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Capillary Pressure and Wettability Tests  
on Samples from (Permian) Reservoir Sandstones

By

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

PETROLEUM TECHNOLOGY SECTION

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INTRODUCTION

This report presents results of a mercury injection capillary pressure study on sandstone samples from gas and condensate producing zones in the subject well. Pore size distribution for each of the samples was calculated from the capillary pressure data. Finally imbibition tests were performed on four samples to gain some idea of the nature of reservoir rock wettability.

PROCEDURE AND APPARATUS

Ten  $\frac{3}{4}$  inch diameter plugs were drilled out, parallel to bedding, from  $3\frac{1}{2}$  inch and  $4\frac{1}{2}$  inch whole core samples. The plugs were trimmed with a diamond saw to approximately  $1\frac{1}{4}$  inches in length, then extracted with toluene and oven-dried for 24 hours at  $110^{\circ}\text{C}$ . Upon cooling, effective porosity and absolute permeability were measured on the plugs.

Capillary pressure tests were then conducted on the above samples in a Ruska mercury injection apparatus. After extensive evacuation of the plugs in a mercury pump reservoir they were saturated with mercury in pressure "steps". The volume of mercury injected into each of the samples was measured on the pump vernier scale after stabilization at each of the pressure "steps" had been achieved.

Capillary pressure curves were then compiled from the above pressure/volume relationship data, after minor pump expansion and mercury surface conformance corrections were applied. The curves so obtained were used for the calculation of pore size values for each of the samples tested, using

the formula: 
$$r = \frac{2 \gamma \cos \theta}{\Delta P}$$

The pore entry values ( $r$ ) of each sample were calculated by reference to the corresponding capillary pressure curve and the average pressures used throughout the particular saturation interval. Values of 480 dyres/cm for mercury surface tension ( $\gamma$ ), and  $140^{\circ}$  for mercury/rock contact angle were taken from a reference paper \* by W.R. Purcell.

Finally, imbibition tests were conducted on samples drilled adjacent to four of the capillary test samples. These were saturated with kerosene and immersed in water. The relative wetting was determined by noting the amounts of oil displaced by water in particular time intervals over a ten-day period. Because of the positive nature of results obtained, the corresponding tests for oil wetting were not carried out.

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\* Petroleum Transactions, A.I.M.E., February, 1949.

## DISCUSSION

Individual capillary pressure curves are presented in figures 1 - 9. Pore size distribution data calculated from the capillary pressure curves are presented in Tables IIa and IIb, while Table I contains porosity and permeability values and the results of imbibition tests. Sections of the electrical log covering the particular intervals investigated and the position of samples used in the tests are shown in Figure 10.

Three zones of interest were studied in this report; the lower part of the main producing interval between 6859' - 64', and two minor sand intervals between 6614' - 18' and 6882' - 94'. Capillary tests on the lower part of main sand gave good results, with very low threshold pressures and low irreducible water saturations. Additionally, although porosities of this interval averaged a moderate 17%, some 60% of the effective pore space was calculated to have pore radii ranging from 1.4 to 46.3 microns.

The two minor sand intervals studied showed poor porosity and permeability values and high irreducible water saturation and threshold pressures. Results could not be obtained for one of the samples tested (6892'), because mercury penetration at ultimate test pressure could not be effected.

Imbibition tests carried out on the plugs showed them to be moderately to strongly water-wet. Upon immersion of the samples in water, the latter was readily imbibed and displaced some of the saturating oil in the plugs. The amount of displaced oil (by water imbibition) stabilized at 41% - 51% of pore volume after 10 days of immersion in water.

## CONCLUSIONS

- 1) Capillary pressure curves of the lower part of the main producing sands were characterized by very low threshold pressures, and moderate to low irreducible water saturations.
- 2) Samples from the lower part of the main producing zone were shown to have a multitude of large pores. Some 60% of the pores had radii ranging from 1.4 microns to 46.3 microns.
- 3) Absolute permeability to nitrogen measured through the producing zone was found to be moderate to good, averaging 208 millidarcys.
- 4) The samples were shown to be strongly water-wet. Water was imbibed into the oil-saturated samples to a maximum extent of 51% of pore volume after 10 days' immersion.

TABLE 1

Well Name and Number	Core Number	Sample Depth (feet)	Absolute Permeability to Nitrogen (Millidarcy)	Porosity (% Bulk Volume)	Saturating Medium	Volume of Water Imbibed (% Pore Volume)				
						1 Day	2 Days	3 Days	7 Days	10 Days
Gidgealpa No. 2	2	6614	less than 0.5	7.6	Not Tested for Imbibition					
"	2	6618	2.9	11.8	Kerosene	39.5	40.6	40.6	40.6	42.0
"	4	6859	162	16.5	"	22.8	30.0	33.7	38.5	41.0
"	4	6890'6"	323	18.9	Not Tested for Imbibition					
"	4	6861'6"	228	16.7	Not Tested for Imbibition					
"	4	6862'6"	160	15.8	Kerosene	25.3	30.3	32.8	43.0	45.5
"	4	6864	166	17.6	"	32.7	39.7	46.6	51.3	51.3
"	6	6882	less than 0.5	12.0	Not Tested for Imbibition					
"	6	6888	"	11.2	Not Tested for Imbibition					
"	6	6892	"	11.8	Not Tested for Imbibition					

