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# Observation No. 1 Special Core Analysis Tests on Samples from the (Basal Cretaceous) Birdrong Formation

*by*

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### INTRODUCTION

Observation No. 1 (PE 260H) was one of a series of wells drilled by West Australia Petroleum Pty. Ltd. on various islands in the Exmouth Gulf area, Western Australia, to obtain more information on the stratigraphy and hydrocarbon potential of the off-shore portion of the Carnarvon Basin.

The well was spudded-in on 31st December, 1967. It penetrated Tertiary, Cretaceous and Triassic formations down to the total drilled depth of 7,510 feet.

Hydrocarbon shows were encountered below 3,000 feet in the basal-Cretaceous Birdrong Formation. These were drill-stem tested, but no hydrocarbon production was obtained.

The following report presents the results of the analysis tests, (porosity, permeability, capillary pressure, pore size distribution), and formation damage/repair tests on five samples from the 3024'-3032' interval in the Birdrong Formation. These tests were conducted in an attempt to resolve the lack of hydrocarbon productivity in this interval.

### PROCEDURE AND APPARATUS

Two separate sets of core samples were used in the tests - five $\frac{3}{4}$-inch diameter plugs for capillary pressure and pore size distribution tests and five adjacent plugs, $1\frac{1}{8}$-inch diameter, for porosity, permeability and formation damage/repair tests. These plugs were trimmed to approx. $1\frac{1}{2}$ inches in length, and dried in an oven at 110°C for 48 hours.

When the samples had cooled sufficiently, porosity was measured on each of the plugs in a Ruska-type mercury porosimeter, and permeability with respect to nitrogen in a rubber-sleeved Hassler cell. Subsequently, equivalent liquid permeability was evaluated in the Hassler cell using the $1\frac{1}{8}$-inch diameter plugs. Using nitrogen as the flowing phase, the permeability of each sample was measured at several (four) different mean, but constant differential pressures. These permeability values for each sample were then plotted as a function of the reciprocal mean pressure, giving the non-reactive liquid permeability.

Single-phase liquid flow tests were then performed on each of the samples to determine their compatibility with fresh water and 1.5% NaCl brine. Each of these tests was preceded by extraction and drying of the samples.

Subsequent to the tests with the 1.5% NaCl brine, each of the samples was flushed with Soltrol-C oil to residual brine saturation, upon which permeability to Soltrol was determined. Formation damage and repair tests (simulating mud filtrate invasion around the well bore followed by subsequent improvement due to oil production) were evaluated by a fresh-water flood to residual oil saturation, then flooding with oil to residual invasion water saturation. Permeability to each flooding phase was determined after production of the displaced phase had ceased in the effluent stream.

Mercury injection capillary pressure tests, following a method by Purcell (Petroleum Transactions, A.I.M.E., 1949) were then conducted on the set of $\frac{3}{4}$-inch diameter plugs, in a Ruska-type mercucy injection apparatus. Upon extensive evacuation, each of the samples was subjected to an increasing mercury pressure, and the volume of mercury injected at each pressure step was measured.

To obtain hysteresis capillary imbibition or withdrawal curves, the pressure in each sample was reduced in steps from 1500 to 0 psia. After correction for mercury surface conformance and pump expansion had been made, two curves, the injection and the withdrawal, were plotted for each sample.

Pore size distribution values were obtained from the mercury injection curves, using the formula $r = \frac{2\gamma\cos\theta}{\Delta P}$ where r=the pore throat radius in microns, and $\gamma,\theta$ respectively equal the mercury surface tension and contact angle of mercury with the solid, and $\Delta P$ being the differential injection pressure at the respective saturation intervals.

DISCUSSION

The data for the porosity, permeability, single and two-phase flow tests are presented in Table 1. Capillary pressure curves for each of the samples are shown in Figures 1-5; the corresponding pore size distribution results are listed in Table 2. The Klinkenberg or non-reactive liquid permeability tests are shown in Figure 6, while the position of the 5 samples is shown in Figure 7.

The results of the single-phase liquid permeability tests to fresh water and brine, shown in Table 1 generally indicate very poor compatibility between the rock (samples) and an aqueous phase. The flow capacity in these tests varied from a maximum of 64% to a minimum of 1.2% of equivalent liquid permeability when brine and fresh water were respectively used as the saturation and flowing media.

