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# Concentration Measurement System for Diffusion Experiments in Laboratory Flumes

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UNPUBLISHED REPORT
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# Concentration Measurement System for Diffusion Experiments in Laboratory Flumes

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## 1. Introduction

In diffusion or dispersion experiments in open channel flows, experiments are carried out by measuring concentration profiles of a tracer which is injected into the flow. During a typical experiment, the desired hydraulic conditions (uniform flow with given velocity at a given depth) are set up and the tracer is then injected into the flow at a constant rate. The concentration measuring device (in this case a conductivity probe) is traversed perpendicular to the flow at a number of stations at different distances from the tracer source. The output signals from the probe are then recorded for subsequent analysis.

This report describes the construction, set up and operating procedures for the concentration measuring system that includes the conductivity probe and the bridge circuit, the salt-methanol tracer solution and the injection apparatus.

## 2. Bridge Circuit

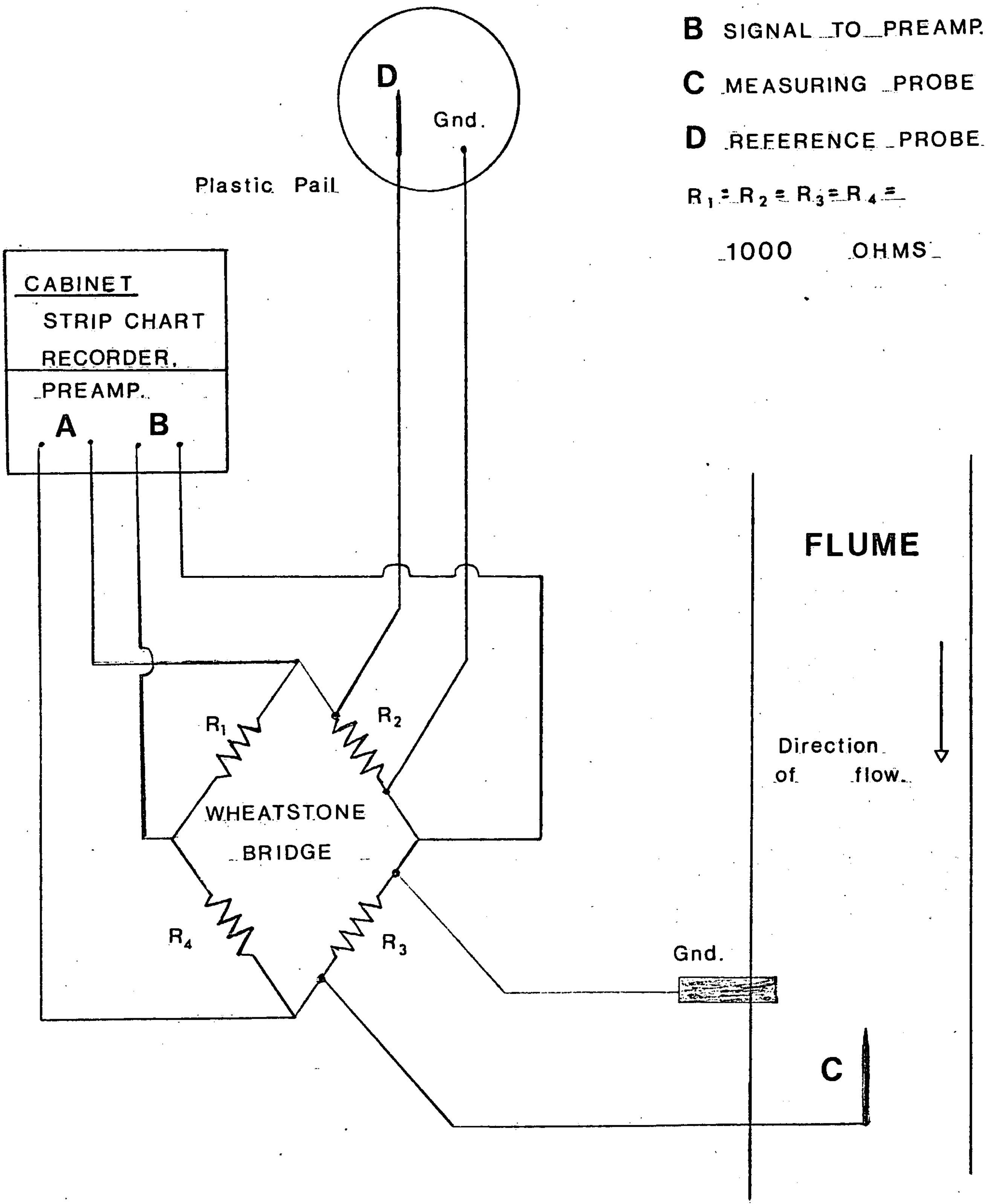
The circuit is shown in Figure 1. The measuring probe forms one arm of the bridge circuit. A reference probe, immersed in a bucket of water from the flume, forms another arm. The reference probe was required in order for the bridge to be balanced. Power from a Hewlett Packard carrier Pre-Amplifier (model 8850A) drives the circuit and the output signal is then fed back to the pre-amplifier strip chart recorder (model 7100BM).