TABLE II<sub>a</sub>

	SATURATION (% PORE VOLUME)									SAMPLE DEPTH (feet)
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	
AVERAGE PORE ENTRY RADIUS (MICRONS)	0.17	0.15	0.13	0.11	0.09					6614
		1.57	1.23	0.83	0.49	0.27	0.13			6618
	33.3	21.3	14.6	9.4	4.7	2.1	0.95	0.27		6859
	46.3	30.5	21.8	14.8	8.3	4.1	1.7	0.43		6860'6"
	25.0	18.7	12.9	8.7	5.5	3.1	1.5	0.46	0.11	6861'6"
	42.7	22.2	13.4	7.8	3.8	1.7	0.56	0.11		6862'6"
	30.5	18.4	10.9	5.6	3.0	1.4	0.57	0.12		6864

TABLE IIb

	SATURATION (% PORE VOLUME)									SAMPLE DEPTH (feet)
	0-2	2-4	4-6	6-8	8-10	10-12	12-14	14-16	16-18	
AVERAGE PORE ENTRY RADIUS (MICRONS)	0.13	0.08								6882
		0.16	0.14	0.12	0.11	0.10	0.09	0.08	0.07	6888

FIGURE 1

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No.1 SAMPLE DEPTH-6614'

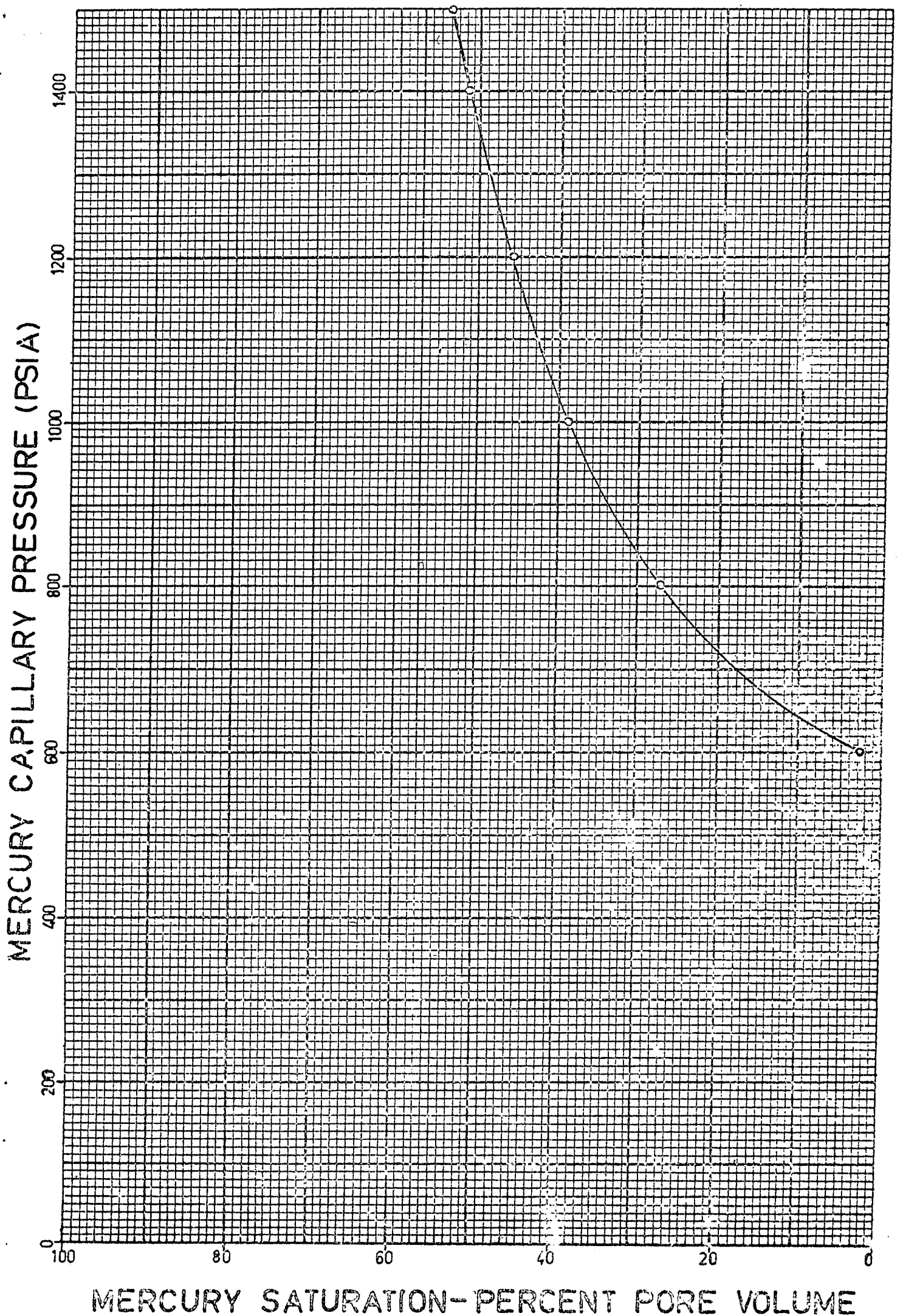




FIGURE 2

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No.2 SAMPLE DEPTH-6618'