The most severe reduction of flow capacity was noted in samples from 3024, 3026, and 3028 feet. The effluents during flow tests on these three plugs were very cloudy, indicating a considerable amount of particle displacement. However, variations in flow capacity when using fresh water and brine were not great, indicating a minimal content of swelling clays.

Even more severe formation damage is indicated under two-phase flow conditions. In the case of a well bore invaded with mud filtrate (fresh water flood) reductions in permeability in excess of 99% at residual oil saturation were noted. Flow capacity was partially restored by the re-flushing of the water-invaded cores with oil; however the results indicate a considerable time is required to restore permeability to anywhere near its former value.

The mercury injection capillary pressure curves indicate the five samples from this interval to have low threshold pressures and low indicated water saturations at ultimate test pressure. The largest pore throat radii invaded at entry pressures ranged from 12 to 26 microns. The mercury withdrawal curves, simulate the hydrocarbon producing characteristics of this reservoir by imbibition, whereby a wetting phase (air) displaces a non-wetting phase (mercury). These tests indicate hydrocarbon recoveries up to 35% of pore volume; the highest recovery occurring in the "cleaner" sands below 3030 feet.

The core analysis reports, 1 (a), (b), (c), for this interval indicate residual oil saturations of up to 16% of pore volume, and water saturations between 55% and 80% of pore volume. A drillstem test of the interval produced 38 barrels of saline water only.

Porosity, permeability and capillary pressure characteristics of this formation suggest that this interval could be hydrocarbon productive. However, the "borderline" residual oil saturations determined in routine core analysis, plus the strong probability of formation damage occurring around the wellbore, as shown in this report, tend to confirm the negative drillstem test results.

## CONCLUSIONS

The tests revealed the interval under consideration to have some good reservoir characteristics; both porosity and permeability (to nitrogen) were high, while capillary pressure characteristics showed low threshold pressures and low indicated residual water saturations.

However, single and two-phase flow tests using fresh water, brine and oil revealed this formation to be highly subject to permeability damage. Simulated fresh water invasion tests surrounding a well bore, showed permeability reductions greater than 99%. Permeability was only partially restored through resaturation and lengthy flushing with oil.

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1 (a) Exploration Logging of Australia Inc., Core Analysis Report, January 10, 1968.
(In the Well Completion Report)

(b) Core Laboratories Inc.,
Core Analysis Report, January 18, 1968.
(In the Well Completion Report)

(c) Bureau of Mineral Resources
Petroleum Technology Section
Core Analysis Report, January 17, 1969.

Table 1.

| Sample Depth (Feet) | Porosity (% Bulk Volume) | Permeability to Nitrogen (Md) | Equivalent Liquid Permeability (Md) | Permeability to Fresh Water (%E.L.P*) | Permeability to 1.5% Nacl Brine (% E.L.P.*) | Permeability to Soltrol-c at Residual Brine Saturation (% E.L.P*) | FORMATION DAMAGE AND REPAIR TESTS: Permeability to Fresh water at Residual Oil Saturation (% E.L.P.*) | FORMATION DAMAGE AND REPAIR TESTS: Permeability to Oil at Terminal Fresh Water (% E.L.P.*): Immediate | FORMATION DAMAGE AND REPAIR TESTS: Permeability to Oil at Terminal Fresh Water (% E.L.P.*): After 24 Hours |
|---|---|---|---|---|---|---|---|---|---|
| 3024 | 33.0 | 491 | 412 | 2.4 | 26 | 23 | .04 | 4.2 | 20 |
| 3026 | 29.7 | 1125 | 990 | 1.2 | 8.8 | SAMPLE BROKEN UP | | | |
| 3028 | 33.0 | 489 | 445 | 7.9 | 20 | 16 | .36 | 3.0 | 13 |
| 3030 | 22.0 | 116 | 95 | 24 | 64 | 53 | 11 | 37 | 37 |
| 3032 | 24.5 | 710 | 660 | 4.4 | 28 | 24 | 4.1 | 27 | 28 |

* E.L.P. = Equivalent Liquid Permeability.

