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RADIOACTIVE TRACER STUDY IN RIO DE LA PLATA

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RADIOACTIVE TRACER STUDY IN RIO DE LA PLATA

REPORT

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RADIOACTIVE TRACER STUDY IN RIO DE LA PLATA

1. INTRODUCTION

The work performed with radioactive tracers in Río de la Plata described in this report is part of a project carried out by Sir William Halcrow and Partners, studying the feasibility of a channel from the mouth of the river Paraná de las Palmas to Puerto Nuevo.

Radioactive tracers were used in order to gather information about sediment transportation in the area designed for the construction of the abovesaid channel. The advantages of using radioisotopes as tracers studying sediment transportation have been discussed elsewhere, in connection with work carried out in different countries all over the world (1) (2) (3) (4) (5) (6) (7) (8) (9) (10) (11) (12).

This report describes the development of the method used for labelling sediment from Río de la Plata, the labelling operation, the injection and counting of the radioactive tracer, the calibration of the equipment used for counting and the tests for checking effectiveness of the procedures.

The radioactive tracer study was carried out by the Argentine Atomic Energy Commission, in collaboration with Sir William Halcrow and Partners and the Hydraulics Research Station of Wallingford, U.K.

2. DETECTION EQUIPMENT

2.1 DETECTOR

The detector consists of an assembly of six Geiger Müller counters, Harshaw type 617 LP, active length 17 inches, diameter 13/32 inches, with an operating voltage range of 680 to 825 volts.

The G.M. counters are housed in a brass protection tube of 13 centimeters diameter and 65 centimeters length, which is mounted on a sledge

with a connecting cable of at least 50 meters (Fig. 2-2). This detector can be used either on the sledge for continuous radiation monitoring or for hand-held point measurements, when mounted on a special device.

The G.M. counters are connected in such a way as to operate either all six counters simultaneously or 2 or 4 counters at a time.
The assembly of 2, 4 or 6 G.M. counters is symmetric with regard to the axis of the protection tube in order to keep geometry relative to the river bed invariable.

2.2 TRACKING SLEDGE

The sledge for continuous measurement is made of iron, and weighs 60 to 70 kilograms. It is of welded design and has few projections, so as to reduce the disturbance of the river bed to a minimum. The G.M. counters are in constant geometry relative to the river bed, regardless of the sledge position. (Diagrams are shown in Fig. 2.3 and photographs in Fig. 2.4). At the front of the sledge on each side, are two rings where the towing cable is attached. The distance between the sledge and the apex of the towing cable is 2 meters; from this apex a 50 meters cable is available for towing the sledge along the river bed with a boat. For tracking operations the sledge was towed 25 meters behind the boat, the remaining cable being held on the boat by a block and a winch.

The recording cable is protected against abrasion and battering of rocks by a strong rubber tube secured within the sledge to the towing cable. The recording cable is joined at intervals to the towing cable by means of snap hooks, which can easily be attached to or removed from loops lain on the towing cable. These loops do not prevent the cable from passing through the block.

2.3 HAND-HELD POINT MEASUREMENT DEVICE

The point measurement device is such that the protection tube with the G.M. counters can be mounted so that geometry with regard to the river bed remains the same as when mounted on the sledge (Fig. 2.5).

2.4 ELECTRONIC EQUIPMENT

The electronic instrumentation used in this work was designed trying to get a very simple equipment, reliable and easy to check or to repair.

Although more sophisticated instrumentation could be developed, a few percent accuracy were neglected to increase reliability and decrease power consumption.

The electronic instrumentation consists basically of a scaler and a counting rate-meter.

The scaler was designed using two Dekatron counting tubes (GC 10/B) having 4 kc/s repetition rate and a Sodeco mechanical counter. The circuit is fully transistorized and battery operated. Specifications are as follows:

Counting capacity	:	One million (10^6) two Dekatrons and a four digit Sodeco counter.
Resolution	:	250 micro/sec.
Geiger input sensitivity	:	250 Volts.
High voltage	:	Variable up to 825 Volts.
Power supplies	:	8 flashlight batteries and 12-67.5 Volts radio batteries for the G.M. voltage.
Test oscillator	:	A neon relaxation oscillator.
Cabinet	:	A metal humidity proof carrying case.

COUNTING RATE-METER

The counting rate-meter is also fully transistorized and was designed using the diode pump principle of operation, according to the following specifications:

Ranges	:	a) 0 - 1,000 cpm b) 0 - 10,000 cpm c) 0 - 100,000 cpm
Time constant	:	a) long : 10 seconds b) short: 2 seconds
High voltage	:	Variable up to 825 Volts.
Instrument	:	50 micro-amp; moving coil, cpm calibrated.
Recording output	:	Provision for 1 mA moving coil recorder.
Geiger input sensitivity	:	250 Volts
Accuracy	:	1% full scale.

Note: In the first 1/10 of the scale, indication is about one minor division in advance. This is valid for all three ranges.

Power supply	:	The same as used for the Scaler.
Cabinet	:	The same as used for the Scaler.

RECORDER: (') Graph recorder made by Everett Edgcumbe, type 1 mA, impedance 650 ohms, with chart speeds of 1 and 3 inches per minute. These rates are suitable for tracking at a boat speed of about 2 knots. A time marker-pen workable from a 12 volt source is incorporated in the instrument, enabling marks to be made on the chart coincident with the moment of fixing the position of the boat. This allows the activity trace to be matched against the boat's course.

Other equipment available for laboratory measurement of radioactive material were end-window G.M. counters, crystal scintillation detectors, a pulse hight analyzer and monitors.

(') In loan from the Hydraulic Research Station, Wallingford, Berkshire, U.K.

3. METHOD FOR LABELLING AND BEHAVIOUR OF THE LABELLED SEDIMENT

3.1 CHARACTERISTICS OF THE SEDIMENT

Sediment from the area between the river Paraná de las Palmas and Puerto Nuevo consists of 1 to 20% clay, 50 to 80% silt and 5 to 40% sand.

Clay is mainly formed by montmorillonite ore; silt by quartz, feldspar volcanic glass and opal; sand by quartz, feldspar, mica, volcanic glass, hornblende, augite, zircon, garnet, tourmaline, hyperstenes, etc. Organic material can be present in variable proportions, a rough estimation being 1 to 2%.

Size analysis by pipette method (15) gave for samples collected at sites N, Km 19 and Km 3, the results shown in table 3.1.

Table 3.1

GRAIN SIZE OF SEDIMENT IN DIFFERENT SAMPLES

Sample	larger than 62 microns	from 62 to 4 microns	finer than 4 microns
Position N	7.3%	74.8%	18.0%
Km 19 (Canal Costanero)	2.4%	79.0%	18.8%
Km 3 (Canal Norte)	16.3%	64.2%	19.5%

Several analysis of particle distribution were carried out with samples collected in the abovesaid area (See Fig. 3.1). The results of these analysis are shown in Fig. 3.2 and 3.3.

Several sedimentation tests were made with Sample Nº 5 using natural water from Río de la Plata, water from Ezeiza, distilled water and water containing 0.5% alum. Results are indicated in Fig. 3.4.

3.2 ADSORPTION TESTS FOR NATURAL SEDIMENT

Labelling natural sediment with Sc-46 or Ag-110 proved to be effective on clay, but not on the heavier component of the sediment.

Natural sediment was shaken with a solution containing Sc-46 or Ag-110 for several minutes, filtered and dried. In all experiments radioactivity was found to be in the sediment fraction rather than in solution.

The labelled sediment was separated by decantation into two fractions: one of fine grain size corresponding to clay, the other being the heavier component: silt and sand.

Specific activity of each fraction was found to be as indicated in Table 3.2.

Table 3.2

SPECIFIC ACTIVITY OF Sc-46 AND Ag-110 IN NATURAL SEDIMENT LABELLED BY ADSORPTION

	Specific Activity of Ag-110 $\frac{\text{c.p.m.}}{\text{gram}}$	Specific Activity of Sc-46 $\frac{\text{c.p.m.}}{\text{gram}}$
Heavier component	280	480
Clay	5600	8700

These results indicate that the tracer is easily adsorbed on clay, but not on the heavier fraction, which represents 80 to 99% of natural sediment.

3.3 ADSORPTION TESTS

The foregoing tests show that it is advisable to remove clay particles before labelling the sediment. Sediment from shoals contains less clay (1 to 10%), easily separable from the other components of the sediment. This was done by stirring natural sediment with water from Río de la Plata and letting it decant for a quarter of an hour, which proved to be sufficient to allow the heavier fraction to go to the bottom, whereas clay remained suspended. This procedure was repeated until all clay was removed.

Initially, the adsorption method of Krone was tested for labelling the sediment.[1] This was done by shaking about one gram of sediment with a solution containing radioactive silver, filtering the mixture and determining the activity fixed on the sediment.

Different tests of fixation were carried out with the labelled sediment, shaking it vigorously with natural water from Río de la Plata for different periods of time and counting the activity of silver fixed on the sediment. These tests were performed with samples taken at sites A and C. The results obtained are shown in Fig. 3.6, and indicate that initial retention is considerable, if a labelling solution with a very small amount of inactive silver carrier is used. However the retention decreases rapidly when increasing amounts of carrier are used. This is shown in another series of tests performed with a labelling solution prepared with 0.4 miligram Ag/gram of sediment, which is the smallest ratio obtainable with the activity supplied by Harwell (See 4.2). Analysis of the data given by these tests showsthat silver activity is not firmly fixed to the sediment, because after shaking the labelled sediment with natural water from Río de la Plata, a considerable amount of activity goes over to the water.

A modification of this method was also tested treating the sediment with a radioactive solution containing Sc-46 or Ag-110, and drying it under an infrared lamp. Under these conditions, retention will be 100% before washing the sediment.

Fixation tests show that the radioactive tracer is removed when sediment is treated with water. These tests were carried out as follows: One gram of sediment labelled with Sc-46 or Ag-110 was vigorously shaken with water from Río de la Plata for different periods of time. Supernatant water was separated by centrifugation and activity fixed to the sediment was counted. The results are shown in Table 3.3.

Table 3.3

RETENTION OF Ag-110 AND Sc-46 BY SEDIMENT FROM RIO DE LA PLATA AFTER VIGOROUS TREATMENT

Time of washing	Percentage of activity fixed on the sediment	
Minutes	Ag-110	Sc-46
0	100	100
5	86	80
15	61	63
30	54	58
60	49	53
140	45	50

These tests show that even when Sc-46 or Ag-110 is initially fixed to the sediment, a considerable part of the tracer goes gradually over to the water with which it was shaken.

3.4 TESTS PROVING THE SILVER REDUCTION METHOD

Sediment from which clay had been removed was labelled with radioactive silver, fixing it by reduction on the grains of sediment.

This method consists in treating the sediment with a solution of silver nitrate (Ag-110) and Seignette salt. The labelling solution must be sufficient to cover all the grains of sediment, without being excessive. The test solution was prepared in the laboratory with 50 grams of sediment and about 8 mililiters of labelling solution (Ag-110 with silver carrier plus reducing agent). The relative amounts of solution and sediment that mix well vary according to the nature of the sediment (about 10 miligrams inactive silver per gram of sediment were used as carrier for Ag-110). When sediment and solution have come into close contact, the reduction of silver is accelerated by exposing it to sunlight for several days.

Fixation and settling comparison tests were performed with the sediment that had been labelled by this method, in order to confirm that labelled sediment behaves like natural sediment.

One gram of sediment labelled by reduction of radioactive silver was shaken vigorously with water from Río de la Plata for some time, supernatant water was separated by decantation and activity fixed on the sediment was counted. The results are shown in Table 3.4.

Table 3.4

RETENTION OF Ag-110 ON THE SEDIMENT LABELLED BY THE METHOD OF REDUCTION AFTER VIGOROUS TREATMENT

Time of washing (minutes)	Percentage of activity retained on the sediment
0	100
15	94
30	91
60	88
150	85
240	82
330	80

Settling conditions of labelled sediment and natural sediment were compared in the following way: A glass tube, 90 centimeters long and 2.5 centimeters bore with its lower end drawn to 0.6 centimeters on which a rubber tube closed by a pinch clamp was fitted, was used. This tube was filled with water from Rfo de la Plata, about 1 gram natural sediment and 100 miligrams dry labelled sediment, that were dispersed by successive inversions of the tube. At predetermined intervals of time sediment-water samples of equal volume were withdrawn by opening temporarily the pinch clamp. After centrifuging, the weight and activity of the withdrawn samples were determined, and specific activity was calculated. The total weight of dry silt after performing this experiment was about 1.04 gram. The results are shown in Table 3.5.

Table 3.5

SETTLING COMPARISON TEST FOR NATURAL SEDIMENT MIXED WITH LABELLED SEDIMENT

Settling time (minutes)	Weight of settled silt (mg)	Specific activity $\frac{\text{(c.p.m.)}}{\text{mg}}$	Settled silt %	Settled activity %
1	126	2900	12.6	14.5
2	125	2500	12.0	12.5
4	247	2200	23.8	22.5
6	186	2250	17.8	16.6
9	175	2230	16.8	15.5
20	183	2440	17.8	17.8

Accumulated sample weight was plotted against settling time. From these data, a settling speed curve was obtained for each sample of sediment tested by the method of Oden (15). Settling curves for dry labelled sediment, natural sediment and dry treated sediment were obtained using this procedure (Fig. 3.5).

3.5 CONCLUSIONS ABOUT PRELIMINARY TESTS

Bearing in mind the results of these tests and the facilities of our laboratory for processing activities at curie level, the silver reduction method would be the most attractive one for labelling sediment from Río de la Plata.

The method of scandium adsorption is not convenient because retention is low and activity would gradually be eluted into the river water. Besides scandium oxide (the only way scandium activity is supplied), is very difficult to dissolve, even in hot hydrochloric acid, and processing it at curie level would require special facilities.

The behaviour of labelled sediment and natural sediment is similar. It should be pointed out that by the method of reduction, sediment is labelled proportionally to its volume, rather than to the surface of the grains, as one would expect (Table 3.5). Although this represents an advantage in our case, it is difficult to explain.

We believe that initially, when the silver ions have not been completely reduced, an important fraction enters into the grain volume of the sediment. Afterwards, when the sediment is exposed to sunlight, the silver atoms on the surface are reduced to a fine film of metallic silver that blocks the outlet of the atoms located inside the grains. Presumably, these atoms will also be be reduced to metallic silver. This phenomenon is not observed when labelling coarse grain sand: specific activity is higher in the fraction of fine grain size. Further studies on this fact are being carried out.

4. LABELLING OF THE SEDIMENT

4.1 SEPARATION OF PARTICLES FINER THAN 15 MICRONS

Before starting the process of labelling, all particles finer than 15 microns, as well as clay, were removed by decantation. Sediment was collected at sites A, B and C, about 200 kilograms from each, using two hundred liter cylinders with a 30 centimeters hole at the bottom (Fig. 4.1). Natural sediment, 25 kilograms in each batch, was shaken with water from Ezeiza for 20 minutes, followed by a 45 minutes decantation period, estimated by Stokes' law, in order to allow all particles coarser than 15 microns to go to the bottom (Fig. 4.2).

Supernatant water was removed until being level with the hole. A semi-industrial stirrer driven by an electric motor was used at 400 r.p.m. speed. This procedure was repeated, with the same batch, until all particles finer than 15 microns had been removed: about 15 times for sediment from sites A and C, but only 3 times for sediment from site B, which contains less clay. Total removal of clay and particles smaller than 15 microns was checked by grain size analysis.

Settling characteristics of the sediment do not vary when treating it with water from Ezeiza or water from Río de la Plata, as can be seen in the sedimentation curves of Fig. 3.4, which shows also the curves obtained with distilled water, and water containing 0.5% alum.

Analysis of water from Ezeiza used for separating clay from sediment:

pH	7,8
CO_3H^-	575 mg/liter
$CO_3^=$	0 mg/liter
Total hardness	32.4 Grad. Fr.
Hardness CO_3Ca	324
Dry residue at 105ºC	927 mg/liter
Cl^-	68 " "
$SO_4^=$	34 " "
NO_3^-	60 " "
Ca^{++}	72 " "
Mg^{++}	36 " "
Fe^{+++}	0.6 " "
F^-	0.6 " "

When sediment was considered free from clay and from particles finer than 15 microns, it was dried by sunlight in wooden trays, clods being dispersed with a hard wood roller. Dry sediment was passed through a sieve of coarse

mesh to remove stones, shells, sticks, leaves and organic material.

Sediment ready for labelling was stored in polyethylene bags.

4.2 RADIOACTIVE LABELLING

Radioactive silver (Ag-110) was furnished by A.E.R.E.Harwell, U.K., as granulated metal, in three standard irradiation cans, each containing 40 gram silver of about 1.5 Curies activity.

This silver had to be processed chemically in order to obtain a labelling solution suitable to the method previously described. Irradiated silver was disolved in 50% nitric acid and diluted with distilled water; silver nitrate dissolved in water was added to serve as carrier for Ag-110. Ammonia was added until obtaining a clear solution that was mixed with a reducing solution of Seignette salt.

This labelling solution and the sediment were mixed in a concrete mixer for 8 to 10 minutes, in order to wet all grains of sediment.

The whole process was performed in a specially built facility in order to handle radioactive material semi-automatically by remote control.

Radioactive silver was dissolved and the labelling solution was prepared on a tray shielded with 10 centimeters of lead. All operations were performed from without with an assembly of tongs, the liquids being transferred by pressure or vacuum in closed containers. A scheme of the apparatus used is shown in Fig. 4.3.

Labelled sediment was placed on wooden trays of about 2 square meters surface, covered inwardly with sheets of plastic, that were left in the open air for exposure to sunlight. The handles of these trays were long enough to reduce to a minimum the dosis of radiation received by the persons who carry them. The sediment was exposed to sunlight for 5 to 15 days, depending on climatic conditions. The trays were covered with plastic hoods during the night and on windy or rainy days.

The sediment was stirred frequently (every 20 minutes during the first hours after labelling and every hour later on) in order to make sure that the drying process was uniform. Wooden rakes with long handles were used, to remain at some distance from the radioactive material. A light roller was passed over the sediment now and then, in order to scatter clods that eventually might have appeared.

When the radioactive silver had been completely reduced over the grains of sediment, it was treated with natural water from Río de la Plata, in order to remove the radioactive material that had not been firmly fixed.

4.3 WASHING LABELLED SEDIMENT

Water was transported in 200 liter tanks from Río de la Plata to Ezeiza (50 kilometers from the coast) where the labelling and washing processes were carried out.

The labelled sediment, 25 kilograms in each batch, was treated with 150 liters of natural water from Río de la Plata, shaking it in the previously described way for 90 minutes. Sediment was allowed to decant for an hour, and supernatant water was removed, being stored in closed cylinders for waste disposal. The semiwet sediment was stored in double plastic bags, ready for injection.

4.4 FIXATION TEST AND SIZE ANALYSIS OF LABELLED SEDIMENT

Before injecting the sediment that had been taken from sites A, B and C, and had been labelled according to the abovesaid method, several samples were taken from each for calibration, fixation test and size analysis, in order to calculate the total activity to be injected at each site.

For the fixation test each sample was vigorously shaken for different periods of time (violent shaking: about 180 jerks per minute) and activity fixed on the sediment was determined. The curves for sediment from sites A, B and C are shown in Fig. 4.4 Each point on the curve is the mean of four samples of each sediment.

Activity fixed to the sediment, after treating it with natural water from Río de la Plata as described in 4.3, was as follows:

Sediment A : 88.1 %

Sediment B : 81.0 %

Sediment C : 85.0 %

Curves for size analysis carried out with natural unlabelled sediment from sites A, B and C, are shown in Fig. 4.5, 4.6 and 4.7.

Size analysis for sediment from sites A and C was performed with the tube described in 3.4. Tables 4.1 and 4.2. that give the data of the settling tests for sediment from sites A and C, indicate the percentage of sediment, the mass and the percentage of activity deposited in a time t. The last column of each table gives the specific activity of each fraction for each interval of time.

The settling curve for the sediment from site B was obtained by passing the material through different sieves. Table 4.3 indicates the fraction of sediment separated by this procedure, the percentage of total weight of each fraction and the specific activity of each fraction.

Table 4.1

SETTLING TEST OF LABELLED SEDIMENT FROM SITE A

Settling time (minutes)	Percentage of total settled sediment	Percentage of total settled activity	Specific activity of each fraction $\frac{c.p.m.}{gram}$
1	17.1	27.2	7300
2	33.7	45.9	5160
4	57.7	67.4	4070
6	72.0	79.2	3700
10	85.3	89.6	3500
20	94.3	96.6	3600
40	97.2	100	5170

Table 4.2

SETTLING TEST OF LABELLED SEDIMENT FROM SITE C

Settling time (minutes)	Percentage of total settled sediment	Percentage of total settled activity	Specific activity of each fraction $\frac{c.p.m.}{gram}$
1	29.8	36.1	6700
2	53.1	58.2	5200
4	79.2	80.4	4700
6	89.0	89.0	4900
10	94.8	94.4	5160
20	97.4	98.0	7600
40	98.2	100	14600

Table 4.3

GRAIN SIZE ANALYSIS OF LABELLED SEDIMENT FROM SITE B

Grain size (microns)	Percentage of total sediment	Specific activity $\frac{c.p.m.}{gram}$
295	1.5	1480
295 to 147	7.0	1100
147 to 104	21.6	1000
104 to 74	57.8	900
74 to 50	8.0	1050
50	4.4	2200

4.5 MEASUREMENT OF THE TOTAL ACTIVITY INJECTED AT EACH SITE AND WEIGHT OF THE INJECTED SEDIMENT

Total activity to be injected at each site was determined by taking samples of the sediment from sites A, B and C. Specific activity was determined by comparison with a standard under similar conditions. The standard (15.8 micro-curies per gram of sediment) was prepared with a solution of Ag-110 calibrated in a 4π counter. Activity calculated according to the abovesaid procedure and weight of the sediment injected in each site were as follows:

Site A : 97.2 Kg 844 mC (on April 20, 1966)

Site B : 108.5 Kg 858 mC " " "

Site C : 102.5 Kg 1067 mC " " "

5. INJECTION

The equipment used for injection was designed so that the labelled sediment would be deposited on the river bed as a uniform film, within a radius of 15 meters. It was extremely difficult to obtain good conditions for depositing the sediment in this way. A few hours after injection the tracer was found to make long narrow bands following the direction of the river current.

A landing boat about 14 meters long and 2 meters wide, was used and the injection tank was set up as indicated in Fig. 5.1. The boat and tank are shown in Fig. 5.2

The labelled sediment was deposited as a light slurry, through a rubber tube, 8 centimeters in diameter, extending to the river bed. At the end of this tube a lead block was attached, so that the end of the tube would remain on the river bottom while the boat was moving.

While being transported to the injection site, the sediment was stored in double plastic bags placed in iron cans, in order to prevent scattering of the radioactive material, in case the bag would break before its contents had been transferred to the injection tank. Before each injection, parameters such as bottom current, wind speed and wave height were checked, so that injections would always be carried out with slack water.

The injection was performed as follows:

1) The injection tank was filled with 150 liters natural water from Río de la Plata by a pump available on the boat and the stirrer was put to work.
2) The plastic bag and its protection can (containing 25 kilograms sediment) were hauled over the funnel located on the injection tank. The protection can was withdrawn, leaving the bag exactly over a sharp steel knife, that cuts the bottom of the bag, allowing the sediment to fall into the tank, (Fig. 5.3).

3) When the contents of two bags had been deposited into the tank (about 50 kilograms), the stirrer was operated until obtaining a light slurry.

4) While the stirrer was in operation a valve at the bottom of the tank was opened, allowing the sediment to fall through a rubber tube. Simultaneously the boat moved slowly, so as to distribute the sediment in a uniform way.

This procedure was repeated with another 50 kilograms batch of labelled sediment, each discharge taking about 2 to 3 minutes. After the second discharge the injection tank was rinsed with 20 to 25 liters of natural water, in order to remove the radioactive material that might have remained in the rubber tube.

In order to decrease the dosis received by the personnel during the process of injection, the apparatus was shielded by a semicircular container filled with sand and water, as shown in Fig. 5.4.

6. CALIBRATION

6.1 CALIBRATION FACILITY AND LAYER SOURCE PREPARATION

Calibrations were carried out at the installations of C.N.E.A. in Ezeiza. This place was chosen because of its low background and its facilities for radioactive waste disposal.

For these experiments, a wooden pool was constructed, inwardly covered with a zinc plate, so that it could easily be rinsed. The surface of the pool was 3.83 square meters (1,95 x 1,96 meters) and its height 0,7 meter; the wood used for its construction being one inch thick. Filling it with water would take about 10 minutes and emptying it 5 minutes. (Fig. 6.1.)

The radioactive sediment for calibration experiments was prepared with labelled sediment from site B, its specific activity being at the time of calibration 7,05 microcuries Ag-110/gram. A known amount of labelled sediment was added to unlabelled sediment of grain size similar to that from site B,

until obtaining layers of required thickness.

This was carried out in the abovesaid pool, stirring vigorously the sediment with rakes in order to obtain a uniform mixture. Half an hour of stirring turned out to be necessary. Spot checks on the sediment layer, using a collimated scintillation cyrstal, 1 x 1 inch, connected to a C.N.E.A. type scaler, confirmed a uniformity better than 5%.

6.2 PRELIMINARY TESTS

Before using the equipment described in 2.1, 2.2, 2.3 and 2.4, the operating conditions of the G.M. counters were checked, taking the plateau with 2, 4 and 6 G.M. counters connected in parallel. The results are indicated in Fig. 6.2.