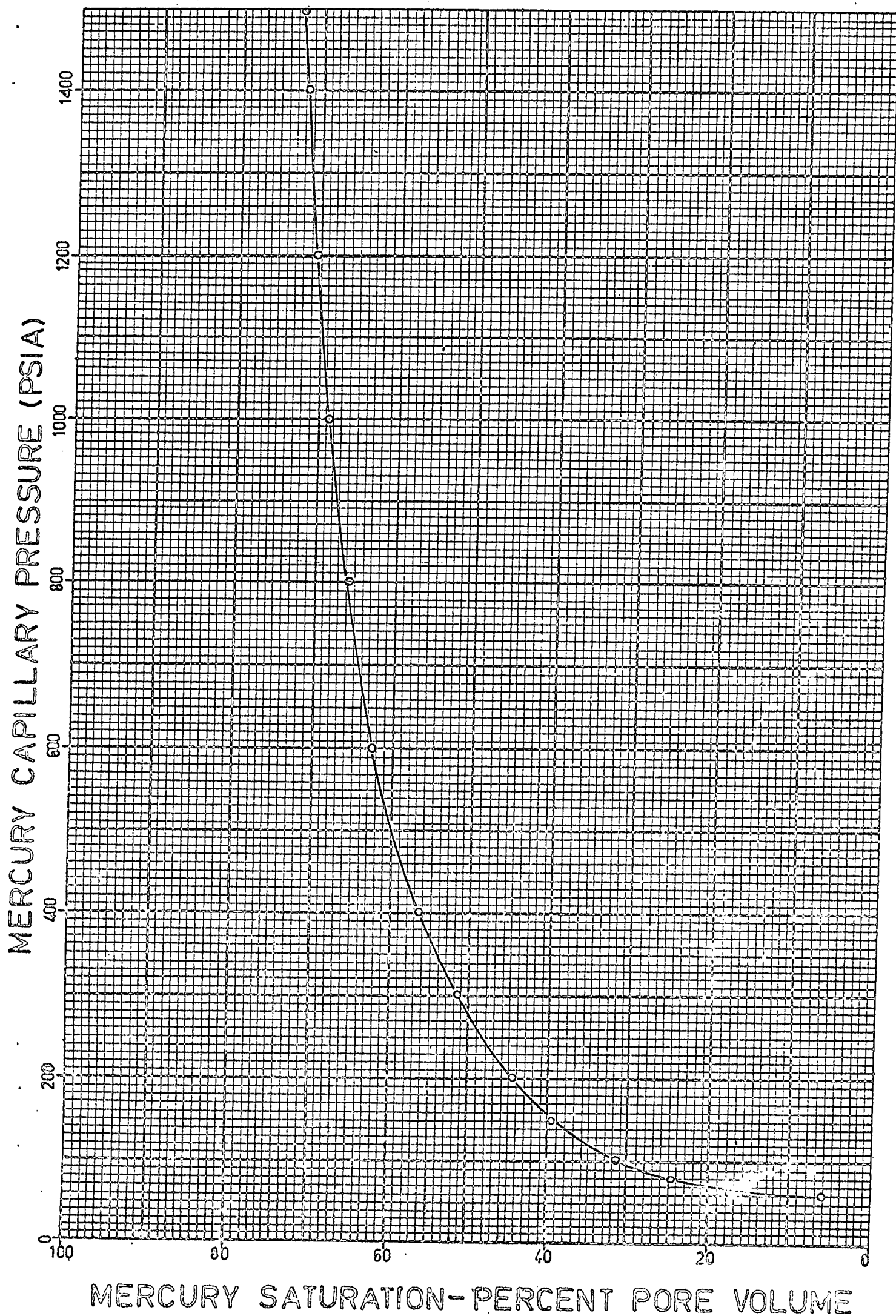


FIGURE 3

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No 2 SAMPLE DEPTH-6859'

