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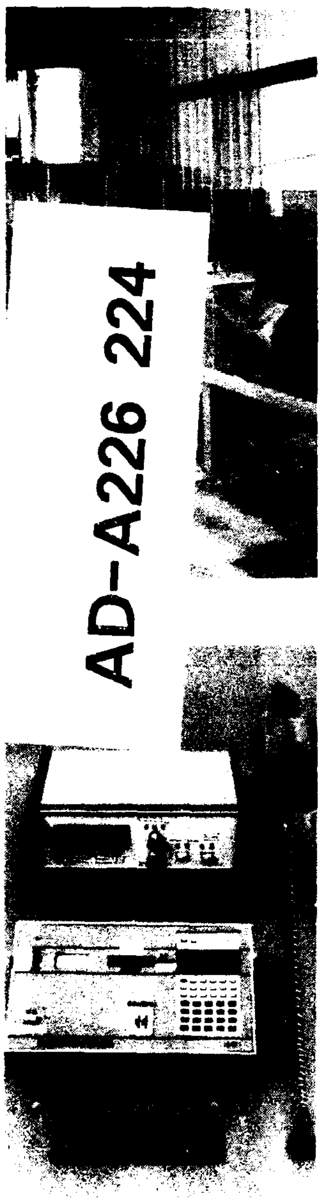

NAVIGATION HYDRAULICS RESEARCH PROGRAM

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EVALUATION OF NANJING HYDRAULIC RESEARCH INSTITUTE PHYSICAL MODEL CURRENT METER

by

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In 1988, an exchange of physical model data measurement devices was made between the US Army Engineer Waterways Experiment Station (WES) and Nanjing Hydraulics Research Institute (NHRI), People's Republic of China. This report contains the WES evaluation of NHRI physical model current meter. The meter was subjected to tests in several WES facilities and found to be a useful instrument in studies involving large-scale physical models, flumes, and structural models.

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PREFACE

This work was performed during the period July 1988 to November 1988 by the US Army Engineer Waterways Experiment Station (WES), under the Navigation Hydraulics (NAV HYD) research program sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE), under NAV HYD Work Unit No. 32510, "Effects of Navigation Hydraulics and Sedimentation on Channel Design." This work was a part of the United States–People's Republic of China Transportation Research Protocol signed in 1983 and amended in 1985. An Annex to the Protocol, signed in 1987, included the US Army Corps of Engineers activities. Dr. W. E. Roper, Assistant Director, Directorate of Research and Development, HQUSACE, was the US Army Project Officer. Messrs. Bruce McCartney and Glenn Drummond, HQUSACE, were the former and present NAV HYD Technical Monitors, respectively.

Personnel of the WES Hydraulics Laboratory performed this work under the direction of Messrs. F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory, R. A. Sager, Assistant Chief of the Hydraulics Laboratory, W. H. McAnally, Jr., Chief of the Estuaries Division (ED), and J. V. Letter, Chief of the Estuaries Simulation Branch (ESB). Mr. R. F. Athow, Estuarine Engineering Branch, ED, was the principal investigator, and Mr. N. J. Brogdon, Jr., ESB, was the project engineer. Former and present NAV HYD research program managers were Messrs. J. E. Glover, former Chief, Waterways Division, and T. Pokrefke, Assistant Chief, Waterways Division. Technicians assisting in the testing were Messrs. John Ashley and Charles Holmes, ESB. Messrs. Brogdon and Athow prepared this report.

During report publication, COL Larry B. Fulton, EN, was Commander and Director of WES. Technical Director was Dr. Robert W. Whalin.

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CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

US Customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
degrees (angle)	0.01745329	radians
feet	0.3048	metres
inches	25.4	millimetres

EVALUATION OF NANJING HYDRAULIC RESEARCH INSTITUTE PHYSICAL MODEL CURRENT METER

PART I: INTRODUCTION

Background

1. As a portion of the US Army Annex to a Protocol between the U.S. Department of Transportation and the Peoples Republic of China Ministry of Communications, an exchange of physical model data measurement devices was made between the USACE Waterways Experiment Station (WES) and Nanjing Hydraulic Research Institute (NHRI). This equipment exchange was for a period of two years for evaluation purposes, with WES supplying an air capacitance water level detector, and NHRI supplying a flow velocity meter. Formal exchange of equipment took place in Nanjing, PRC, on March 12, 1988. At the end of the evaluation period, the instruments were to be returned to their respective owners.

Purpose

2. The purpose of this test program was to evaluate the NHRI instrument which could provide hydraulic laboratories with a highly accurate and relatively inexpensive instrument for point measurements of physical model current velocities, both magnitude and direction.

Approach

3. Evaluation of the model velocity meter was conducted through a two phase test program. Phase I was calibration tank tests to establish the limits and response characteristics of the meter in a controlled environment. Phase II was actual physical model (in situ) tests of the meter.

