ROBERTSON RESEARCH INTERN

SPECIAL CORE ANALYSIS STUDY FOR STATOIL-DEN NORSKE STATS OLJESELSKAP A.S. WELL: 15/9 - 11 NORWEGIAN NORTH SEA

TECHNICAL REPORT

Heimdal im.

CONTENTS

1. INTRODUCTION

This Final Report comprises the results of Special Core Analysis tests performed on a suite of samples from well 15/9-11. The plug samples were received on the 23rd November 1981 and were accompanied by a letter from Mr J Ringen and identified by your reference: LAB:JKR/AB.

The report includes results from the following tests; (1) Helium porosity measurement (2) Gas permeability measurement at three mean pressures and extrapolated to infinite mean pressure to determine Klinkenberg permeability (3) Formation Factor determination (4) Capillary Pressure determination by the Air-Brine, steady state, porous plate cell method (5) Resistivity Index measurement with 'n-exponent' determination and (6) Residual gas determination by waterflooding.

All procedures followed in making the above measurements are outlined in detail in section 2 of this report, pages 3 to 13. The results of the tests are presented in both tabular and graphical form (where appropriate) in Sections 4, 5, 6 and 7.

2

SPECIAL CORE ANALYSIS PROCEDURES

2:1 SAMPLE PREPARATION

Seven one and one half inch plugs were received for inclusion in Special Core Analysis testing. Each sample was trimmed to a length of approximately two and one half inches using a 120,000 p.p.m.NaCl solution as saw coolant.

Each plug was extracted of residual reservoir/drilling fluids with a low boiling point solvent (Toluene/Methanol mixture) and the residual soluble salts were leached with methanol. The samples were carefully dried at a temperature of 60°C and in a humidity controlled atmosphere set for 40% relative humidity.

2:2 HELIUM POROSITY AND KLINKENBERG PERMEABILITY MEASUREMENT

Following completion of cleaning and drying procedures the porosity of each sample was determined by the Boyle's Law, Helium expansion method. Gas permeability was measured at the following three mean pressures; 1.0, 2.0 and 3.4 bars. For each sample a plot of gas permeability versus the reciprocal of the mean pressure was drawn and the gradient extrapolated to determine Klinkenberg permeability (K_L). The mean pressures, gas permeabilities and Klinkenberg permeabilities for each sample are presented in tabular form on page 16.

2:3 FORMATION FACTOR DETERMINATIONS

The seven samples were evacuated and pressure saturated with a simulated formation brine (see page 14 for composition). After allowing the samples to reach equilibrium saturation, the weights were determined and the saturated pore volumes calculated.

The electrical resistivities of the saturating brine and of the seven samples were measured. Each measurement was repeated over a period of several days until they stabilized, indicating that ionic equilibrium within the sample had been attained. The Formation Factor of each sample was then calculated from these resistivities. A graph of Formation Factor versus Porosity Fraction was plotted and the cementation factor 'm' and intercept 'a' determined.

The Formation Factor Values are presented in tabular form on pages 27 and 28. The Formation Factor versus Porosity Fraction plot is presented on page 29. Two gradients have been included and identified as 1 and 2, each being accompanied by respective cementation factor 'm' and intercept 'a' values. Gradient 1 is a statistically assessed 'best-fit' line including all sample data points. Gradient 2 is a statistically 'best-fit' line including all sample data points except

for sample 21A. This sample is atypical of the suite.

2:4 AIR-BRINE CAPILLARY PRESSURE

Porous Plate Cell, Steady State Method

On completion of Formation Factor measurements the seven samples were loaded onto a brine saturated, porous plate, in a cell arranged for air-brine, steady state capillary pressure testing.

The levels of desaturation were recorded at each of the specified applied pressures (0.1, 0.2, 0.4, 0.7, 1.5 and 12 bars) after allowing the system to reach a steady-state and equilibrium at each pressure.

The results of the capillary pressure determinations are reported in tabular form on page 18 and in graphical form on pages 19 to 26.

2:5 RESISTIVITY INDEX DETERMINATIONS

Resistivity Index determinations were made in conjunction with the air-brine capillary pressure measurements. At each point of steady-state desaturation the samples were removed from the porous plate cell, weighed and the electrical resistivity measured.

For each resistivity measurement the Resistivity Index was calculated and plotted against the appropriate, measured, brine saturation. For each sample the plot gradient and thus saturation exponent 'n' was determined.

Resistivity Index values and respective brine saturations are presented in tabular form on pages 27 to 28, and in graphical form on pages 29 to 36.

2:6 RESIDUAL GAS DETERMINATION

The samples from the Steady-State capillary pressure test were wrapped in "cling-film" and aluminium foil and stored in a humidified atmosphere prior to testing. The Specific Air Permeability (KA) at Irreducible Water Saturation (Swir) of each sample, was measured using humidified nitrogen prior to mounting in the overburden cell of the Residual Gas Apparatus (Figure 1). The maintenance of the originally obtained Water Saturation (Sw) was verified by intermediate weight checks on the samples, which remained within 0.5 percent pore volume.

The test programme was run in the apparatus detailed in Figure 1. The main components of the flow system are evident from the schematic lay-out. There are two flow paths for the saturated synthetic formation brine to take a) flow-rate setting circuit whilst the overburden cell is isolated either in the loaded or unloaded condition with the sight-gauge always back-pressured to approx. 17 bars, b) test path which is activated by the instantaneous diversion of the set flow rate (4cc/hour) through the mounted and gas saturated sample.

The upstream and downstream plattens are especially designed for low dead-volume (0.3 cc total volume). The downstream end stem is fitted with a unique water breakthrough detector for precise notation

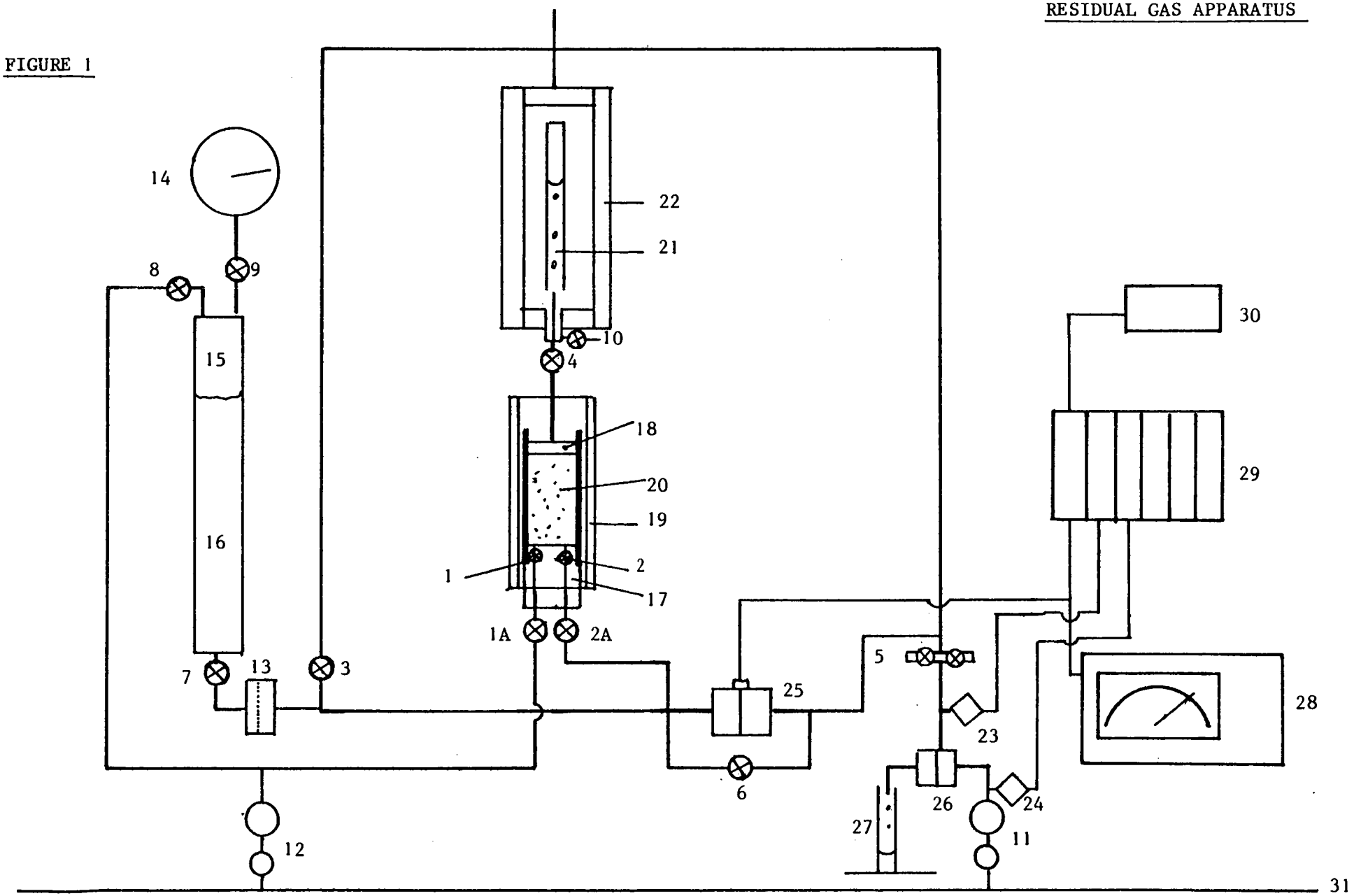
of time. The gas volume collected above water in the burette inside the sight-gauge is calibrated against the liquid effluent emerging from the precision back-pressure regulator. The agreement in the data is better than ±1 percent at the 10cc gas volume level. The elapsed time to water breakthrough was in the order of two and a half hours. The flooding was continued until 2-3 pore volumes of gas saturated brine was flooded normally overnight.