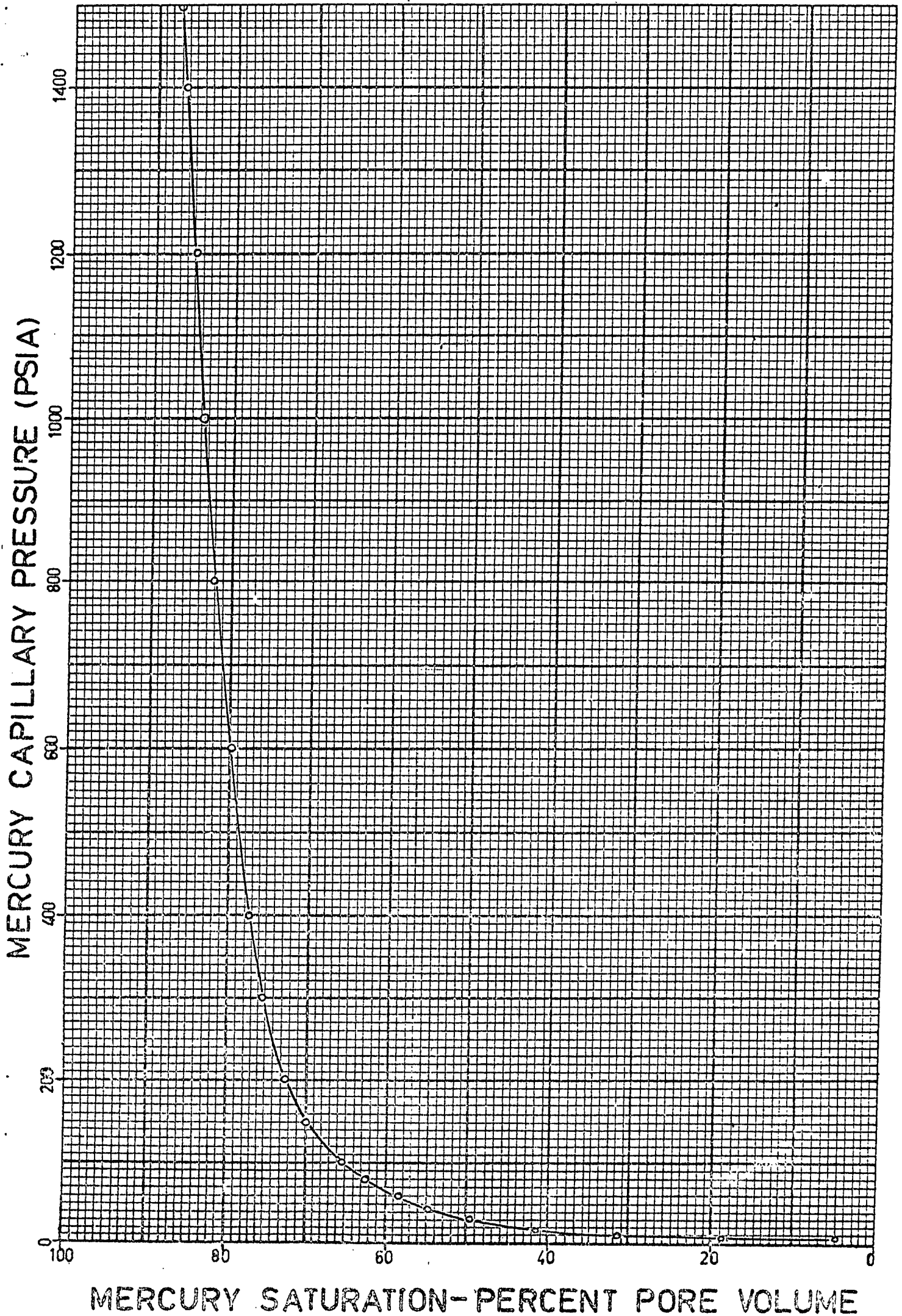


FIGURE 4

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No.2 SAMPLE DEPTH-6860'6"

