SPECIAL CORE ANALYSIS STUDY

FOR

STATOIL

WELL: 34/10-3

CORE LABORATORIES UK LTD.

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KOH/js

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Norway.

January, 1980.

Attention: Karl Sigurd Årland

Subject: Special Core Analysis Study
Well: 34/10-3
North Sea,
Norway.
File: UKSCAL 7932

Gentlemen,

In a letter dated the 20th June, 1979 from Karl Sigurd Årland of Statoil to our Keith Hughes, Core Laboratories UK Limited were requested to perform a series of special core analysis measurements on core samples from the subject well. The results of these measurements are presented herein and serve to confirm those already submitted in preliminary form.

In preparation for the study five full diameter preserved core samples were provided by Statoil. Cylindrical plug samples of one and a half inches diameter were cut from the core pieces using synthetic formation brine as a drilling lubricant. This brine consisted of approximately 48,400 mg/l sodium chloride and was synthesised from information provided by Statoil. The

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plug samples were poorly consolidated and very friable so required careful handling, and they are described with respect to depth and lithology on page 1 of this report.

The samples were extracted and leached in cool solvents then dried in an humidity controlled oven before measurement of air permeability and helium injection porosity.

Air-Brine Capillary Pressure Data (Page 2)

One plug sample from each of the five core pieces was selected to undergo air-brine capillary pressure measurements. The clean, dry samples were evacuated and pressure saturated with synthetic formation brine. The plugs were then placed in a porous plate cell and humidified nitrogen introduced at increasing incremental pressures up to 200 psi. At equilibrium saturations the samples were removed from the cell and the brine saturations determined gravimetrically.

Sample numbered 3A collapsed during analysis due to it's very friable nature. The results of the measurements are presented in tabular form on page 2 and in graphical form on pages 3 through 6.

Formation Factor and Resistivity Index Data (Page 7)

Prior to performing capillary pressure measurements electrical resistivities of the brine saturated samples and the saturant brine were measured. The measurements were repeated on consecutive days until the results stabilised indicating ionic equilibrium within the core samples.

Formation resistivity factors were calculated and the results are presented in tabular form on page 7 and in graphical form on page 8. The resultant plot yields a value of unity for the intercept 'a' and an average value of 1.75 for the cementation exponent 'm'.

Electrical resistivities of the partially saturated plugs were measured in conjunction with the capillary pressure measurements. Resistivity index values were calculated and the results are presented in tabular form on page 7 and in graphical form on pages 9 through 13. The resultant plots yield values of 'n' the saturation exponent ranging from 1.42 to 2.10 with an average of 1.95.

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Formation Resistivity Factor as a Function of Overburden Pressure (Page 14)

Following resistivity index measurements the plug samples were again leached then dried in an humidity controlled oven, and underwent measurement of air permeability and helium injection porosity. The samples were evacuated and pressure saturated with synthetic formation brine then mounted in an hydraulic core holder. Electrical resistivities of the samples were measured at effective overburden pressures of 200 psi and 500 psi while maintaining a constant internal pore pressure of 200 psi.

Pore volume reductions with the application of increasing overburden pressure were monitored by the measurements of brine displaced from the samples.

The results are presented in tabular form on page 14 and in graphical form on pages 15 and 16. The resultant plots yield values of unity for 'a' the intercept and values of 2.00 and 2.01 for 'm' the cementation exponent.

Water Permeability as a Function of Overburden Pressure (Page 17)

Following formation factor measurements as a function of overburden pressure the plugs were allowed to stand submerged in synthetic formation brine for one week to allow for hysteresis effects. The samples were then mounted in an hydraulic core holder and permeability to synthetic formation brine measured at effective overburden pressures of 200 psi and 500 psi. Reverse flow direction permeability was measured while the plug was still under 500 psi effective overburden pressure. The results of these measurements are presented in tabular form on page 17.

Rock Compressibility Data (Page 18)

Due to the poorly consolidated and very friable nature of the core samples, only one plug was available for rock compressibility measurements. The clean, dry sample was mounted in heat shrinkable tubing, placed in an hydraulic core holder, and saturated with a brine consisting of 31,000 mg/L sodium chloride.

External and internal pressure were raised to 5520 psi and 5320 psi respectively and, having reached pressure stabilisation, the internal pore pressure was reduced incrementally to simulate reservoir depletion

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and corresponding pore volume reductions recorded. Compressibilities were calculated from a plot of pore volumes versus effective overburden pressure and, from the curve, the instantaneous change in pore volume per unit overburden pressure was determined. The resultant compressibilities were corrected for uniaxial loading[1], and the data is presented in tabular form on page 18.

It has been a pleasure working with Statoil on this study. Should you have any questions, or if we can be of any further assistance, please do not hesitate to contact us.

Yours faithfully,
CORE LABORATORIES UK LIMITED

K.O. Hughes

Keith O. Hughes
Laboratory Manager of Special Core Analysis

[1] Uniaxial loading conditions transformed from hydrostatic data as per Teeuw, Dirk: "Prediction of Formation Compaction from Laboratory Compressibility Data." Trans AIME (1971) 251, 263-271.

TABLE OF CONTENTS

**CORE LABORATORIES UK LTD.**
*Petroleum Reservoir Engineering*
LONDON—ABERDEEN



File: UKSCAL 7932

COMPANY: STATOIL
WELL: 34/10-3
FIELD:

FORMATION:
COUNTY:
STATE: NORWAY

## Identification and Description of Samples

| Sample Number | Depth, Metres | Lithological Description |
|---|---|---|
| 1B | 1937.03 | sst, cream-brn, med coarse g, v sft, subang-subrdd, frly wl std, v prly cmt, tr carb mat, med high mica cont. |
| 2A | 1965.62 | sst, cream-brn, f-mg, v sft, subang-subrdd, frly wl std, prly cmt, low-med mica cont, sevrl lrge fracs. |
| 3A | 1972.68 | sst, cream-brn, f-mg, v sft, subrdd, frly wl std, v prly cmt, tr carb mat occrng in bnds across plug, tending to fracs parallel to these, low mica cont. |
| 4A | 1993.97 | sst, brn, vcg, v sft, and frly wl std, prly cmt, tr carb mat, tr mica. |
| 5A | 2005.90 | sst, cream-brn, f-mg, soft, subrdd-subang, frly wl std, prly cmt, tr carb mat, tr mica. |
| 5B | 2006.07 | A.A. |

