

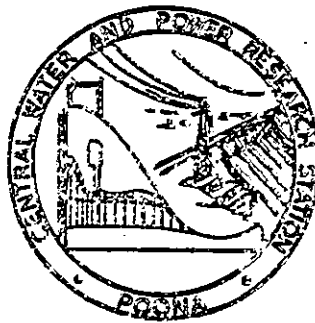
BED PROFILE RECORDER

by

P K Kulkarni

and

S Y Phatak



Technical Memorandum IST 1

December 1964

GOVERNMENT OF INDIA

CENTRAL WATER AND POWER RESEARCH STATION

Poona, India

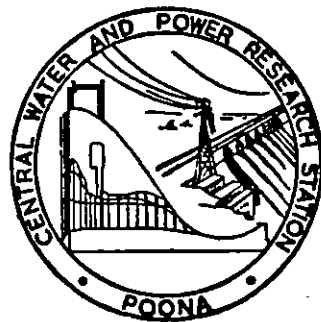
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FOREWORD

The importance of accurate observations in any experimental work needs no emphasis. While testing design features in hydraulic models with mobile beds, changes in bed configurations are of great importance. The present method of point to point measurement by depth rod leaves much to be desired and experimenters had always felt the need for precise instrumentation. In view of this need, a bed profile recorder described in this brochure, was developed at the Research Station.

Besides outlining the principles of working, the memorandum covers other details of the equipment such as mechanical design of the recorder, principles of electronic circuit for servomotor control, detailed specifications of special components etc. with a view to make it useful to other research institutions, desiring to manufacture similar units.

The development work on this recorder was carried out by the staff of the Instrumentation Section of the Research Station. Shri S.Y.Phatak, Research Officer, was responsible for development of electronic part. Mention must be made of Shri P.V.Gokhale, Electrician, who did experimental work and made useful suggestions in improving the equipment.

SYNOPSIS

The necessity of an equipment to measure bed cross-sections in mobile bed hydraulic models is explained. Bed profile recorder is developed to meet this need. The principle of change of resistance of an electric probe with proximity to bed is used in this unit and the mechanical arrangement and electronic circuit is outlined to describe the working of the unit. The accuracy attained in recording of bed profile, as well as speed at which such record can be made, is given. The appendix gives comprehensive information, useful for designing and manufacturing the unit. Details of mechanical design of trolley and its horizontal drive, probe raising arrangement, recording drum etc. are included. The basic information for design of probe and electrical bridge is outlined and considerations for selection of type of circuit and component values are fully dealt with. Specifications of special parts, such as synchronous and servo-motor, relay etc., their source and cost are recorded for guidance. Lines on which improvements can be made in future design, are also indicated.

BED PROFILE RECORDER FOR HYDRAULIC MODELS

1 INTRODUCTION

In several hydraulic model investigations, variations in bed configurations with different experimental conditions are of great importance; scour pattern at the toe of a dam, downstream of a barrage, around a bridge pier, changes in bed cross-sections due to training works in a river model being some of the examples. Efficacy of a particular design evolved to solve these problems, is judged by comparison of bed contours with and without the various alternatives tested in the model. Accurate observation of bed profiles in a model is, therefore, very vital for valid comparisons.

Experimenters have all along been aware of the shortcomings of the familiar depth-rod and taut string method used for point to point observations of bed cross-sections in hydraulic models. A need had always existed for a better method of measurement. The bed profile recorder was, therefore, developed to meet this requirement. Work done on the development of the recorder was reported⁽¹⁾⁽²⁾⁽³⁾ from time to time. This technical memorandum describes the finally developed equipment.

2 WORKING OF THE BED PROFILES RECORDER

Figure 1 shows block diagram of the equipment giving essentials of mechanical arrangement and electronic circuit. Fig.2 is a view of the trolley and recording drum while fig.3 shows the unit in operation on a model.

The recorder consists of a trolley(Fig.1), moving on a pair of horizontal rails, on which is mounted a recording drum. A small single phase A.C. motor fitted on the trolley drives it on the rails at a constant speed through a sprocket wheel and chain. This motor also rotates the recording drum through a reduction gearing of such a ratio that one foot travel of the trolley causes one inch circumferential movement of the drum which represents movement along X axis, i.e. across the cross-section.

For delineating vertical depths of a cross-section to be measured, that is Y axis, an electrical probe is used as a sensing element. The probe consists of a silver wire, which is well insulated from surrounding water except at the lower tip which is exposed. Electrical resistance between the silver tip of this probe and another electrode permanently immersed in water, rapidly changes when the probe approaches within 2 mm of bed and becomes very large when the tip

touches the bed. Advantage is taken of this particular property for controlling the distance of the probe tip from the bed of a model.

This probe is mounted on a nut which is moved vertically up and down by a screw rotated by a split-field D.C.servo-motor. The D.C.Servo-motor has two fields and by energizing either one or the other, the direction of rotation of the motor can be very quickly altered.

The electrical probe and the permanently submerged electrode form one leg of an electrical bridge circuit(Fig.1). This bridge circuit is fed from an Oscillator with an output of 12 volts at 6 Kc. frequency. Unbalanced output of the bridge is fed to an amplifier and then to a detector to convert the bridge output to D.C. This D.C.output is fed further to a polarised relay with a three position armature. This relay controls the D.C.supply to the two fields of the D.C.servo-motor responsible for moving the probe.

Initial balancing of the bridge circuit and connections to the relay are so made that when the probe tip is away from bed and immersed in mass of water, the servo-motor continuously rotates in a direction so as to move the probe down, thus bringing it nearer the bed. When the probe comes within a distance of 1 mm from bed, the relay takes a neutral position and the servo-motor stops lowering the probe further down. If the distance

between the probe tip and bed becomes smaller than 1 mm due to rising bed, the bridge output increases further, the relay switches over contact and energizes the other field of the D.C. servo; this alters the direction of rotation of the servo and probe is moved up, away from the bed. The motor again stops, when the distance is about 1 mm

The vertical probe movement is transferred to a pen moving parallel to the axis of the recording drum through gearing at 1:1 ratio. The pen registers the changing probe position, in ink, on paper wrapped round the drum. The object of the electronic circuit is to adjust the probe position through servo-motor, in such a manner that the tip of the probe remains always within 1 mm from the bed. This makes it possible for the probe to follow all undulations of the bed closely, when the probe is traversed by the trolley across a section.

The entire unit is thus capable of recording, in ink, directly on the drum a bed cross-section, when the trolley is traversed across it at a uniform speed, the horizontal distance being recorded as X axis to a reduced scale due to rotation of drum and bed depth, as Y axis due to movement of probe and pen caused by servo-motor controlled by electronic circuit.

