SPECIAL CORE ANALYSIS STUDY

for

Sandia National Laboratories

Multi-Well Experiments No. 1 and 2 Wells
Mesa Verde Formation
Rulison Field
Garfield County, Colorado
File Number: SCAL 203-860019

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CORE LABORATORIES, INC.

May 9, 1986

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Sandia National Laboratories
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Attention: Mr. Allan R. Sattler
Ms. Sharon Finley

Subject:

Special Core Analysis Study
Multi-Well Experiment No. 1 and 2 Wells
Mesa Verde Formation
Rulison Field
Garfield County, Colorado
File Number: SCAL 203-860019

Gentlemen:

On February 20, in a meeting with representatives of Core Laboratories, Incorporated, Mr. Allan R. Sattler and Ms. Sharon Finley of Sandia National Laboratories requested a special core analysis study on core material recovered from the subject wells. This work is part of the Western Gas Sands Project sponsored by the Department of Energy, Morgantown Energy Technology Center, Morgantown, West Virginia. Enclosed are the final results of the following requested analyses:

1) Klinkenberg Permeability (Gas Slippage Corrected) Determinations.

2) Air-Brine Centrifuge Capillary Pressure.

3) Air-Methanol Centrifuge Capillary Pressure.

4) Formation Resistivity Factor at Ambient and Overburden Conditions.

5) Formation Resistivity Index at Ambient Conditions.

6) Calculation of Clay-Corrected Resistivity Parameters.

7) Specific Liquid Permeability Measurements.

8) Core Photography.

All samples utilized in this study were pre-drilled, one-inch diameter core plugs. Each sample was extracted of hydrocarbons and leached of salts with cool toluene and cool methyl alcohol, respectively, in a centrifuge solvent reflux apparatus, then dried in a controlled-humidity oven until individual sample weights stabilized. Lithological descriptions of each sample are presented on Pages 1 through 8. Permeability to air and Boyle's Law porosity values for each sample are presented in tabular form on Pages 9 through 13, graphically on Page 14. It should be noted that samples having permeability to air values of <0.01 millidarcys are not represented graphically.

1) **Klinkenberg Permeability (Gas Slippage Corrected) Determinations:**

Klinkenberg permeabilities were measured on each selected sample at effective overburden pressures of 1000, 3000, and 4000 psi by the non-steady state method. Sample numbers 522, 524, 526, 528, 529, 544, 631, 633, 762, and 764 produced only partial data during testing, possibly due to pore geometry effects. Mercury injection testing with pore entry radii calculations or petrologic analyses are recommended to further define the phenomena. Results of the Klinkenberg permeability tests are presented in tabular form on Pages 15 through 18.

2) **Air-Brine Centrifuge Capillary Pressure:**

Samples selected for Air-Brine Centrifuge Capillary pressure testing were evacuated, then pressure-saturated with a brine containing 30,000 ppm NaCl, as per instructions from Mr. Sattler. Fully saturated, the core plugs were spun in the centrifuge at rates of rotation equivalent to between 1 and 1000 psi. Sufficient time was allowed at each rotation rate to assure an equilibrium condition at the established pressure; the resultant pressures and volumes of water displaced at each pressure were used to calculate the capillary pressure data. The air-brine capillary pressure test results are presented in tabular form on Page 19, graphically on Pages 20 through 27.

3) **Air-Methanol Centrifuge Capillary Pressure:**

Samples selected for Air-Methanol Centrifuge Capillary Pressure testing were loaded into hydrostatic core-holders and dynamically saturated with methanol (methyl alcohol); back-pressure was applied to the downstream end of the samples to assure complete saturation. The samples were then tested in the manner described above. Air-methanol capillary pressure test results are presented in tabular form on Page 28, graphically on Pages 29 through 34.

4) Formation Resistivity Factor at Ambient and Overburden Conditions:

Of the four samples originally selected for electrical resistivity testing, sample number 678 was unavailable, and was replaced with sample number 674, as per instructions from Mr. Sattler. The core plugs were evacuated and pressure-saturated with the 30,000 ppm NaCl brine previously described. Resistivities of the fully-saturated samples and the brine were measured on successive days at ambient conditions until sample resistivities stabilized, indicating that ionic equilibrium had been attained. Following ambient testing, sample resistivities were measured at effective overburden pressures of 200 and 3000 psi. Formation resistivity factors were plotted as a function of porosity from which a cementation exponent "m" was derived for each overburden pressure. The samples exhibited normal trends of increasing formation resistivity factors and cementation exponents ("m") with increasing effective overburden pressures. Resultant data is presented in tabular form on Page 35 and graphically on Pages 36 through 38.

5) Formation Resistivity Index at Ambient Conditions:

Following the described overburden testing, the samples were desaturated in a high-speed centrifuge at rotation rates equivalent to pressures of between 100 and 1500 psi. After each rotation, the samples were sealed in Saran™ wrap and aluminum foil for a minimum of 24 hours, allowing redistribution of pore fluids to occur. The samples were then weighed and their resistivities measured, saturations determined gravimetrically. Formation resistivity index determinations were plotted as a function of water saturation, from which a saturation exponent "n" was determined for each sample. Resultant data is presented in tabular form on Page 39, and graphically on Pages 40 through 43; a composite graph is presented on Page 44.

6) Calculation of Clay-Corrected Resistivity Parameters:

Cation-exchange capacity values for the electrical resistivity samples, from previous file number SCAL 203-830019, were used to clay-correct formation factor and resistivity index parameters; the CEC values are presented in tabular form on Page 45.

Results of the cation exchange capacity determinations and electrical resistivity data generated on each sample have been combined to derive a*, m*, and n* values. Several technical references are available which detail the calculation procedures, including:

Waxman, M. H., and Smits, L. J. M., "Electrical Conductivities in Oil-Bearing Shaly Sands", J. Soc., Petr. Engr. (June, 1968), pp. 107-122, Trans., AIME, 1968.

Waxman, M. H. and Thomas, E. C., "Electrical Conductivities in Shaly Sands - I. The Relation Between Hydrocarbon Saturation and Resistivity Index: II. The Temperature Coefficient of Electrical Conductivity", J. Pet. Tech. (February, 1974) pp. 213-255, Trans., AIME, 257.

The tabular results of these calculations are presented on Pages 46 and 50; corrected graphs are presented on Pages 47 through 49 and Pages 51 through 54, with a composite "n" graph on Page 55.

The following table summarizes the resistivity results:

Cementation Exponent

Pressure, psi	"a"	"m"	"m*"
0	1.00	1.72	1.92
200	1.00	1.79	2.00
3000	1.00	1.89	2.08

Saturation Exponent

Sample Number	"n"	"n*"
658	1.55	2.00
660	1.36	1.80
666	1.24	1.68
674	1.17	1.80
Composite	1.37	1.83

7) **Specific Liquid Permeability Measurements:**

Of the four samples originally selected for liquid permeability testing, sample number 669 fractured during centrifuge capillary pressure determinations, and was eliminated from further testing. The remaining samples were evacuated and pressure-saturated with the 30,000 NaCl brine described previously.

Each sample was placed into a hydrostatic core-holder and injected with the brine, under the influence of back-pressure, until flow stabilized, at which time liquid permeabilities were measured. Results are presented in tabular form on Page 56.

8) **Core Photography:**

Photographs of selected samples are presented at the conclusion of this report, with the exception of sample number 337, which was unavailable.

Thank you for the opportunity to perform this study for Sandia National Laboratories. Should you have any questions pertaining to these test results, or if we can be of further assistance, please contact us at (303)751-9334.

Very truly yours,

CORE LABORATORIES, Inc.

Stephen H. Leeds

Stephen H. Leeds
Special Core Analysis Supervisor

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde - F Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
522	5450.5	Sltst: gry, wl ind, sil, tr mic, frac
524	5458.5	Sltst: gry, wl ind, sil, tr mic, frac
526	5464.5	Sltst: gry, wl ind, sil, tr mic
528	5470.8	Sst: gry, f gr, wl srtd, wl ind,sil, slty, tr mic
529	5474.7	Sst: gry, f gr, wl srtd, wl ind, sil, slty, volc frag
530	5467.5	Sst: gry, f gr, wl srtd, wl ind, sil, slily slty, volc frag
532	5480.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, volc frag
533	5481.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
535	5486.4	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
541	5490.5	Sltst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
544	5498.8	Sltst: gry, wl ind, sil, tr mic, frac w/calc cmt

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde - E Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
549	5508.5	Sltst: gry, wl ind, sil, tr mic
552	5514.7	Sst: gry, f gr, wl srtd, wl ind, sil, slty, volc frag
553	5515.3	Sst: gry, f gr, wl srtd, wl ind, sil, slily slty, tr mic, volc frag
555	5515.7	Sst: gry, f gr, wl srtd, wl ind, sil, slily slty, volc frag
557	5517.3	Sst: gry, f gr, wl srtd, wl ind, sil, slily slty, tr mic, volc frag
558	5520.4	Sst: gry, f gr, wl srtd, wl ind, sil, slily slty, tr pyr, volc frag, frac
559	5522.3	Sst: gry, f gr, wl srtd, wl ind, sil, slily slty, tr mic, volc frag
560	5524.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, tr pyr, volc frag
561	5528.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, tr mic, volc frag
564	5535.4	Sltst: gry, wl ind, sil, sh lam
566	5544.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, tr mic, volc frag
570	5548.6	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, volc frag
573	5552.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, volc frag

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde - E Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
574	5553.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, volc frag
578	5557.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, sh lam, volc frag
583	5561.6	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, volc frag
587	5566.5	Sst: gry, wl ind, sil, tr mic, frac

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde - D Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
608	5608.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, tr mic, slily slty, volc frag
610	5613.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, shly, lam, carb
611	5616.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, shly, lam, carb, volc frag
612	5617.5	Sst: lt gry, f-med gr, prly srtd, wl ind, lam, shly, carb, volc frag
614	5620.5	Sltst: gry, wl ind, sil, slily sdy, frac
615	5622.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, volc frag
617	5624.3	Sst: lt gry, f gr, wl srtd, wl ind, sil, volc frag
619	5626.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
620	5627.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
621	5628.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, frac w/calc cmt volc frag
622	5629.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde - D Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
624	5631.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
627	5634.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
628	5635.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slily slty, volc frag
631	5642.5	Sltst: gry, wl ind, sil, slily sdy, frac
633	5648.5	Sltst: gry, wl ind, sil, slily sdy, frac

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde - A Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
762	5950.2	Sst: gry, f gr, wl srtd, wl ind, sil, volc frag
764	5954.5	Sst: gry, f gr, wl srtd, wl ind, sil, shly, lam, volc frag
769	5959.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
771	5961.5	Sst: ltgry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
773	5963.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, volc frag
775	5965.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, volc frag
777	5967.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
779	5969.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
781	5971.5	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag
789	5987.6	Sst: lt gry, f gr, wl srtd, wl ind, sil, slty, volc frag

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
		Air-Brine Capillary Pressure Samples
662	5717.5	Sst: lt gry, f-med gr, prly srtd, wl ind, slily slty, volc frag
669	5725.5	Sst: lt gry, f-med gr, prly srtd, wl ind, slily slty, volc frag
715	5829.6	Sst: lt gry, f-med gr, prly srtd, wl ind, slily slty, volc frag
722	5837.6	Sst: lt gry, f-med gr, prly srtd, wl ind, slily slty, slily shly, lam, volc frag
		Electrical Resistivity Samples
658	5713.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
660	5715.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
666	5722.5	Sst: lt gry, f-med gr, prly srtd, wl ind, sil, slily slty, volc frag
674	5730.5	Sst: gry, f-med gr, prly srtd, wl ind, sil, slily slty, lam
		Air-Brine/Air-Methanol Capillary Pressure Samples
667	5723.4	Sst: lt gry, f-med gr, prly srtd, wl ind, slily slty, volc frag
6VM	5732.0-32.6	Sst: lt gry, f gr, wl srtd, wl ind, sil, volc frag

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IDENTIFICATION AND LITHOLOGICAL DESCRIPTION OF SAMPLES

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Lithological Description
6HM	5732.0-32.6	Sst: lt gry, f gr, wl srtd, wl ind, sil, slily shly, volc frag
6VF	5732.0-32.6	Sst: lt gry, f gr, wl srtd, wl ind, sil, slily shly, lam, frac w/calc cmt
7VM	5734.1-34.7	Sst: lt gry, f gr, wl srtd, wl ind, sil, slily shly, lam, volc frag
7VF	5734.1-34.7	Sst: lt gry, f gr, wl srtd, wl ind, sil, frac w/calc cmt
		Core Photography Samples Multi-Well Experiment No. 2
332	8108.7	Sst: gry, wl ind, f gr, wl srtd, shly, carb, lam
337	8114.2	Sample utilized for CEC File 203-820044

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PERMEABILITY TO AIR, POROSITY, AND GRAIN DENSITY

Company: Sandia National Laboratories
Formation: Mesa Verde - F Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Grain Density, Gm/Cc
522	5450.5	<0.01	3.2	2.72
524	5458.5	<0.01	2.2	2.69
526	5464.5	<0.01	1.7	2.70
528	5470.8	<0.01	1.5	2.70
529	5474.7	<0.01	0.8	2.69
530	5467.5	0.01	5.5	2.69
532	5480.5	0.03	7.6	2.67
533	5481.5	0.03	6.8	2.66
535	5486.4	0.01	6.1	2.67
541	5490.5	0.02	6.4	2.73
544	5498.8	<0.01	1.3	2.69

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PERMEABILITY TO AIR, POROSITY, AND GRAIN DENSITY

Company: Sandia National Laboratories
Formation: Mesa Verde - E Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Grain Density, Gm/Cc
549	5508.5	<0.01	1.3	2.70
552	5514.7	<0.01	1.4	2.71
553	5515.3	<0.01	2.3	2.69
555	5515.7	<0.01	2.6	2.69
557	5517.3	<0.01	3.5	2.68
558	5520.4	<0.01	3.3	2.70
559	5522.3	<0.01	1.8	2.69
560	5524.5	0.01	4.1	2.69
561	5528.5	<0.01	4.0	2.68
564	5535.4	<0.01	2.1	2.70
566	5544.5	<0.01	5.0	2.68
570	5548.6	0.04	7.1	2.66
573	5552.5	0.02	5.9	2.66
574	5553.5	0.02	7.6	2.66
578	5557.5	0.03	7.9	2.66
583	5561.6	0.01	6.4	2.66
587	5566.5	0.01	2.1	2.64

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PERMEABILITY TO AIR, POROSITY, AND GRAIN DENSITY

Company: Sandia National Laboratories
Formation: Mesa Verde - D Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Grain Density, Gm/Cc
608	5608.5	<0.01	3.7	2.72
610	5613.5	0.01	5.3	2.63
611	5616.5	0.24	4.7	2.68
612	5617.5	0.01	5.0	2.66
614	5620.5	<0.01	3.4	2.71
615	5622.5	<0.01	2.0	2.71
617	5624.3	<0.01	4.6	2.68
619	5626.5	0.01	7.4	2.70
620	5627.5	0.01	6.8	2.68
621	5628.5	0.01	7.1	2.67
622	5629.5	0.01	6.3	2.67
624	5631.5	0.01	6.8	2.66
627	5634.5	<0.01	4.8	2.69
628	5635.5	<0.01	5.9	2.67
631	5642.5	<0.01	1.0	2.67
633	5648.5	<0.01	0.3	2.69

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PERMEABILITY TO AIR, POROSITY, AND GRAIN DENSITY

Company: Sandia National Laboratories
Formation: Mesa Verde - A Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Grain Density, Gm/Cc
762	5950.2	<0.01	2.0	2.71
764	5954.5	<0.01	1.9	2.68
769	5959.5	0.01	5.0	2.69
771	5961.5	0.01	5.8	2.68
773	5963.5	0.01	5.7	2.68
775	5965.5	0.01	5.4	2.70
777	5967.5	0.02	6.4	2.69
779	5969.5	0.02	6.6	2.68
781	5971.5	0.01	5.0	2.68
789	5987.6	0.02	7.1	2.70

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PERMEABILITY TO AIR, POROSITY, AND GRAIN DENSITY

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample Identification	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Grain Density, Gm/Cc
Air-Brine Capillary Pressure				
662	5717.5	0.08	9.9	2.66
669	5725.5	0.15	11.0	2.67
715	5829.6	0.20	10.7	2.67
722	5837.6	0.03	8.0	2.68
Electrical Resistivity				
658	5713.5	0.03	5.8	2.69
660	5715.5	0.05	7.4	2.66
666	5722.5	0.06	8.8	2.65
674	5730.5	<0.01	4.8	2.68
Air-Brine/Air-Methanol Capillary Pressure				
667	5723.4	1.4	10.3	2.66
6VM	5732.0-32.6	0.01	6.4	2.68
6HM	5732.0-32.6	0.02	7.8	2.68
6VF	5732.0-32.6	0.21	6.8	2.69
7VM	5734.1-34.7	0.17	6.7	2.68
7VF	5734.1-34.7	1.9	7.5	2.67

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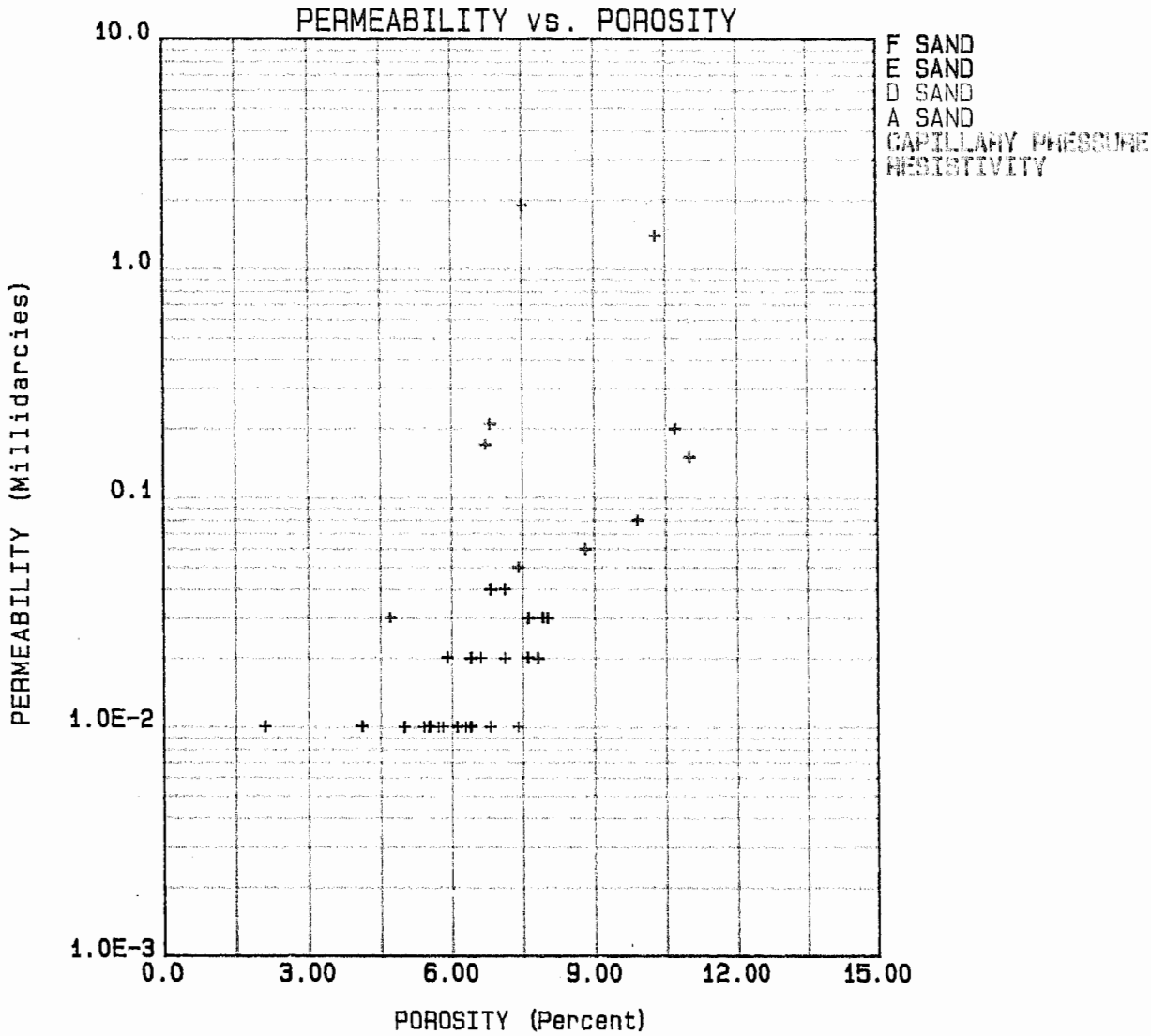

SANDIA NATIONAL LABORATORIES
MULTI-WELL EXPERIMENT
MESA VERDE FORMATION -- RULISON FIELD
GARFIELD COUNTY, COLORADO

These analyses, opinions or interpretations are based on observations and material supplied by the client to whom, and for whose exclusive and confidential use, this report is made. The interpretations or opinions expressed represent the best judgement of Core Laboratories, Inc. (all errors and omissions excepted), but Core Laboratories, Inc. and its officers and employees, assume no responsibility and make no warranty or representations as to the productivity, proper operation, or profitableness of any oil, gas or other mineral or sand in connection with such report is used or relied upon.

