66/183
c.3

Copy 3

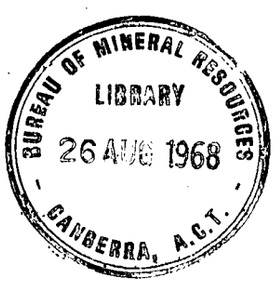
COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS

RECORDS:

1966/183



The information contained in this report has been obtained by the Department of National Development, as part of the policy of the Commonwealth Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

5928/65

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

RECORDS:

RECORD No. 1966/183

EAST MEREENIE NO.1

MERCURY INJECTION CAPILLARY PRESSURE AND FLUID IMBIBITION TESTS

by

B.A. McKAY

The information contained in this report has been obtained by the Department of National Development, as part of the policy of the Commonwealth Government, to assist in the exploration and development of mineral resources. It may not be published in any form or used in a company prospectus without the permission in writing of the Director, Bureau of Mineral Resources, Geology and Geophysics.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PETROLEUM TECHNOLOGY SECTION

1966/183

EAST MEREENIE NO. 1

MERCURY INJECTION CAPILLARY PRESSURE AND FLUID IMBIBITION TESTS

BY

B. A. McKAY

The East Mereenie No. 1 well was drilled in 1964 on Oil Permit 43 issued to the Magellan Petroleum (N.T.) Pty. Ltd. The drilling operation was conducted by Exoil (N.T.) Pty. Ltd. under farmout agreement with Magellan Petroleum (N.T.) Pty. Ltd. Partners with Exoil were Farmout Drillers N.L. and Krewliff Investments Pty. Ltd.

The total depth reached by the well was 4710 feet. The well was completed in the 1130 feet of open hole from 3580 feet to 4710 feet for the production of gas with condensate from the Pacoota Formation of Ordovician age.

The operation was approved for subsidy but the companies concerned did not elect to claim the payment of subsidy.

The Draft Completion Report in respect of this drilling operation was submitted by Exoil (N.T.) Pty. Ltd. in 1965.

EAST MEREENIE NO. 1

MERCURY INJECTION CAPILLARY PRESSURE AND FLUID IMBIBITION TESTS

INTRODUCTION:

This report presents results of porosity, permeability, fluid imbibition, and mercury injection capillary pressure tests carried out on core samples from gas producing zones in the East Mereenie No. 1 well. Pore size distribution values, which are included in the report, were calculated from the capillary pressure test data.

PROCEDURE AND APPARATUS

Three sets of samples from eleven cores were selected for test purposes. These were twenty-seven $1\frac{1}{8}$-inch diameter plugs for fluid imbibition tests, thirty $\frac{3}{4}$-inch diameter plugs for porosity, permeability and capillary pressure tests, and fifteen $1\frac{1}{8}$-inch diameter samples for supplementary (micro) permeability tests. The micro-permeability tests were conducted in a high pressure Hassler cell on samples from the above zones having permeability less than 0.5 md.

The plugs were all drilled parallel to bedding and trimmed to a minimum length of $1\frac{1}{4}$ inches. After extended extraction with toluene in a Soxhlet-type apparatus, the samples were dried in an oven for 24 hours at 110°C, and after cooling the effective porosity and absolute permeability (using dry nitrogen) were determined on each of them.

Capillary pressure tests were performed in a Ruska-type mercury injection apparatus, following the method described by Purcell in Petroleum Transactions, AIME, 1949. According to this method, mercury, which is used as the saturating, non-wetting phase, is injected into the samples at increasing pressures ("pressure steps"). The stabilized or equilibrium pressure values obtained at the end of each "step" are recorded, and capillary pressure curves are constructed from the completed test results.

Pore size distribution values were calculated from the capillary pressure data using the formula: $r = \frac{2\sigma \cos \theta}{\Delta P}$. Average pore entry or "throat" radii for the corresponding saturation-pressure intervals were

calculated using values of 480 dynes/cm for mercury surface tension (γ), and 140° as the mercury-rock contact angle (θ) in this formation.

Fluid imbibition tests were conducted on twenty-seven samples to determine their preferential wetting characteristics. After a thorough saturation with oil (kerosene) the plugs were immersed in water; the amount of oil displaced by water from the samples was recorded as a measure of the relative wettability of the samples.

DISCUSSION OF RESULTS

The mercury injection capillary pressure curves derived from the test results included in Table II are shown in Figures 1 - 27; values of pore entry radii calculated from the capillary pressure test results are shown in Table I. Results of fluid imbibition tests are listed in Table III, while the position of samples tested is shown on the electric log in Figure 28.

The wide range of permeability values determined on the test samples was strongly reflected in the capillary pressure results. Very low and very high displacement pressures and residual water saturations were obtained throughout the intervals tested. Ten of the samples showed fair to good permeabilities, low irriducible water saturations and low initial displacement pressures. The balance of samples tested (20) exhibited low to very low permeabilities, high irriducible water saturations, and moderate to very high displacement pressures. Three of the latter samples could not be utilized for capillary pressure tests, as no mercury penetration into their matrix was achieved within the limits of the laboratory test pressure range (1500 psia).

The configuration of the capillary pressure curves is noteworthy; saturation profiles of the more permeable samples were characterised by low, long slopes in relation to the abscissae, rapidly changing and becoming essentially assymptotic to the ordinate axes at irriducible water saturation values. Although much less pronounced, a similar trend was noted in many of the less permeable samples.

This curve configuration generally indicates a well sorted pore distribution, a condition which was verified by microscopic examination. However, subsequent wettability tests on the samples indicated that imbibition forces probably also had a relatively favourable influence on saturation by the non-wetting phase (oil) over some of the intervals tested. Although all the samples tested showed preferential wetting by water, many (especially those from the upper intervals) indicated that attractive forces to the aqueous phase were very weak, and would offer limited resistance to saturation by a non-wetting fluid.

It was also noted that susceptibility to wetting by the aqueous phase increased with depth. Samples from the lower sections of the well (± 4600') were found to be strongly water-wet; after seven days of immersion the volume of water imbibed at this depth ranged up to 62% of pore volume. Conversely, wetting tests on samples from the upper test zones in the well indicated wetting forces to be much weaker, with water imbibition averaging about 12% to 15% of pore volume after seven days of immersion.

Additional testing of cores from other wells in this area, and tests on "fresh" cores from future wells which might be drilled would be warranted in order to evaluate more fully the wetting characteristics of this material.

CONCLUSIONS

1. The formations tested in this well were generally of low permeability and porosity. However, good reservoir characteristics were found in samples having a permeability greater than 10 md.

2. The more permeable sections of the reservoirs showed very low threshold (entry) pressures and low irriducible water saturations (from 15% to 22% of pore volume).

3. Maxima values of pore entry (throat) radii as calculated from the capillary pressure information were 27 microns.

4. Wettability tests performed on the samples showed them to vary from lightly to strongly water-wet. There was an apparent increase of wetting by the aqueous phase with increasing depth.

TABLE I

AVERAGE PORE ENTRY RADIUS (MICRONS)									SAMPLE DEPTH (FEET)
	SATURATION (% PORE VOLUME)								
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	
	24	22	20	18	15	12	6		3824
		18	17	15	14	12	8.5	1.2	3826
	26	25	23	22	19	16	11	0.95	3828
	27	25	24	22	20	18	14	4.3	3830
		0.34	0.30	0.22	0.13				3849
	10	9.3	8.3	7.4	6.4	5.3	2.8		3850
	8.9	8.3	7.6	6.7	5.6	4.0	0.85		3853
	9.7	8.9	8.2	7.4	6.5	5.2	2.5	0.23	4125
	0.50	0.40	0.31	0.19					4128
		1.3	0.97	0.74	0.56	0.38	0.13		4132
		7.0	6.1	5.3	4.5	3.8	2.5	0.71	4136
		8.8	8.2	7.6	6.7	5.4	1.9	0.26	4273
	9.0	8.6	8.1	7.4	6.5	5.1	1.9	0.21	4277
		1.6	1.3	1.1	0.85	0.64	0.37	0.12	4281
			0.09						4288
		0.92	0.72	0.51	0.36	0.23	0.10		4292
			0.23	0.17	0.11				4297
			0.38	0.23	0.18	0.12			4302
			0.16	0.12					4490
	0.98	0.64	0.45	0.32	0.23	0.16	0.10		4496
				0.24	0.11				4511
			0.79	0.62	0.43	0.23			4517
			0.10						4521
		1.8	0.98	0.48	0.22				4529
		0.17	0.16	0.15					4668
		3.2	2.2	1.6	1.2	0.73	0.35		4690
		1.3	1.1	0.89	0.62	0.20			4694

TABLE II

MERCURY SATURATION (% PORE VOLUME)							SAMPLE DEPTHS (FEET)
5	15	25	35	45	55	65	
4.4	4.8	5.3	5.6	6.9	8.5	14.7	3824
5.7	6.0	6.4	6.9	7.6	8.8	11.8	3826
4.0	4.3	4.6	5.0	5.6	6.5	8.5	3828
4.0	4.2	4.5	4.8	5.3	6.0	7.3	3830
	308.0	348.00	480.0	745.0	1370.0		3849
10.4	11.6	12.8	14.4	16.3	19.5	29.4	3850
12.2	12.9	14.0	15.9	18.7	24.8	53.0	3853
11.0	12.0	13.2	13.8	16.4	19.8	31.0	4125
213.0	260.0	485.0	1250.0				4128
	85.0	110.0	138.0	188.0	260.0	540.0	4132
	14.9	16.6	18.8	21.6	26.8	38.0	4136
	12.1	12.7	13.8	15.7	19.0	34.0	4273
	12.4	13.2	14.4	16.2	19.8	34.0	4277
	68.0	78.0	95.0	120.0	162.0	252.0	4281
	800.0	1120.0					4288
	114.0	140.0	198.0	295.0	448.0	870.0	4292
		453.0	610.0	920.0	1480.0		4297
	300.0	380.0	468.0	580.0	865.0		4302
	605.0	678.0	840.0				4490
110.0	170.0	240.0	320.0	445.0	640.0	1000.0	4496
		300.0	390.0	850.0			4511
	108.0	132.0	168.0	235.0	395.0	1000.0	4517
	410.0	810.0					4521
	57.0	100.0	210.0	435.0			4529
	620.0	652.0	710.0	1180.0			4668
	34.0	50.0	68.0	92.0	133.0	260.0	4690
	86.0	100.0	118.0	160.0	340.0		4694

(MERCURY) CAPILLARY PRESSURE (PSIA)

TABLE III

Well Name and Number	Core No.	Sample Depth (feet)	Porosity (% Bulk Volume)	Dry-Nitrogen Permeability (md)	Saturating Medium	Volume of Water Imbibed (% Pore Volume)			
						After 1 Day	After 2 Days	After 3 Days	After 7 Days
East Mereenie No.1.	7	3822	1.7	< 0.01	-	-	-	-	-
"	7	3824	10.0	274.00	Kerosene	6.1	6.1	6.1	8.5
"	8	3826	11.0	237.00	"	16.7	16.7	16.7	16.7
"	8	3828	11.6	276.00	"	18.5	18.5	18.5	18.5
"	8	3830	13.2	615.00	"	7.1	7.1	7.1	7.1
"	9	3840	5.8	< 0.01	-	-	-	-	-
"	9	3849	5.9	0.70	Kerosene	0	13.1	13.1	13.1
"	9	3850	9.9	47.00	"	11.2	12.3	12.3	12.3
"	10	3853	7.8	23.00	"	28.6	35.7	35.7	35.7
"	11	4125	7.6	18.00	"	10.6	12.0	13.3	13.3
"	11	4128	2.9	0.047	"	0	0	0	0
"	12	4132	7.0	0.11	"	12.8	19.2	25.6	25.6
"	12	4136	9.3	10.00	"	5.4	9.5	16.2	16.2
"	12	4138	5.3	< 0.01	-	-	-	-	-
"	13	4273	9.5	50.00	Kerosene	6.8	8.7	11.6	11.6
"	13	4277	10.1	51.00	"	0	4.5	7.2	11.7
"	13	4281	9.3	0.91	"	0	4.7	6.0	7.1
"	13	4288	2.9	< 0.01	"	10.0	16.0	16.0	16.0
"	13	4297	5.9	0.057	"	19.5	24.4	29.2	34.1
"	13	4302	5.0	0.063	"	13.6	18.2	27.2	27.2
"	14	4490	2.7	< 0.01	"	9.3	12.0	12.0	12.0
"	14	4496	5.4	0.11	"	23.5	29.4	40.0	41.0
"	15	4511	6.6	0.07	"	25.6	35.8	35.8	35.8

TABLE III (Continued)

Well Name and Number	Core No.	Sample Depth (feet)	Porosity (% Bulk Volume)	Dry-Nitrogen Permeability (md.)	Saturating Medium	Volume of Water Imbibed (% Pore Volume)			
						After 1 Day	After 2 Days	After 3 Days	After 7 Days
East Mereenie No.1.	15	4517	6.3	0.096	Kerosene	20.7	20.7	20.7	20.7
"	15	4521	2.0	< 0.01	"	0.0	0.0	0.0	0.0
"	15	4529	6.6	0.71	"	12.5	39.5	39.5	39.5
"	16	4668	3.6	< 0.01	"	13.2	15.0	15.0	15.0
"	17	4690	10.3	7.5	"	42.5	46.5	46.5	46.5
"	17	4694	6.8	1.6	"	47.0	61.0	61.0	62.5