The horizontal speed of the trolley with which a particular section can be recorded depends on two

factors;

- (i) the rate of acceleration of servo-motor and the maximum rate at which probe can be raised up. With the present circuit, the maximum vertical speed of probe is 10 cm/min.
- (ii) the steepest slope to be recorded in a cross-section.

The horizontal speed of the trolley should be such that the probe is able to adjust itself to the steepest slope. It will be clear that the horizontal trolley speeds for different maximum bed slopes would be as follows:-

Maximum Bed Slope.	Horizontal Trolley speed. Cm/min
1:1	10
1:2	20
1:4	40

As slopes in a model laid in sand can rarely be steeper than 1:3, a speed of 30 cm/min for trolley is considered satisfactory, in order to match maximum vertical speed of probe. The trolley speeds provided in the present design are 10,20 and 40 cm/min to enable measurements on steeper or flatter slopes

2 PERFORMANCE

The main advantage of the unit lies in the accuracy with which a bed configuration can be plotted. This is made possible firstly by the very small diameter of the probe tip viz. 1 mm and secondly due to the high sensitivity of the entire mechanism and circuit with which its position

is controlled. The probe, while traversing a cross-section, practically remains within a narrow zone of 0.5 to 1 mm from bed without ever touching it, thus responding even to small depressions and ripple patterns. It would be appreciated that this accuracy could hardly be matched by conventional depth-rod method.

Tests were done to find out whether the bridge circuit and probe design was suitable for different bed materials. The equipment operated satisfactorily with bed laid in sand, crushed coal as well as concrete bed. No difficulty was also encountered with either water/running in the model or with water, stagnant.

With a view to check repetitive accuracy of the unit, an irregular bed profile was recorded several times on the same paper with trolley moving in both directions. The closeness with which even small singularities in the previous plot were followed in the successive runs was remarkable.

The same unit can also be used for recording progressive increase in depth of scour at a fixed point in a model against time, e.g., rate of scour around bridge piers. The probe in such a case can follow the bed closely as progressive scour takes place.

3 IMPROVEMENTS IN PRESENT DESIGN

Electronic circuit

Electronic circuit underwent many changes⁽¹⁾⁽²⁾⁽³⁾ in design as experience was gained and better components became available. The circuit which is shown in Fig.10 and discussed in detail in Appendix 1 has proved entirely satisfactory. The only modification contemplated in future is the use of an A.C.Servo-motor in place of D.C.servo as this would simplify the circuit in certain respects.

Mechanical design

The mechanical design is also discussed in detail in Appendix 1. Though the present design is basically sound, there is still scope for streamlining it in following respects:-

- (i) Reduction gearings for drum rotation and horizontal trolley movement could be made more compact. More speed ratios, giving different horizontal trolley speeds and scale reductions for drum rotation, would be advantageous.
- (ii) The probe assembly can be made lighter so that faster rates of vertical travel could be attained. This would enable the servo-motor to negotiate steeper slopes with greater

horizontal speeds.

- (iii) The projection of probe assembly bracket below rails could be reduced. This would obviate the necessity of high stands below the rails, as required at present(Fig.3).

REFERENCES

- (1) "Bed Profile Recorder",
Annual Research Memoirs 1960;
Central Water and Power Research
Station, Poona. Page 276-277.
- (2) "Bed Profile Recorder for model studies",
Annual Research Memoirs 1961;
Central Water and Power Research
Station, Poona. Page 332-334.
- (3) "Bed Profile Recorder"
Annual Research Memoirs 1962(Not
printed), Central Water and Power
Research Station, Poona.

APPENDIX 1

1. MECHANICAL DETAILS (FIG. 4).

The unit consists of five sub-assemblies.

- (i) Girder with machined track for moving the unit across the cross-section to be gauged.
- (ii) Trolley, carrying drum and probe.
- (iii) Motor drive for horizontal movement of trolley through sprocket and roller chain.
- (iv) D.C. Servo-motor and probe.
- (v) Recording drum with writing pen.

2. GIRDER AND TRACK

The track for movement of trolley must be machined to have smooth movement of the trolley as well as to serve as a correct datum line with reference to which depths are measured. Widths of cross-sections in a model ordinarily range between 2 - 6 m. When the length of cross-section is small, i.e., below 2.5 m, girder made of two, 2 in. x 2 in x $\frac{1}{4}$ in. or 3 in. x 3 in. x $\frac{1}{4}$ in. angle-irons or suitable tees, if available, is considered desirable. The top edge of angle-irons should be machined to serve as track for trolley. For spans longer than 2.5 m, heavier section becomes necessary. Facilities for machining lengths of this order (6 m) are not easy to obtain. This difficulty can be overcome by employing two joists or channels of required strength to carry the trolley load

of 30 Kg. with deflection limited to 1 mm. On the top of the joists or channels, angle-irons with edges machined should be mounted to serve as trolley track. These angle-irons can be in smaller lengths of 1.5 to 2 m for the convenience of machining and should be fixed on joists with adjustable bolts and nuts for facilitating initial adjustment of track level. A suitable design is shown in fig.5.

Where cross-sections longer than 6 m are to be measured, it is found difficult to design a sufficiently light and rigid girder which can be handled by two men. It would be more convenient, in such cases, to measure long sections in two portions instead of making an unwieldy girder unless it is employed at one section only and is stationary.

3. TROLLEY

The trolley, carrying recording drum and probe along with drive, is made from aluminium angles and sheet and moves on four, ball bearing mounted wheels. Two wheels on one side are double flanged to prevent lateral trolley movement, while the remaining two wheels on the other side are plain.

4. TROLLEY DRIVE

An A.C. motor mounted on the trolley is used for moving the trolley horizontally along the track. The

motor(Synchronous in the particular unit, 50 c/s, 230 volts, 12 watts, RPM 3000) drives through a worm and worm wheel reduction, a horizontal shaft on which a sprocket wheel is mounted. Along the track is stretched a cycle roller chain which is supported at intermediate points to prevent sagging. Tension on the chain is adjustable. The sprocket wheel rotated by the motor engages this chain and thus provides the power for moving the trolley along the track.

The speed of horizontal trolley movement can be varied by change gears. In the present design, 10,20 and 40 cm/min speeds are provided. The sprocket wheel can be disengaged from the drive shaft by means of a disengaging pin so that the trolley can be moved without rotation of the motor. This facilitates quick initial positioning of the trolley. The motor drive can be brought in operation by engaging the pin again.