PERMEABILITY, POROSITY, AND KLINKENBERG PERMEABILITY

Company: Sandia National Laboratories
Formation: Mesa Verde - F Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample I.D.	Depth, feet	Porosity, Percent	Permeability to Air, millidarcys	Overburden Pressure, psi 1000	3000	4000
				Klinkenberg Permeability		
522	5450.5	3.2	<0.01	0.00036	0.00009	*
524	5458.5	2.2	<0.01	0.00018	0.00009	*
526	5464.5	1.7	<0.01	0.00010	*	*
528	5470.8	1.5	<0.01	0.00010	*	*
529	5474.7	0.8	<0.01	0.00007	*	*
530	5467.5	5.5	0.01	0.00130	0.00070	0.00050
532	5480.5	7.6	0.03	0.01373	0.00048	0.00042
533	5481.5	6.8	0.03	0.01025	0.00329	0.00062
535	5486.4	6.1	0.01	0.00445	0.00092	0.00064
541	5490.5	6.4	0.02	0.00700	0.00258	0.00061
544	5498.8	1.3	<0.01	0.00001	*	*

* Indicates sample did not produce data.

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PERMEABILITY, POROSITY, AND KLINKENBERG PERMEABILITY

Company: Sandia National Laboratories
Formation: Mesa Verde - E Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample I.D.	Depth, feet	Porosity, Percent	Permeability to Air, millidarcys	Overburden Pressure, psi 1000	3000	4000
				Klinkenberg Permeability		
549	5508.5	1.3	<0.01	0.00098	0.00034	0.00016
552	5514.7	1.4	<0.01	0.00105	0.00078	0.00036
553	5515.3	2.3	<0.01	0.00324	0.00227	0.00068
555	5515.7	2.6	<0.01	0.00042	0.00038	0.00016
557	5517.3	3.5	<0.01	0.00064	0.00038	0.00028
558	5520.4	3.3	<0.01	0.00339	0.00207	0.00159
559	5522.3	1.8	<0.01	0.00088	0.00041	0.00017
560	5524.5	4.1	0.01	0.00419	0.00240	0.00089
561	5528.5	4.0	<0.01	0.00101	0.00040	0.00024
564	5535.4	2.1	<0.01	0.00086	0.00072	0.00020
566	5544.5	5.0	<0.01	0.00112	0.00083	0.00037
570	5548.6	7.1	0.04	0.01267	0.00371	0.00061
573	5552.5	5.9	0.02	0.00717	0.00405	0.00122
574	5553.5	7.6	0.02	0.00813	0.00322	0.00101
578	5557.5	7.9	0.03	0.01172	0.00351	0.00059
583	5561.6	6.4	0.01	0.00460	0.00179	0.00075
587	5566.5	2.1	0.01	0.00149	0.00039	0.00020

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PERMEABILITY, POROSITY, AND KLINKENBERG PERMEABILITY

Company: Sandia National Laboratories
Formation: Mesa Verde - D Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample I.D.	Depth, feet	Porosity, Percent	Permeability to Air, millidarcys	Overburden Pressure, psi 1000	3000	4000
				Klinkenberg Permeability		
608	5608.5	3.7	<0.01	0.00025	0.00020	0.00019
610	5613.5	5.3	0.01	0.00273	0.00126	0.00035
611	5616.5	4.7	0.24	0.04665	0.00345	0.00259
612	5617.5	5.0	0.01	0.00352	0.00078	0.00061
614	5620.5	3.4	<0.01	0.00051	0.00018	0.00012
615	5622.5	2.0	<0.01	0.00046	0.00023	0.00010
617	5624.3	4.6	<0.01	0.00202	0.00101	0.00051
619	5626.5	7.4	0.01	0.00434	0.00089	0.00070
620	5627.5	6.8	0.01	0.00411	0.00170	0.00107
621	5628.5	7.1	0.01	0.00154	0.00053	0.00035
622	5629.5	6.3	0.01	0.00382	0.00089	0.00079
624	5631.5	6.8	0.01	0.00489	0.00131	0.00071
627	5634.5	4.8	<0.01	0.00036	0.00029	0.00014
628	5635.5	5.9	<0.01	0.00058	0.00041	0.00020
631	5642.5	1.0	<0.01	0.00014	*	*
633	5648.5	0.3	<0.01	0.00010	*	*

* Indicates sample did not produce data.

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PERMEABILITY, POROSITY, AND KLINKENBERG PERMEABILITY

Company: Sandia National Laboratories
Formation: Mesa Verde - A Sand
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample I.D.	Depth, feet	Porosity, Percent	Permeability to Air, millidarcys	Overburden Pressure, psi 1000	3000	4000
				Klinkenberg Permeability		
762	5950.2	2.0	<0.01	0.00008	*	*
764	5954.5	1.9	<0.01	0.00006	*	*
769	5959.5	5.0	0.01	0.00339	0.00172	0.00089
771	5961.5	5.8	0.01	0.00379	0.00073	0.00066
773	5963.5	5.7	0.01	0.00334	0.00077	0.00062
775	5965.5	5.4	0.01	0.00367	0.00104	0.00076
777	5967.5	6.4	0.02	0.00696	0.00184	0.00088
779	5969.5	6.6	0.02	0.00629	0.00177	0.00069
781	5971.5	5.0	0.01	0.00333	0.00086	0.00070
789	5987.6	7.1	0.02	0.00473	0.00297	0.00210

* Indicates sample did not produce data.

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SUMMARY OF CAPILLARY PRESSURE TEST RESULTS

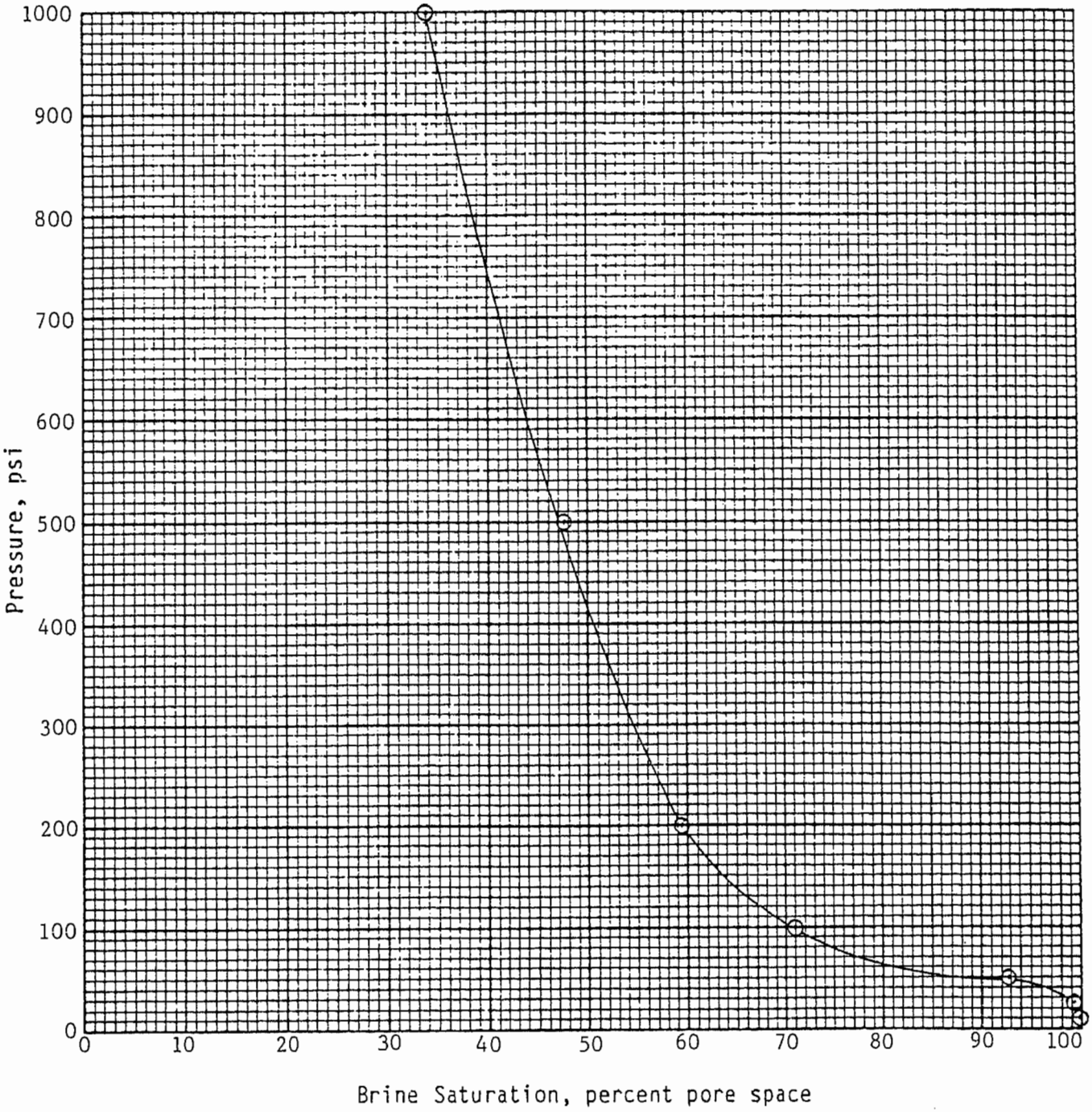
Company: Sandia National Laboratories
Well: Multi-Well Experiment No. 1
Field: Rulison
Formation: Mesa Verde
County, State: Garfield, Colorado

Fluid System: Air-Water
Test Method: High-Speed Centrifuge

Sample I.D.	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Pressure, psi: 1	2	5	10	25	50	100	200	500	1000
				Brine Saturation, percent pore space									
662	5717.5	0.08	9.9	100.0	100.0	100.0	100.0	99.3	92.9	71.0	59.6	47.7	34.0
667	5723.4	1.4	10.3	100.0	100.0	100.0	100.0	90.0	75.1	64.0	53.6	44.5	37.2
669	5725.5	0.15	11.0	100.0	100.0	100.0	100.0	90.0	74.0	63.5	53.6	42.7	32.9
6HM	5732.0-32.6	0.02	7.8	100.0	100.0	100.0	100.0	100.0	100.0	88.5	72.9	55.9	40.6
6VM	5732.0-32.6	0.01	6.4	100.0	100.0	100.0	100.0	100.0	100.0	94.6	86.3	68.7	56.8
7VM	5734.1-34.7	0.17	6.7	100.0	100.0	100.0	100.0	100.0	100.0	94.2	86.9	74.3	64.9
715	5829.6	0.20	10.7	100.0	100.0	100.0	100.0	82.4	66.4	55.2	47.1	35.8	25.9
722	5837.6	0.03	8.0	100.0	100.0	100.0	100.0	100.0	99.7	89.5	77.3	62.0	44.9

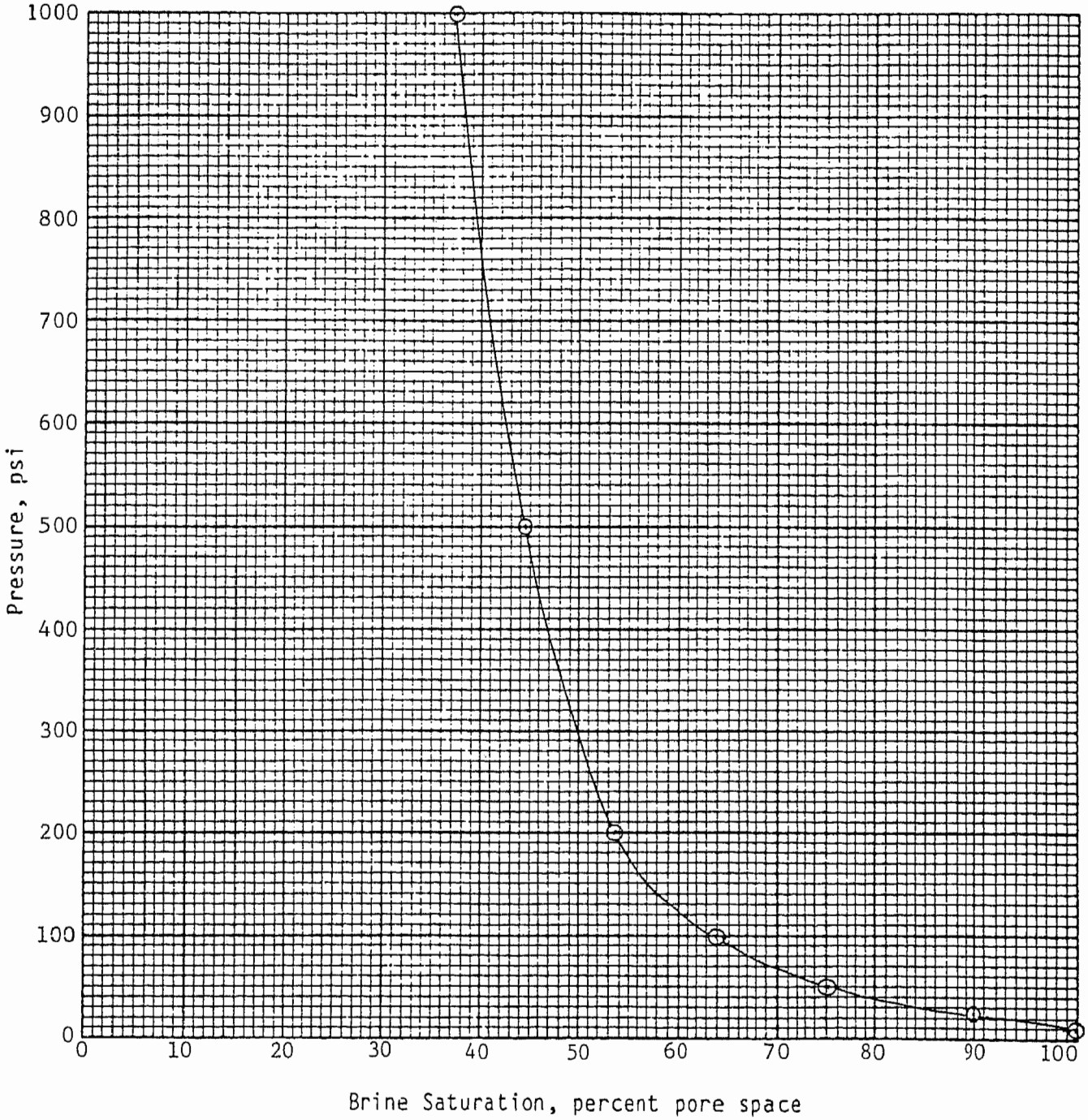
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 662



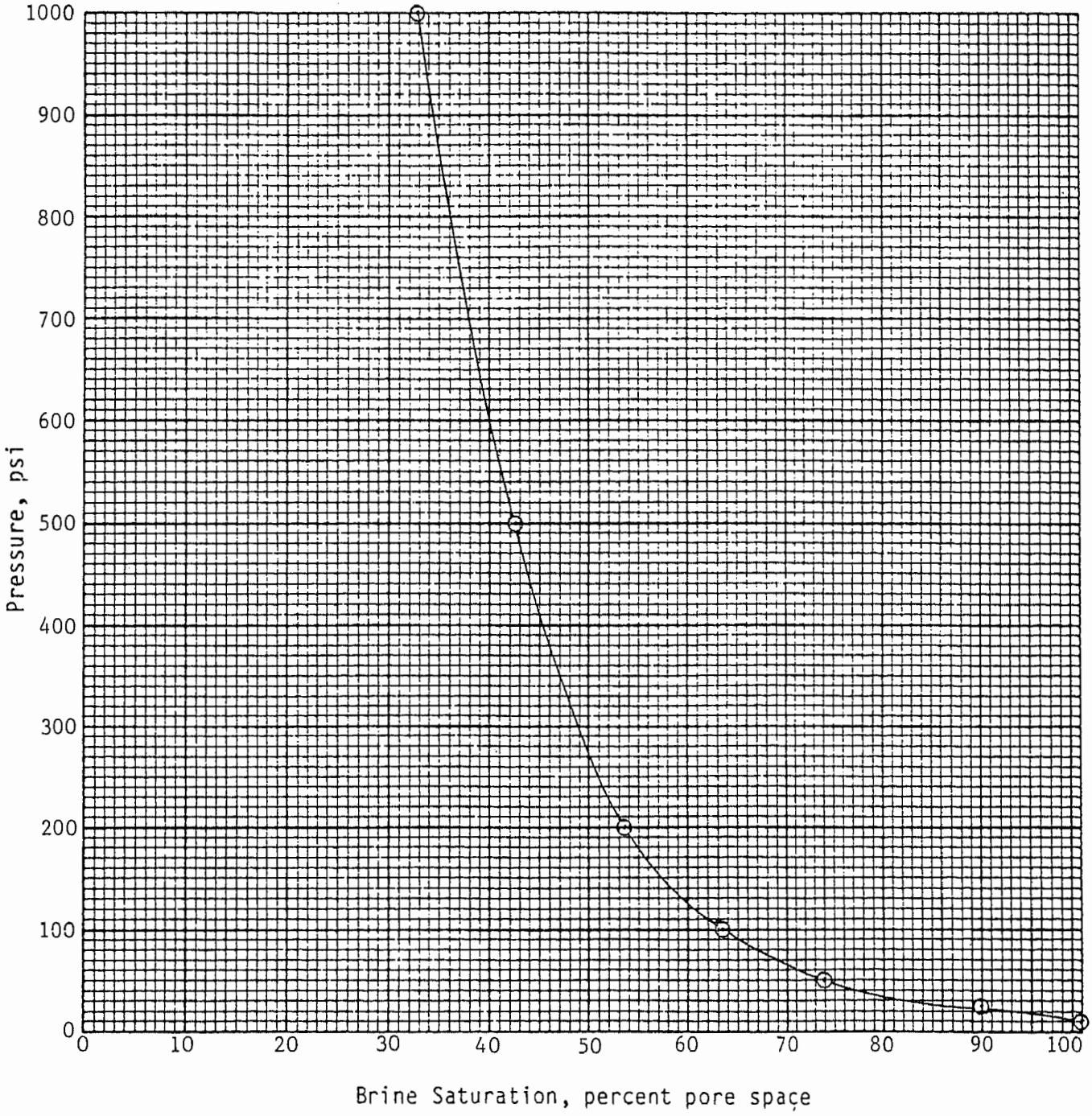
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 667