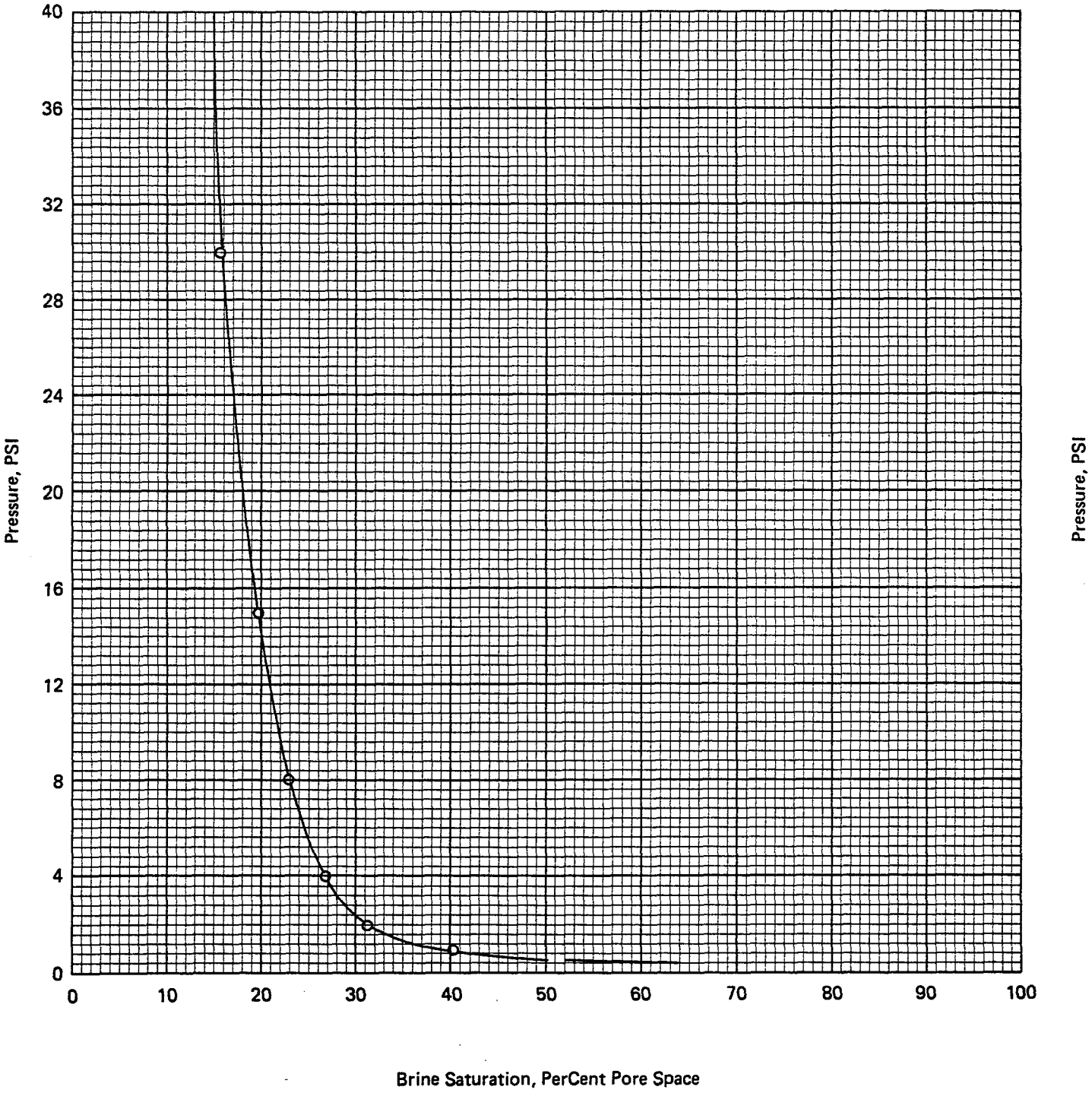
## AIR-BRINE CAPILLARY PRESSURE DATA

| Sample Number | Permeability Millidarcys | Porosity Per Cent | Brine Saturation, Per Cent Pore Space | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Pressure, PSI: | | | 1 | 2 | 4 | 8 | 15 | 30 | 200 |
| 4A | 7520 | 34.2 | 40.2 | 31.2 | 26.7 | 22.8 | 19.7 | 15.7 | 13.1 |
| 5A | 722 | 32.3 | 75.9 | 56.9 | 36.5 | 31.1 | 26.8 | 23.5 | 20.4 |
| 1B | 134 | 32.5 | 100.0 | 86.5 | 70.0 | 56.8 | 46.6 | 38.9 | 35.1 |
| 2A | 110 | 32.7 | 100.0 | 100.0 | 90.4 | 69.8 | 55.5 | 46.5 | 44.7 |

Sample Number 3A Collapsed During Analysis

Company STATOIL Formation
Well 34/10-3 Country NORWAY
Field

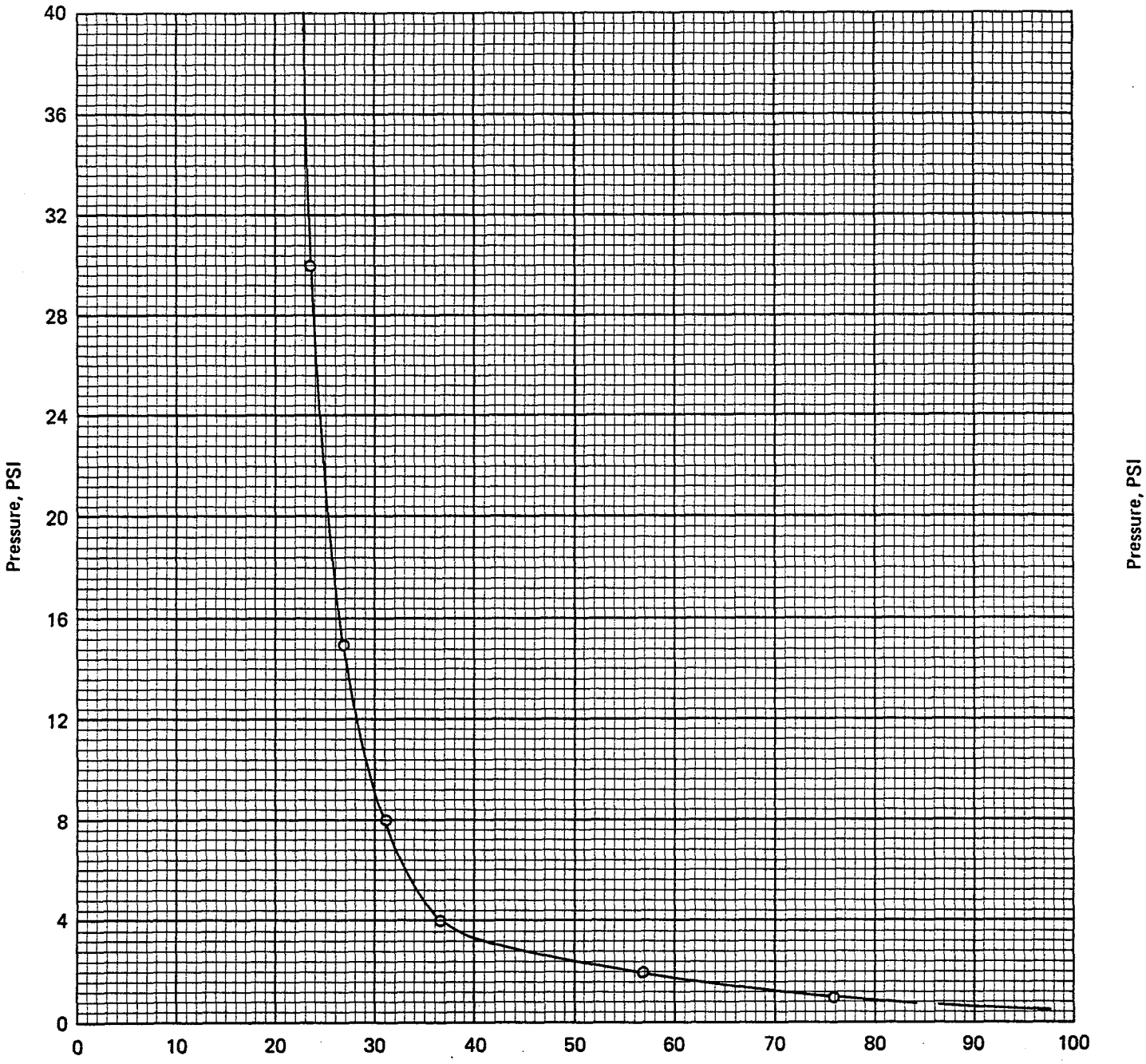
SAMPLE NUMBER: 4A
AIR PERMEABILITY,MD: 7520