Table 2.

| | SATURATION (% PORE VOLUME) | | | | | | | | Sample Depth (Feet) |
|---|---|---|---|---|---|---|---|---|---|
| | 0-10 | 10-20 | 20-30 | 30-40 | 40-50 | 50-60 | 60-70 | 70-80 | |
| AVERAGE PORE ENTRY RADIUS (MICRONS) | 12.5 | 9.7 | 7.9 | 5.9 | 4.4 | 3.1 | 1.4 | 0.46 | 3024 |
| | 14.2 | 11.5 | 9.7 | 7.2 | 5.6 | 2.0 | 0.19 | | 3026 |
| | | 11.2 | 9.7 | 7.6 | 5.6 | 2.7 | 0.63 | | 3028 |
| | 17.2 | 15.2 | 12.9 | 10.7 | 6.9 | 3.0 | 0.71 | 0.17 | 3030 |
| | 26.6 | 22.2 | 19.5 | 12.5 | 7.1 | 2.8 | 0.82 | 0.19 | 3032 |

FIGURE 1

# MERCURY CAPILLARY PRESSURE

WELL NAME — OBSERVATION No 1 SAMPLE DEPTH - 3024′

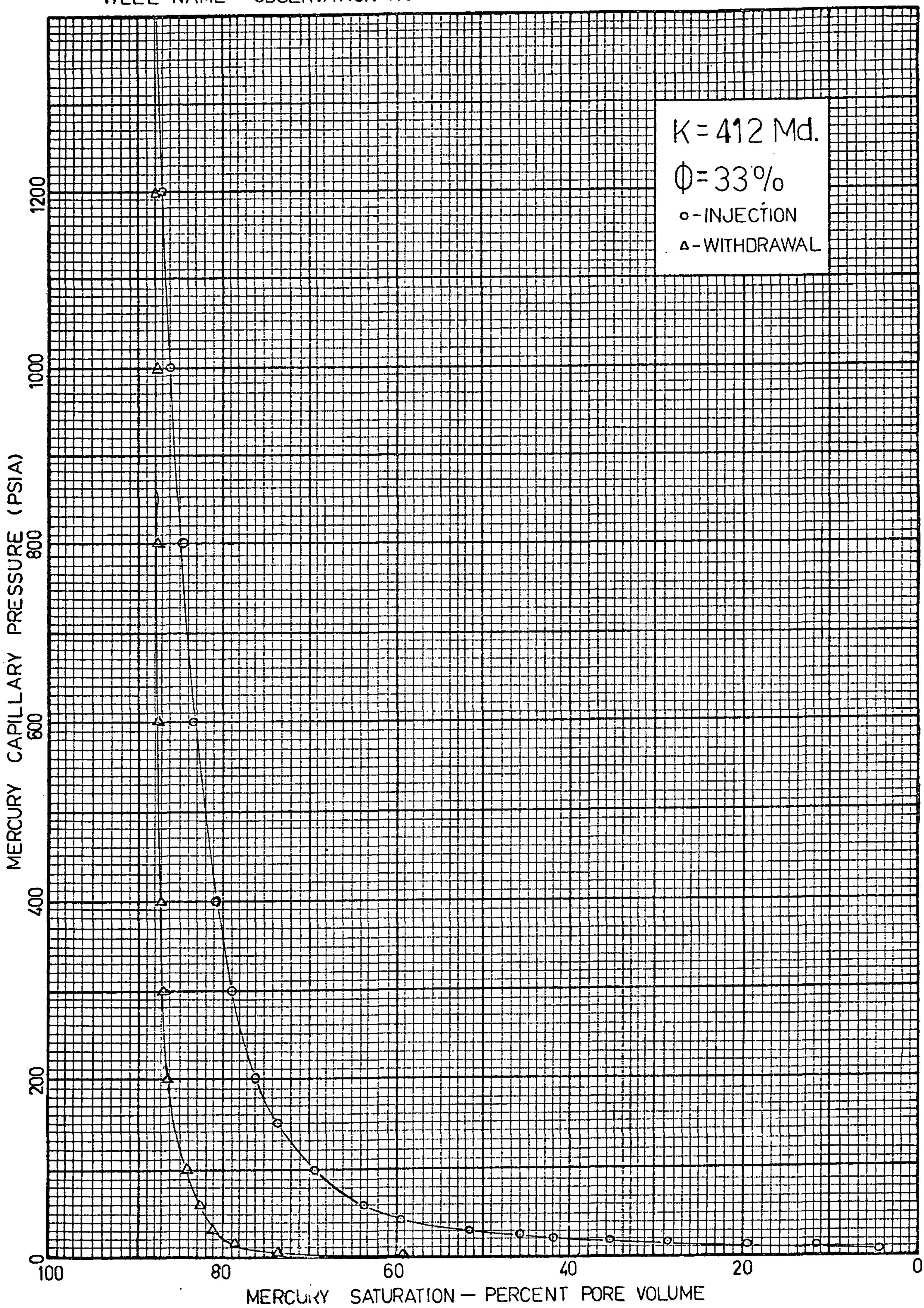

FIGURE 2

# MERCURY CAPILLARY PRESSURE

WELL NAME — OBSERVATION No.1 SAMPLE DEPTH-3026'