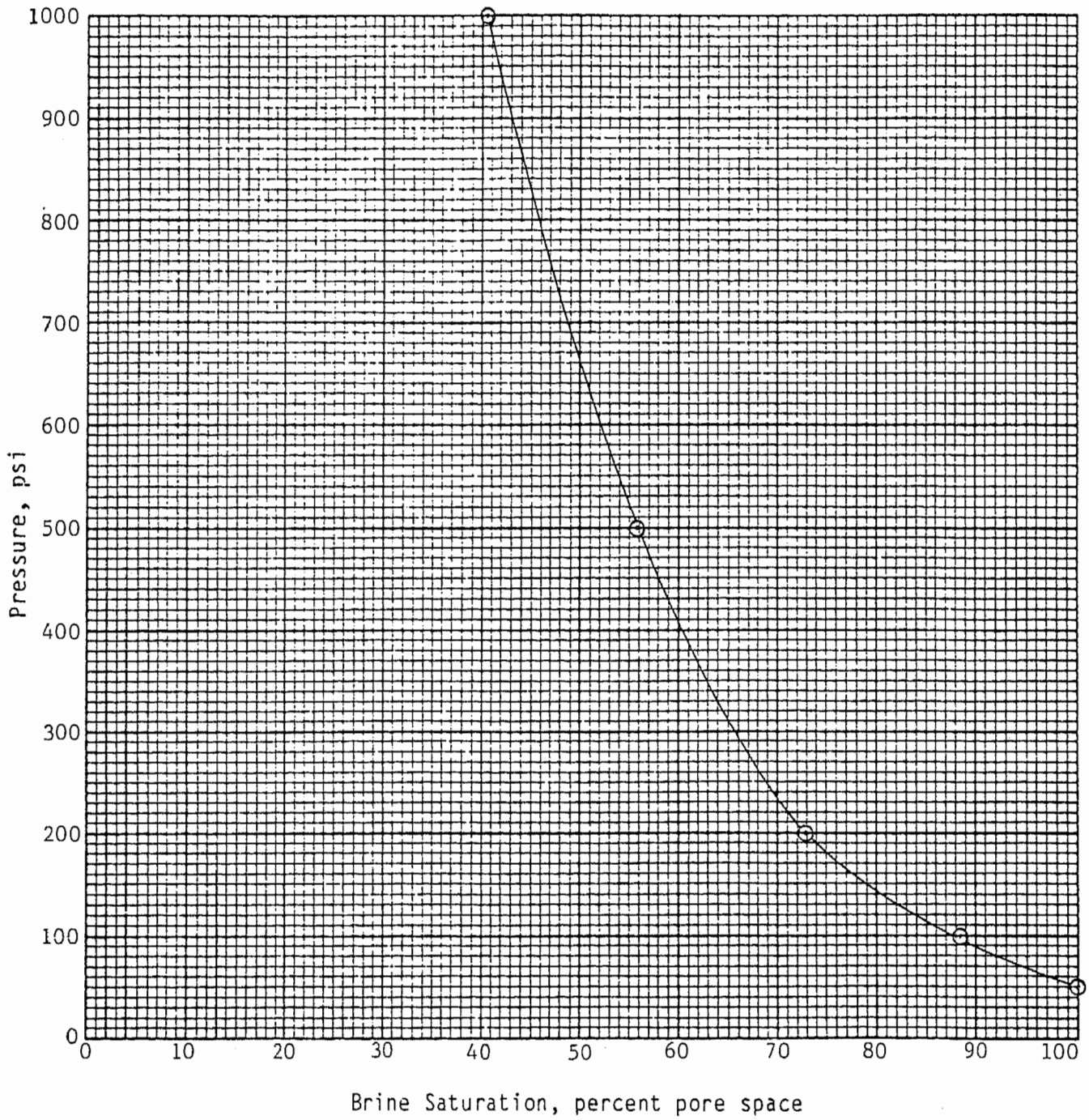
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 669



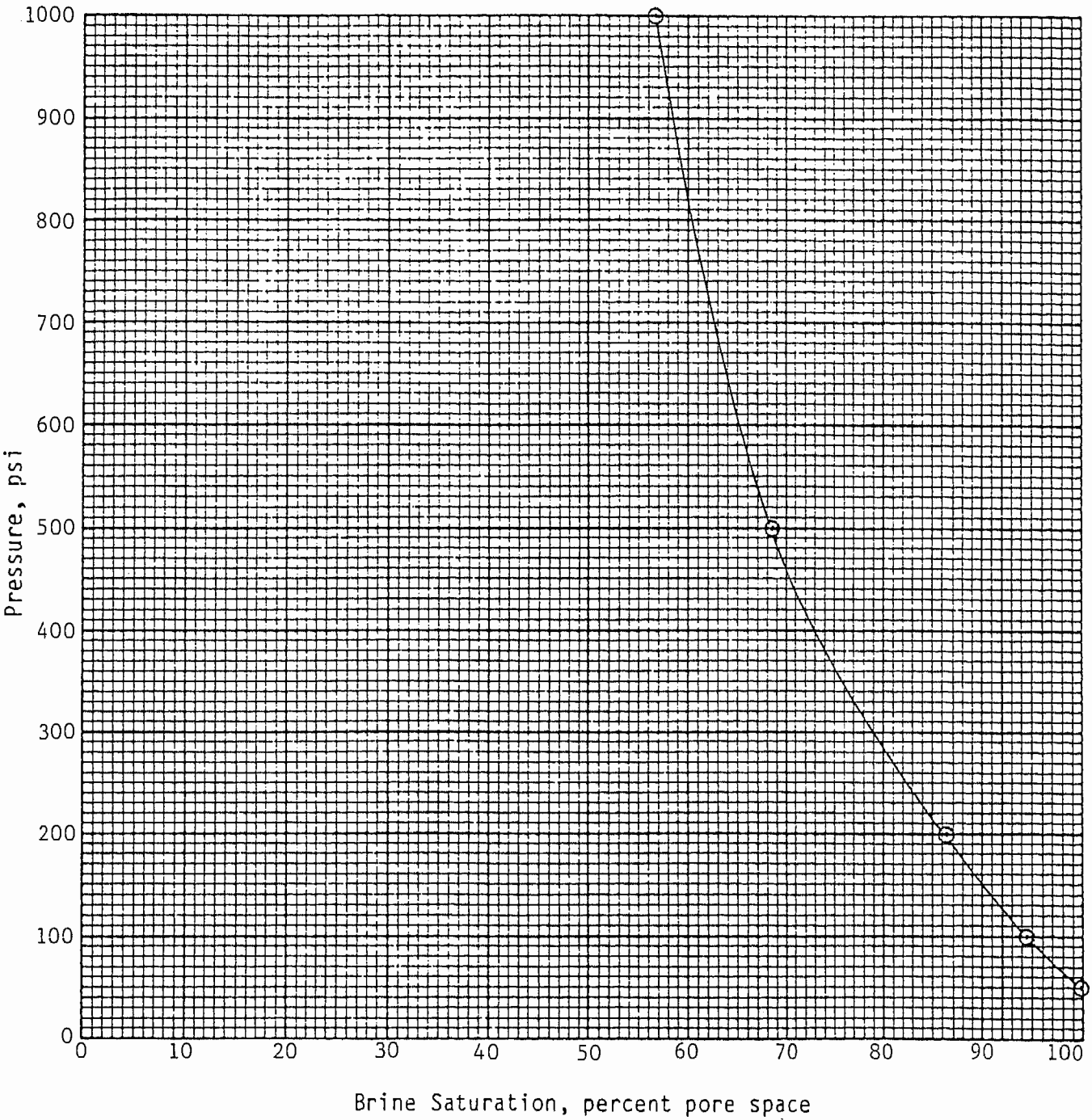
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 6HM



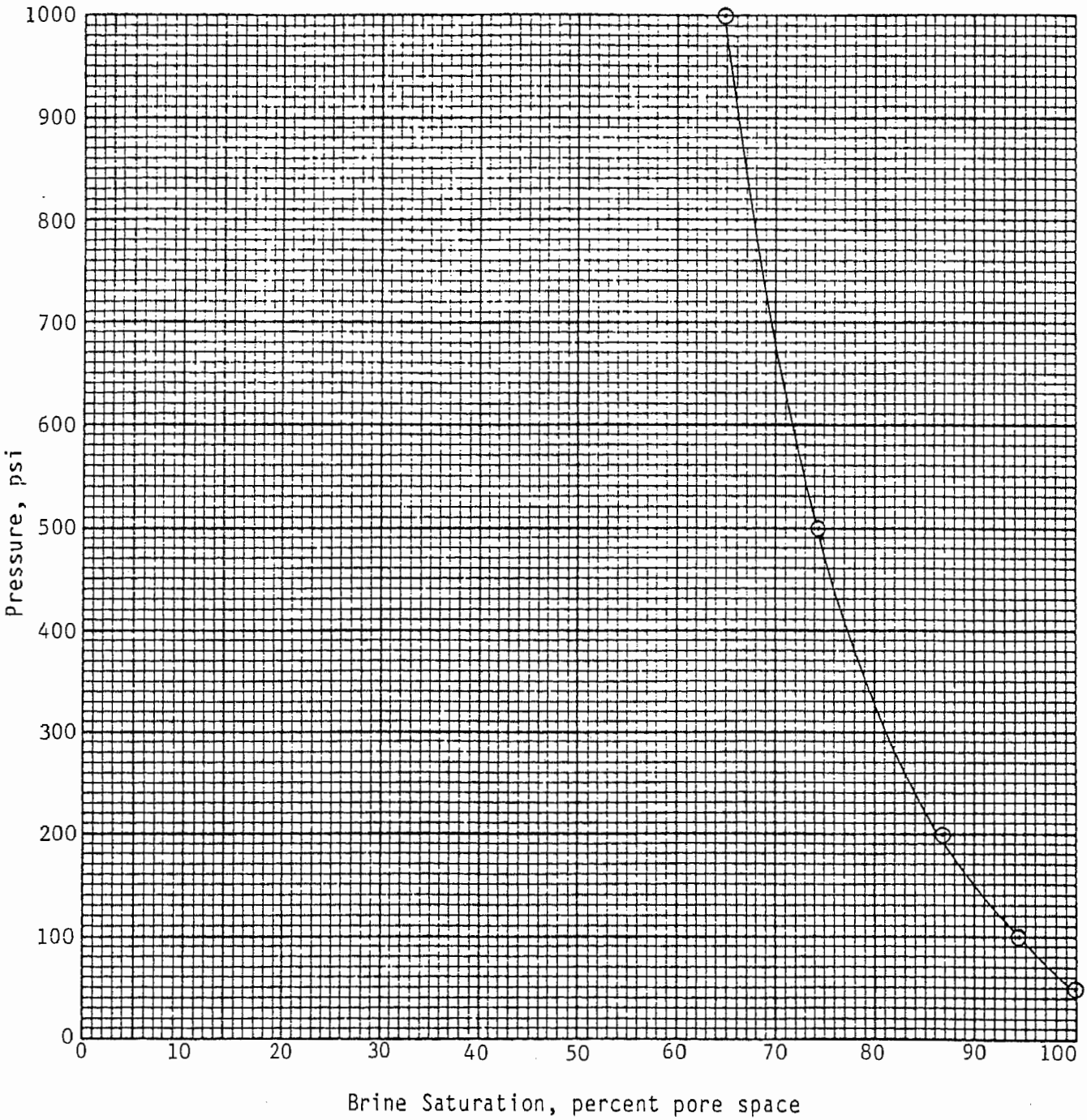
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 6VM



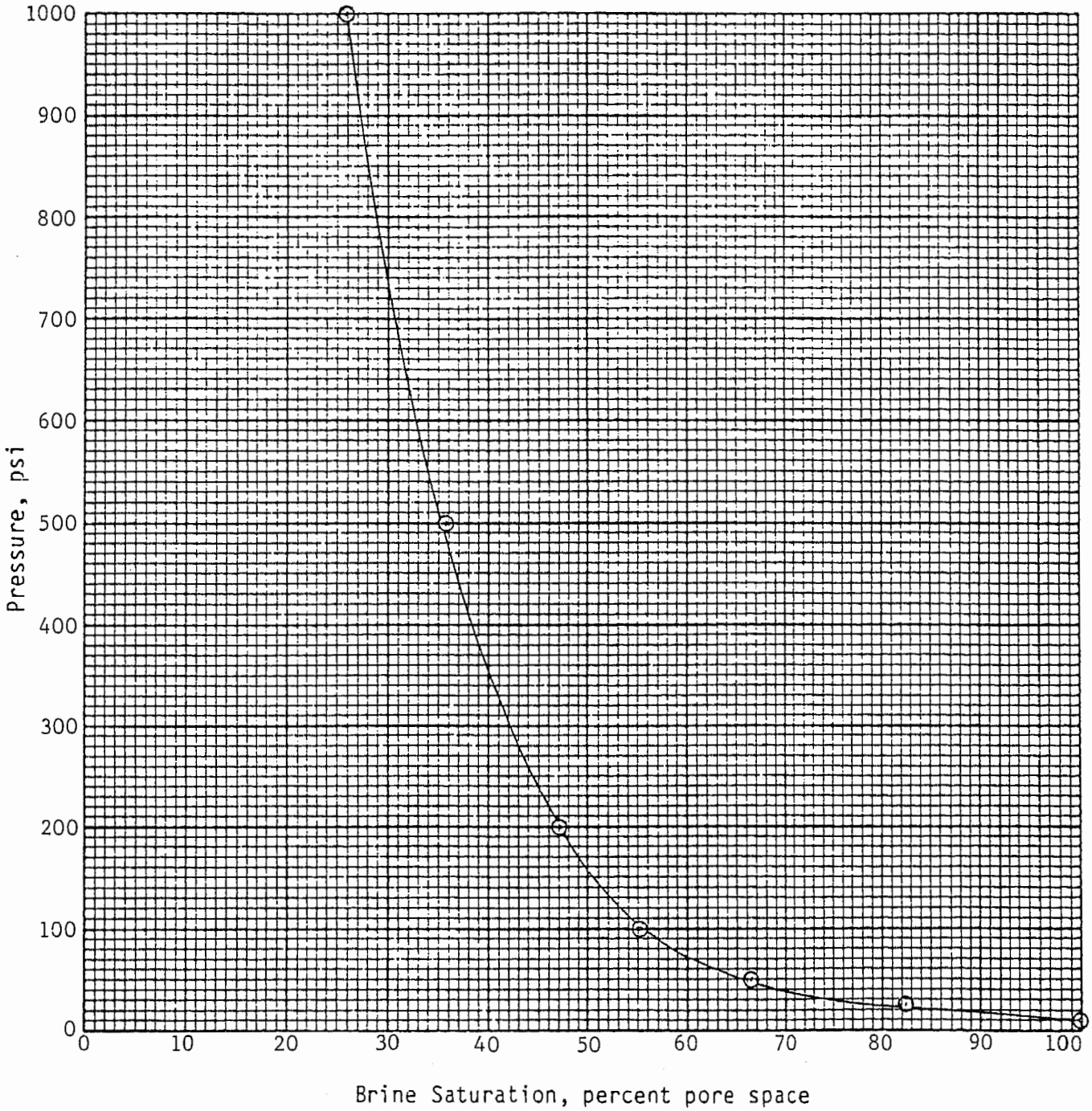
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 7VM



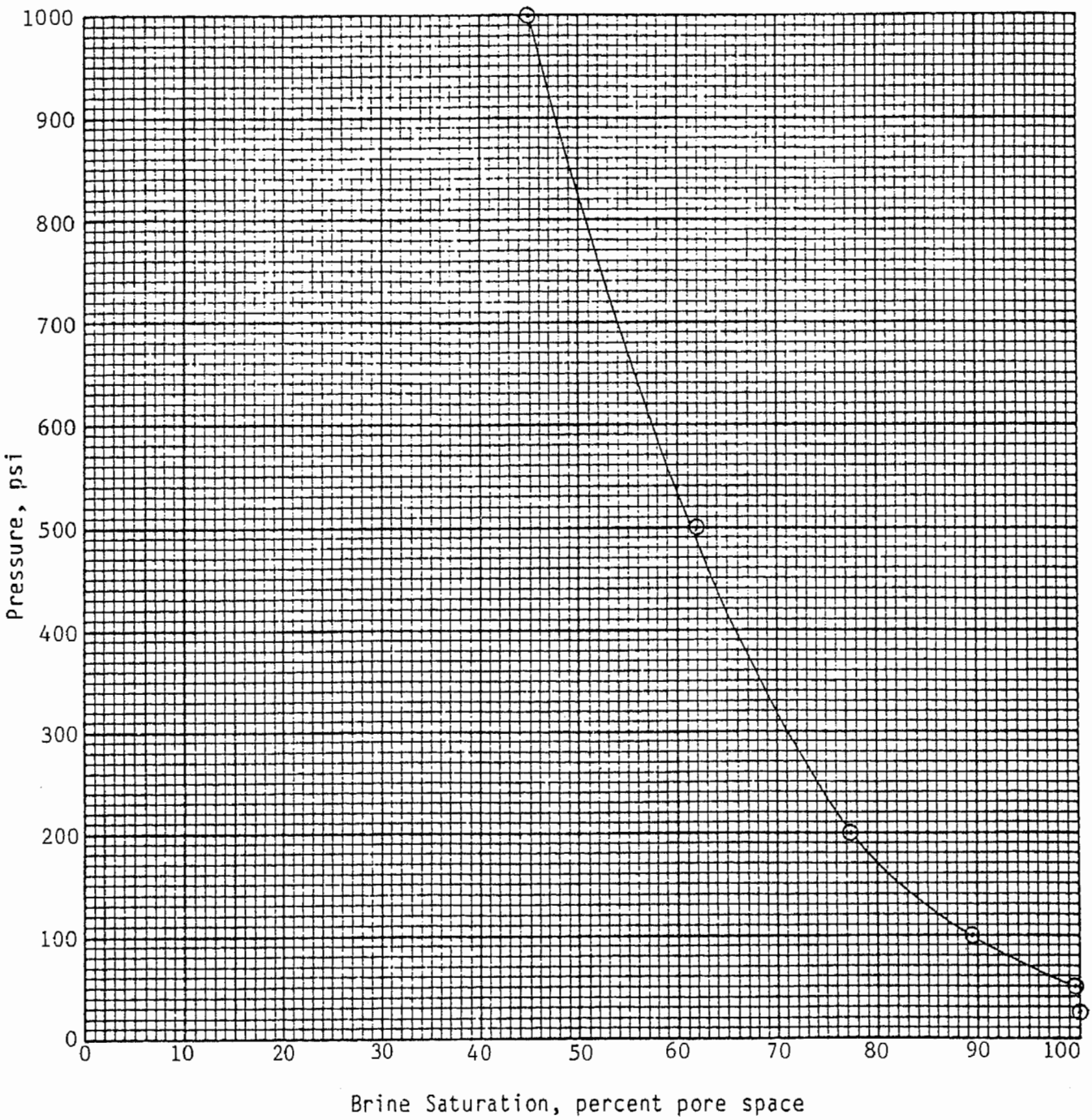
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 715



Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 722



SUMMARY OF CAPILLARY PRESSURE TEST RESULTS

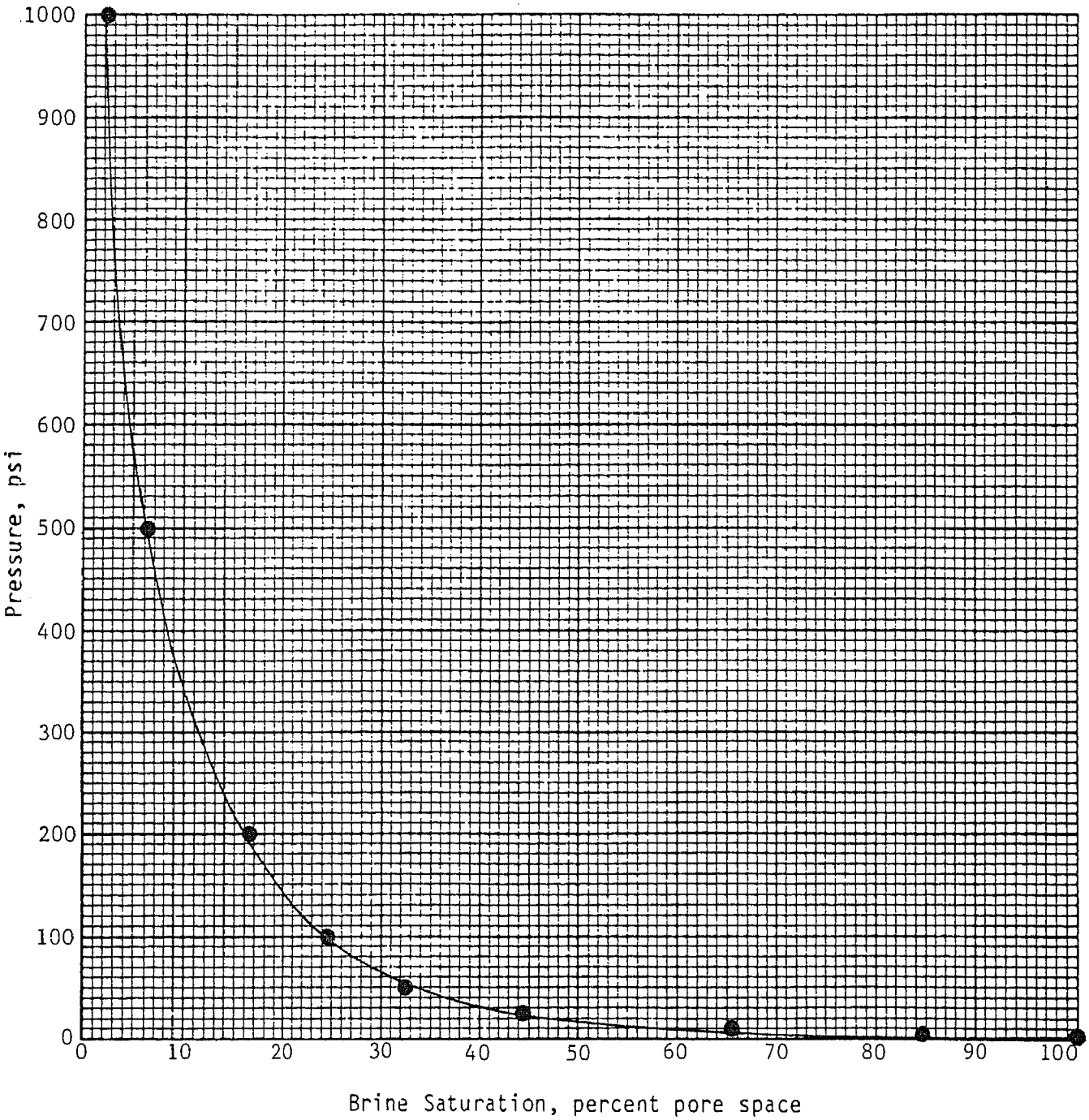
Company: Sandia National Laboratories
Well: Multi-Well Experiment No. 1
Field: Rulison
Formation: Mesa Verde
County, State: Garfield, Colorado

Fluid System: Air-Methanol
Test Method: High-Speed Centrifuge

Sample I.D.	Depth, feet	Permeability to Air, millidarcys	Porosity, percent	Pressure, psi: 1	2	5	10	25	50	100	200	500	1000
				Brine Saturation, percent pore space									
667	5723.4	1.4	10.3	100.0	100.0	84.8	65.4	44.5	32.5	24.7	16.4	6.2	2.3
6VM	5732.0-32.6	0.01	6.4	100.0	100.0	100.0	95.4	88.2	81.6	73.2	61.5	39.6	26.4
6HM	5732.0-32.6	0.02	7.8	100.0	100.0	100.0	98.3	87.9	80.7	71.6	63.0	49.9	40.8
6VF	5732.0-32.6	0.21	6.8	100.0	100.0	100.0	98.3	92.0	88.8	84.2	76.2	60.3	50.3
7VM	5734.1-34.7	0.17	6.7	100.0	100.0	100.0	98.8	92.0	84.9	76.8	65.7	46.4	34.2
7VF	5734.1-34.7	1.9	7.5	100.0	100.0	100.0	90.0	74.0	70.0	62.0	53.2	35.6	24.9

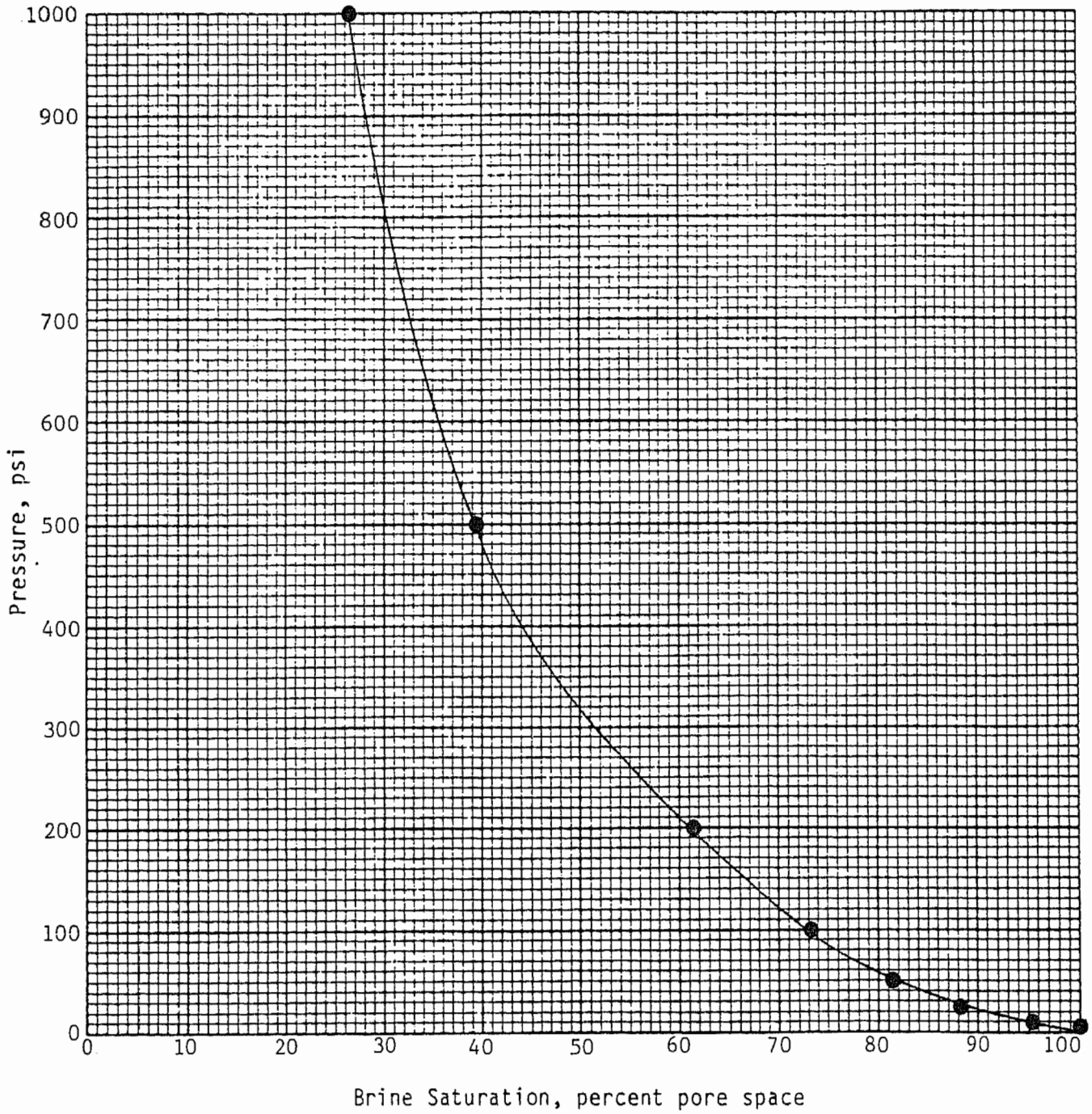
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 667



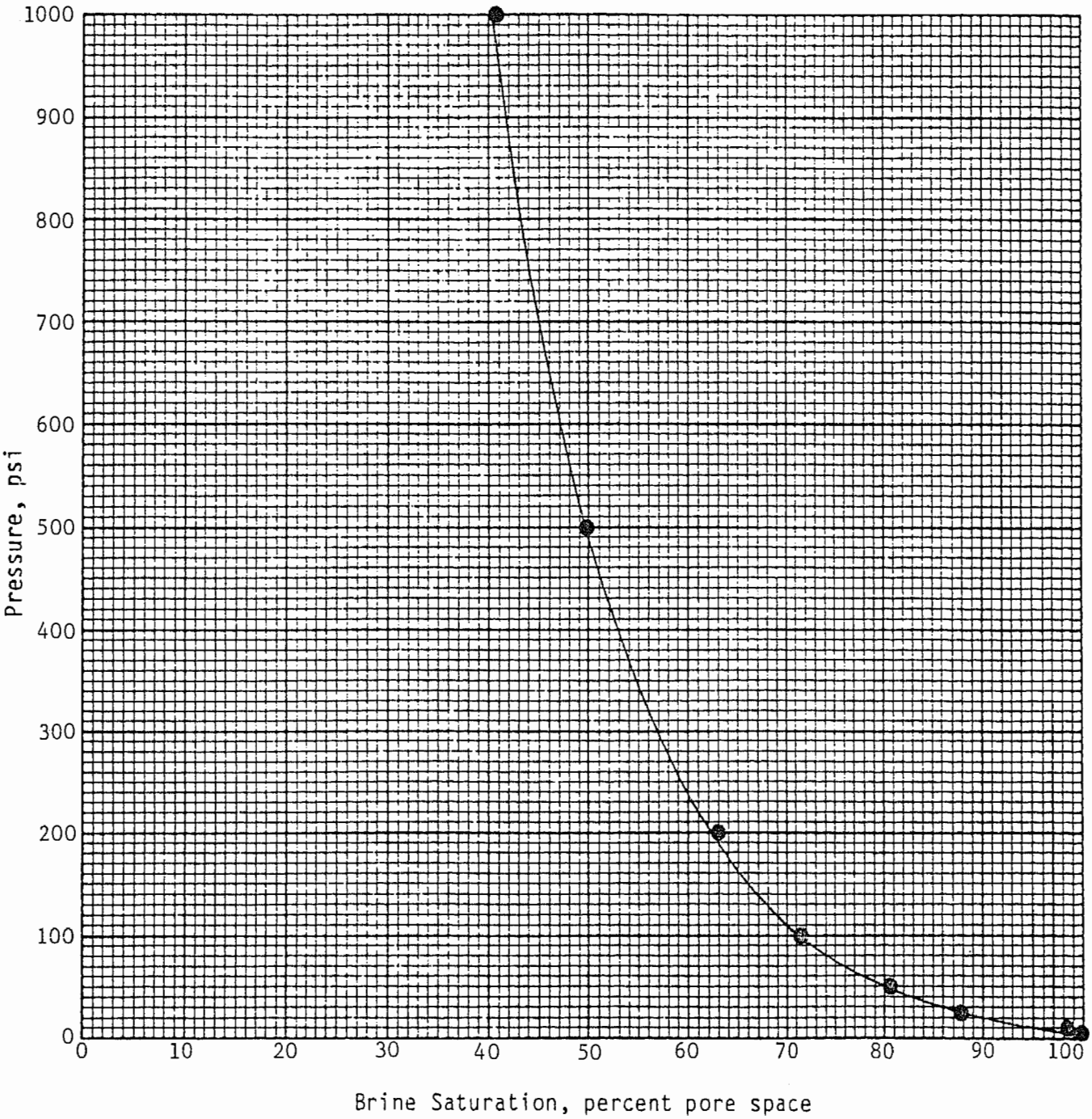
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 6VM



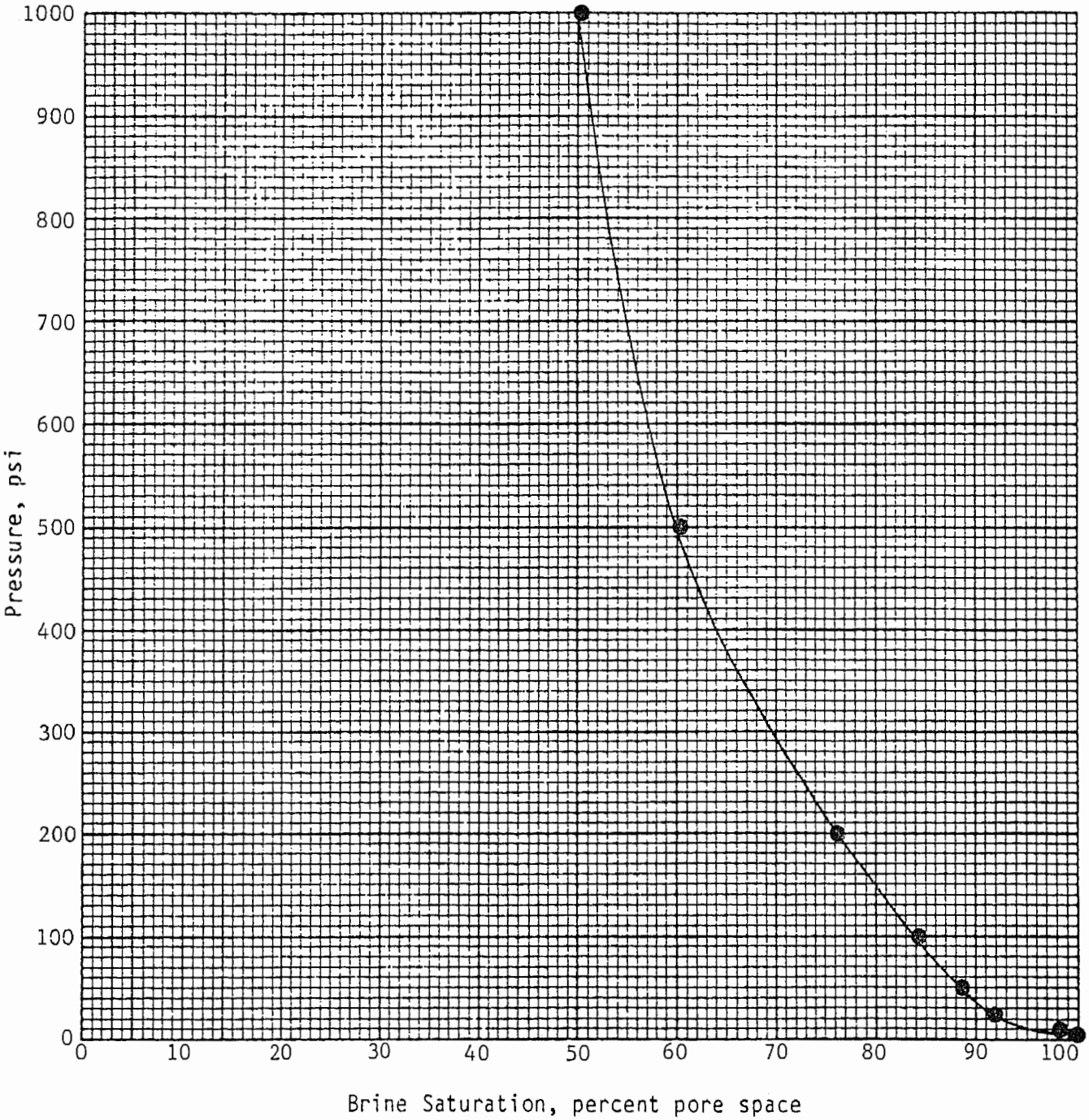
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 6HM