Company STATOIL
Well 34/10-3
Field

Formation
Country NORWAY

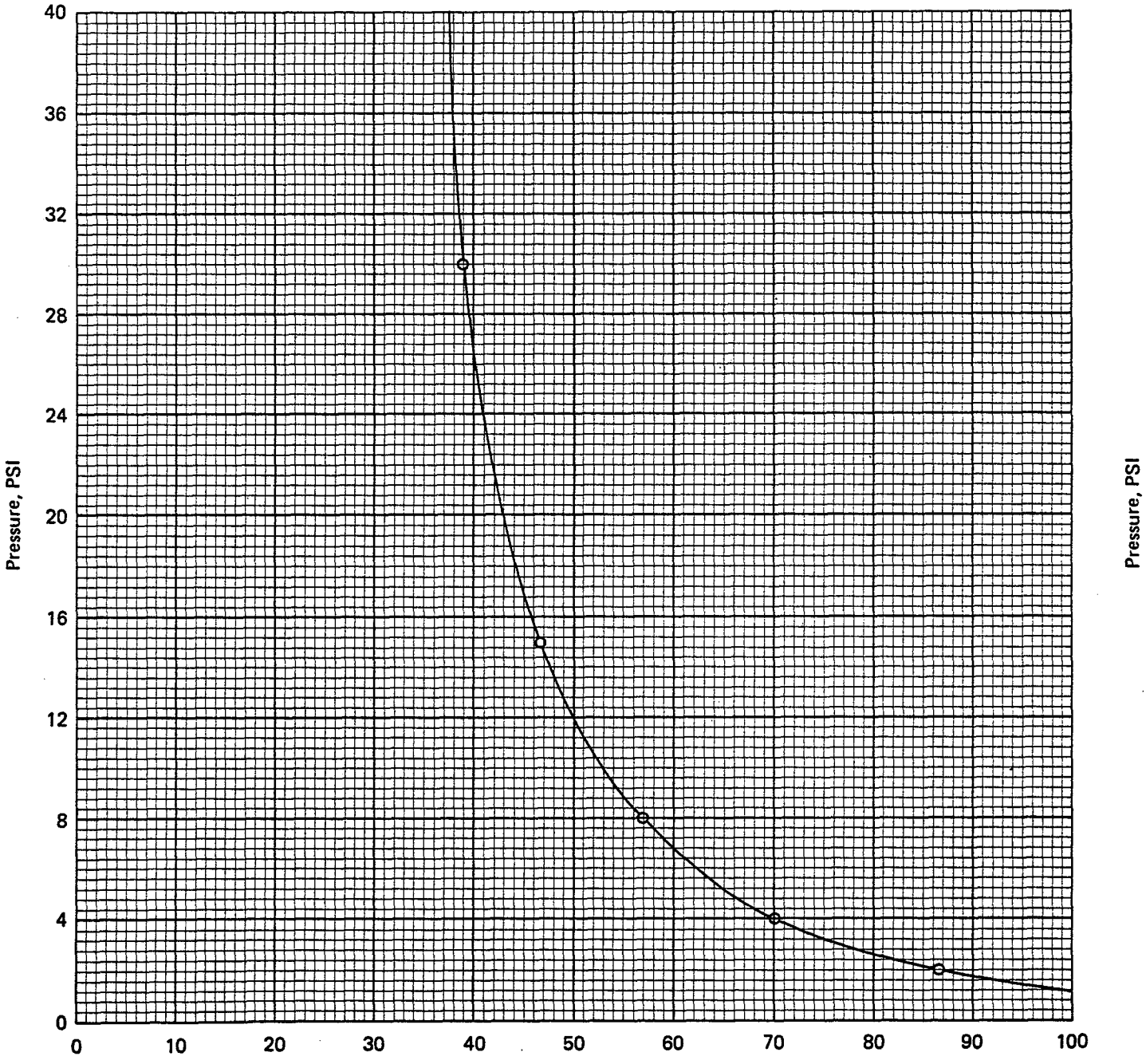
SAMPLE NUMBER: 5A
AIR PERMEABILITY,MD: 722



Company STATOIL
Well 34/10-3
Field

Formation
Country NORWAY

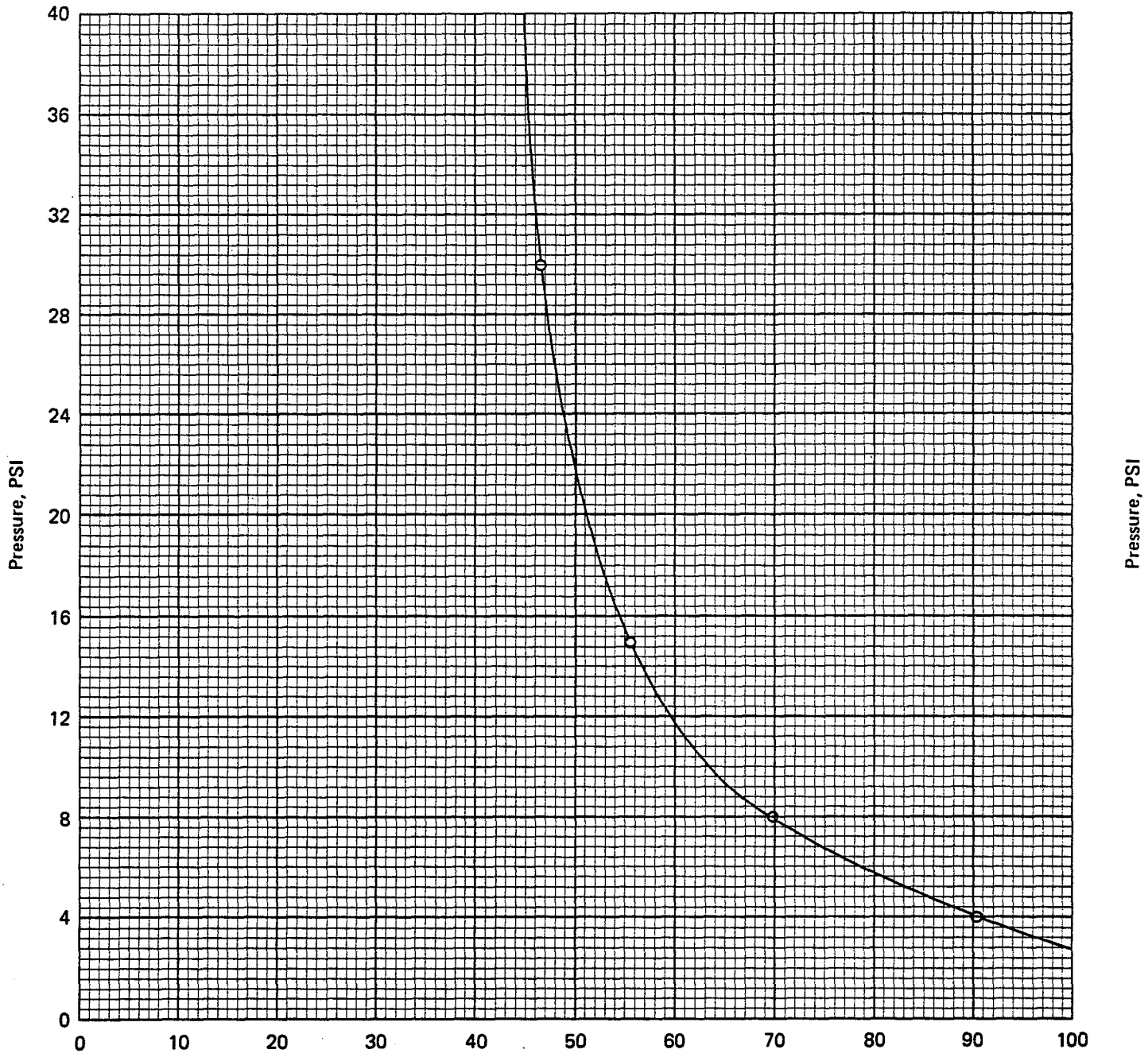
SAMPLE NUMBER: 1B
AIR PERMEABILITY,MD: 134