The final Water Permeability (Kw) was measured in duplicate with an agreement better than ±1 percent of the reported value. The Residual Gas value after water breakthrough did not increase at all but during the night there was about 1 percent reduction in the observed value.

During the tests, sample number 8A was inadvertently spoiled by incorrect operation of valve sequence, and therefore Sample No.1A was substituted after consultation with the client.

RESIDUAL GAS APPARATUS

FIGURE 1



SPECIAL CORE ANALYSIS STUDY
STATOIL, NORWAY
WELL 15/9-11

RESIDUAL GAS EVALUATION

LIST OF RESIDUAL GAS APPARATUS COMPONENTS

1&2 - PLATTEN FACE OPERATING VALVE

1A,2A,3,4,6,7,8 & 9 - QUICK ACTION BALL VALVES (⅜ & ¼)

5 - EXTRA FINE METERING VALVE

10 - PURGE VALVE - REGULATING PATTERN

11&12 - PRECISION GAS REGULATING ASSEMBLY

13 - HIGH PRESSURE FILTER (0.45μ)

14 - PRESSURE GAUGE (0-35 bars)

15 - NITROGEN GAS CAP

16 - NITROGEN GAS SATURATED SYNTHETIC FORMATION BRINE

17 - SPECIAL LOW-DEAD VOLUME UP-STREAM PLATTEN

18 - LOW DEAD - VOLUME DOWN - STREAM PLATTEN

19 - OVERBURDEN CELL

20 - TEST SAMPLE

21 - GAS BURETTE

22 - SIGHT-GAUGE

23 - SYSTEM BACK - PRESSURE TRANSDUCER

24 - BACK-PRESSURING VALVE TRANSDUCER

25 - DIFFERENTIAL PRESSURE TRANSDUCER

26 - PRECISION BACK - PRESSURE CONTROLLER

27 - EFFLUENT COLLECTOR

28 - TRANSDUCER SIGNAL CONDITIONING UNIT

29 - MULTI-CHANNEL CHART RECORDER

30 - DIGITAL VOLT METER

31 - NITROGEN GAS MAIN

3. BRINE ANALYSIS

Composition

ION	PPM
Na +	41,270
K +	1,470
Mg 2+	1,380
Ca 2+	4,750
Ba 2+	257
Sr 2+	302

Salts

$CaCl_2.6H_2O$

$MgCl_2.6H_2O$

$SrCl_2.6H_2O$

KCl

NaCl

Density = 1.0934 gm/cc at 20°C

Viscosity = 1.292 cp at 20°C

Resistivity = 0.0677 ohm metres at 20°C

4

HELIUM POROSITY AND KLINKENBERG PERMEABILITY DATA

COMPANY: STATOIL
WELL: 15/9-11
FIELD:

FORMATION:
LOCATION: NORTH SEA
COUNTRY: NORWAY

HELIUM POROSITY AND KLINKENBERG PERMEABILITY

SAMPLE NUMBER	DEPTH (METRES)	POROSITY (PERCENT)	MEAN PRESSURE Bar.	KLINKENBERG PERMEABILITY KL (md)
1A	2395.25	23.8	1.023 2.018 3.400	189
2A	2395.85	23.3	1.023 2.251 3.388	149
8A	2403.45	25.3	1.023 2.010 3.388	596
12A	2413.90	25.0	1.023 1.470 3.051	553
15A	2419.80	24.0	1.468 2.010 3.042	269
18A	2422.50	25.0	1.023 1.464 3.052	150
21A	2445.90	31.8	1.466 2.133 3.388	198

5

AIR-BRINE CAPILLARY PRESSURE TEST RESULTS

Porous Plate Cell, Steady State

COMPANY: STATOIL
WELL: 15/9-11
FIELD:
FORMATION:
LOCATION: NORTH SEA
COUNTRY: NORWAY

AIR-BRINE CAPILLARY PRESSURE DATA

				PRESSURE, Bar:	0.1	0.2	0.4	0.7	1.5	12
SAMPLE NUMBER	DEPTH (METRES)	PERMEABILITY (KL) (md)	POROSITY (%)	BRINE SATURATION, PERCENT PORE SPACE						
1A	2395.25	189	23.8		96.5	56.5	42.2	35.4	29.4	24.3
2A	2395.85	149	23.3		96.7	60.7	42.3	36.7	30.4	25.4
8A	2403.45	596	25.3		80.6	39.7	29.4	25.6	22.1	18.7
12A	2413.90	553	25.0		73.8	40.6	31.0	27.1	23.8	20.2
15A	2419.80	269	24.0		94.7	47.6	34.9	30.3	24.2	21.4
18A	2422.50	150	25.0		87.8	51.2	40.3	34.7	28.6	23.9
21A	2445.90	198	31.8		95.7	65.0	49.7	44.0	37.4	30.6

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/9-11

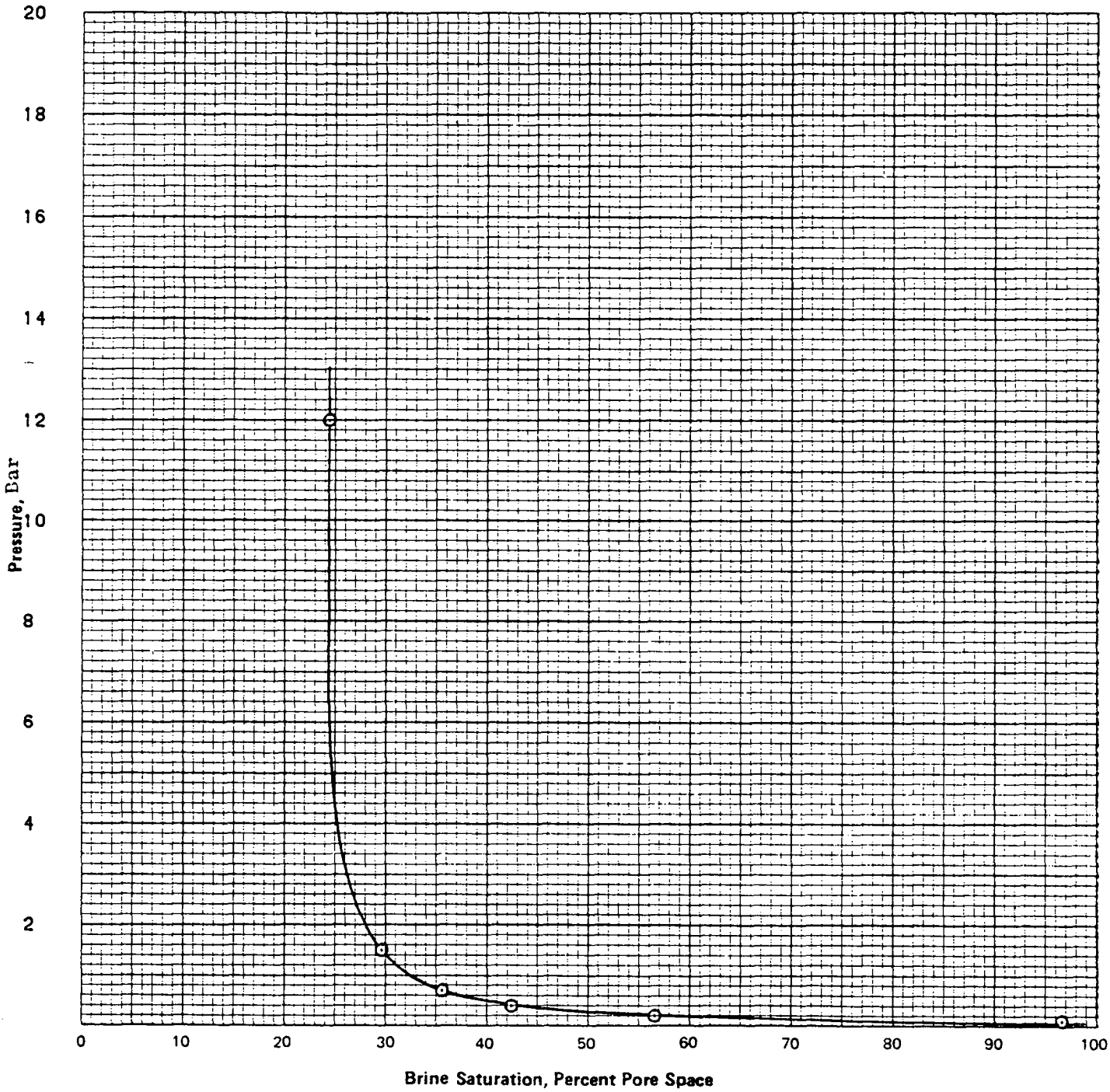
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 1A