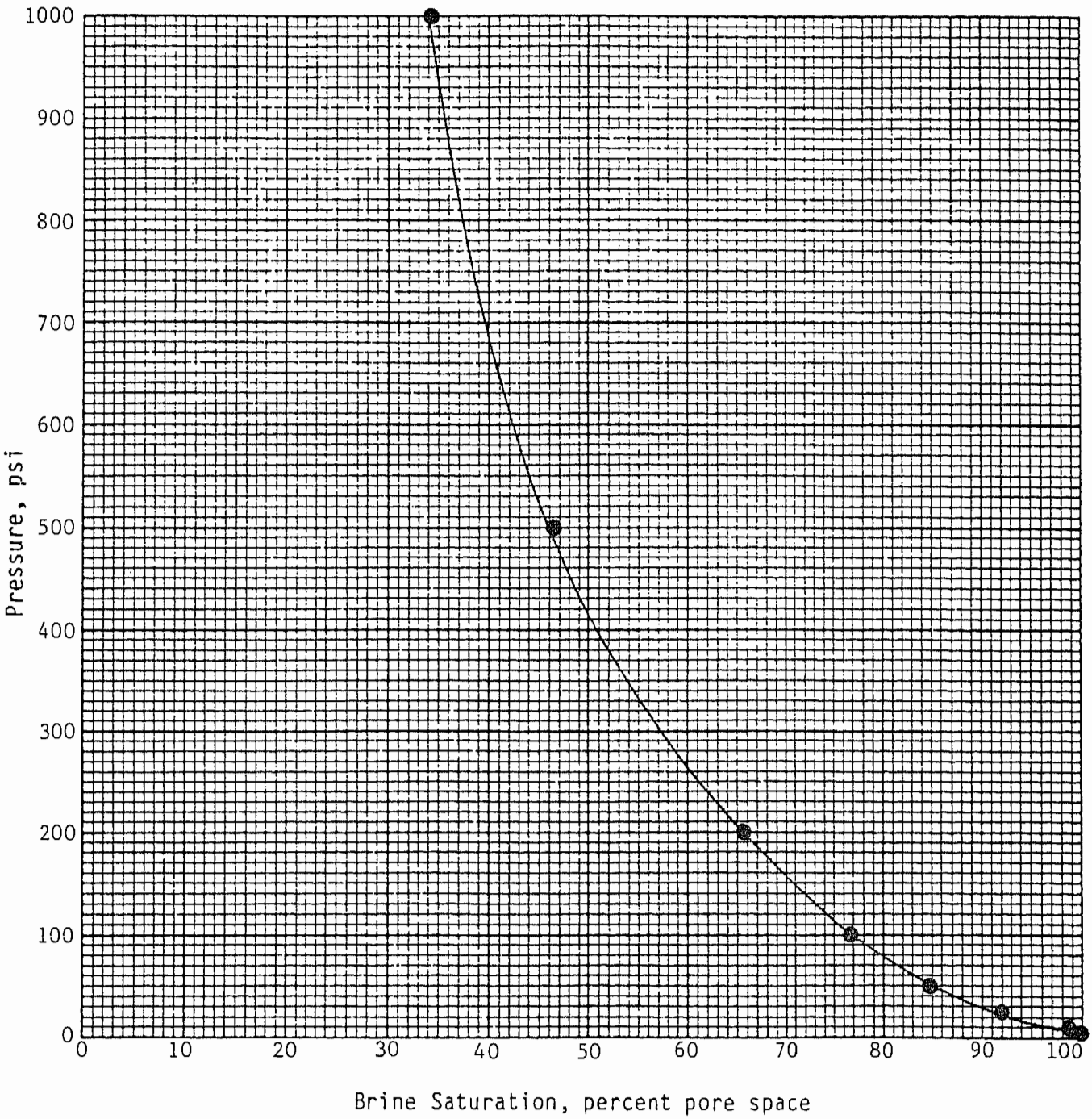
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 6VF



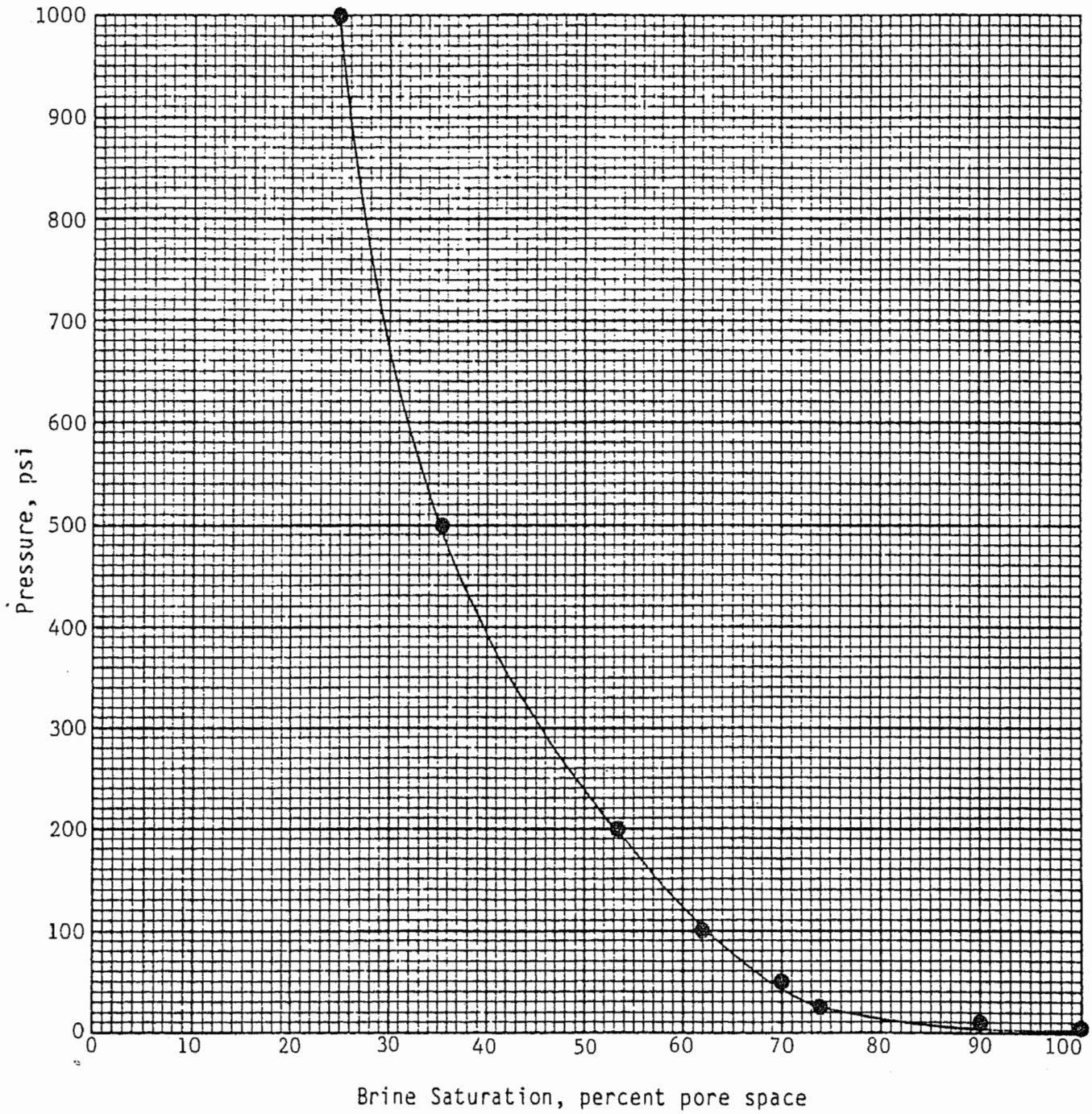
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 7VM



Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 7VF



FORMATION RESISTIVITY FACTOR AS A FUNCTION OF OVERBURDEN PRESSURE

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Saturant: 30,000 ppm NaCl
Resistivity of Saturant: 0.194 ohm-meters at 77°F.

Sample I.D.	Depth, feet	Permeability to Air, Millidarcys	Porosity, Percent	Overburden Pressure, psi 0.0	200	3000
				Formation Resistivity Factor		
658	5713.5	0.03	5.8	132	166	
			5.6*			235
660	5715.5	0.05	7.4	92.0	111	
			7.1*			136
666	5722.5	0.06	8.8	77.0	88.4	
			8.6*			119
674	5730.5	<0.01	4.8	146	179	
			4.6*			276

* Reduced porosity due to overburden stress.

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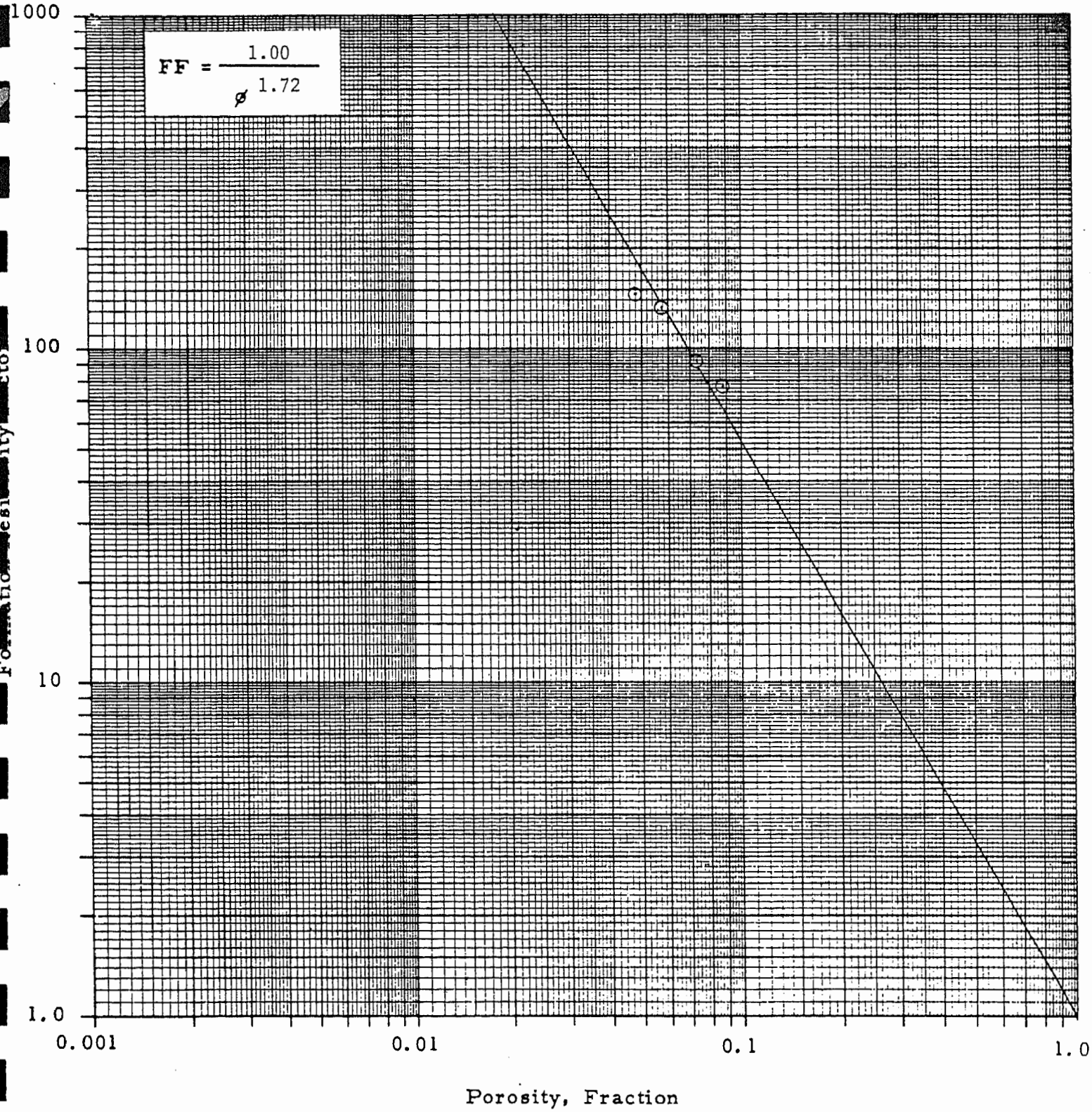
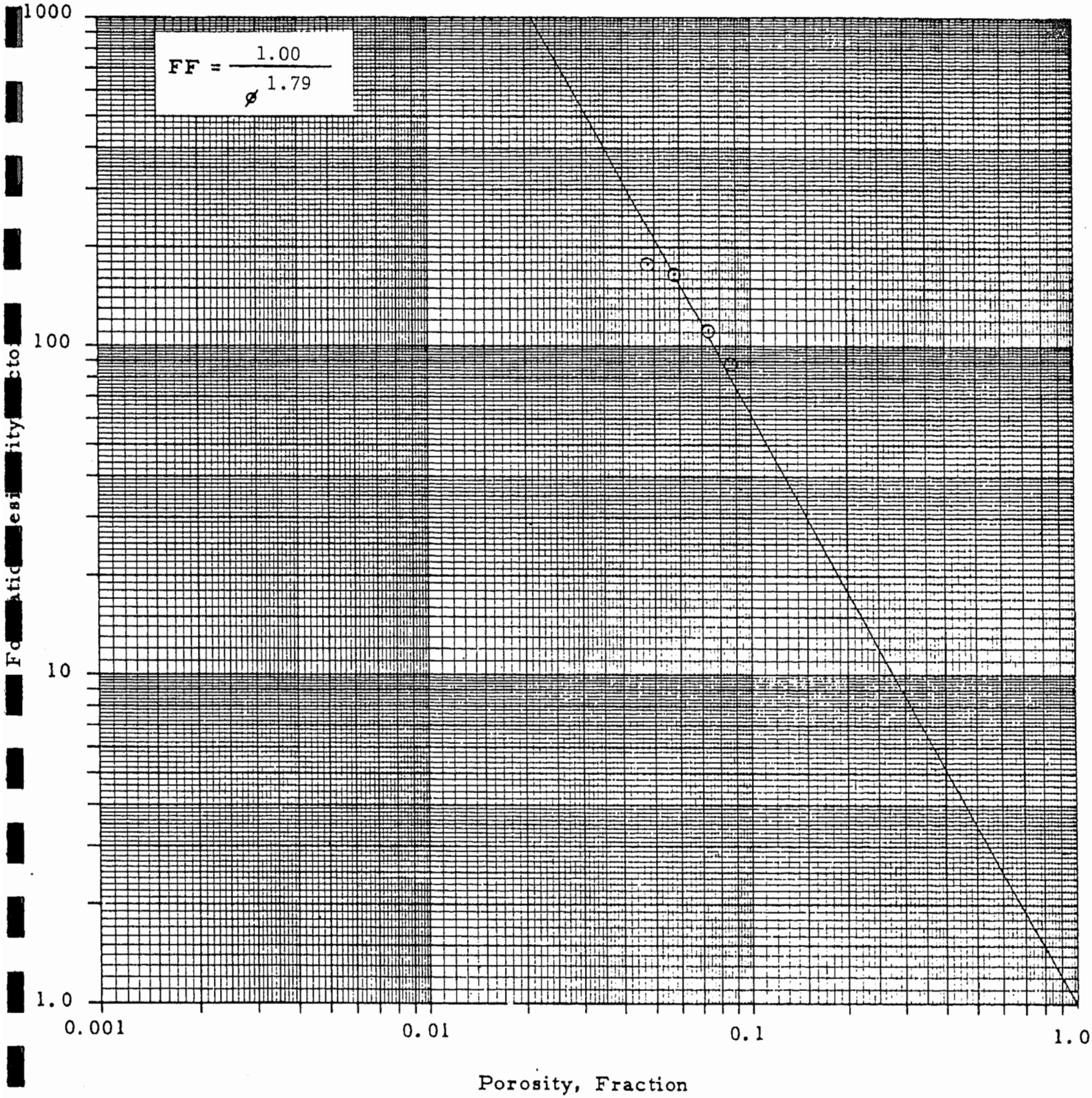
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

0.00 psi Effective Overburden



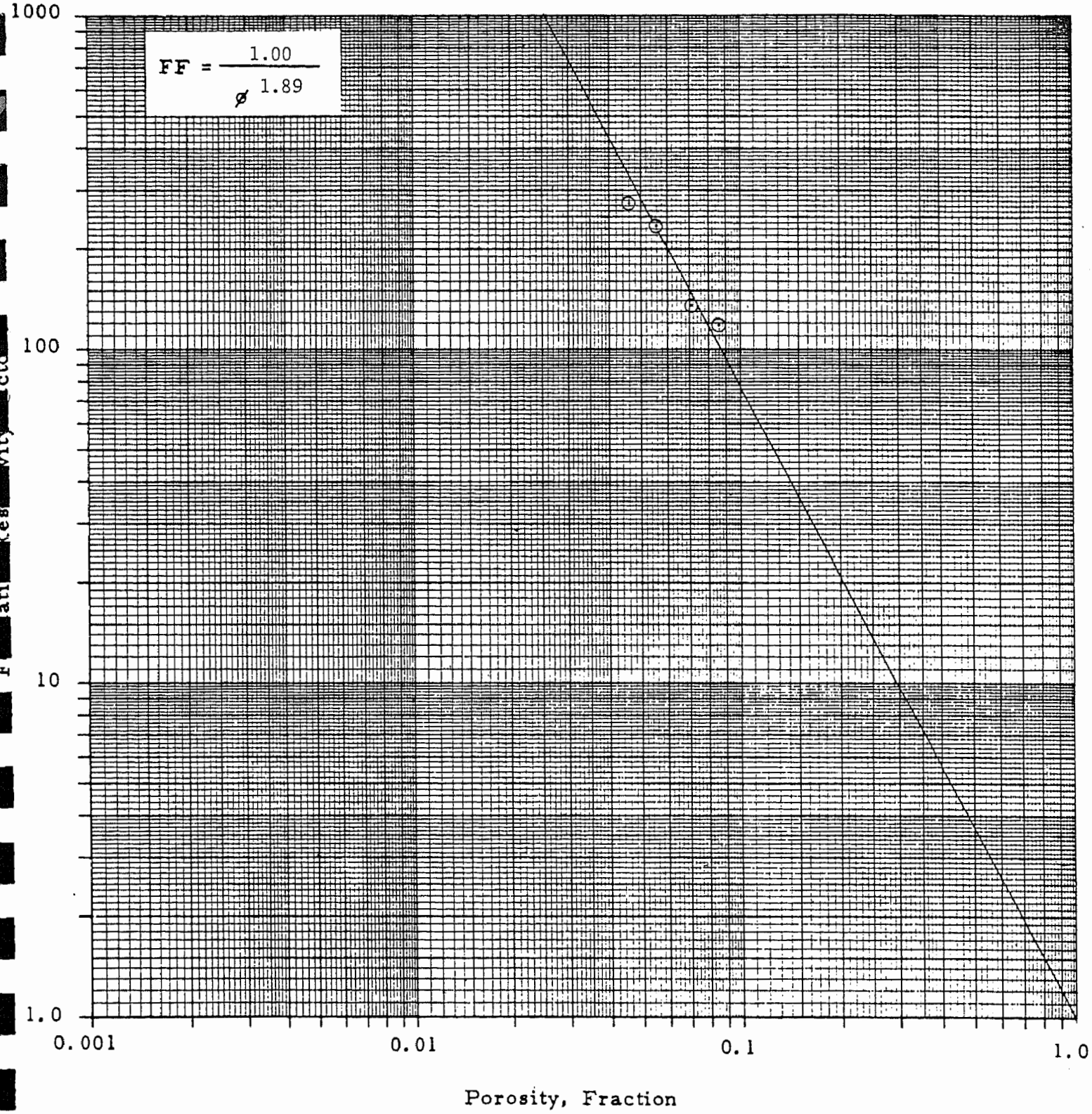
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