During field work, the counting systeme was controlled periodically, without finding any significant variations. However, after surveying the background of the river bed, two G.M. counters had to be replaced, as they proved to have less efficiency than the rest. Natural background is therefore affected by an error of about 12 to 15%, owing to increased efficiency of the counting system after replacing two counters.

Another preliminary test that was performed, was determining the effect of gamma ray dispersion in water. A flat radioactive source of 7 microcuries of Ag-110 was used, uniformly distributed over a one square meter aluminium plate.

In order to check the effect of water depth on the count rate, this flat source was placed on the bottom of the pool with the counter system over it. The count rates determined at different heights of water, for 2, 4 and 6 G.M. counters connected in parallel, are shown in Fig. 6.3. According to these results, in each calibration run the pool had to be filled with 35 centimeters of water, measured from the contact surface between the sediment and the sledge.

Linear correspondence between the amount of counts read on the instrument (c.p.m.) and actual activity (d.p.m.) was checked counting a series of point sources of increasing activity. The results are shown in Fig. 6.4 The maximum activity used was 15 microcuries of Ag-110, that give about 90.000 counts per minute, when using the assembly of six G.M. counters.

6.3 AREA SENSITIVITY OF THE DETECTOR

The sensitivity of the G.M. assembly to the location of the activity found on a horizontal surface was determined measuring the detector response with a "point" source at different positions relative to the detector. These positions were chosen on a horizontal plane coincident with the sledge base, so that the readings are representative of the activity spread on the surface of the river bed.

The "point" source used was made of 12 microcuries of Ag-110, in a plastic container of 2 centimeter diameter and 1 centimeter height. The detector was located at the center of a wooden plate, crossed with lines every 12 centimeters along both its axis. The "point" source was placed at each intersection and counted in this way in 100 different positions. All measurements were carried out under a water layer of 35 centimeters. These results give by interpolation the isoactivity curves of Fig. 6.5.

Integrating the activity observed over the finite areas centered at the detector and limited by the curves of isoactivity, the percentage of total activity corresponding to each area was obtained. The isoactivity curves limit elliptical areas, whose major axis corresponds to the axis of the G.M. counters' system. These results lead to the conclusion that 95% of the activity detected by the counters is located on an area of about one meter diameter, concentric with the geometrical center of the detector (0.78 square meters or 8.7 square feet).

6.4 CALIBRATIONS RESULTS

Before carrying out the calibration experiments, background activity was counted within the pool, with a 2 centimeters layer of inactive sediment, covered by 35 centimeters of water and the tracking sledge located at the center of the pool. This background was substracted from the values obtained in all calibration experiments.

The response of the detector assembly operating with 2 or with 6 G.M. counters for increasing activities of Ag-110 dispersed in a 2.2 centimeters uniform layer of sediment was determined adding known amounts of labelled sediment to inactive sediment, as described in 6.1. The tracking sledge, or the device for point measurements, was placed at the geometrical center of the pool, so as to reproduce the counting conditions found on the river bed, being covered with 35 centimeters of water. The results for 6 G.M. counters are shown in Fig. 6.6 and for 2 G.M. counters in Fig. 6.7.

The effect of dispersion for a known amount of labelled sediment in increasing layers of sediment was determined as follows: Increasing amounts of unlabelled sediment were added to a 1 centimeter layer of labelled and unlabelled sediment, the maximum thickness tested being 19,5 centimeters. Silver activity remained constant: 79.4 microcuries/square meter. The results are given by the curves of Fig. 6.8 and indicate that the tracer located at more than 20 centimeters depth, will not contribute in a significant way to the total activity measured.

6.5 RELATION BETWEEN GRAPHIC RECORDER AND RATE-METER REGISTRATION

During field work simultaneous readings were taken with a rate-meter and the graph recorder described in 2.4. Therefore it showed to be useful to determine the relationship between these instruments.

Counts per minute, or pulses per minute, were fed into the counting instrument by a pulse generator with low time constant. The number of counts per minute was established before every read-out. Working under these conditions for each of the different scales of the instrument, the curves of Fig. 6.9, 6.10 and 6.11 were obtained, giving the number of pulses fed in by the generator vs. counts read on the rate-meter and on the graph recorder.

The absorption by water of the radiations emitted by a layer source of sediment was checked counting its radioactivity with the detector assembly placed at different heights over the layer surface located on the bottom of the calibration pool. Results are shown in Fig. 6.12.

7. BACKGROUND RADIATION SURVEY

Before injecting the labelled sediment at sites A, B and C, a survey was made of the background radiation, controlling in each case an area of about 2 kilometers radius centered at the point of injection.

The background was surveyed with the counting equipment and sledge for continuous survey, described in sections 2.1, 2.2 and 2.4. The results are shown in Fig. 2.1.

The background does not vary considerably throughout the areas that were examined, and can be taken as constant. The only exception is Canal Sud, where it becomes almost twice as high as on the shoals. This effect is possibly caused by an increase of the detector efficiency, as the sledge might be ploughing a track into the soft muddy bed of the channel.

8. COUNTING LABELLED SEDIMENT ON THE BED OF RIO DE LA PLATA

The radioactive tracer was counted on the river bed using the set-up described in 2.1, 2.2 and 2.4. The results that were obtained and a detailed description of the set-up have been sent to the Hydraulic Research Station of Wallingford, through Sir William Halcrow and Partners.

9. MEASUREMENT OF CORE SAMPLES

Core samples were taken with the device shown in Fig. 9.1 by personnel of Sir William Halcrow and Partners, and were sent to our laboratory in PVC liners. These liners were 60 centimeters long and 7 centimeters in diameter, with a wall thickness of 2 milimeters, having a series of holes for water outlet, 5 milimeter in diameter, on a vertical line every 2 centimeters.

The samples were kept in vertical position for two days, so that they would become cohesive and easy to slice.

The samples that had been taken first (site C Nº 4 and 8, site A Nº 2 and N.N.) were sliced every 2 centimeters within the liners, with a thin-bladed endless saw. Each portion was placed in a Petri dish of 9 centimeters in diameter and was duly identified.

Before drying at 120-130º C in an oven, the sections next to the lateral holes were discarded (about 1/3 of the total volume) in order to eliminate errors due to material that might have been pushed down by the cores when they were taken. When the sediment was completely dry it was divided into 65 grams fractions and counted.

Subsequent analysis were carried out with two modifications. The PVC liners were removed immediately, leaving the sediment uncovered, the disturbed zones were discarded and a vertical trimming was performed, so as not to include active material from the lateral surface. The sediment cylinders were sliced every centimeter. Each portion was prepared as described above and counted.

Radioactivity was counted with a 2 x 2 inch NaI (Tl) crystal, shielded with 5 centimeters lead rings, connected to a Nuclear Data Multichannel (spectrometer) analyzer with 256 channels. The samples were placed directly over the crystal. Activity was counted for 20 minutes and background was substracted automatically for an equal amount of time.

"Activity measured" was taken as the integration of the 0.66 and 0.86 MeV peaks of Ag-110. The activity as microcuries/gram was obtained by comparison with two standard samples, prepared by adding to 65 grams and 45 grams fractions of inactive sediment known amounts of a standardized solution of Ag-110, the activity of each standard sample being 3.7 x 10-3 microcurie/gram. The results are shown in Fig. 9.2, 9.3 and 9.4.

10. APPENDIX I

MEASUREMENT OF THE Ag-110 ACTIVITY SUPPLIED BY HARWELL, U.K.

Radioactive silver was supplied by Harwell, U.K., in a special lead container with three standard irradiation cans, each containing 40 grams silver granules. Activity of Ag-110 was measured in the following way:

1) Can A was extracted from its lead container and activity was measured with a previously calibrated monitor at 8 meters distance. Calculations were made bearing in mind the disintegration scheme of Ag-110, and gave 1.3 curies.

2) Metallic silver from each can was dissolved in nitric acid and 3/4 of this solution were used for labelling 100 kilograms sediment. When the sediment had been labelled, but before being treated with water from Rio de la Plata, a sample was taken and its specific activity was estimated by comparison with a standard sample labelled with a known amount of Ag-110. In this way, total activity contained in each can is easily calculated.

   Results were as follows:

   Can A : 1.4 curies
   Can B : 1.5 curies
   Can C : 1.6 curies

3) Metallic silver contained in can C was dissolved in nitric acid and an aliquot was counted in a 4π proportional counter calibrated for Ag-110. By this method activity in can C was found to be 1.7curies.

   Obviously there might be some error in these determinations of activity, but it would be expected to lie within 25%. In any case, total activity sent by Harwell amounts to not more than 5.6 curies.

REFERENCES

1. Annual Report on Silt Transport Studies Utilizing Radioisotopes.
   R.B.KRONE et al., Contract Nº DA-04, 203, Civ.Eng. 57-61.

2. The Measurement of Sand Transport by Means of Radioactive Tracers.
   M.J.CRICKMORE and G.H.LEAN, Proc. Roy. Soc. A. volume 266, and
   Radioisotopes in Hydrology Proc. Symposium - Tokyo, I.A.E.A., 1963.

3. Radioactive Tracer Study of Sediment Transported in Alluvial Rivers.
   J.E.CHABERT, P.JAFFRY, G.COURTOIS and R.ICURS. Proc.Symposium, Tokyo,
   I.A.E.A., 1963.

4. Radiotracer Experiment on Literal Drift in Japan.
   M.KATO et al., Proc. Symposium Tokyo, I.A.E.A., 1963.

5. Tracing Under Sea Sand Movement with Radioactive Silver.
   A.GIBERT et al., Laboratorio Nacional de Engenharia Civil, Lisboa,
   1960.

6. Investigations of Sand Movement Using Radioactive Sand Fund Studies
   in Geography.
   J.DAVIDSON, Ser. A. Physical Geography, 12, 1958.

7. Movement of Bottom Sediment Coastal Waters by Currents and Waves;
   Measurements with the Aid of Radioactive Tracers in the Netherlands.
   J.J.ARLMAN et al., Deltadienst, Rijkswaterstaat, 1957.

8. Silt Movement Investigation in the Oxcars Ground, Firth of Forth,
   Using Radioactive Tracers, 1961 and 1964.
   D.B.SMITH and T.V.PARSONS. A.G.R.E. - R 498C

9. Radioactive Tracer Techniques for Sand and Silt Movement under Water.
J.L.PUTMAN and D.B.SMITH, Inst. J. App. Rad. Isot., I 24, 1956.

10. Experiments with Radioactive Sand as a Tracer of Beach Sand Movement.
D.L.INMAN and T.K.CHAMBERLAIN. P/2357 - U.S.A.

11. Neutron-Irradiated Quartz as Tracer of Sand Movements.
E.D.GOLDBERG and D.L.INMAN, Geol. Sec. America Bull., 66, 611, 1955.

12. Estudio del movimiento de arenas en las cercanías del Puerto de Mar del Plata usando arena marcada con Ag-110.
FEDERICO LACHICA y GREGORIC B. BARO, Informe Nº 100 CNEA, Argentina, 1963.

13. The Calibration of Radiation Detectors Used in Sediment Tracer.
Investigations by the Hydraulic Research Station.
M.J.CRICKMORE and C.B.WATERS. Report N: INT.48 - Wallingford, England.

14. Los sedimentos del fondo del Río de la Plata en la zona comprendida entre el Río Paraná de las Palmas y Puerto Nuevo.
Tesis from the University of La Plata, Argentina, 1956.
EDMUNDO CHAAR.

15. Manual of Sedimentary Petrography.
W.C.KRUMBEIN, F.J.PETTIJOHN.
Appleton-Century-Crofts, Inc., N.Y., 1938.

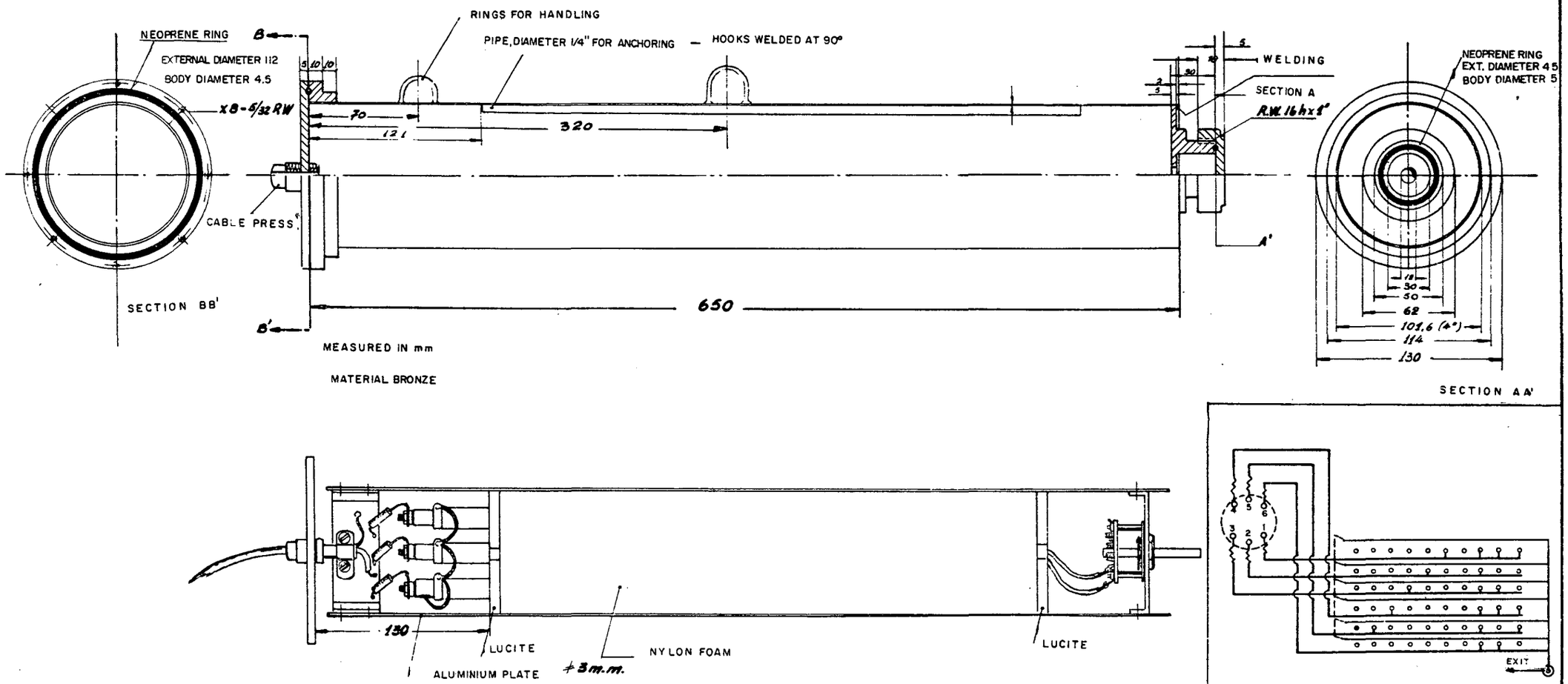


FIG. 2-1 SCHEME OF PROTECTION TUBE AND GM. ASSEMBLY

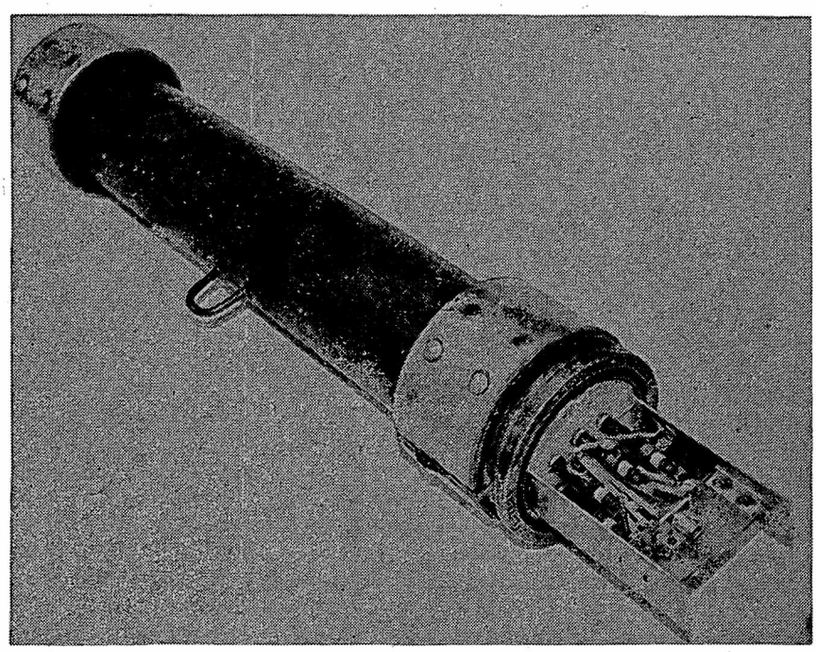


FIG. 2-2 ASSEMBLY OF GEIGER MÜLLER COUNTERS HOUSED IN THE BRASS PROTECTION TUBE.