Company STATOIL
Well 34/10-3
Field

Formation
Country NORWAY

SAMPLE NUMBER: 2A
AIR PERMEABILITY,MD: 110



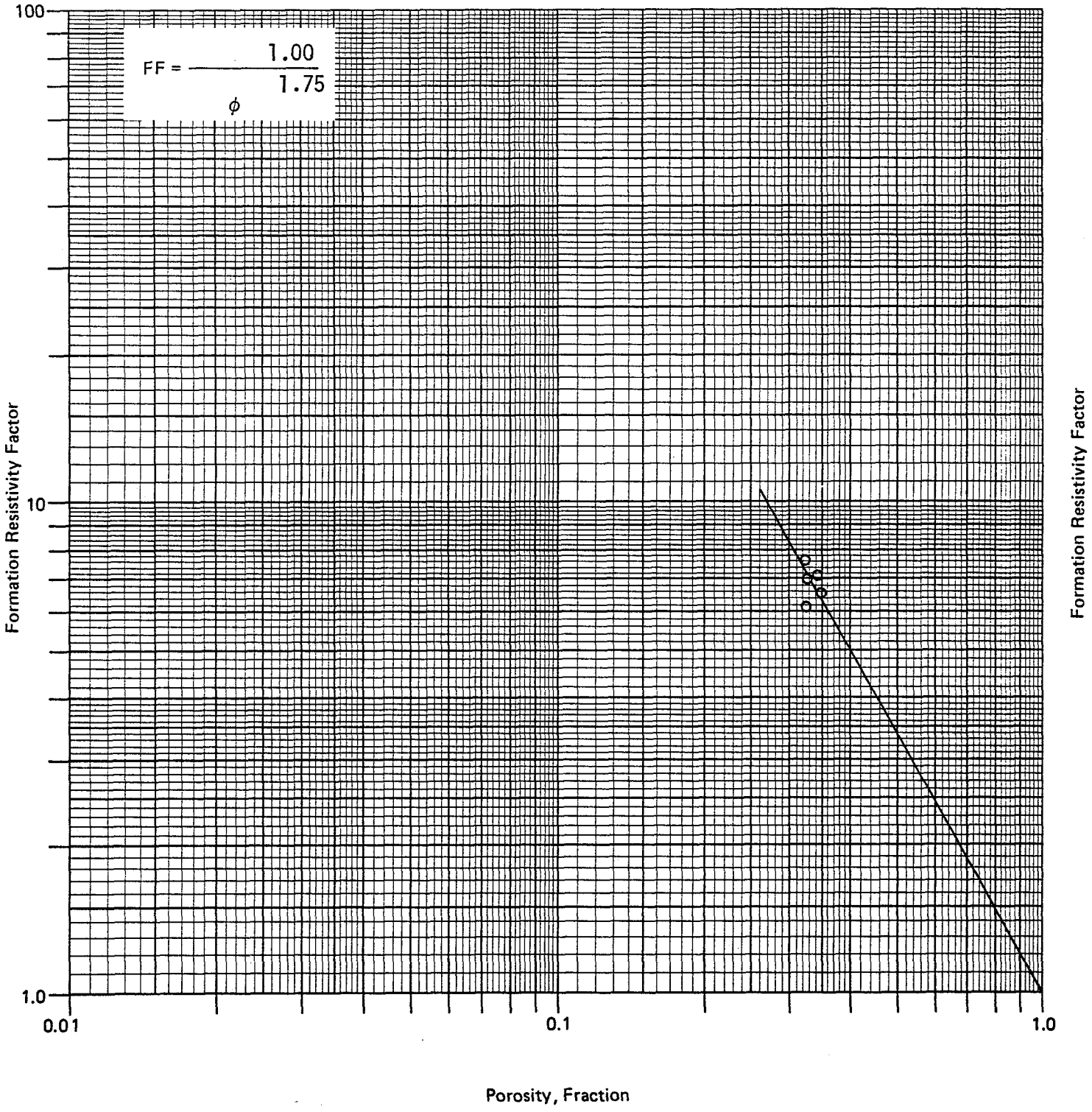
## FORMATION FACTOR AND RESISTIVITY INDEX DATA

Resistivity of Saturating Brine, Ohm-Meters: .202 @ 60°F

| Sample Number | Air Permeability Millidarcys | Porosity Per Cent | Formation Factor | Brine Saturation Per Cent Pore Space | Resistivity Index |
|---|---|---|---|---|---|
| 3A* | 209 | 34.8 | 6.6 | 100.0 | 1.00 |
| 4A | 7520 | 34.2 | 7.1 | 100.0 | 1.00 |
| | | | | 40.2 | 9.98 |
| | | | | 31.2 | 11.6 |
| | | | | 26.7 | 17.5 |
| | | | | 22.8 | 20.4 |
| | | | | 19.7 | 31.5 |
| | | | | 13.1 | 66.9 |
| 2A | 110 | 32.7 | 7.0 | 100.0 | 1.00 |
| | | | | 90.4 | 1.22 |
| | | | | 69.8 | 1.82 |
| | | | | 55.5 | 2.37 |
| | | | | 46.5 | 3.04 |
| | | | | 44.7 | 3.13 |
| 1B | 134 | 32.5 | 6.1 | 100.0 | 1.00 |
| | | | | 86.5 | 1.36 |
| | | | | 70.0 | 1.95 |
| | | | | 56.8 | 2.96 |
| | | | | 46.6 | 4.11 |
| | | | | 38.9 | 8.08 |
| | | | | 35.1 | 10.6 |
| 5A | 722 | 32.3 | 7.6 | 100.0 | 1.00 |
| | | | | 75.9 | 1.48 |
| | | | | 56.9 | 3.08 |
| | | | | 36.5 | 6.74 |
| | | | | 31.1 | 7.65 |
| | | | | 26.8 | 10.9 |
| | | | | 23.5 | 15.0 |
| | | | | 20.4 | 23.0 |