200 psi Effective Overburden



Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

3000 psi Effective Overburden



FORMATION RESISTIVITY INDEX

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Saturant: 30,000 ppm NaCl
Resistivity of Saturant: 0.194 ohm-meters at 77°F

Sample I.D.	Depth, feet	Permeability to Air Millidarcys	Porosity, Percent	Brine Saturation percent pore space	Resistivity Index
658	5713.5	0.03	5.8	60.7	2.25
				49.5	2.94
				36.5	4.55
660	5715.5	0.05	7.4	75.9	1.42
				61.7	1.80
				45.4	3.15
666	5722.5	0.06	8.8	78.7	1.33
				63.3	1.58
				43.2	3.09
674	5730.5	<0.01	4.8	82.1	1.22
				69.6	1.49
				59.8	1.85

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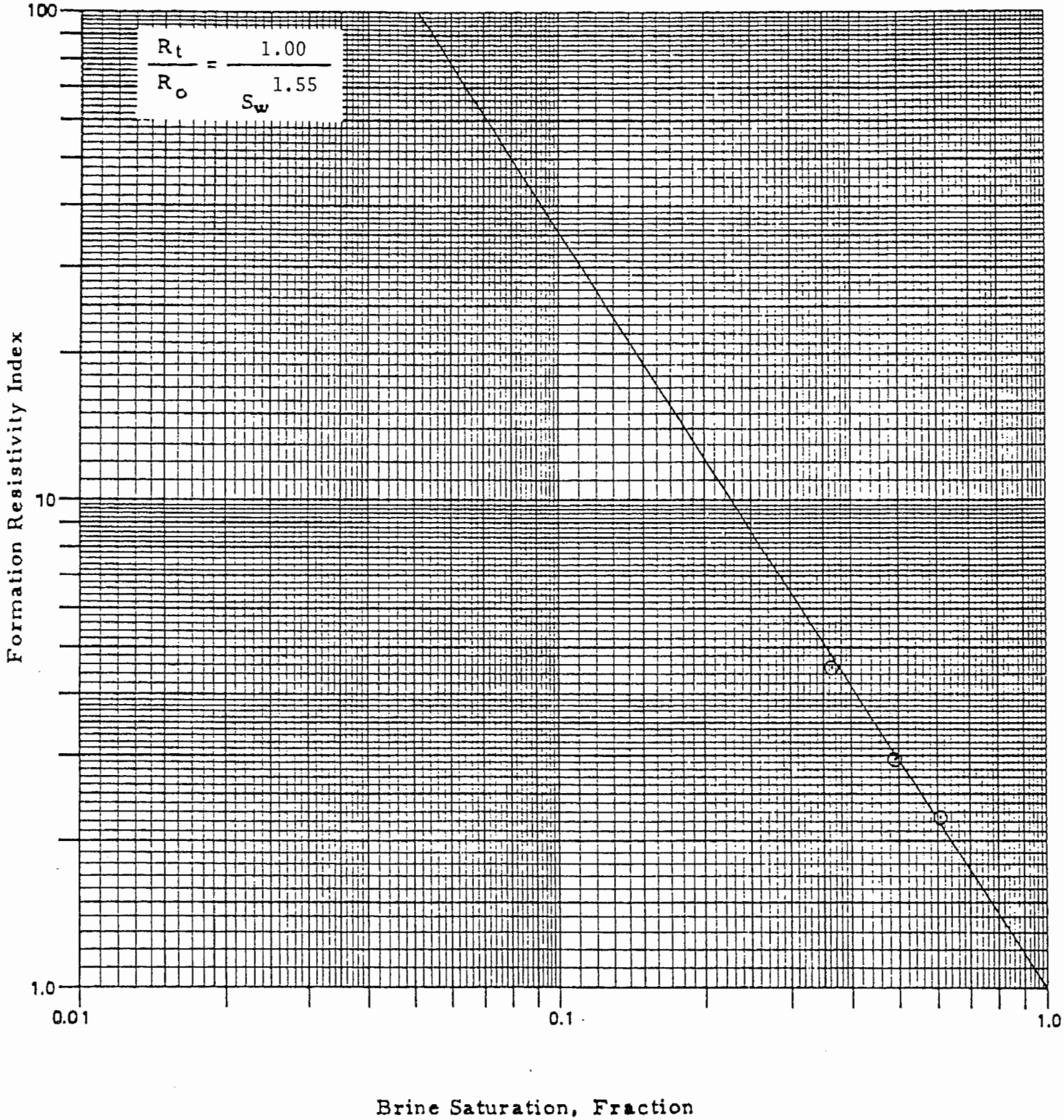
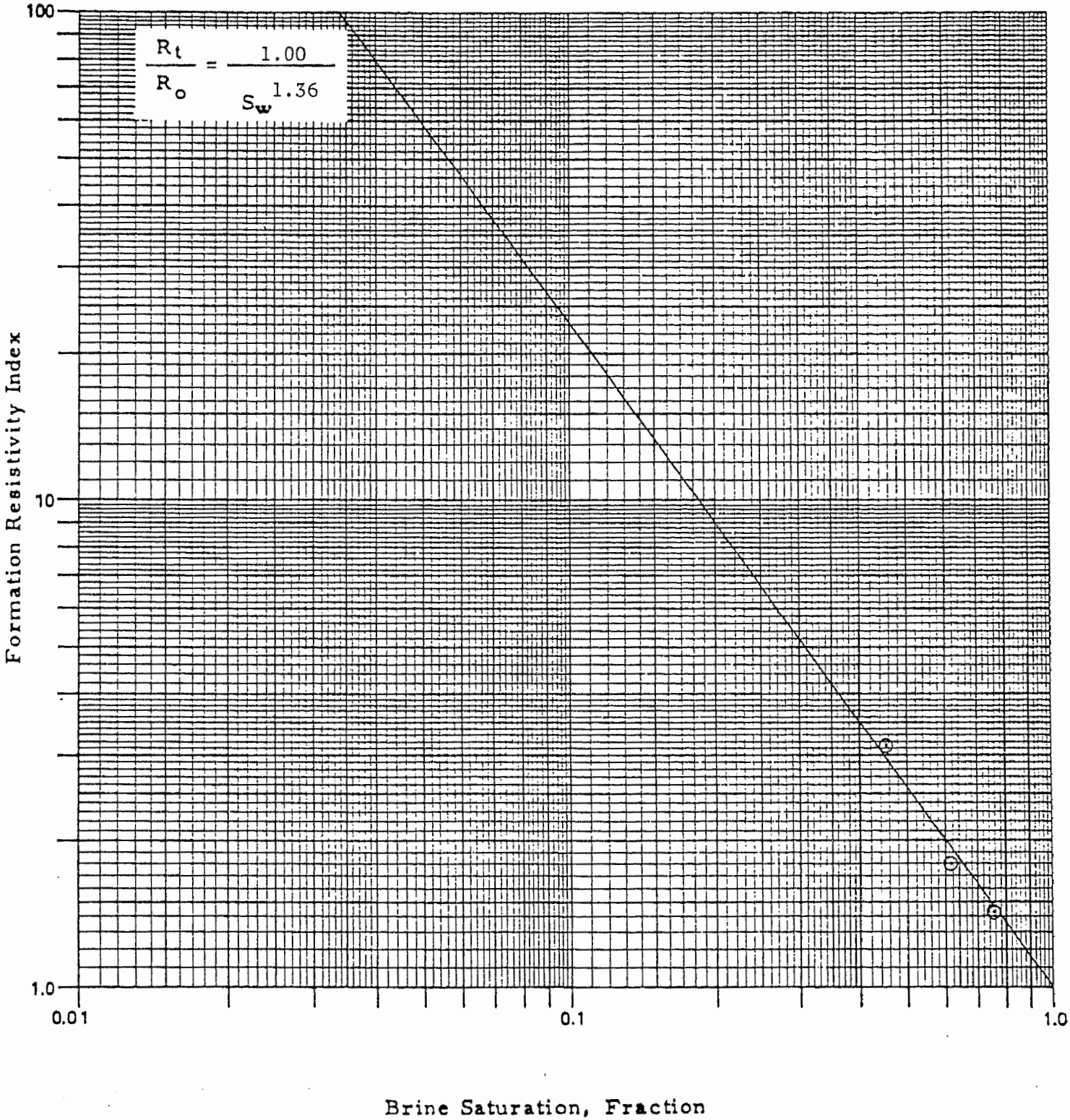
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 658



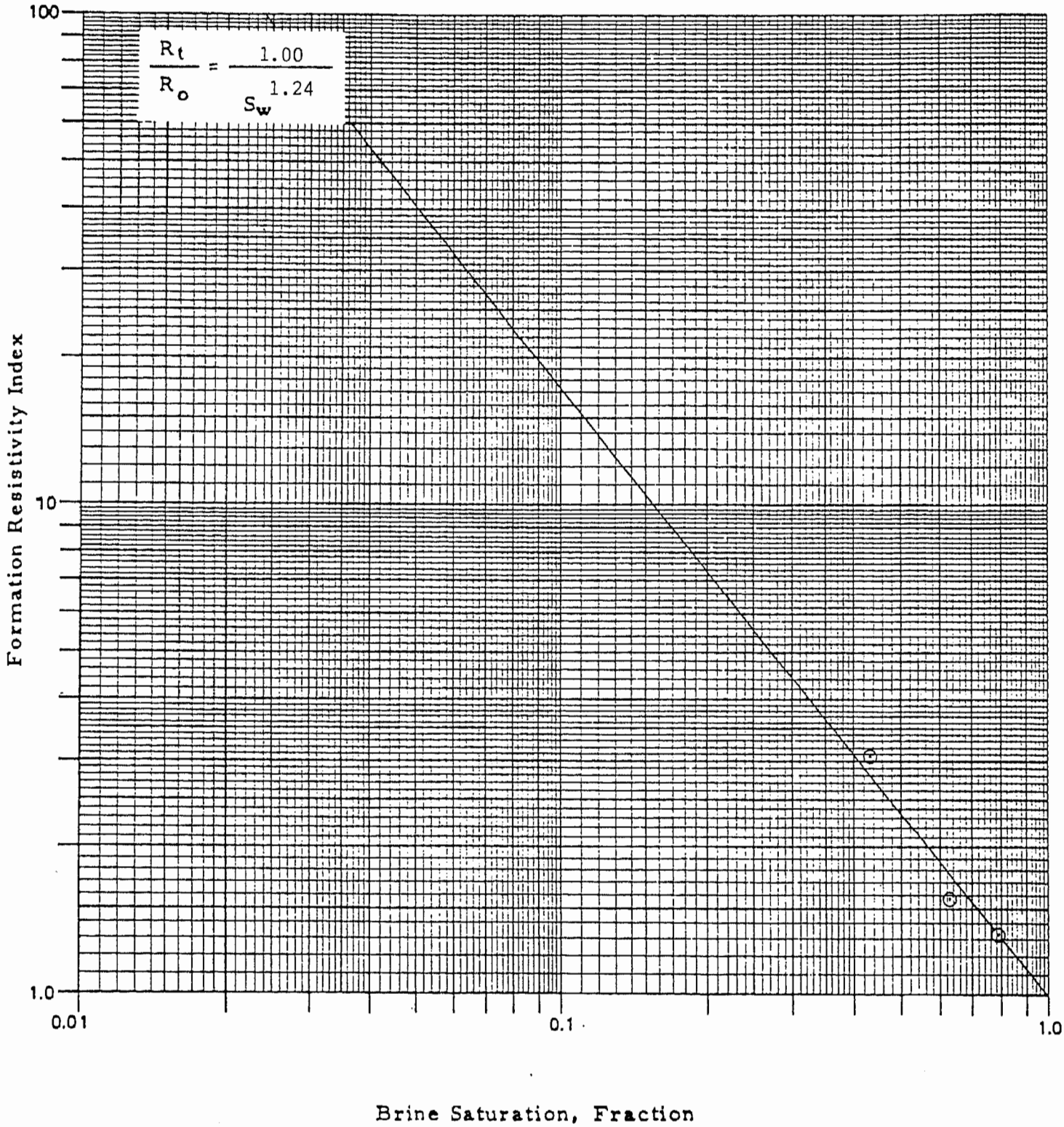
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 660



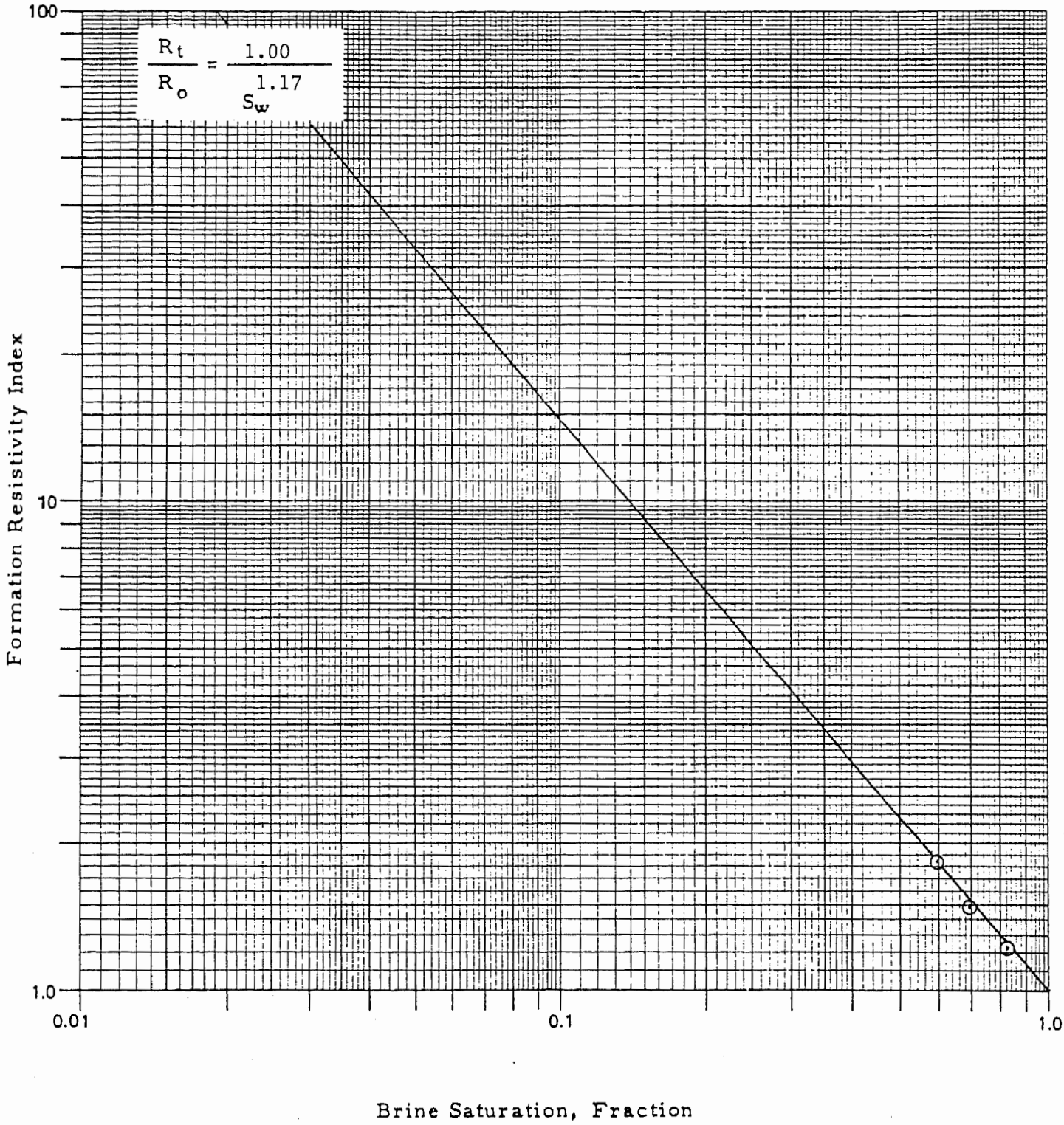
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 666



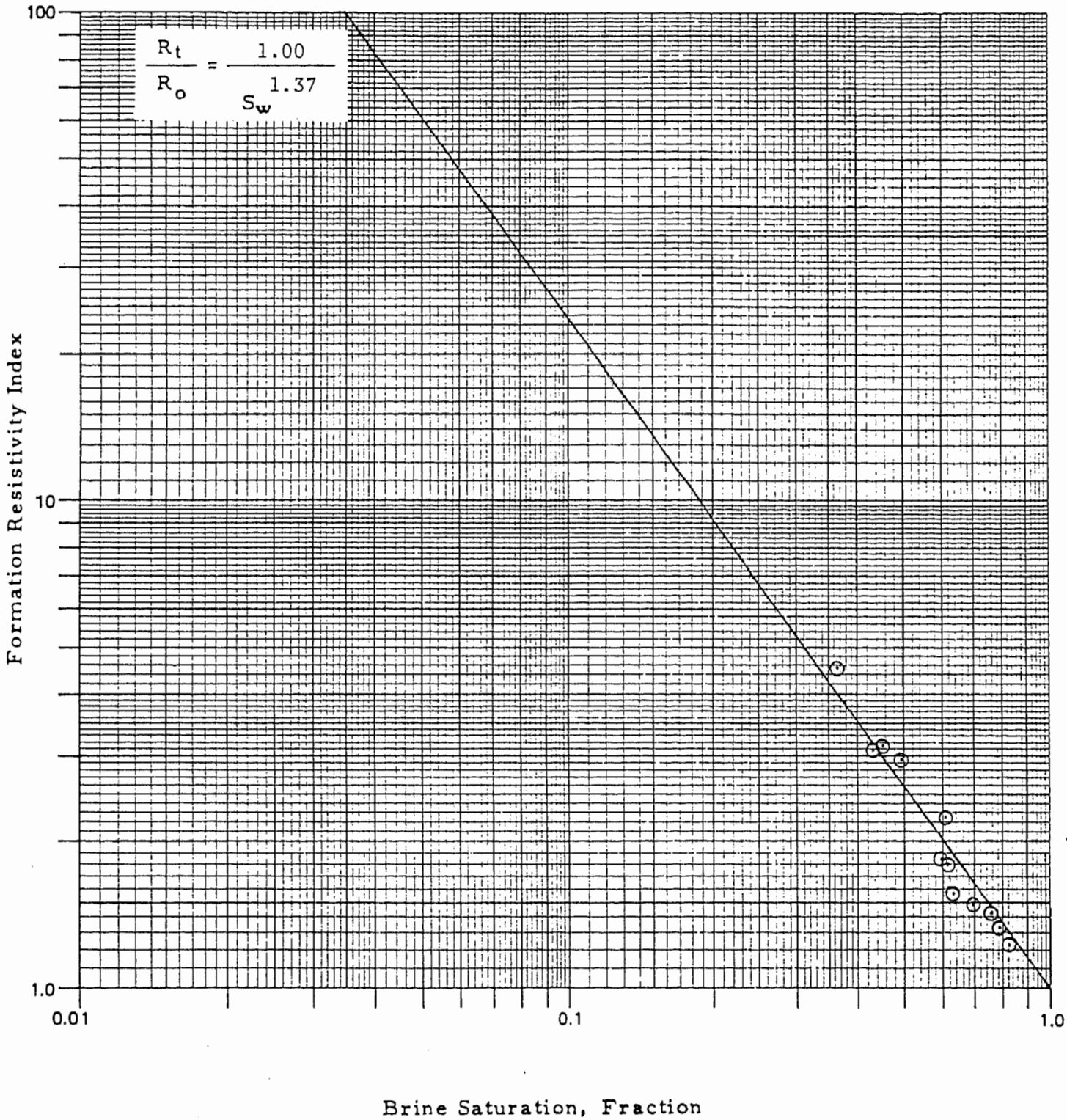
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 674



Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Composite Plot



CATION EXCHANGE CAPACITY - ADSORBED WATER METHOD

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Sample I.D.	Depth, feet	Cation Exchange Capacity meq/100 grams
658	5713.5	1.8*
660	5715.5	2.3*
666	5722.5	2.8*
674	5730.5	3.0*

* Utilized from previous file number SCAL 203-830019

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FORMATION RESISTIVITY FACTOR AS A FUNCTION OF OVERBURDEN PRESSURE
Corrected for Clay Effects

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Saturant: 30,000 ppm NaCl
Resistivity of Saturant: 0.194 ohm-meters at 77°F.