## 3. Conductivity Probes

### 3.1 Probe Construction

The concentration measuring devices used in the diffusion experiments are

# BRIDGE CIRCUIT.



**A** POWER FROM PREAMP.

**B** SIGNAL TO PREAMP.

**C** MEASURING PROBE

**D** REFERENCE PROBE

$R_1 = R_2 = R_3 = R_4 =$

1000 OHMS

Fig. I

single electrode conductivity probes. The shaft section of the probe (See Figure 2) is laminated brass that provides stiffness and acts as a shield (as does the braid of the co-axial cable.)

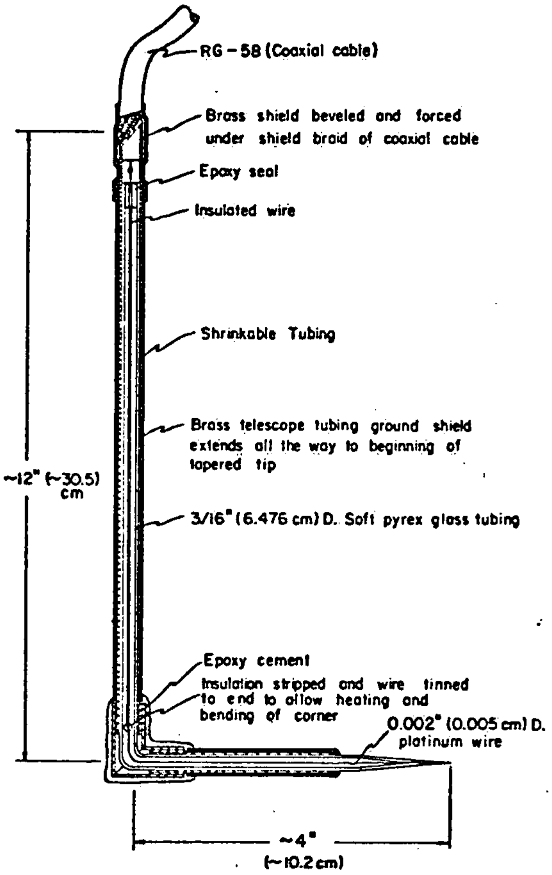
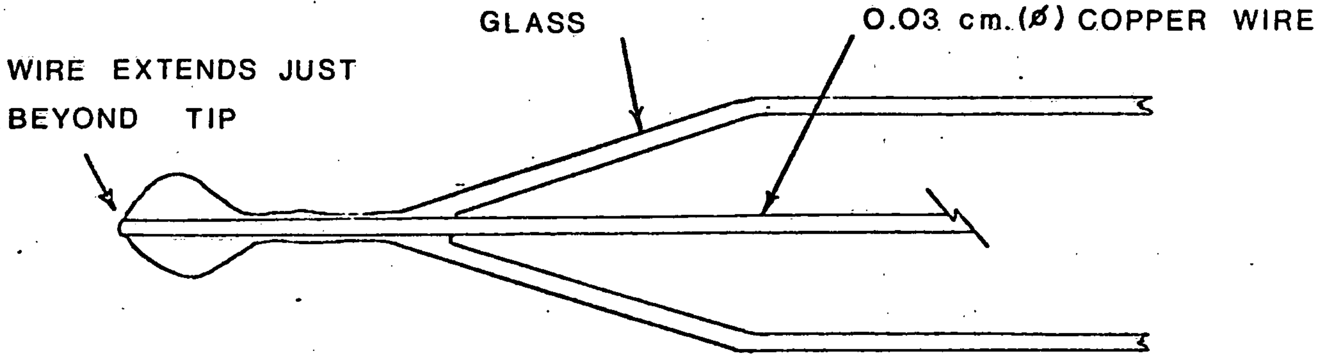


