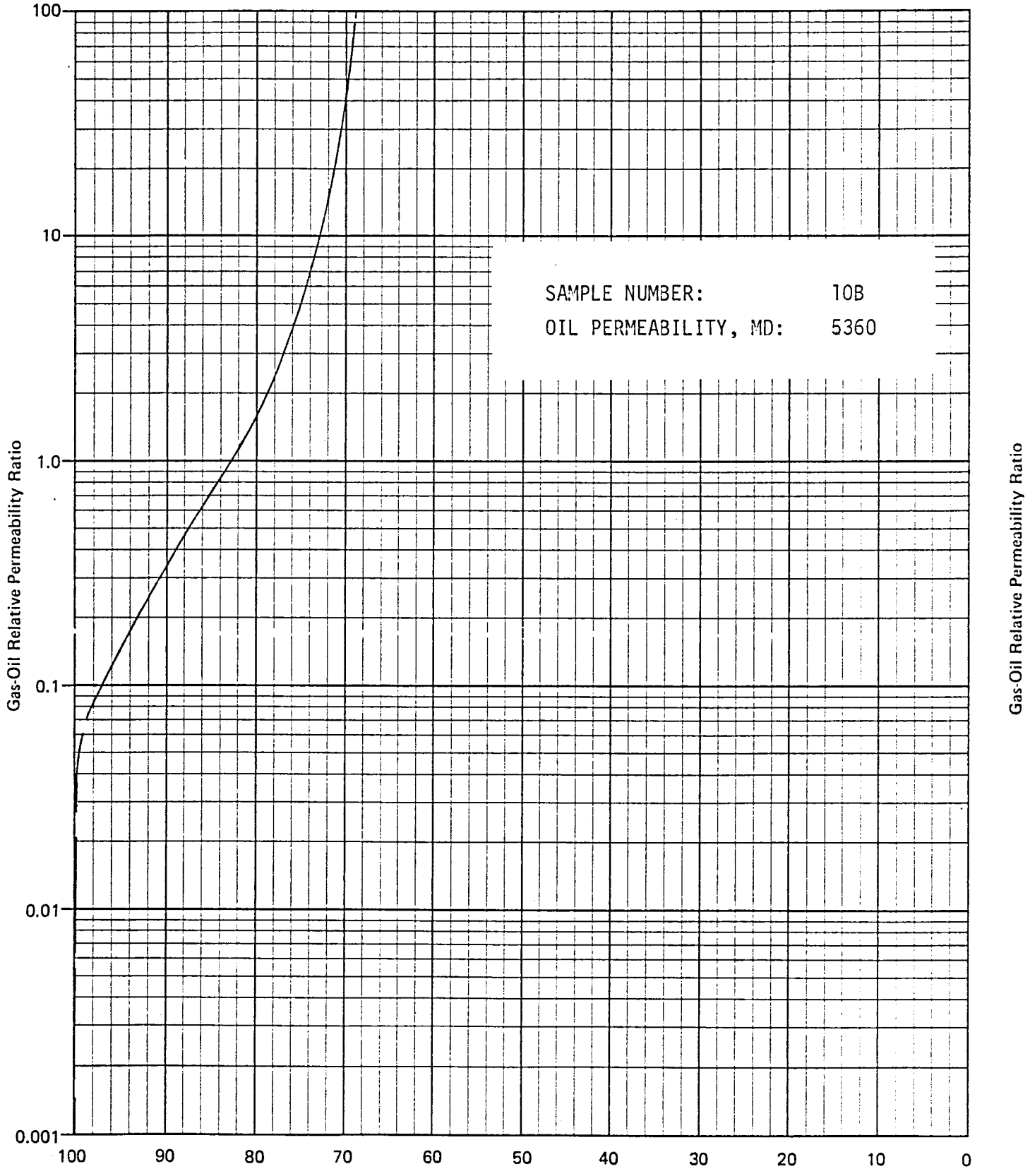
Company NORSKE SHELL EXPL. & PROD
Well 31/2-2
Field

