EQUIPMENT FOR CALIBRATING CURRENT METERS

IN THE BEDFORD INSTITUTE

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by

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INTRODUCTION

Dependable and accurate flow measurements are an absolute necessity in any scientific hydraulic investigation. To achieve this, it is essential that current meters be examined regularly to ascertain their accuracy and reliability. This refers not only to the usual maintenance, but requires that each instrument be given a careful pre- and post-service test. These examinations are important in assuring reliable recording rates. They allow variations to be taken into consideration and, if necessary, new calibration curves to be derived. This is of special importance after prolonged field use where various natural factors may have modified the performance of the instrument.

Current meters are generally calibrated in straight rating channels. The layout of such a channel is large, its length being in the order of 100 m to 150 m and the equipment required during testing is bulky and relatively expensive. A large carriage is required which, besides its own weight, must transport the propeller or rotor, the recording equipment and two persons for service and observation. A powerful motor is necessary to drive the carriage.

From experience obtained in working with model current meters and intermediate-sized prototype current meters (Ott current meter), a circular rating flume is suggested for the calibration of the Institute's current meters. This type of rating tank is less bulky, requires little equipment, is easy to handle and is far less expensive, in its initial installation and later operation.

The principal advantages and disadvantages of both types of calibration channels are:

A. <u>Straight Channel</u>

1) Large layout: the length of this type of rating channel varies from 100 to 150 feet.

2) Limited test range: only 70 to 75 percent of the length of the channel is available for testing.

3) Test procedure is time consuming and in many respects inconvenient compared with that of a circular tank. For each test run the carriage must be accelerated to test speed and then stopped at the other end. The return trip is of use only if the propeller can be turned around to face the water in the other direction.

4) Large carriage: besides the propeller or rotor and its own weight, the car must also carry the recording equipment and two persons for service and observation. A motor with a strength in excess of 15 HP is required to overcome the friction of the system, to accelerate the load and to overcome the running resistance.

5) The rolling parts of the equipment must always be kept in excellent condition.

6) The advantage of a straight channel is that it could be used alternatively as an ordinary hydraulic flume and as a wave flume.

B. Circular Channel

1) Small layout: an area of 10 to 12 m in diameter for a maximum test speed of 8 knots.

2) The circular channel is equivalent to an infinitely long straight channel in which the calibration length and thus the accuracy, can be increased as desired.

3) Calibration of a meter can be conducted in a continuous uninterrupted process, the test speed being increased in steps without stopping or reversing direction. Therefore, the time required for calibration in a circular tank is only a fraction of that required in a straight channel.

4) Relatively small motor: only the propeller must be driven through the water, thus a 5 HP motor is sufficient.

5) Recording equipment and observer are stationary; electrical connections are easily made through slip rings.

6) No tracks and rolling equipment are required.

DESIGN OF CIRCULAR CALIBRATION TANK

The main requirement in calibrating current meters is that they be towed through still water at a uniform speed over a relatively long distance. The calibration is obtained by relating the speed of the instrument (m/sec) to the rate of rotation of the propeller or rotor (rev/sec). The speed of the instrument is estimated from the time it takes to complete a certain number of revolutions of the testing tank. The method used may vary from manual - using a stop-watch - to automatic - using a time and revolution recorder or an electronic timer. The rate of rotation of the propeller or rotor is measured by the counting device on the instrument or can be determined by a spectroscope. The driving mechanism of the rotating arm is preferably of the variable speed type. A voltage regulator is probably required to maintain the motor at constant speed.

In general, towing tanks should be designed so that the obstruction ratio, i.e., the cross-sectional area of the model, is about 1% of the cross-sectional area of the tank. The obstruction due to the propeller is as follows for the various current meters in use at the Institute:

1. Hydrowerkstätten, approx. 50% disc. area - 0,030 m^2
2. Braincon - 0,050 m^2
3. Geodyne - 0,050 m^2
4. Plessey - 0,015 m^2
5. Kelvin-Hughes - 0,010 m^2
6. Ott - 0,008 m^2

The maximum "obstruction area" of 0.05 m^2 occurs with the Braincon and Geodyne meters. According to the previously mentioned design rule, the cross-section of the flume should be:

$0.05\ m^2 \times 100 = 5.0\ m^2$

The cross-section of such a channel should be

2.24 m x 2.24 m.