FIGURE 1

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-3824

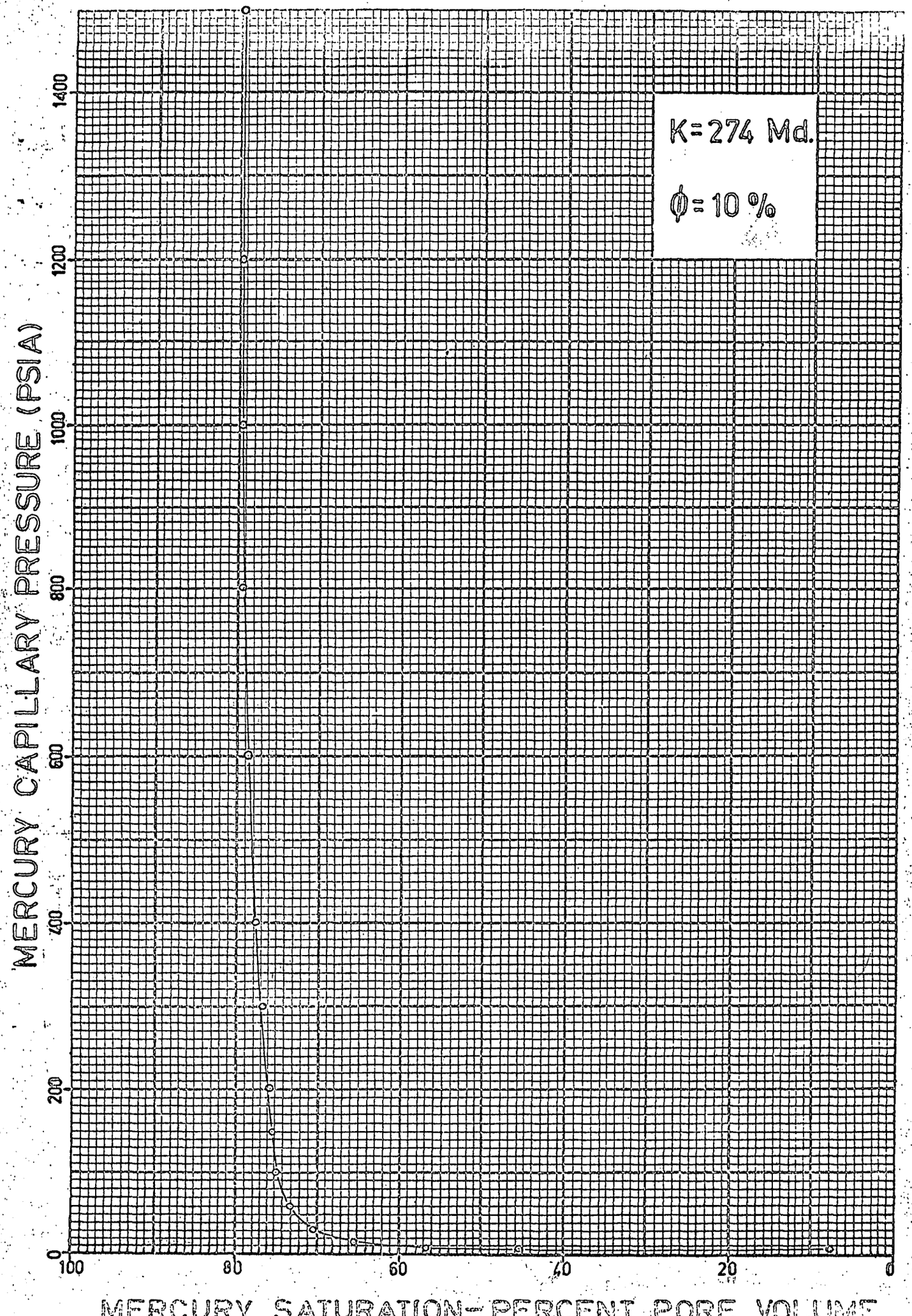


FIGURE 2

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-3826

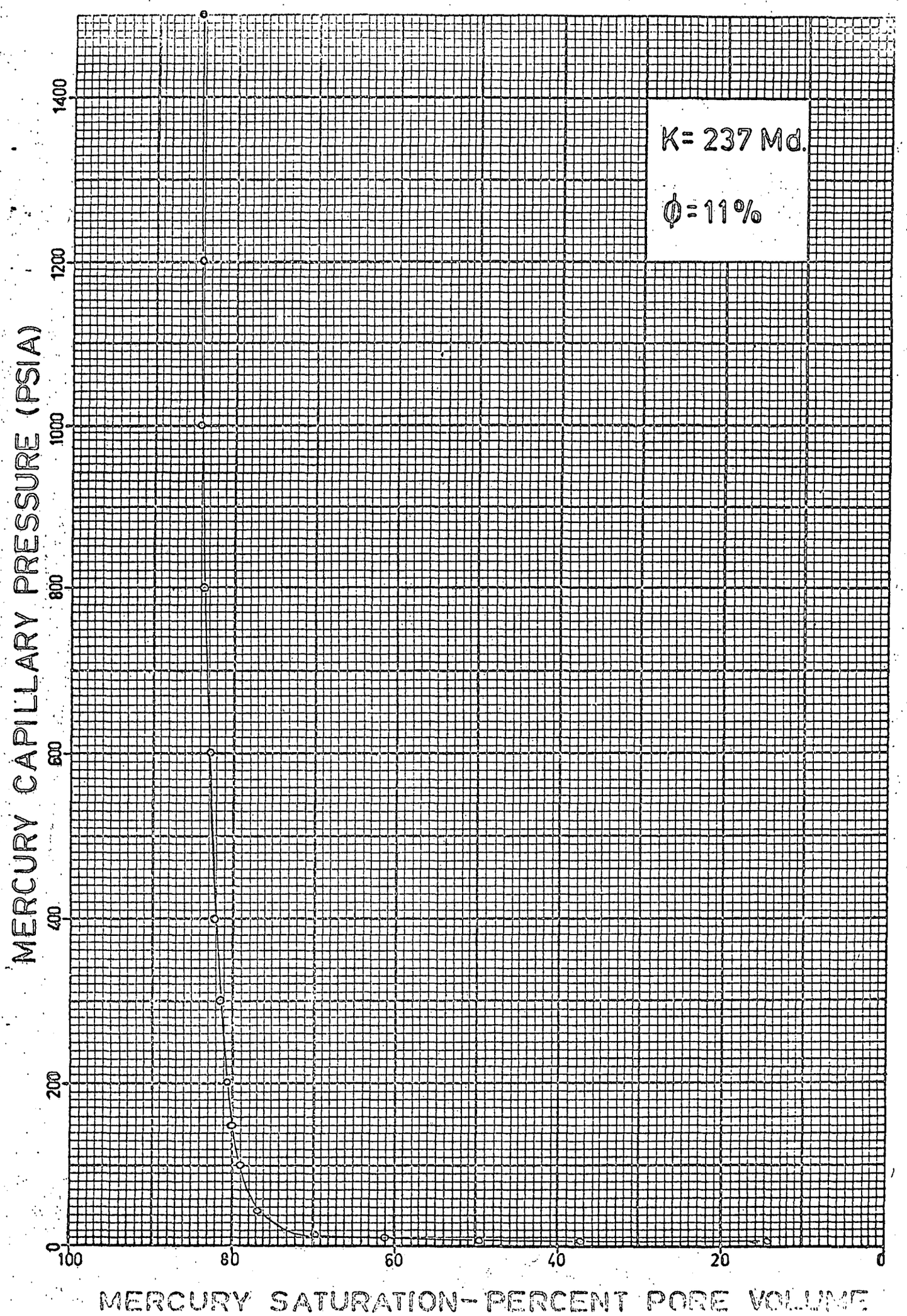


FIGURE 3

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No1 SAMPLE DEPTH-3828

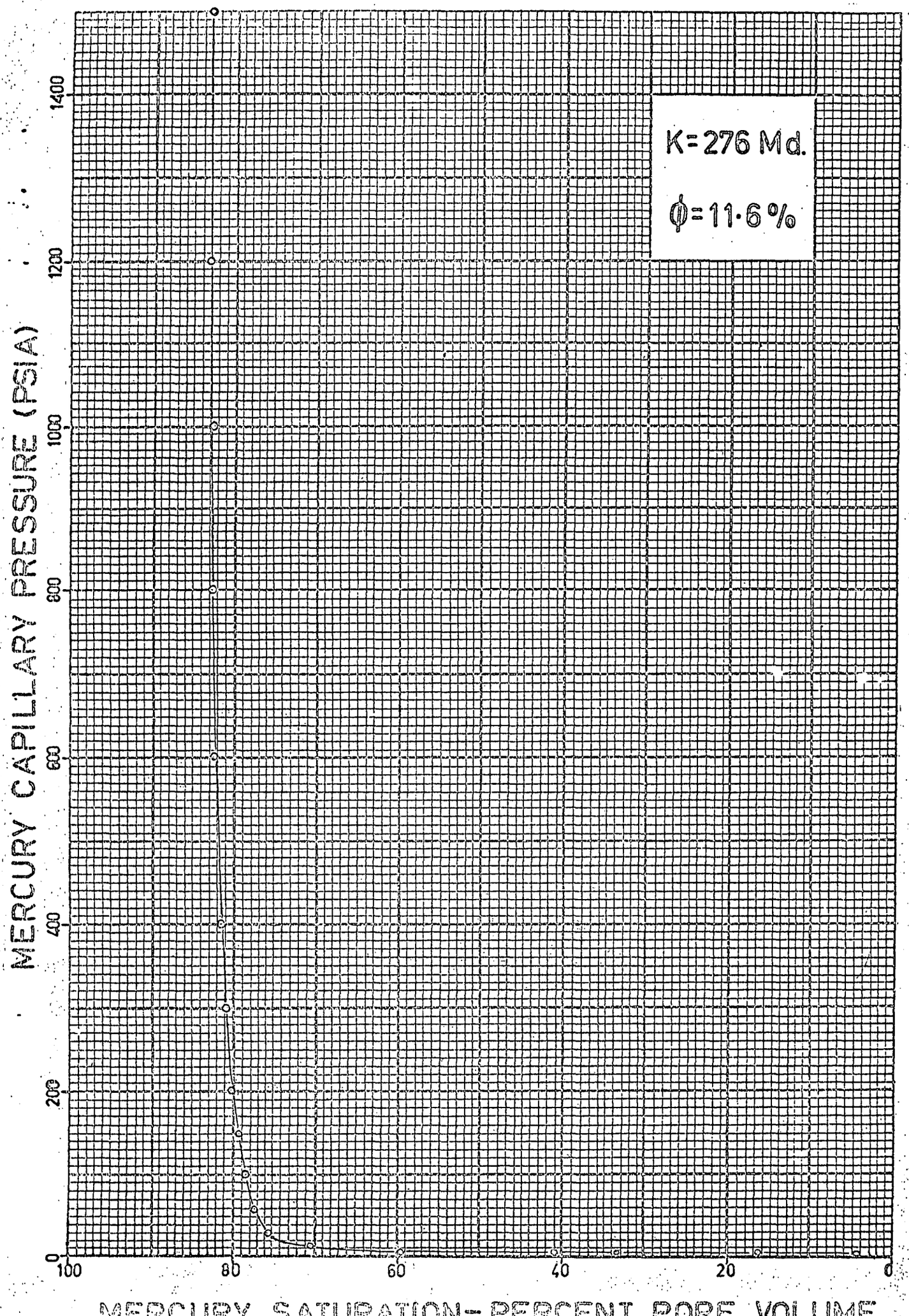


FIGURE 4

MERCURY CAPILLARY PRESSURE

WELL NAME: E. MEREENIE No.1 SAMPLE DEPTH-3830

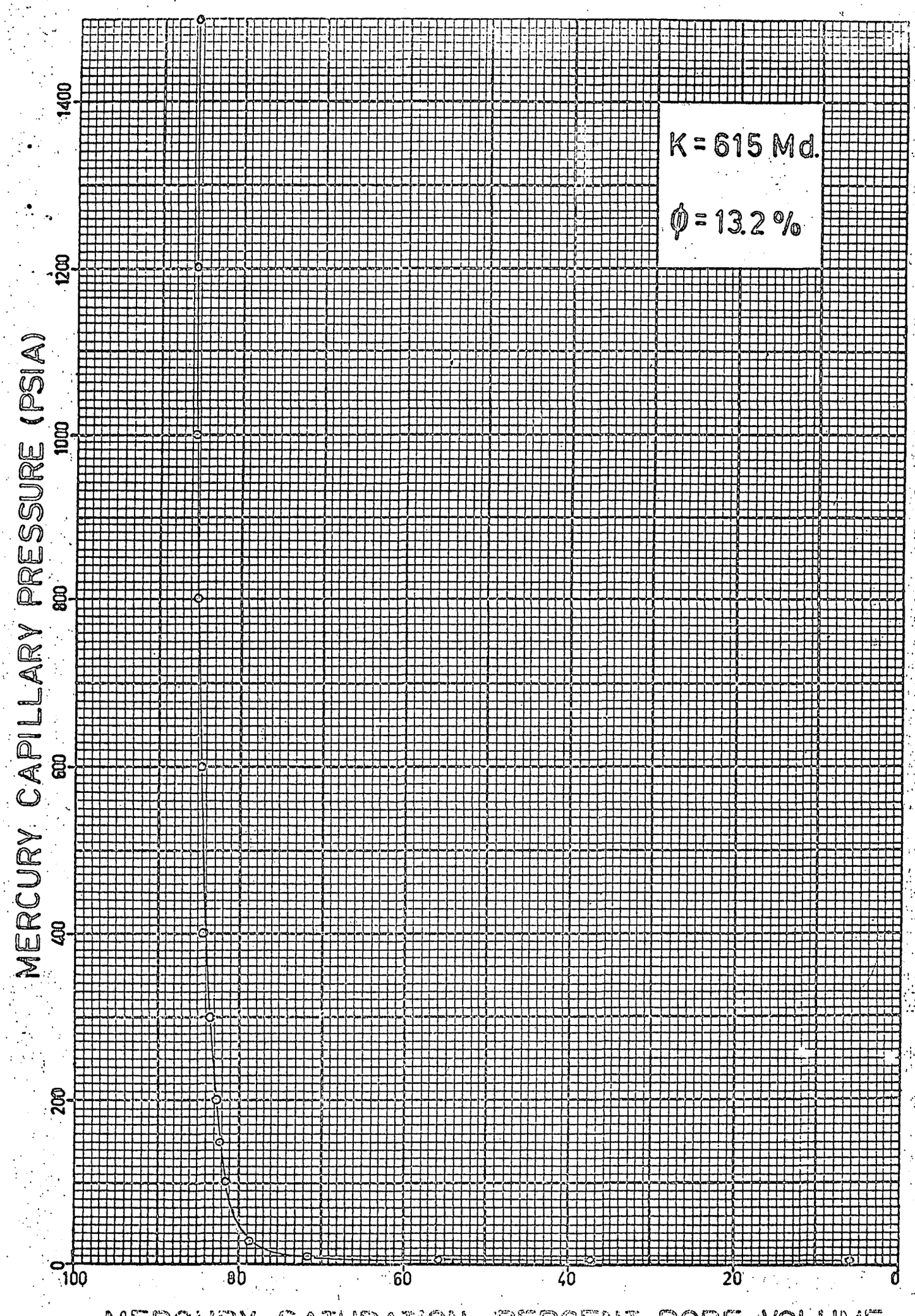


FIGURE 5