* Sample Failed

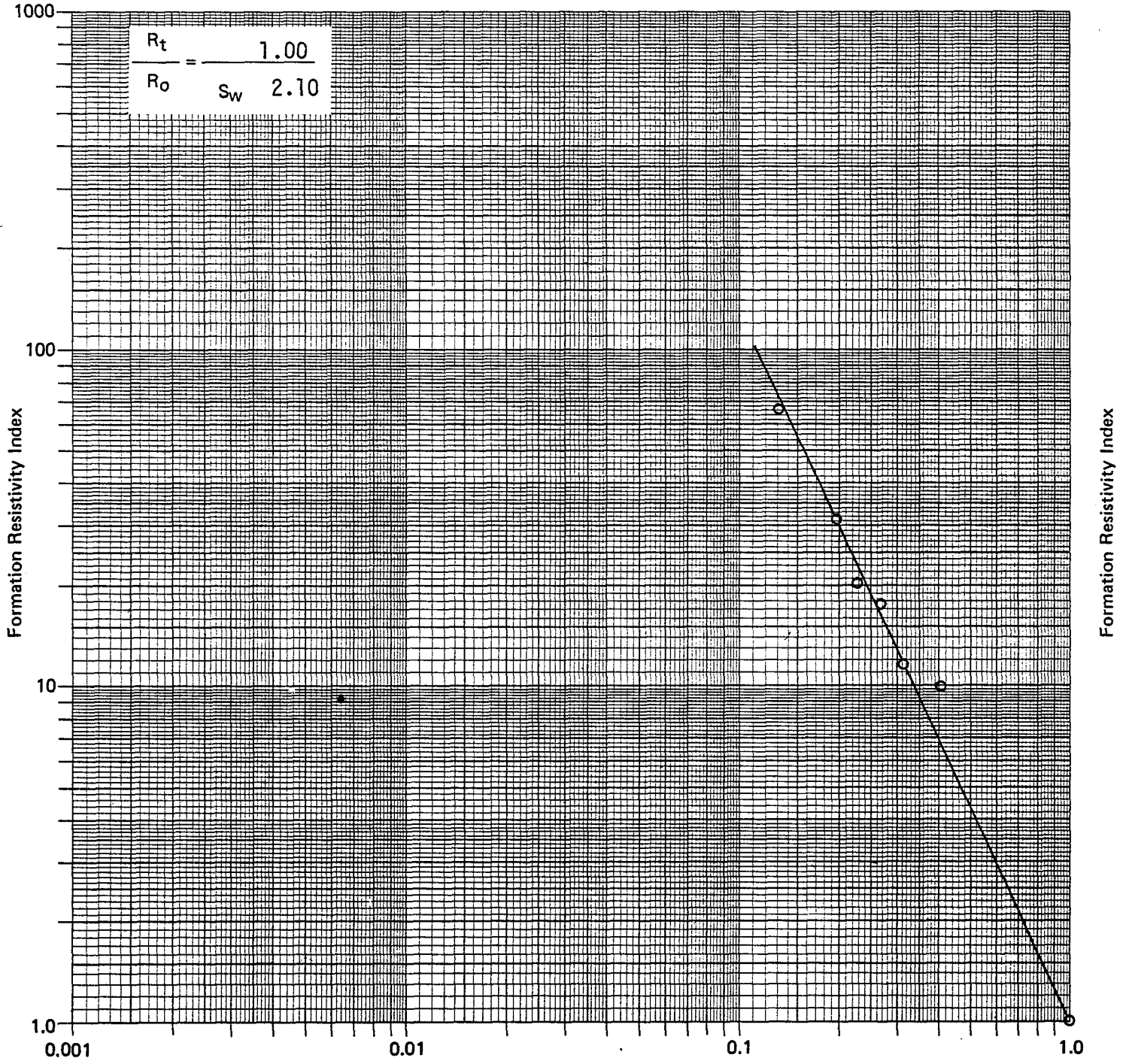
Company STATOIL Formation
Well 34/10-3 Country NORWAY
Field