FIGURE 2

The centre conductor consists of either a teflon coated platinum wire, 0.005 cm diameter or a piece of 0.03 cm diameter copper wire. In either case only a small portion of the conductor is exposed beyond the glass tip as shown in Fig. 3. The platinum wire tip is extremely delicate and prone to breakage while the copper wire tip is quite rugged but less sensitive.

FIG. 3 PROBE TIP

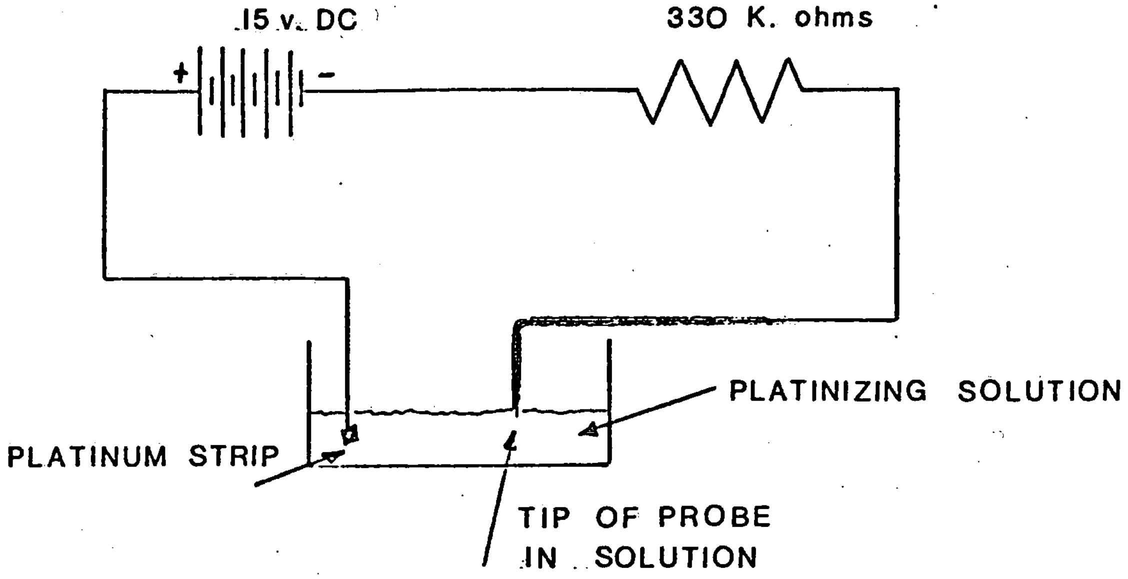


Because only steady mean concentrations were required for the present experiments the copper tipped probe was used. The typical output in a solution of 3 grams/litre is around 1500 millivolts.

## 3.2 Method of Platinization

A coating of platinum black is required on the probe tips for good response. This coating deteriorates with use and when this happens the mean output voltage will drift rapidly. Replatinizing is then necessary. Normally a probe would need replatinizing after eight or ten hours of use.