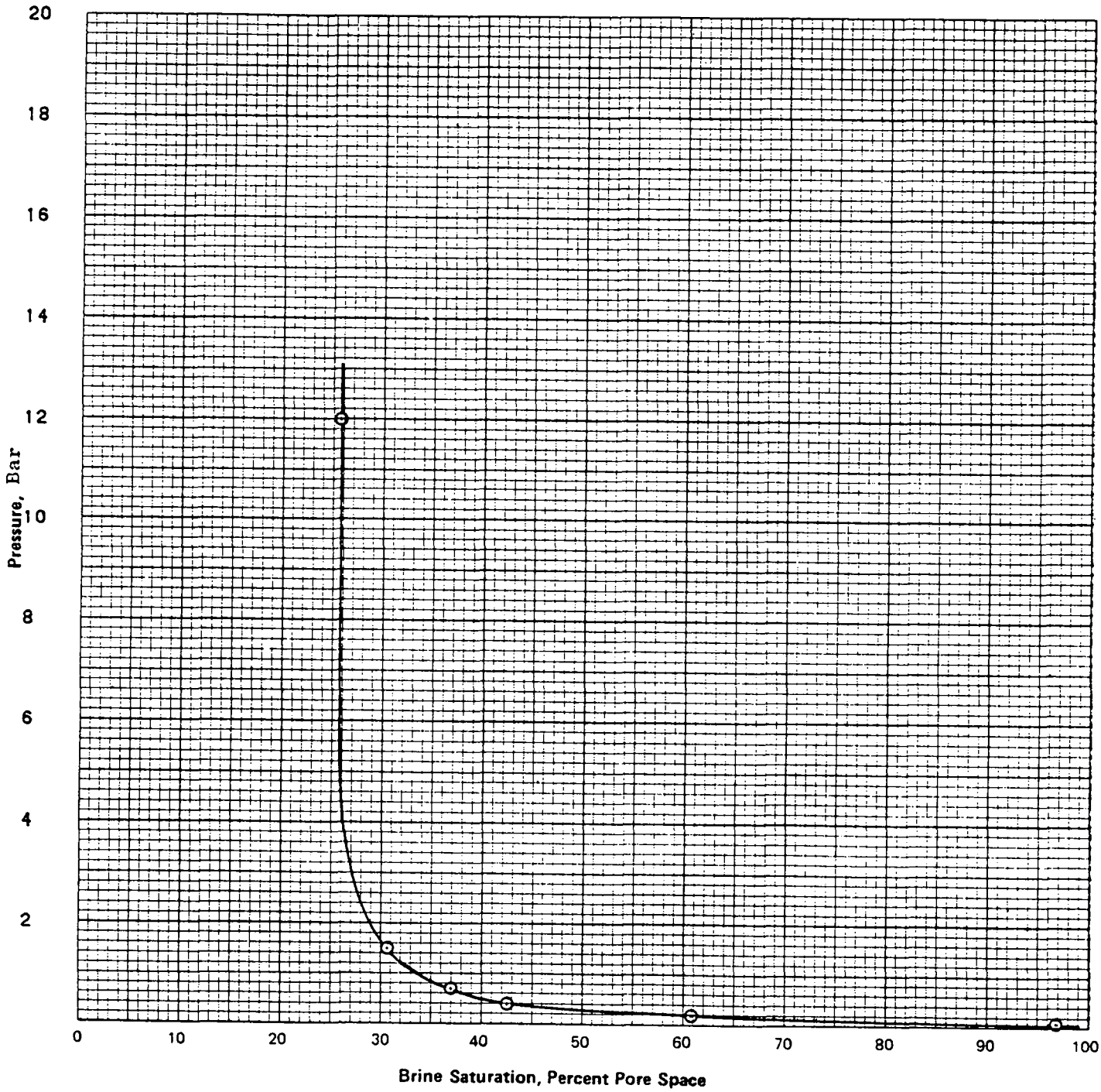
PERMEABILITY KL 189md



ROBERTSON RESEARCH

COMPANY: STATOIL
WELL: 15/9-11
FIELD:
SAMPLE NUMBER: 2A

FORMATION:
LOCATION: NORTH SEA
COUNTRY: NORWAY
PERMEABILITY KL 149 md



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/9-11

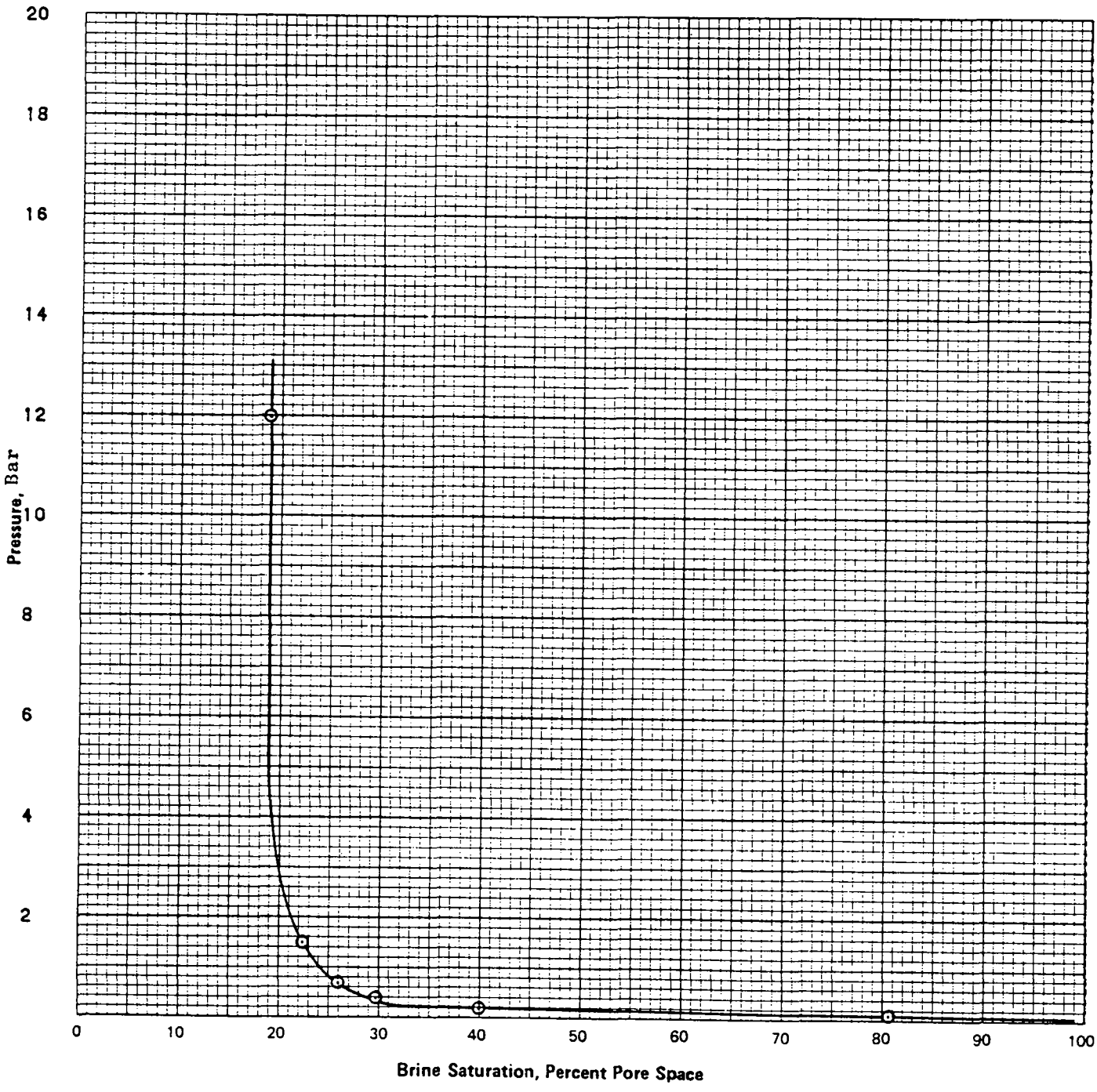
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 8A

PERMEABILITY KL 596 md



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

WELL: 15/9-11

FIELD:

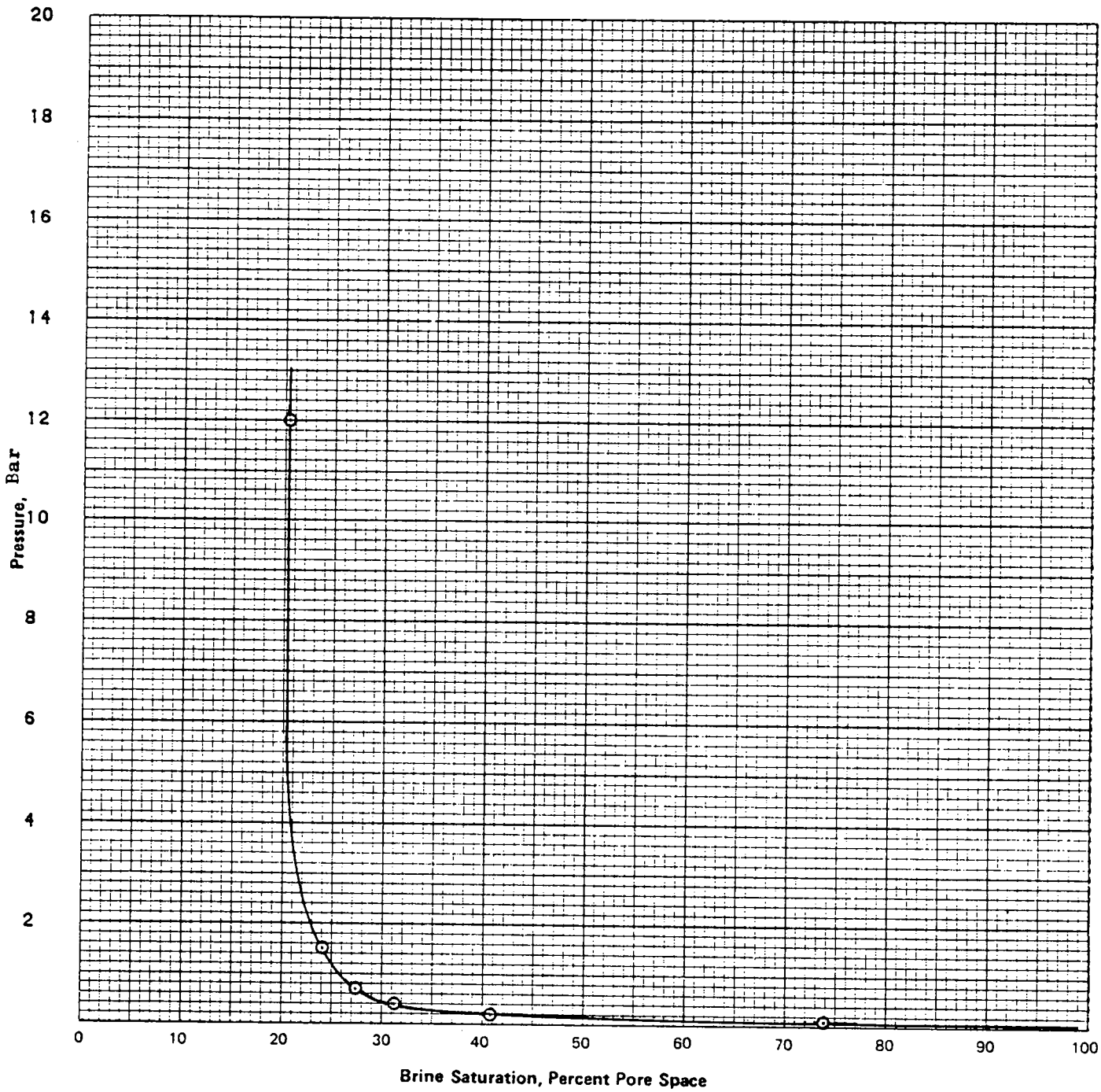
SAMPLE NUMBER: 12A

FORMATION:

LOCATION: NORTH SEA

COUNTRY: NORWAY

PERMEABILITY KL: 553 md



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/9-11

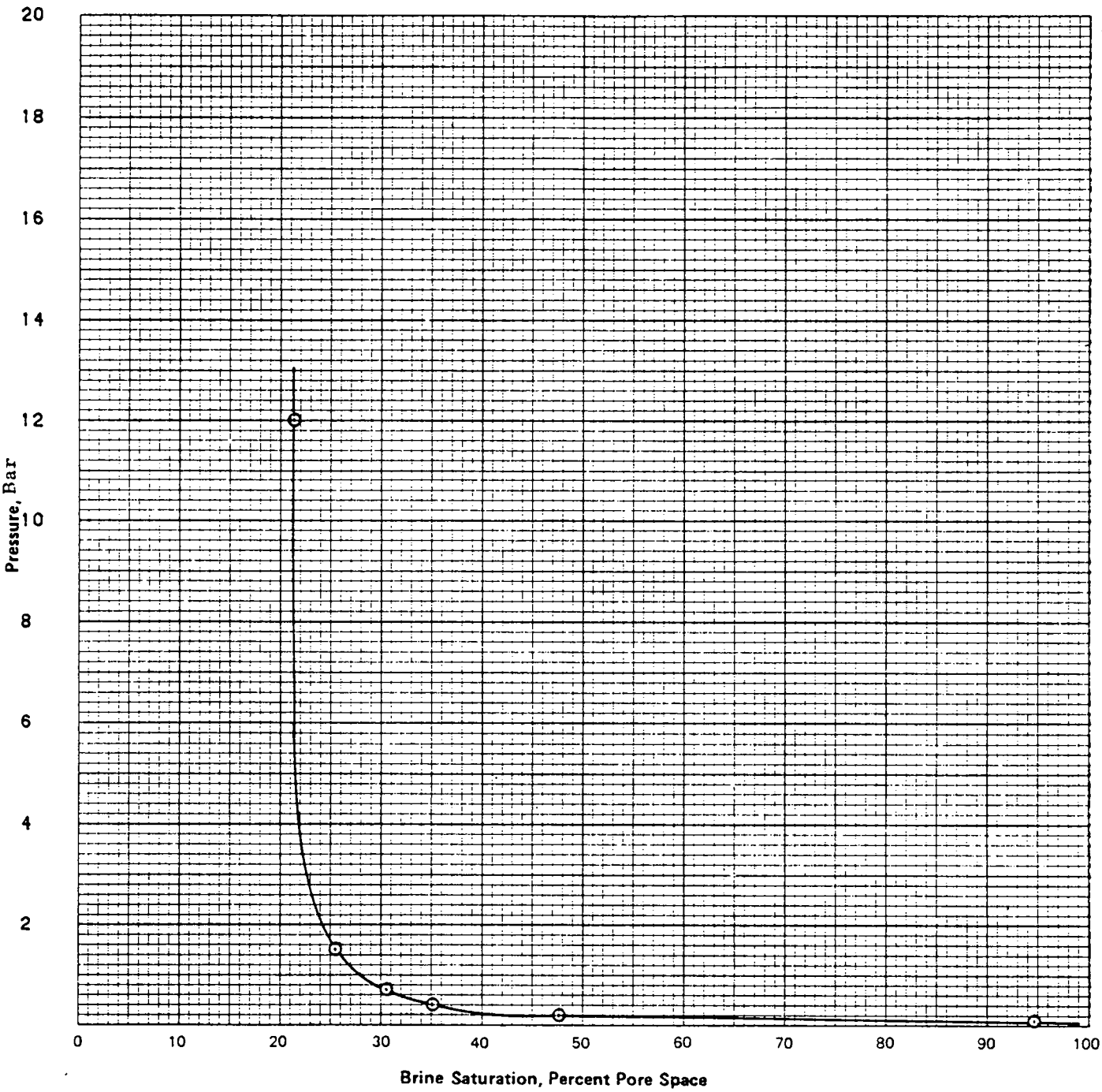
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 15A

PERMEABILITY KL 269 md



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/9-11

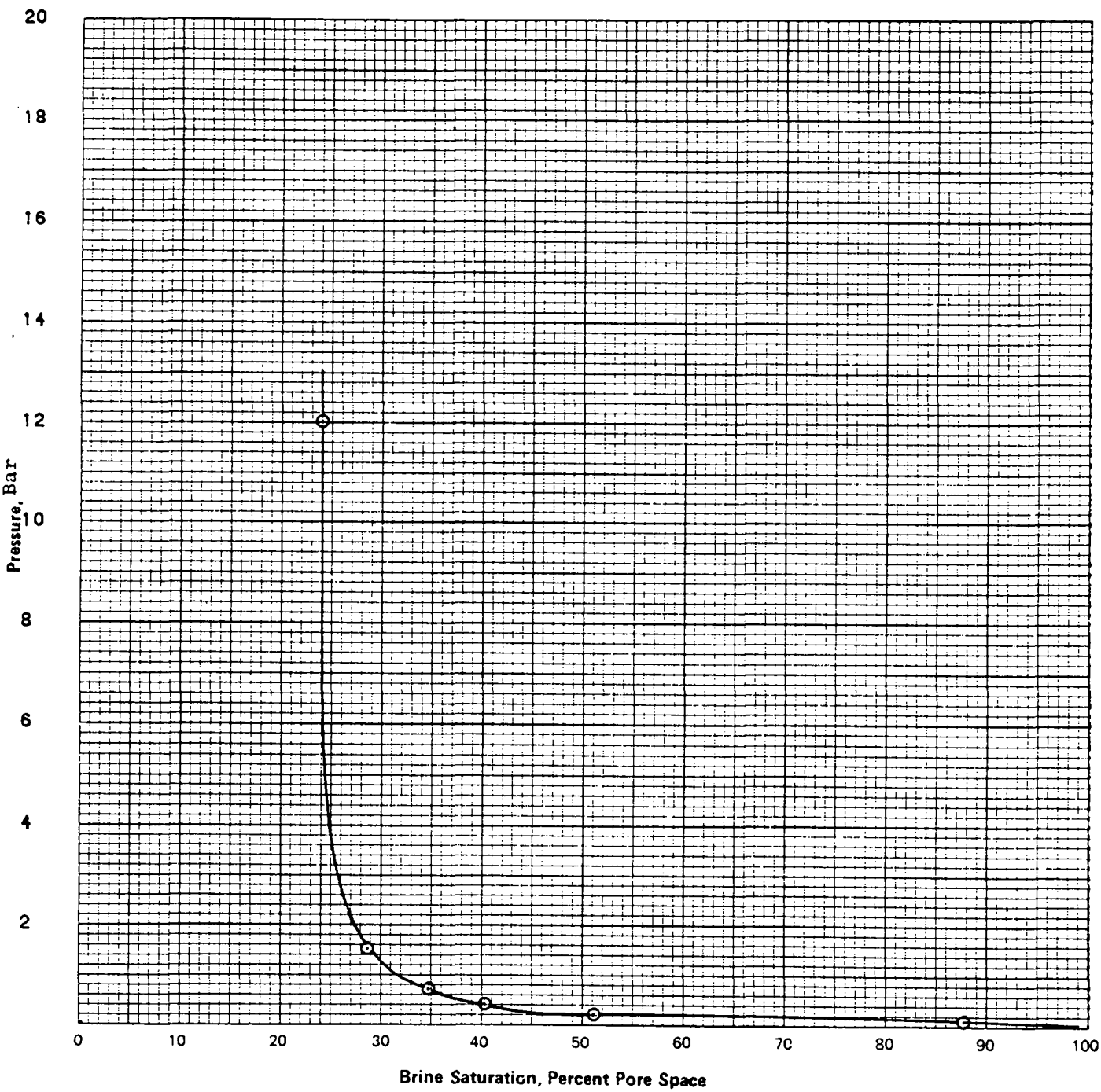
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 18A

PERMEABILITY KL 150 md



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

WELL: 15/9-11

FIELD:

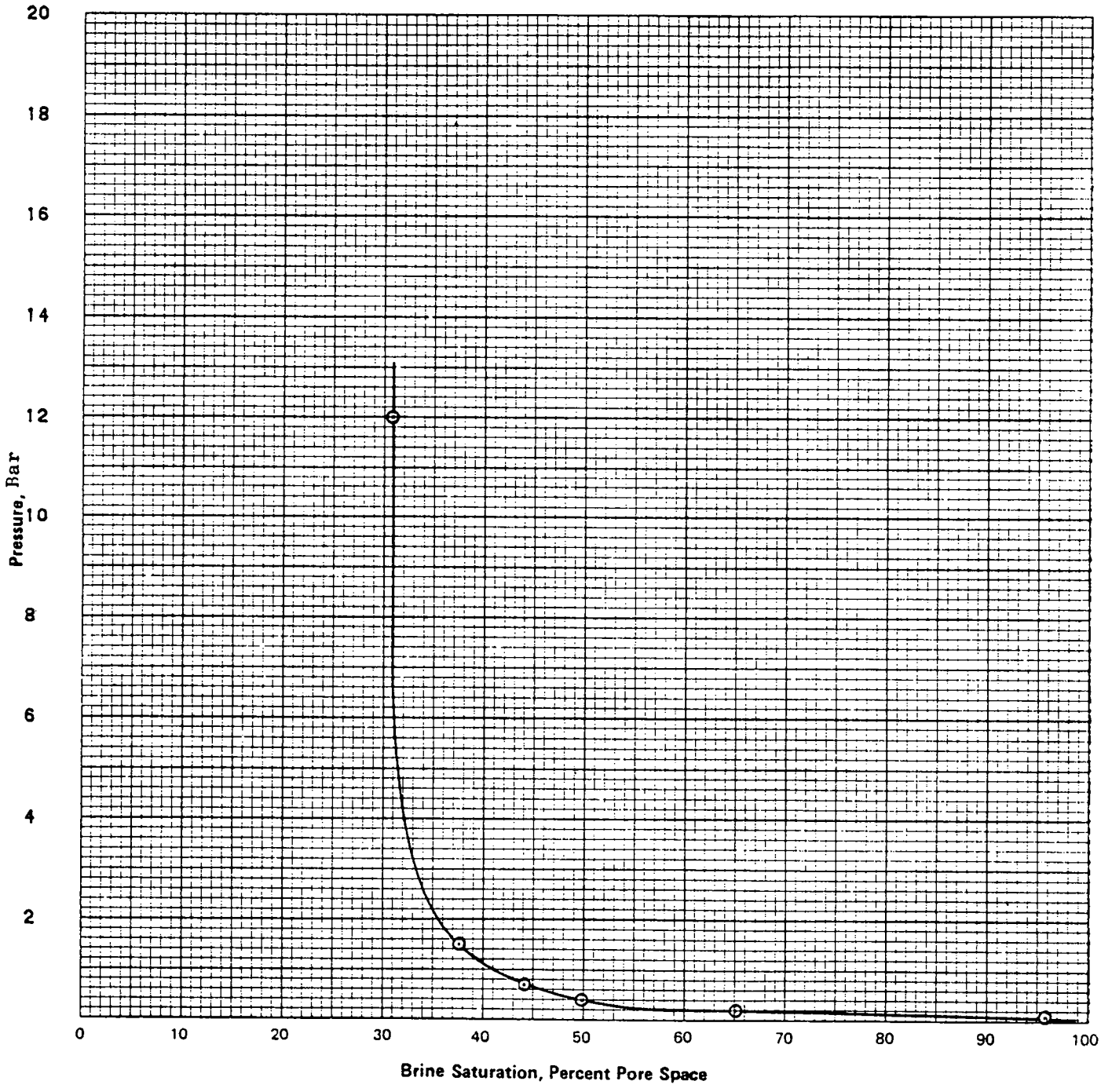
SAMPLE NUMBER: 21A

FORMATION:

LOCATION: NORTH SEA

COUNTRY: NORWAY

PERMEABILITY KL 198 md



6

FORMATION FACTOR AND RESISTIVITY INDEX

TEST RESULTS

COMPANY: STATOIL
FORMATION:
WELL: 15/9-11
LOCATION: NORTH SEA
FIELD:
COUNTRY: NORWAY

FORMATION FACTOR AND RESISTIVITY INDEX DATA

RESISTIVITY OF SATURATING BRINE, ohm-metres: 0.0677 @ 68°F(20°C)

SAMPLE NUMBER	DEPTH (METRES)	POROSITY (PERCENT)	FORMATION FACTOR	BRINE SATURATION (PERCENT PORE SPACE)	RESISTIVITY INDEX
1A	2395.25	23.8	13.2	100	1.00
				96.5	1.06
				56.5	3.10
				42.2	6.46
				35.4	8.95
				29.4	14.1
				24.3	22.5
2A	2395.85	23.3	13.9	100	1.00
				96.7	1.08
				60.7	2.83
				42.3	6.21
				36.7	8.33
				30.4	13.2
				25.4	21.8
8A	2403.45	25.3	11.1	100	1.00
				80.6	1.46
				39.7	6.06
				29.4	12.7
				25.6	18.3
				22.1	26.1
				18.7	36.3
12A	2413.90	25.0	11.5	100	1.00
				73.8	1.84
				40.6	6.15
				31.0	11.6
				27.1	16.8
				23.8	23.0
				20.2	34.7
15A	2419.80	24.0	12.0	100	1.00
				94.7	1.07
				47.6	4.34
				34.9	9.30
				30.3	13.2
				24.2	20.0
				21.4	28.5

COMPANY: STATOIL

FORMATION:

WELL: 15/9-11

LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

FORMATION FACTOR AND RESISTIVITY INDEX DATA

RESISTIVITY OF SATURATING BRINE, ohm-metres: 0.0677 @ 68°F(20°C)

SAMPLE NUMBER	DEPTH (METRES)	POROSITY (PERCENT)	FORMATION FACTOR	BRINE SATURATION (PERCENT PORE SPACE)	RESISTIVITY INDEX
18A	2422.50	25.0	11.6	100	1.00
				87.8	1.29
				51.2	4.21
				40.3	7.70
				34.7	10.7
				28.6	16.1
				23.9	26.8
21A	2445.90	31.8	8.70	100	1.00
				95.7	1.05
				65.0	2.07
				49.7	3.51
				44.0	4.40
				37.4	6.30
				30.6	10.8

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/9-11

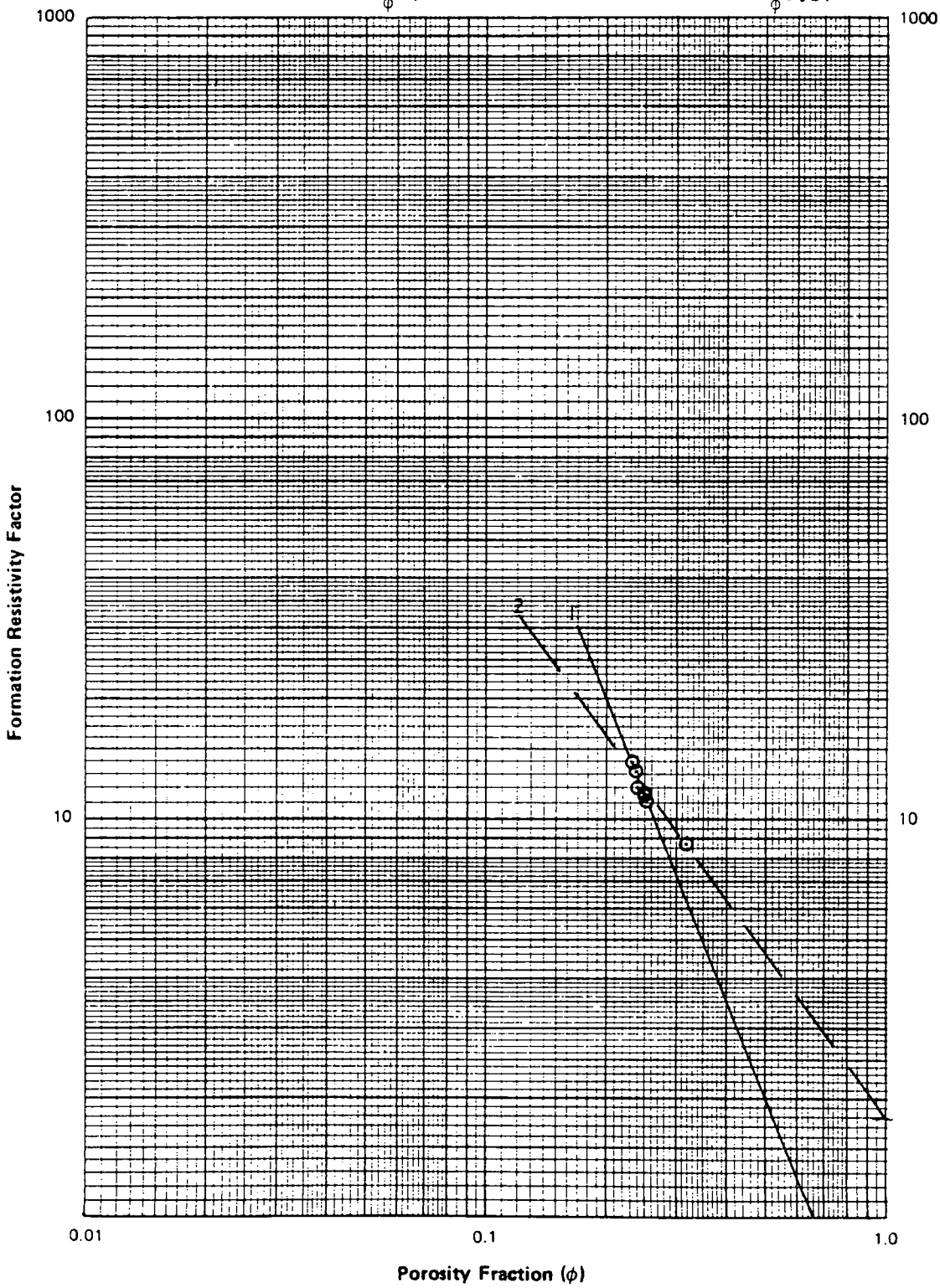
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

DATA AT ROOM CONDITIONS (SEE TEXT, PAGE 6)

LINE 1 FF = $\frac{0.356}{\phi^{2.50}}$ LINE 2 FF = $\frac{1.77}{\phi^{1.37}}$



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

WELL: 15/7-11

FIELD:

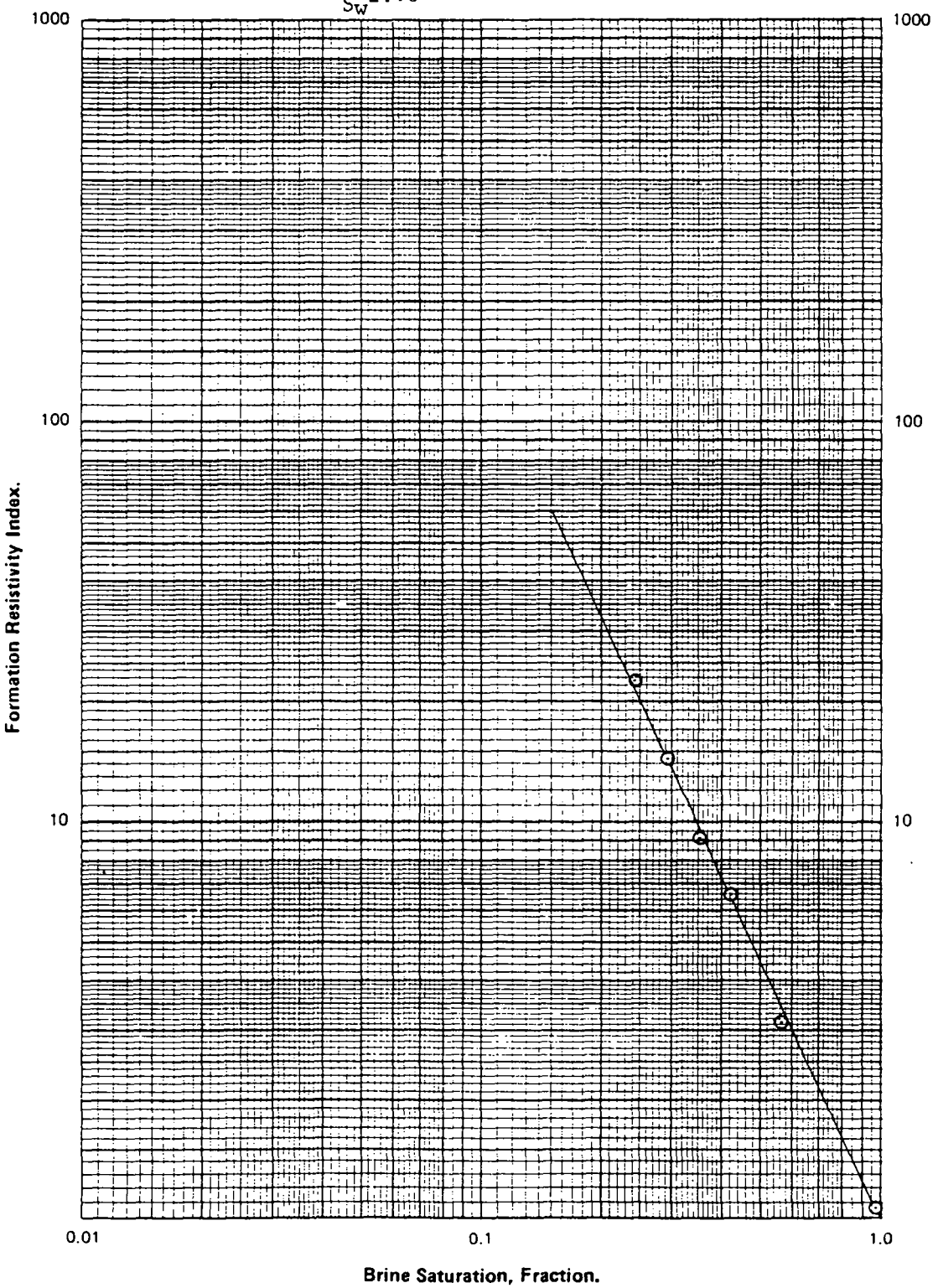
SAMPLE NUMBER: 1A

FORMATION:

LOCATION: NORTH SEA

COUNTRY: NORWAY

$$RI = \frac{1.00}{S_w^{2.16}}$$



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/7-11

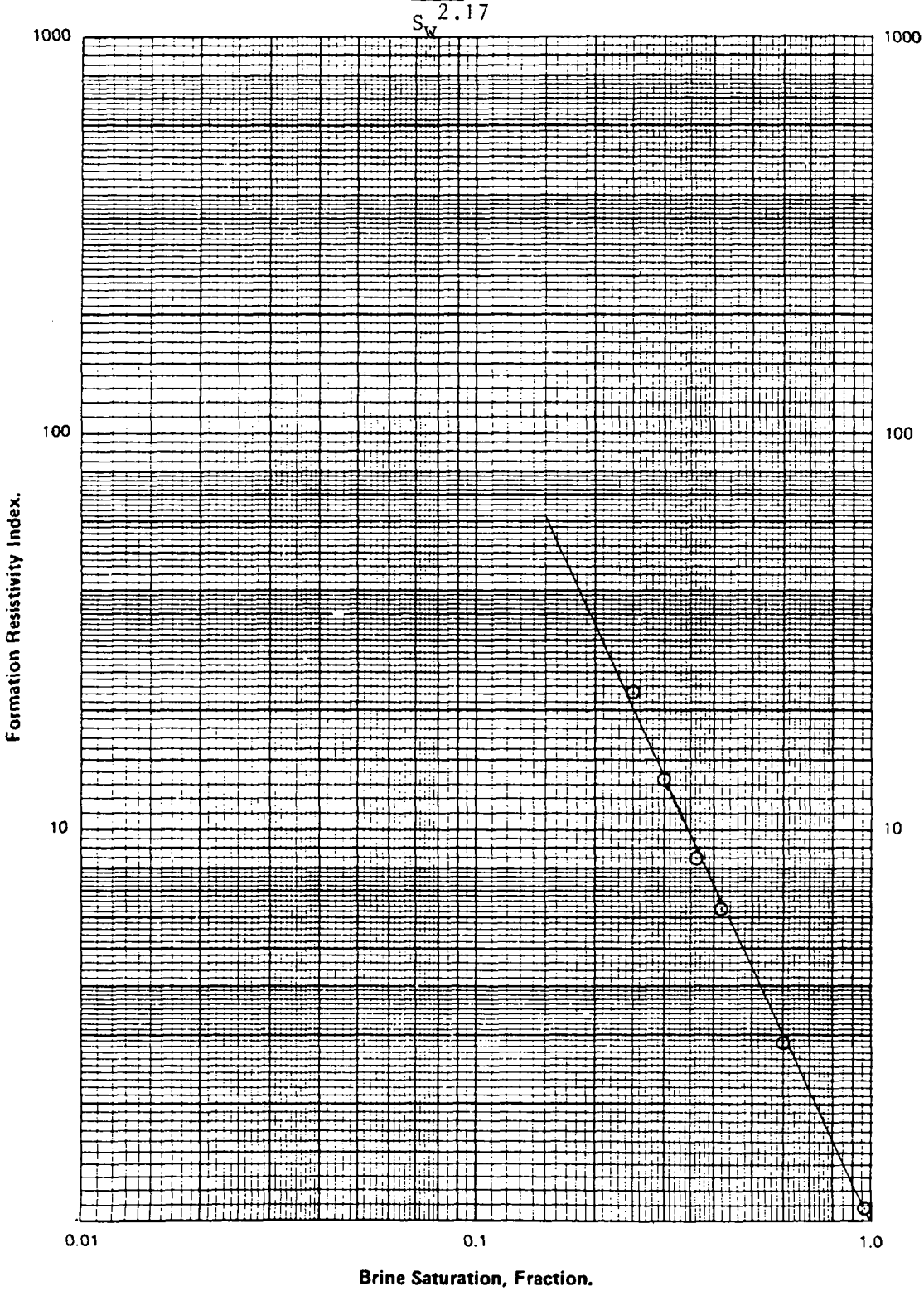
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 2A