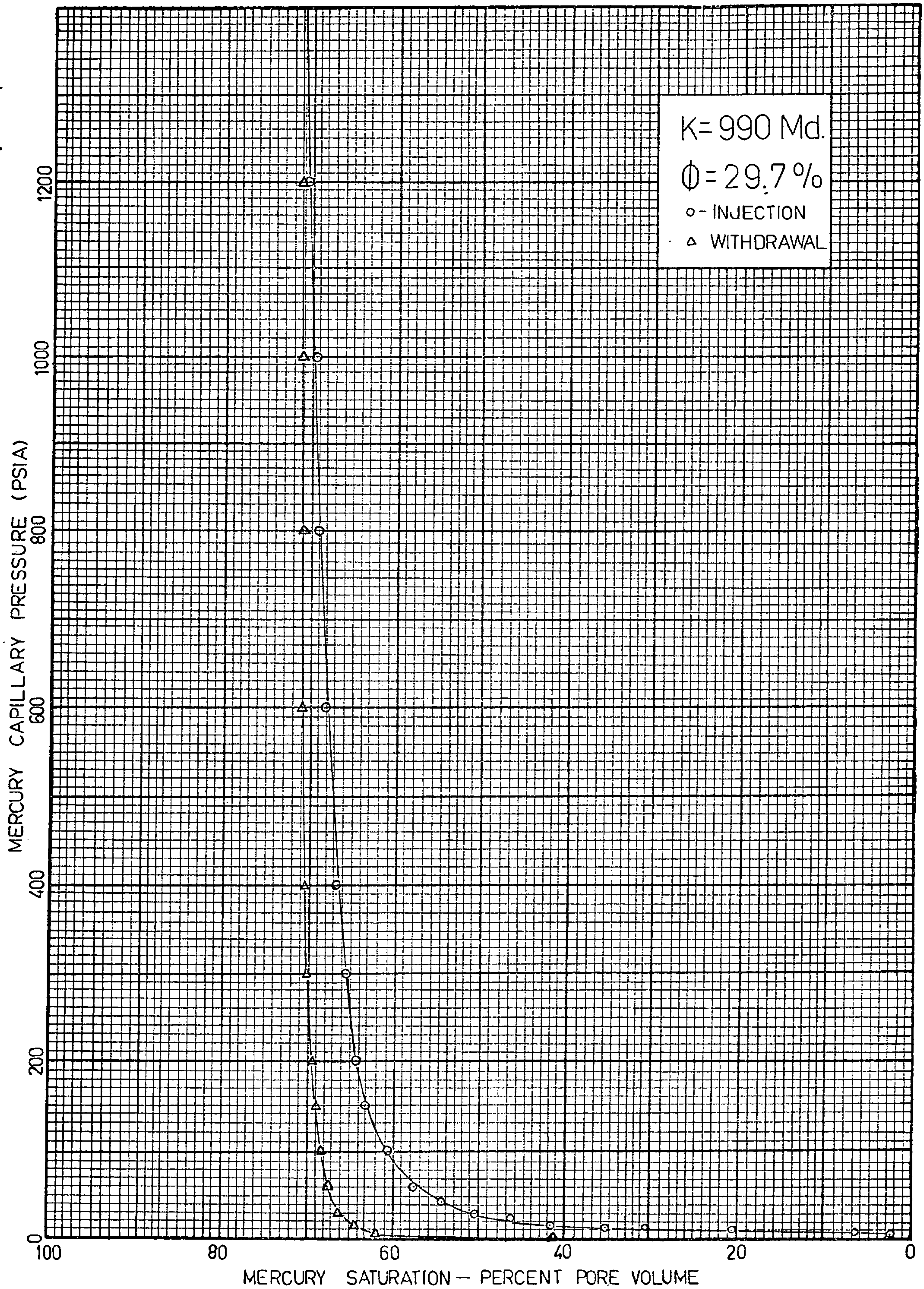

FIGURE 3

# MERCURY CAPILLARY PRESSURE

WELL NAME — OBSERVATION No. 1 SAMPLE DEPTH - 3028'