Chain drive for horizontal movement was preferred to rack and pinion arrangement on following considerations:

- (i) Rigid alignment is not required for chain drive as for rack and pinion.
- (ii) Relative cheapness and ease of assembly.

5 PROBE ASSEMBLY

A rigid frame of cast aluminium mounted on the trolley holds a vertical screw of $3/4$ in. dia. with 16 TPI, in ball bearings at its extremities. A pipe with a short nut at one end and guide bush at the other engages the screw. The length of nut is purposely kept small so as to minimize friction as far as possible. A square pipe, vertically adjustable, is mounted on the pipe with nut. The probe is mounted at the lower end of the square pipe. A scale is provided on the main frame for initial adjustment of probe position. The nut assembly is prevented from rotating with screw by a pin moving in a vertical slot.

At the upper end of the screw-rod, is fitted a worm wheel which engages a worm mounted on a D.C. split-field servo-motor. The reduction ratio is 45:1. The servo-motor is thus able to raise or lower the probe by rotating the screw.

6 RECORDING DRUM

The recording drum, $100.4 \frac{\text{mm}}{\text{dia.}}$ and 271 mm long is made from a brass pipe. In future, it would be made in aluminium casting. The outside diameter of drum has to be so adjusted as to get the desired ratio or ratios between distance travelled by trolley and circumferential drum movement. The drum is mounted on a shaft which is

supported by two brackets at ends with ball bearings. The same synchronous motor used for trolley drive rotates the drum through a reduction worm and worm wheel. The gearing for trolley drive and drum is so adjusted that for 12 cm horizontal movement of trolley, the drum receives 1 cm circumferential rotation, i.e. 12:1 ratio for plotting. For a specific model, this ratio can be chosen to give easy conversion to prototype scale directly. Paper is attached to the drum by an easily removable spring clip arrangement.

As already described, vertical probe movement is caused by the worm mounted on D.C.Servo-motor. The same worm rotates another worm wheel identical to the probe driving wheel. The second worm wheel rotates a horizontal screw($3/4$ in.dia., 16 TPI), which is supported at its ends in ball bearings. A half nut rests on the upper half of the screw rod and is prevented from turning by a pin and slot arrangement. The writing pen for recording probe movement on paper in ink is mounted on this half nut. The pen position can be easily shifted for initial adjustment by lifting the half nut. In short, the pen and probe assemblies are similar systems, both moved by the D.C.Servo-motor. The ratio of probe to pen movement is 1:1 in the present design but can be altered, if necessary.

The pen is mounted between two pivots and has a balancing weight on the other side so that writing pressure on paper can be easily adjusted. A spring operated friction clutch is incorporated between one drum flange and driving shaft. The drum can be easily rotated by hand pressure, relative to the driving shaft; this adjustment being necessary for initial positioning of the pen correctly, relative to the trolley location along the cross-section.

7 PROBE (FIG.6)

The probe for detecting the presence of bed boundary below, is made of a silver wire of 1 mm dia. placed coaxially in a copper tubing of 6 mm dia., which essentially provides mechanical rigidity. The silver wire projects about 15 mm. from the copper tubing and is sealed by means of an Araldite plug at both ends. The plug at the bottom end is tapered so that only the flat circular end face of the silver wire remains exposed for contact with water. Electrical connection is made at the top of the wire.

Another electrode is immersed permanently in water at a considerable distance from the probe and electrical circuit between these two is completed through water. The electrical resistance of such a system is a function of the distance of the probe tip from any obstruction to current flow such as bed. A theoretical study of variation of resistance of this system was made. There was a close agreement between the values given by theory and those

experimentally observed. The experimental resistance variation is shown in Fig.9. This property of the probe is used to detect bed in the vicinity of the probe.

8. ELECTRONIC CIRCUIT(FIG.10 AND 11)

Electronic circuit controlling the D.C.split field servo-motor, underwent several modifications since 1961⁽²⁾. Two circuits were finally evolved.

(i) Fig.(11)

In this circuit, the motor fields were fed by electronic valves with output current limited to 15 mA. Secondly, there was no neutral position for the probe, the motor moving it up or down all the time. This constant hunting was not desirable as it caused considerable wear and tear on gears, screw etc.

A very high sensitivity was attained with this circuit; even 0.2% variation in probe resistance(one arm of bridge) was sufficient to reverse direction of servo-motor, i.e., when the probe was near the bed, reversal of direction took place with 0.5 mm movement of probe.

(ii) Fig.(10)

This circuit is identical to that in Fig.(9) as regards, bridge, oscillator, D.C.supply design.

The amplified output after the bridge in this circuit operates a polarised, three position relay which controls the servo-motor fields. This gives a neutral position for the probe; thus the motor remains idle when the probe is within 0.5 to 1.0 mm from bed. This reduces motor hunting practically to nil.

9. BRIDGE (FIG.7)

As seen from fig.9, the resistance of a probe varies by about 40% when it approaches within 1 mm of bed. However, the resistance of the probe far from the bed, is itself not constant over a period of time but is a function of probe geometry, temperature and salinity of water, although the ratio R_p due to proximity of bed remains same. In order to eliminate effect of change in R_p , an electrical bridge is employed. The probe impedance consisting of resistance R_p and associated cable capacitance C_p in parallel with it are connected as one arm of a bridge. C_p is constant but R_p is changing.

A parallel combination R_b, C_b is connected as another arm of the bridge, where C_b serves to give the reactance balance. Other two arms of the bridge are provided by a potentiometer, the adjustable arm providing the amplitude balance. Measured value of C_p is 300 pF

while R_p is nominally about 18 K ohm and is expected to vary from about 10 K ohm to 27 K ohm, over the usual ambient temperature range. One of the bridge balance conditions is $R_p C_p = R_b C_b$ and hence C_b should be adjustable between 167 to 420 pF. A variable capacitor of 500 pF is, therefore, used. An 18 K ohms resistance is used as a fixed value for R_b .

For maximum sensitivity, all bridge arms should be of equal impedance which shows that a potentiometer of about 40 K ohms is needed. However, due to the limited resolution of an ordinary potentiometer and because very high bridge arm ratios are not necessary, a fixed resistance of 10 K ohm is wired in each of the other two arms together with a common 25 K ohm potentiometer. This bridge circuit gave very satisfactory results.

10 OSCILLATOR

An A.C. supply to the bridge circuit is necessary as D.C. would cause polarization at the probe. The probe impedance which depends upon the supply frequency was, therefore, measured at a number of frequencies and is shown in Fig. 3. The resistance decreases noticeably with frequency and rate of change of resistance with frequency is much higher at low frequencies than at

high values. Thus, if a low audio frequency is employed, a drift in the oscillator frequency will cause a permanent shift in probe resistance and thus disturb the stability of adjustments. A frequency of 6 Kc. was, therefore, chosen where the slope of the curve is quite small and the frequency is not too high to cause unwanted effects in the bridge and the amplifier due to stray reactances.