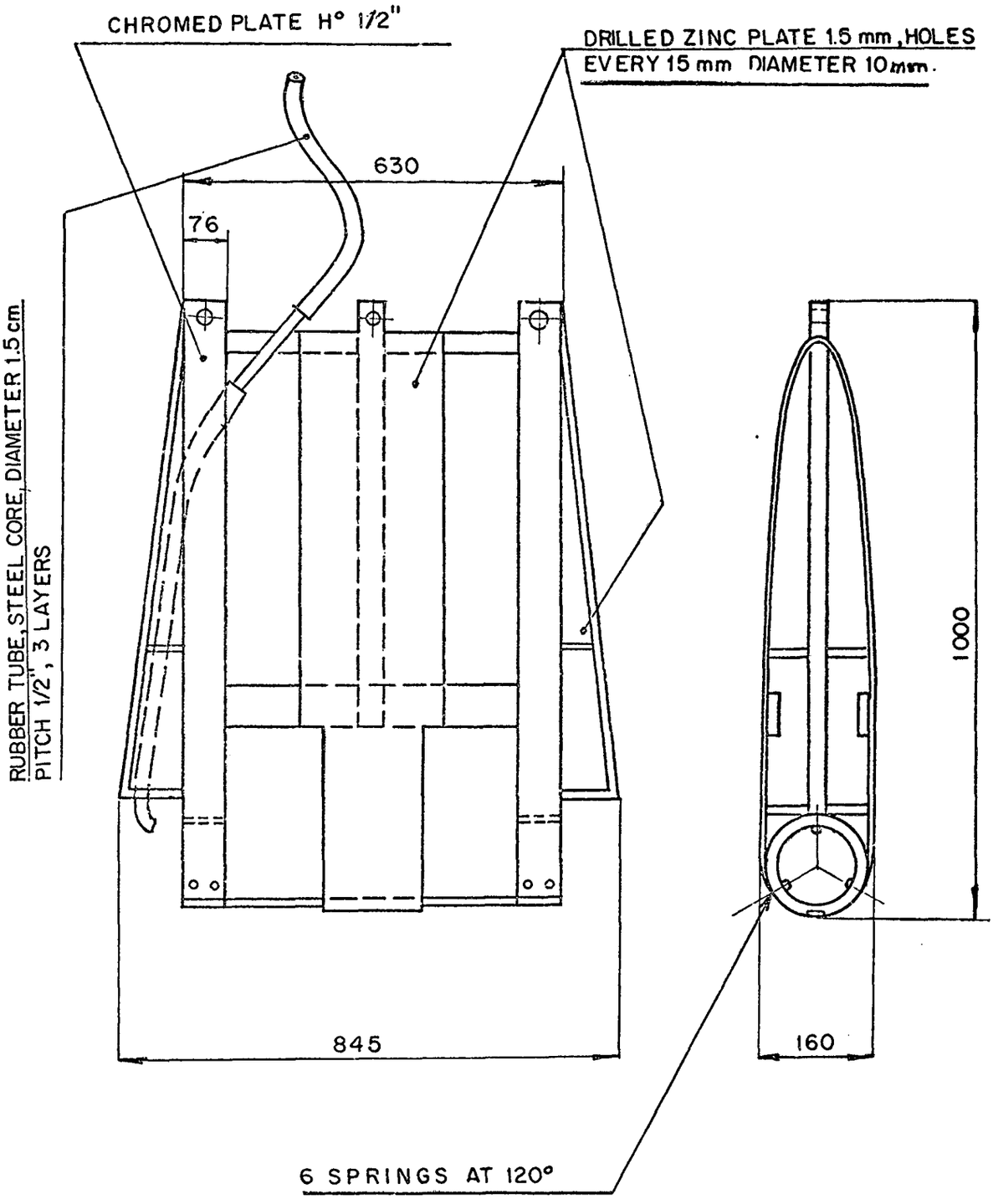


FIG. 2-3 SCHEME OF THE TRACKING SLEDGE

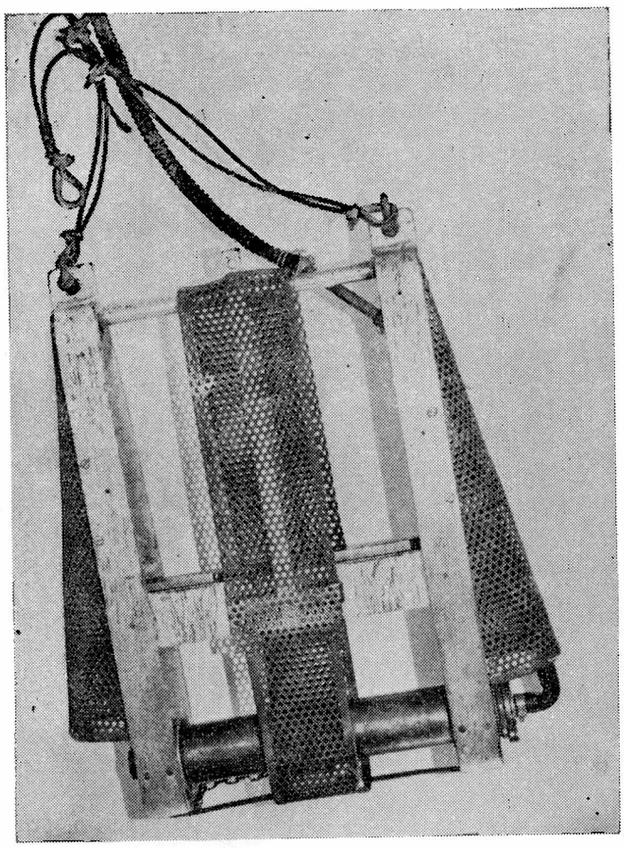


FIG. 2-4 TRACKING SLEDGE

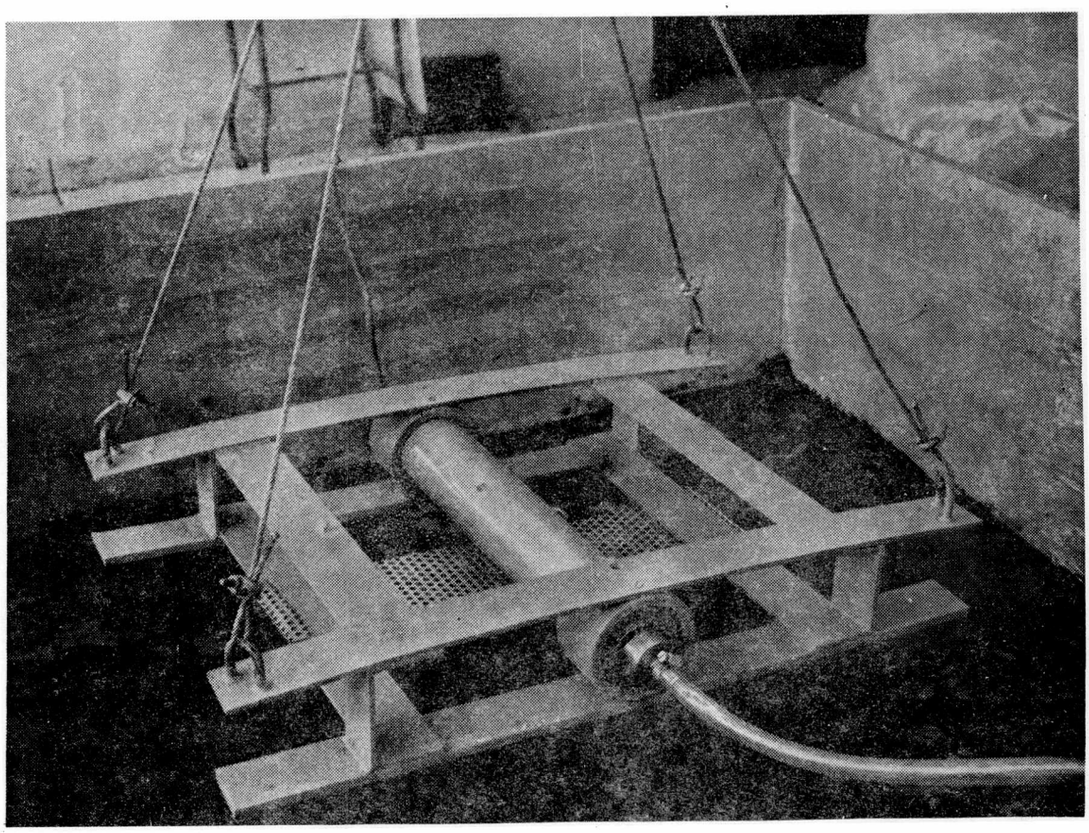


FIG. 2-5 HAND-HELD POINT MEASUREMENT DEVICE

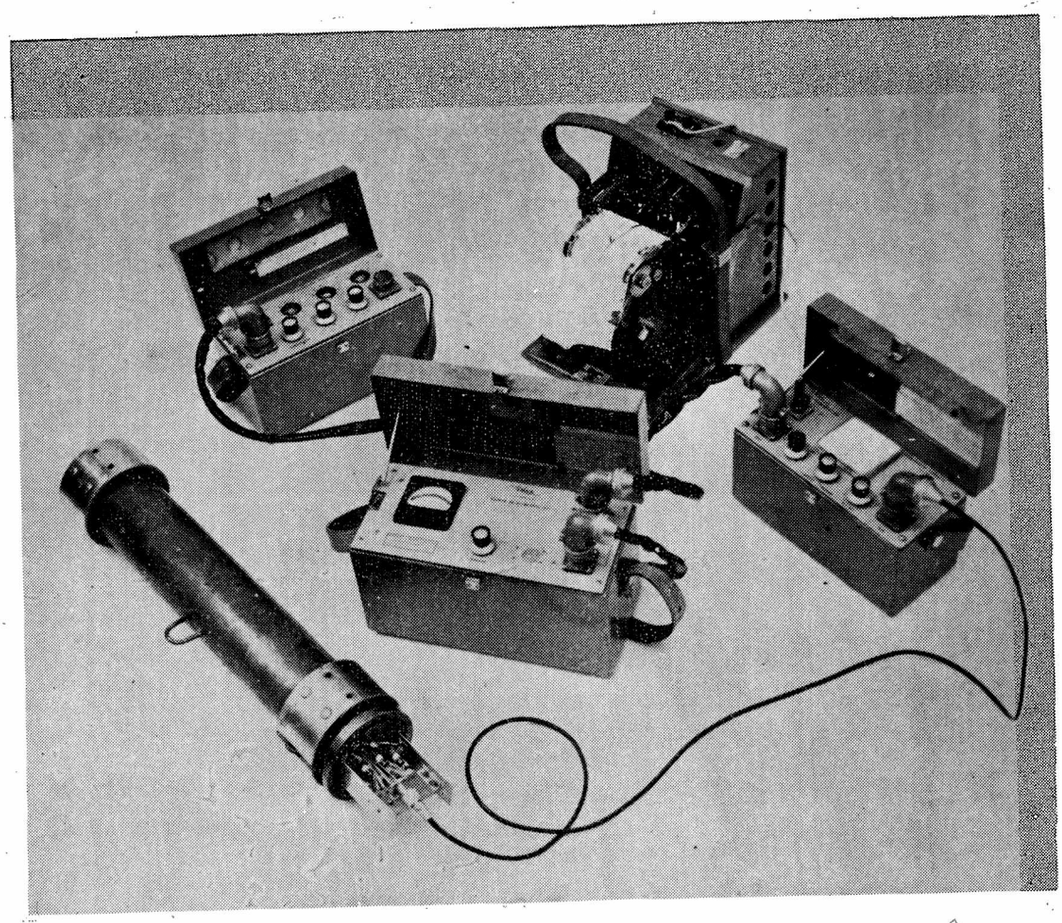


FIG. 2-6 ELECTRONIC EQUIPMENT

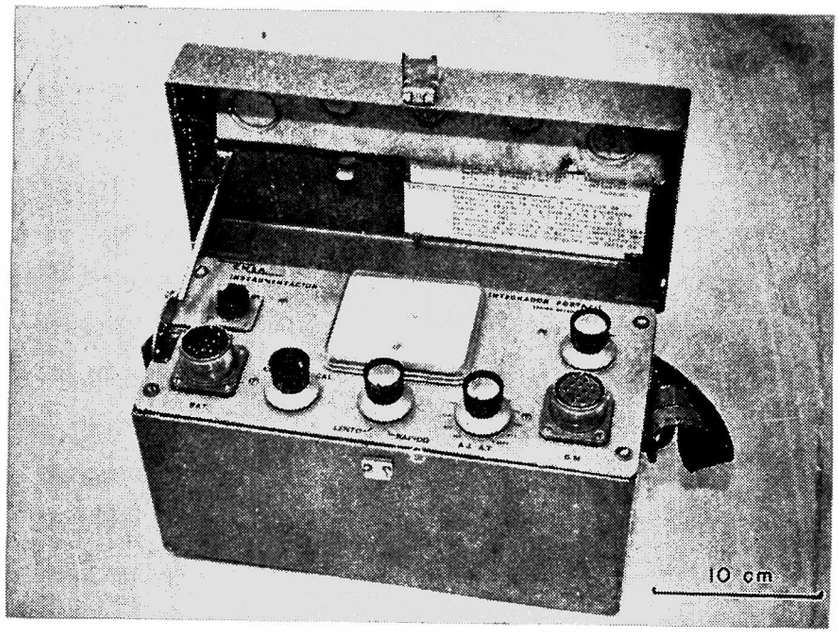


FIG. 2-7 COUNTING RATE METER

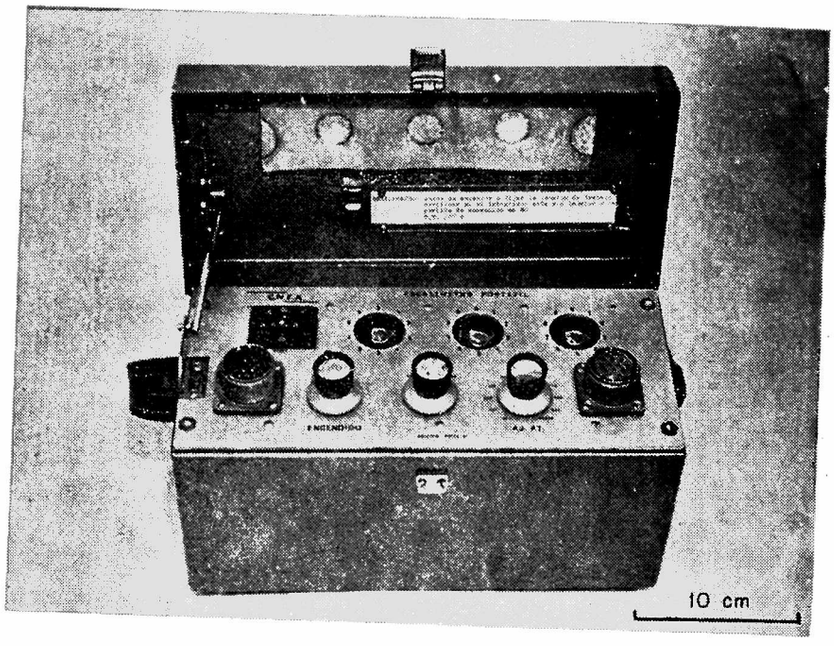


FIG. 2-8 SCALER

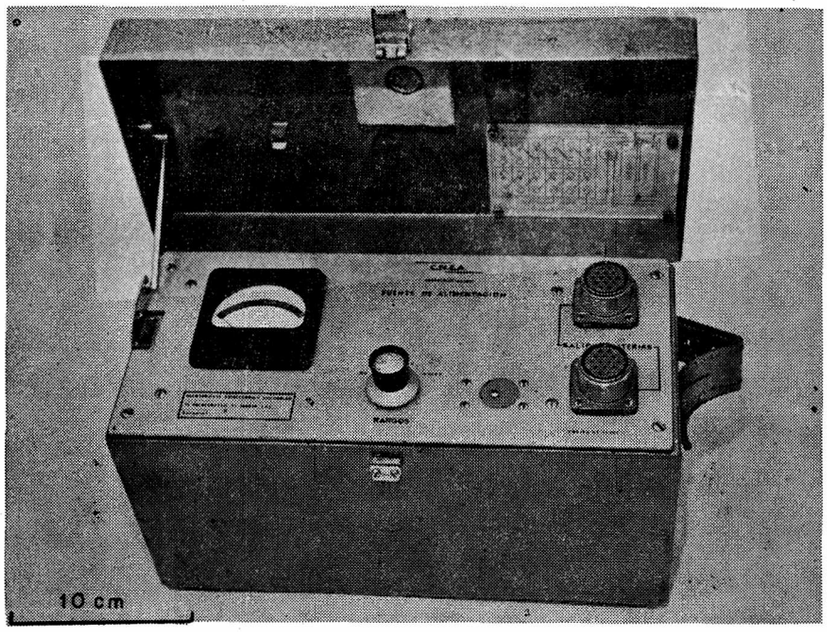


FIG. 2-9 POWER SUPPLY ASSEMBLY

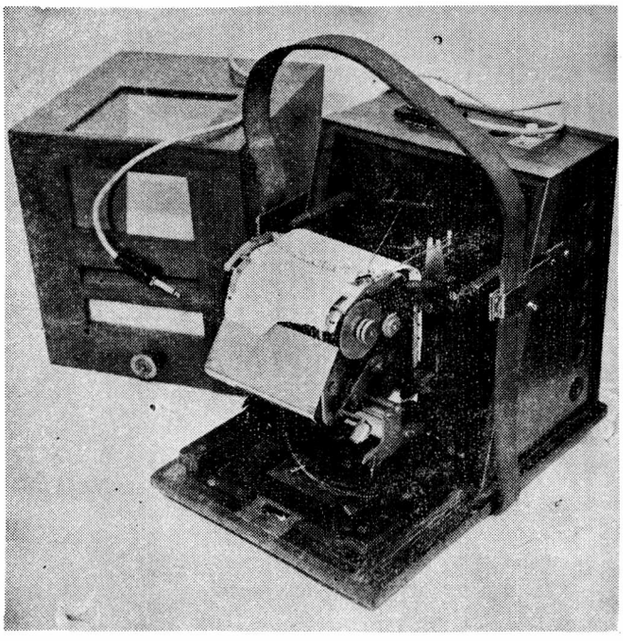
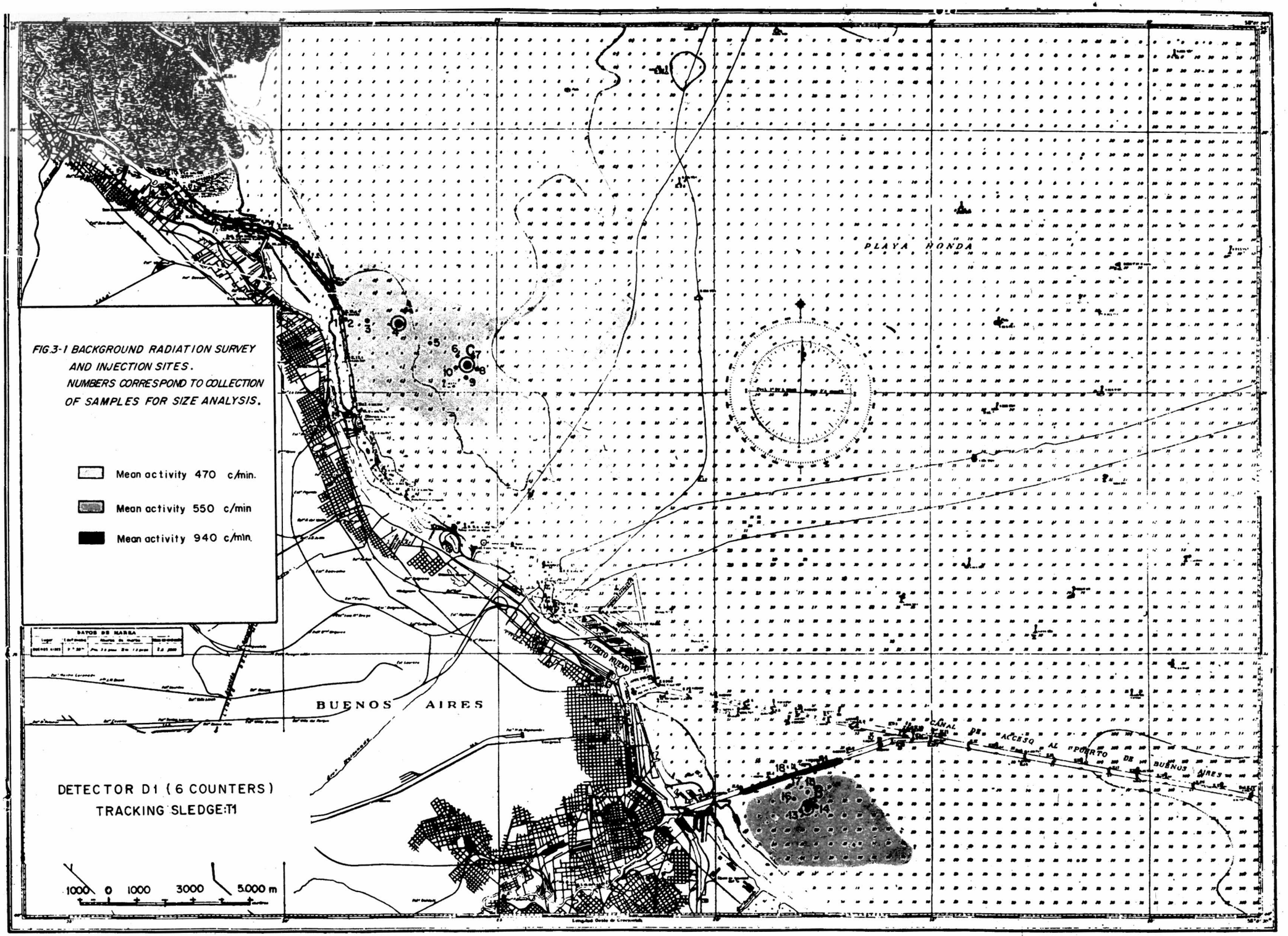


FIG. 2-10 GRAPH RECORDER


PLAYA HONDA
BUENOS AIRES
PUERTO NUEVO
CANAL DE ACCESO AL PUERTO DE BUENOS AIRES
DATOS DE MAREA
FIG.3-1 BACKGROUND RADIATION SURVEY AND INJECTION SITES. NUMBERS CORRESPOND TO COLLECTION OF SAMPLES FOR SIZE ANALYSIS.
Mean activity 470 c/min.
Mean activity 550 c/min
Mean activity 940 c/min.
DETECTOR D1 (6 COUNTERS)
TRACKING SLEDGE:T1
1000 0 1000 3000 5.000 m