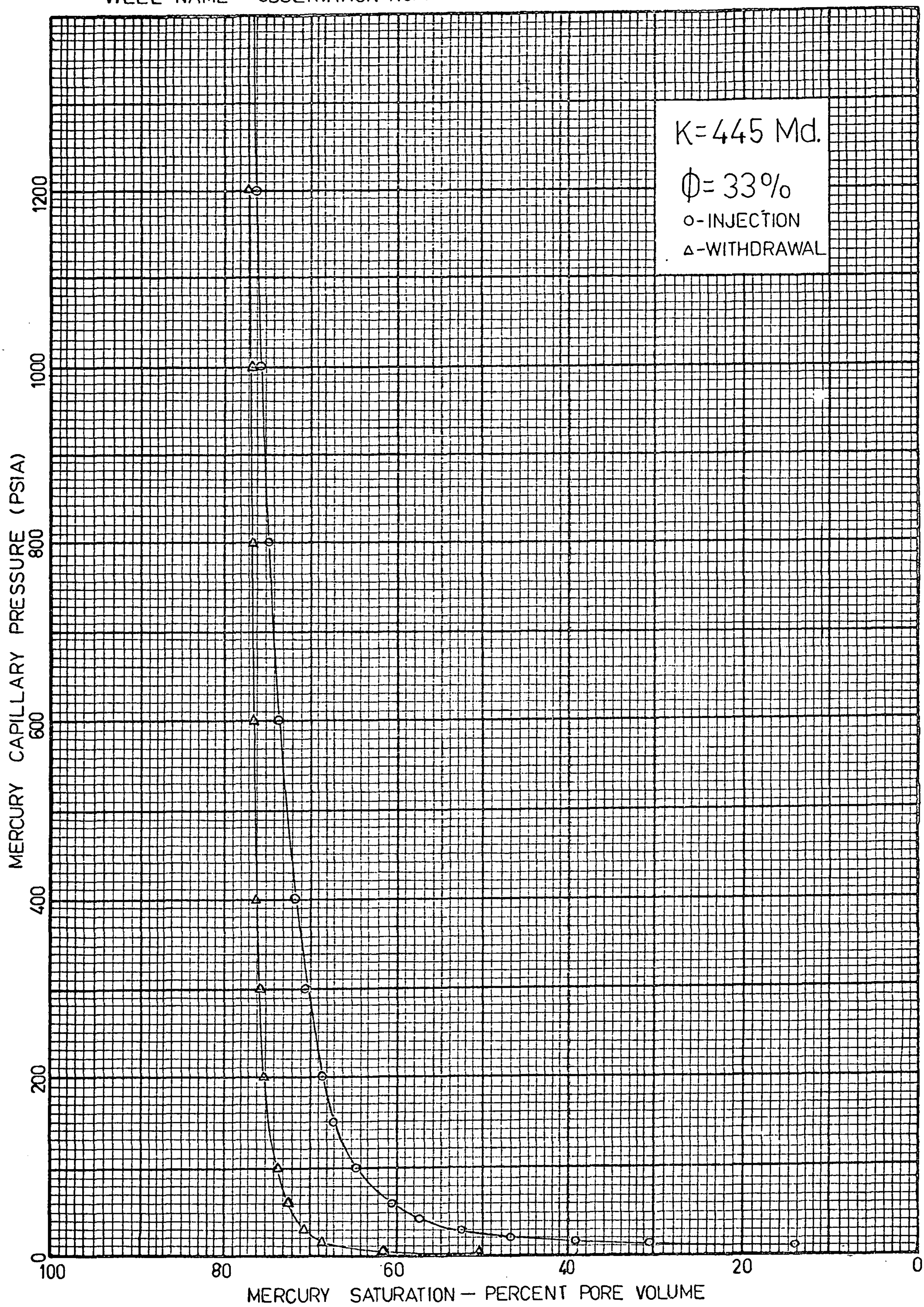

FIGURE 4

# MERCURY CAPILLARY PRESSURE

WELL NAME — OBSERVATION No 1 SAMPLE DEPTH - 3030'