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-3849

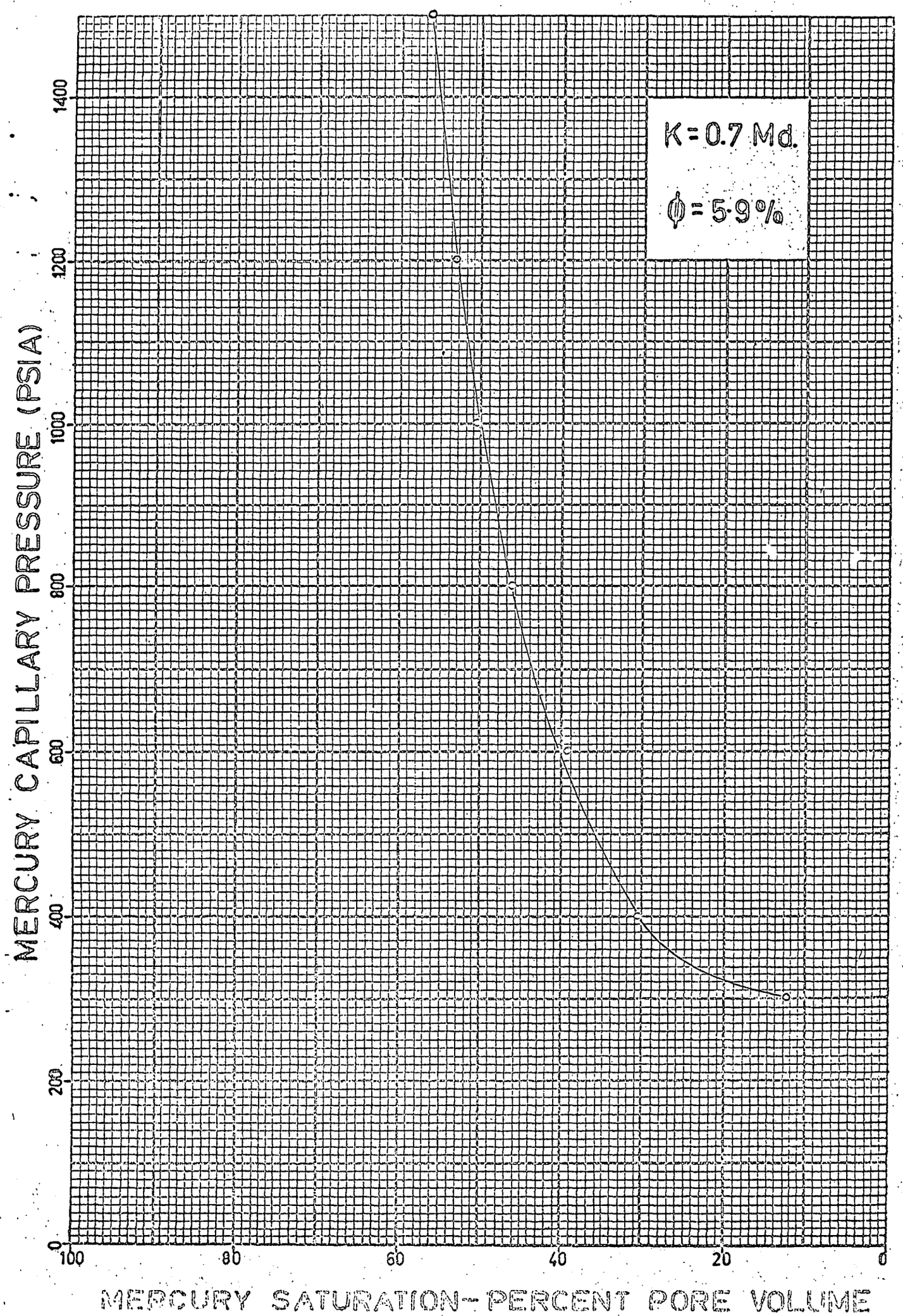


FIGURE 6

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-3850

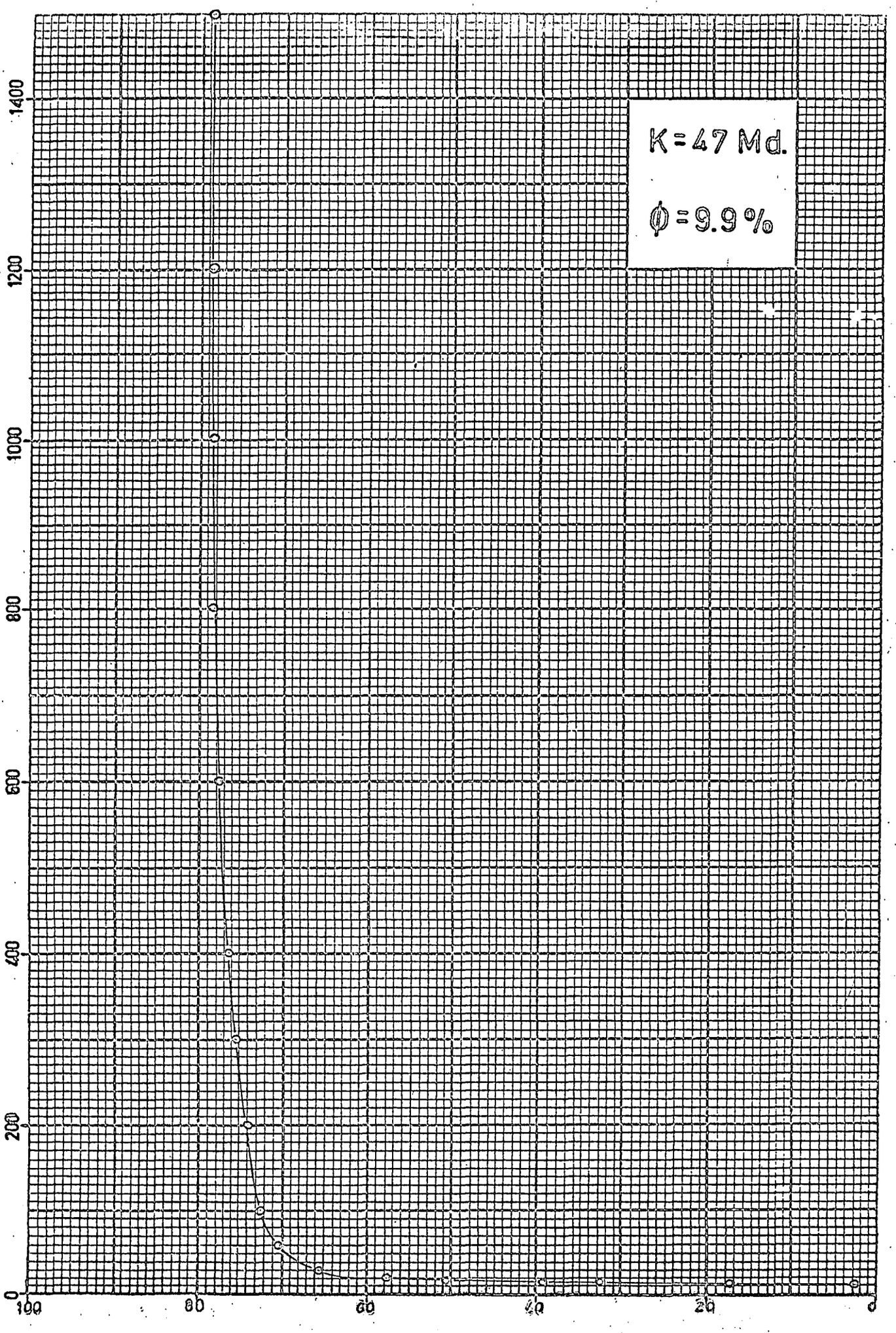


FIGURE 7

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-3853

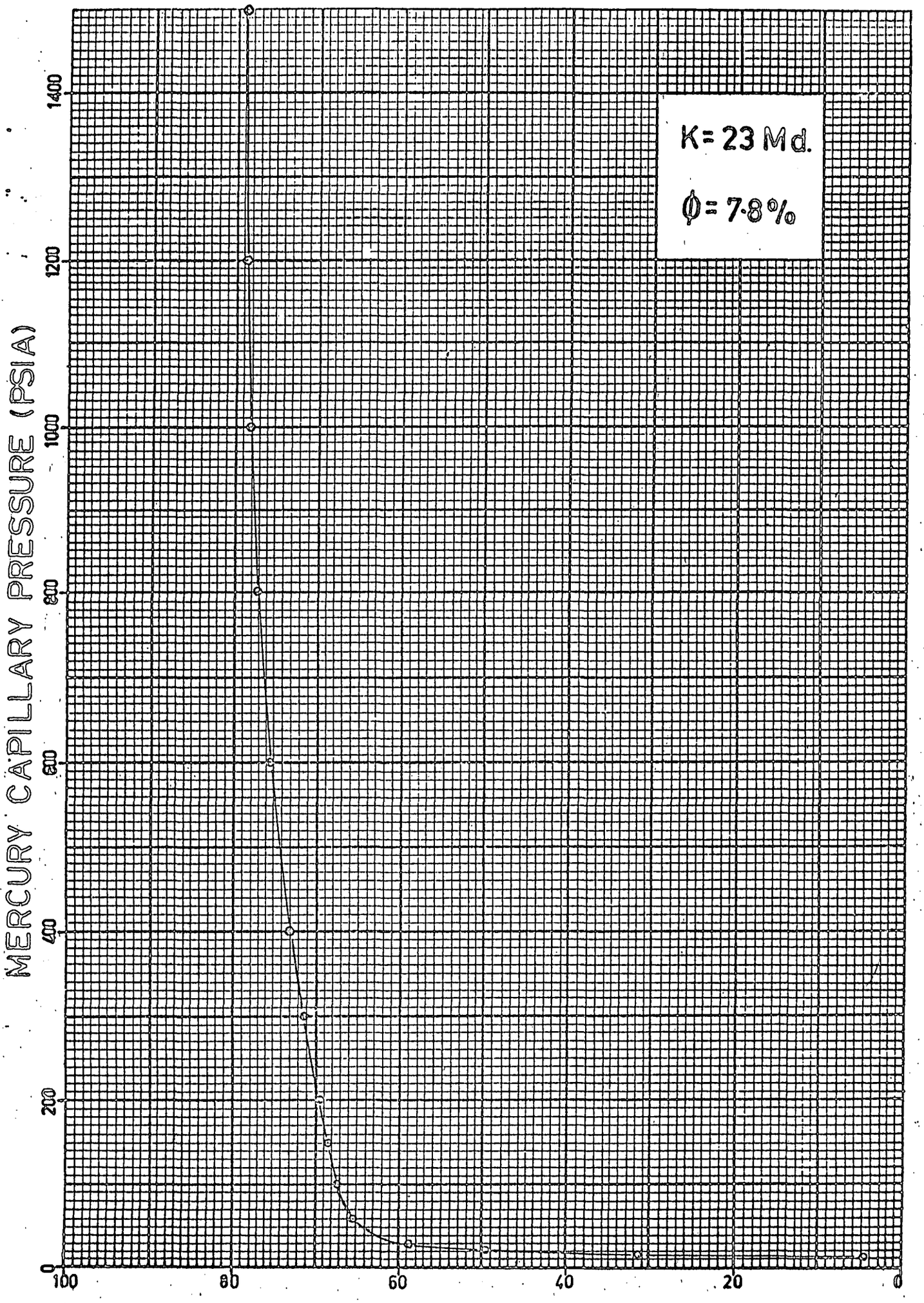


FIGURE 8

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4125

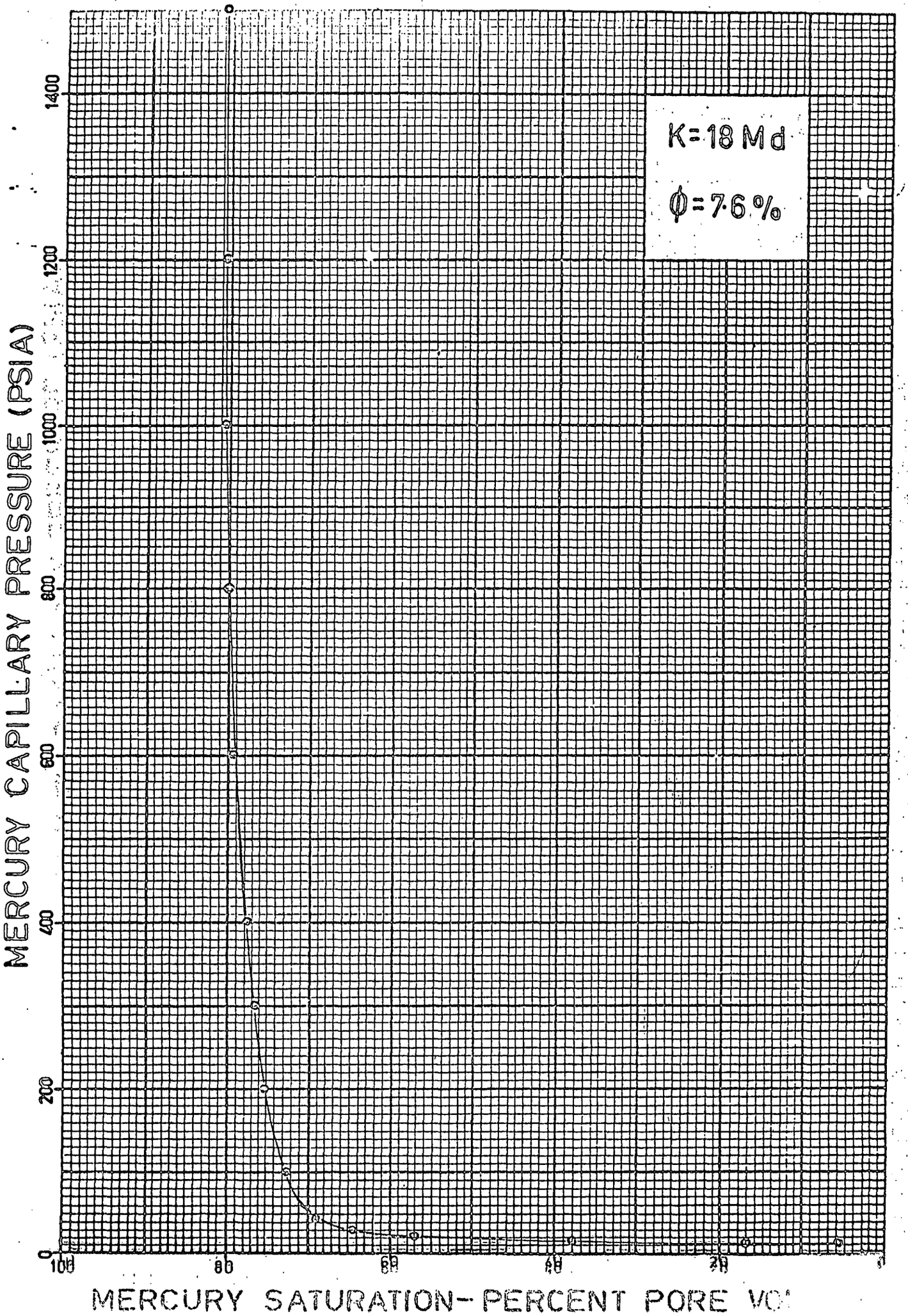


FIGURE 9

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4128