In the Hydraulics Laboratory of the NRC, I tested the performance of a prototype Ott current meter in a circular model rating tank. The "obstruction area" of the propeller with respect to the cross-section of the flume was 9%. The calibration obtained differed from that provided by the manufacturers by only 1%. This difference was negligible since the calibration of the propeller could have changed by this amount from the time of the purchase, seven years earlier.

From these results it can be concluded, that an increase of the "obstruction area" to 2% of the cross-sectional area of the flume, does not affect the accuracy of the calibration noticeably. The wetted cross-section chosen for the calibration flume is, therefore, 1.50 m high and 2.00 m wide with a cross-sectional area of 3.00 m^2.

The maximum speed at which the propellers and rotors should be tested is 8 knots. The profile drag of the meters and the power to overcome this drag can be computed from the following equations:

Drag force: $D = A \times 1/2 \rho V^2 \times C_d$

Power: $P = \frac{D \times v}{76.04}$

In these equations A is the "obstruction area", ρ the density of the water, V the speed of the meter and C_d the drag coefficient. 1 HP is 0.07604 mt/sec; A of a Braincon meter is 0.05 m^2; ρ for seawater is 0.104 t sec^2/m^4; V is 8 knots or 4.133 m/sec; C_d = 1.15. The drag coefficient of 1.15 is the coefficient of a stiff disc. This value is too high for propellers and rotors whose plates rotate. This factor, however, was chosen to take into account skin friction which has not been taken into consideration.

Substituting the given values into the equations for the drag force and power, we obtain:

$$D = 0.05 \times 0{,}5.0{,}\ 104 \cdot 4{,}133^2 \times 1{,}15 = 0{,}051\ (t)$$

$$P = \frac{0{,}051 \times 4{,}113}{0{,}07604} = 2.8\ (HP)$$

A 5 HP motor is suggested to provide ample power for the driving mechanism and to overcome gear friction. This motor should be of the variable speed DC type, 0 to 1,725 RPM. As shown on Fig. 1 a variable voltage rectifier to provide speed control, a gearbox with a ratio 200:1, and a friction clutch to prevent damage to gearbox in case of sudden stoppage of the rotating arm are required, in addition to the motor. A 4-conductor commutator is necessary to connect the current meter to the recorder. A counter with a stop-watch or an electronic counting device for counting the revolutions of the rotating arm are also required.

For a motor with 1,725 RPM and a gear ratio of 200:1, the time required to complete a revolution is:

$$t = \frac{1}{1{,}725} \times 60 \times 200 = 6{,}96\ sec.$$

Hence, the maximum speed with which a meter should be tested is 8 knots or 4,113 m/sec, the circumference - or path travelled along the center line of the circular tank during one revolution - to achieve this is 4,113 x 6,96 = 28.6 m. The circumference chosen is 30 m and the diameter of the center line is 4,775 m. The layout and the dimension of the flume are shown on Figs. 1 and 3.

In discussions the fear was frequently expressed that the drag from the current meter would impose a movement on the water in the circular channel, thus affecting the accuracy of the calibration.

I have studied this carefully on the equipment in the National Research Council. It was found that with an arrangement of baffles, as shown on the enclosed photograph on Fig. 4, the movement was kept well below one quarter of a percent of the speed of the propeller, regardless of the length of time the meter was towed. Dye injected in one of the compartments of the flume was carried only half-way around the circle by a large laboratory-type propeller meter operating for half an hour at a speed of more than 1 m/sec.

COST ESTIMATE

The cost estimate for the circular flume and the equipment is only approximate. The estimate does not include the shelter, the water supply, the drainage and the electricity. It is assumed that the flume is placed either on a concrete floor or on plain ground which can bear the load and which will not heave as a result of frost.