Formation
Country NORWAY

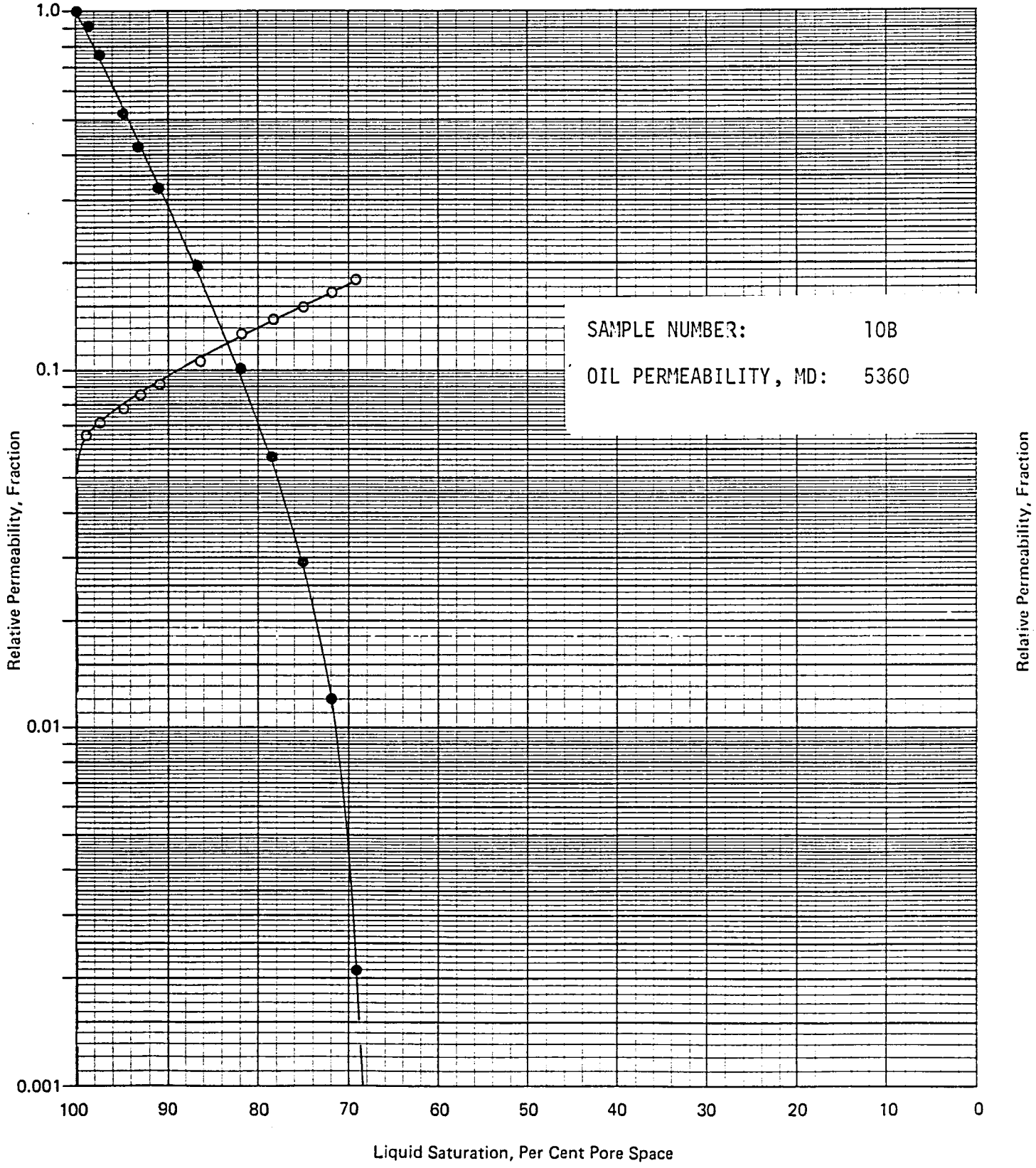


Company NORSKE SHELL EXPL. AND PROD
Well 31/2-3
Field

Formation
Country NORWAY

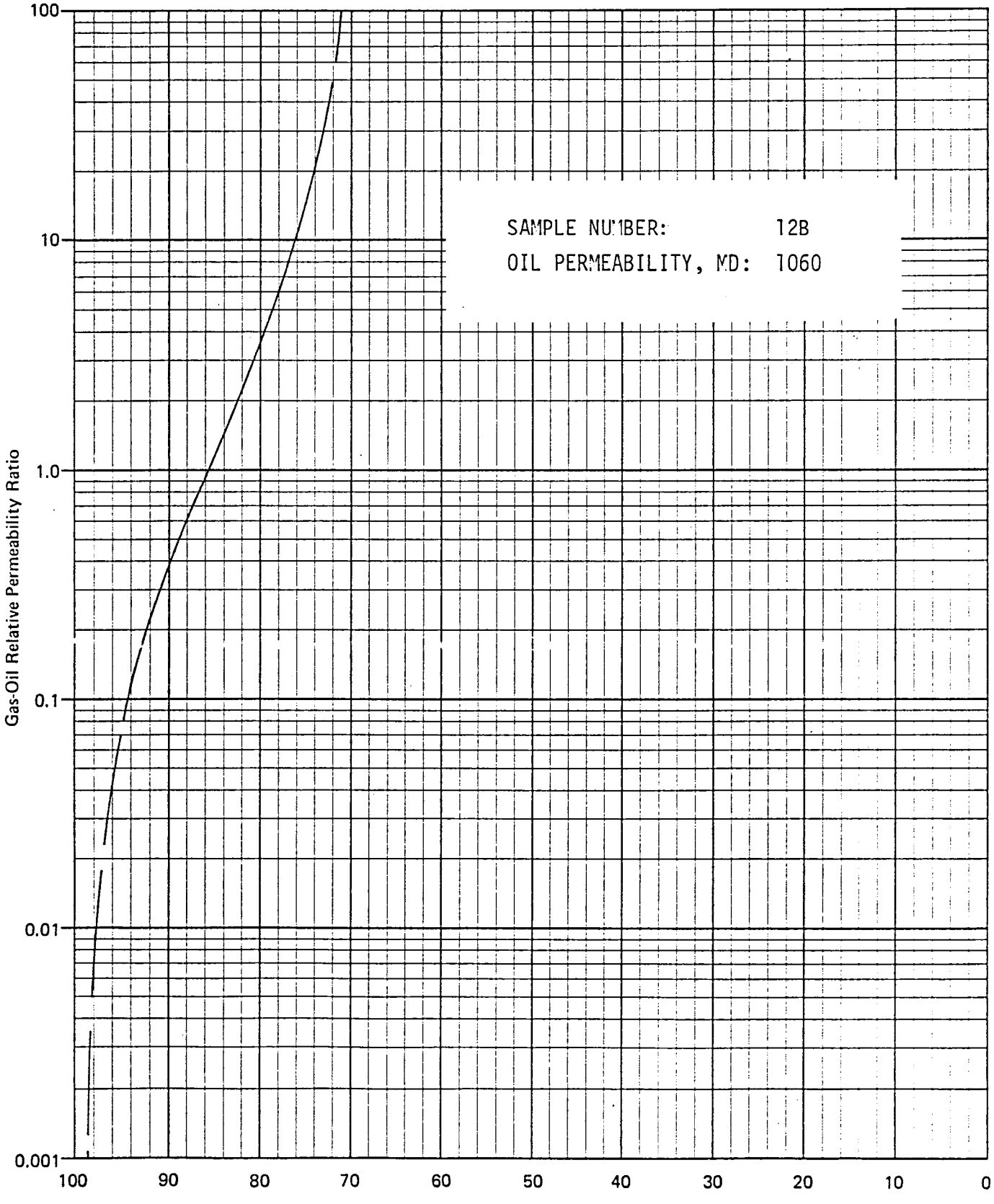


Company NORSKE SHELL EXPL. & PROD. Formation