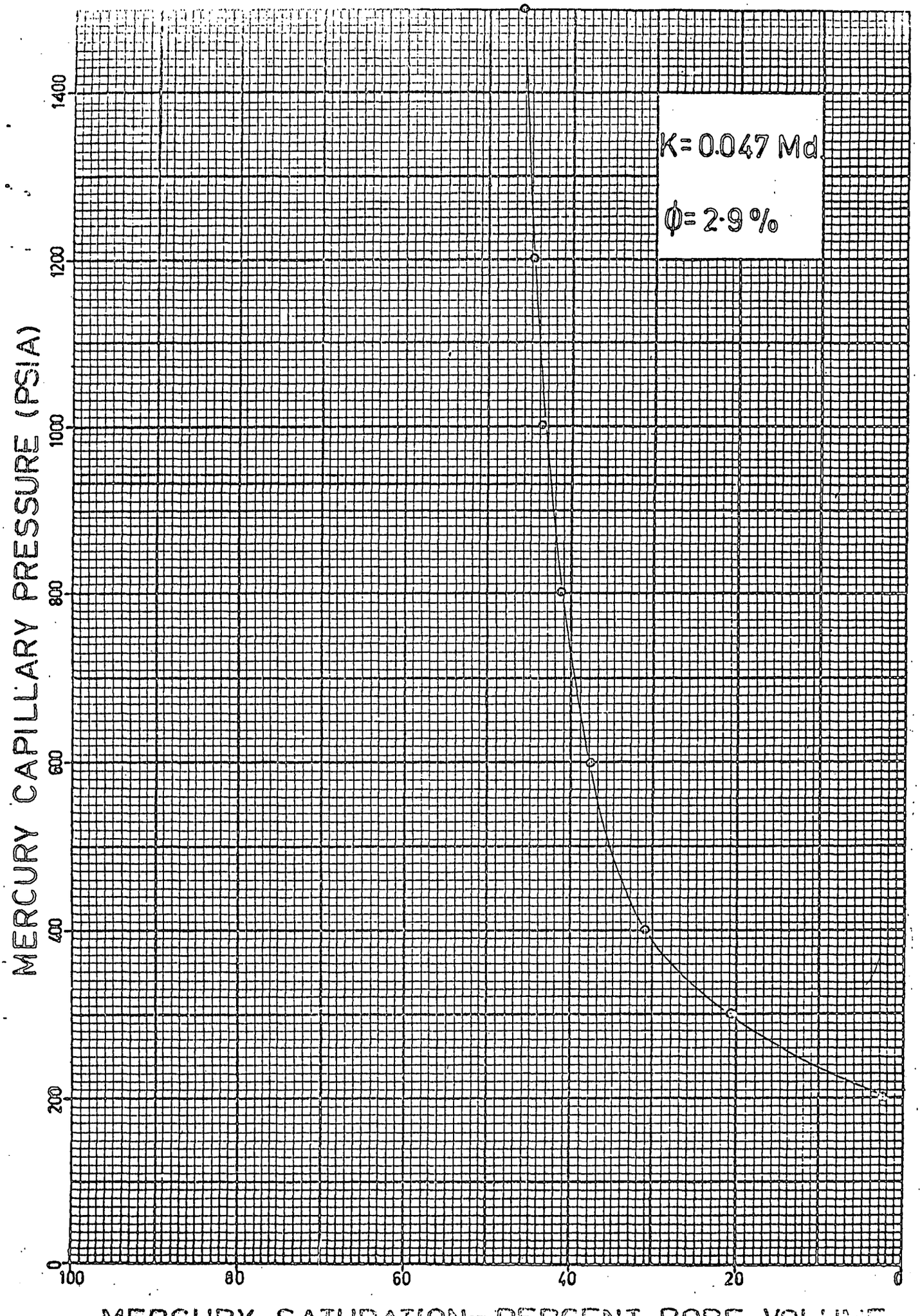


FIGURE 10

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4132

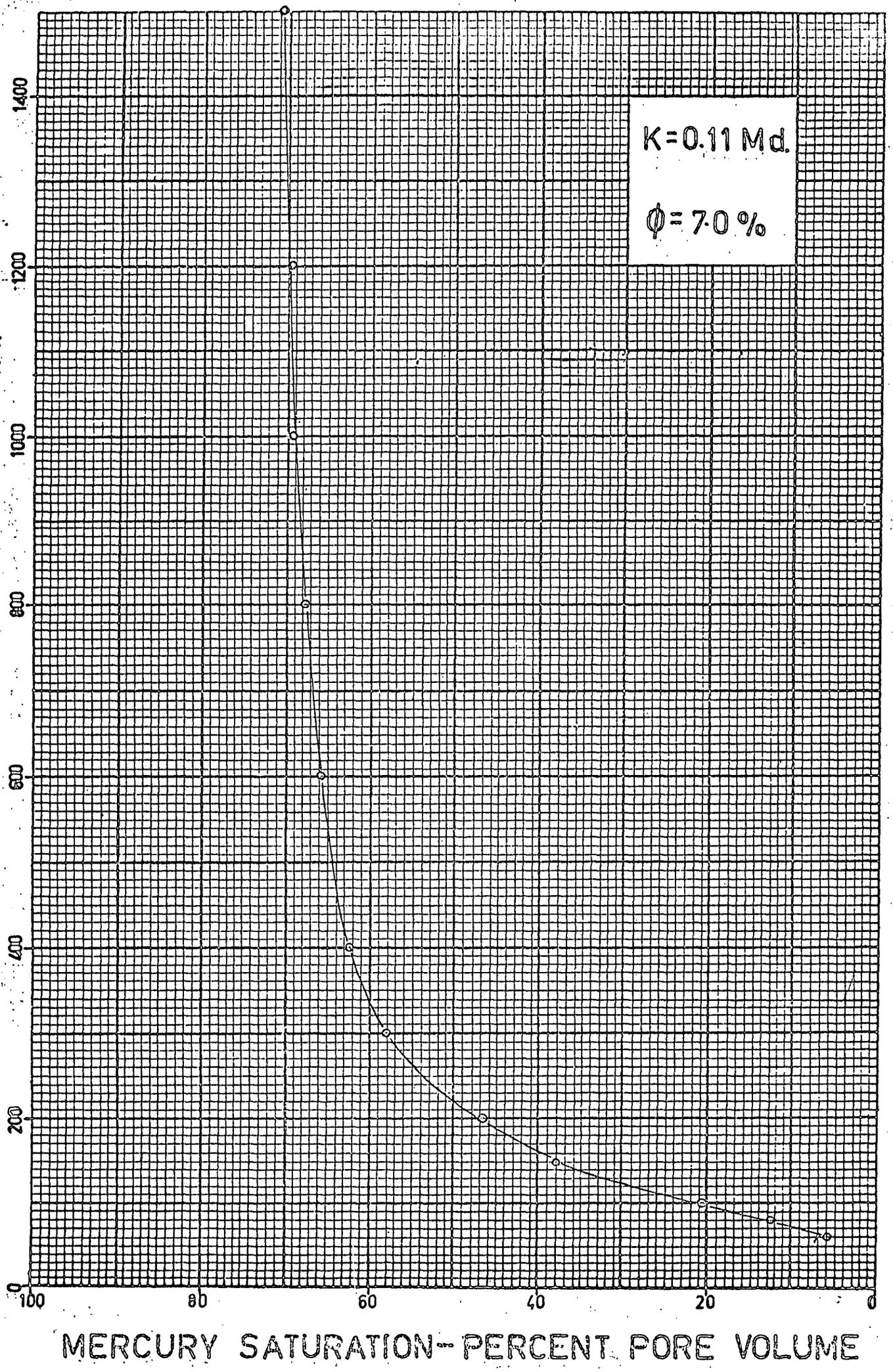


FIGURE 11

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No1 SAMPLE DEPTH-4136

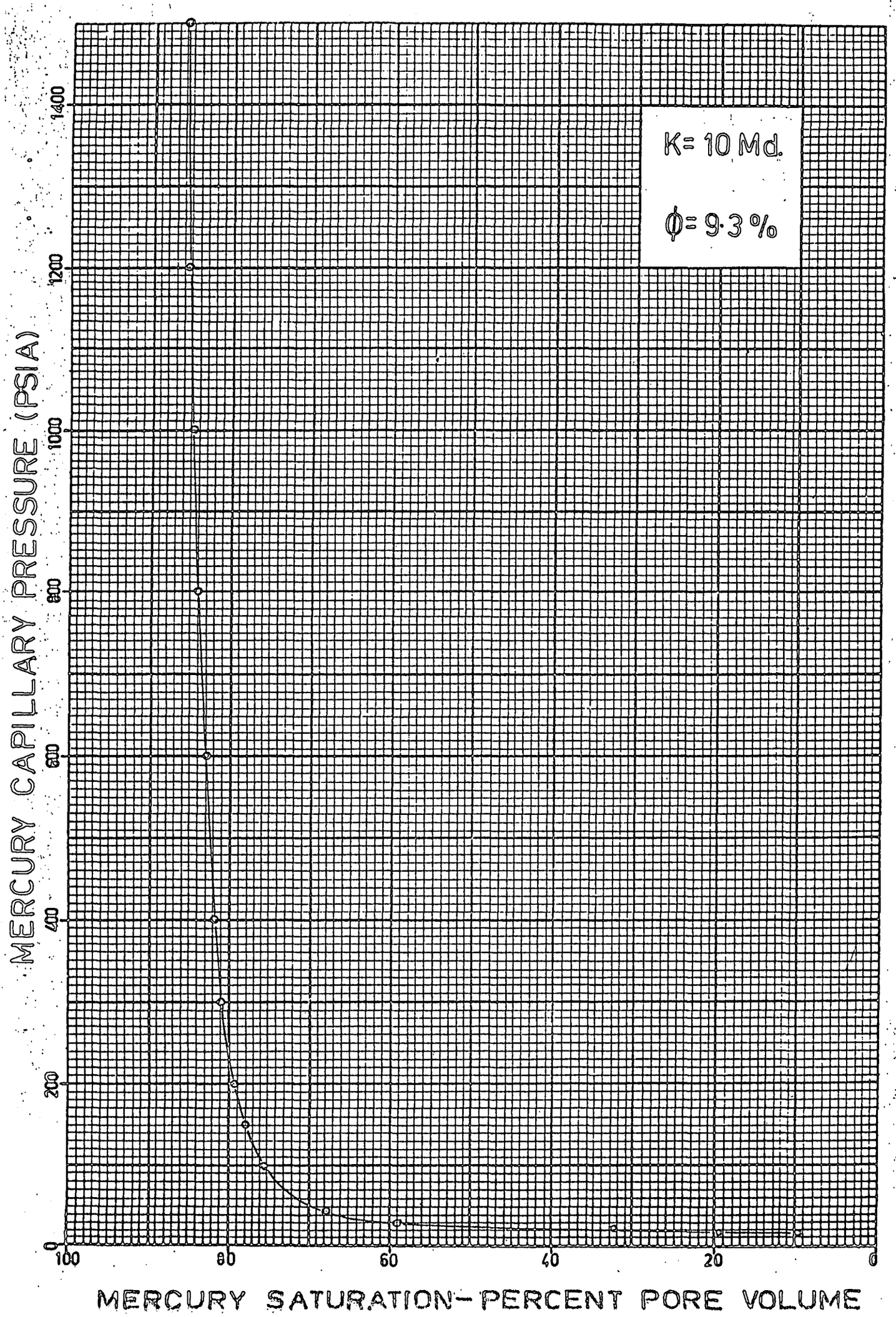


FIGURE 12

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4273

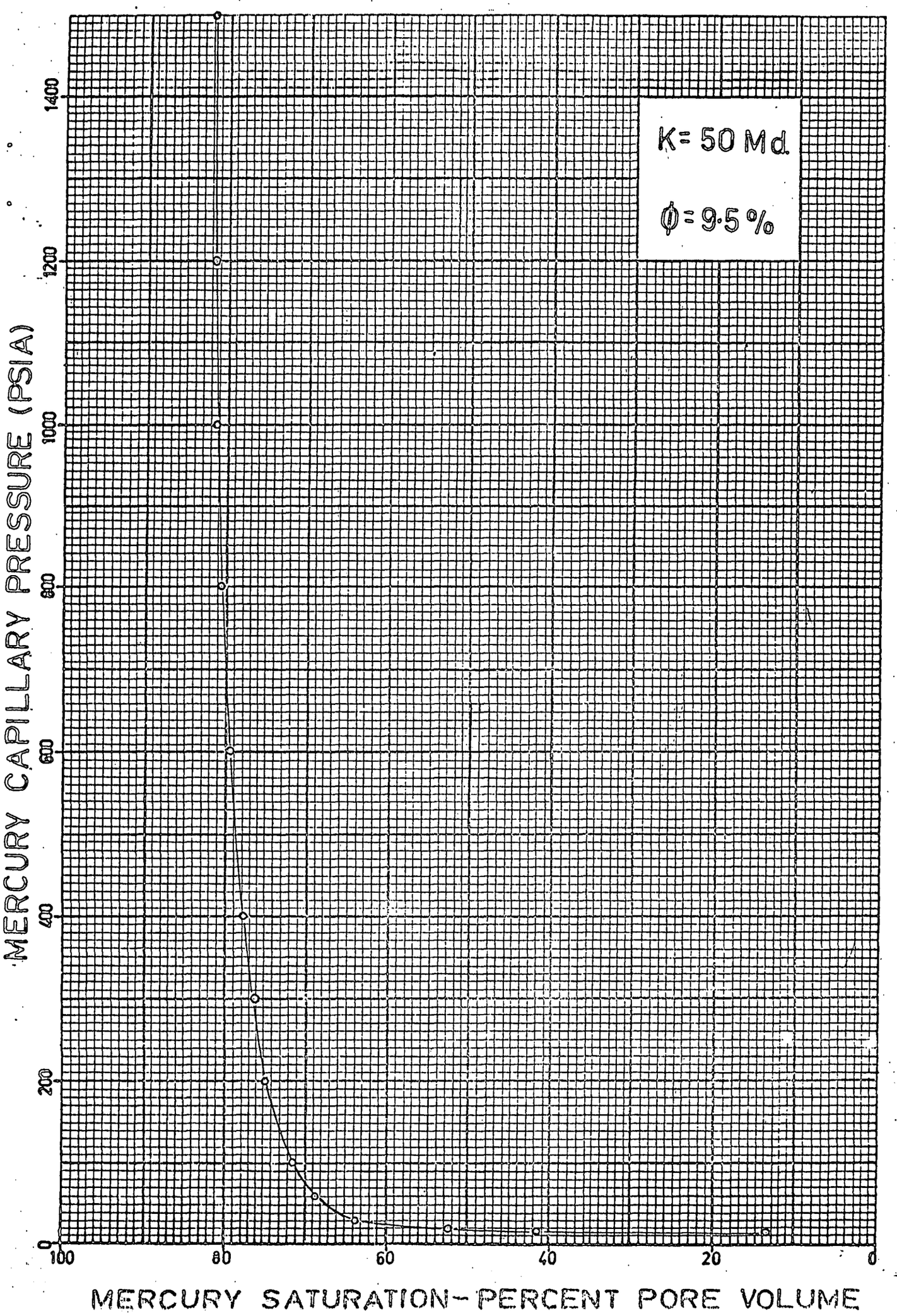


FIGURE 13

MERCURY CAPILLARY PRESSURE

WELL NAME-EMEREENIE No.1 SAMPLE DEPTH-4277.