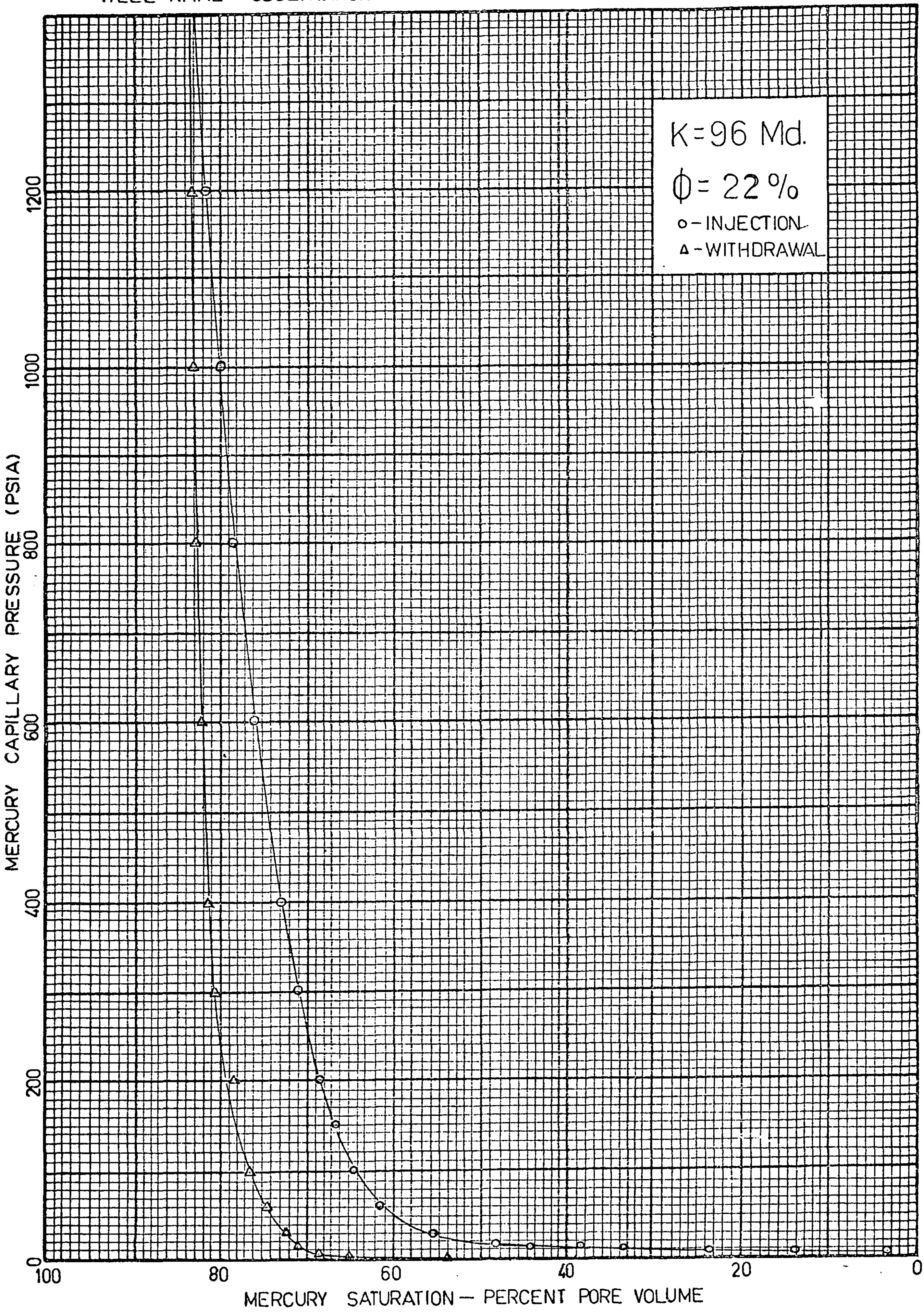

FIGURE 5

# MERCURY CAPILLARY PRESSURE

WELL NAME — OBSERVATION No 1 SAMPLE DEPTH - 3032'