FIG. 4 PLATINIZING CIRCUIT



## 3.2 Method of Platinization Cont'd

The probe is connected into the circuit as shown in Figure 4 and immersed in the platinizing solution (1.5 gms Chloroplatinic acid $(H_2Pt\ Cl_6\ 6H_2O)$ in 50 m/s distilled water to give a 1% solution). Current from a 15 Volt D.C source is passed between the probe and a platinum strip for a period of 30-60 seconds. A steady stream of tiny bubbles from the tip indicates that the correct current is flowing. Otherwise the resistance in series with the probe can be altered. After platinizing, the probe can be rinsed and checked for sensitivity. If the response is still not high enough an additional time period of 15-20 seconds in the bath may be necessary.

## 3.3 Method of Cleaning

During actual experiments, the probe tip is easily contaminated by algae or other small debris in the water. Thus it is often necessary to clean the probe

## 3.3 Method of Cleaning Cont'd

tip to maintain uniform response. The cleaning solution consists of a mixture of 0.10 $m^3$ isopropyl alcohol, 0.10 $m^3$ ethyl ether, 0.05 $m^3$ concentrated hydrochloric acid and 0.05 $m^3$ of distilled water. The probe tip is dipped into this solution and agitated for from 1-2 minutes or (in our case) the solution can be sprayed onto the tip from a wash bottle. In both cases the tip should be rinsed with distilled water after cleaning to remove all excess cleaning solution.

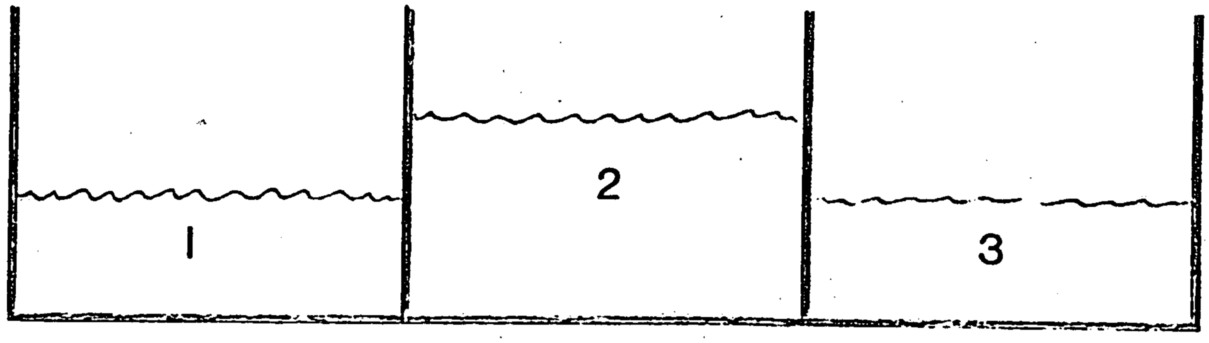
## 3.4 Sensitivity Checks

To assure uniform response during experimentation, sensitivity checks should be made frequently. The probe is removed from the flume and zeroed in a bucket of flume water. It is then lowered into a solution of known concentration (3 grams/litre) and a reading is taken. If this reading compares with the original, the probe can go back in the flume. If not it should be cleaned or replatinized.

## 3.5 Calibration of Probe

Calibrations were performed in a container with 3 compartments as shown in Figure 5. The compartments are connected to a common ground.