A. Concrete Work

1) The amount of reinforced concrete required for the flume is 60 cu.yd. (see Fig. 3). The price per cubic yard includes the complete working process with materials, i.e., forms, reinforcements, concrete, finishing and labour. Price per cubic yard of finished reinforced concrete: $60.

   Price for the entire flume: $60 x 60 = $3,600.

2) For the foundation of the driving mechanism 8 cu. yd. of light reinforced concrete are required (see Fig. 1).

   Price per cubic yard: $40.

   Price for the foundation: $40 x 8 = $ 320. $ 3,920.

B. Work and Test Platform

This item includes a wooden 1.2-m wide platform around the flume and a test area with railing and stairs.

Platform, supports, railing, stairs and labour: $ 500. $ 500.

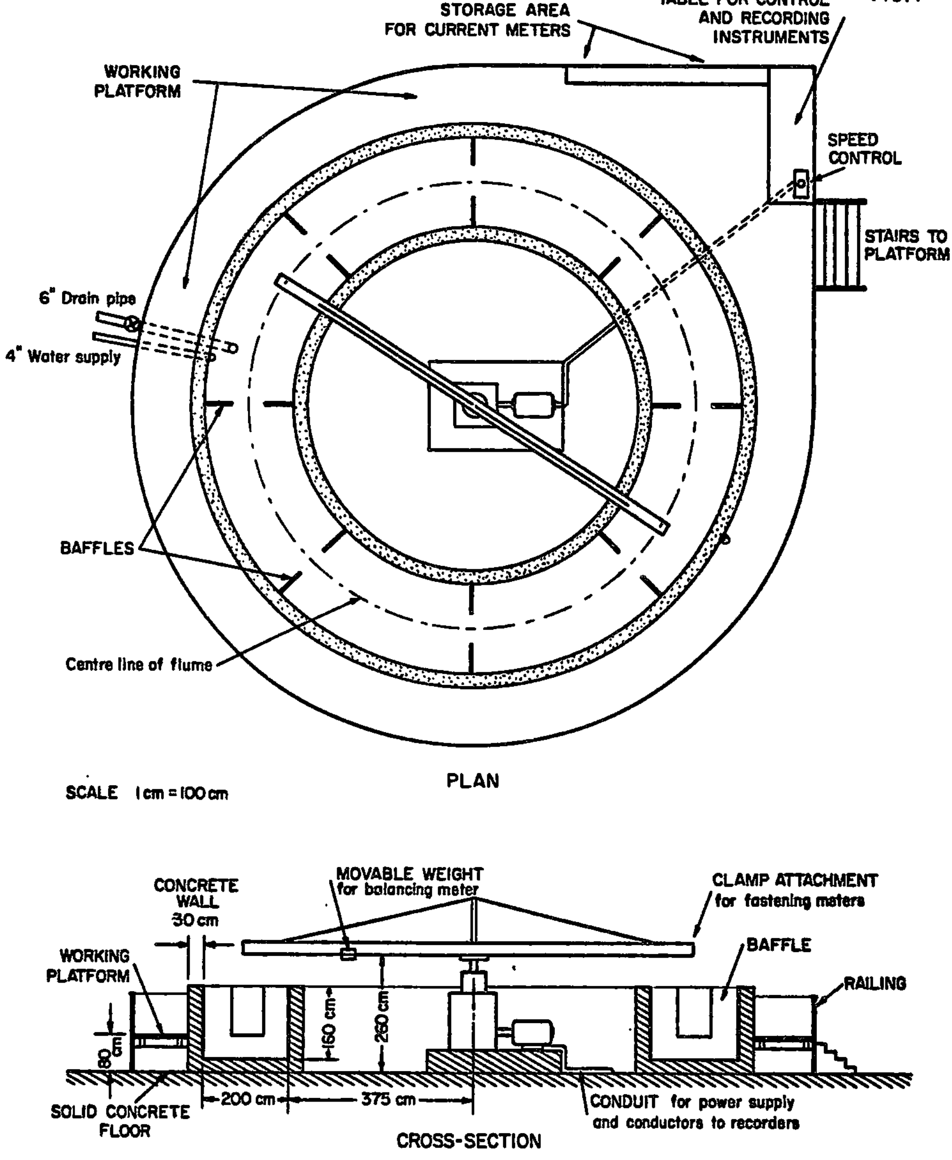
C. Equipment

1) 5 HP, DC variable speed motor: $ 500.