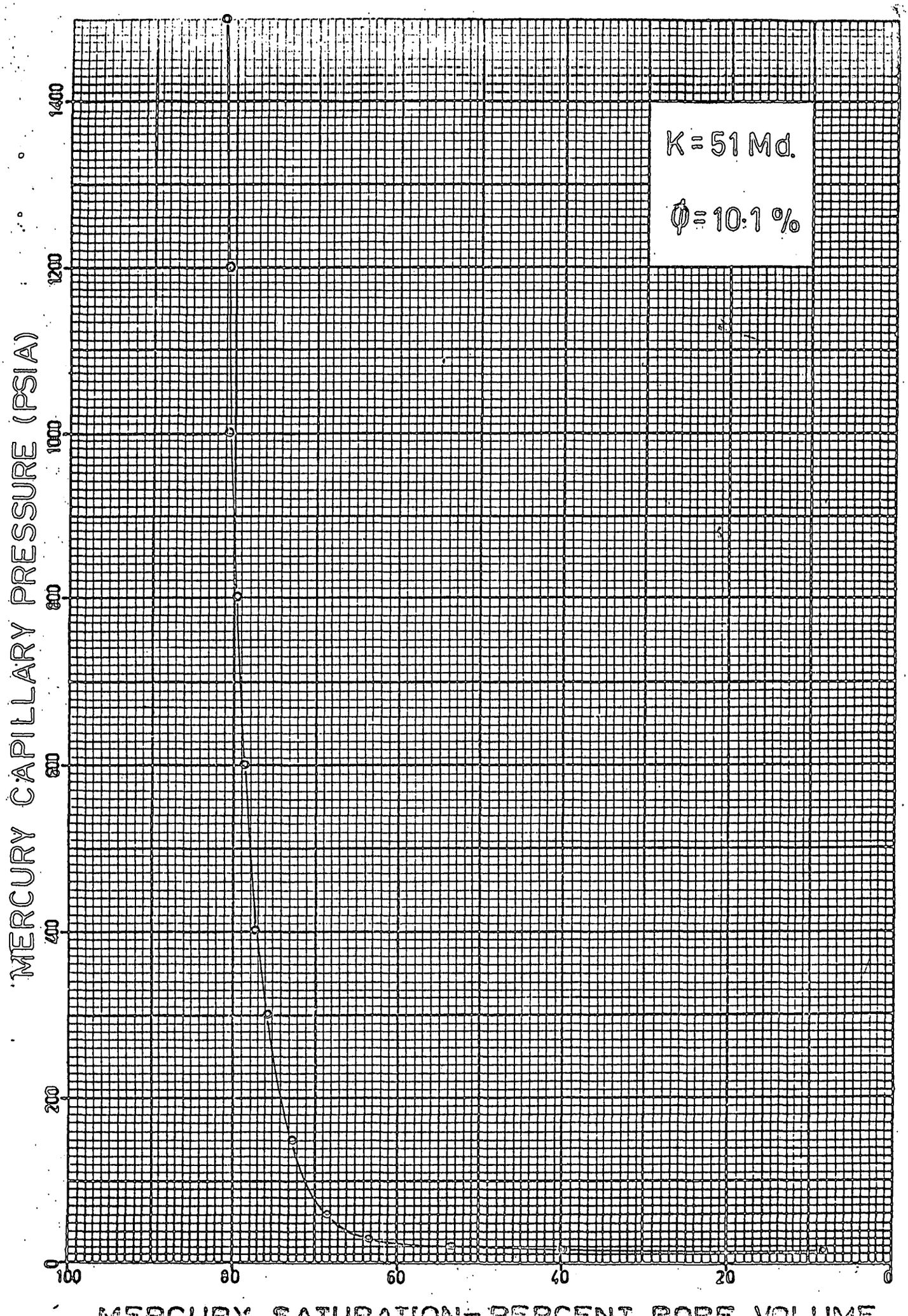


FIGURE 14

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4281

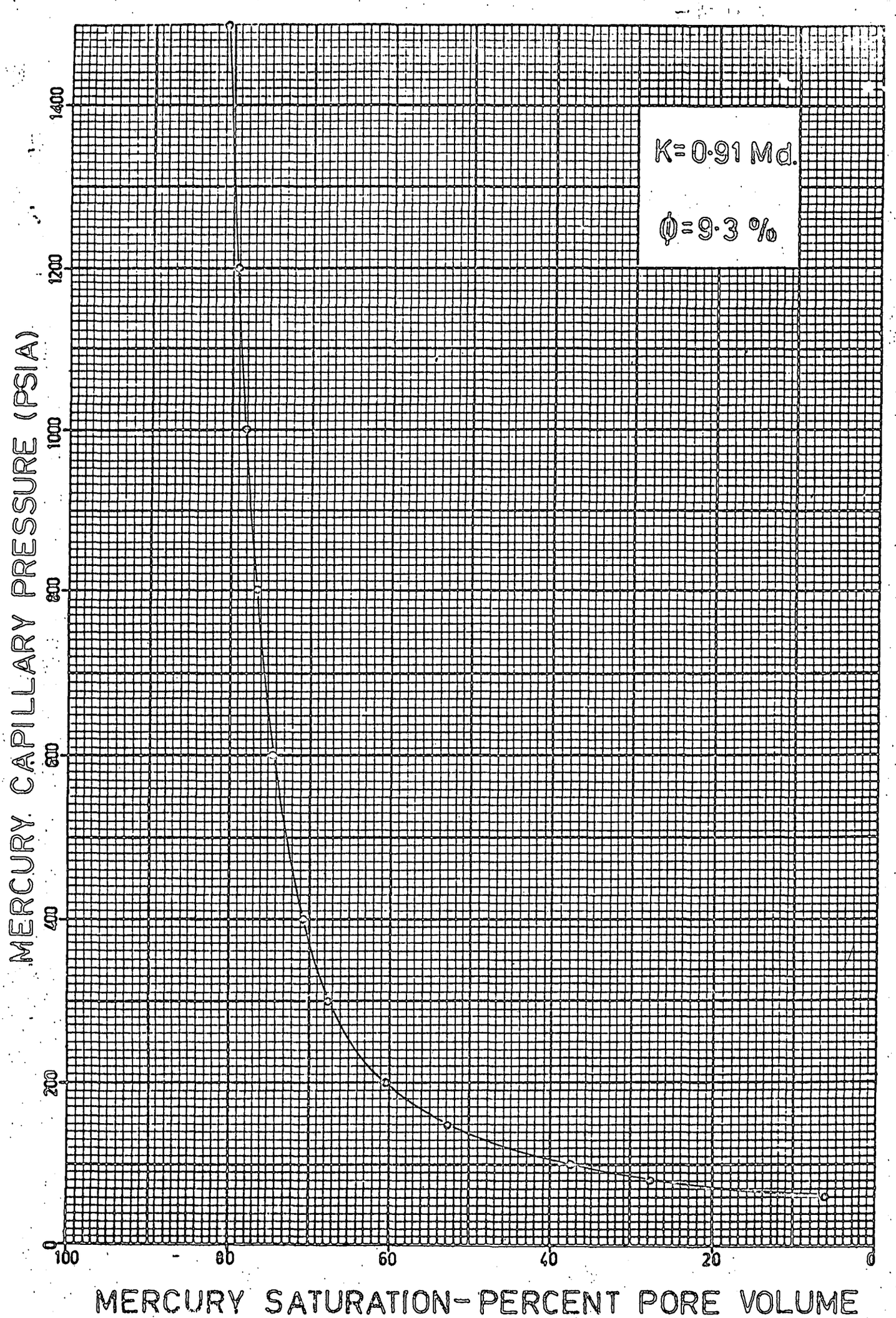


FIGURE 15

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4288

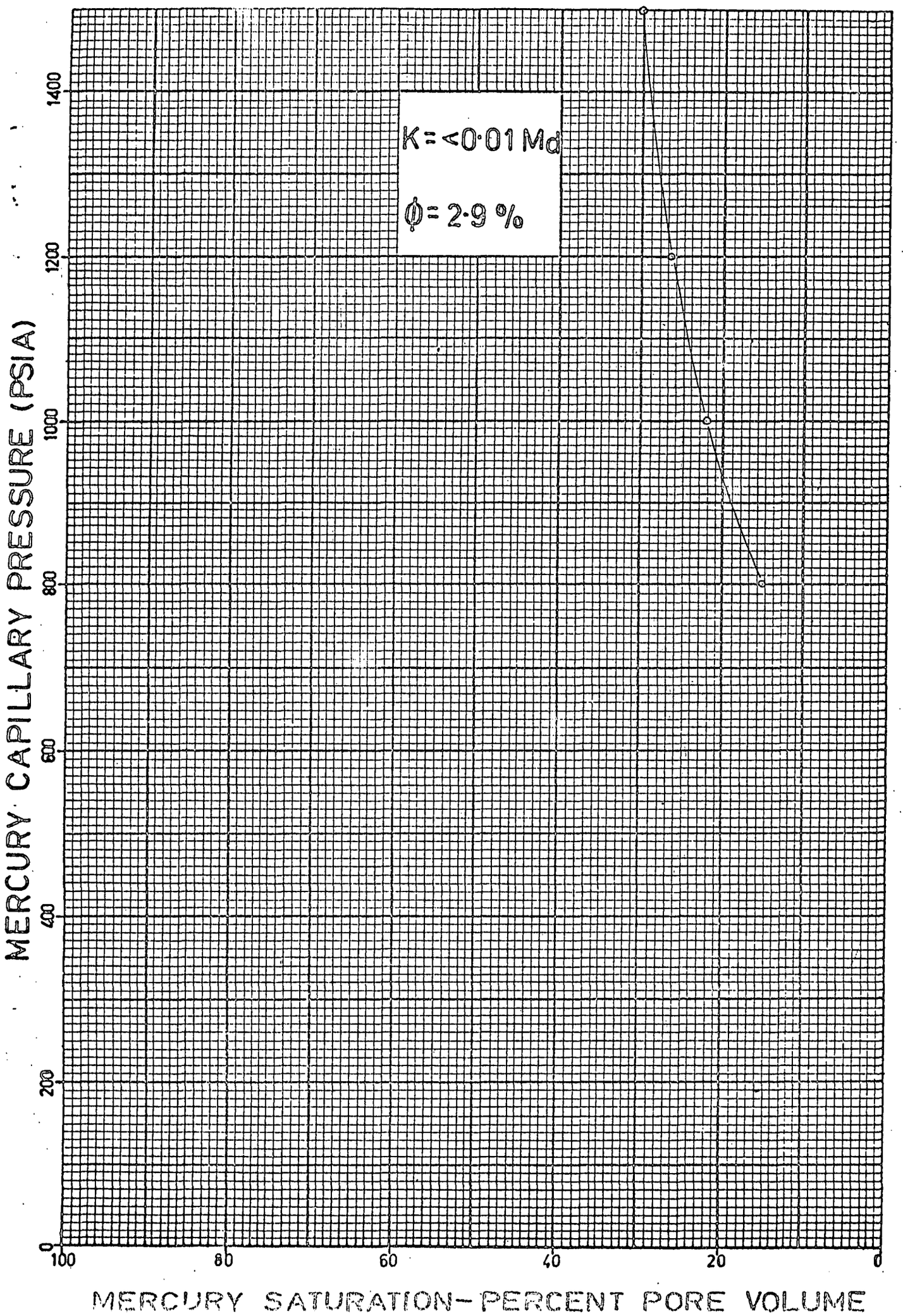


FIGURE 16

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4292

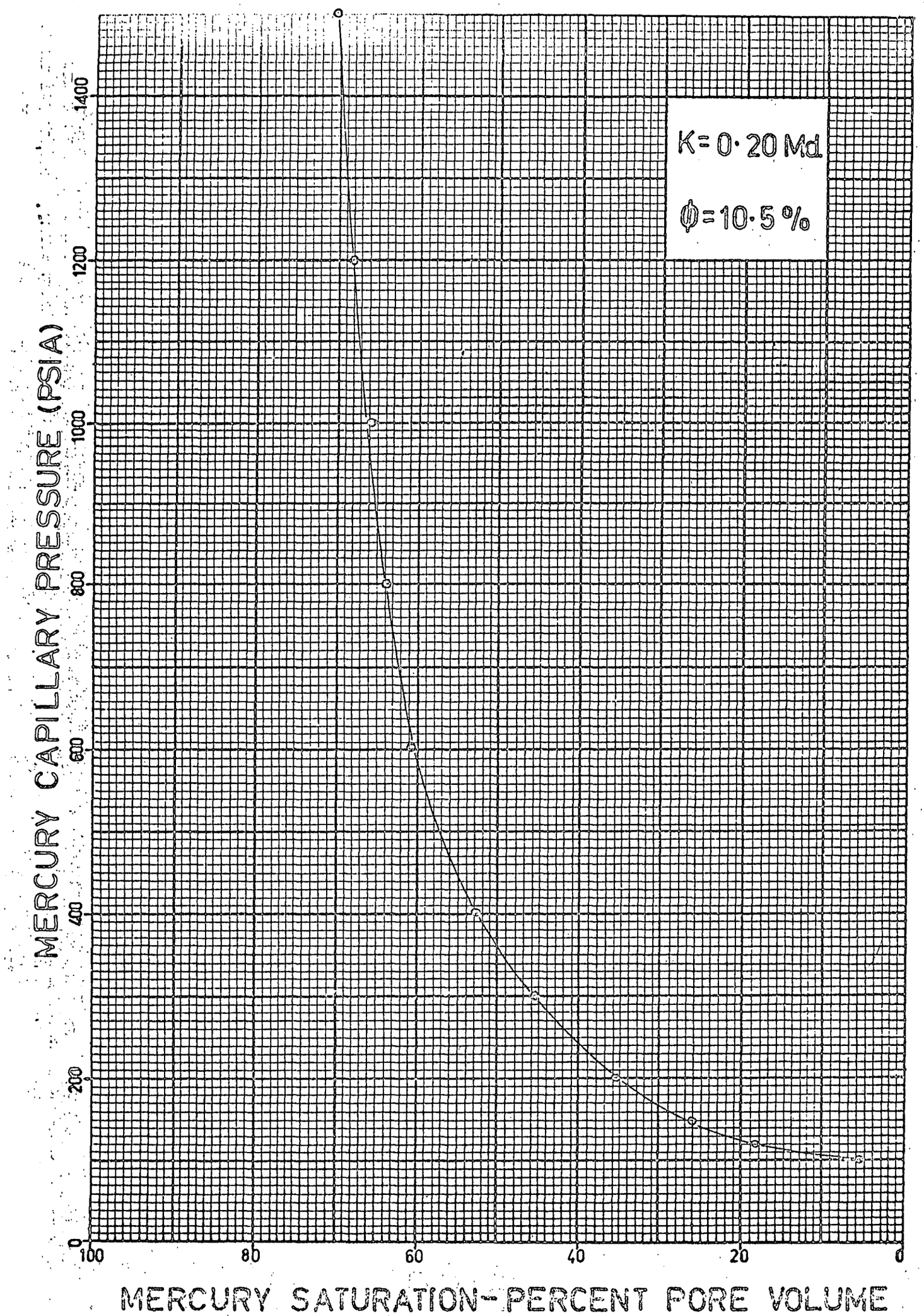


FIGURE 17

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4297