Well 31/2-3 Country NORWAY
Field



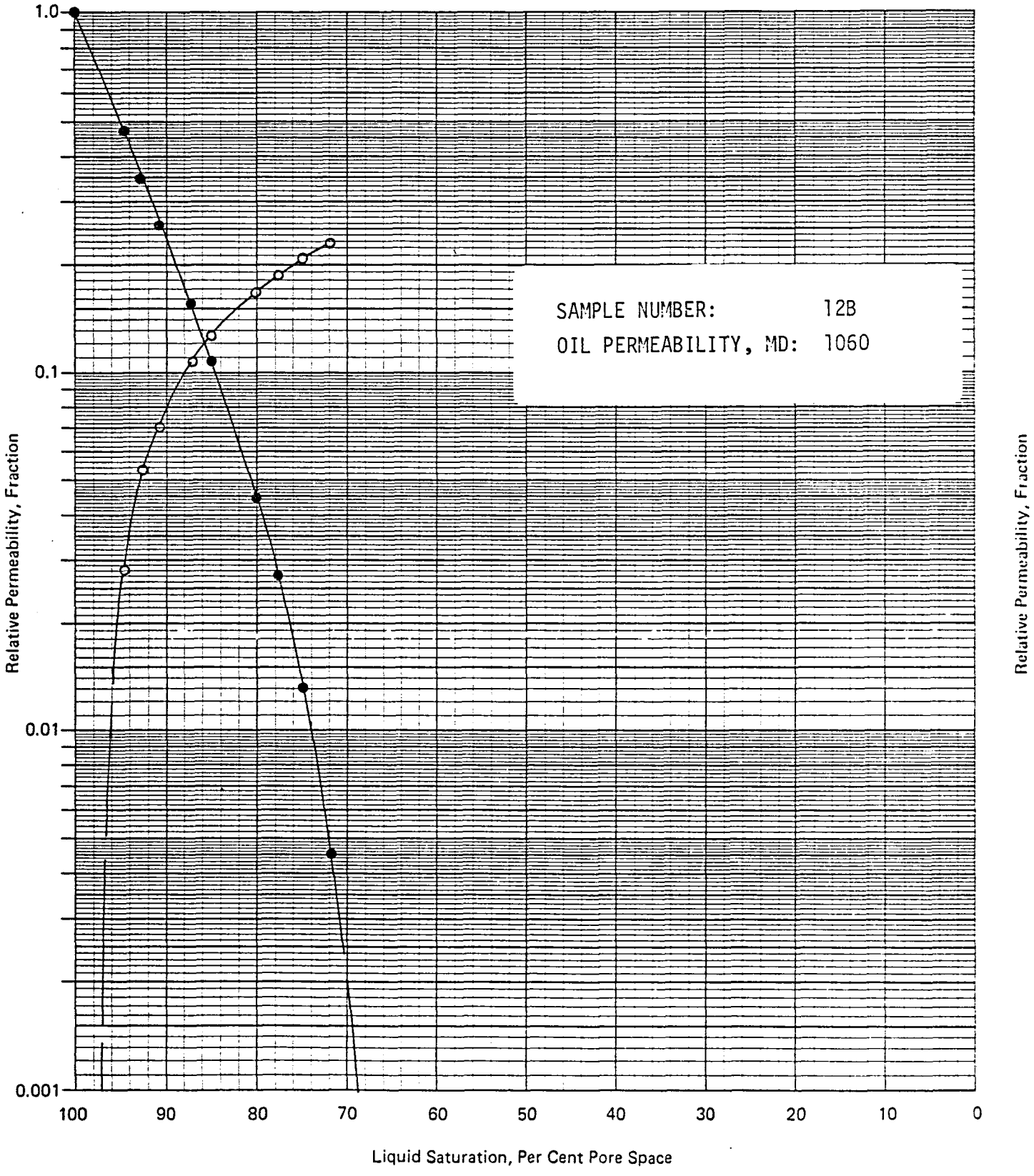
Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



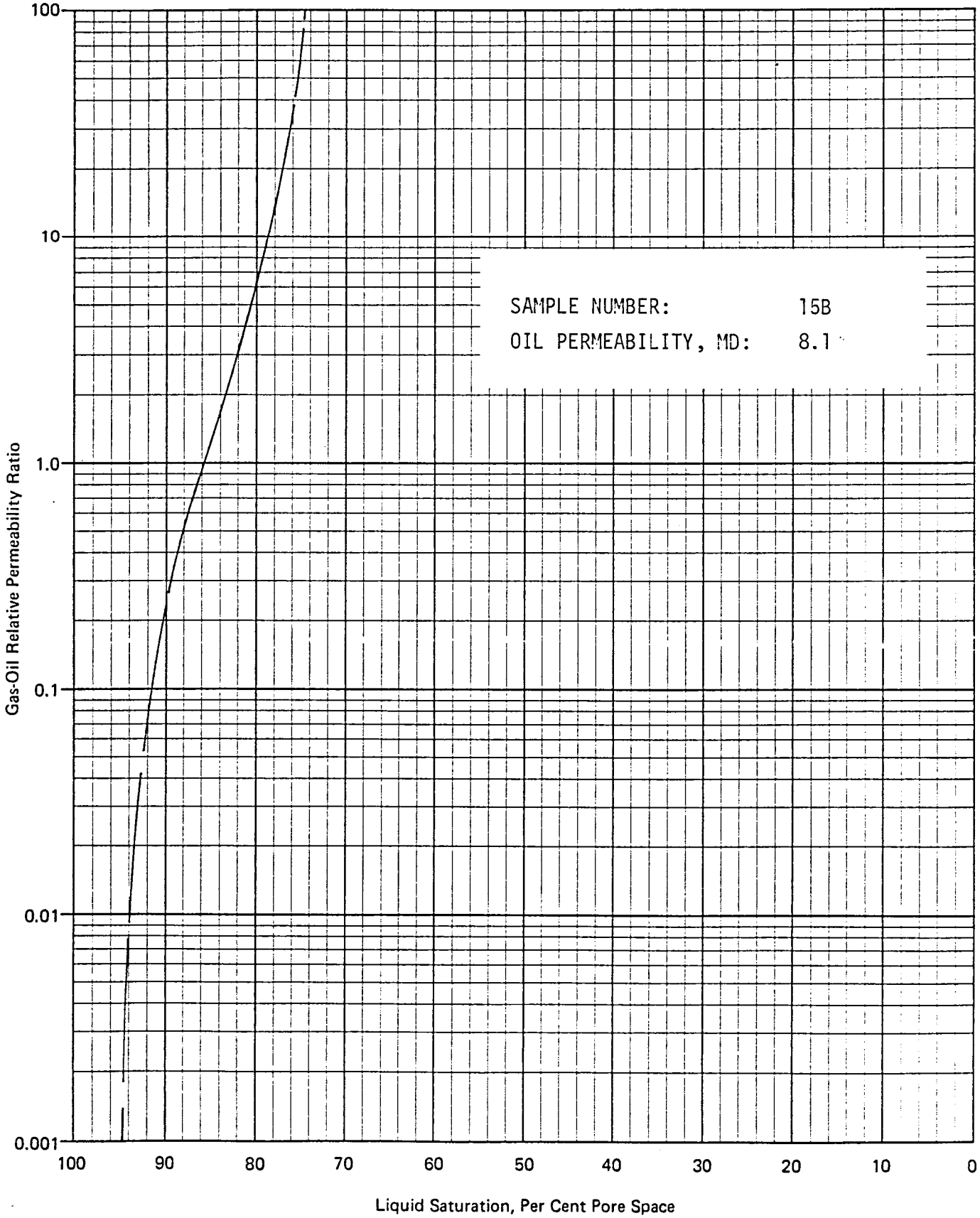
Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