2) Variable speed control: $ 500.

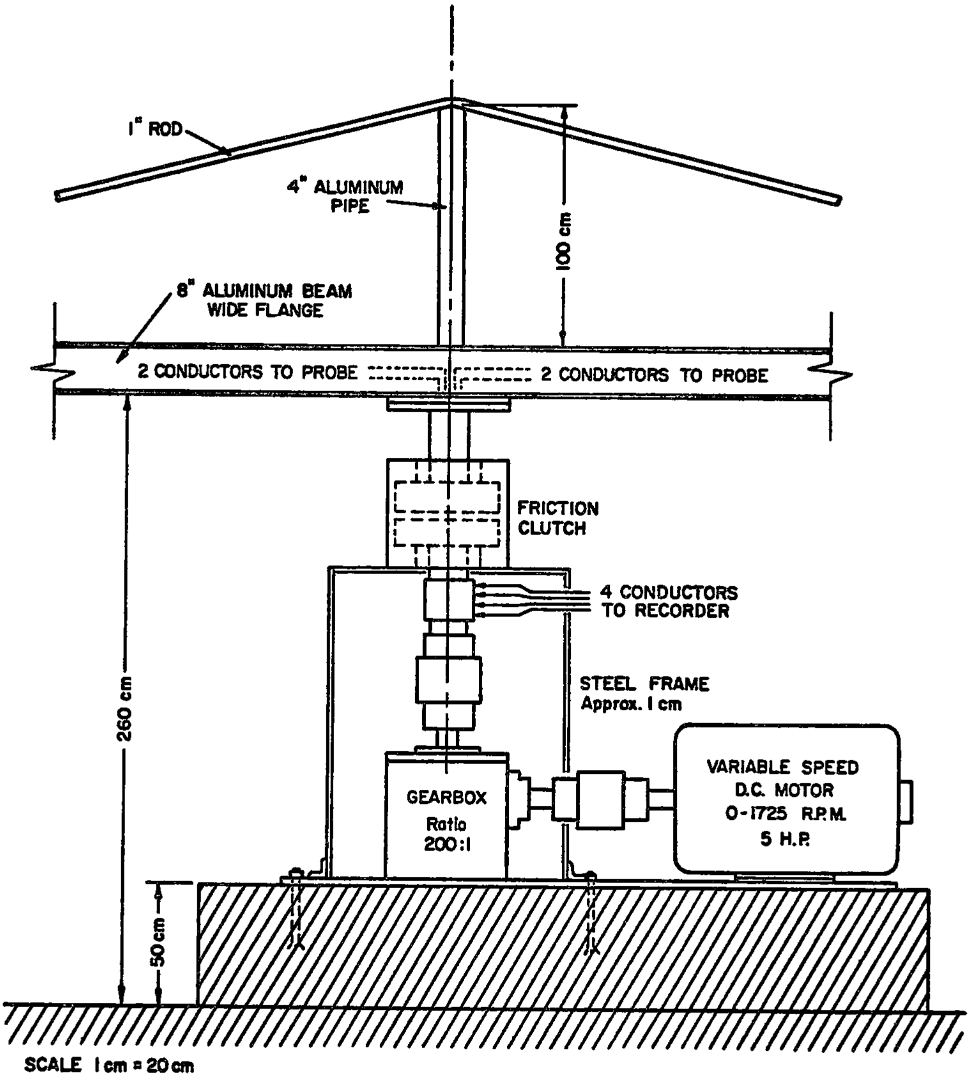
	3) Gearbox, ratio 200:1:	$ 200.	
	4) Friction clutch and bearing:	$ 200.	
	5) 4-Conductor commutator:	$ 100.	
	6) Structural pieces, such as beam, plates, pipes, valves, etc.:	$1,200.	
	7) Timing equipment and electrical accessories:	$ 500.	$ 3,200.
D.	Installation of Equipment		
	300 working hours @ $5./hour	$1,500.	$ 1,500.
		SUB-TOTAL	$ 9,120.
	40% Overhead and Profit: $9,120. x 0.40 =		$ 3,648.
	TOTAL EXPENSE FOR CALIBRATION FLUME - - - - - -	GRAND TOTAL	$12,768.