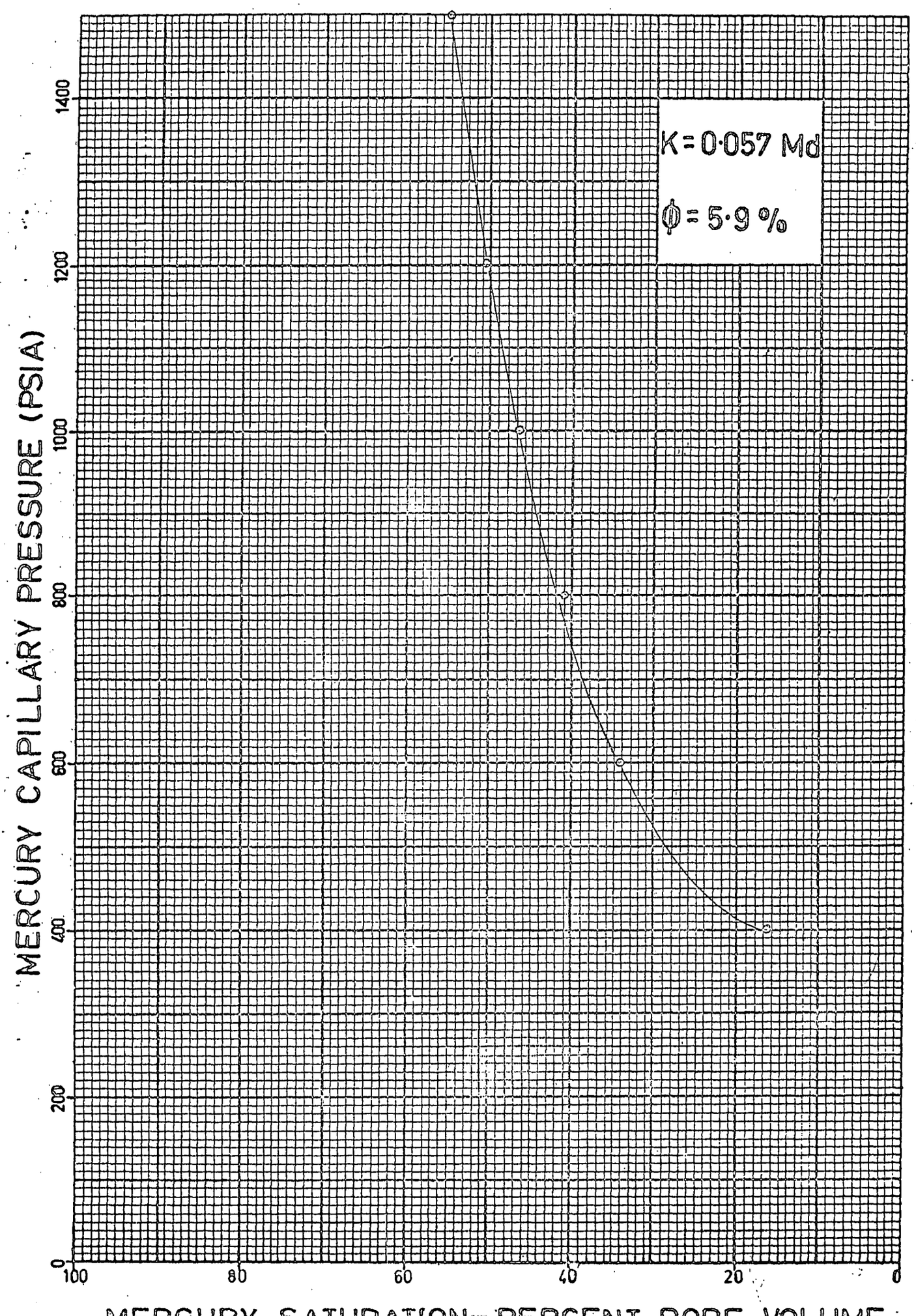


FIGURE 18

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No1 SAMPLE DEPTH-4302

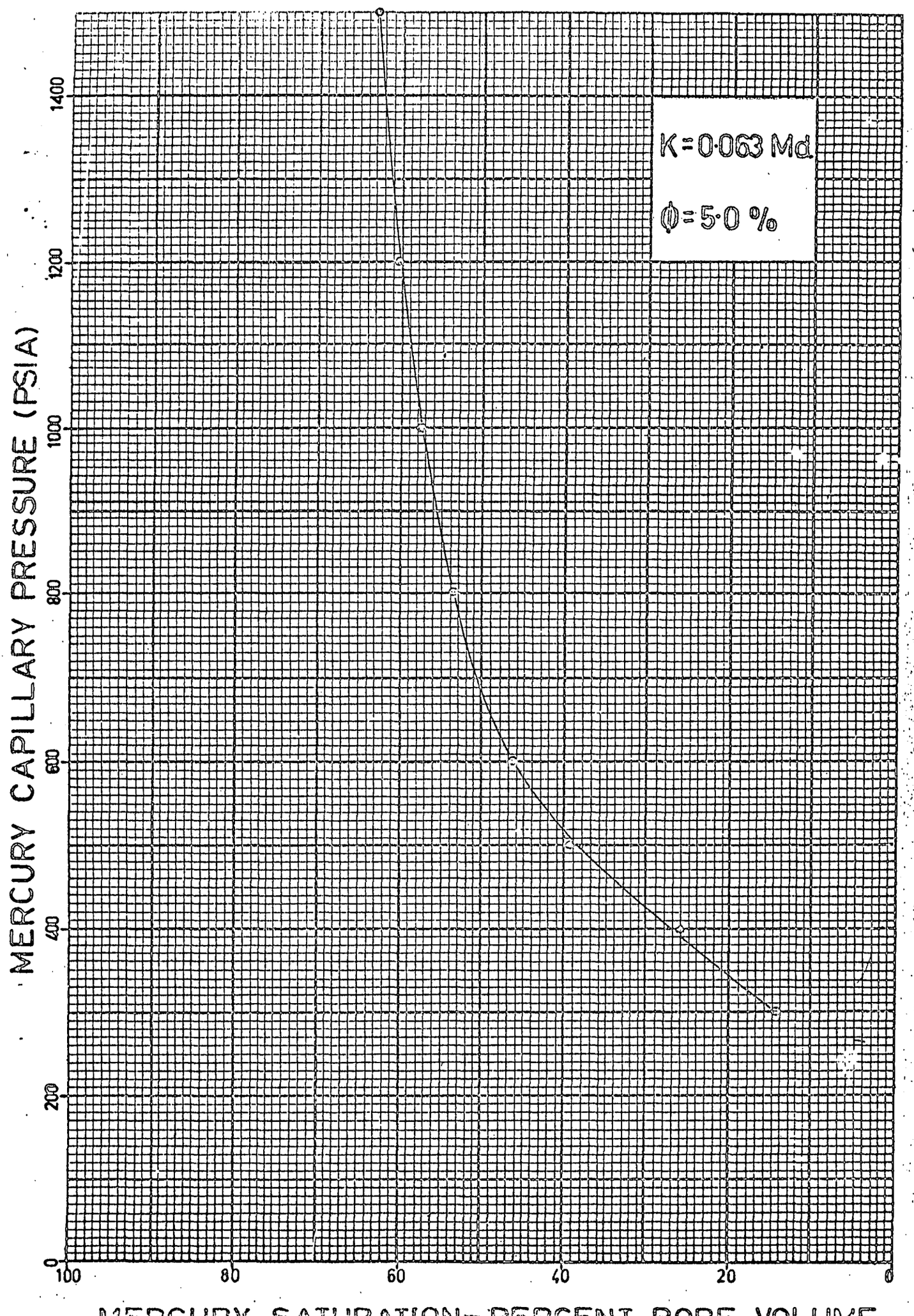


FIGURE 19

MERCURY CAPILLARY PRESSURE

WELL NAME E.MEREENIE No.1 SAMPLE DEPTH 4490

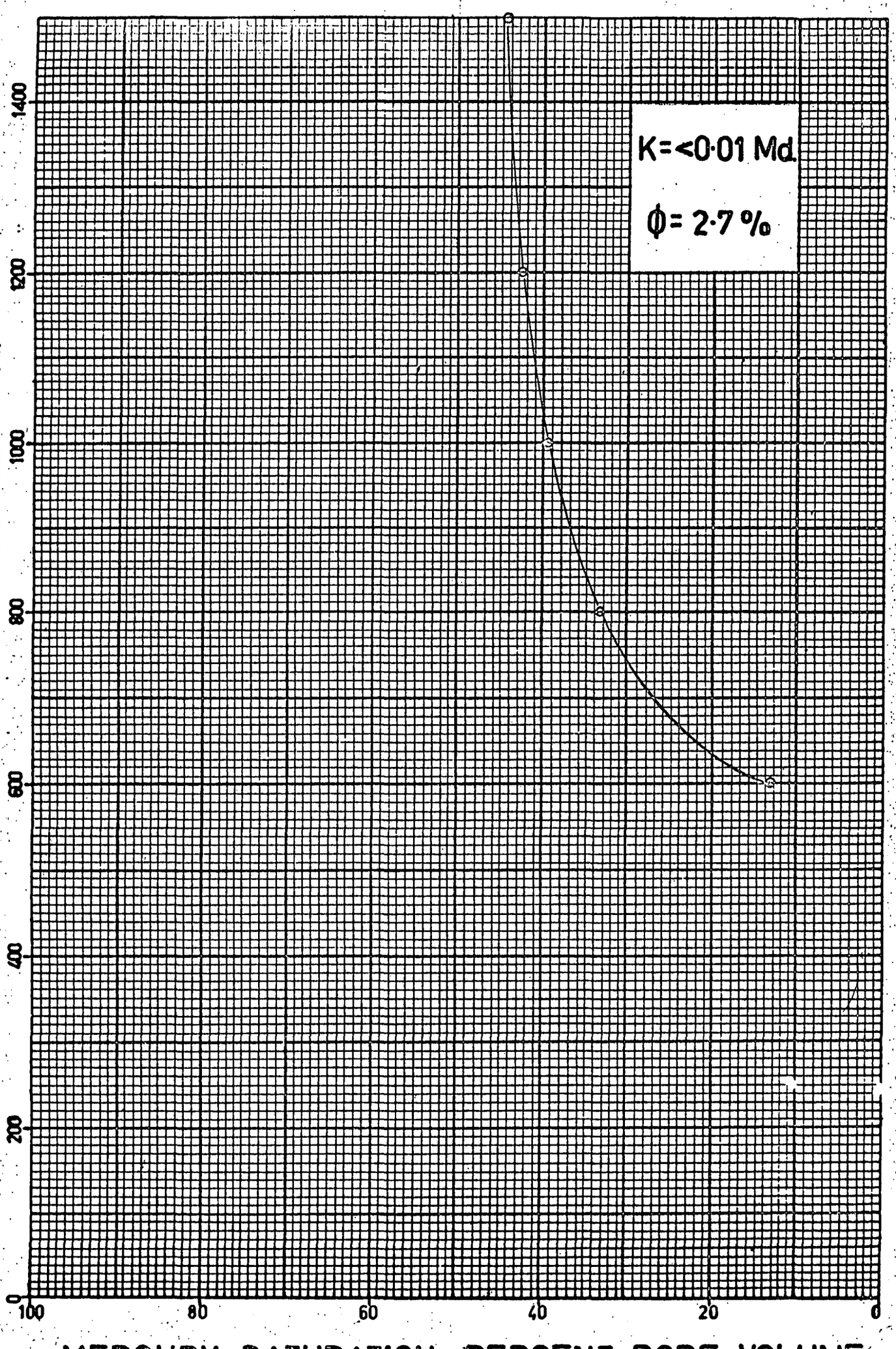


FIGURE 20

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4496

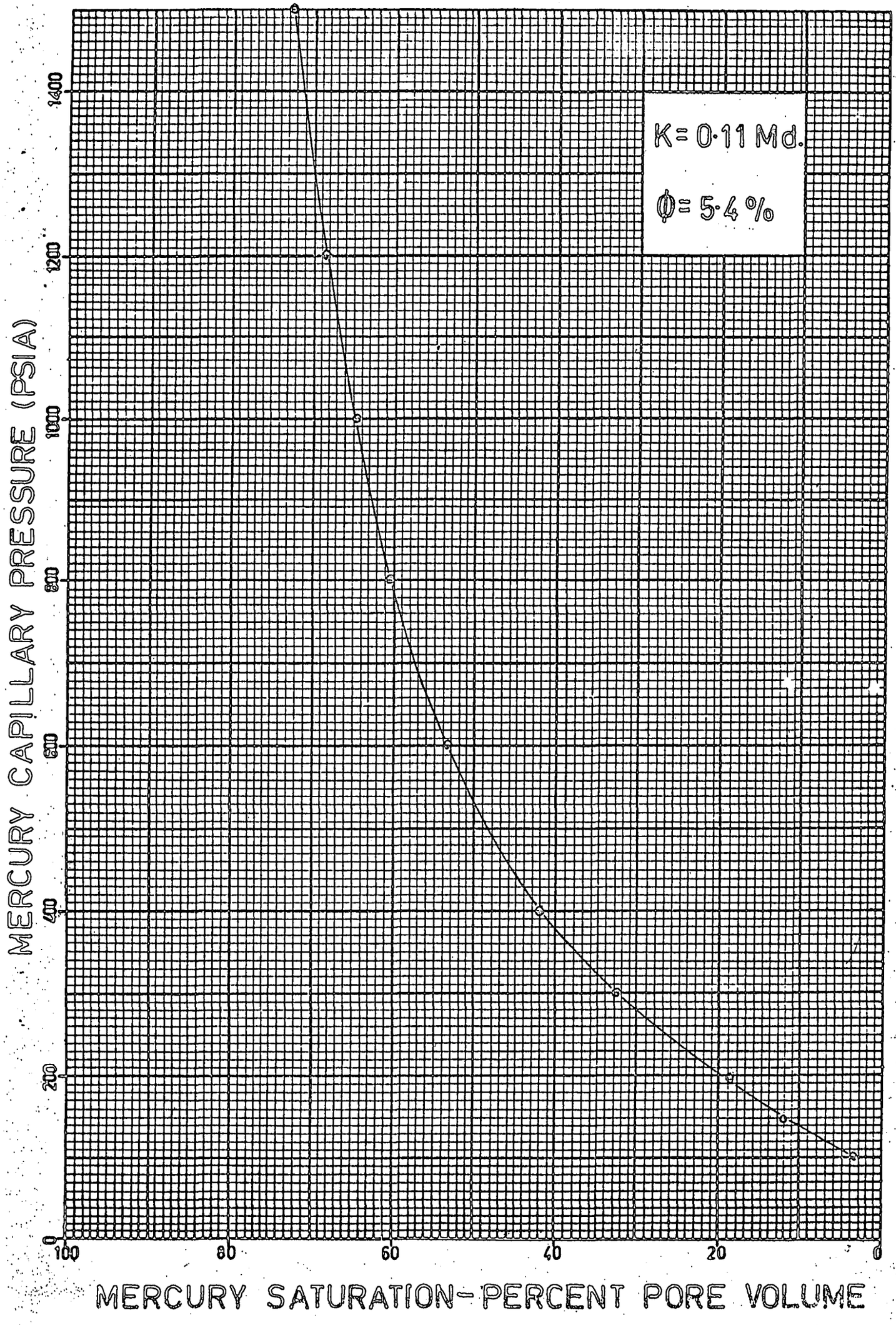


FIGURE 21