The electrical bridge described above, is sensitive to the source impedance, i.e. the output impedance of the oscillator driving the bridge. Higher the output impedance, worse is the sensitivity of the bridge. The output impedance of the oscillator should, therefore, be low compared to the impedance presented by the bridge (about 18 K ohms), i.e., maximum about 2 K ohm. Secondly, the load presented by the bridge to the oscillator is varying and also has a reactive component and if connected directly to the oscillator, can cause changes in the oscillator voltage and frequency. In order to overcome these difficulties, a cathode follower stage is introduced between the oscillator and the bridge.

The Oscillator is a normal Wien bridge type, using a high gain, low noise pentode (EF 86) as the first amplifier and one section of a double triode (12 AV 7) as the second stage. By the proper choice of the

thermister STC type Al5 working on the most sensitive region of its negative incremental resistance characteristic and just below the maximum rated voltage, a really well stabilised voltage of about 12 volts is obtained in this circuit. No change in Oscillator voltage was seen for an H.T. variation from 220 to 290 volts (nominal value 250V) and a simultaneous filament voltage variation from +10% to -15%. For the same H.T. and filament voltage range, the oscillator frequency was also found to be stable within 0.035%. The effective source impedance offered to bridge is only 400 ohms.

11. AMPLIFIER AND DETECTOR

The output of the bridge circuit is fed to an amplifier with a 1:1 interstage transformer coupling. The second stage of the amplifier is a cathode follower/so as to reduce the source impedance of the detector as a high source impedance causes a loss of efficiency of the detector circuit. The amplifier stage gives a gain of approximately 15 and a signal voltage of about 6 mV from the bridge is sufficient to reverse the servo-motor driving the probe.

A single diode OA 81 detects the signal fed by the cathode follower stage of the amplifier. A potentiometer is provided in the detector circuit to control the overall gain of the system. A meter with

0 to 1 mA full-scale deflection is also connected in series with the potentiometer to monitor the signal level at this point and also serve as a null indicator useful for balancing the bridge circuit, a zero meter reading indicating balanced condition.

12 SERVOMOTOR CONTROL

The amplified and detected signal from the bridge is fed to a relay which in turn controls the sense of rotation of the servo-motor and thus the probe position.

The servo-motor is a D.C. motor with two fields (EVERSHED VIGNOLES, type FA/3A/B); the direction of rotation of which can be altered by exciting one or the other field, armature current remaining constant. Though the motor is recommended to work at 220 volts, D.C. supply (ripple less than 2%), the armature voltage was limited to 45 volts D.C., in order to keep the bulk and cost of rectifying unit low. The D.C. supply to the motor armature is obtained from a 31 volts step down transformer by a full bridge of silicon rectifier diodes OY 5064. These were used in the interest of compactness; a metal rectifier stack should be as adequate. The rectified output is smoothed by a resistance capacitor filter as chokes for high D.C. current are difficult to make. Transient switching and charging currents are limited to safe values by a 4 ohm resistance, while an additional dropping resistance of 24 ohm is used to limit motor

armature current to 0.92 Amp. The ripple content with the circuit given, is 1.5%, which is satisfactory.

The relay through which the two servo-motor fields are controlled is a polarized, three position relay with two windings of 9000 ohm each, and a change over contact with a central neutral position. The relay armature can be made to establish contact on either side by choosing proper magnitudes and directions of currents in the two coils. The two fields of the motor are connected one in each side of the relay contact with proper spark suppression circuits. One relay coil is put in series with the detector load and thus has zero D.C. current through it, when the bridge is balanced and the probe is in the main body of water. In this condition, the relay is given a bias to one side by feeding a current of approximately 350 micro A from the H.T. to the other coil through a dropping resistor. This causes the motor to take the probe downwards. When the probe comes close enough to bed, the change of resistance causes a bridge output and consequently a flow of current in the first relay winding, the direction of this current being chosen to oppose the magnetic flux, due to the constant biasing current through the other winding. This neutralises the effect of biasing current in the other winding and the relay assumes 'Off' position, having no magnetic excitation. If the distance between the bed and probe further decreases, the detector coil current becomes higher than biasing current and the relay contact

changes over, thus energizing the other field of the servo-motor. This reverses the motor and pulls the probe away from the bed, till the relay is in neutral position again.

With this circuit, the probe follows bed variations with no hunting of the servo-motor.

13 COST AND SPECIAL COMPONENTS

It is believed that additional information about approximate cost and special components would be useful in building bed profile recorder.

(a)	Approximate cost:	Rs./-
(1)	Trolley and Recorder Unit.	2,500/-
(2)	Electronic circuit	800/-
(3)	D.C.Servo-motor	700/-
(4)	A.C.Induction motor	300/-

Total cost 4,300/-

(b) Power requirement - 100 Watts.(Total).

(c) Drawings of mechanical unit,

Dg.No. of CWPRS.	Particulars.
280/63	Assembly - bed profile recorder.
276/63	Probe assembly.
279/63	Drum mounting details.
277/63	Pen operating arrangement.
275/63	Rail details.
278/63	Component details.

(d) Specifications.

(1) Servo-motor, Split-field D.C. motor.

(i) Specification:

Output 25 V; minimum starting torque
220 oz.inches. Evershed and
Vignoles Ltd., London.
Type FA 3A/B, /B, vertical drive
(Imported)

(ii) Source.

M/s Jost's Engineering Co.,
Great Social Building,
Sir P. Mehta Road,
Bombay.

(iii) Cost - Rs.700/-

(2) Synchronous Motor.

(i) Specification:

220 V, 50 c/s, Break-down torque,
25 gm.cm at 1500 RPM.

(ii) Source.

M/s Adept Laboratories Ltd.,
Karve Road, Poona-4.

(iii) Cost - Rs.300/-

(3) Polarized relay.

(i) Specification.

Siemens Trls 65 V, TBV 3502/5 T
grpL 40T 101 and spring TBF 85 T5
(Imported).

(ii) Source.

M/s Siemens Engineering Mfg.Co. of -
India Ltd., Veer Nariman Road,
Bombay-1.

(iii) Cost - Rs.100/-

(4) Diodes OA 81 .

(i) Specification.

Diodes OA 81.

(ii) Source:

Generally available with all
dealers.

(iii) Cost - Rs.4/-

(5) OY 5064.

(i) Specification:

OY 5064, Make, M/s Intermetall,
West Germany.