Sample I.D.	Depth, feet	Permeability to Air, Millidarcys	Porosity, Percent	Overburden Pressure, psi 0.0	200	3000
				Formation Resistivity Factor		
658	5713.5	0.03	5.8	208	262	
			5.6*			376
660	5715.5	0.05	7.4	144	173	
			7.1*			217
666	5722.5	0.06	8.8	121	139	
			8.6*			188
674	5730.5	<0.01	4.8	317	389	
			4.6*			616

* Reduced porosity due to overburden stress.

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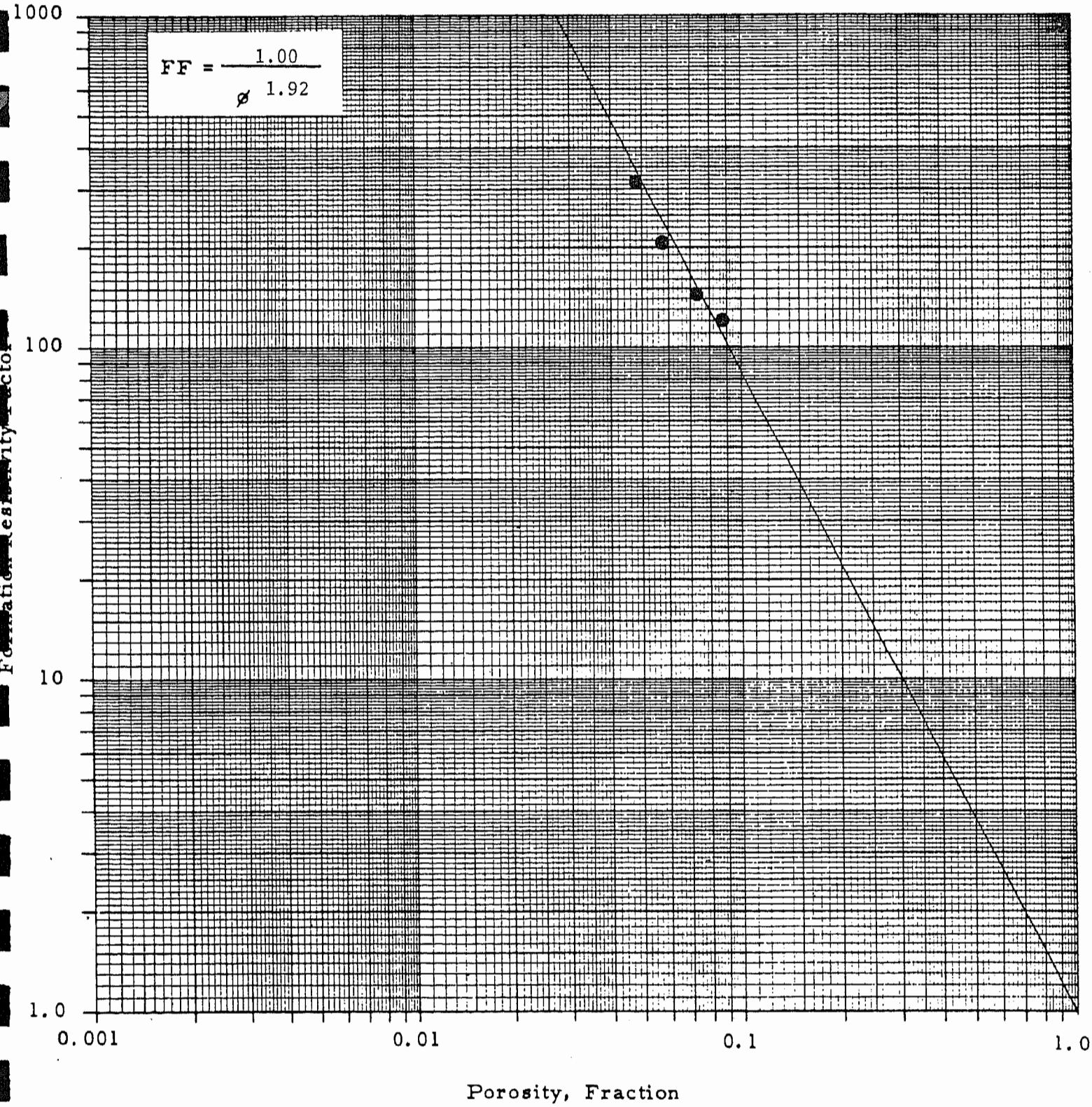
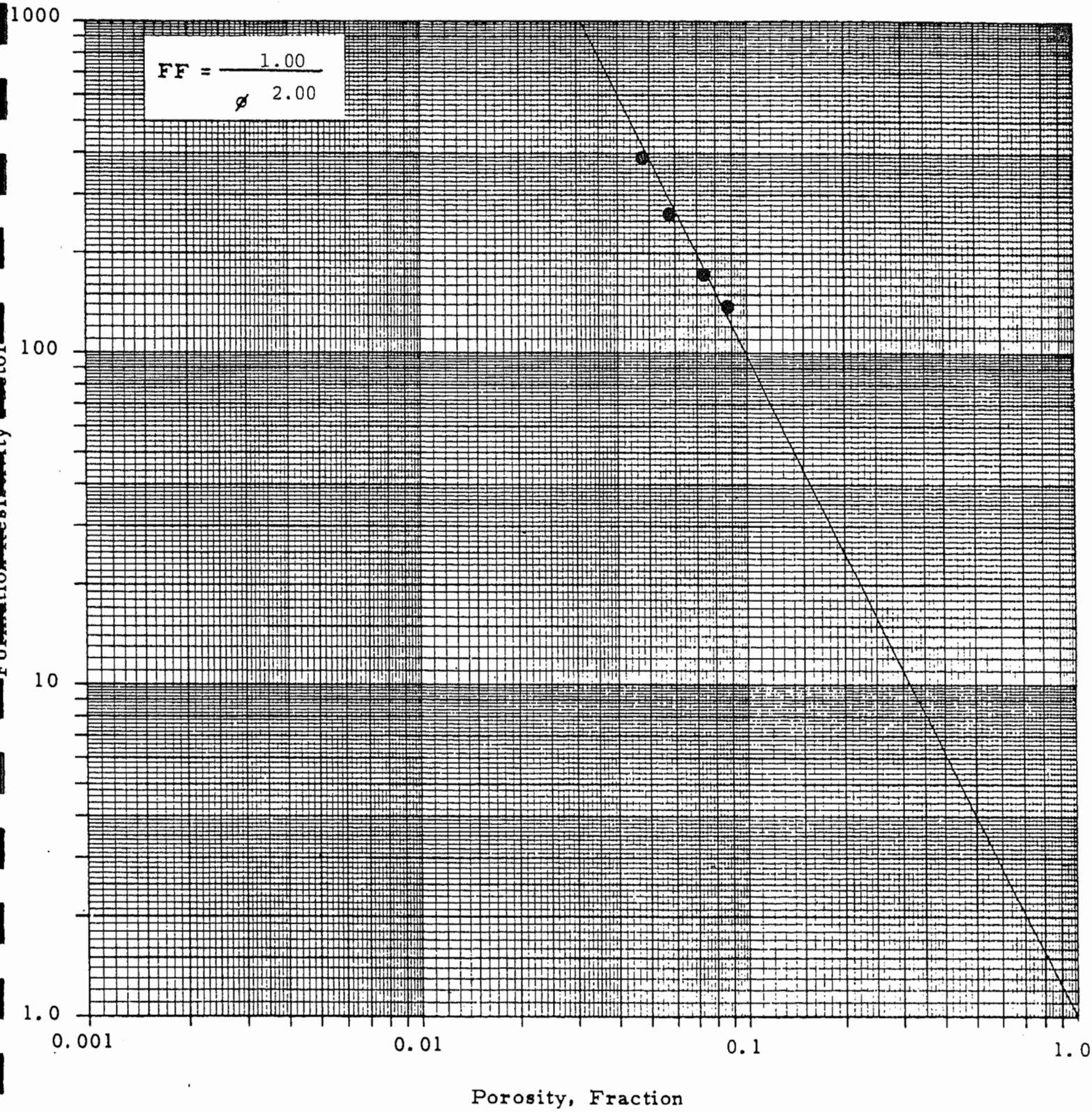
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

0.00 psi Effective Overburden
Clay-Corrected



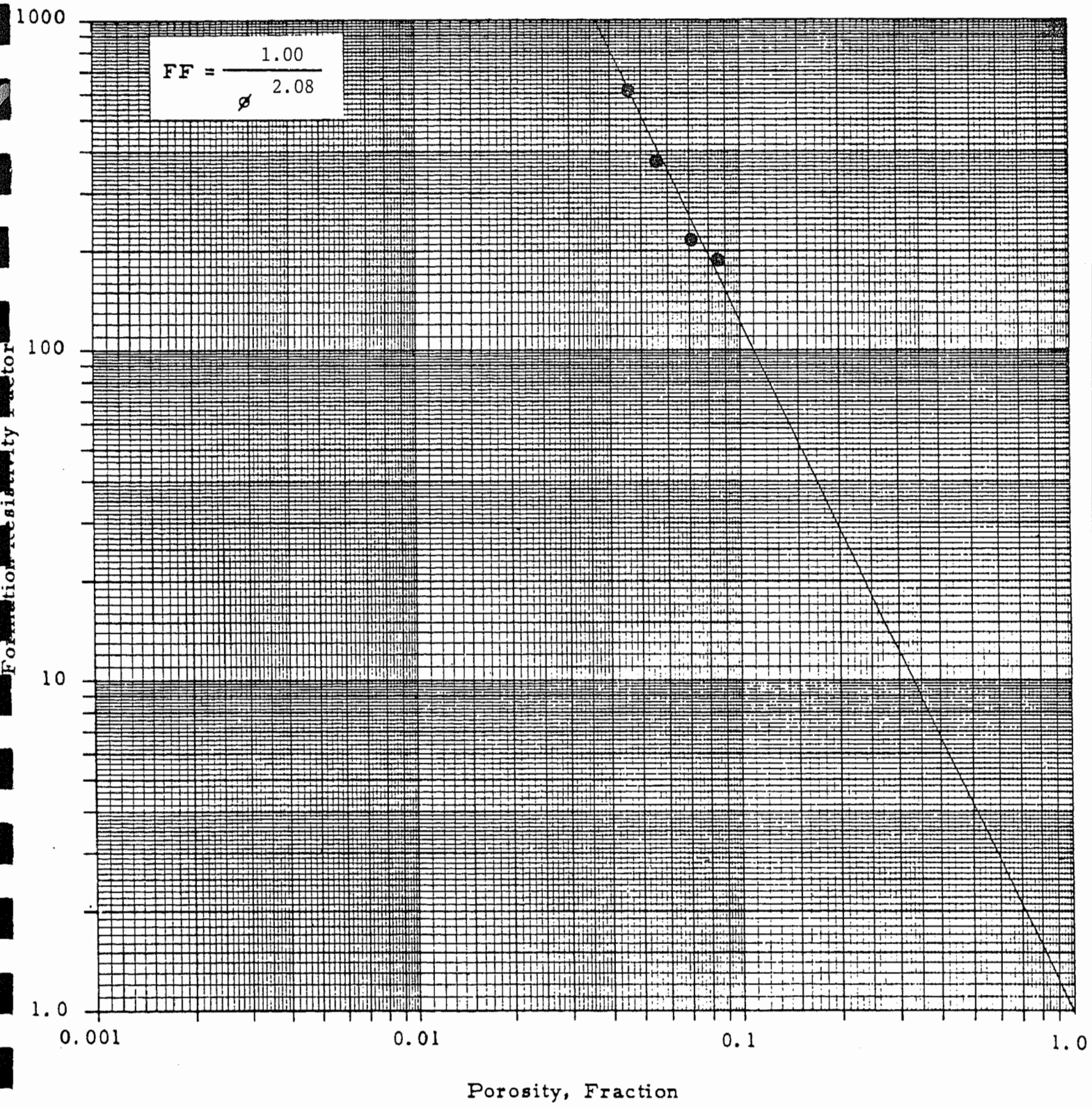
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

200 psi Effective Overburden
Clay-Corrected



Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

3000 psi Effective Overburden
Clay-Corrected



FORMATION RESISTIVITY INDEX
Corrected for Clay Effects

Company: Sandia National Laboratories
Formation: Mesa Verde
County, State: Garfield, Colorado

Well: Multi-Well Experiment No. 1
Field: Rulison

Saturant: 30,000 ppm NaCl
Resistivity of Saturant: 0.194 ohm-meters at 77°F

Sample I.D.	Depth, feet	Permeability to Air Millidarcys	Porosity, Percent	Brine Saturation percent pore space	Resistivity Index
658	5713.5	0.03	5.8	60.7	2.78
				49.5	4.04
				36.5	7.45
660	5715.5	0.05	7.4	75.9	1.58
				61.7	2.20
				45.4	4.52
666	5722.5	0.06	8.8	78.7	1.46
				63.3	1.91
				43.2	4.56
674	5730.5	<0.01	4.8	82.1	1.36
				69.6	1.84
				59.8	2.52

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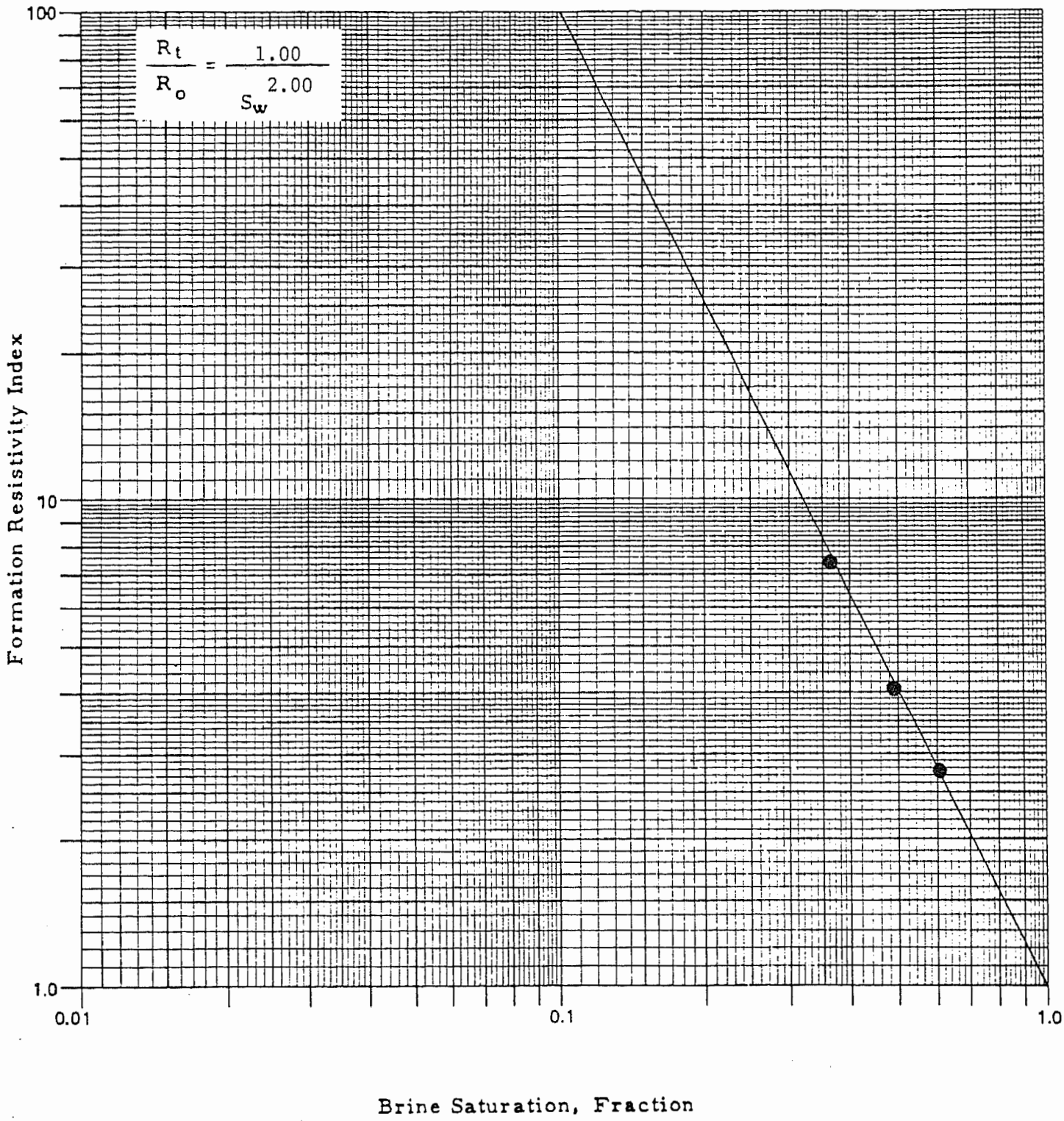
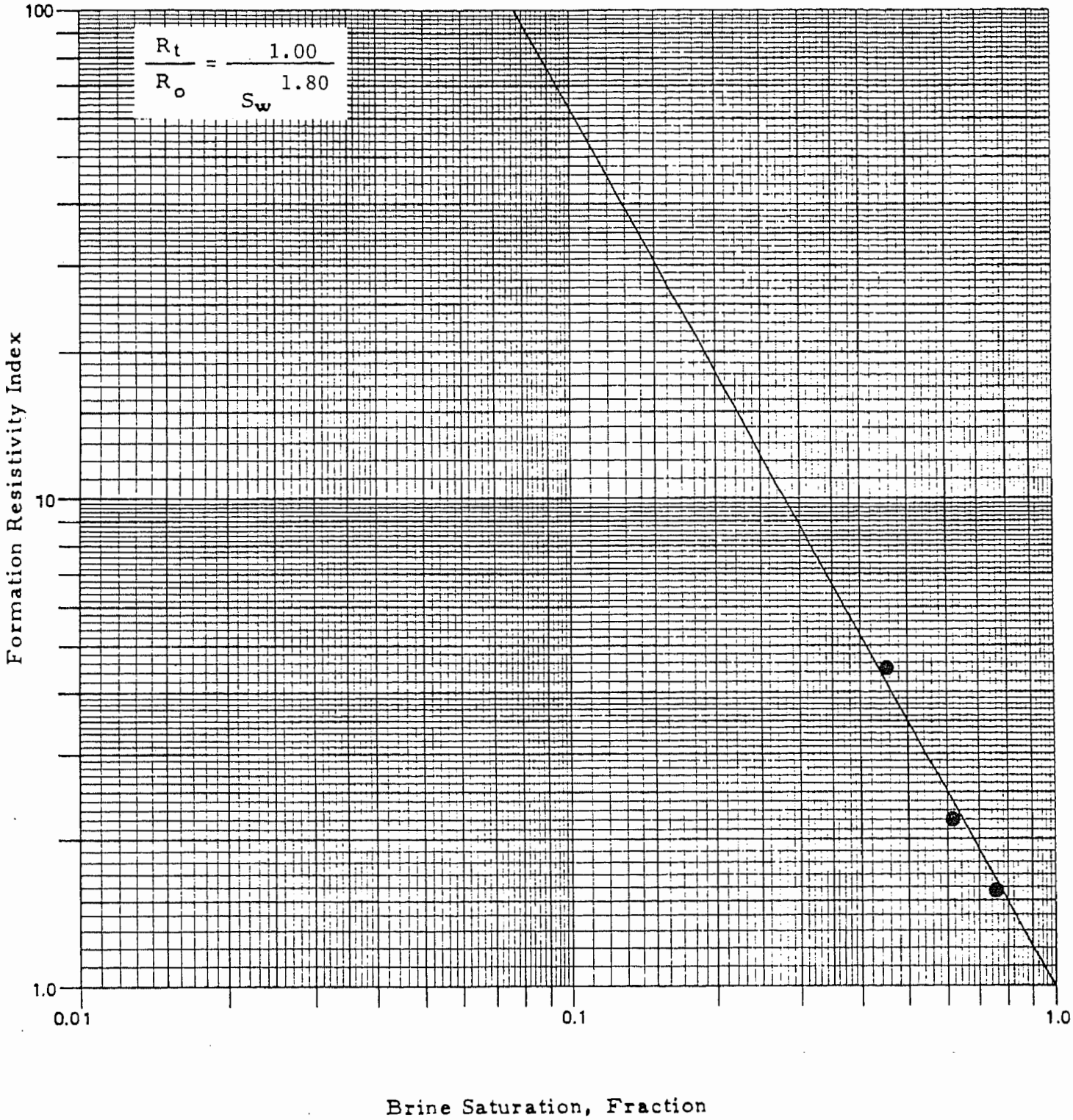
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 658 (Clay-Corrected)