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No 1 SAMPLE DEPTH-4511

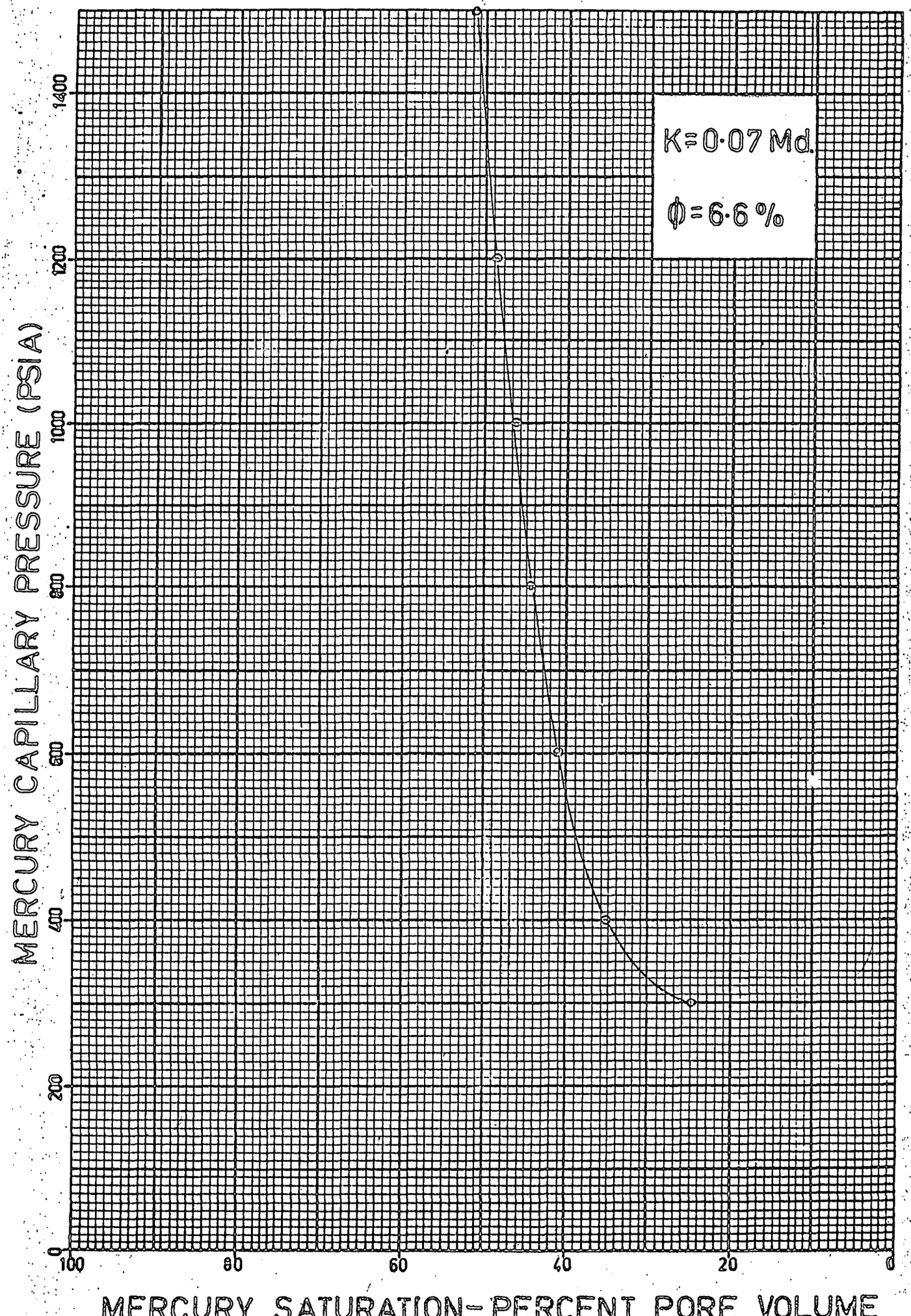


FIGURE 22

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4517

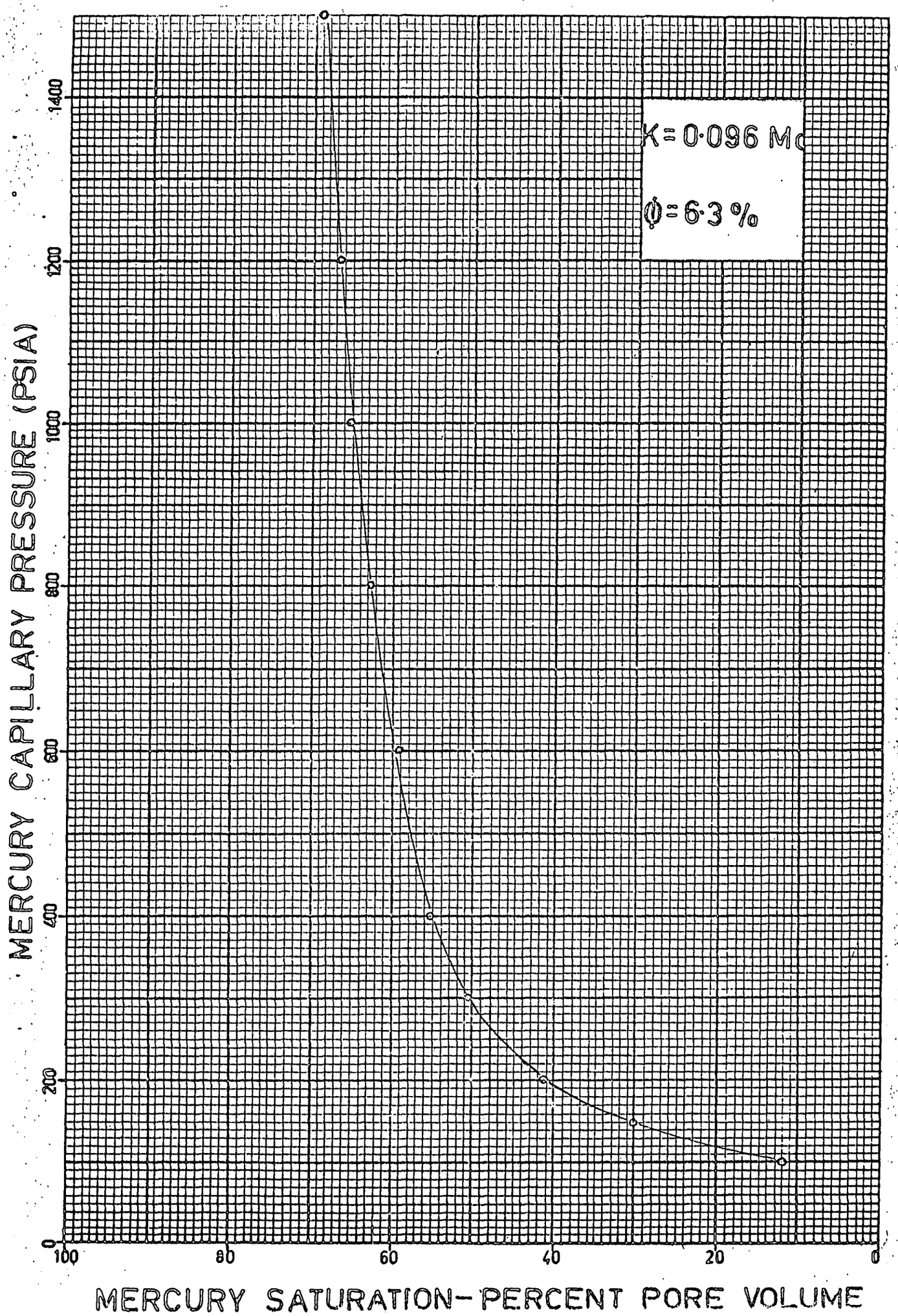


FIGURE 23

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4521

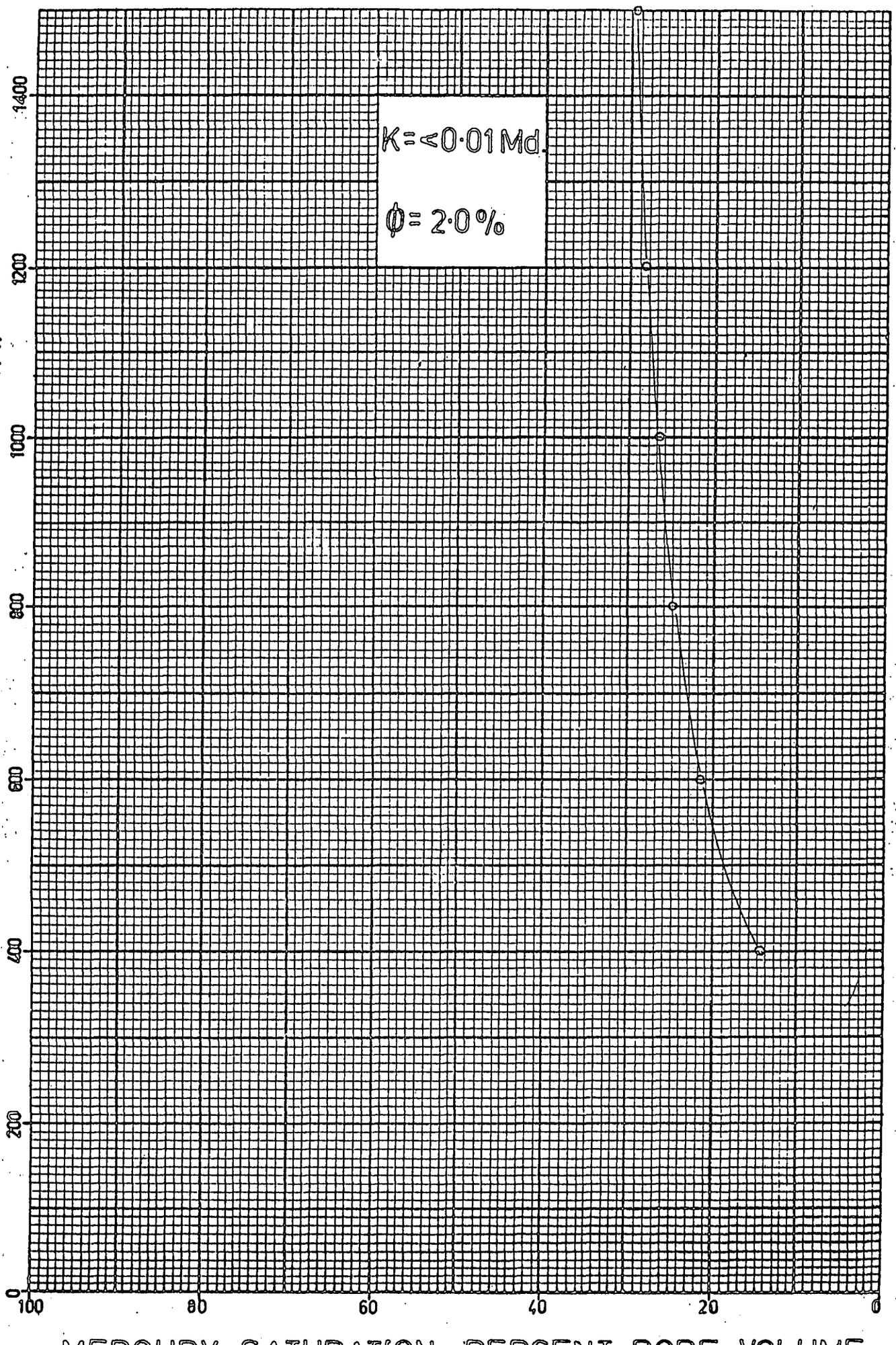


FIGURE 24

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4529

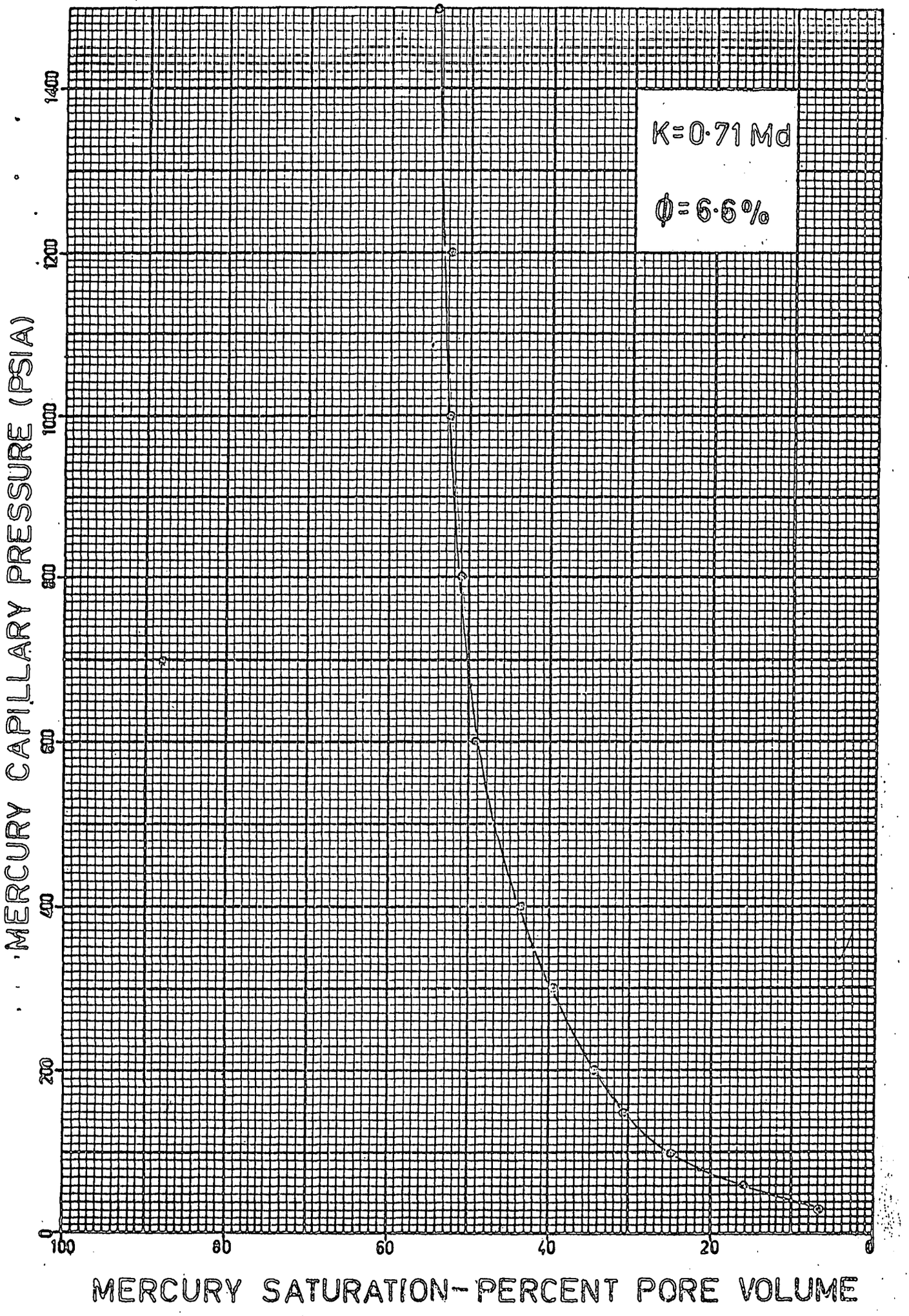


FIGURE 25