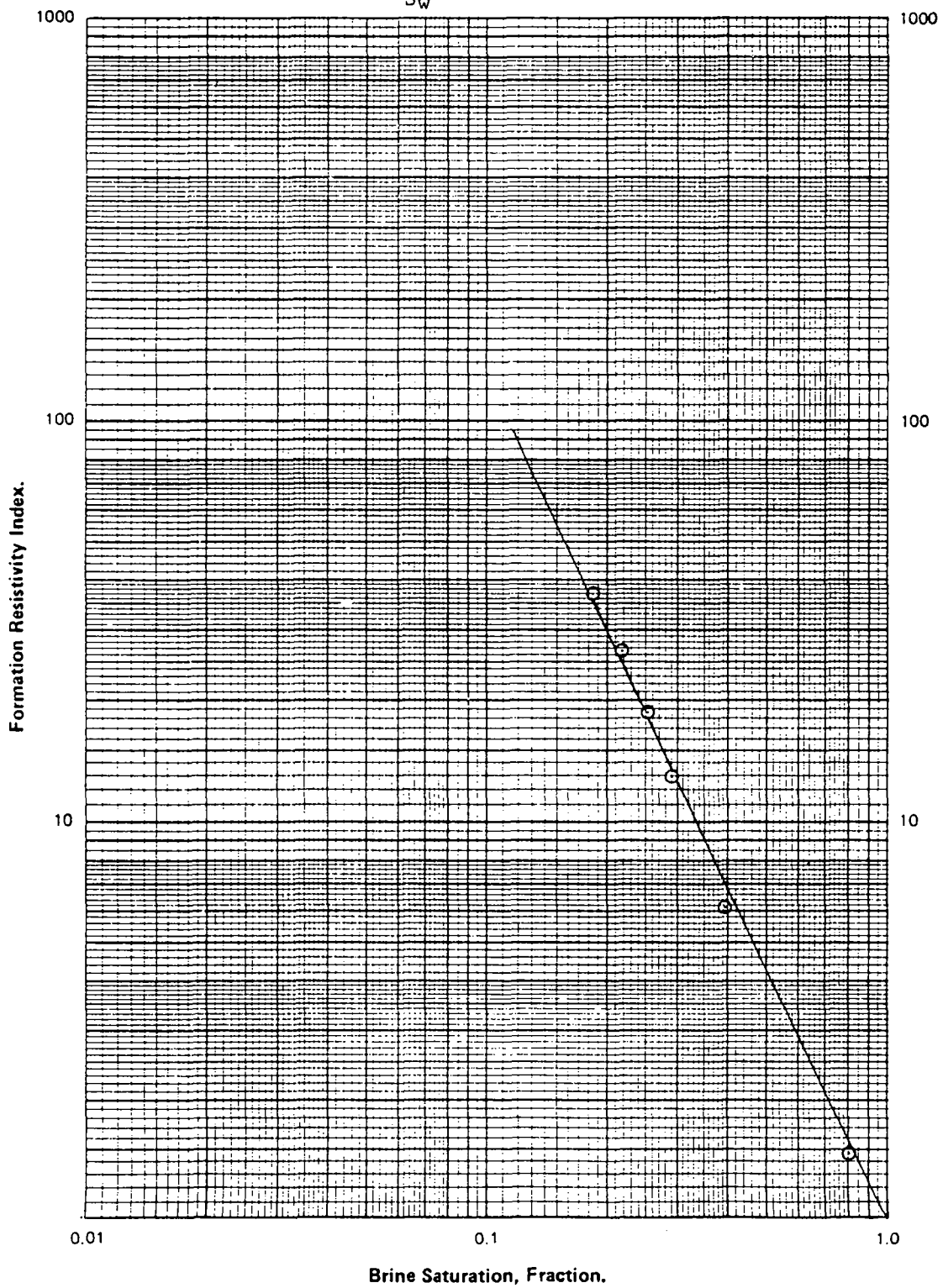
$$RI = \frac{1.00}{S_w^{2.17}}$$



ROBERTSON RESEARCH

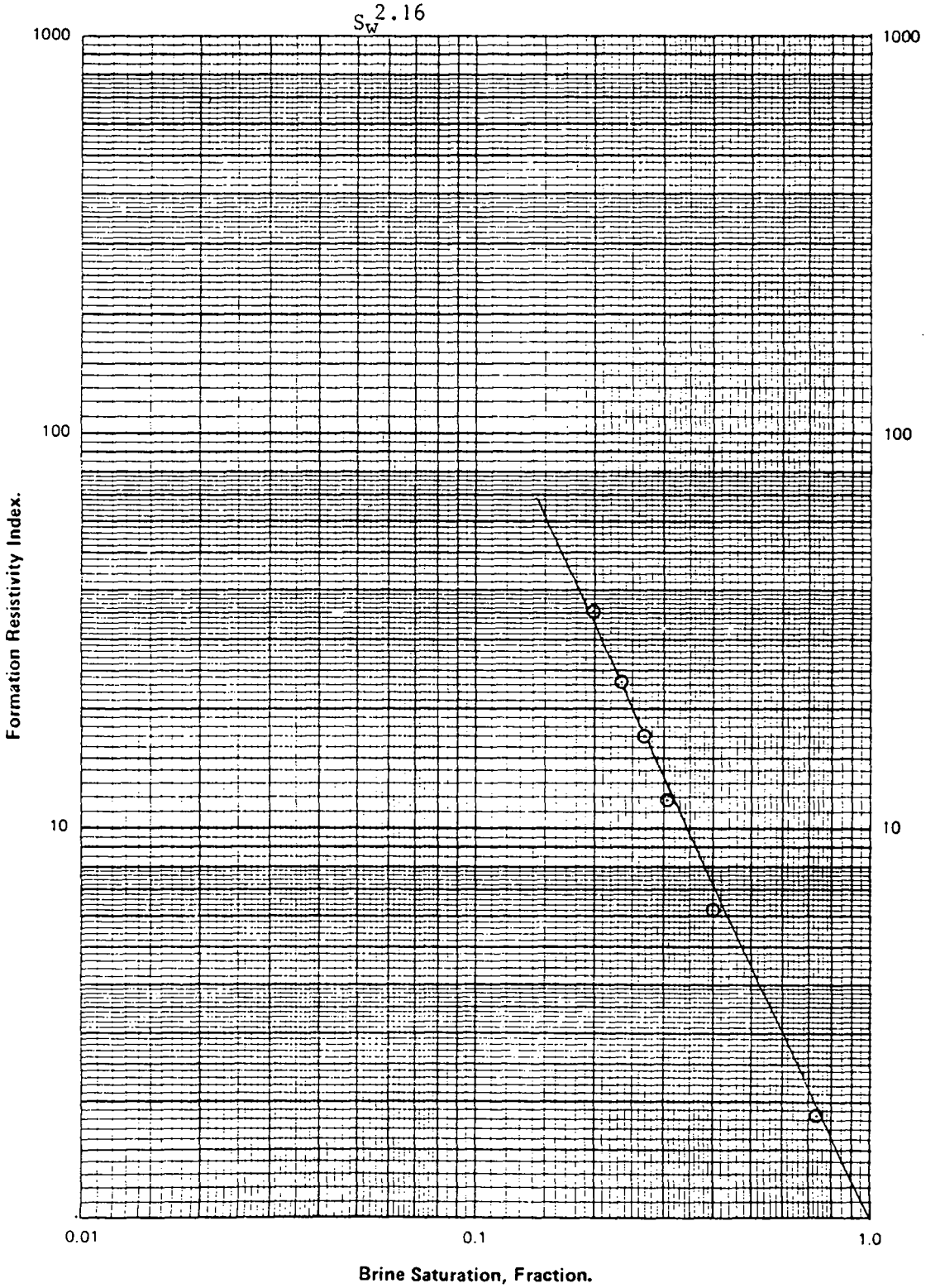
COMPANY: STATOIL
FORMATION:
WELL: 15/7-11
LOCATION: NORTH SEA
FIELD:
COUNTRY: NORWAY
SAMPLE NUMBER: 8A

$$RI = \frac{1.00}{S_w^{2.11}}$$



COMPANY: STATOIL
FORMATION:
WELL: 15/7-11
LOCATION: NORTH SEA
FIELD:
COUNTRY: NORWAY
SAMPLE NUMBER: 12A

$$RI = \frac{1.00}{S_w^{2.16}}$$



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/7-11

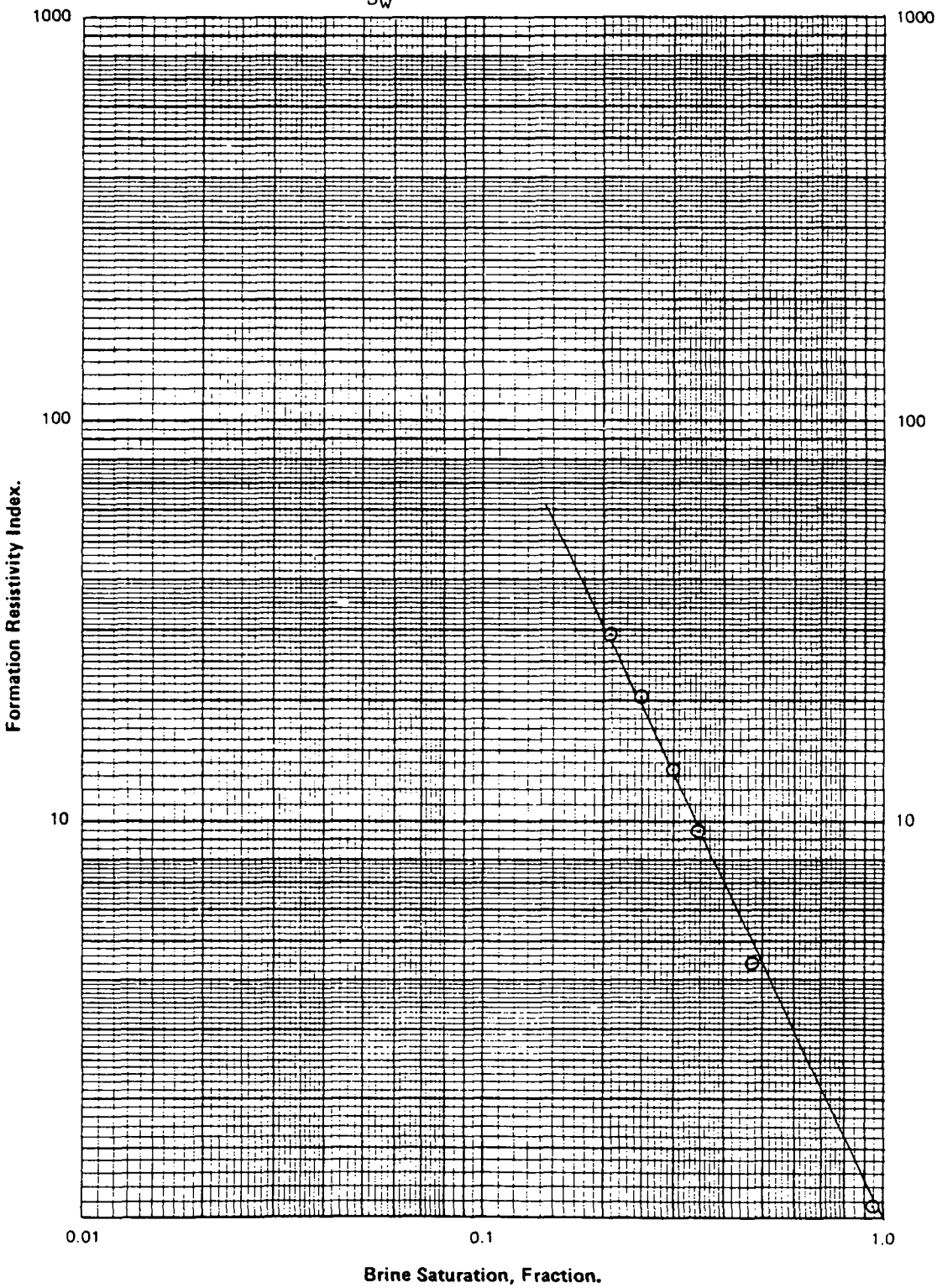
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 15A

$$RI = \frac{1.00}{S_w^{2.12}}$$



ROBERTSON RESEARCH

File No. SCAL-0060

COMPANY: STATOIL

FORMATION:

WELL: 15/7-11

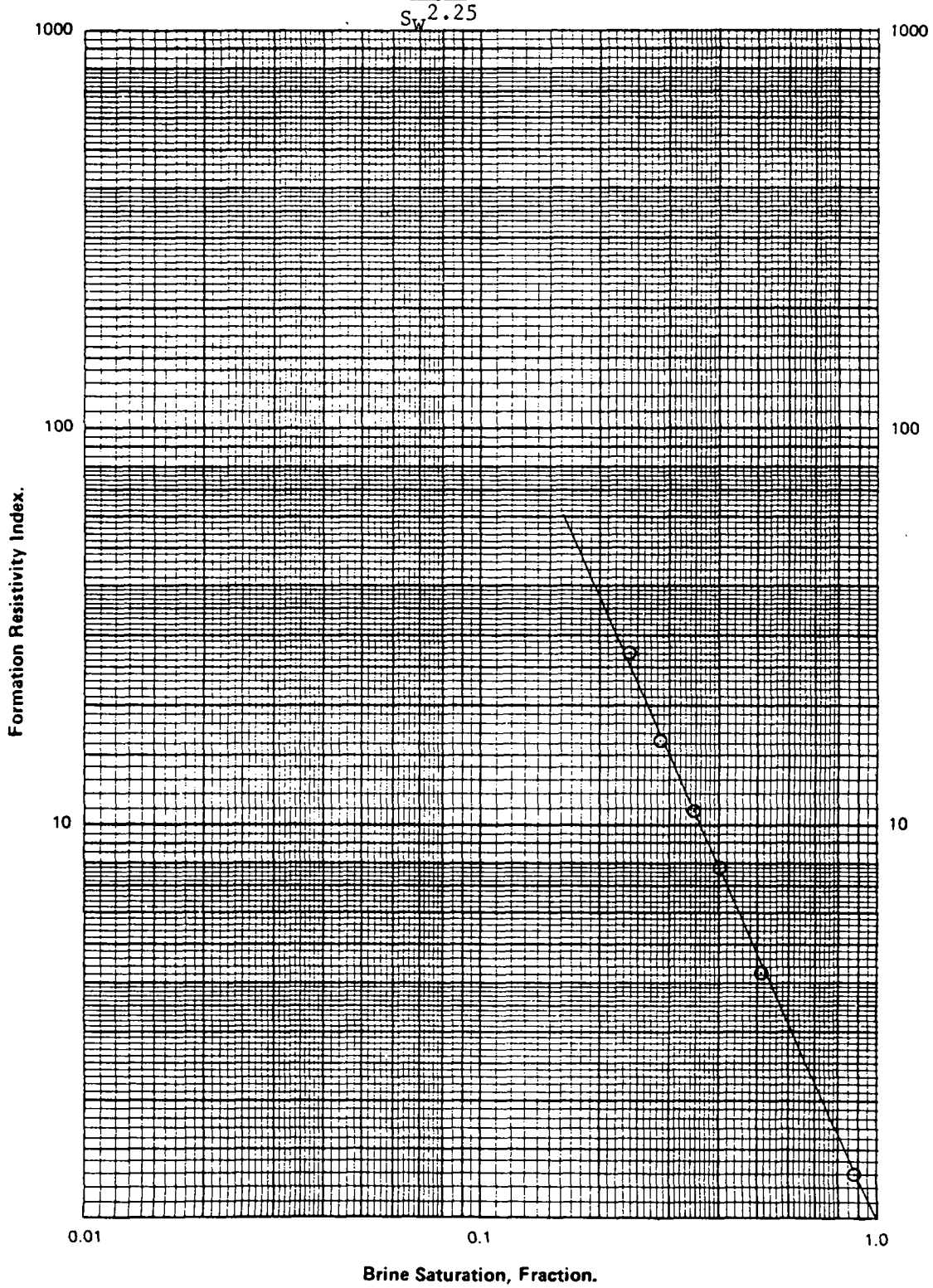
LOCATION: NORTH SEA

FIELD:

COUNTRY: NORWAY

SAMPLE NUMBER: 18A

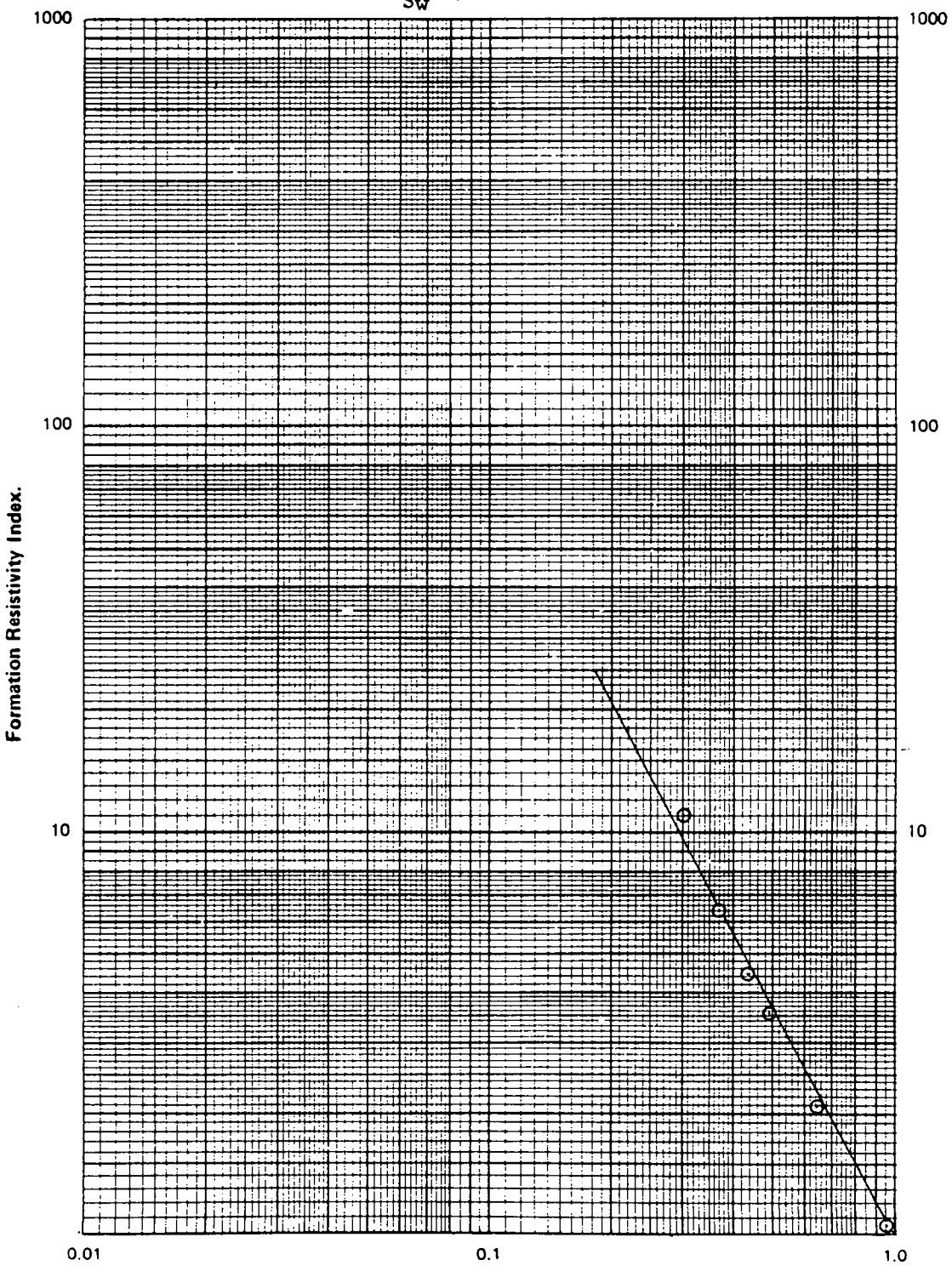
$$RI = \frac{1.00}{S_w^{2.25}}$$



ROBERTSON RESEARCH

COMPANY: STATOIL
FORMATION:
WELL: 15/7-11
LOCATION: NORTH SEA
FIELD:
COUNTRY: NORWAY
SAMPLE NUMBER: 21A

$$RI = \frac{1.00}{S_w^{1.88}}$$



ROBERTSON RESEARCH

7

RESIDUAL GAS TABULAR DATA

ROBERTSON RESEARCH INTERNATIONAL LIMITED

REPORT NO. 4713P/G

SPECIAL CORE ANALYSIS STUDY FOR STATOIL-DEN NORSKE STATS OLJESELSKAP A.S. WELL: 15/9 - 11 NORWEGIAN NORTH SEA

by

L. LOMBOS
M. G. VINCENT
R. EVANS
D. B. ROBERTS

REFERENCE: SCAL - 0060

Prepared by:

Robertson Research International Limited,
Ty'n-y-Coed,
Llanrhos,
Llandudno,
Gwynedd LL30 1SA,
Wales,
U.K.

Prepared for:

Statoil-Den Norske Stats Oljeselskap A.S.,
Forus,
P.O. Box 300,
4001 Stavanger,
Norway.

January, 1982