(ii) Source.

M/s Hind Industrial and Mercantile
Corporation Ltd.,
Bombay.

(iii) Cost - Rs.13/-

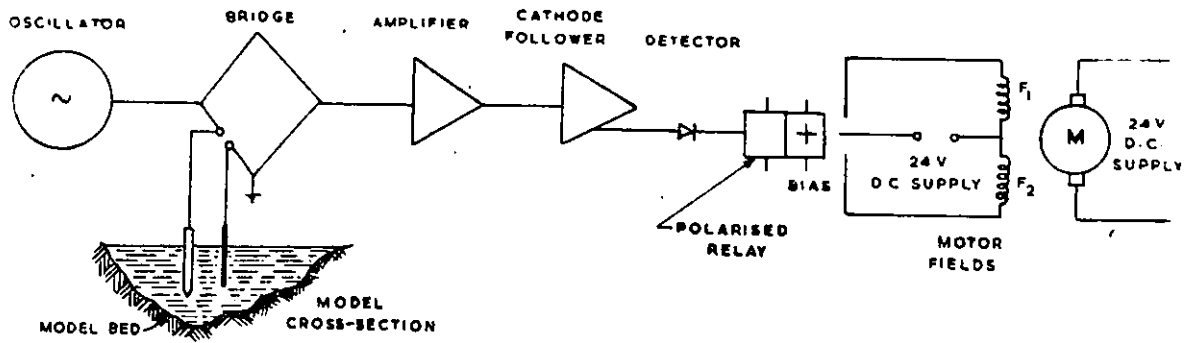


Fig 1 : Block diagram

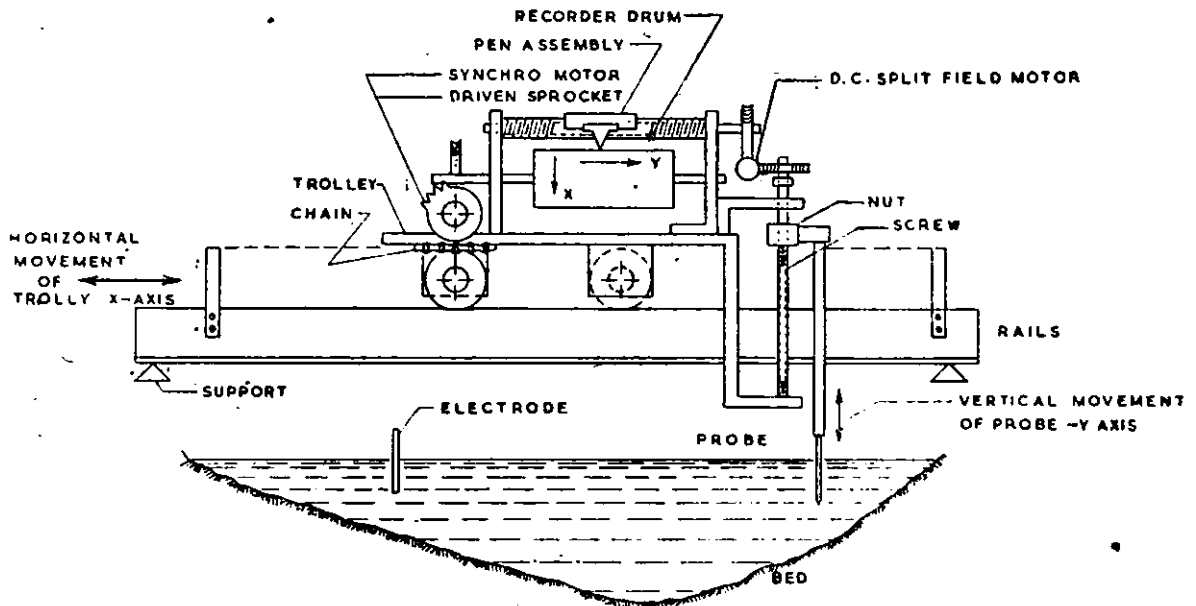


Fig 1 : Bed profile recorder

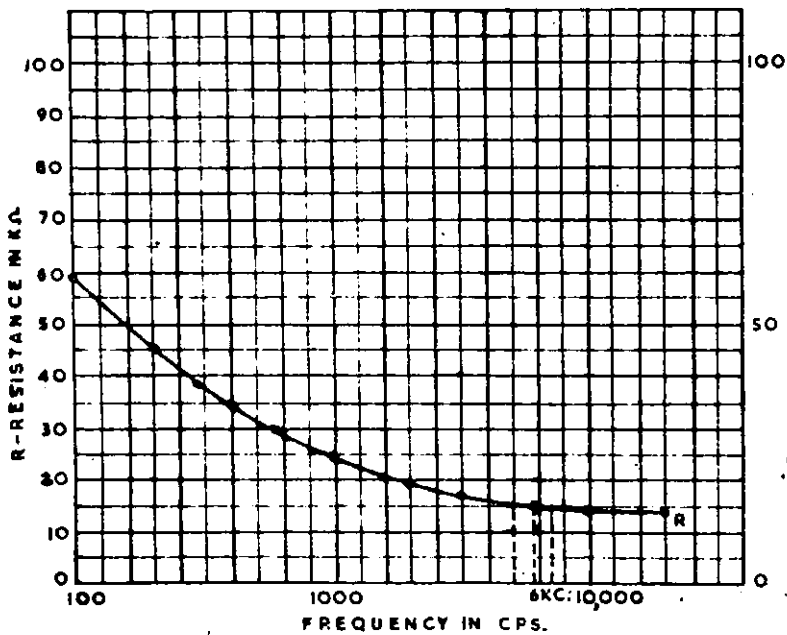
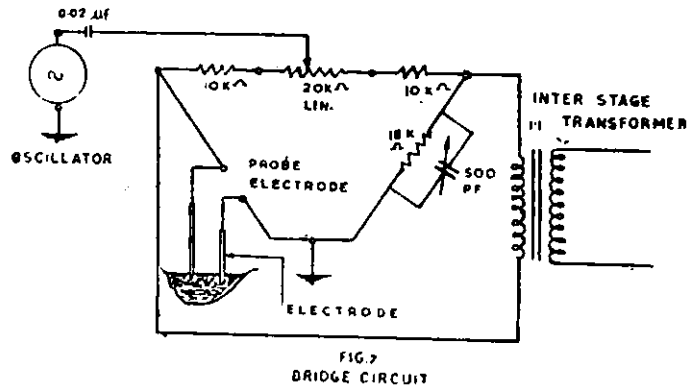
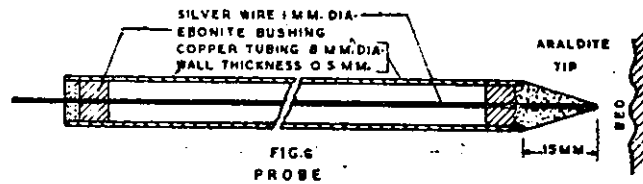
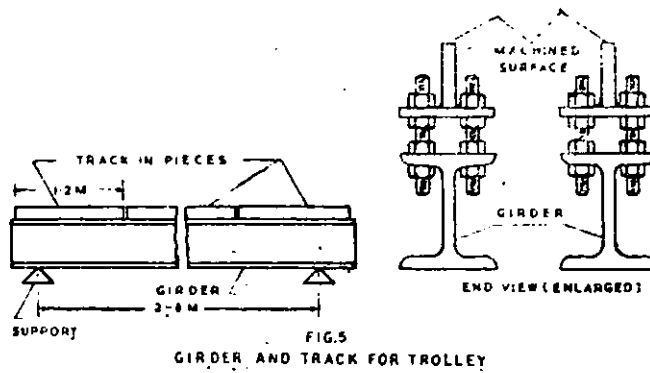