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No1 SAMPLE DEPTH-4668

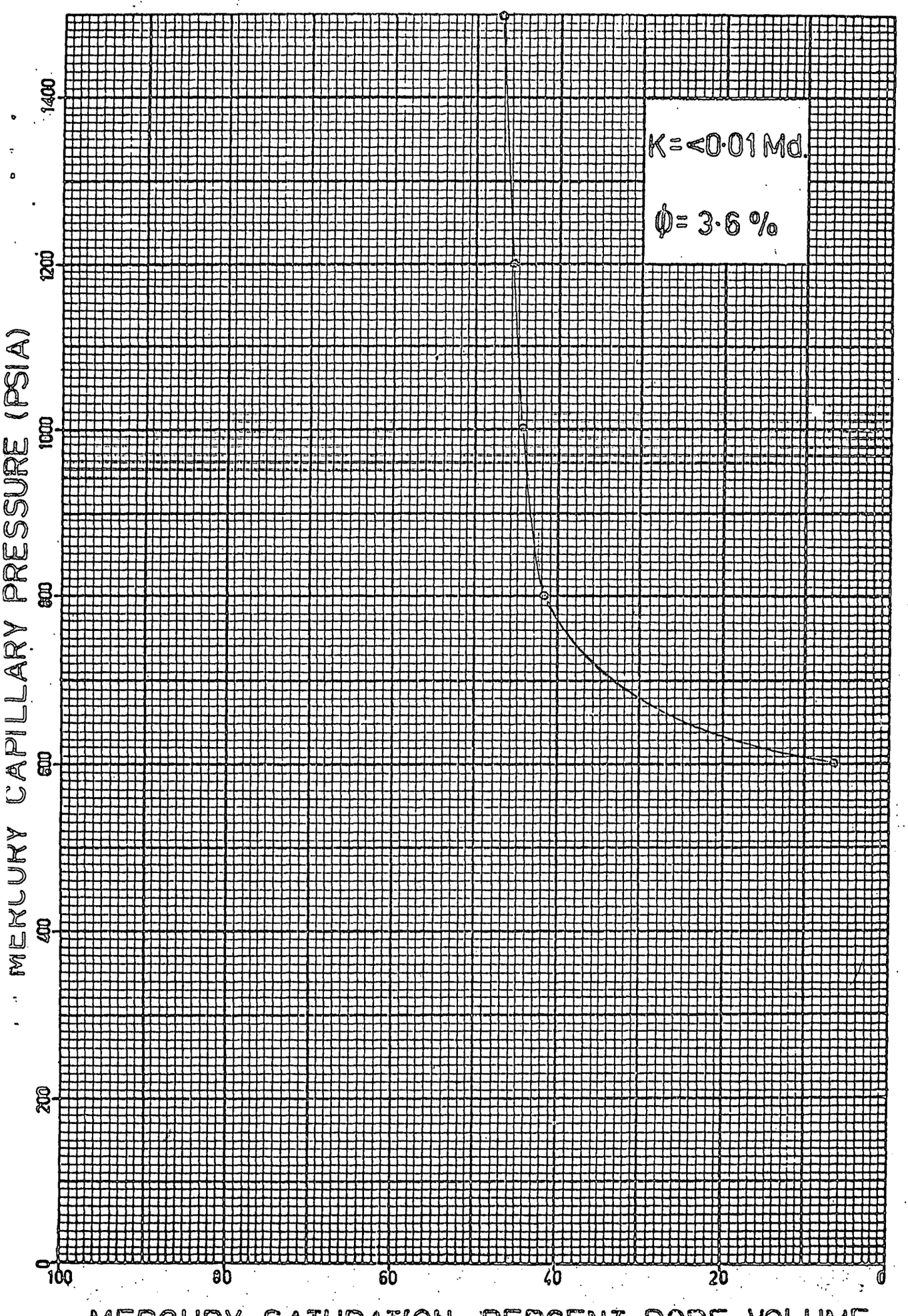


FIGURE 26

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No1 SAMPLE DEPTH-4690

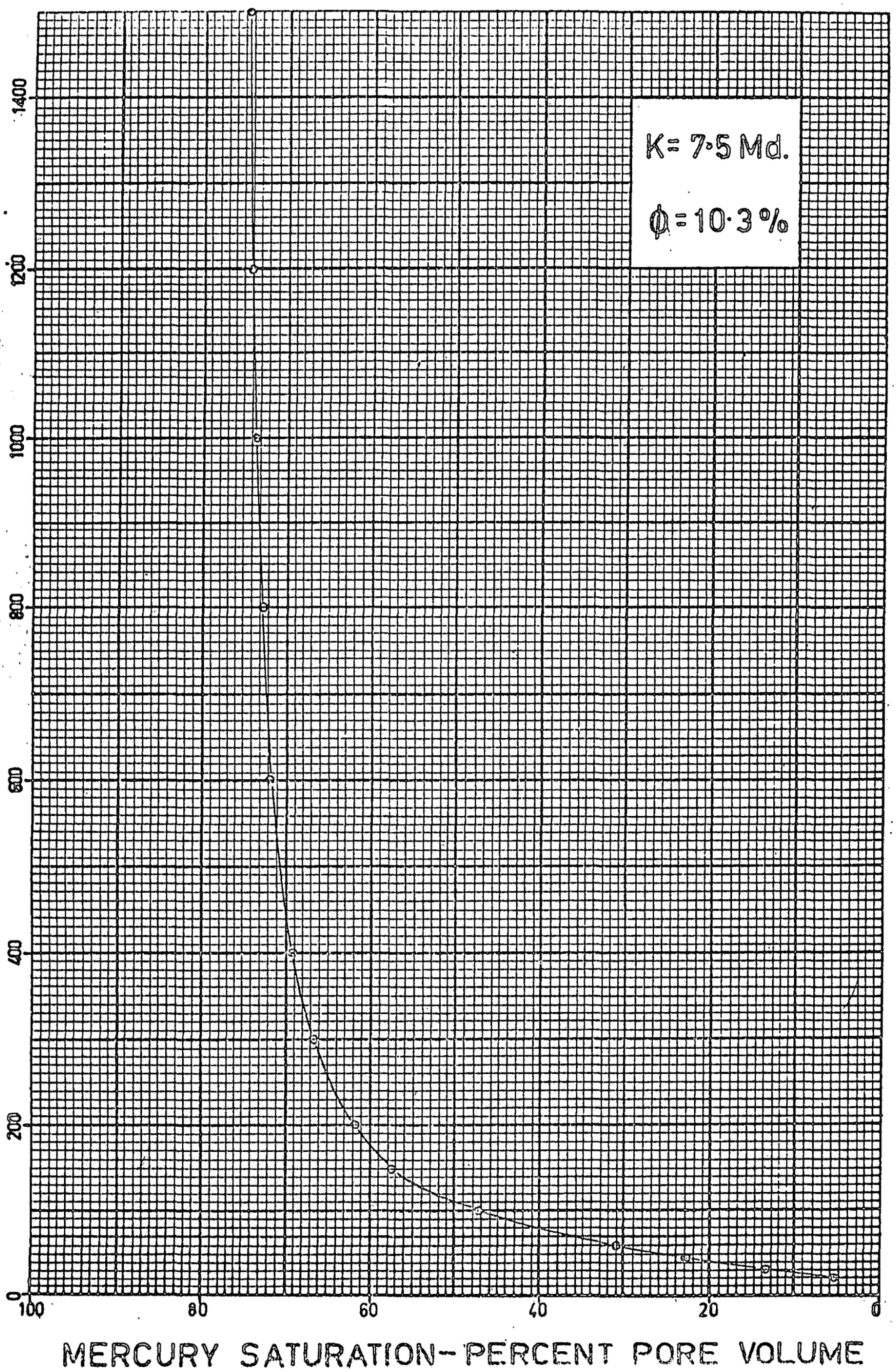


FIGURE 27

MERCURY CAPILLARY PRESSURE

WELL NAME-E.MEREENIE No.1 SAMPLE DEPTH-4694'

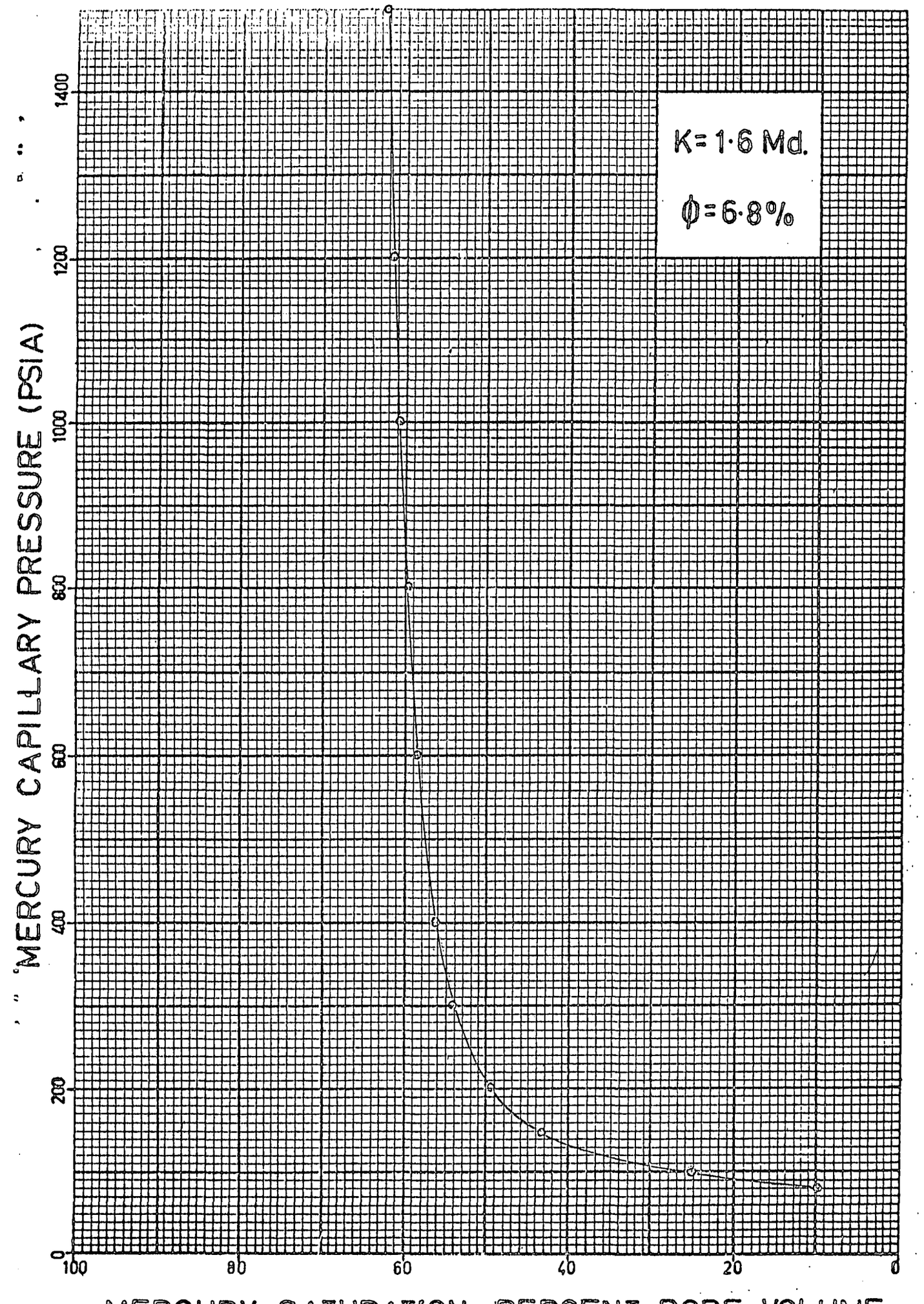
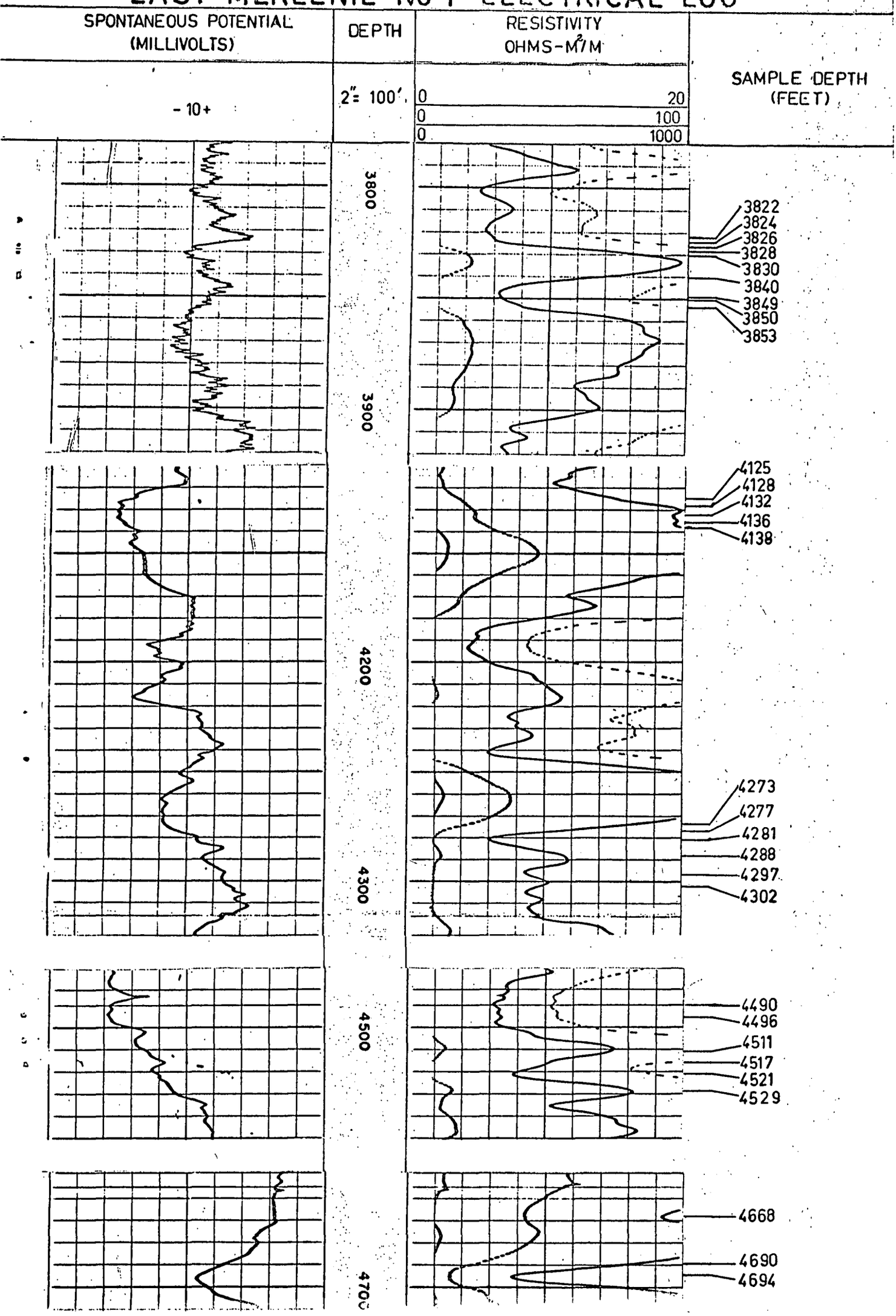


FIGURE 28

EAST MEREENIE No 1 ELECTRICAL LOG