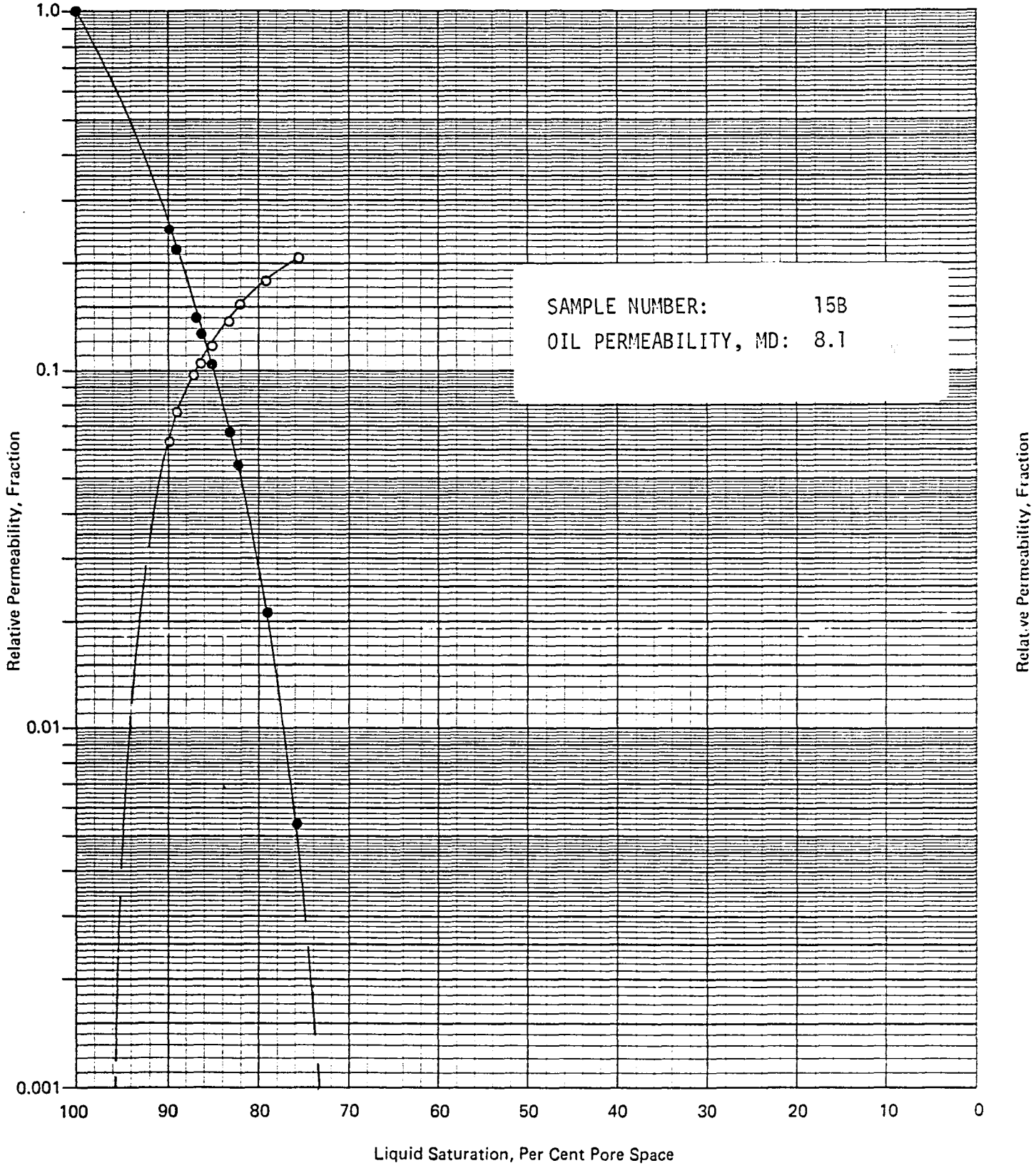
Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