FIG. 5 CONTAINER



1. STANDARD SOL'N. (3 gm/l)

3. FLUME WATER (4 L)

2 FLUME WATER (4-6 L)

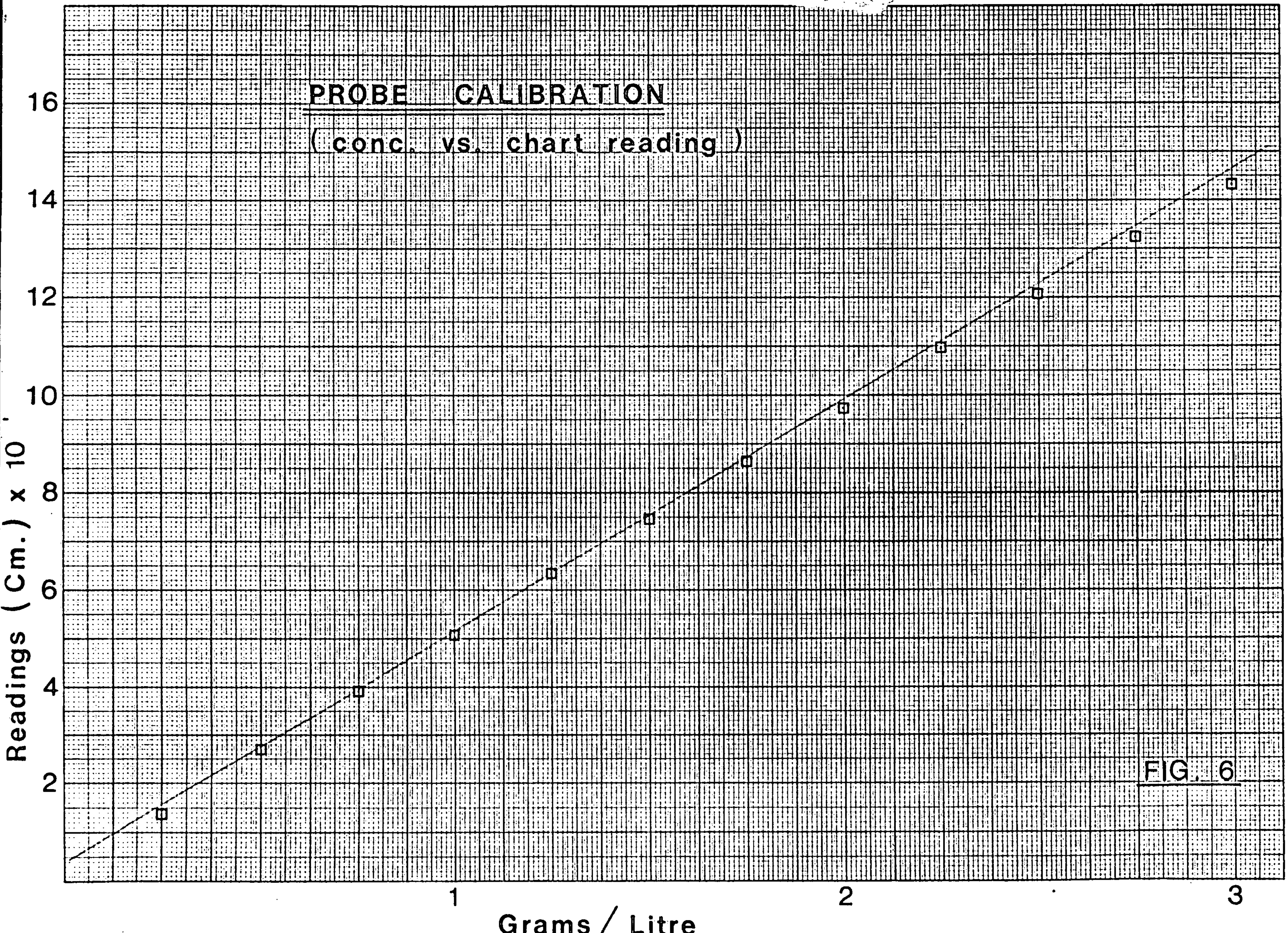
## 3.5 Calibration of Probe Cont'd

Steps in Calibration

1. Clean probe
2. Zero probe in compartment #2 or #3 (Zero should be same)
3. Take sensitivity reading in compartment #1.
4. Check zero.
5. Carefully weigh out 1 gram of salt and dissolve completely in 4 litres of flume water (#3).
6. Take reading in #3.
7. Add 1 gm of salt to #3.
8. Take reading in #3.
9. Repeat steps 5) & 6) till concentration in #3 is 3 gms/litre (same as standard sol'n. (#1)

NOTE: After every third or fourth reading, the sensitivity of the probe should be checked in the standard.