FIG. 8
VARIATION IN PROBE RESISTANCE
AT DIFFERENT FREQUENCIES

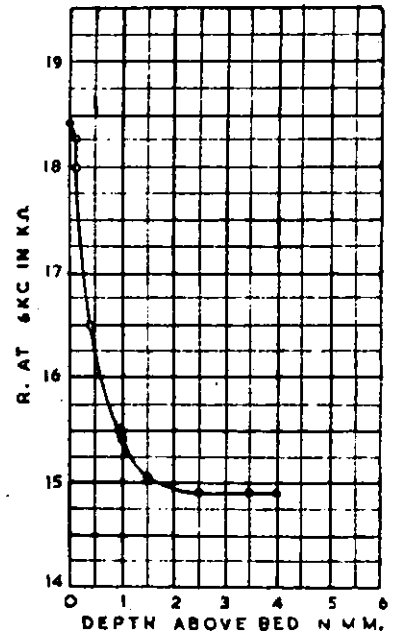


FIG. 9
PROBE IMPEDANCE
AT
VARIOUS DEPTHS ABOVE BED

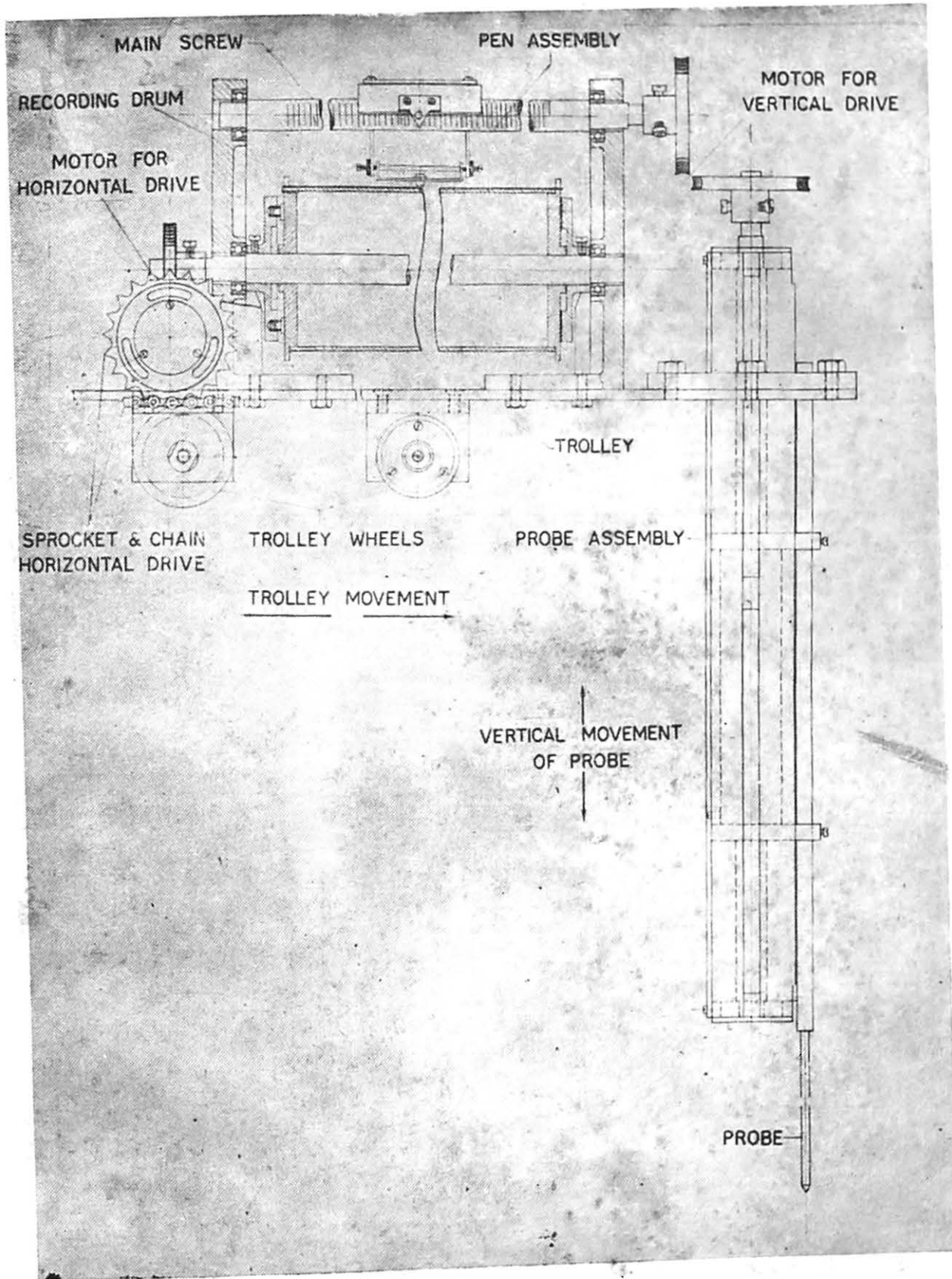