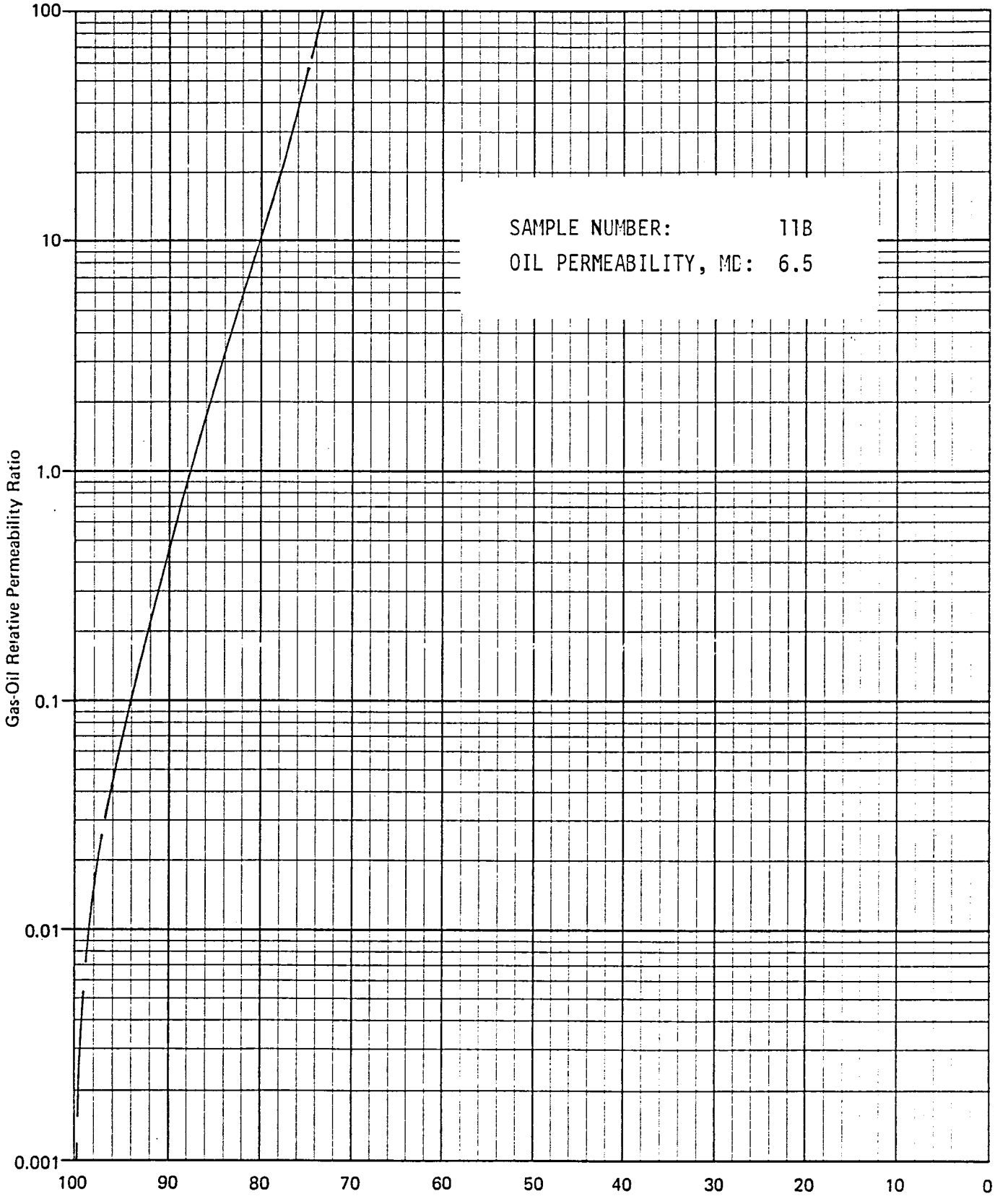
Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



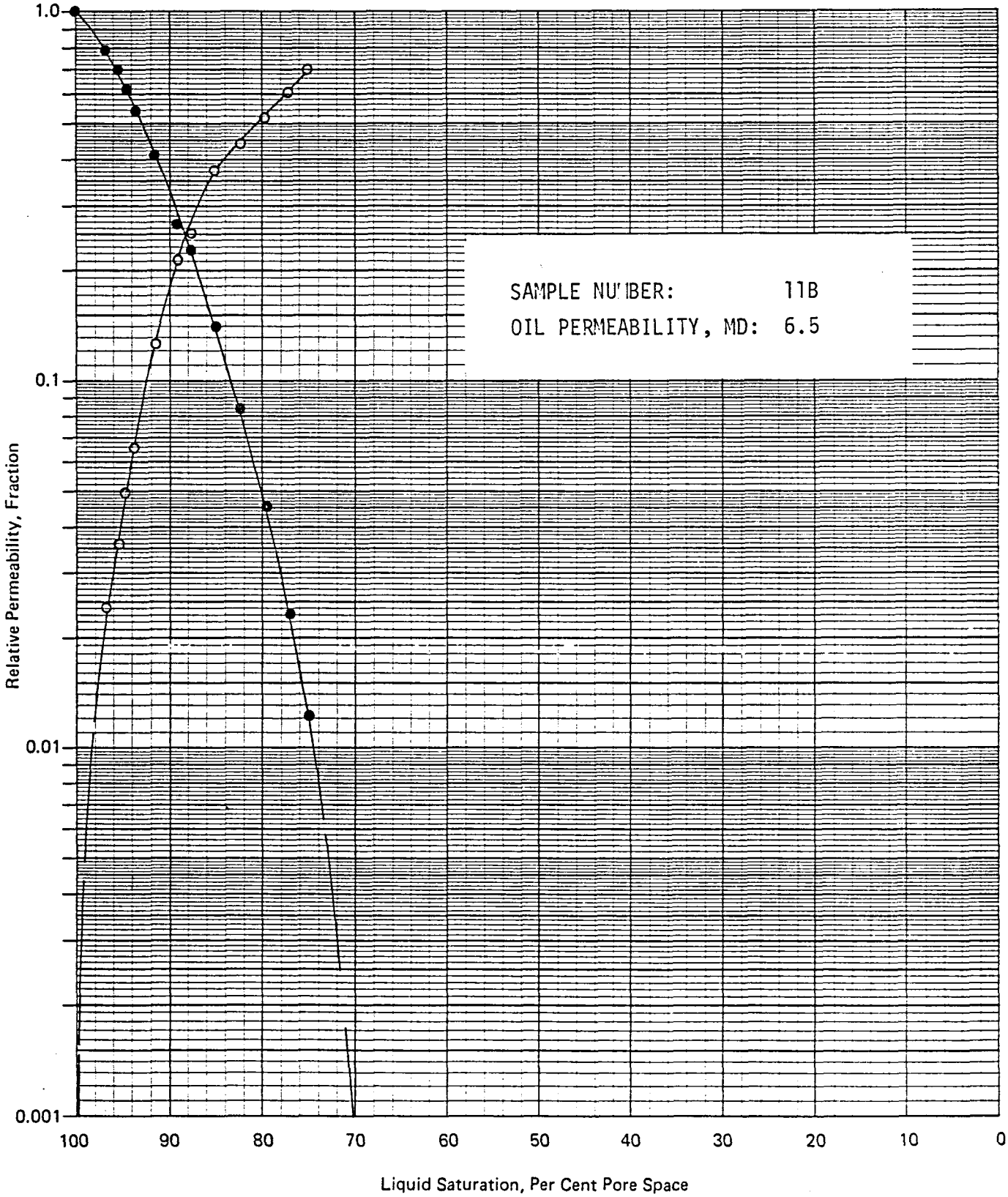
Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