The Meter

4. A detailed description of the current meter and its performance (as provided by NHRI) are included in Appendix A of this report. The meter is

composed of three major components, (1) current velocity and direction sensors, (2) current direction servo-tracking and readout circuit, and (3) current velocity readout circuit. The meter and components are shown in Figure 1*. Current speed is determined by recording the pulse (revolutions) of a small impellor mounted on a horizontal axis on the lower end of a fiber optic rod. The impellor, a small 4 blade type constructed from a plastic material, is 0.433 inches** in diameter. The meter maintains alignment with the current direction. When the triangular wing rudder is deflected by the current, it makes contact with a pole connected to a balanced circuit bridge (the bridge is balanced when the meter is aligned with the current). When the balanced circuit bridge is broken by change in current direction, realignment is achieved by rotating the fiber optic rod and meter with a mini-servomotor. Current speed and direction is automatically displayed on appropriate readout equipment.

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* Dimensions of the meter are shown in Figure 2.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

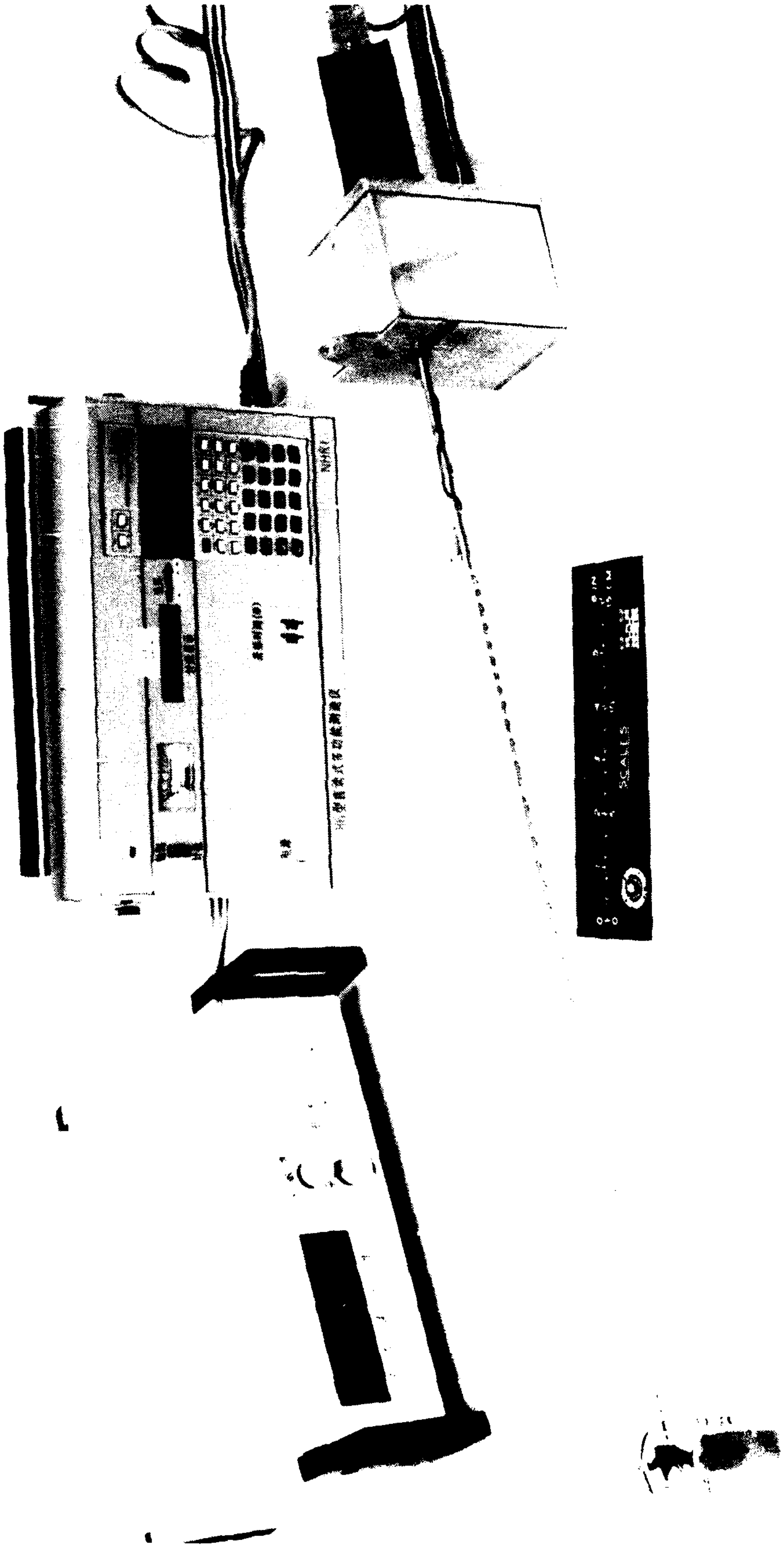
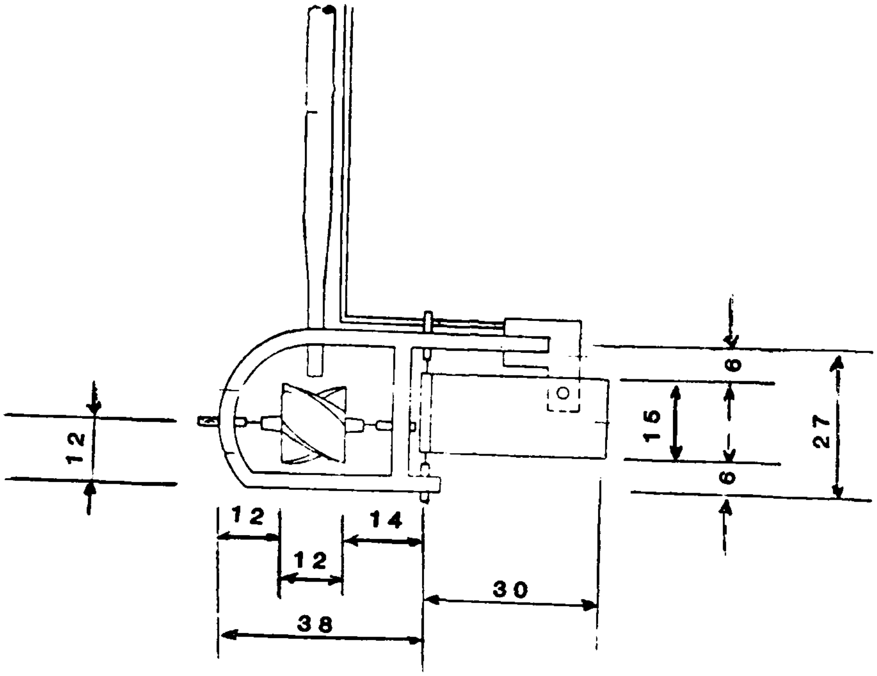