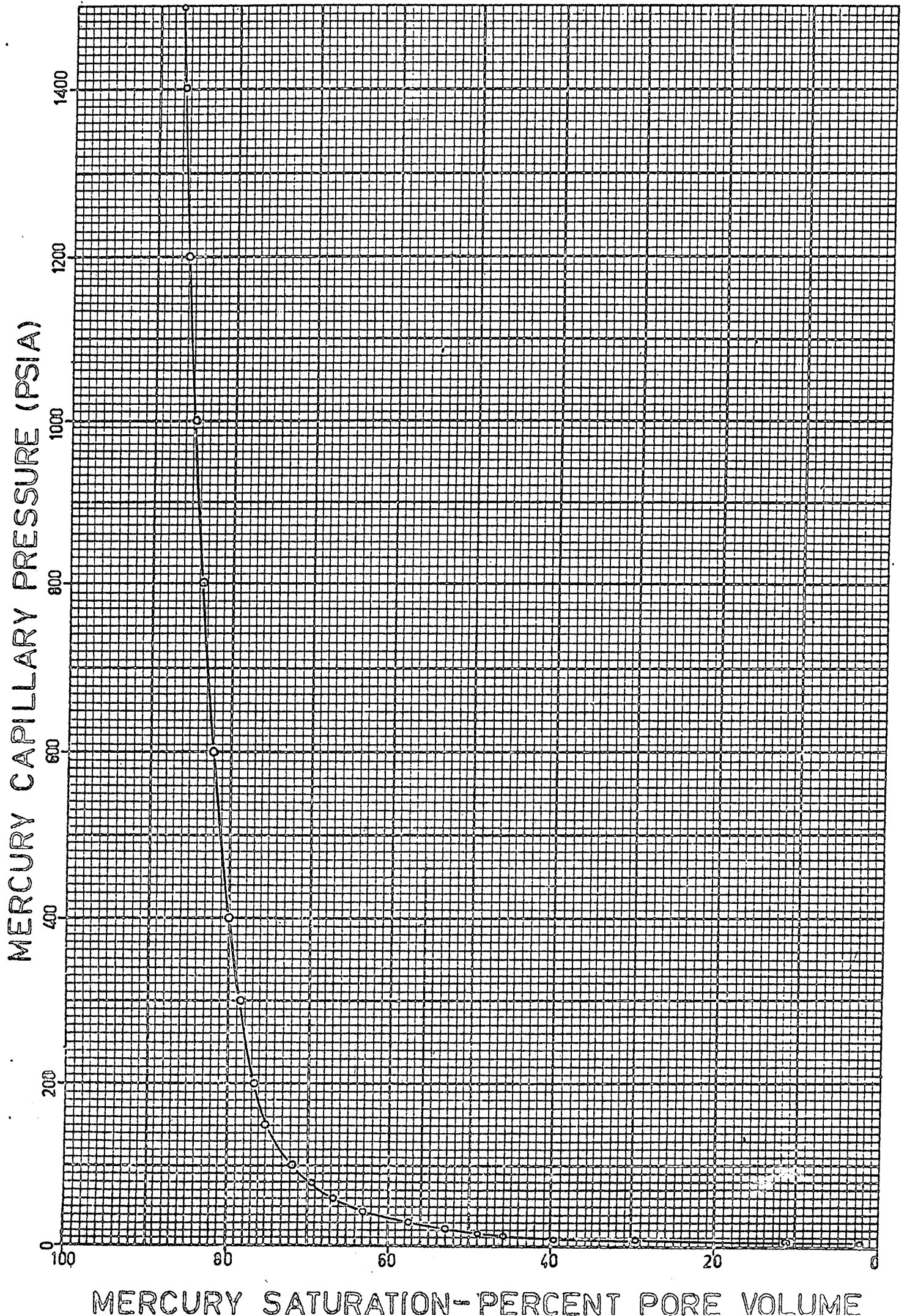




FIGURE 5

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No.2 SAMPLE DEPTH-686' 6"

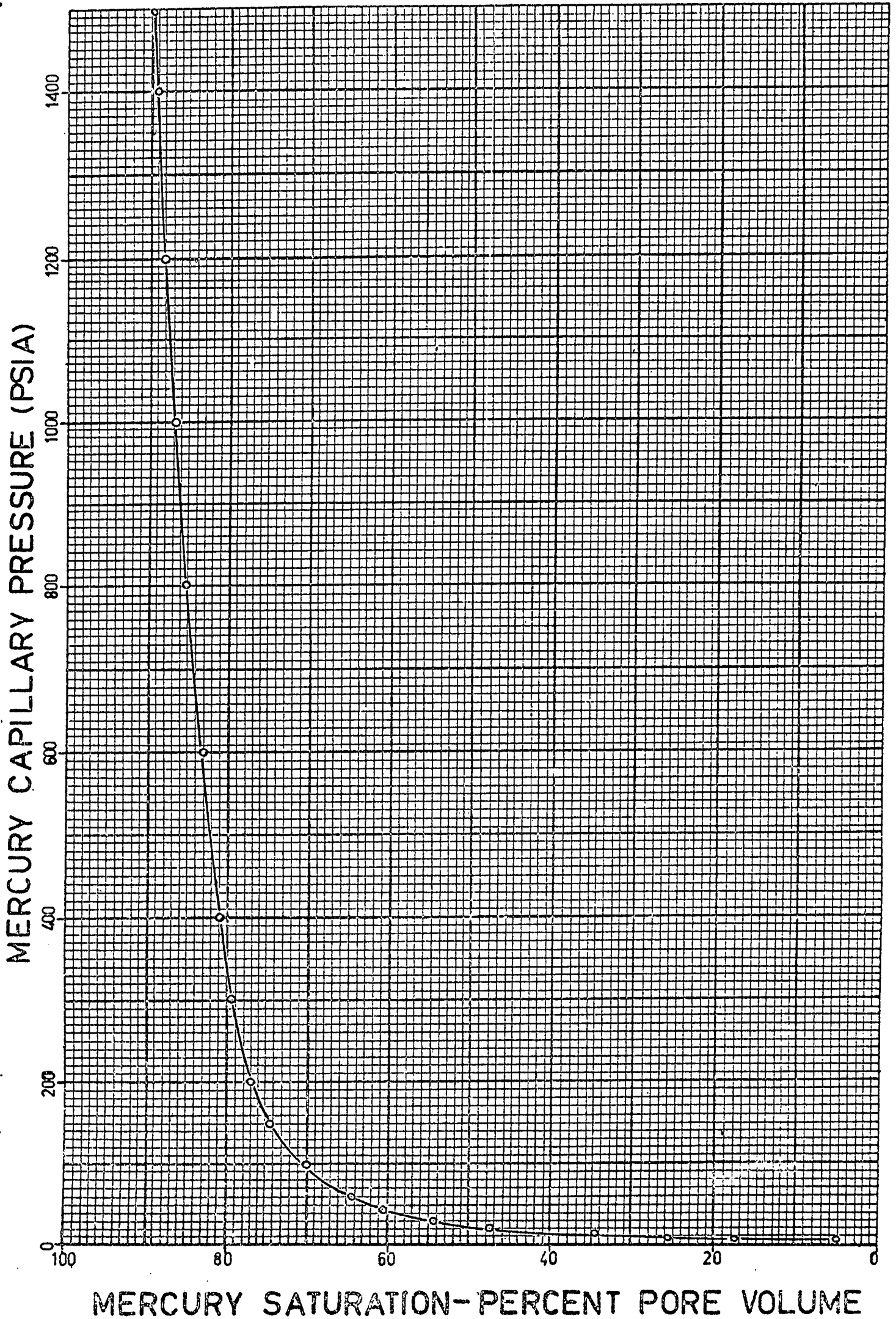


FIGURE 6

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No 2 SAMPLE DEPTH-6862' 6"