## SUMMARY OF WATERFLOOD TEST RESULTS

| Sample Number | Air Permeability Millidarcys | Porosity Per Cent | Initial Conditions: Water Saturation Per Cent Pore Space | Initial Conditions: Oil Permeability Millidarcys | Terminal Conditions: Oil Saturation Per Cent Pore Space | Terminal Conditions: Water Permeability Millidarcys | Oil Recovered: Per Cent Pore Space | Oil Recovered: Per Cent Oil in Place |
|---|---|---|---|---|---|---|---|---|
| | | | | Well: 31/2-2 | | | | |
| 2B | 930 | 39.4 | 18.6 | 800 | 33.7 | 303 | 47.7 | 58.6 |
| 8B | 278 | 32.7 | 30.2 | 168 | 31.1 | 22 | 38.7 | 55.5 |
| | | | | Well: 31/2-3 | | | | |
| 12B | 1110 | 36.2 | 23.2 | 1060 | 29.7 | 216 | 47.1 | 61.3 |

# WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 2B

Air Permeability, Md: 930

Oil Permeability with Initial Water Present, Md: 800

Initial Water Saturation Per Cent Pore Space: 18.6

Porosity, Per Cent: 39.4

| Water Saturation Per Cent Pore Space | Water-Oil Relative Permeability Ratio | Relative Permeability To Water*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 18.6 | .000 | .000 | 1.000 |
| 32.5 | .112 | .040 | .404 |
| 39.7 | .299 | .070 | .234 |
| 44.7 | .647 | .095 | .146 |
| 49.0 | 1.49 | .129 | .087 |
| 51.2 | 2.30 | .151 | .067 |
| 54.3 | 4.52 | .179 | .040 |
| 57.3 | 9.74 | .209 | .022 |
| 58.7 | 15.0 | .234 | .015 |
| 61.0 | 29.7 | .264 | .0089 |
| 62.2 | 55.8 | .290 | .0052 |
| 63.2 | 86.1 | .310 | .0036 |
| 63.8 | 121 | .315 | .0026 |
| 66.3 | - | .379 | .0000 |

* Relative to Oil Permeability

# WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 8B

Air Permeability, Md: 278

Oil Permeability with Initial Water Present, Md: 168

Initial Water Saturation Per Cent Pore Space: 30.2

Porosity, Per Cent: 32.7

| Water Saturation Per Cent Pore Space | Water-Oil Relative Permeability Ratio | Relative Permeability To Water*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 30.2 | .000 | .000 | 1.000 |
| 34.5 | .120 | .091 | .760 |
| 38.4 | .181 | .097 | .537 |
| 45.5 | .396 | .107 | .270 |
| 50.7 | .750 | .112 | .149 |
| 57.3 | 1.72 | .118 | .069 |
| 61.0 | 3.68 | .121 | .033 |
| 63.3 | 8.28 | .124 | .015 |
| 64.6 | 18.2 | .127 | .0070 |
| 65.1 | 23.7 | .128 | .0054 |
| 66.3 | 56.1 | .129 | .0023 |
| 67.1 | 100 | .130 | .0013 |
| 68.9 | - | .131 | .0000 |