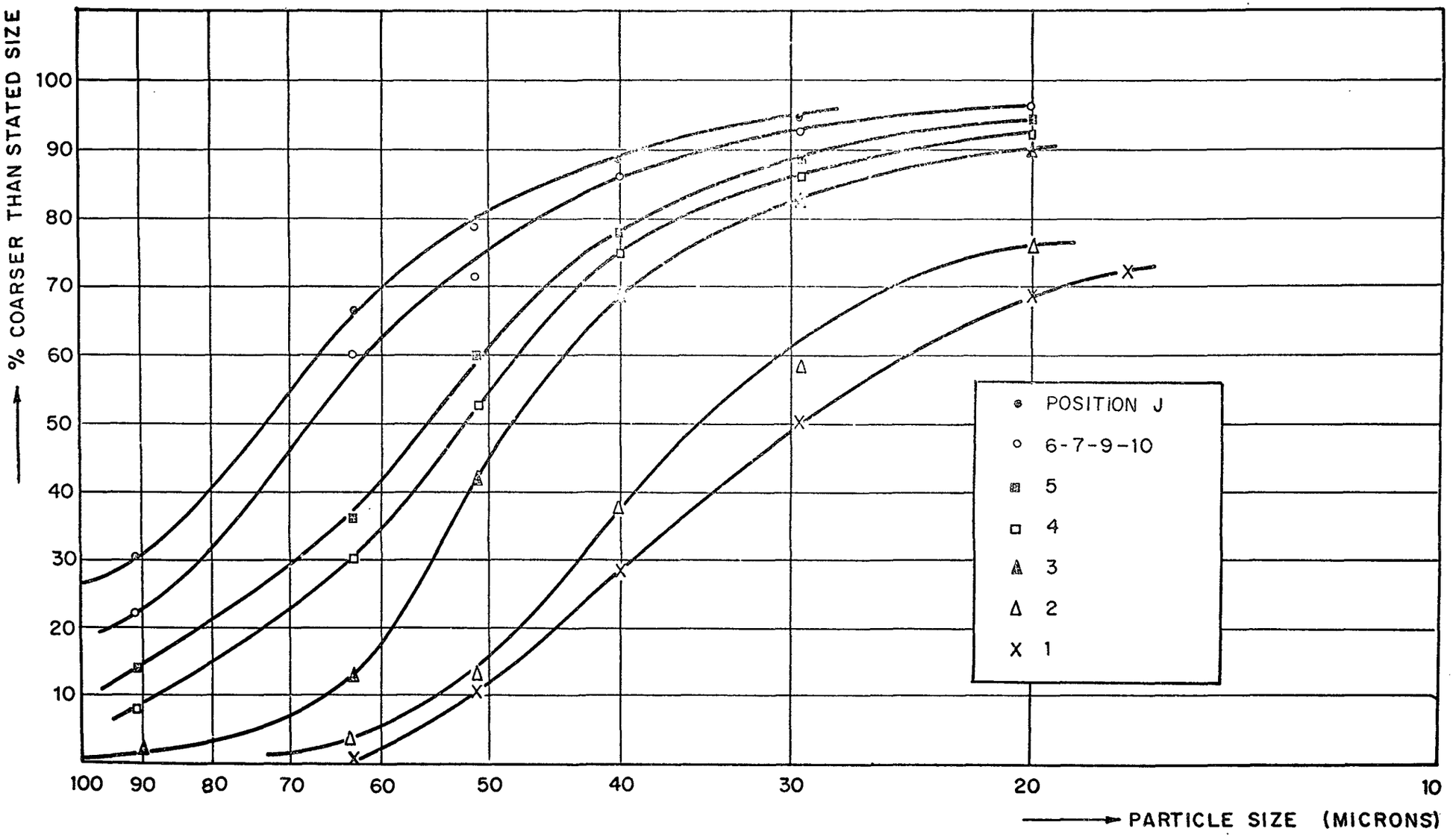


FIG. 3-2 GRAIN SIZE DISTRIBUTION CURVES

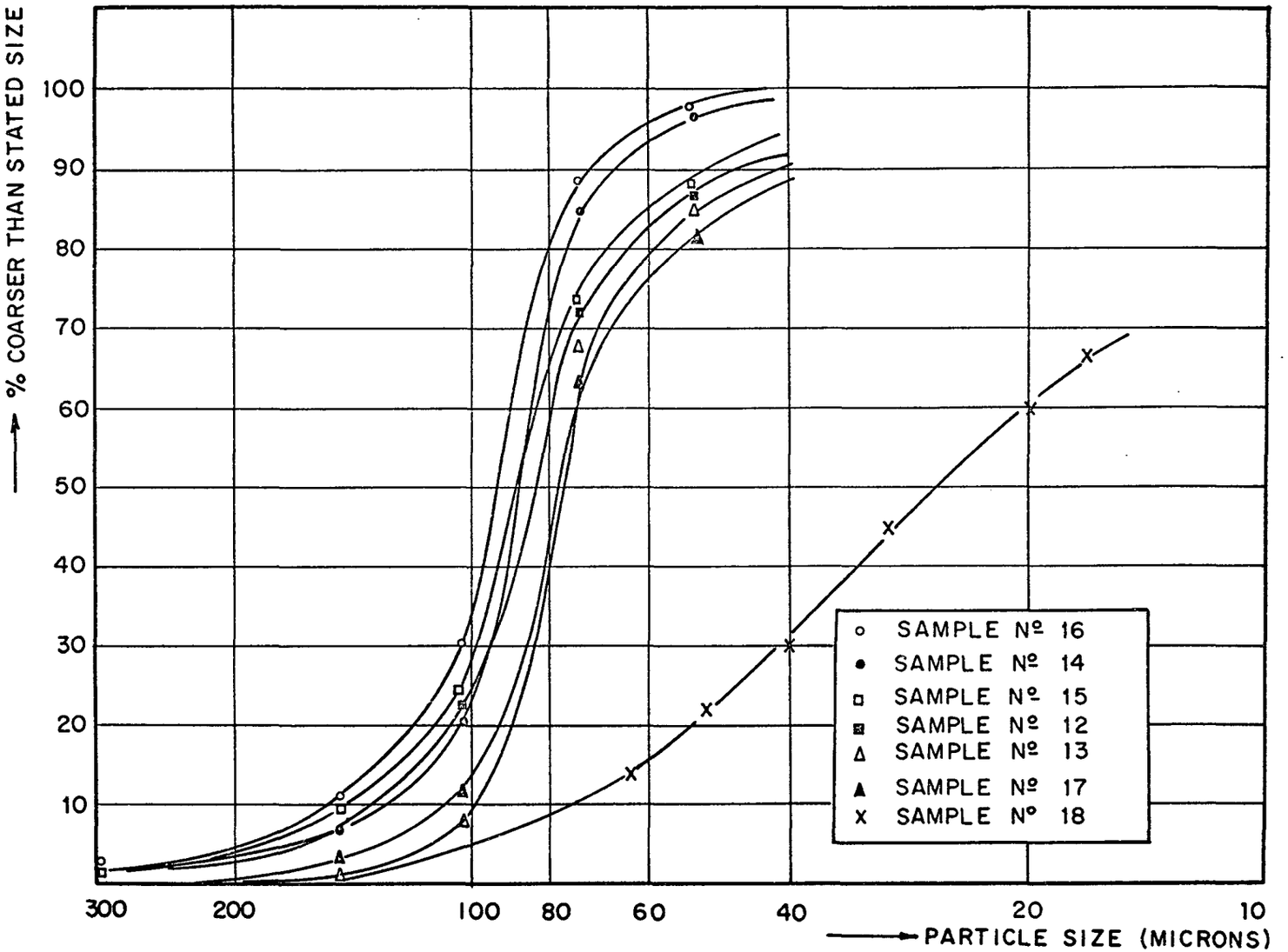


FIG.3-3 GRAIN SIZE DISTRIBUTION CURVES

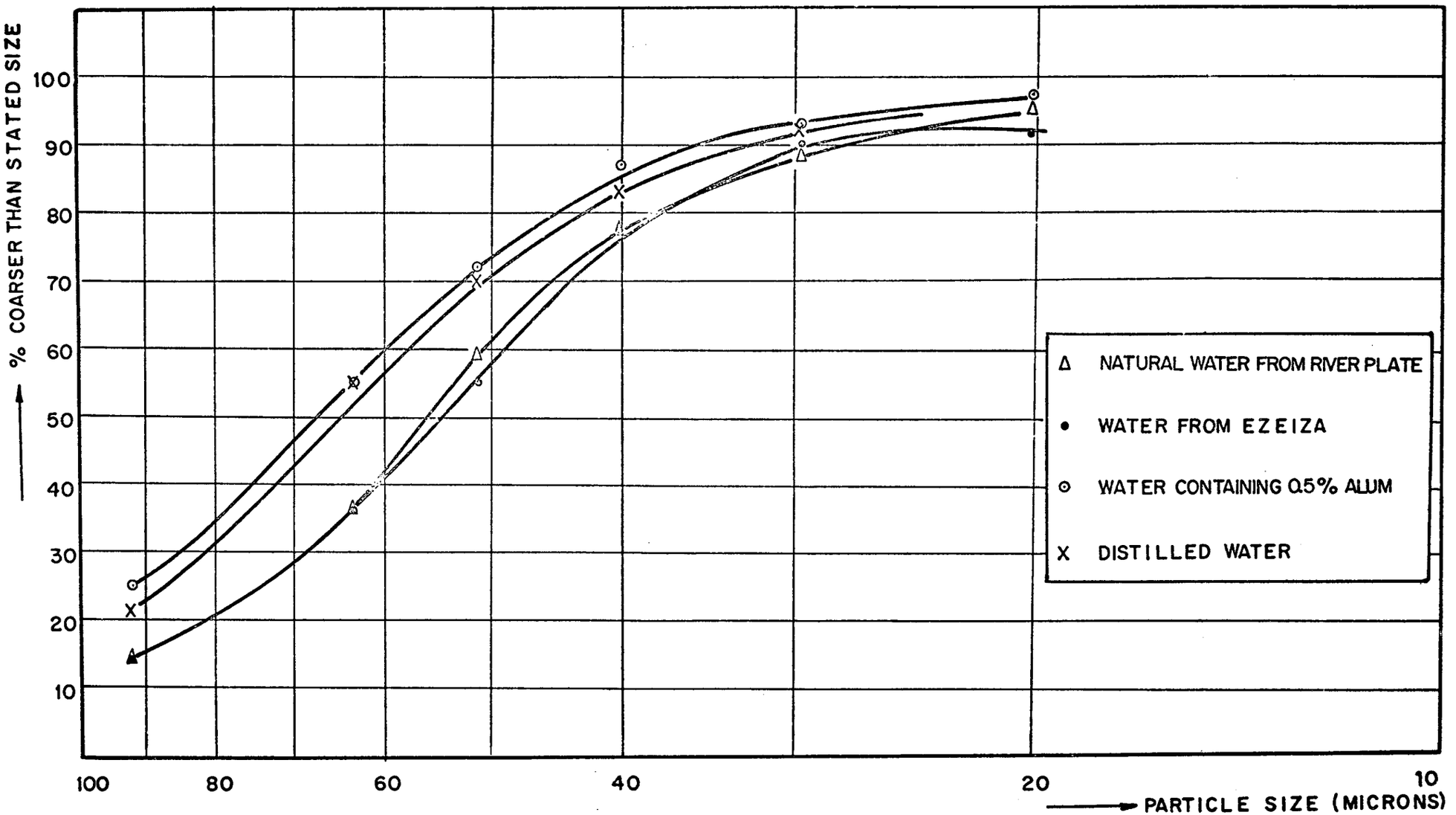


FIG. 3-4 GRAIN SIZE DISTRIBUTION CURVES OBTAINED FOR SAMPLE Nº 5 TREATED WITH DIFFERENT TYPES OF WATER

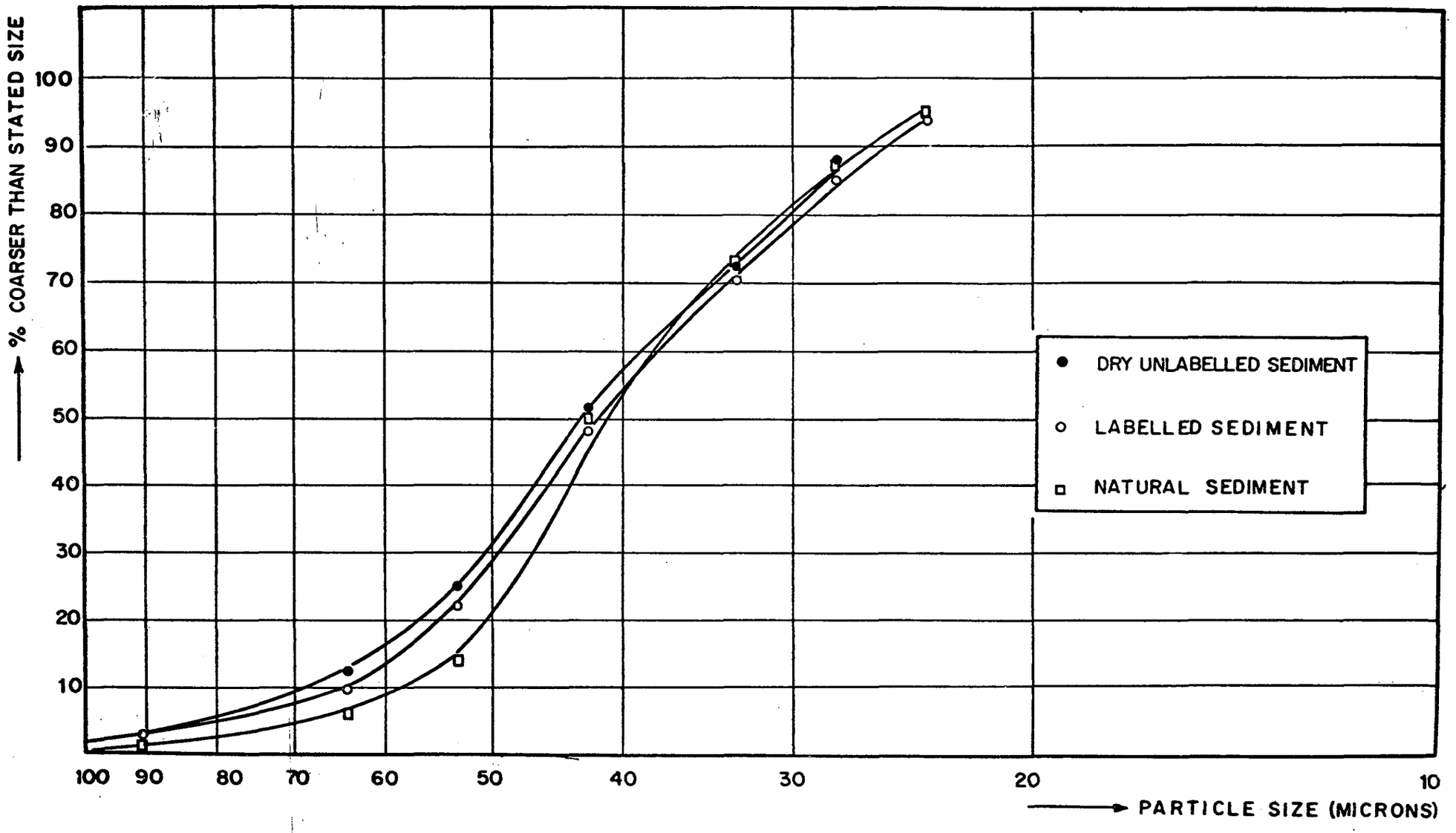


FIG.3-5 SETTLING COMPARISON TESTS

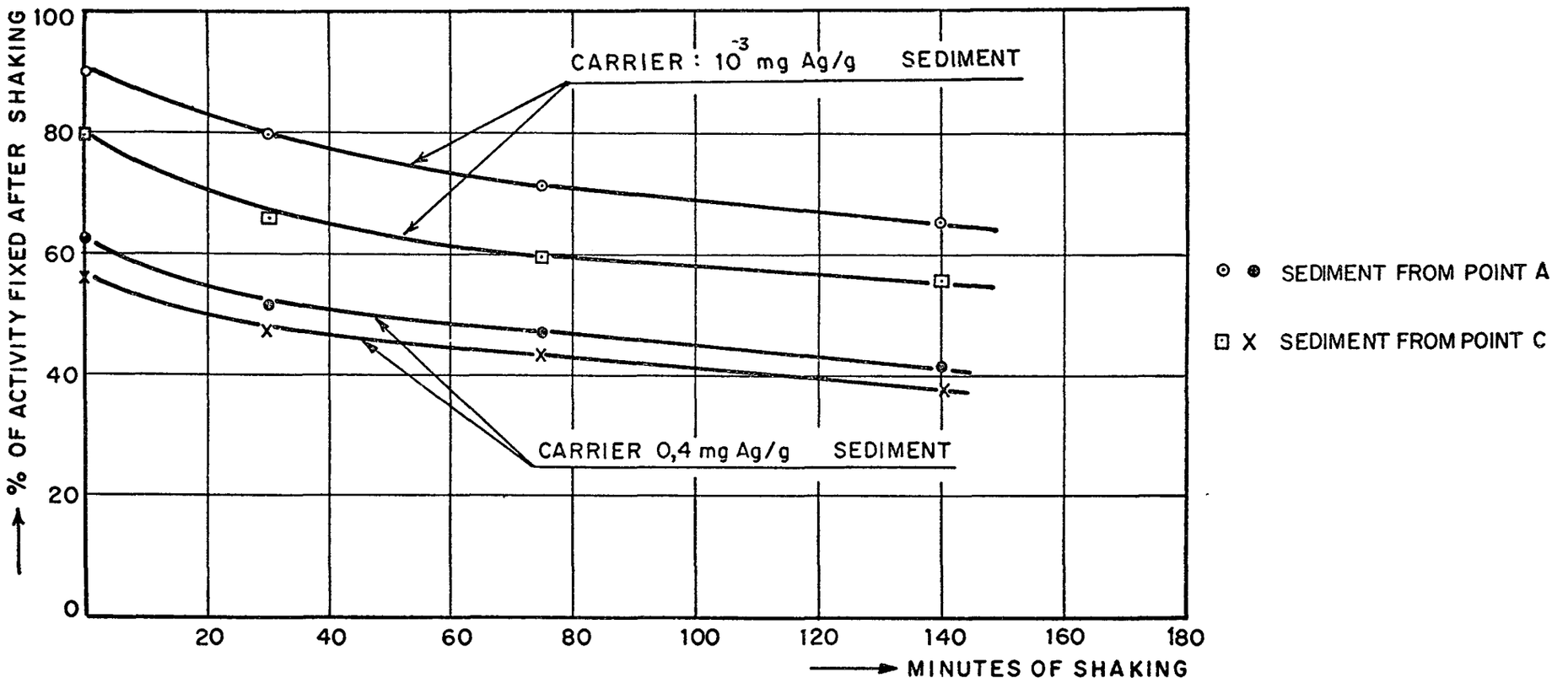


FIG. 3-6 FIXATION TESTS CURVES

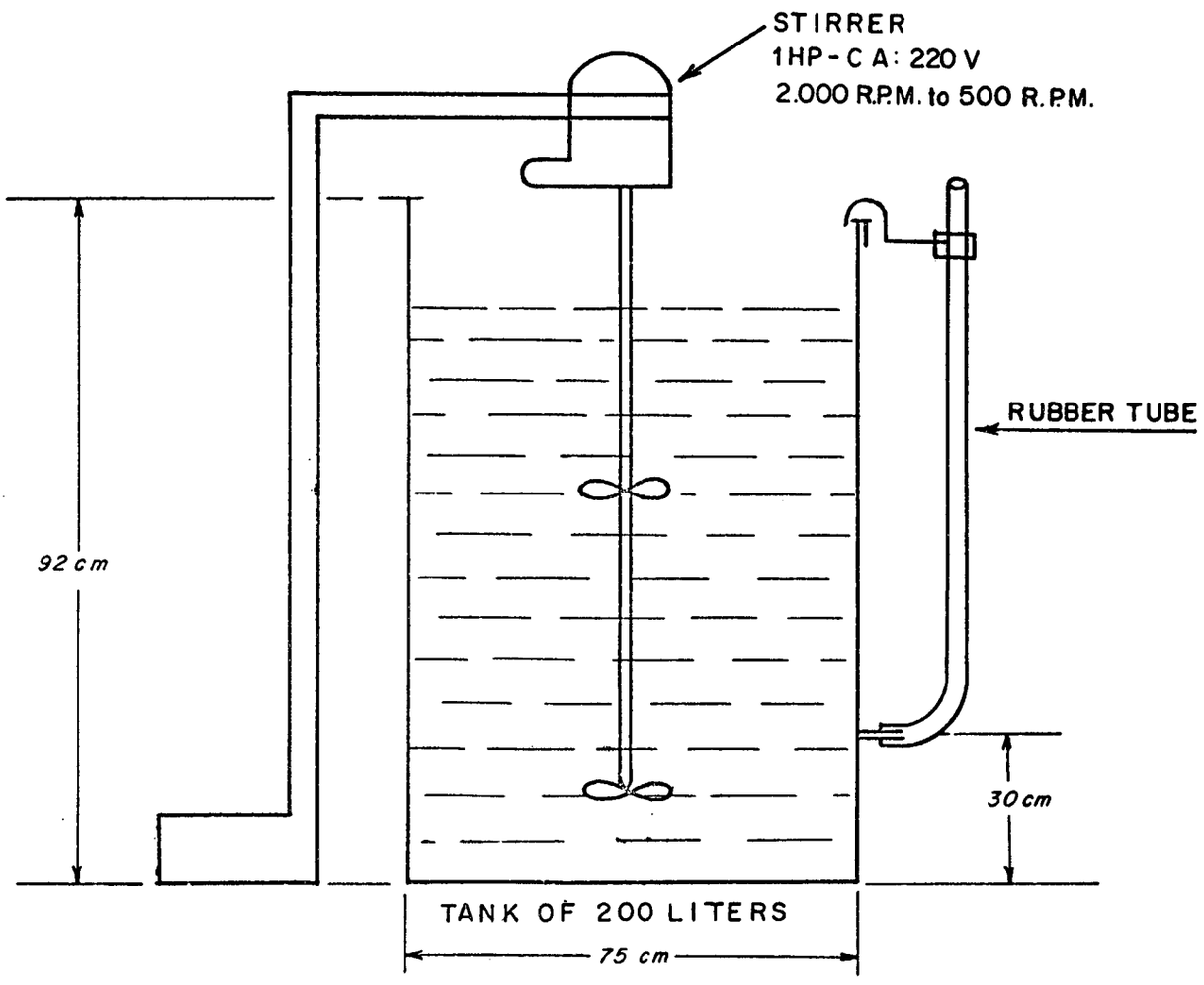


FIG. 4-1 SCHEME OF APPARATUS USED FOR SEPARATING CLAY FROM SEDIMENT.

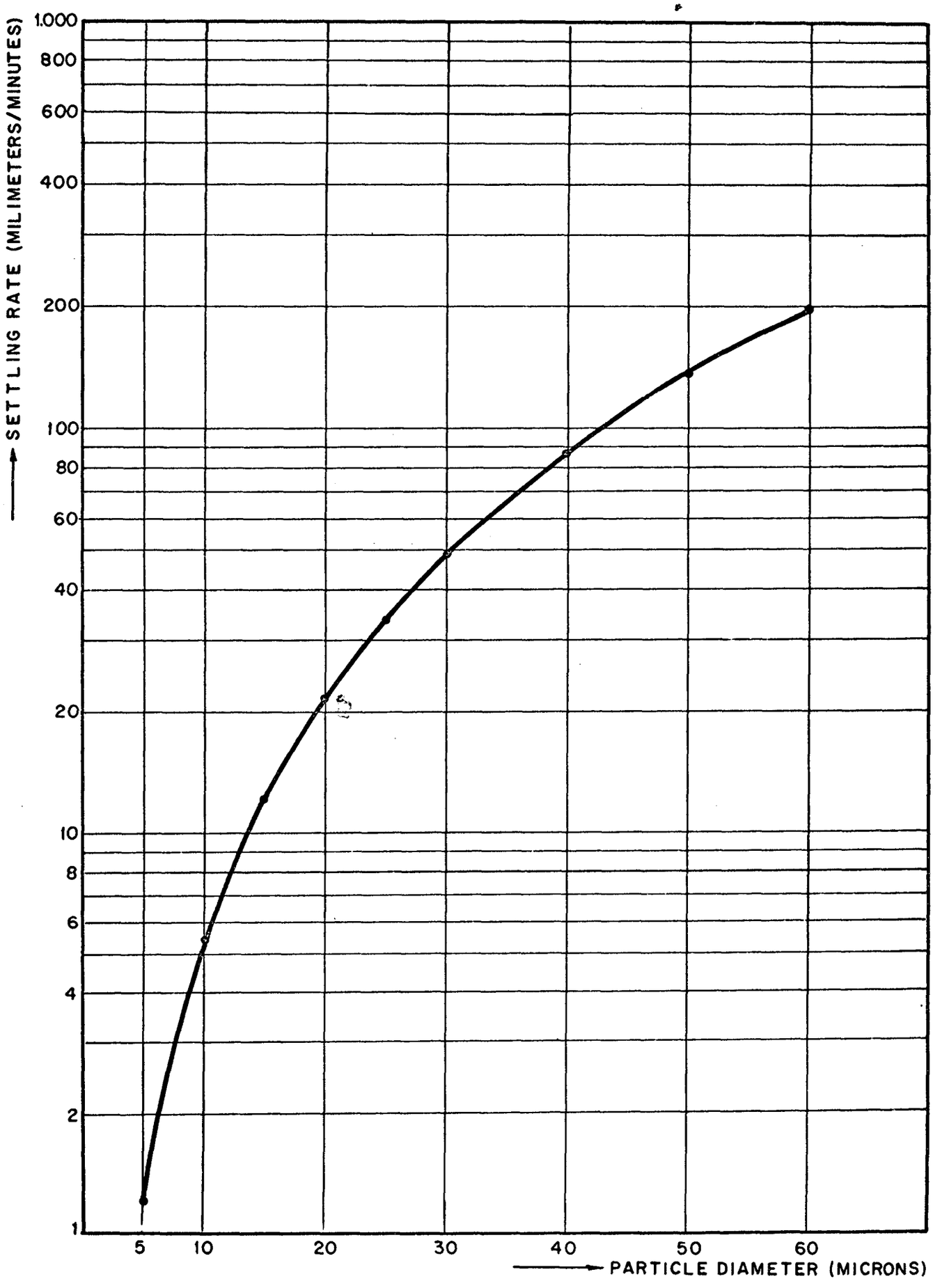


FIG. 4-2 SETTLING RATE OF PARTICLES IN WATER AT 20° C

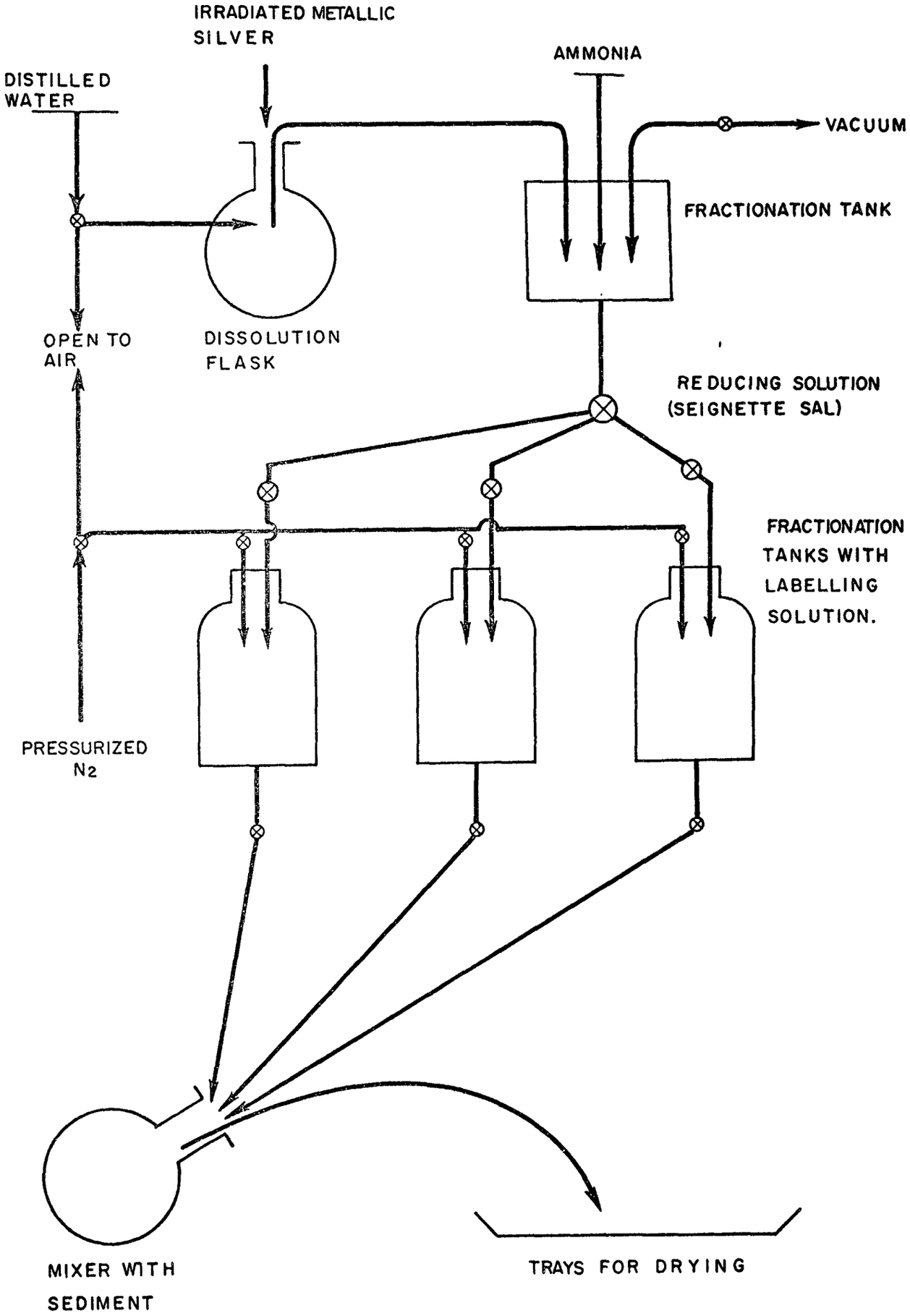


FIG. 4-3 SCHEME OF THE SYSTEM USED FOR LABELLING SEDIMENT WITH Ag-110.

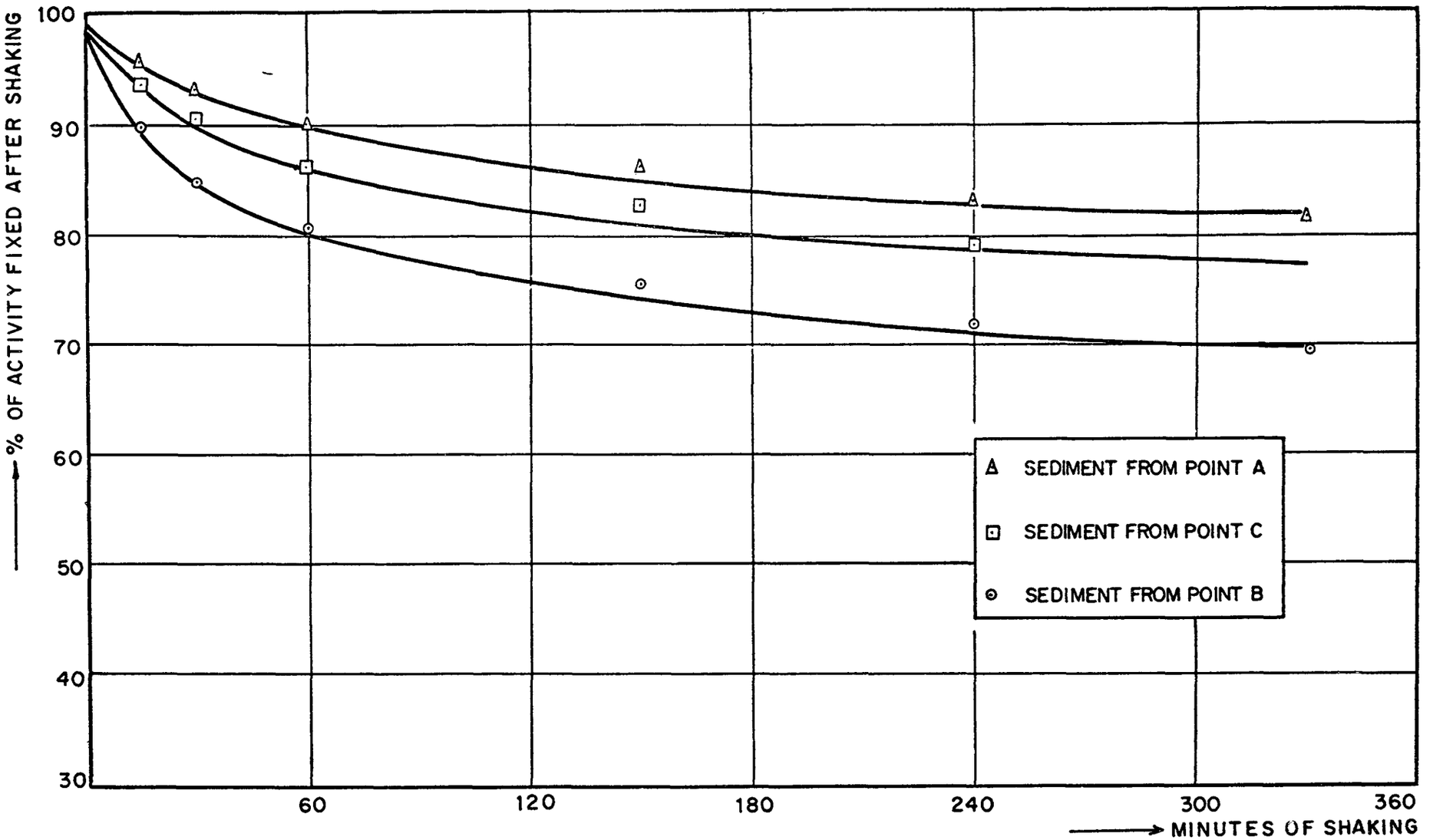


FIG. 4-4 FIXATION TEST CURVES: LABELLED SEDIMENT VIGOROUSLY STIRRED WITH NATURAL WATER FROM RIVER PLATE FOR DIFFERENT INTERVALS OF TIME.