Fig 2 : Assembly of trolley and drum

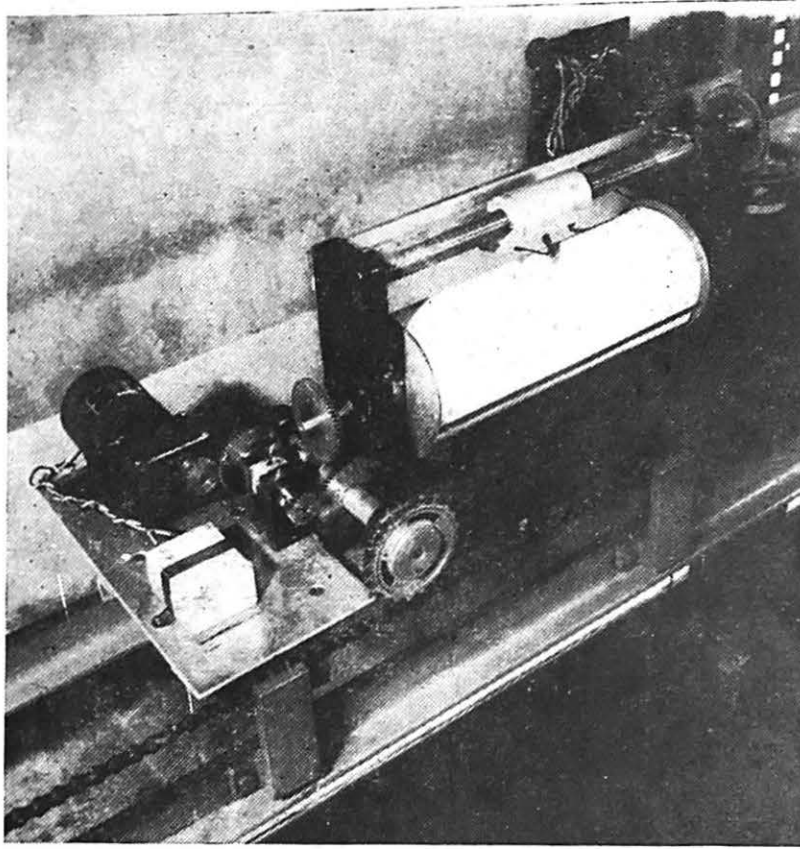


Fig 3 : Trolley and recording drum

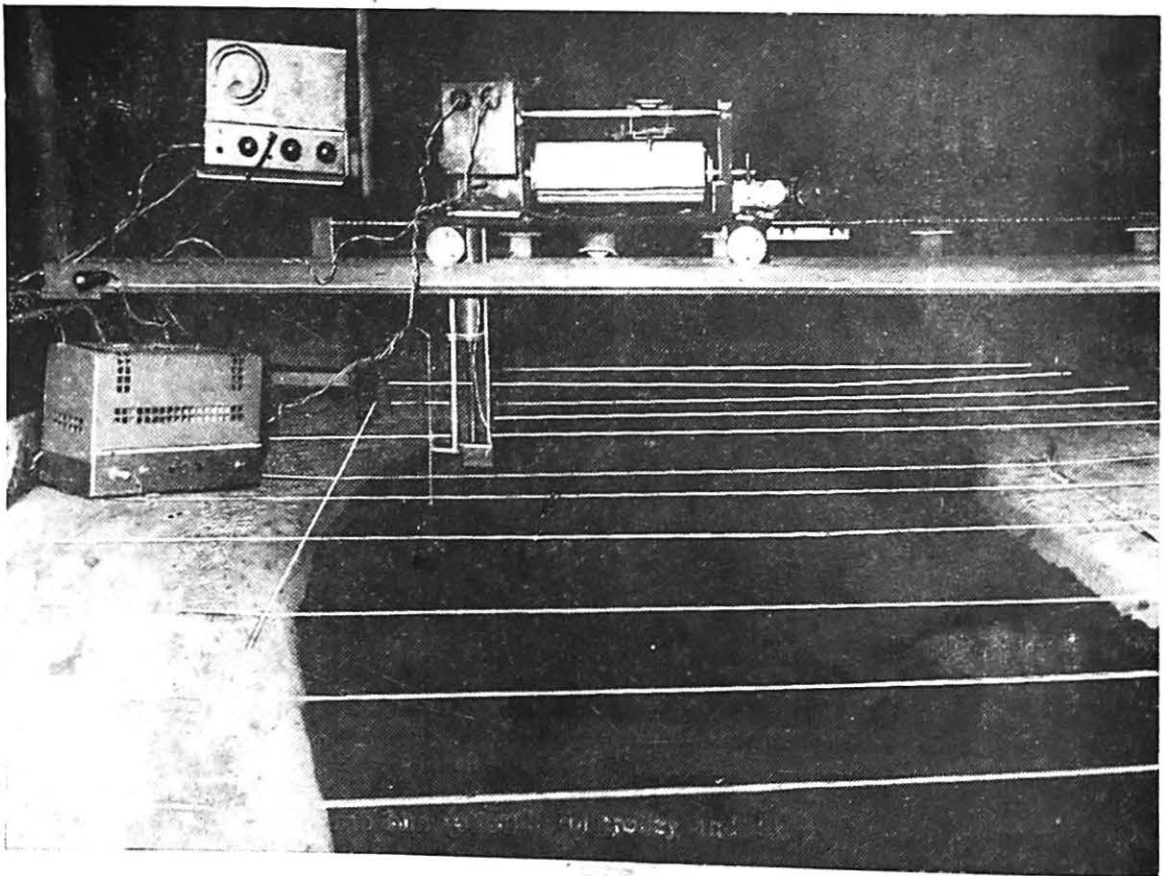
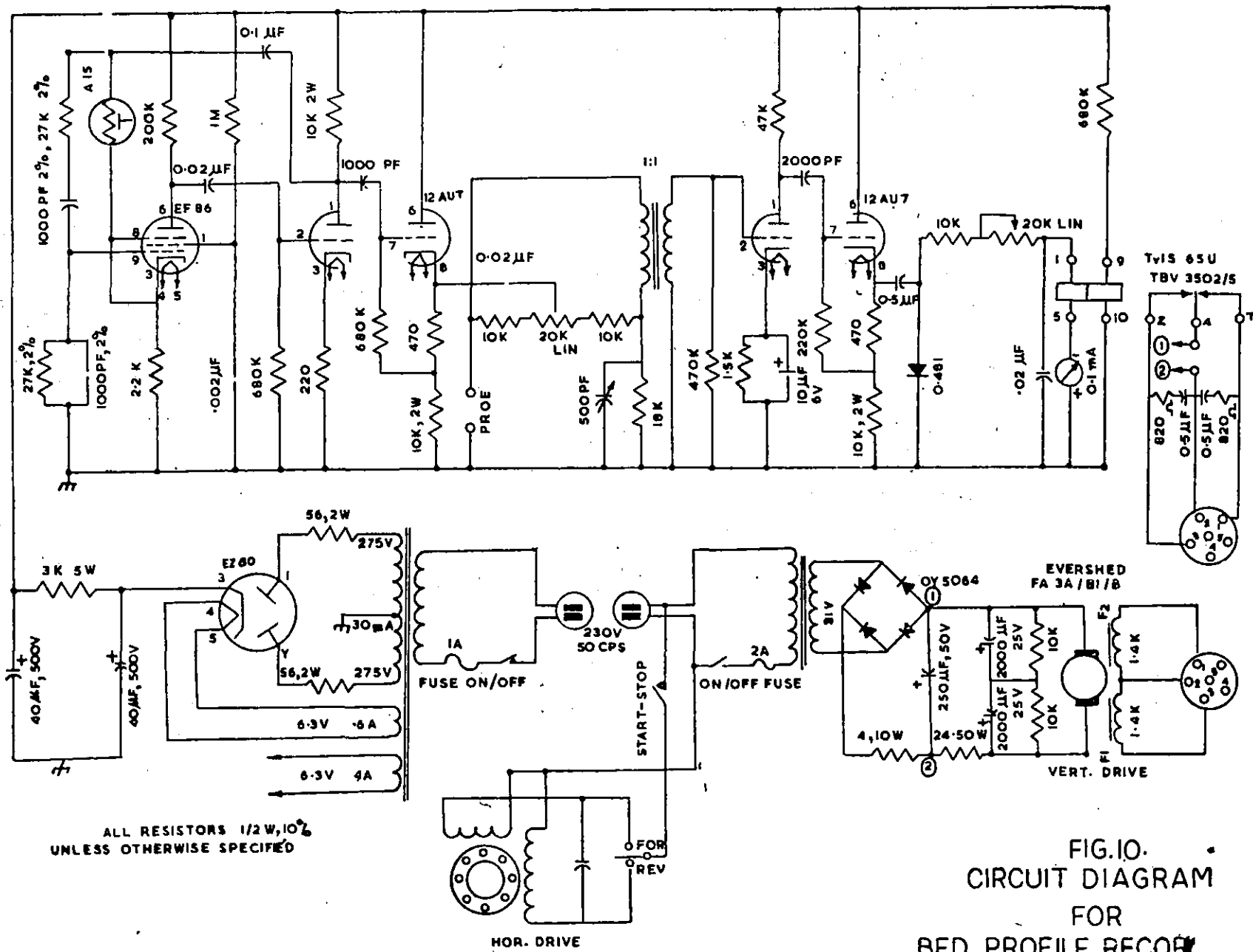