* Relative to Oil Permeability

# WATER-OIL RELATIVE PERMEABILITY DATA

Sample Number: 12B

Air Permeability, Md: 1110

Oil Permeability with Initial Water Present, Md: 1060

Initial Water Saturation Per Cent Pore Space: 23.2

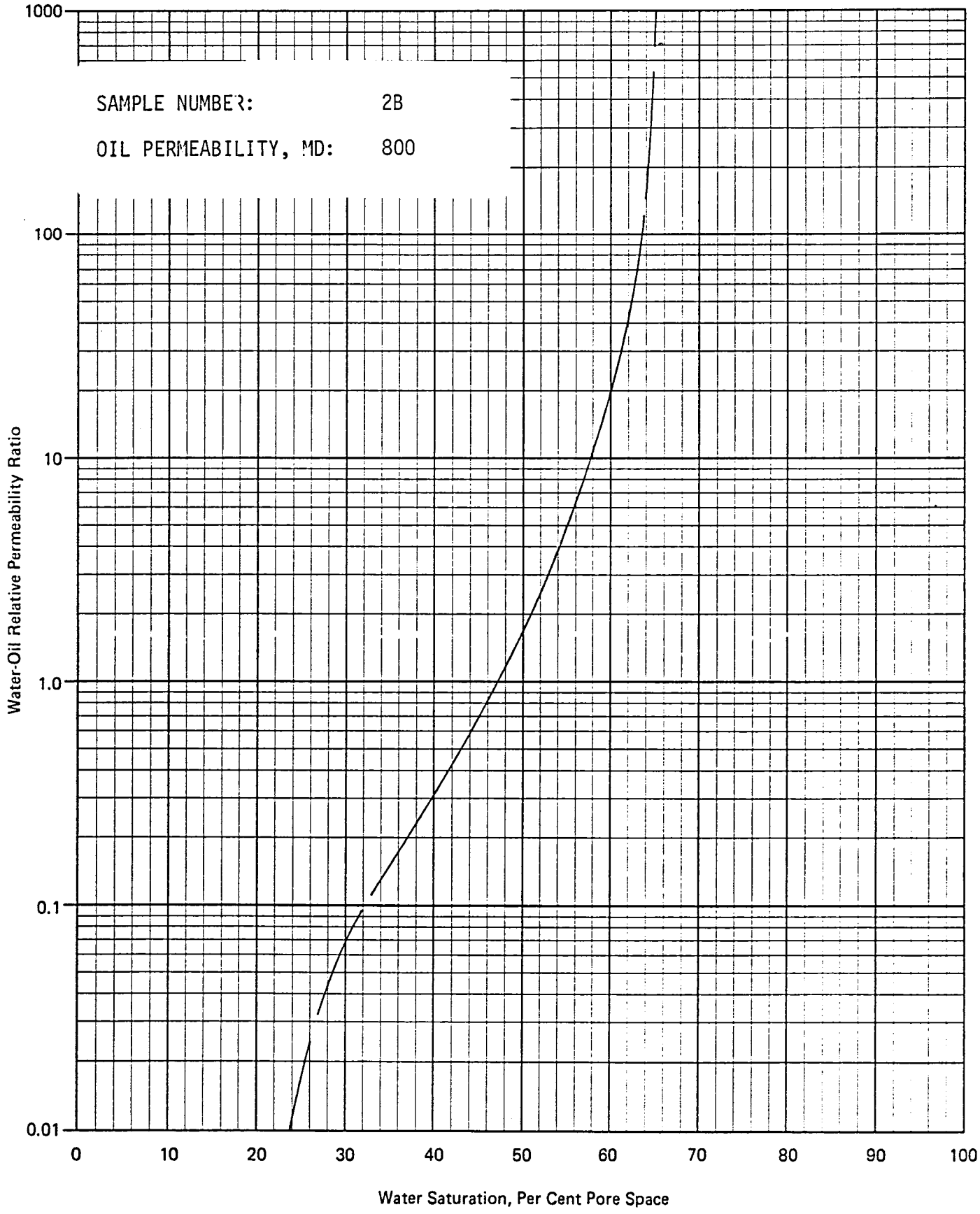
Porosity, Per Cent: 36.2

| Water Saturation Per Cent Pore Space | Water-Oil Relative Permeability Ratio | Relative Permeability To Water*, Fraction | Relative Permeability To Oil*, Fraction |
|---|---|---|---|
| 23.2 | .000 | .000 | 1.000 |
| 46.0 | .283 | .066 | .232 |
| 50.5 | .559 | .090 | .161 |
| 54.3 | 1.08 | .110 | .102 |
| 59.1 | 2.98 | .134 | .045 |
| 60.7 | 4.33 | .143 | .033 |
| 63.0 | 9.06 | .154 | .017 |
| 65.0 | 18.5 | .166 | .0090 |
| 66.1 | 30.4 | .174 | .0057 |
| 67.5 | 63.7 | .182 | .0029 |
| 68.2 | 109 | .185 | .0017 |
| 70.3 | - | .204 | .0000 |

* Relative to Oil Permeability

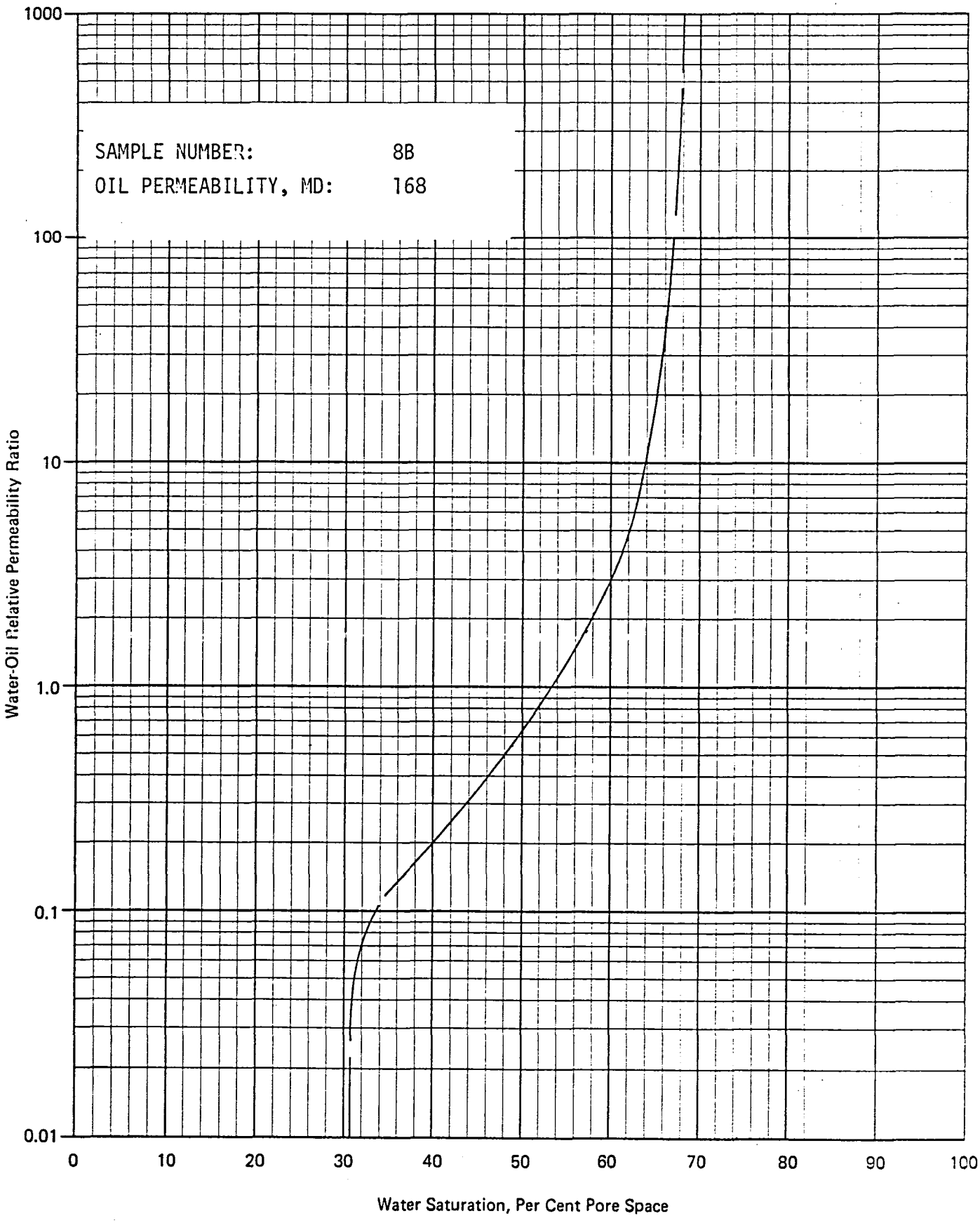
Company NORSKE SHELL EXPL. & PROD
Well 31/2-2
Field