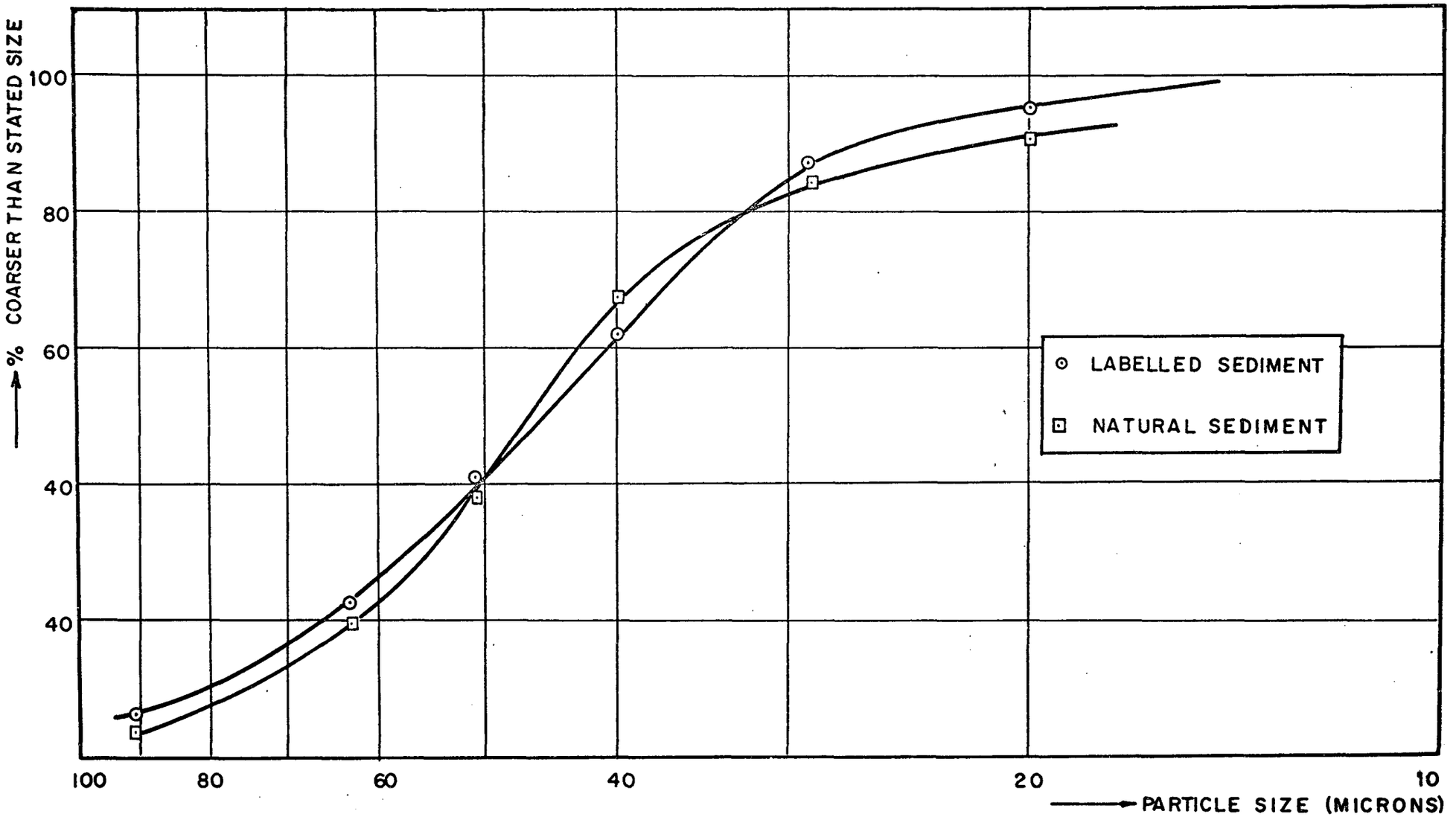


FIG. 4-5 GRAIN SIZE DISTRIBUTION CURVES OF SEDIMENT FROM POINT "A"

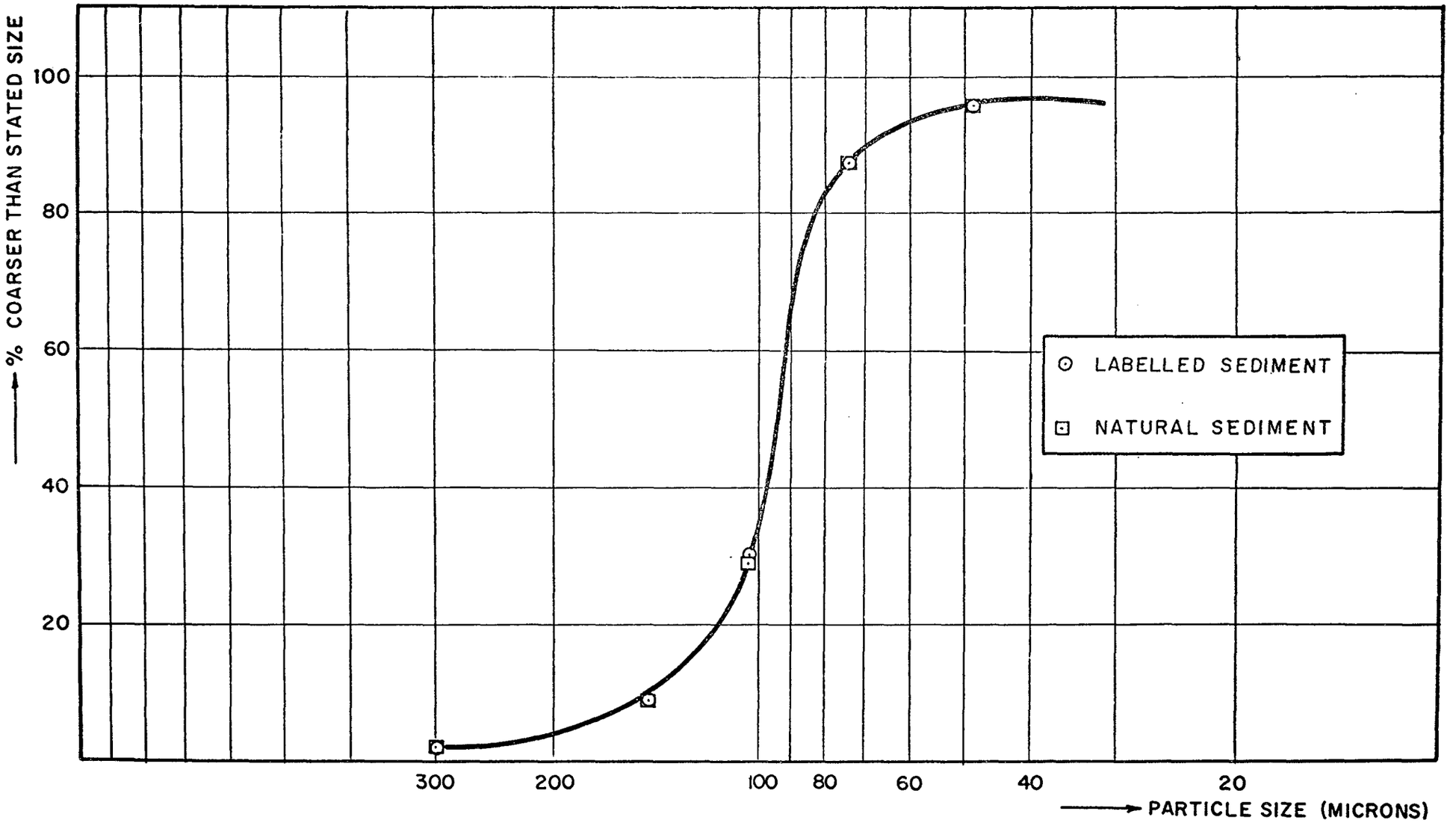


FIG. 4-7 GRAIN SIZE DISTRIBUTION CURVES OF SEDIMENT FROM POINT "B"

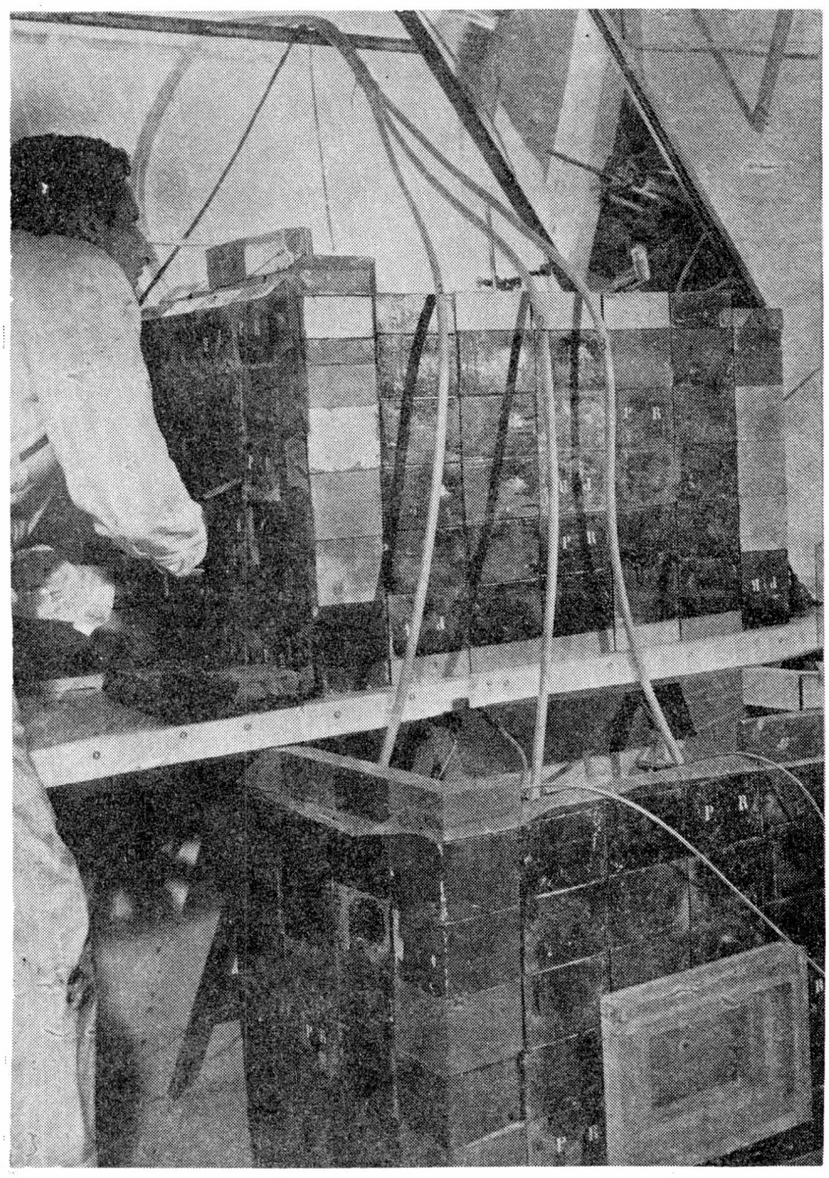


FIG. 4-8 LEAD SHIELDING FOR PROCESING RADIOACTIVE SILVER.

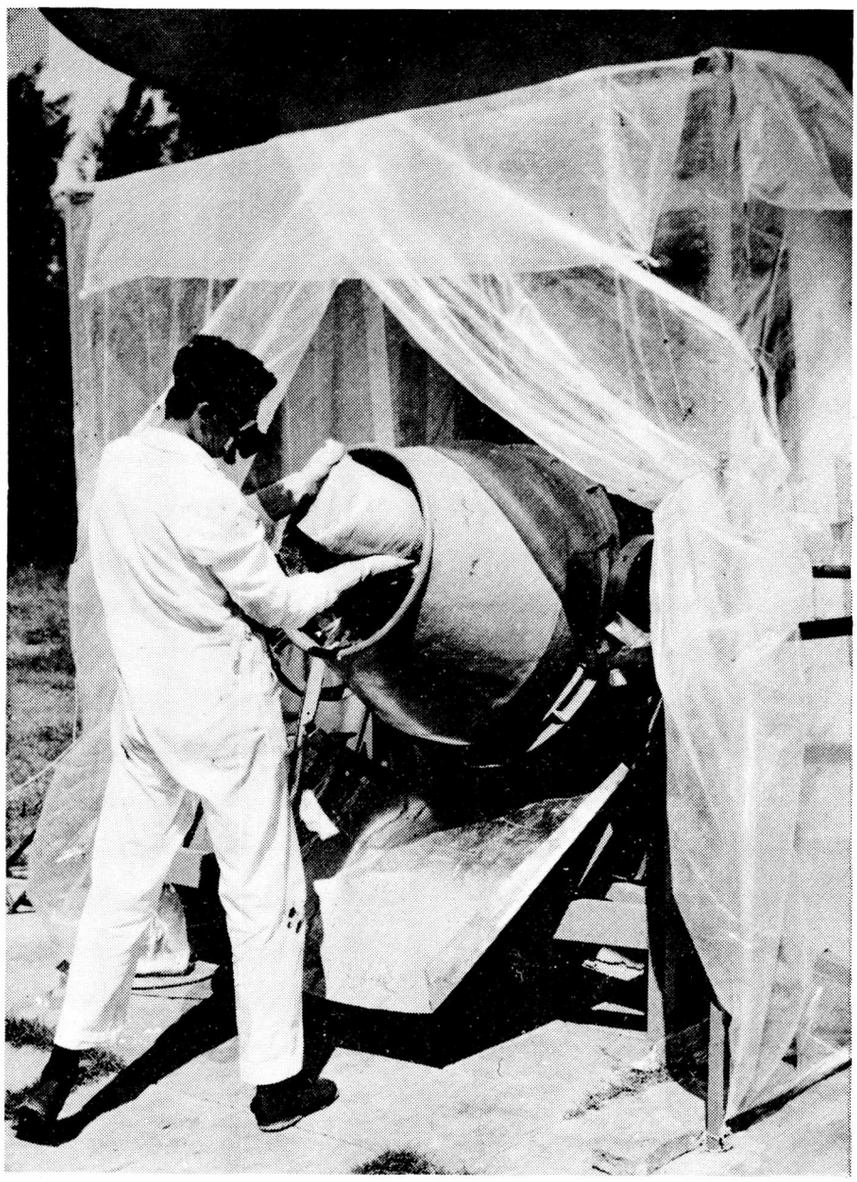


FIG. 4-9 INACTIVE SEDIMENT IS PLACED IN THE MIXER FOR LABELLING WITH Ag-110.

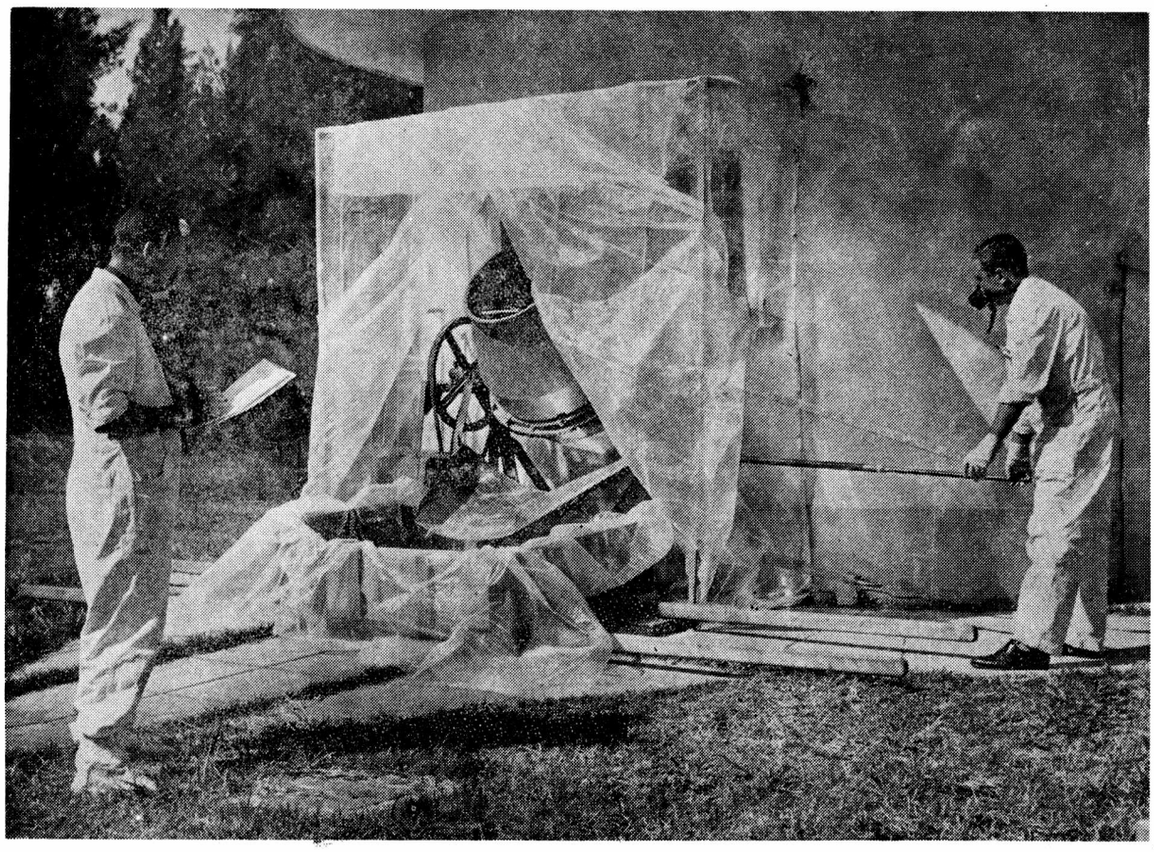


FIG. 4-10 MIXING SEDIMENT TOGETHER WITH THE LABELLING SOLUTION.

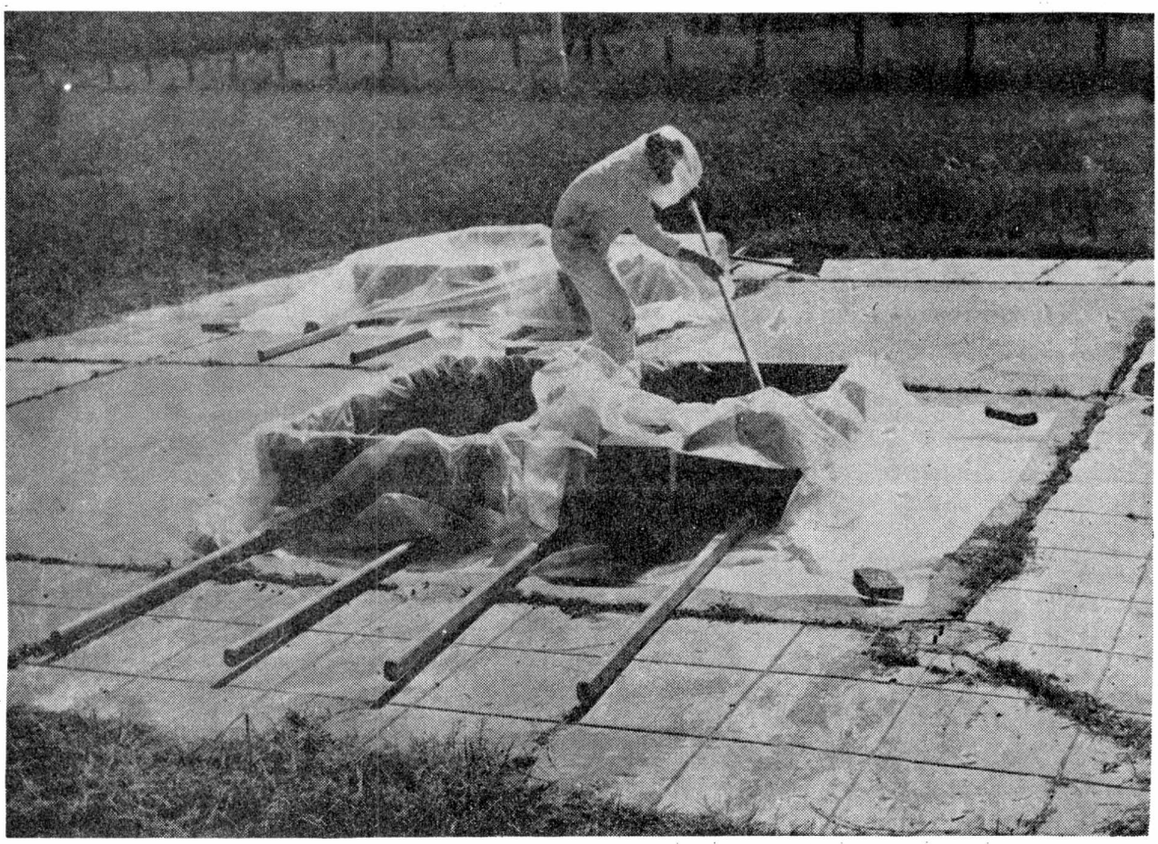


FIG. 4-11 LABELLED SEDIMENT IS PLACED AT OPEN AIR TO THE SUNLIGHT IN ORDER TO CASE THE REDUCTION OF Ag-110.