Company STATOIL
Well 34/10-3
Field

Formation
Country NORWAY

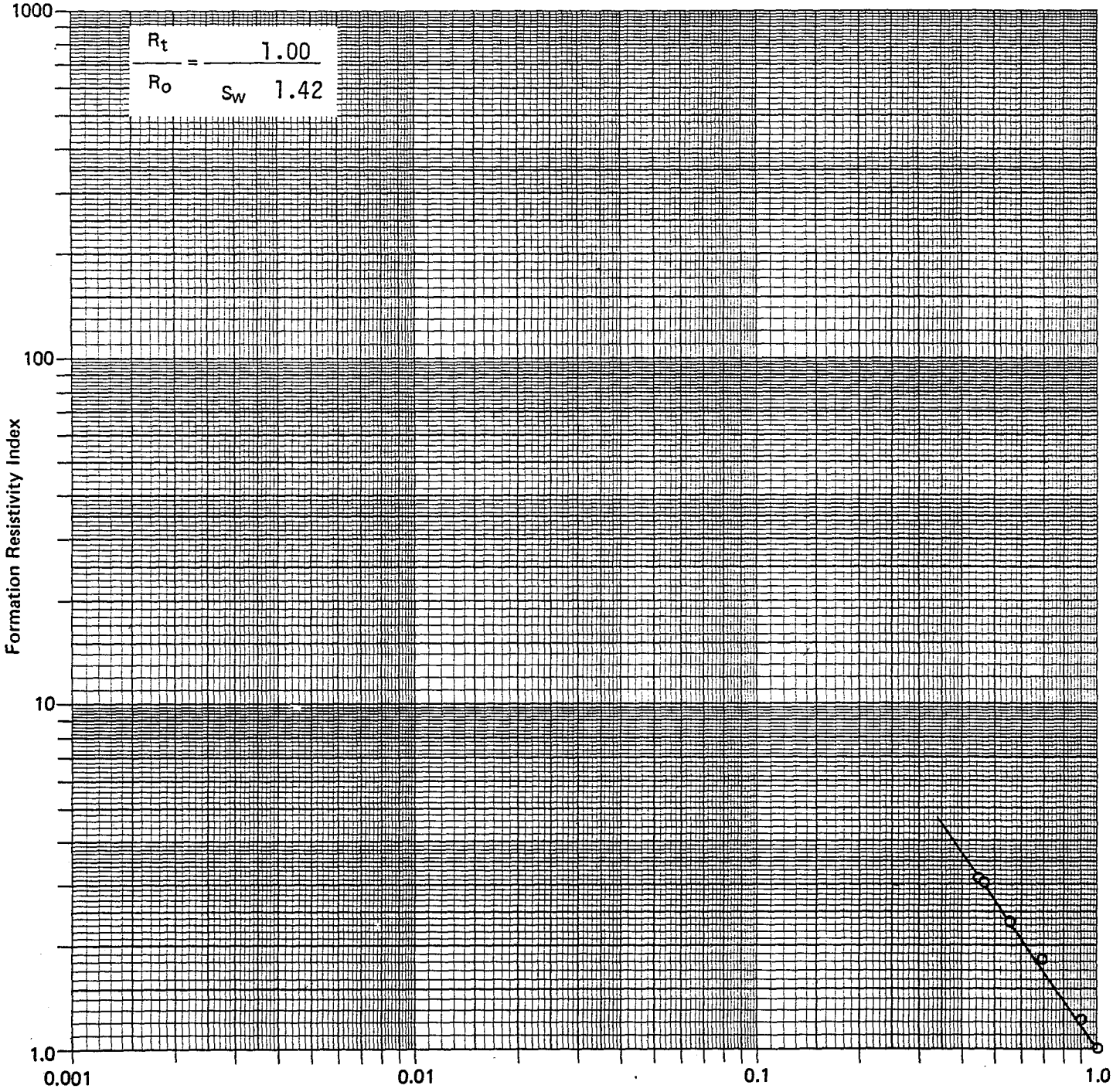
SAMPLE NUMBER: 4A



Company STATOIL
Well 34/10-3
Field

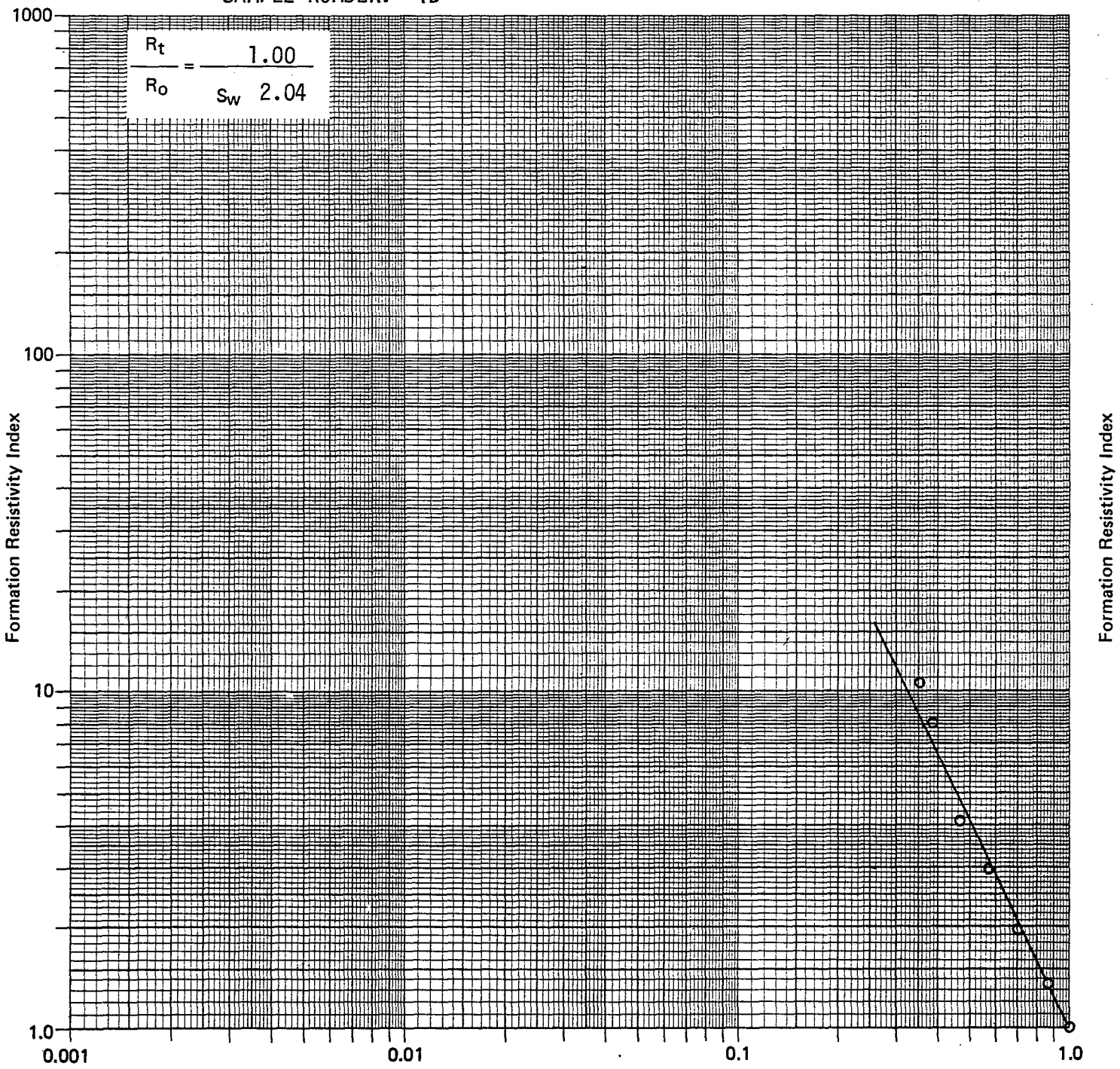
Formation
Country NORWAY

SAMPLE NUMBER: 2A



Company STATOIL Formation
Well 34/10-3 Country NORWAY
Field

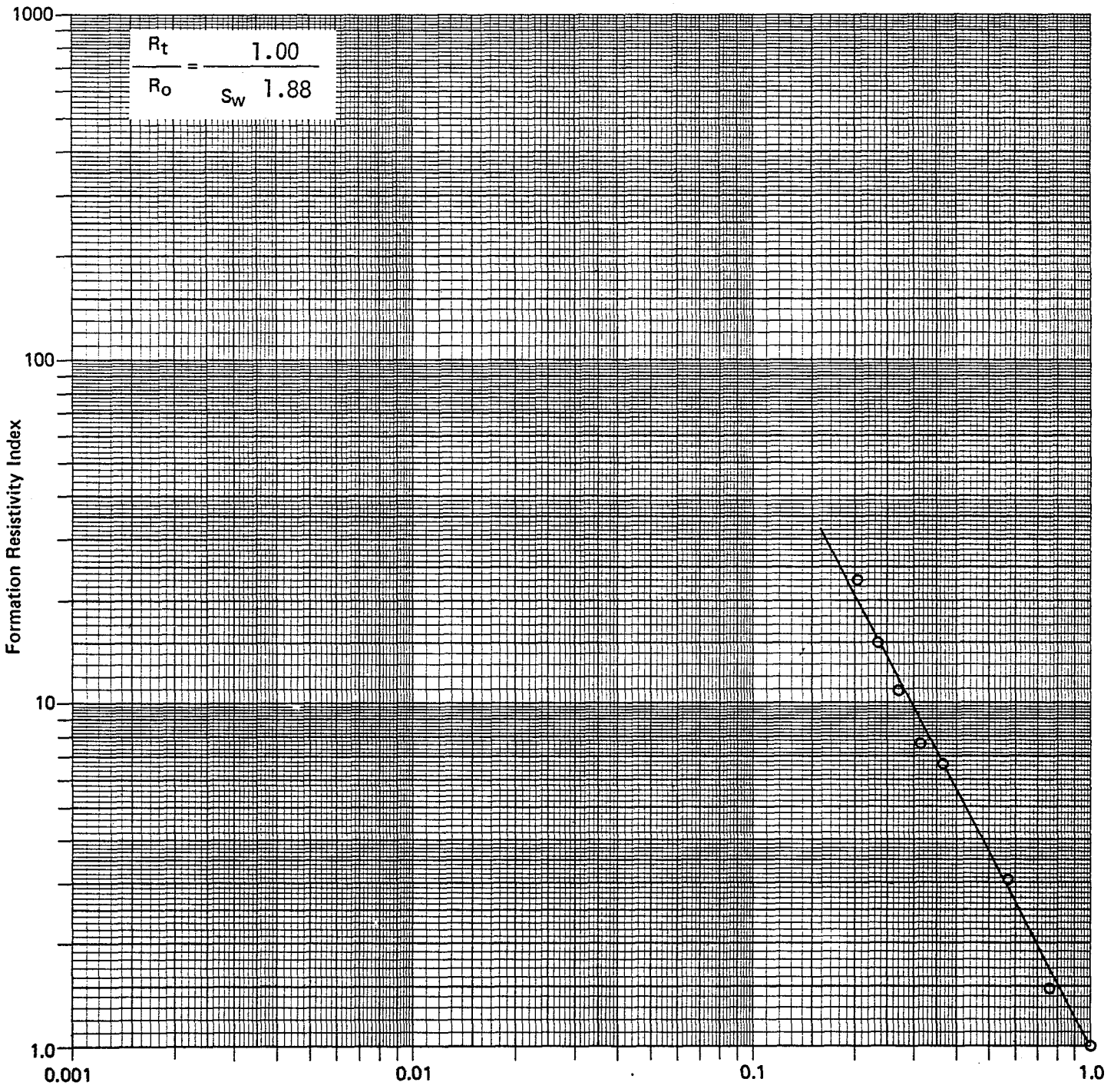
SAMPLE NUMBER: 1B