Formation
Country NORWAY



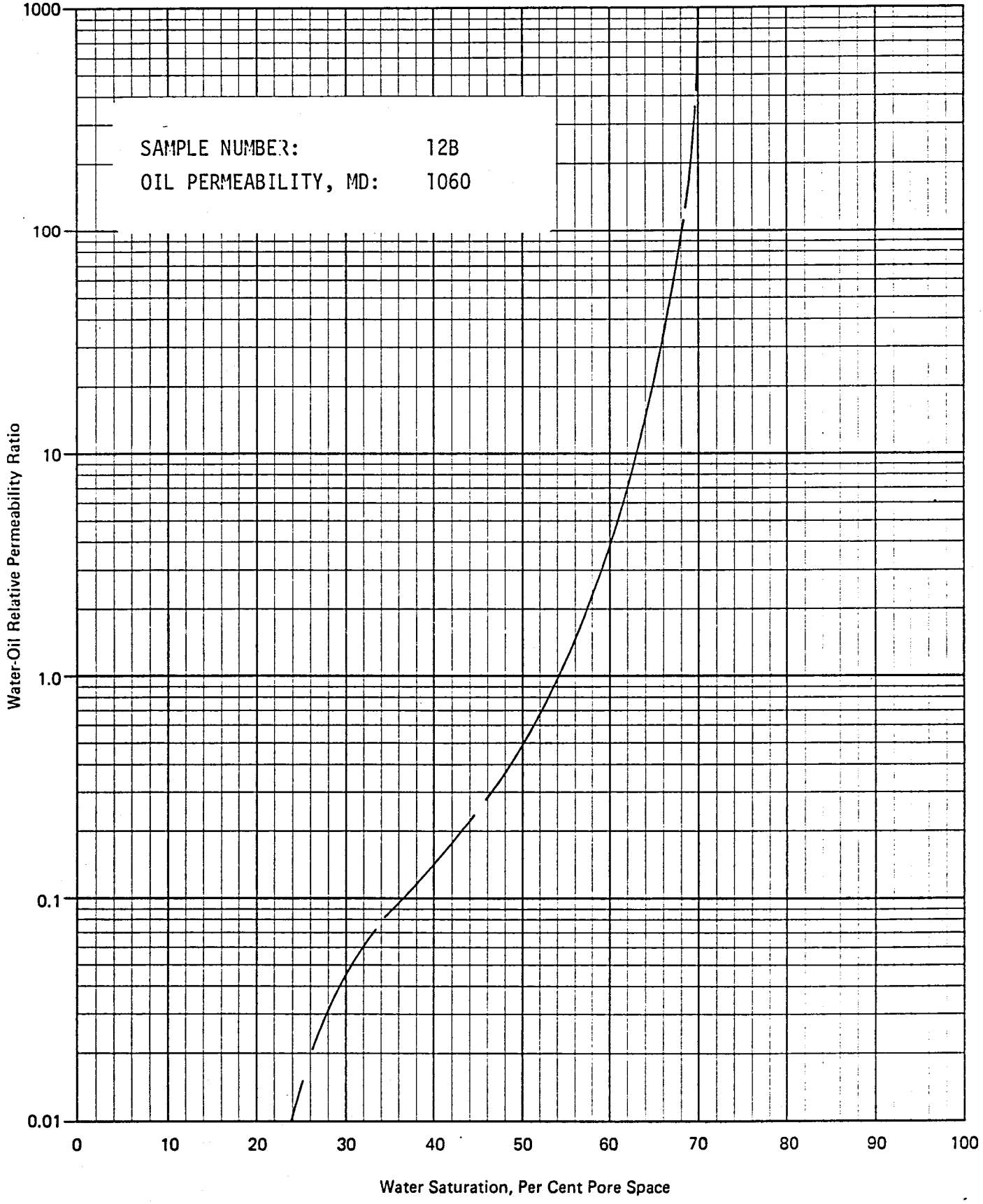
Company NORSKE SHELL EXPL. & PROD
Well 31/2-2
Field

Formation
Country NORWAY



Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY



Company NORSKE SHELL EXPL. & PROD
Well 31/2-3
Field

Formation
Country NORWAY