INJECTION OF LABELLED SEDIMENT ON THE RIVER-BED

LANDING BOAT L.D.2

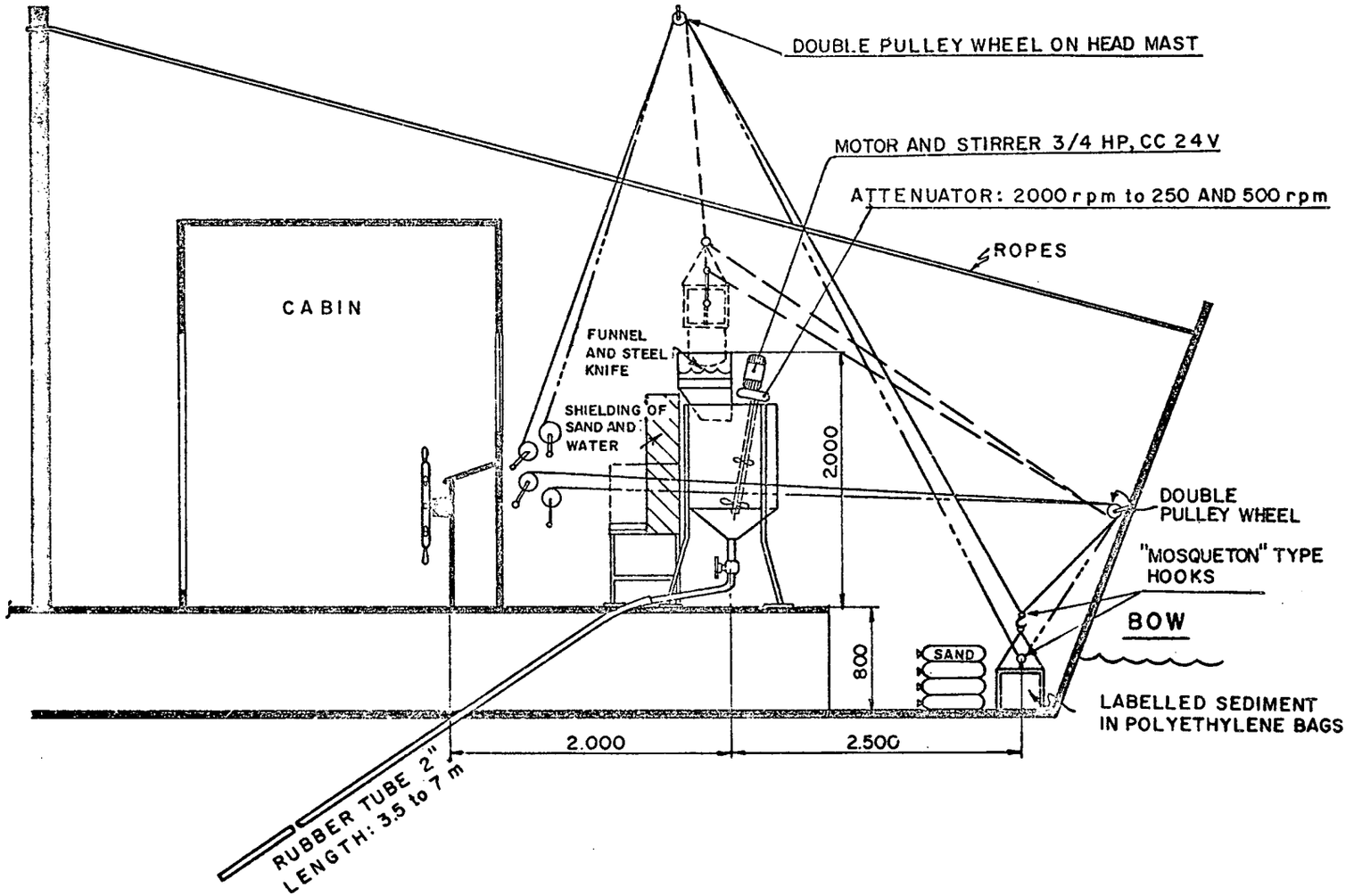


FIG. 5-1 SCHEME OF THE INJECTION SYSTEM

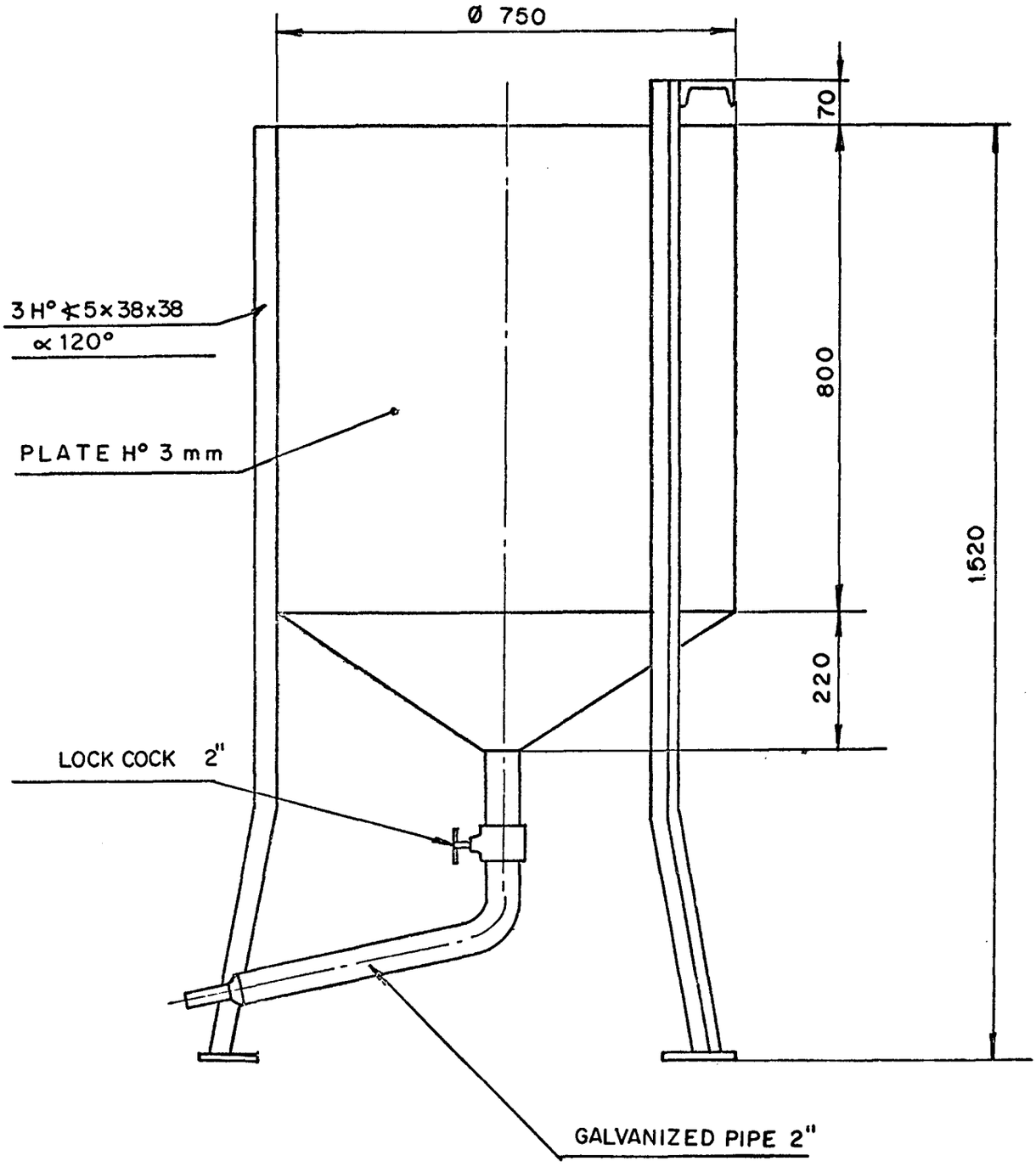


FIG. 5-2 SCHEME OF THE INJECTION TANK

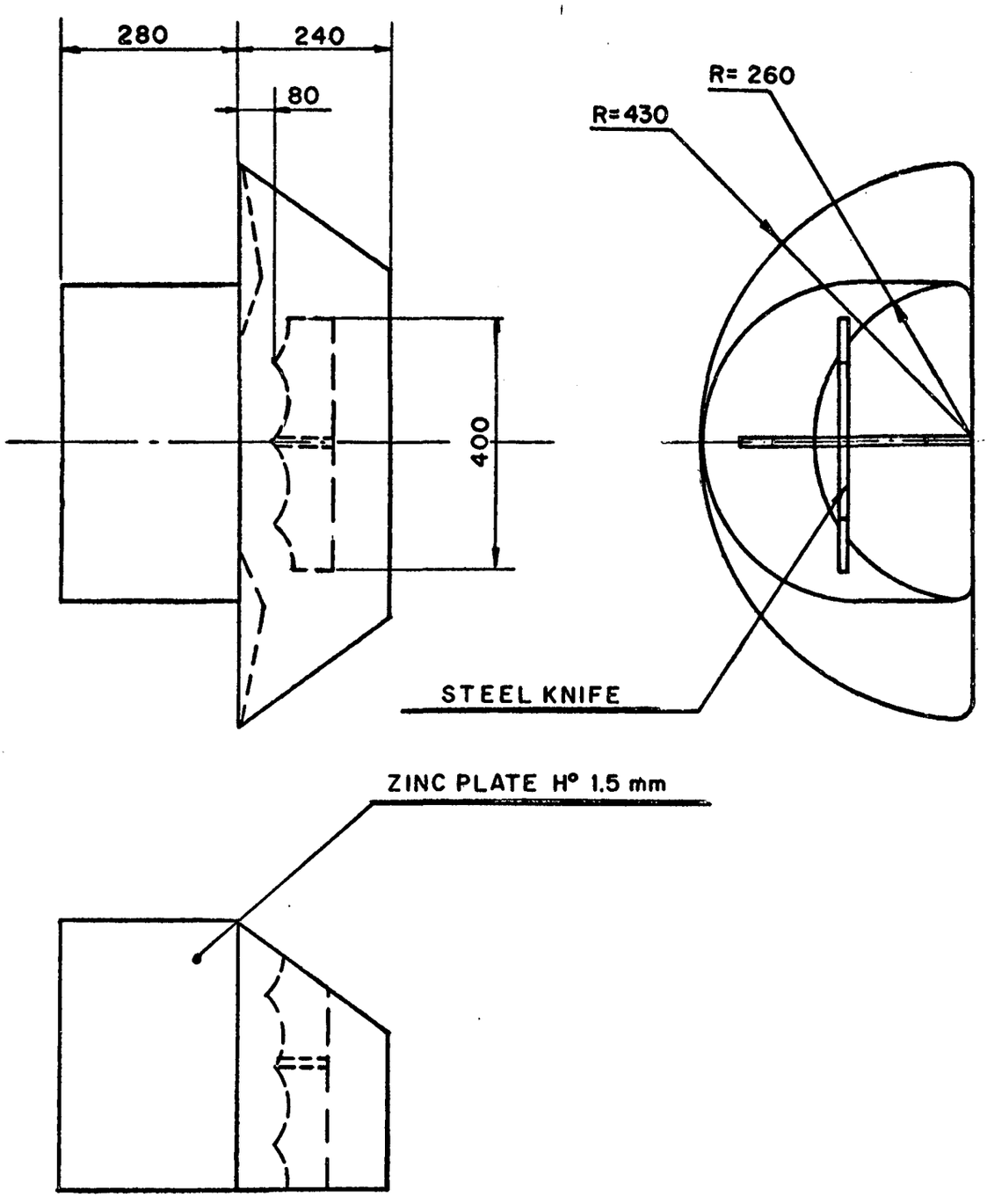


FIG. 5-3 SCHEME OF FUNNEL AND STEEL KNIFE LOCATED ON THE INJECTION TANK

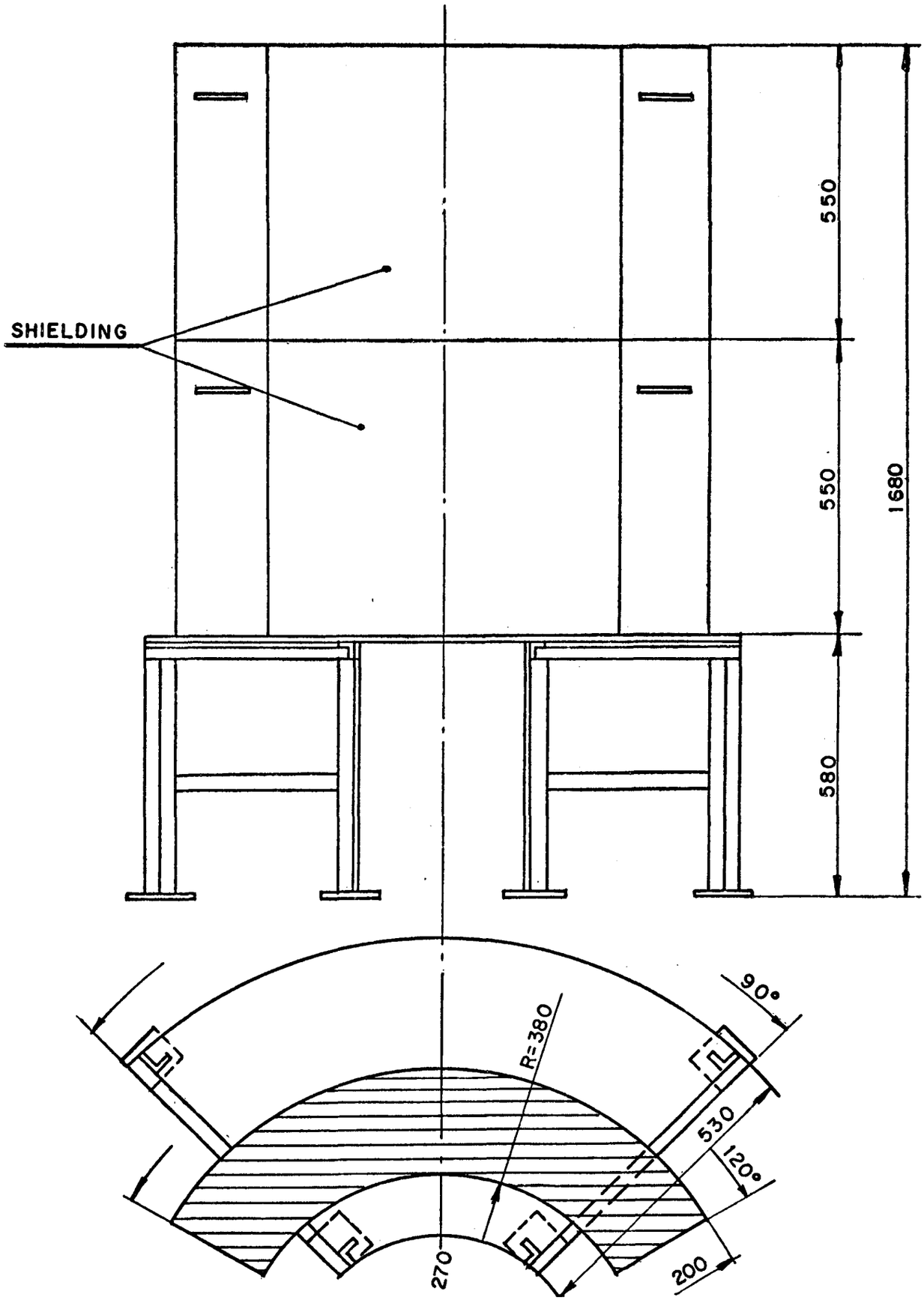


FIG. 5-4 SHIELDING FOR THE INJECTION TANK

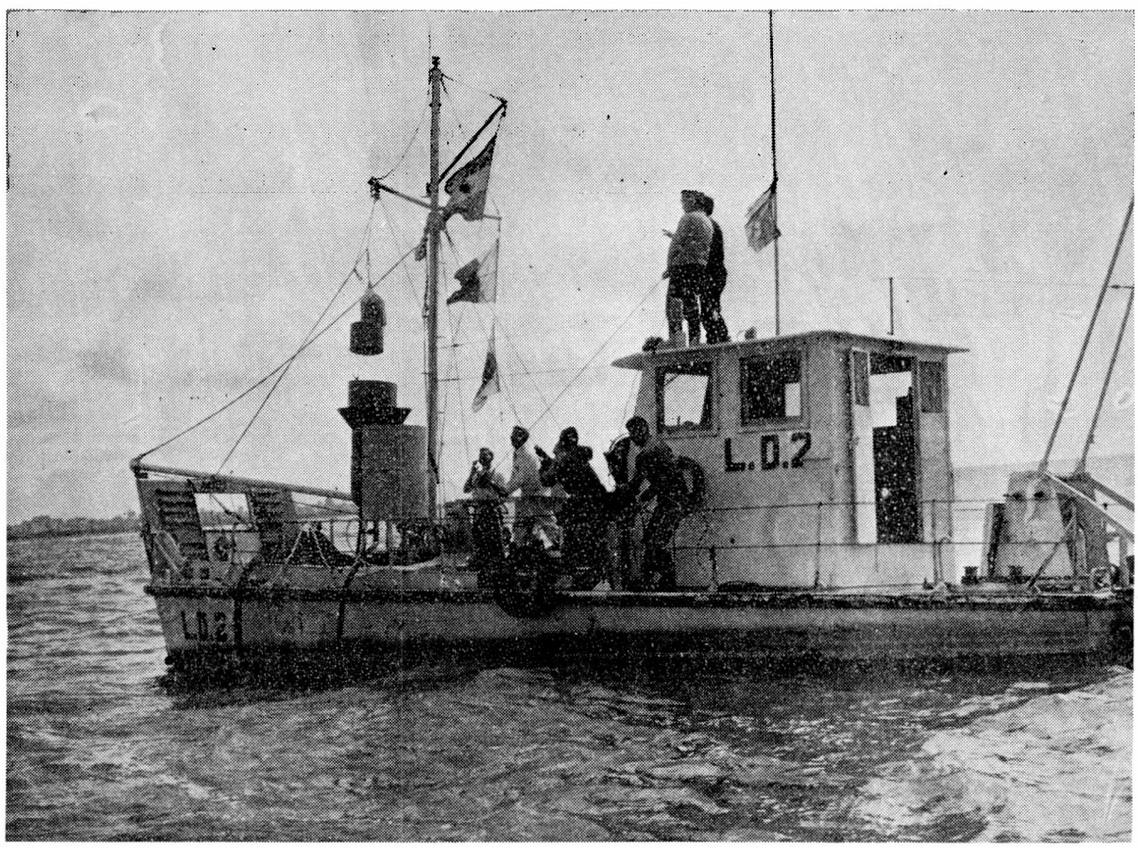


FIG.5-5 INJECTION BOAT OPERATING IN RIO DE LA PLATA

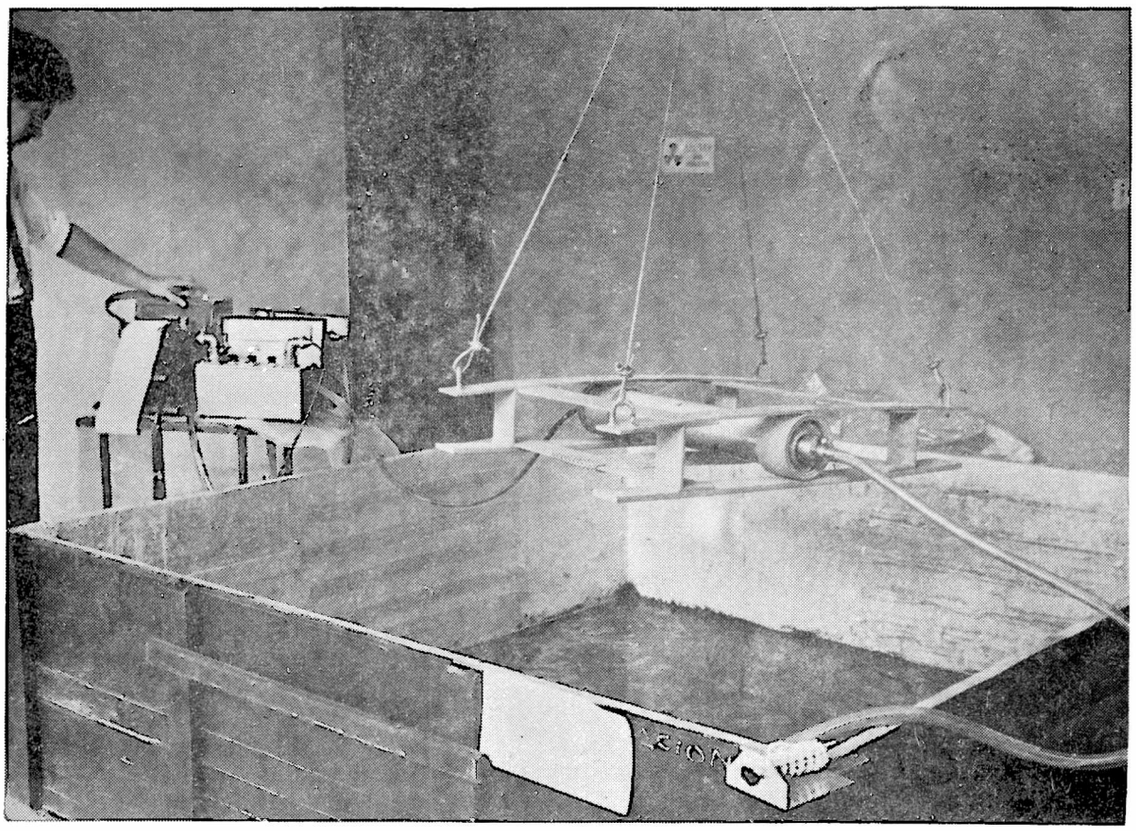


FIG. 6-1 WOODEN POOL FOR CALIBRATION EXPERIMENTS

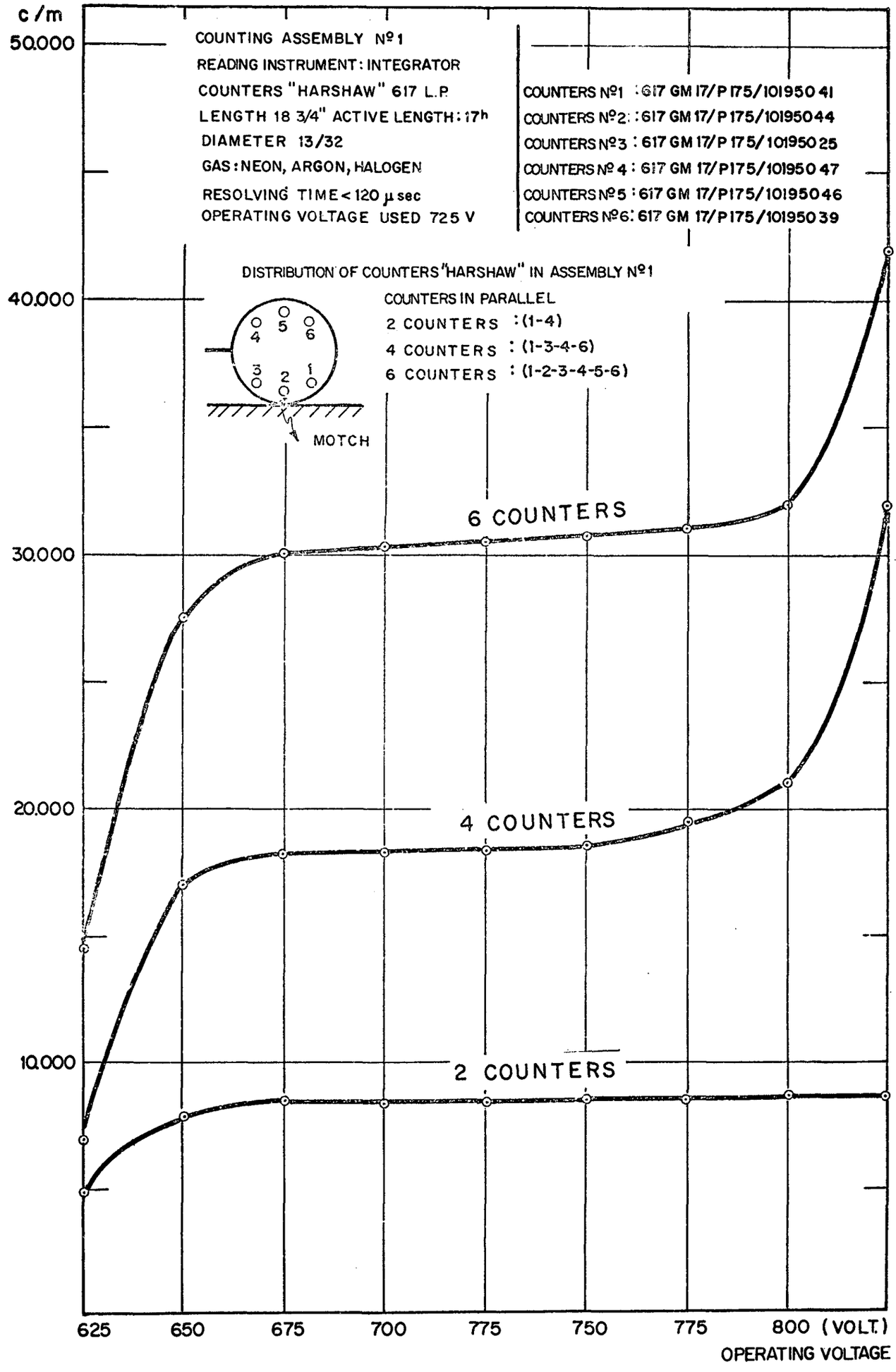
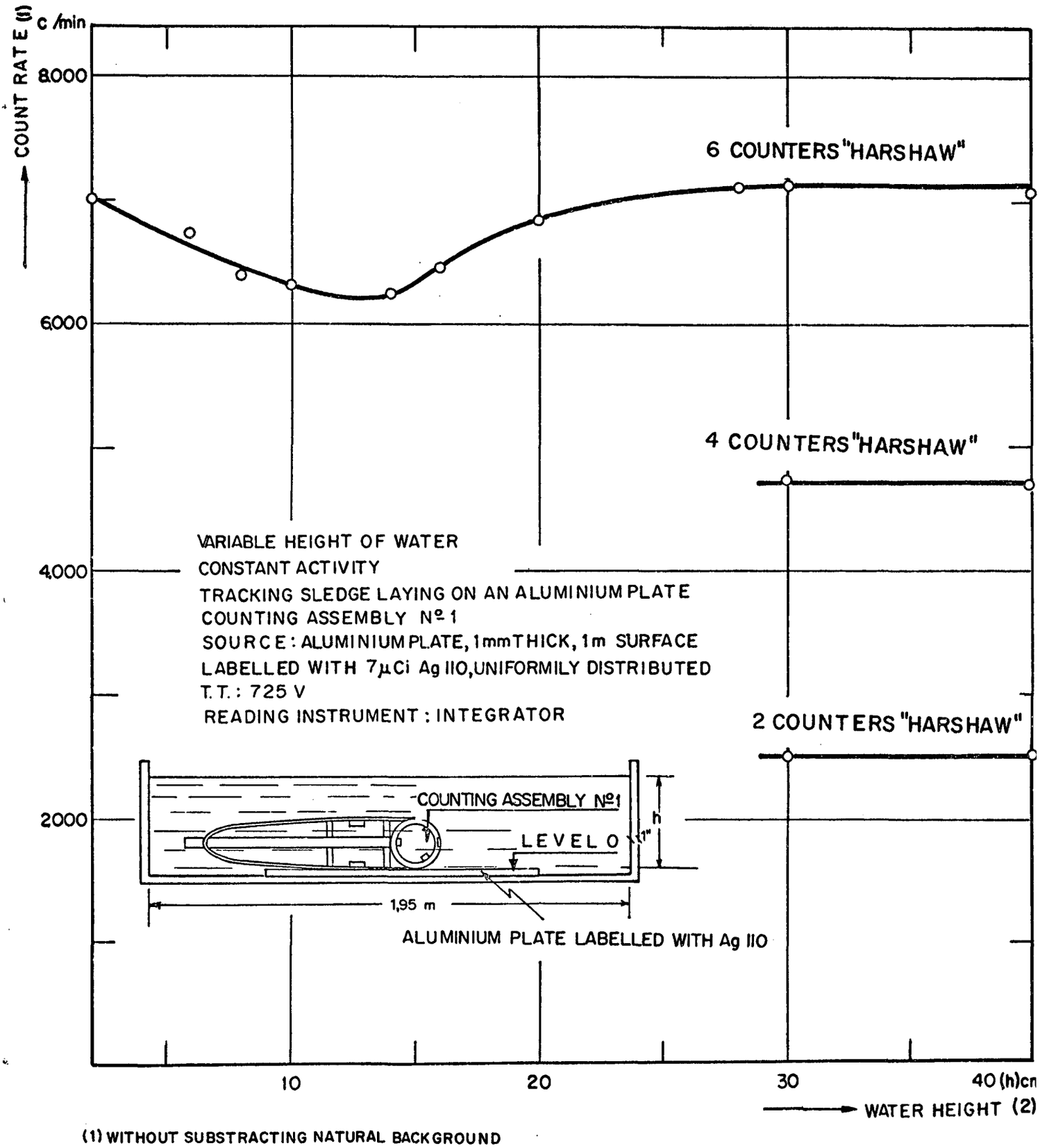


FIG. 6-2 GEIGER-MULLER PLATEAU



(1) WITHOUT SUBSTRACTING NATURAL BACKGROUND

(2) LEVEL ZERO CORRESPONDS TO ALUMINIUM PLATE

FIG. 6-3 EFFECT OF WATER DEPTH ON COUNT RATE

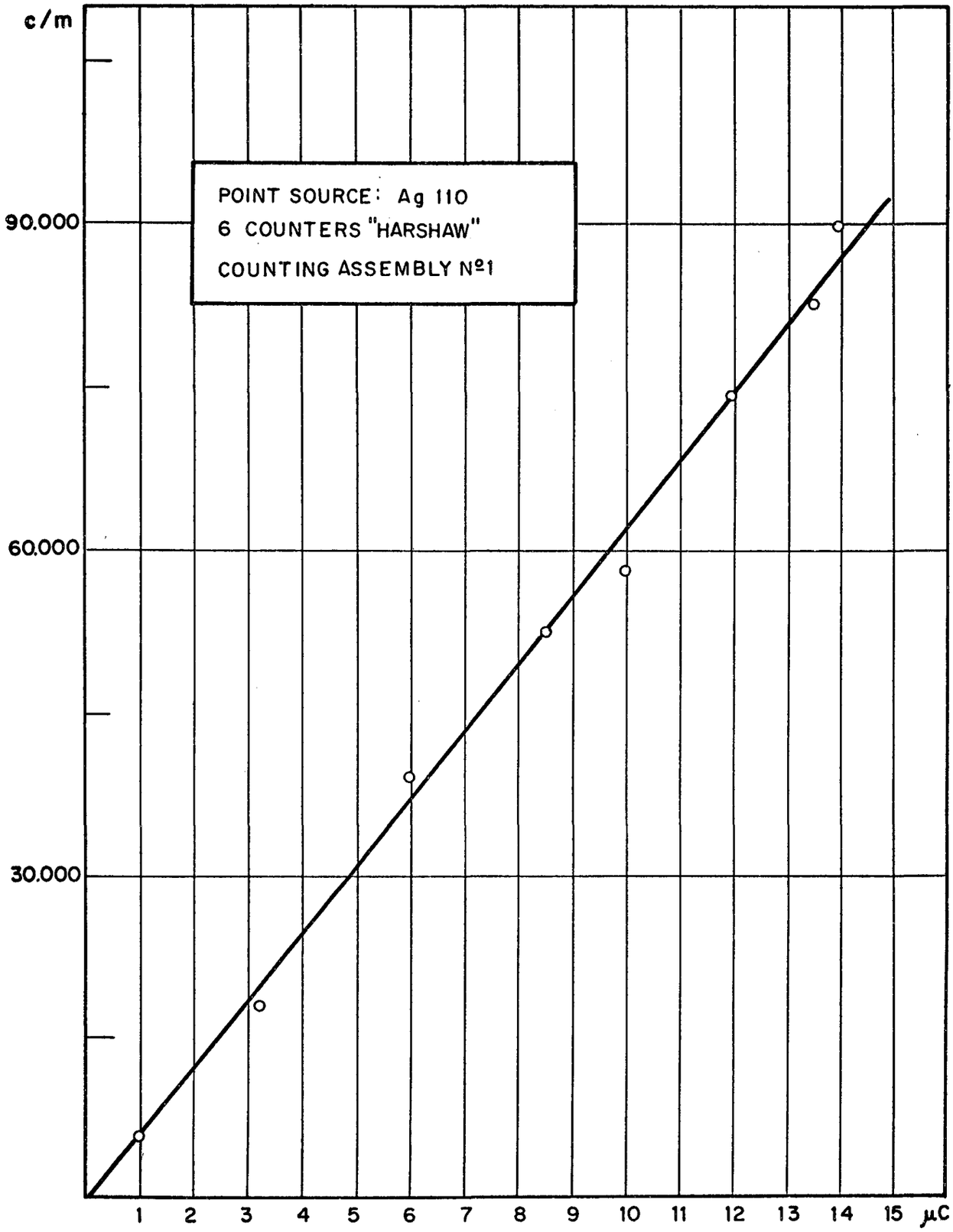
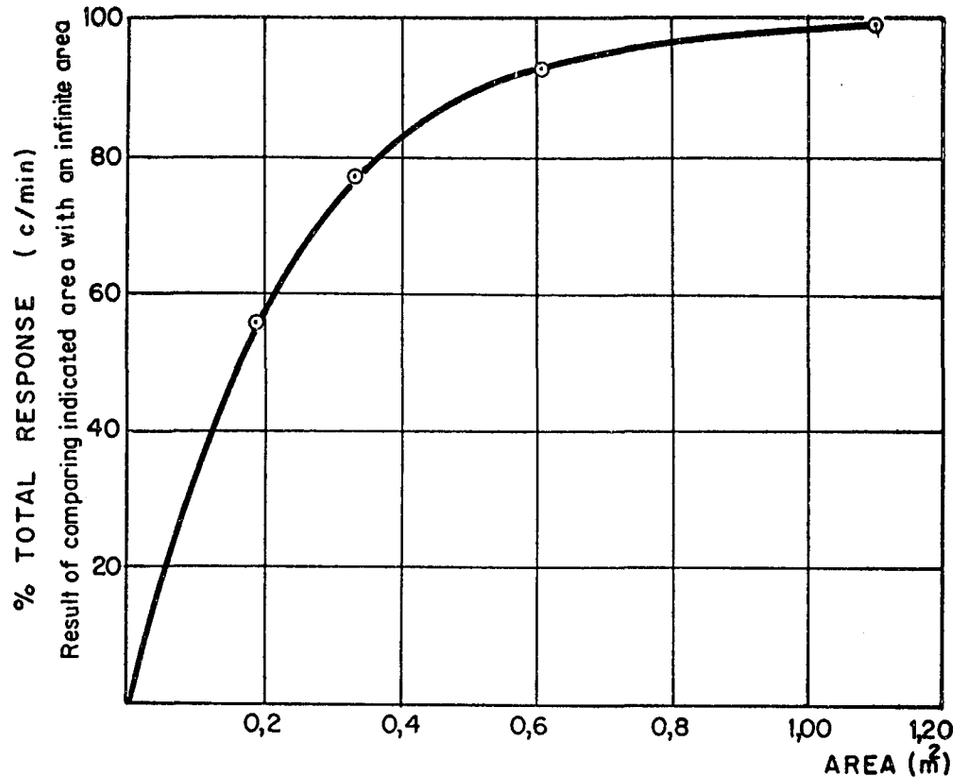


FIG. 6-4 LINEAR CORRESPONDENCE BETWEEN COUNTS READ AND ACTIVITY.