A typical calibration curve is shown in Figure 6.



PROBE CALIBRATION
( conc. vs. chart reading )

FIG. 6

## 4. Salt Tracer Solution

The tracer solution used during our experiments was a neutrally buoyant solution of salt, (NaCl), methanol ($CH_3OH$) and flume water. The ratio between the various ingredients is obtained as follows:

$(S.G)mix$ = specific gravity of mix
$W_s$ = mass of salt
$Vw$ = volume of water
$Vm$ = volume of methanol
$V_{mix}$ = volume of mixture
$\rho_w$ = density of water
$(S.G.)m$ = specific gravity of methanol

$$\text{Density of mixture} = \frac{W_s + \rho_w Vw + \rho_w (S.G.)m\ Vm}{Vw + Vm}$$

S.G. of mixture is to be 1

$$\frac{\frac{W_s}{\rho_w} + Vw + (S.G.)m\ Vm}{Vw + Vm} = 1 \qquad \text{......(1)}$$

$$\text{Salt concentration of the mixture} = \frac{W_s}{Vm + Vw}$$

Required salt concentration is 62.5 gm/litre

$$\frac{W_s}{Vm + Vw} = 62.5 \qquad \ldots\ldots(2)$$

From equations (1) and (2) one gets

$$Vw = Vm \quad \frac{\rho_w}{62.5} \; (1 - (S.G.)m) - 1 \qquad \ldots\ldots(3)$$

The methanol used has specific gravity equal to 0.796 at 20°C.

In our experiment, we mixed 1187.5 grams of salt (Na Cl) with 13.16 litres of Flume Water (not tap water) and 5.83 litres of methanol ($CH_3OH$) to provide 19 litres of working solution.

## 5.0 Injection Unit

The apparatus that provides a uniform flow of salt solution is the constant head injection unit. As seen from Fig. 7 it is constructed almost entirely from acrylic.

The joints are sealed with acryweld 40 and acryfix. The tank can be filled through a 3/4" hole in the top. During an experiment, this hole must be plugged and be airtight. A tight connection where the calibrated rod enters the unit is assured using rubber "O" rings. As long as air is bubbling through the end of the tube, a constant pressure is exerted on the discharge end and therefore the discharge remains constant.