Company STATOIL
Well 34/10-3
Field

Formation
Country NORWAY

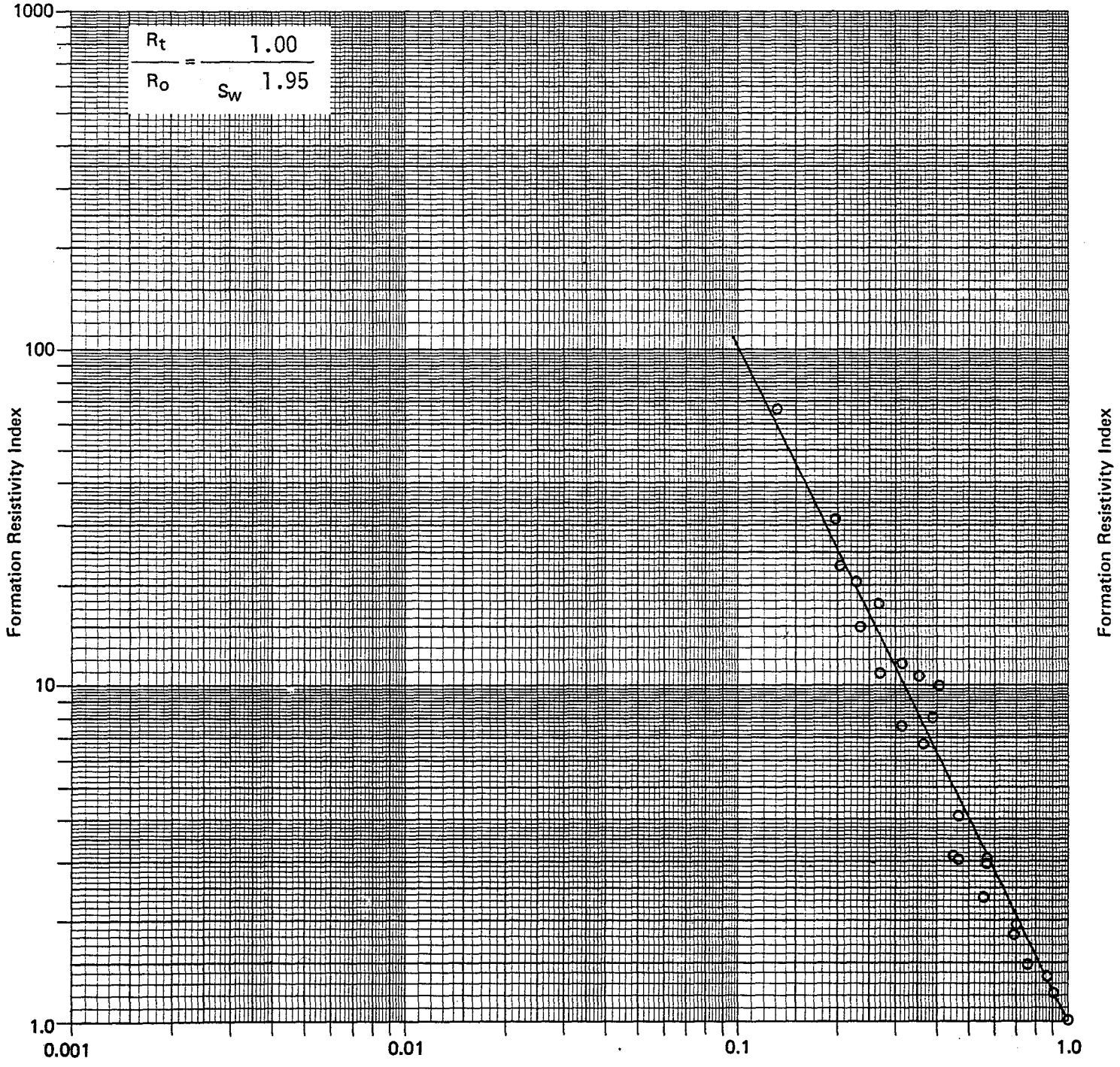
SAMPLE NUMBER: 5A



Company STATOIL
Well 34/10-3
Field

Formation
Country NORWAY

COMPOSITE



## FORMATION RESISTIVITY FACTOR AS A FUNCTION OF OVERBURDEN PRESSURE

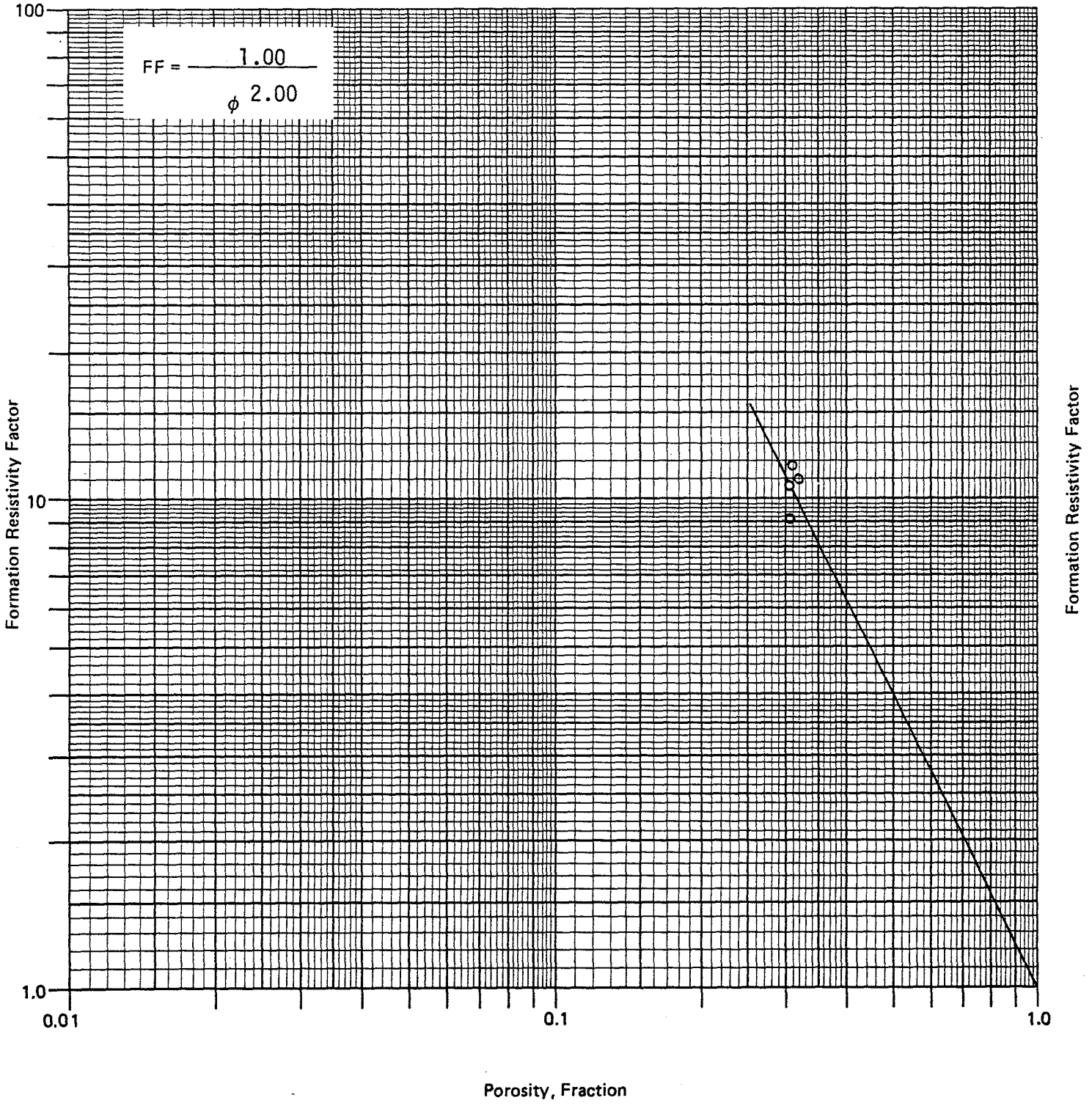
Resistivity of Saturatine Brine, Ohm-Meters: .202 @ 60°F