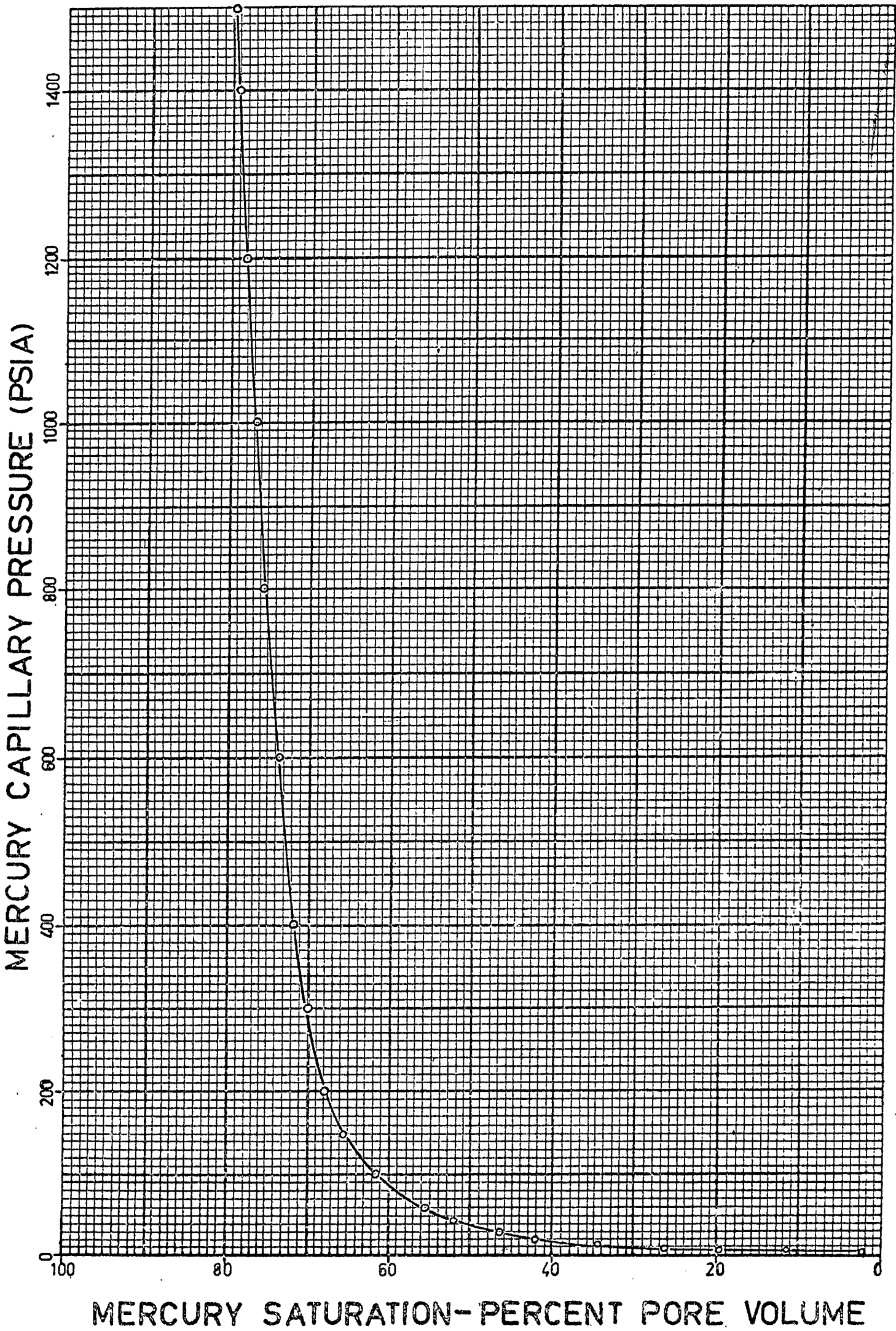


FIGURE 7

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No.2 SAMPLE DEPTH-6864'