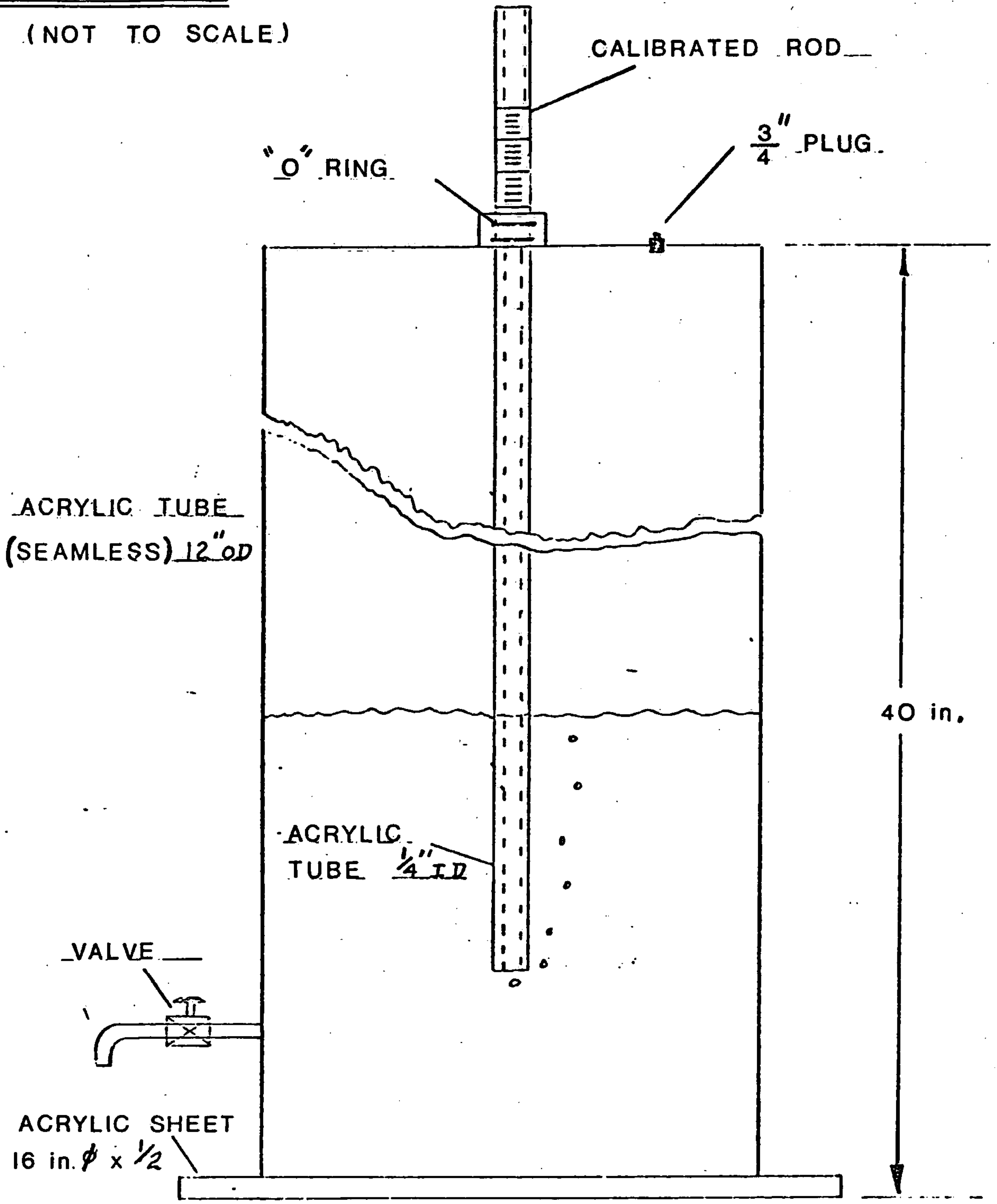
Different flowrates are obtained by either raising or lowering the center rod. The valve is always opened to the same predetermined setting.