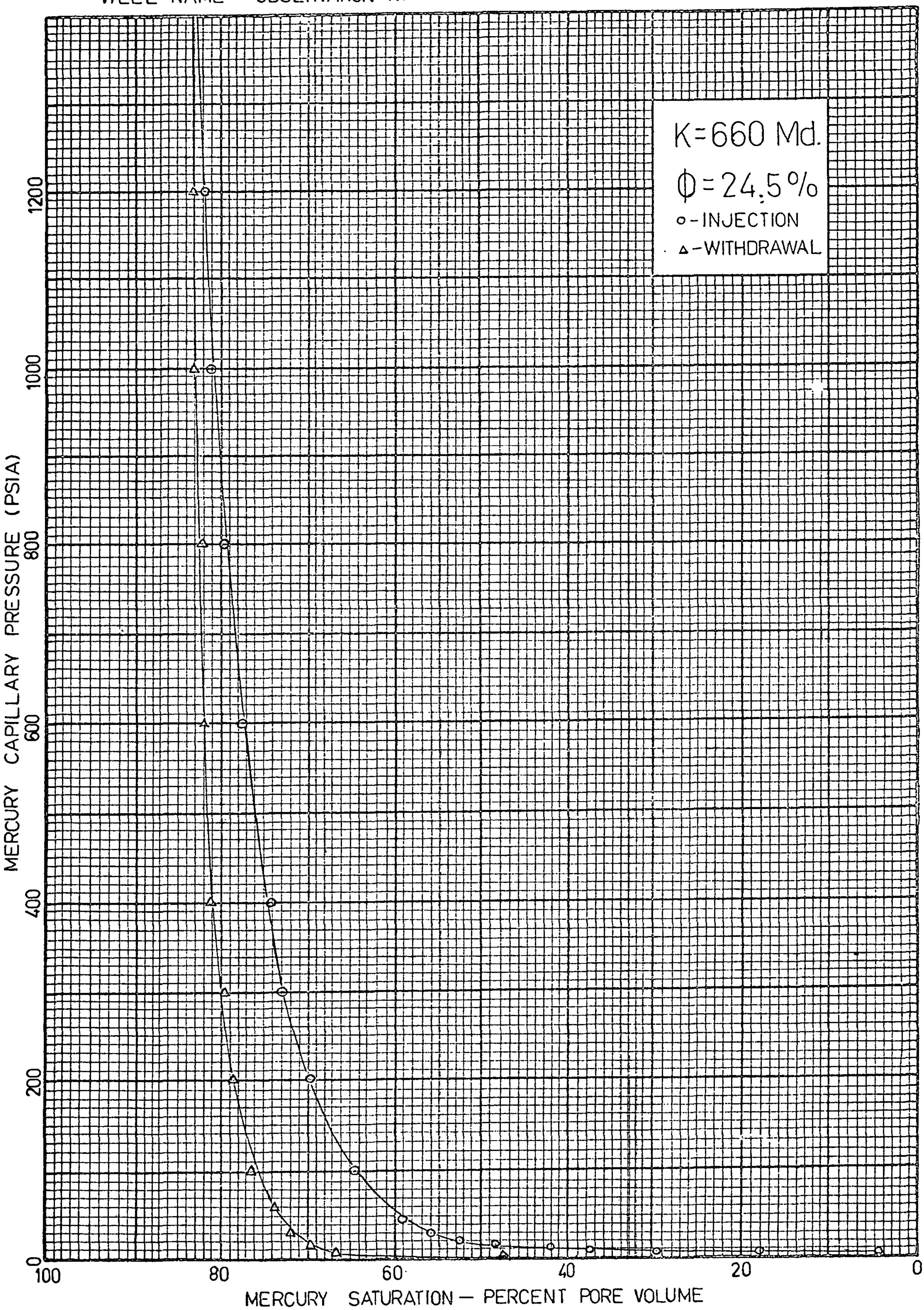

FIGURE 6

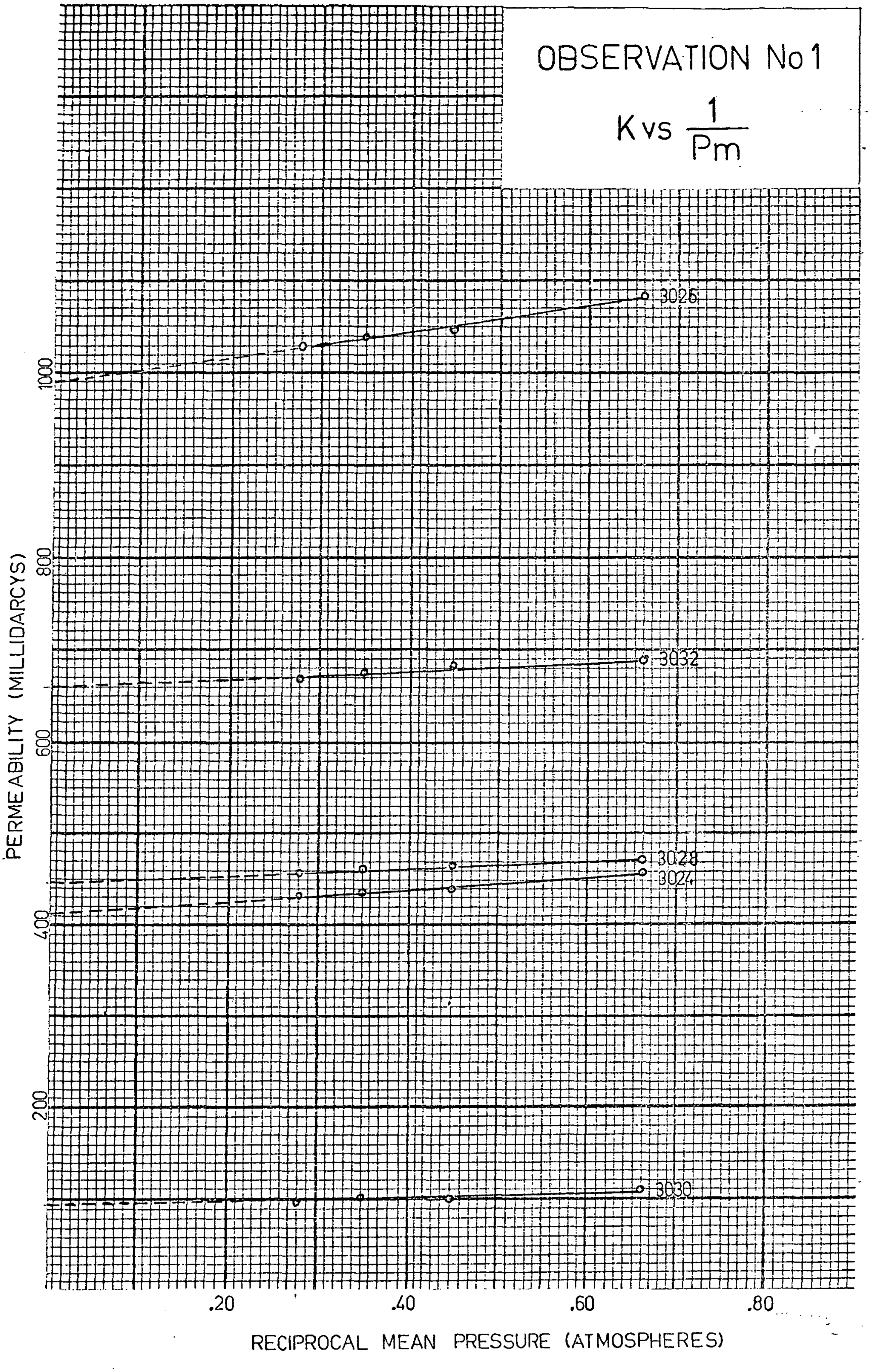
OBSERVATION No 1
K vs $\frac{1}{Pm}$
3026
3032
3028
3024
3030
PERMEABILITY (MILLIDARCYS)
1000
800
600
400
200
.20
.40
.60
.80
RECIPROCAL MEAN PRESSURE (ATMOSPHERES)

FIGURE 7

# OBSERVATION No 1 ELECTRICAL LOG