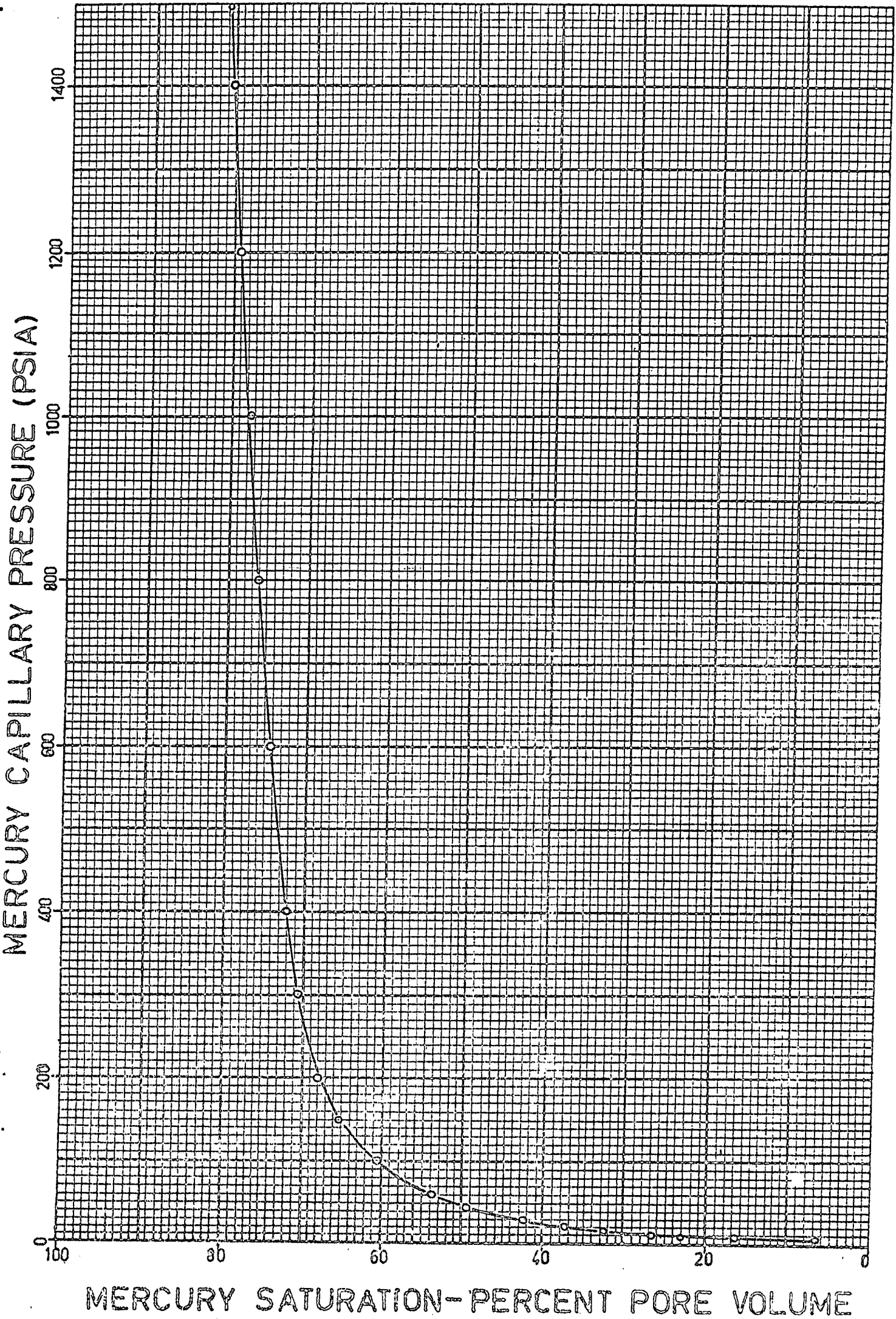




FIGURE 8

# MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No. 2 SAMPLE DEPTH-6882'

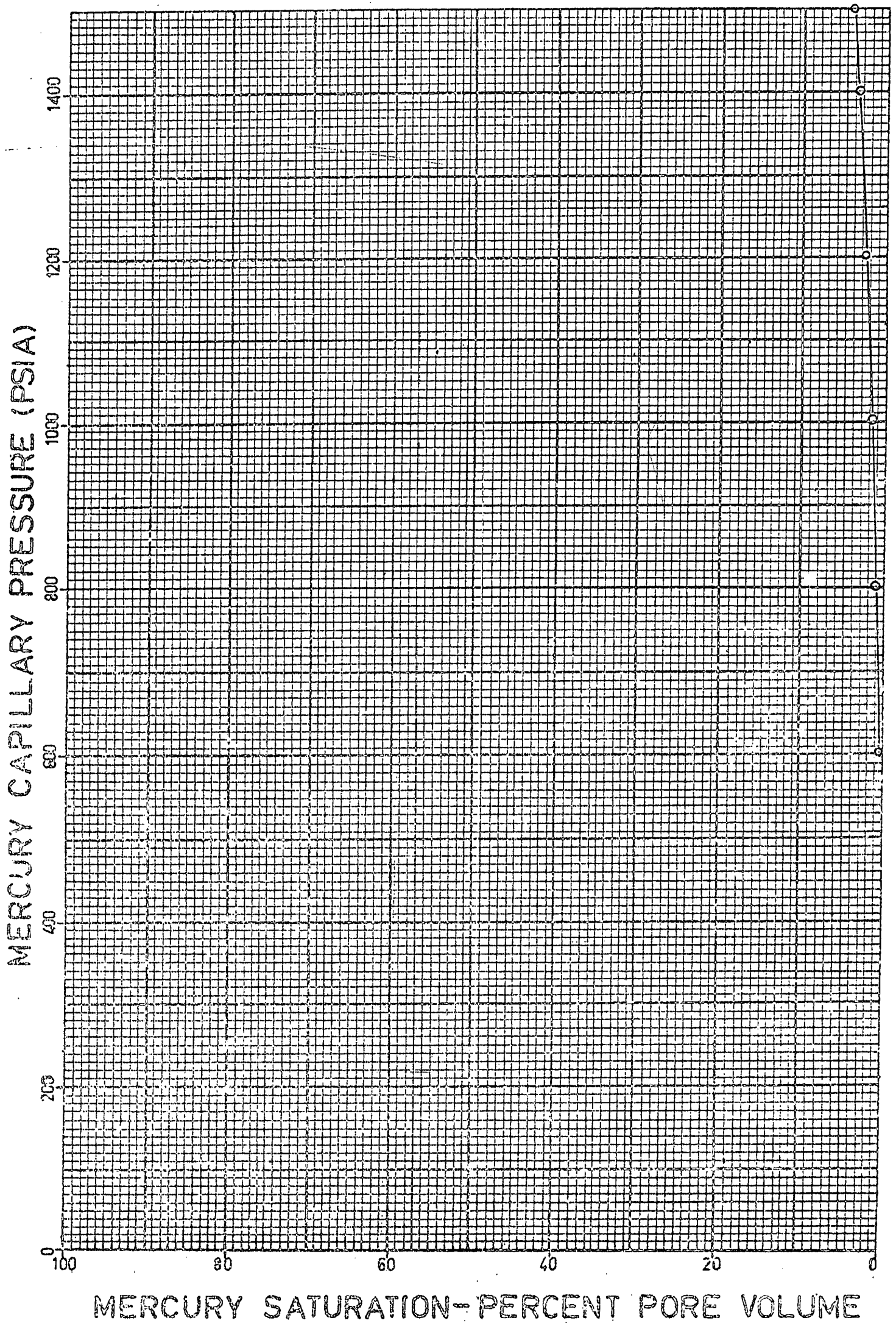