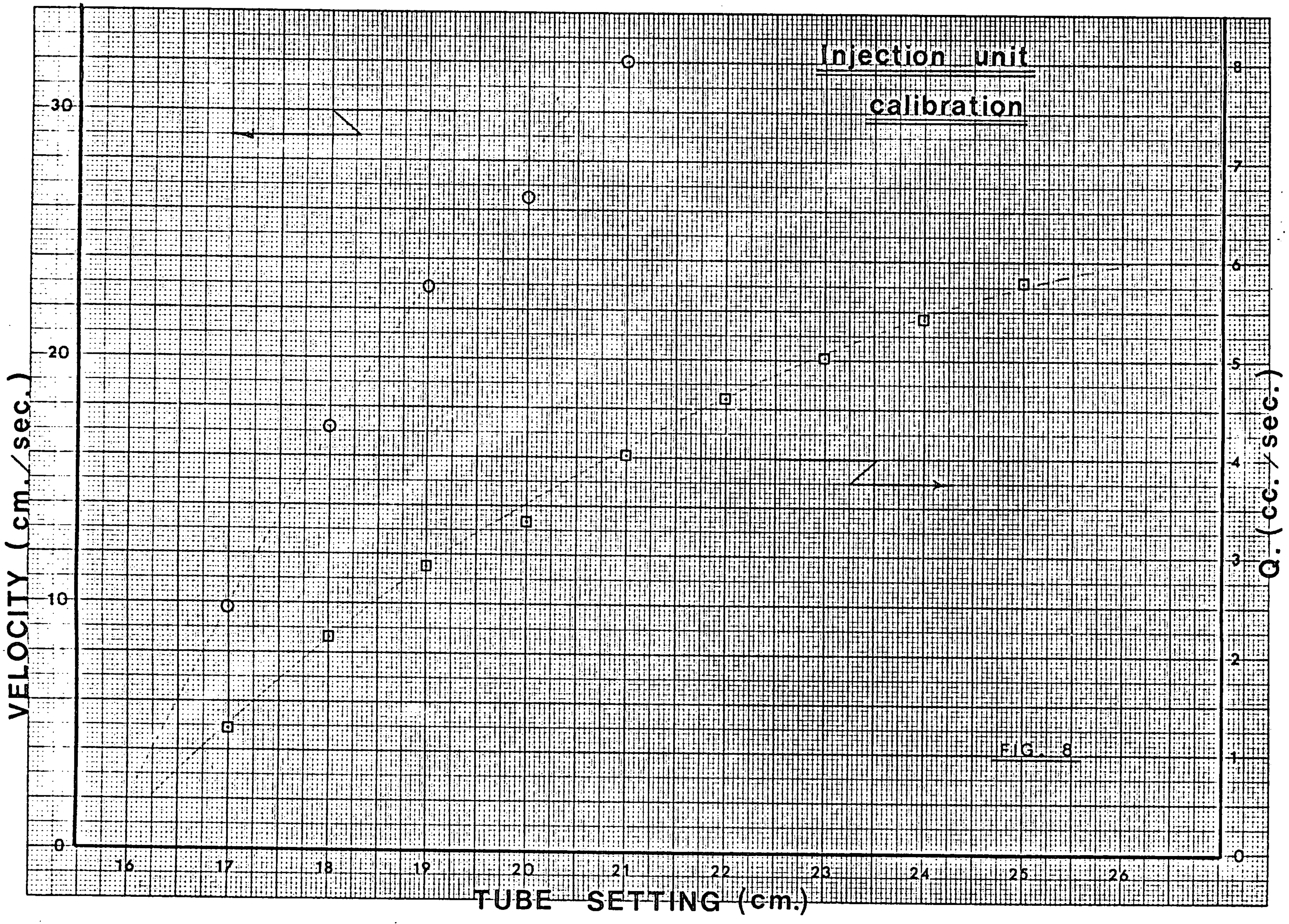
Because the salt solution has to be released into the flume at the same velocity as the flowing water, it is necessary to calibrate the unit so that the centre tube can be set to give a desired discharge. Knowing the velocity of the water (by current meter or other suitable method) and the cross-sectional area of the final nozzle, the desired flow from the injection unit can be calculated. The calibration is as follows. The centre tube and the valve are preset to given settings. The discharge is collected over a period of time (which is measured by a stopwatch). The volume of water collected is measured and the discharge Q is calculated. The tube setting is then changed and another volume and the measurement are recorded. Fig. 8 shows the plot of Q vs tube setting as well as discharge velocity at the nozzle vs tube setting. The usual procedure when starting the tracer injection is to calculate the mean flow velocity from the flume discharge measurement and then setting the centre tube so that the tracer discharge velocity is the same as the mean flow velocity.

FIG. 7

INJECTION UNIT

(NOT TO SCALE)





Injection unit calibration

FIG. 8

# SUMMARY

The system described in the previous sections offer a relatively simple means of performing concentration measurements in open-channel flows. The injection unit is easy to operate and quite reliable. The conductivity probe, if handled with care and given regular maintenance will give good service over a long period of time. Use of the probes with the fine platinum tips makes it possible to measure mean as well as fluctuating concentrations.