FIG. I



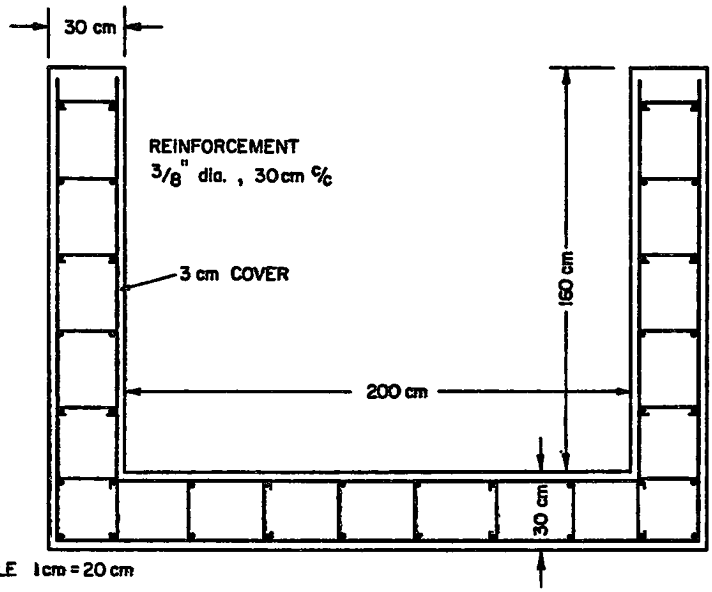
CIRCULAR CALIBRATION FLUME

FIG. 2



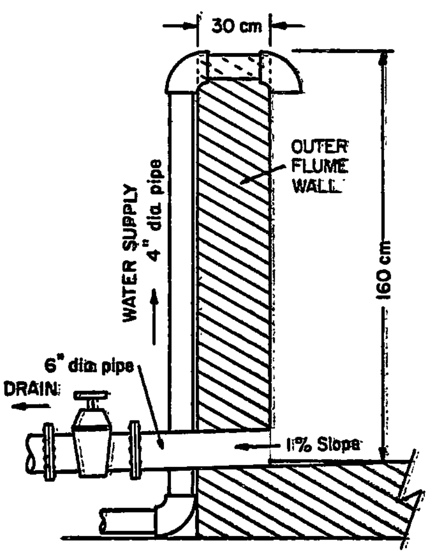
DRIVING MECHANISM
OF CIRCULAR CALIBRATION FLUME

FIG. 3

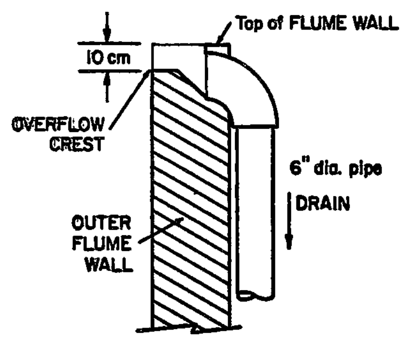


SCALE 1 cm = 20 cm

REINFORCEMENT OF FLUME



SUPPLY AND DRAIN OF FLUME



OVERFLOW FOR CLEANING WATER SURFACE

DETAILS OF FLUME