FIGURE 9  
MERCURY CAPILLARY PRESSURE

WELL NAME-GIDGEALPA No.2 SAMPLE DEPTH-6888'

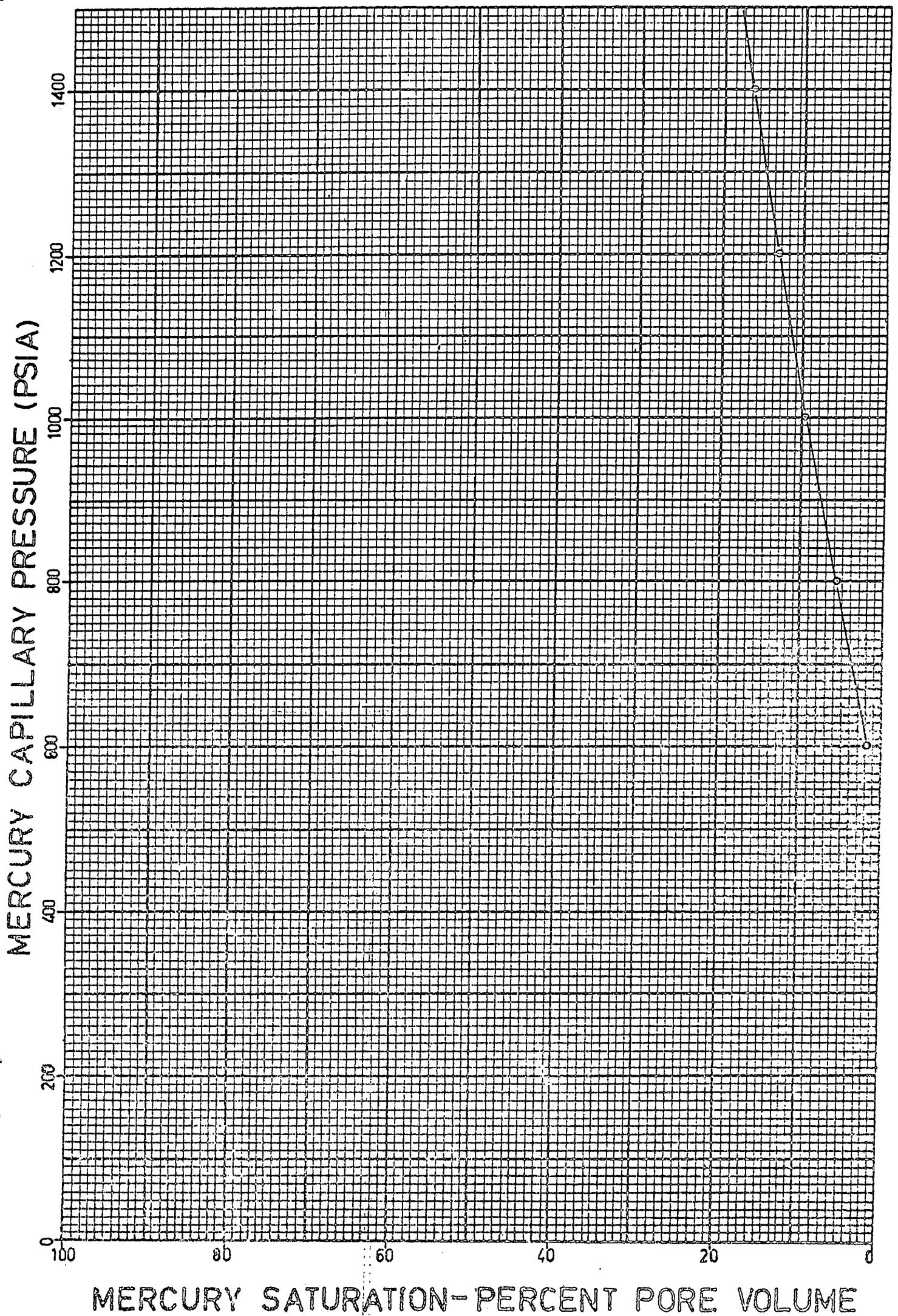




FIGURE 10

# GIDGEALPA No 2 ELECTRICAL LOG