TRACKING SLEDGE
COUNTING ASSEMBLY Nº 1
READING INSTRUMENT: GRAPHIC RECORDER
HEIGHT OF WATER: 30 cm
"POINT" SOURCE OF Ag 110



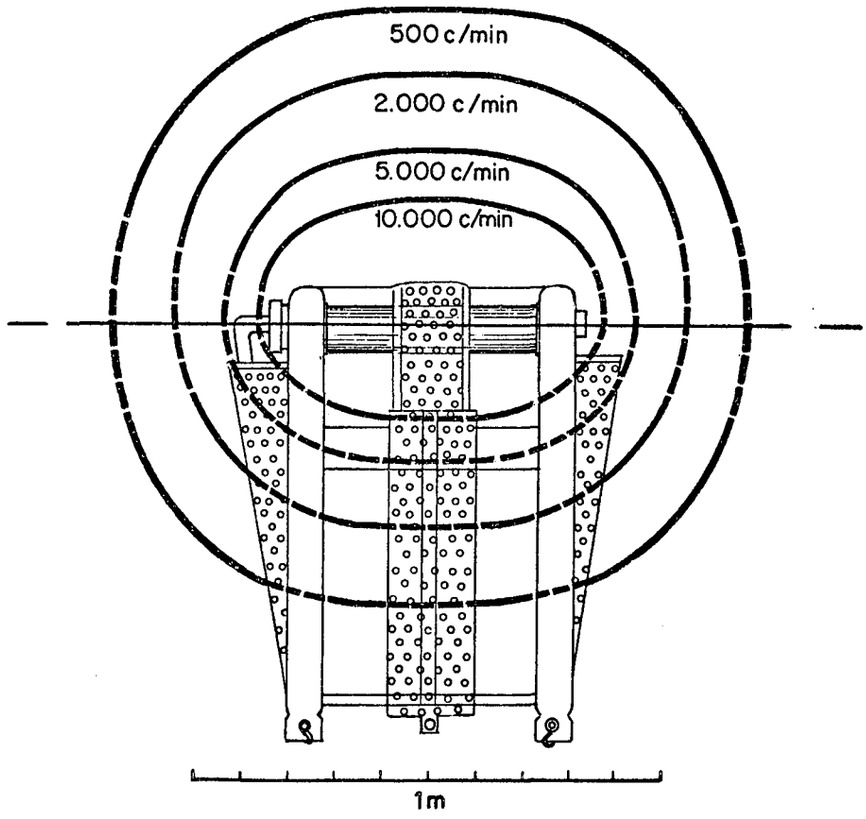


FIG. 6-5 AREA SENSITIVITY OF THE DETECTOR

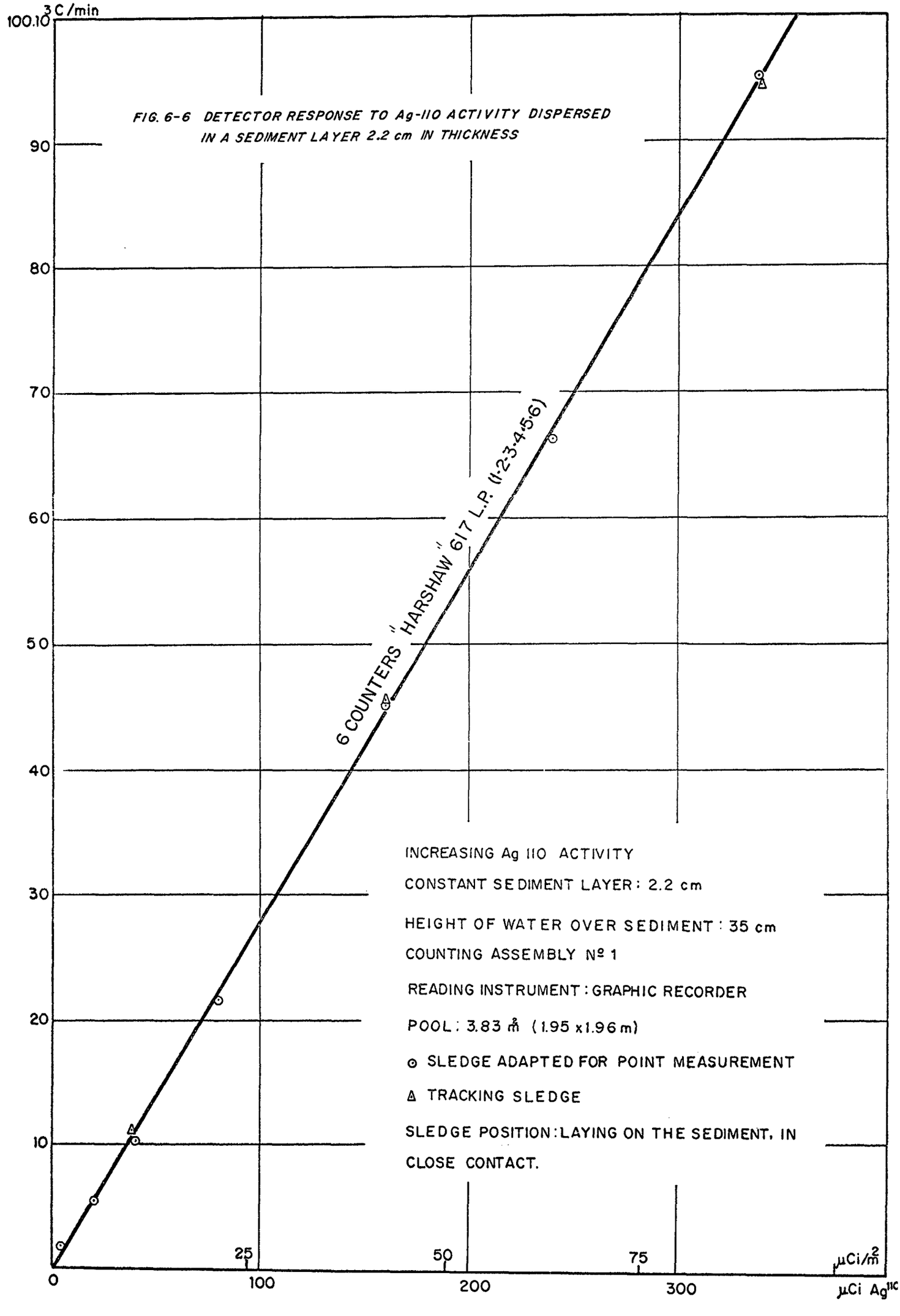


FIG. 6-6 DETECTOR RESPONSE TO Ag-110 ACTIVITY DISPERSED IN A SEDIMENT LAYER 2.2 cm IN THICKNESS

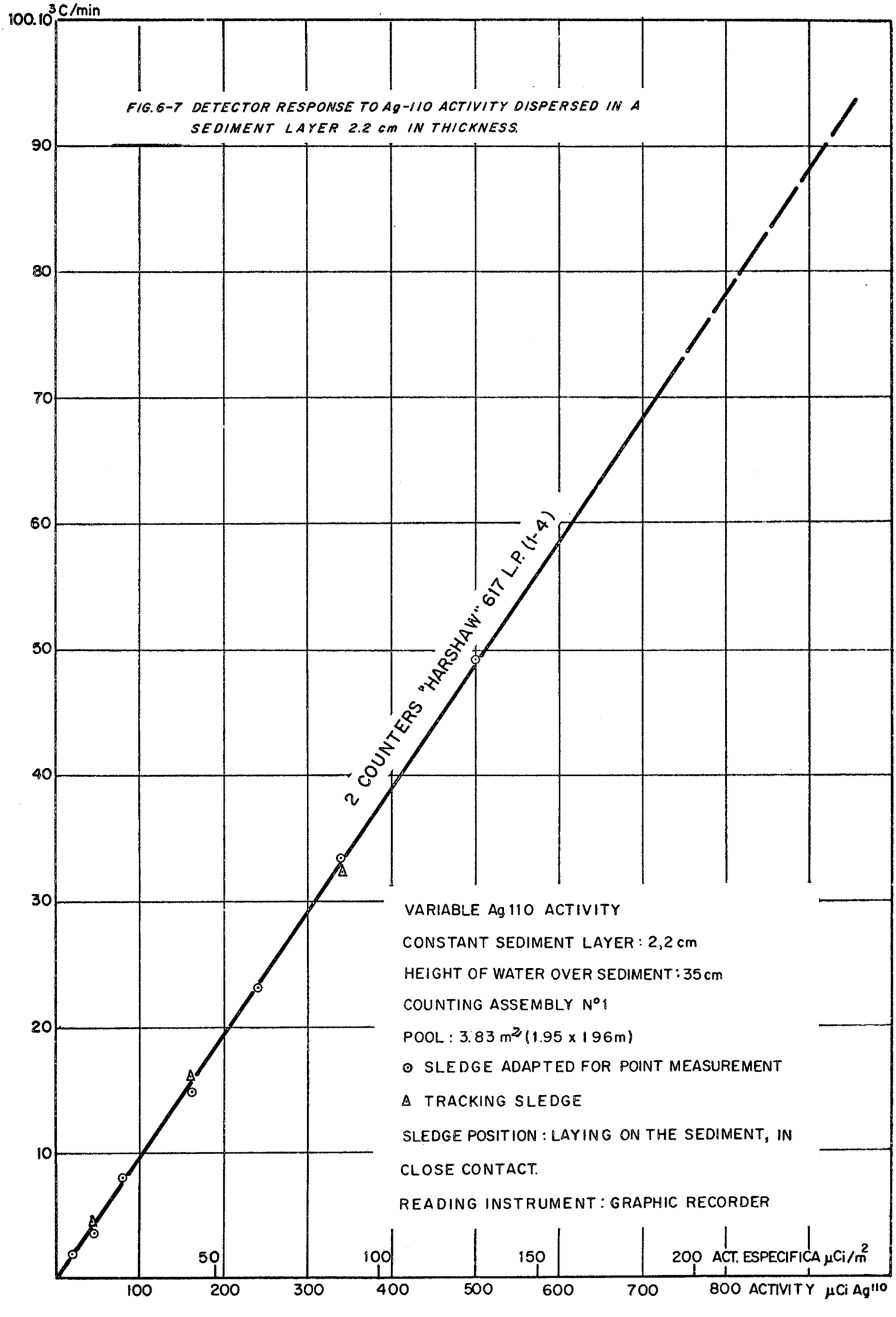


FIG. 6-7 DETECTOR RESPONSE TO Ag-110 ACTIVITY DISPERSED IN A SEDIMENT LAYER 2.2 cm IN THICKNESS.

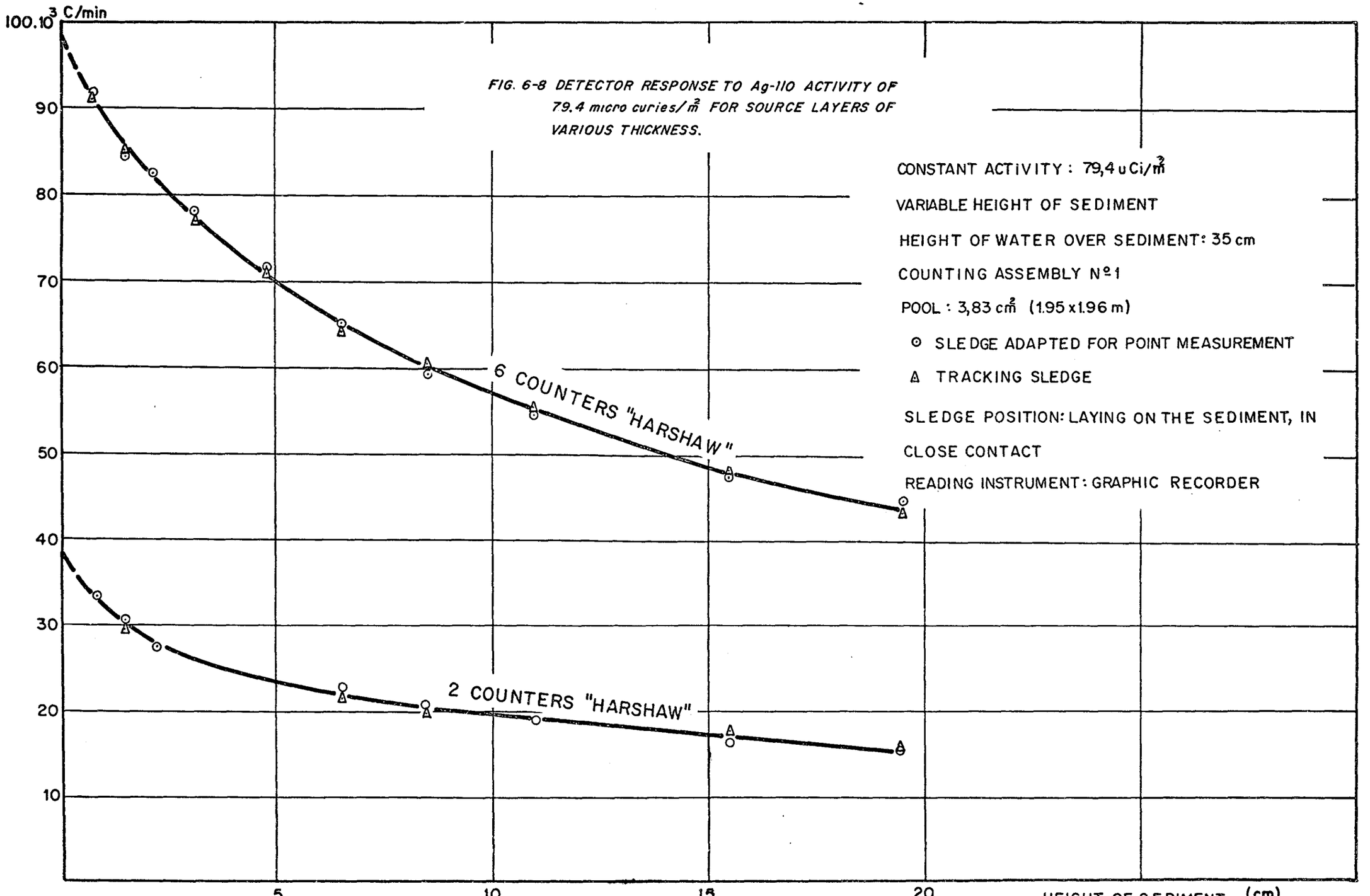


FIG. 6-8 DETECTOR RESPONSE TO Ag-110 ACTIVITY OF 79.4 micro curies/m² FOR SOURCE LAYERS OF VARIOUS THICKNESS.

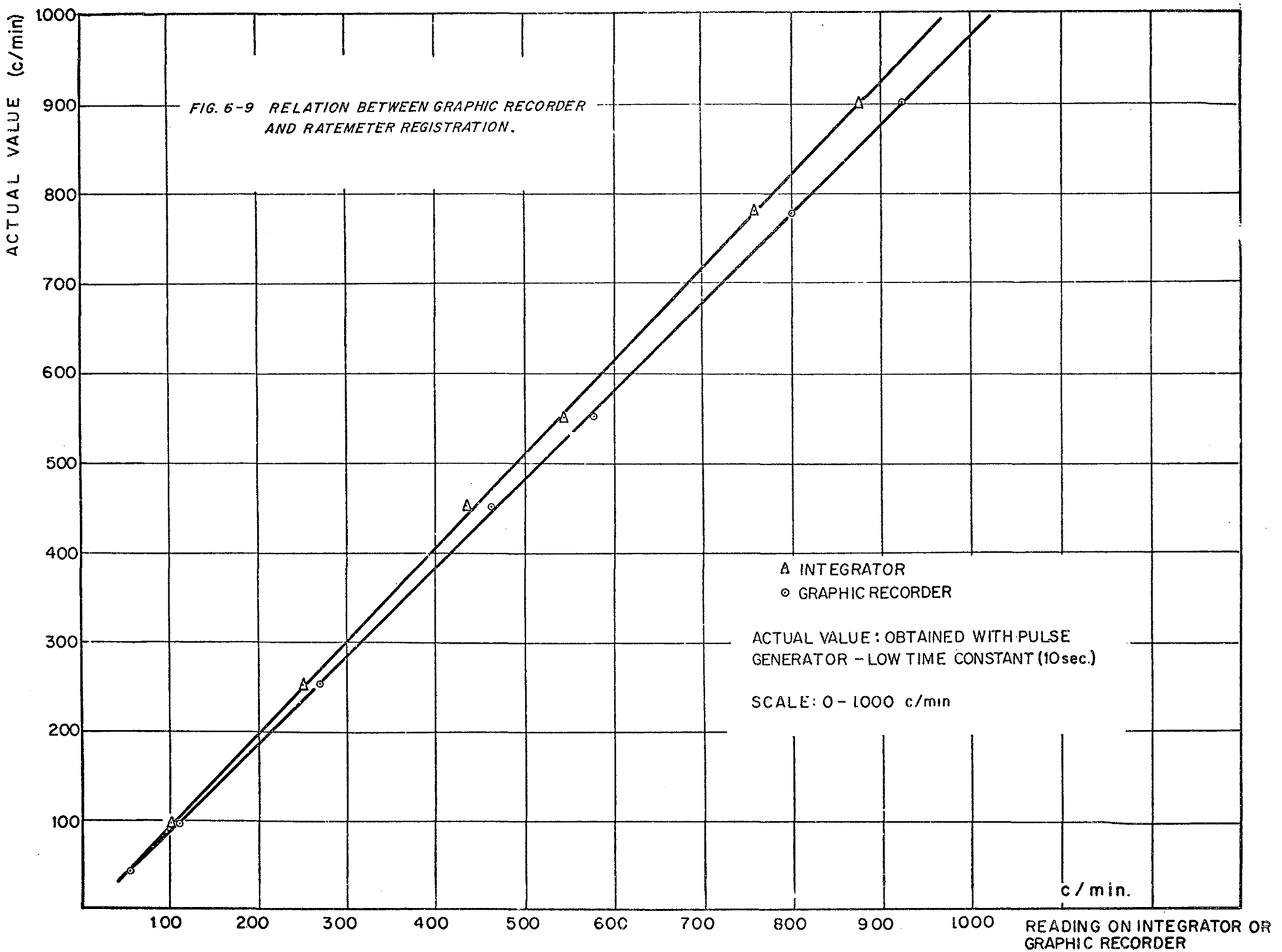
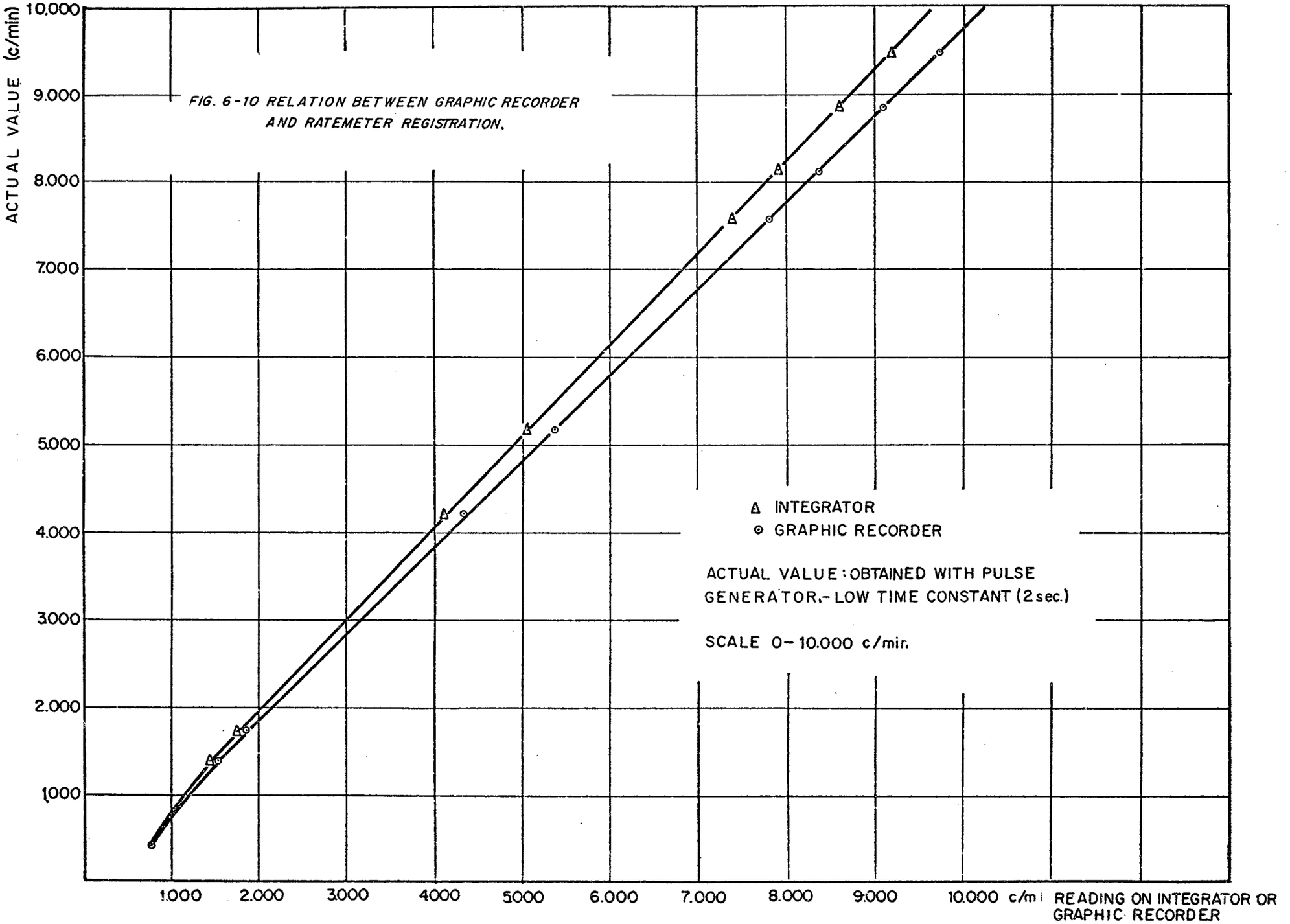
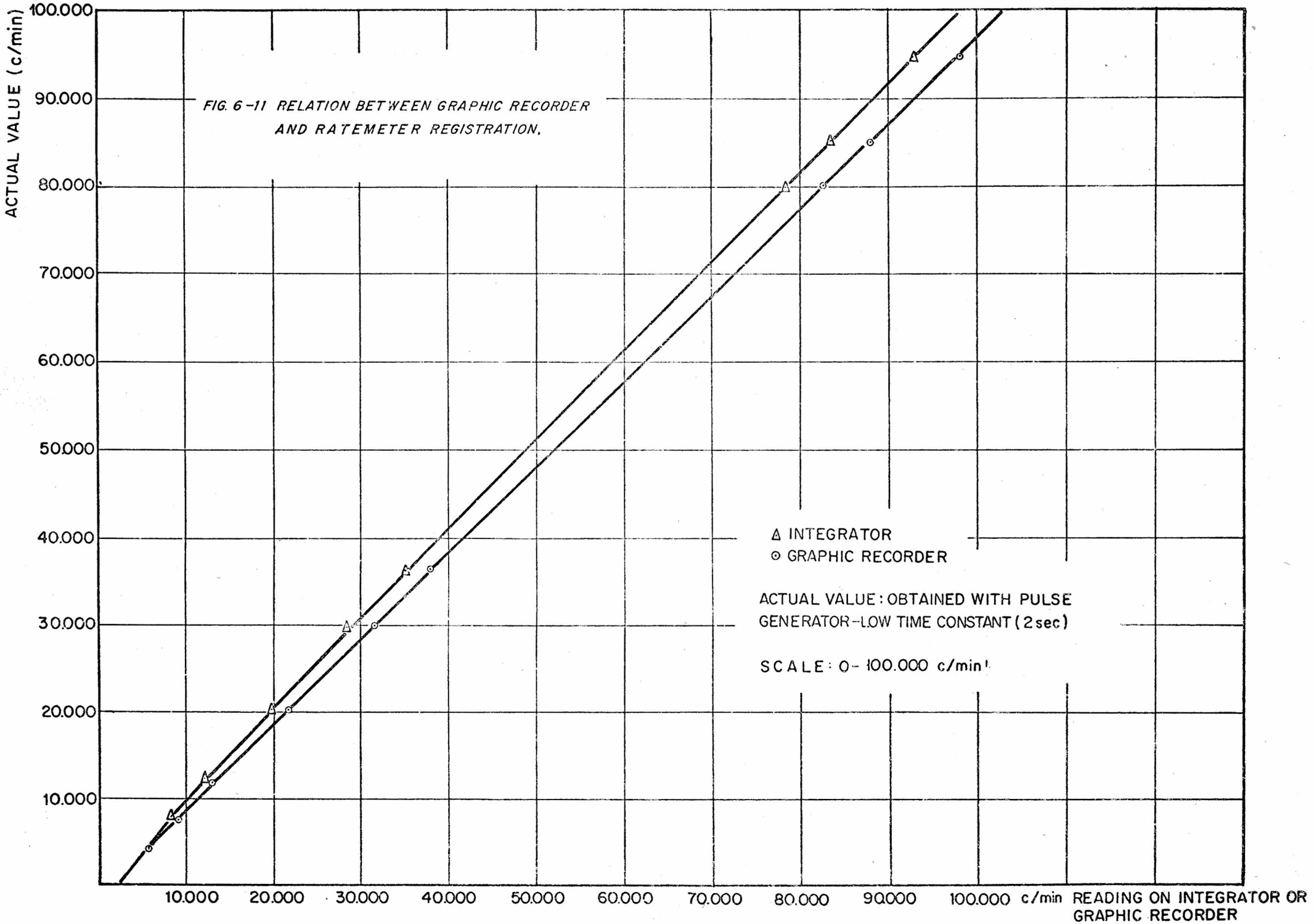