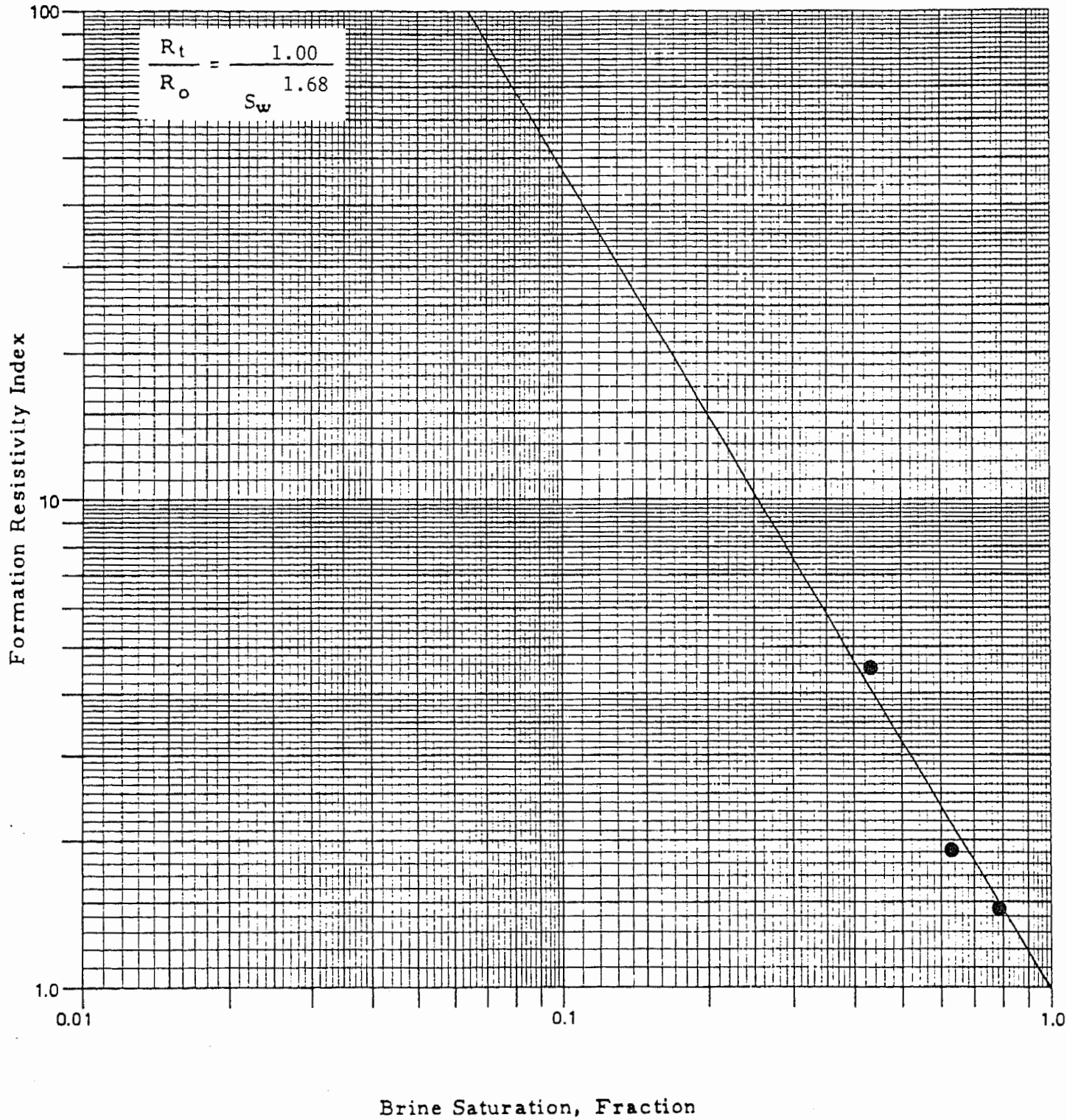
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 660 (Clay-Corrected)



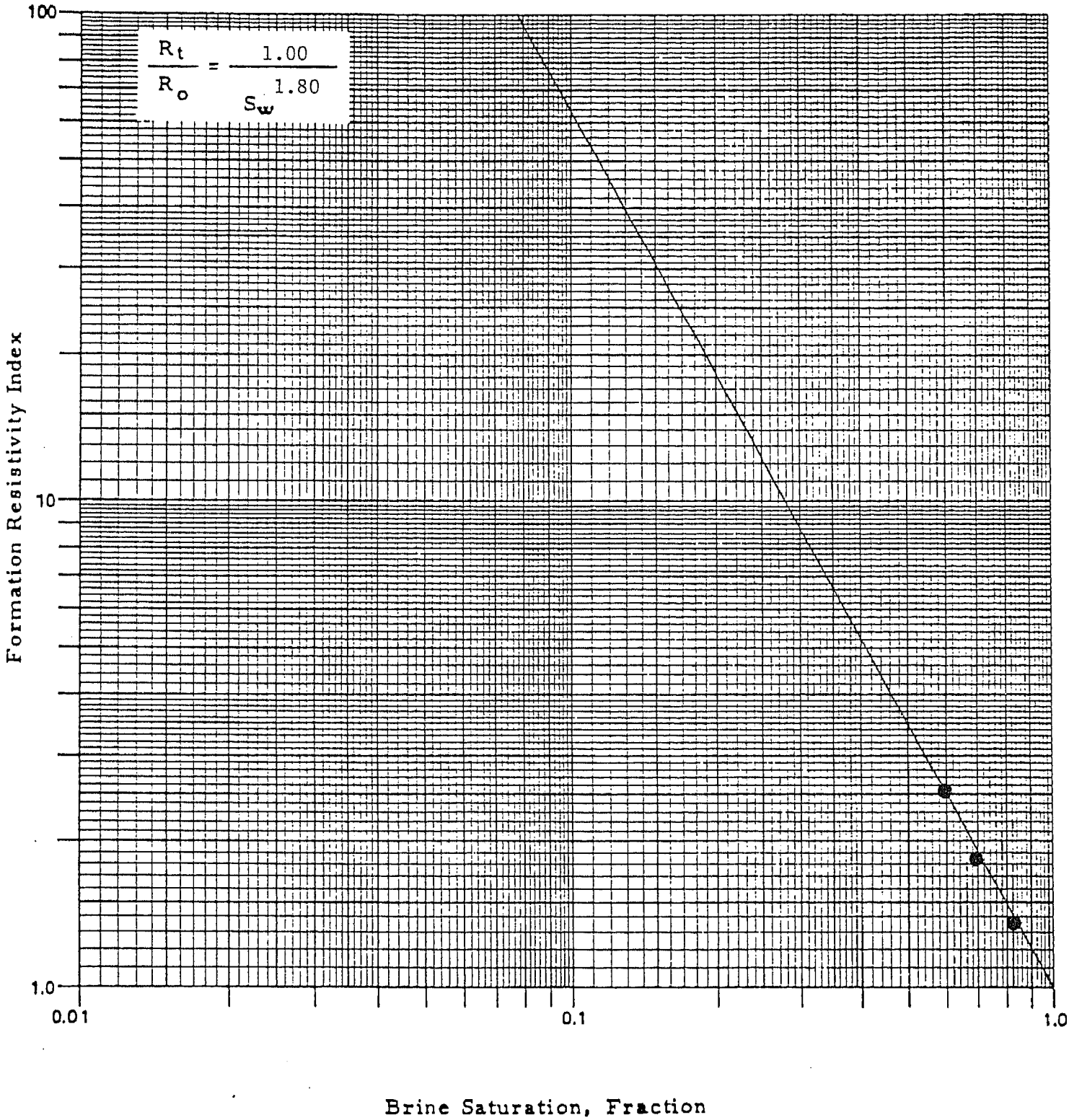
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 666 (Clay-Corrected)



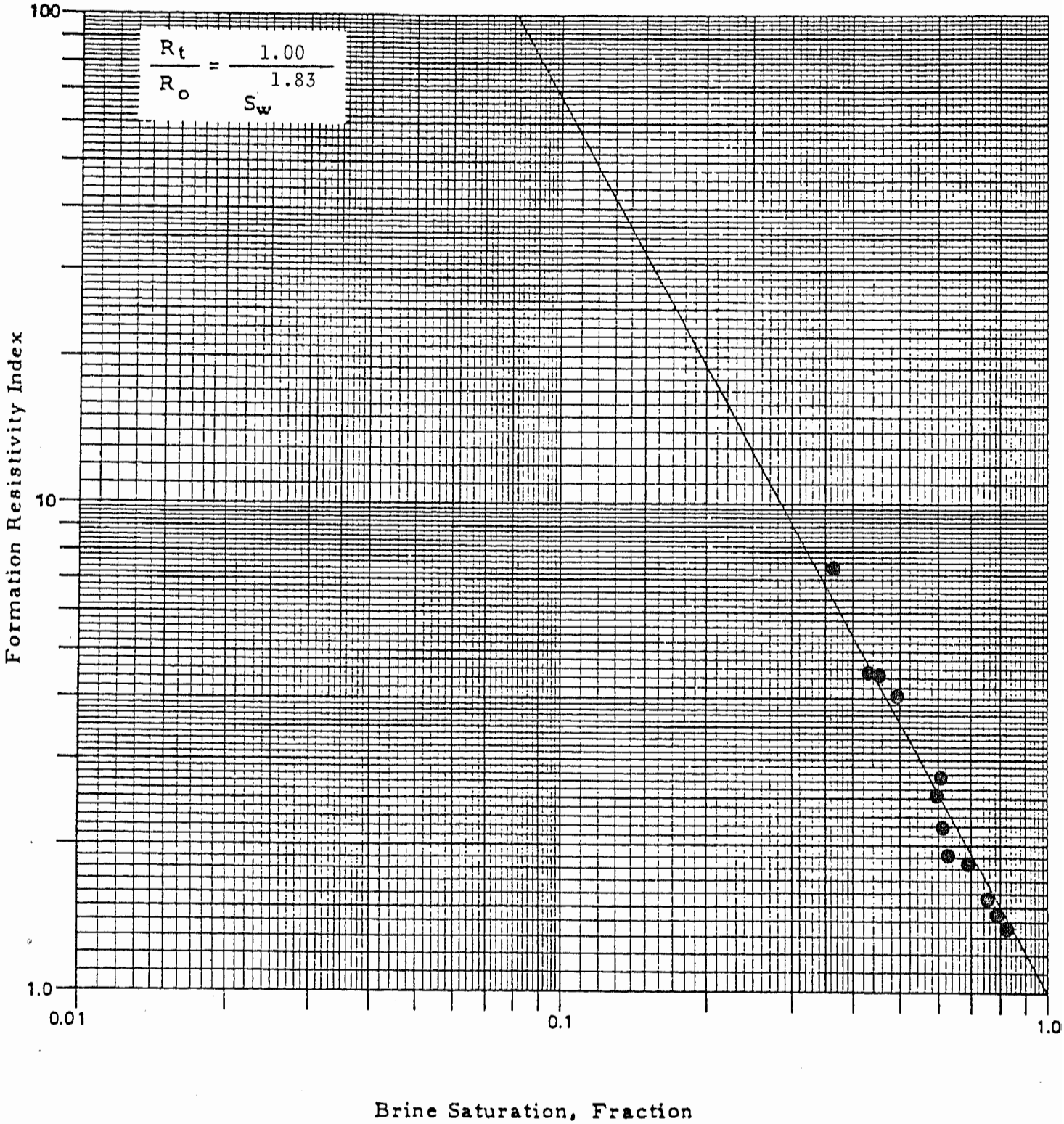
Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Sample - 674 (Clay-Corrected)



Company Sandia National Laboratories
Formation Mesa Verde
Well Multi-Well Experiment No. 1
County Garfield
Field Rulison
State Colorado

Composite Plot (Clay-Corrected)



SPECIFIC PERMEABILITY TO WATER

Company: Sandia National Laboratories Well: Multi-Well Experiment No. 1
Formation: Mesa Verde Field: Rulison
County, State: Garfield, Colorado
Water Identification: 30,000 ppm NaCl

Sample Identification	Depth, feet	Porosity, percent	Permeability to Air, Millidarcys	Specific Permeability to Water, Millidarcys	Permeability Ratio, water/air
662	5717.5	10.2	0.08	0.0003	<0.01
715	5829.6	11.0	0.20	0.0071	0.04
722	5837.6	8.2	0.03	0.0005	0.02

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Litton
Core Lab

COMPOSITIONAL ANALYSIS

for

Sandia National Laboratories

MWX-1 Well
Rulison Field
Garfield County, Colorado
File Number: ARFL-87018

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Litton
Core Lab

10703 East Bethany Drive
Aurora, Colorado
80014-2696
303 751-9334

February 25, 1987

Sandia National Laboratories
P. O. Box 5800, Division 4753
Albuquerque, NM 87185

Attention: Mr. A. R. Sattler

Subject:

Compositional Analysis
MWX-1 Well
Rulison Field
Garfield County, Colorado
File Number: ARFL-87018

Gentlemen:

A liquid and a gas sample collected from the subject well were submitted to our laboratory for analysis. Presented in this report are the results of our test.

The composition of the gas sample was measured through hexanes with a heptanes plus fraction by routine chromatography. This data is presented on page one. The composition of the liquid, measured through decanes with an undecanes plus fraction, follows on page two.

Thank you for the opportunity to be of service to Sandia National Laboratories. Should you have any questions pertaining to these results or if we can be of further assistance, please do not hesitate to contact us at (303)751-9334.

Very truly yours,

Craig L. Bromley

Craig L. Bromley
Reservoir Fluid Supervisor

CLB/JFM/sso
distribution

File ARFL-87018

Company Sandia National Laboratories
Formation Mesa Verde
Well MWX-1
County Garfield
Field Rulison
State Colorado

HYDROCARBON ANALYSIS OF METER GAS SAMPLE

Component	Mol Percent	GPM
Hydrogen Sulfide	0.00	
Carbon Dioxide	1.34	
Nitrogen	12.75	
Methane	77.68	
Ethane	5.55	1.514
Propane	1.55	0.436
iso-Butane	0.36	0.120
n-Butane	0.33	0.106
iso-Pentane	0.15	0.056
n-Pentane	0.10	0.037
Hexanes	0.11	0.044
Heptanes plus	0.08	0.035
	100.00	2.348

Calculated gas gravity (air = 1.000) = 0.681

Calculated gross heating value = 985 BTU per cubic foot of dry gas at 15.025 psia and 60°F.

Collected at 85 psig on December 9, 1986 @ 10:00 hours.

Laboratory opening pressure = 50 psig @ 72°F.

Sample Number 11 Fluvial-B

File ARFL-87018

Company Sandia National Laboratories
Formation Mesa Verde
Well MWX-1
County Garfield
Field Rulison
State Colorado

HYDROCARBON ANALYSIS OF FLUID SAMPLE

Component	Mol Percent	Weight Percent	Density, Gm/Cc @ 60°F.	°API @ 60°F.	Molecular Weight
Hydrogen Sulfide	0.00	0.00			
Carbon Dioxide	0.00	0.00			
Nitrogen	0.00	0.00			
Methane	0.00	0.00			
Ethane	0.00	0.00			
Propane	0.00	0.00			
iso-Butane	0.02	0.01			
n-Butane	0.05	0.02			
iso-Pentane	0.14	0.07			
n-Pentane	0.18	0.09			
Hexanes	1.85	1.09			
Heptanes	7.36	4.95			
Octanes	21.20	15.89			
Nonanes	22.47	19.04			
Decanes	17.01	15.96			
Undecanes plus	29.72	42.88	0.8204	40.8	206
	100.00	100.00			

Properties of Heptanes Plus Fraction

Density, gm/cc @ 60°F.	0.7842
°API @ 60°F.	48.8
Molecular Weight	144

Sample Number 65 from 400 Barrel Tank

Collected November 20, 1986 @ 14:00 hours.