Internal Pore Pressure for Formation Resistivity Factor, Psi : 200

| | Effective Overburden Pressure, PSI | | | |
|---|---|---|---|---|
| | 200 | | 500 | |
| Sample Number | Porosity Per Cent | Formation Factor | Porosity Per Cent | Formation Factor |
| 4A | 31.8 | 11.0 | 30.8 | 11.9 |
| 5A | 30.9 | 11.4 | 29.1 | 12.8 |
| 2A | 30.5 | 9.1 | 29.8 | 9.7 |
| 1B | 30.4 | 10.4 | 29.6 | 11.2 |

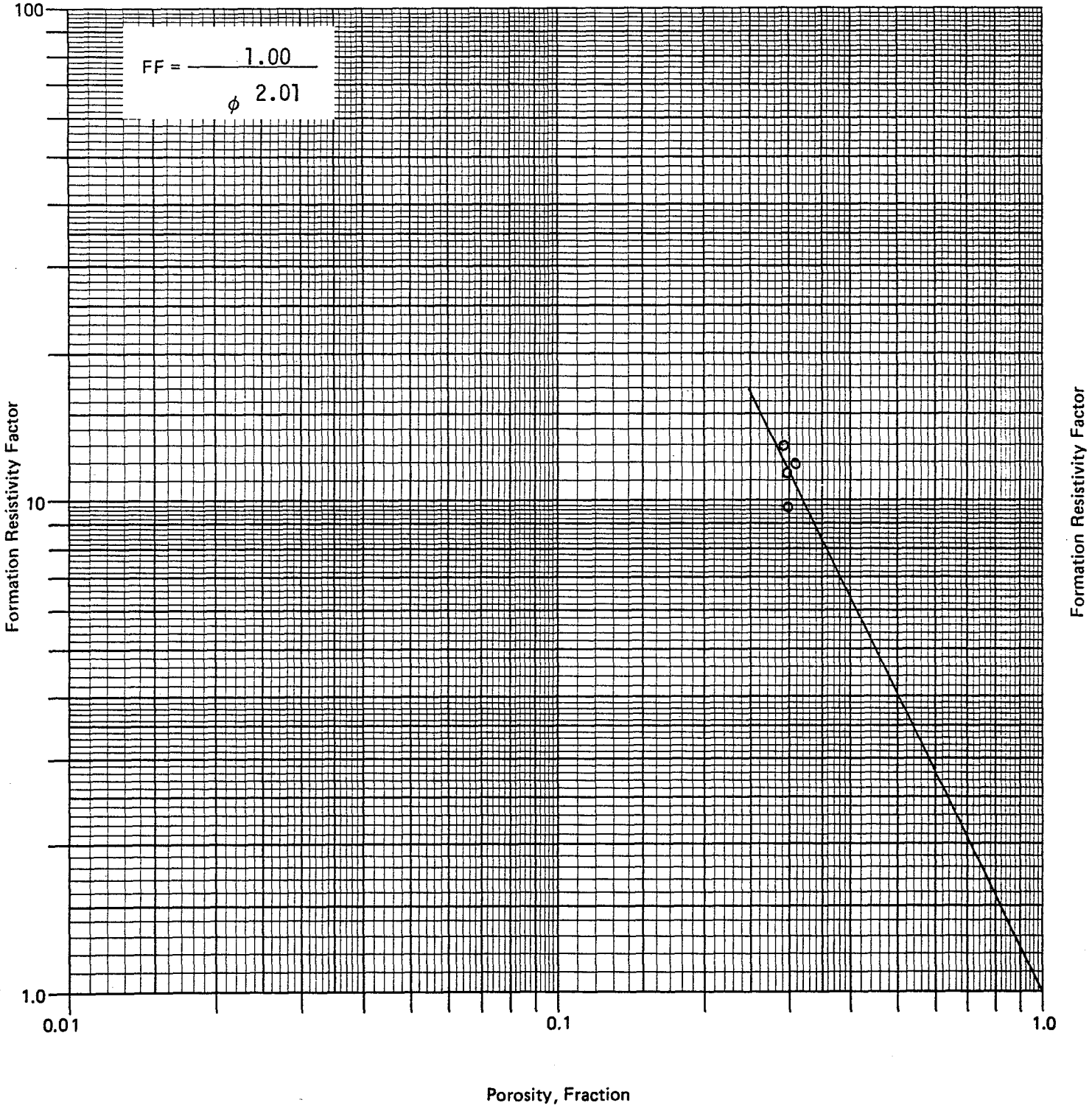
Company STATOIL Formation
Well 34/10-3 Country NORWAY
Field

EFFECTIVE OVERBURDEN PRESSURE, PSI: 200



Company STATOIL Formation
Well 34/10-3 Country NORWAY
Field

EFFECTIVE OVERBURDEN PRESSURE, PSI: 500



## WATER PERMEABILITY AS A FUNCTION OF OVERBURDEN PRESSURE

| Sample Number | Air Permeability Millidarcys | Porosity Per Cent | Effective Overburden Pressure, PSI | Water Permeability Millidarcys |
|---|---|---|---|---|
| 4A | 7400 | 34.2 | 200 | 2100 |
| | | | 500 | 1240 |
| | | | 500 | 1200* |
| 5A | 730 | 32.3 | 200 | 227 |
| | | | 500 | 99 |
| | | | 500 | 95* |
| 1B | 126 | 32.5 | 200 | 11 |
| | | | 500 | 5.3 |
| | | | 500 | 5.5* |
| 2A | 117 | 32.7 | 200 | 14 |
| | | | 500 | 8.3 |
| | | | 500 | 8.4* |

* Measured in reverse direction of flow.

## ROCK COMPRESSIBILITY DATA

| Sample Number | Pressure, PSI: Initial External | Pressure, PSI: Effective Overburden | Pore Volume,cc | Bulk Volume,cc | Porosity, Per Cent | Compressibility,PV/PV/PSIX10$^{-6}$ (1) | Compressibility,PV/PV/PSIX10$^{-6}$ (2) |
|---|---|---|---|---|---|---|---|
| 5B (Ramsay) 5520 | | 200 | 13.88 | 45.07 | 30.8 | - | - |
| | | 500 | 13.83 | 45.02 | 30.7 | 11.1 | 6.8 |
| | | 750 | 13.80 | 44.99 | 30.7 | 11.6 | 7.1 |
| | | 1000 | 13.75 | 44.94 | 30.6 | 12.0 | 7.3 |
| | | 2000 | 13.58 | 44.77 | 30.3 | 13.2 | 8.1 |
| | | 3000 | 13.40 | 44.59 | 30.1 | 14.8 | 9.0 |
| | | 4000 | 13.18 | 44.37 | 29.7 | 17.1 | 10.4 |

(1) Measured in laboratory under hydrostatic Loading conditions.
(2) Uniaxial loading conditions, transformed from hydrostatic data as per Teeuw, Dirk: "Prediction of Formation Compaction from Laboratory Compressibility Data," Trans., AIME (1971) 251, 263-271.