FIG. 6-9 RELATION BETWEEN GRAPHIC RECORDER AND RATEMETER REGISTRATION.


ACTUAL VALUE (c/min)
10.000
9.000
8.000
7.000
6.000
5.000
4.000
3000
2.000
1000
1.000
2.000
3000
4000
5000
6.000
7.000
8.000
9.000
10.000 c/m
READING ON INTEGRATOR OR GRAPHIC RECORDER
FIG. 6-10 RELATION BETWEEN GRAPHIC RECORDER AND RATEMETER REGISTRATION.
INTEGRATOR
GRAPHIC RECORDER
ACTUAL VALUE: OBTAINED WITH PULSE GENERATOR.- LOW TIME CONSTANT (2 sec.)
SCALE 0- 10.000 c/min.


ACTUAL VALUE (c/min)
100.000
90.000
80.000
70.000
60.000
50.000
40.000
30.000
20.000
10.000
FIG. 6-11 RELATION BETWEEN GRAPHIC RECORDER AND RATEMETER REGISTRATION.
Δ INTEGRATOR
⊙ GRAPHIC RECORDER
ACTUAL VALUE: OBTAINED WITH PULSE GENERATOR-LOW TIME CONSTANT (2 sec)
SCALE: 0-100.000 c/min
10.000
20.000
30.000
40.000
50.000
60.000
70.000
80.000
90.000
100.000 c/min READING ON INTEGRATOR OR GRAPHIC RECORDER

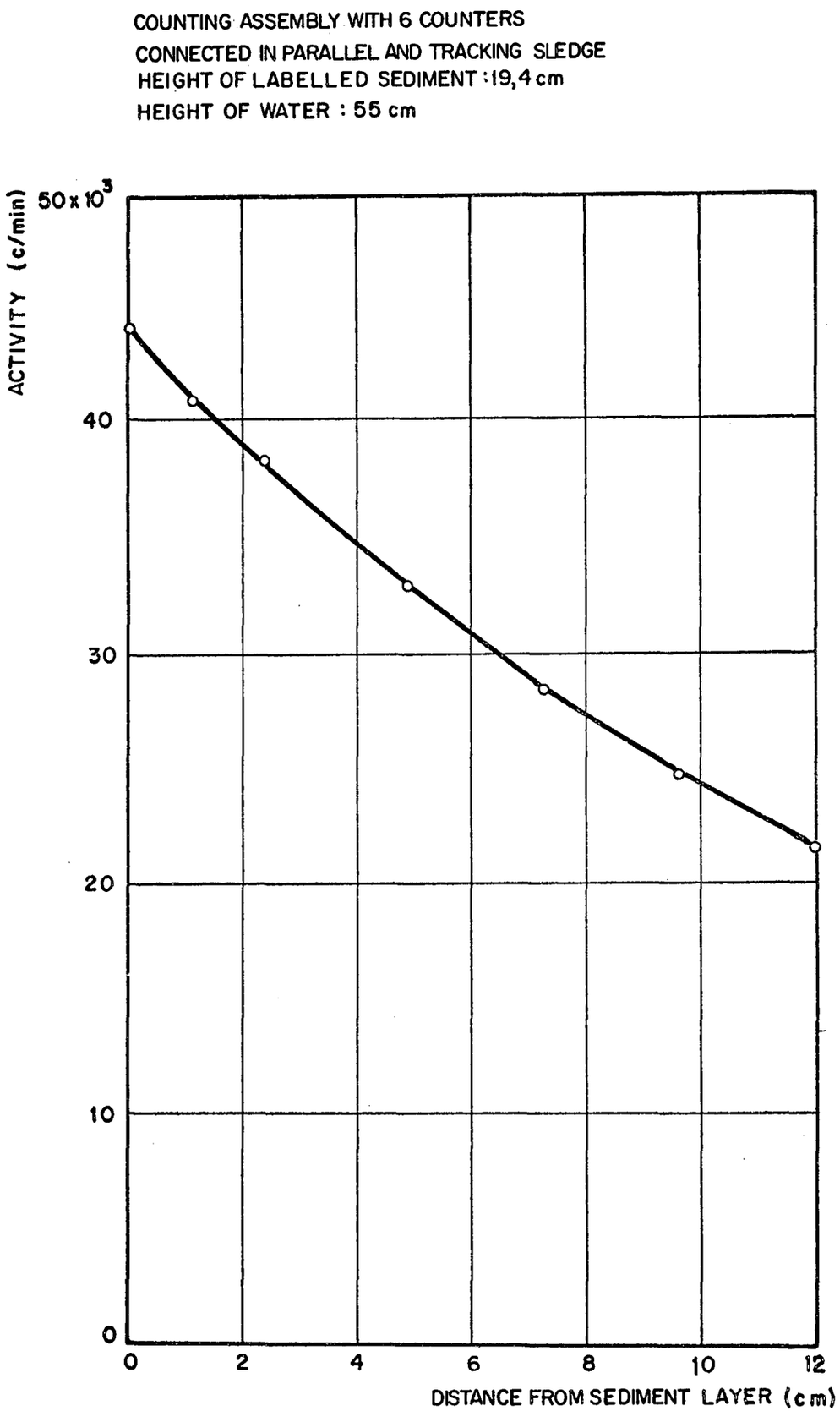
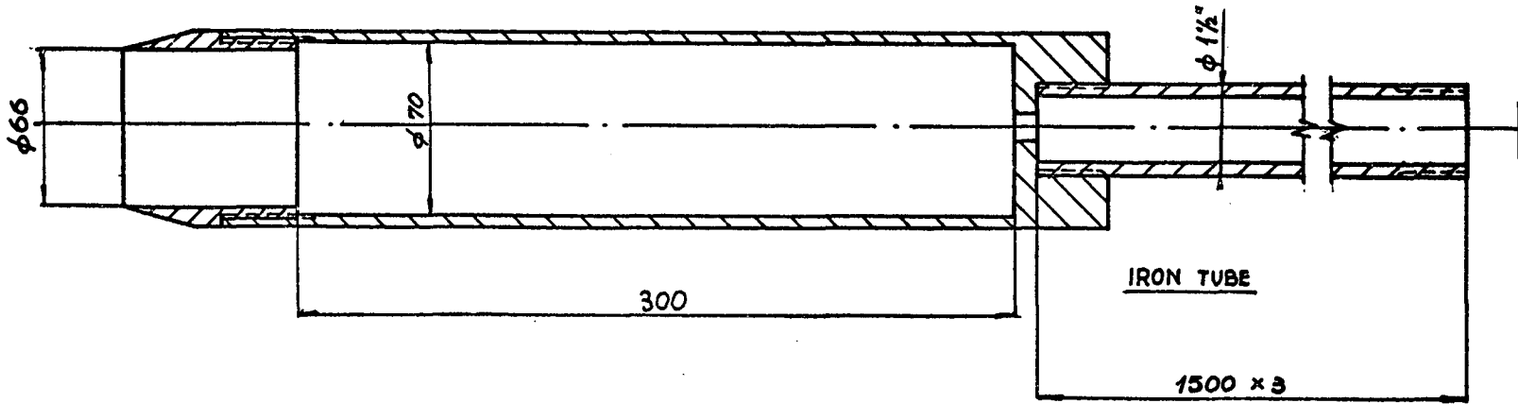
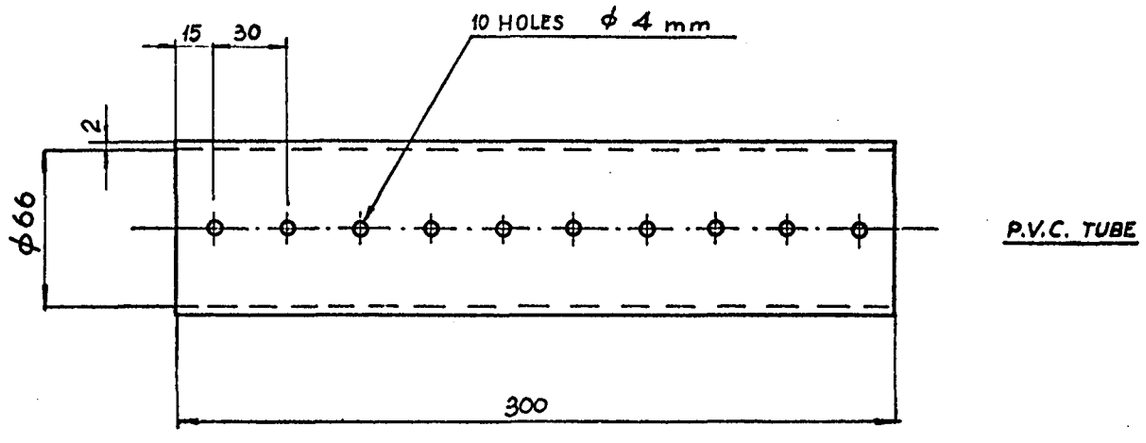


FIG. 6-12 ABSORPTION OF RADIATION OF A LAYER SOURCE OF RADIOACTIVE SEDIMENT BY DIFFERENT HEIGHTS OF WATER.





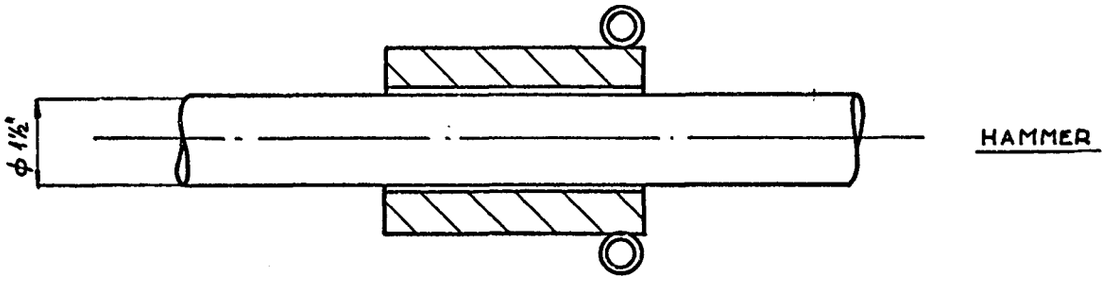


FIG. 9-1 DEVICE FOR COLLECTING CORE SAMPLES

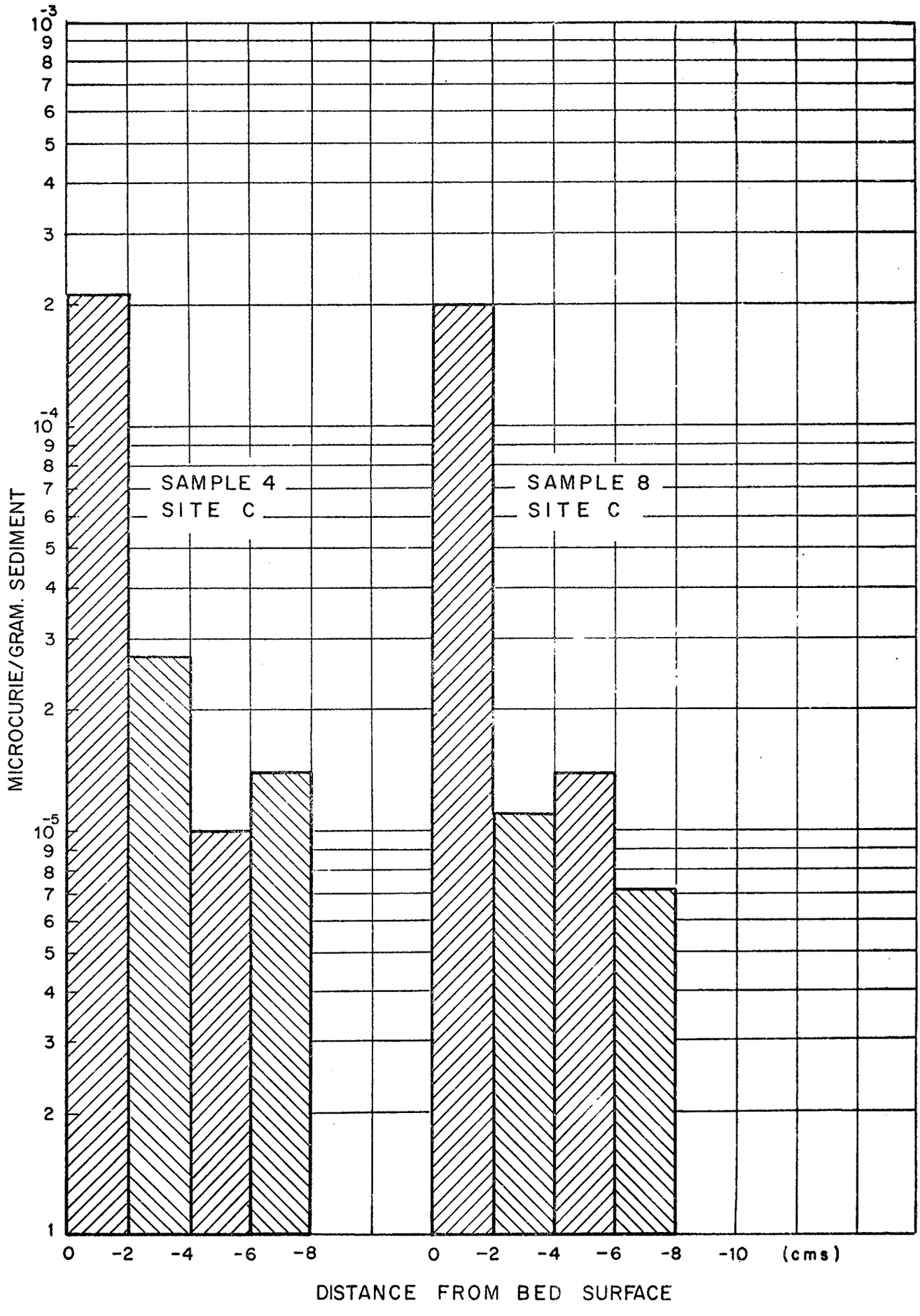


FIG. 9-2 CORE SAMPLES

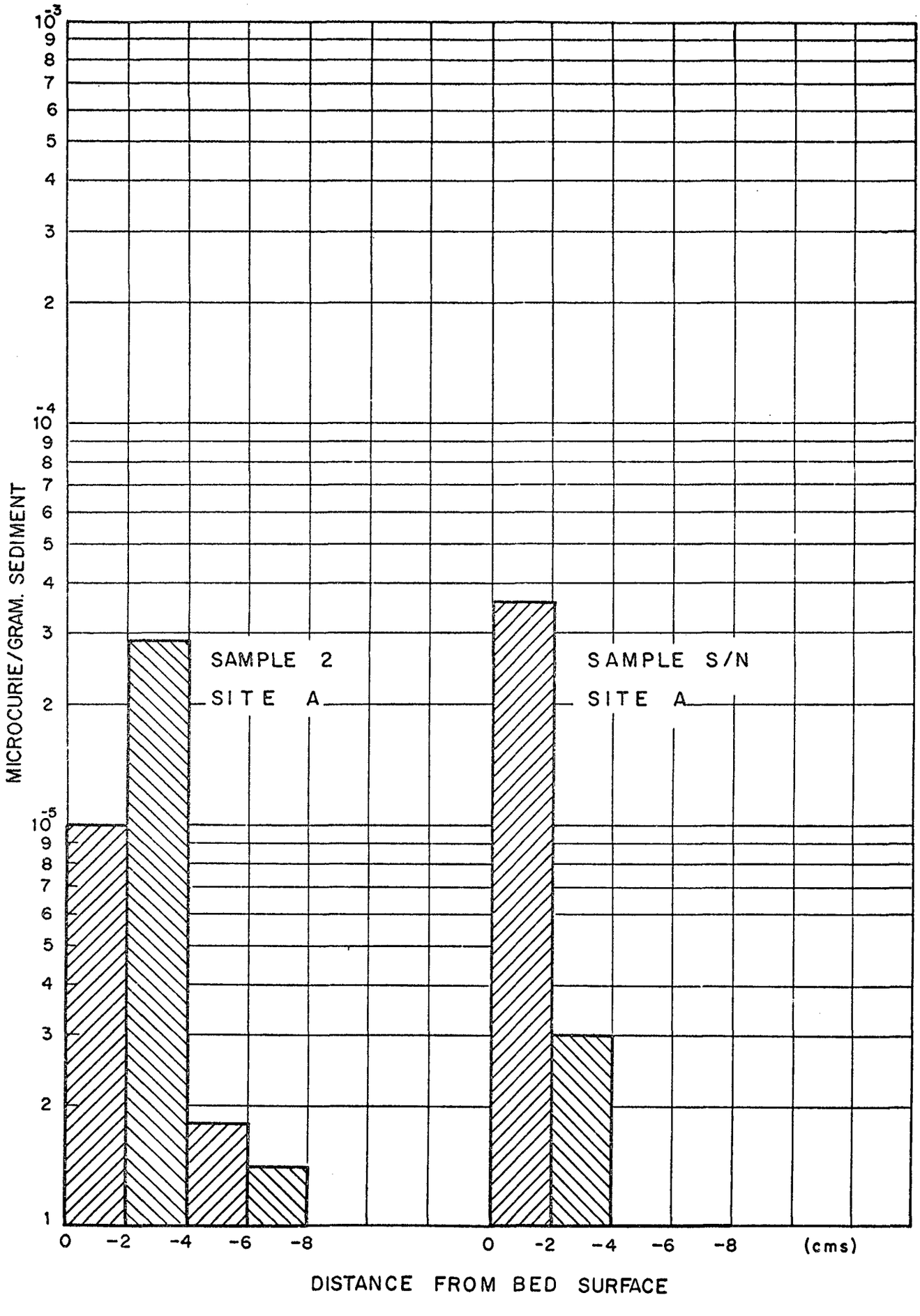


FIG.9-3 CORE SAMPLES

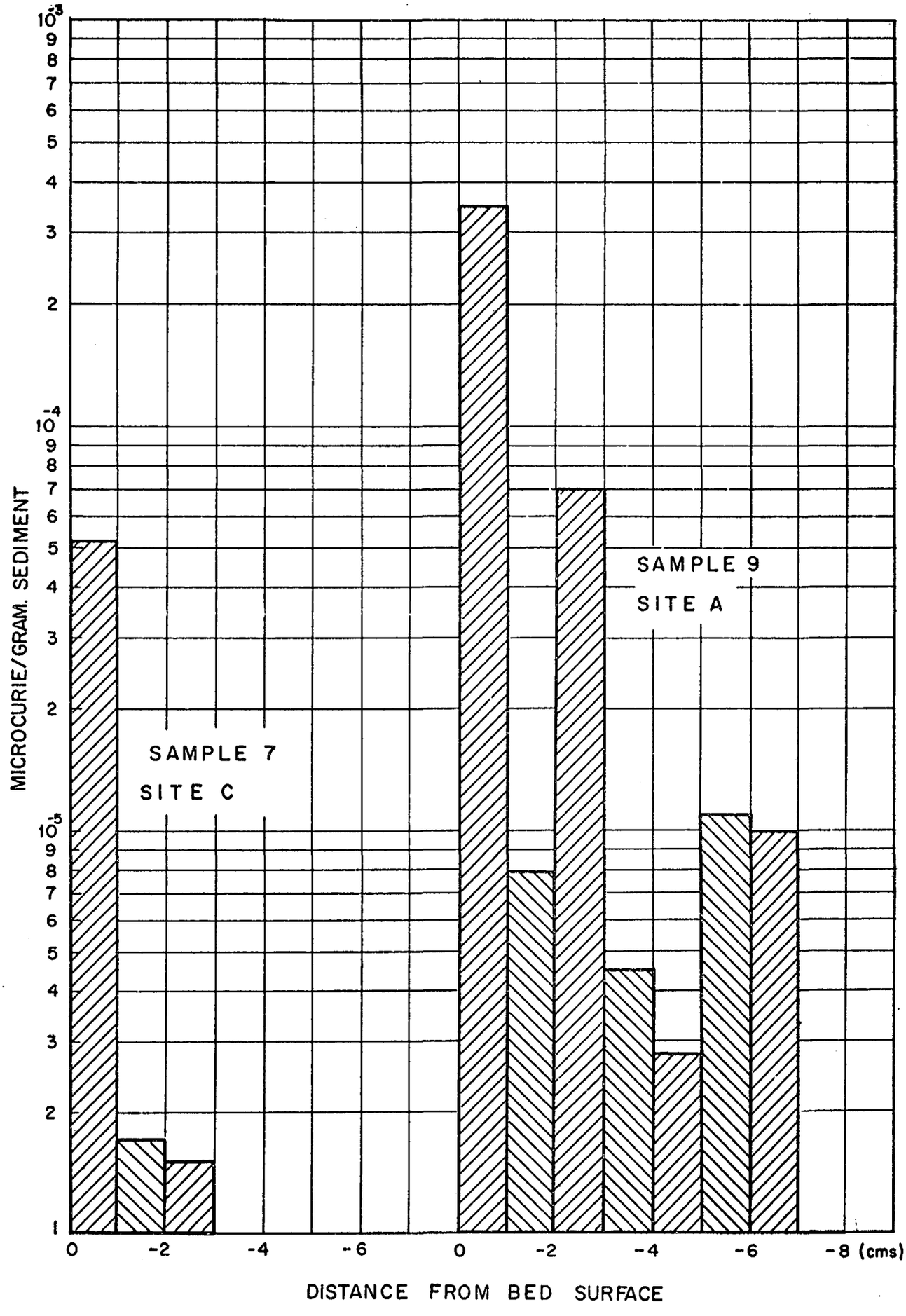


FIG. 9-4 CORE SAMPLES