Fig 4 : Unit in use on a model



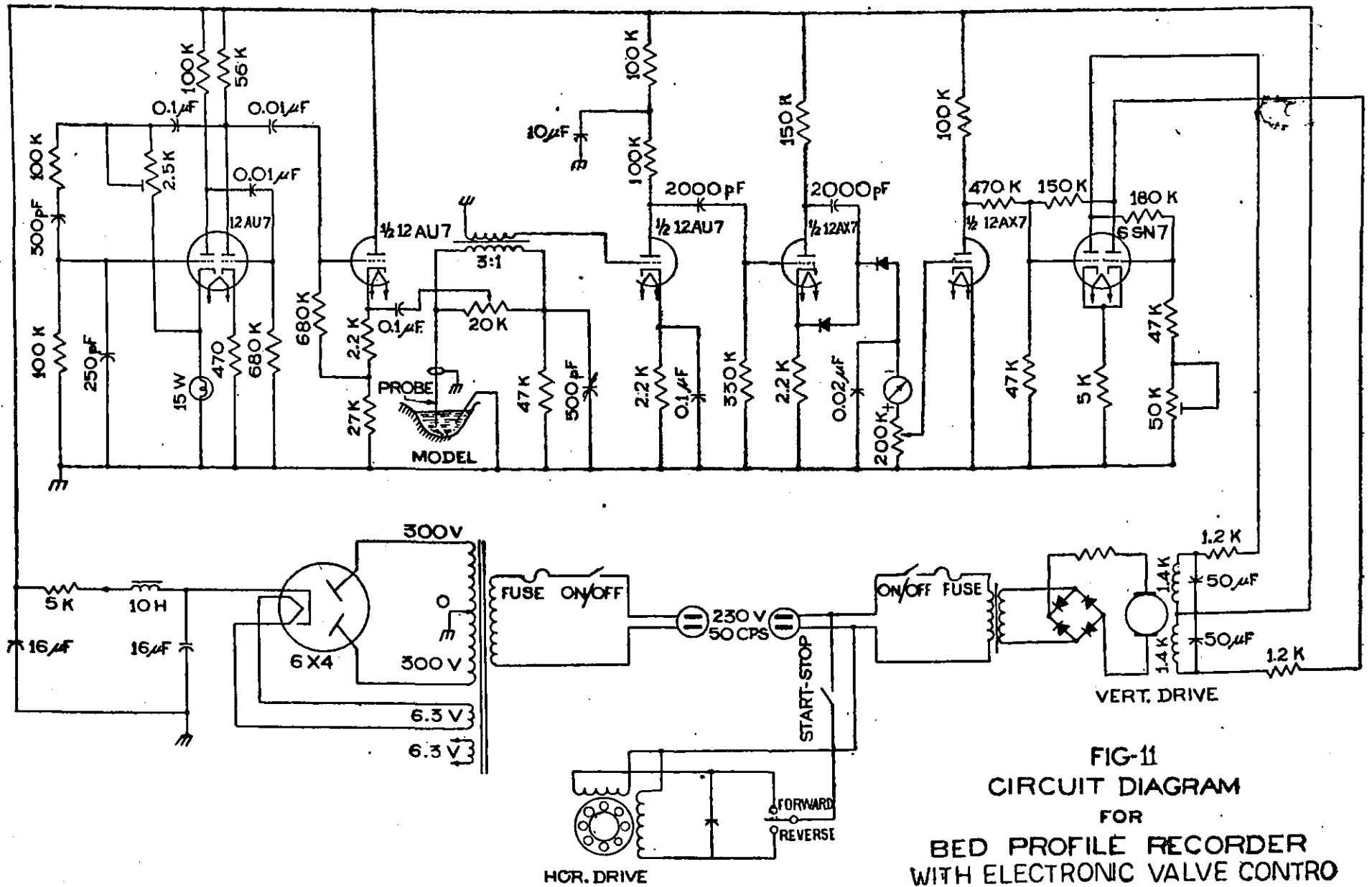


FIG-11
CIRCUIT DIAGRAM
FOR
BED PROFILE RECORDER
WITH ELECTRONIC VALVE CONTROL