Figure 1. NHRI meter and components



DIMENSIONS IN mm

Figure 2. Dimensions of NHRI meter

PART II: TESTING

PHASE I: Calibration Tank Testing Program

Description of test procedures

5. A complete description of the Estuaries Division Calibration Tank and calibration procedures are given in Appendix B. "Memorandum for Record--Current Meter Calibration Facility". Prior to initiation of the testing program, the existing facility 110 volt 50 hz electrical supply had to be adapted to the 220 volt 50 hz electrical system of the NHRI meter. This was accomplished with a converter furnished by WES Instrumentation Services Division. Two points on the facility calibration curve were checked (figure in Appendix B) to ensure an accurate velocity check of the meter. The curve was checked by measuring a point occurring on the high end of the curve (0.8150 fps) and a point on the low end of the curve (0.1099 fps). These two points checked within 0.001 fps, therefore, no further calibration check point data were collected.

6. Following the tests described below, a test was conducted to determine meter drift over a period of 4 hours of continuous monitoring. The tests was conducted in the following manner: An intermediate flow (head of 0.177 ft- velocity of 0.525 fps) was established in the calibration facility and the meter installed. The meter readings (counts per 30 seconds) were recorded every 15 minutes over a period of 4 hours. The facility head was checked also every 15 minutes. These data are presented in Table 1. The counts varied from a low of 136 to a high of 162. No apparent drift in the meter could be observed. The variations in meter count were generally within the limits of meter repeatability established in other tests.

7. The NHRI meter was placed in the WES calibration tank and tested over a 3 day period (Tests A, B, and C). Table 2 shows the resulting data collected during this period. Calibration was initiated following zeroing and balancing as per instructions furnished with the meter. Appendix A, furnished by NHRI, contains a description of the meter and instructions for its operation. The meter revolution counter (actually two readings or counts per revolution) was set to record for a period of 30 seconds. For each flow setting in the calibration tank, the meter counter was read and recorded ten (10) separate times before resetting the flow for a new reading or new calibration

point. The values shown in Table 2 were obtained by averaging the 10 observed readings. The maximum and minimum count were also recorded and are shown in Table 2.

8. Tests were conducted to determine minimum velocity required to activate meter direction sensor. These tests revealed that a minimum velocity of about 0.15 to 0.20 fps (5 - 6 cm/sec) was necessary before the meter would turn and align itself with the flow. The time required for the meter to complete a 180 degree turn was from 60-90 seconds. Several of these tests were made to determine the minimum turning velocity (threshold speed for the direction sensor) and maximum turning speed. Adjustment of the sensitivity knob did not seem to have any effect on the speed of rotation. The maximum angular speed of current direction tracking of 30 degrees per second quoted in the NHKI meter documentation (Appendix A) could not be duplicated in the calibration tank.

9. Following observation of the above problem with the direction sensor, the meter was inspected by WES Instrumentation Services Division (ISD). In a very careful examination, they discovered several loose connections, which were repaired. Following ISD repair to the meter, it was again placed in the calibration tank. The meter then functioned in accordance to specifications given in Appendix A.

Results

10. The results of the calibration tank tests are summarized in Table 2 and Plate 1. These data show that a threshold velocity of near 0.10 fps (3 cm/sec) activated both the counter and direction sensor. Angular tracking speed of 30 degrees/second was verified in the calibration facility by quickly turning (by hand) the entire meter, rod, etc. 90 degrees, and timing its return to a normal position. This procedure was followed for several flows (all above the threshold velocity). The time required for the meter to return to its normal position was always within the 30 degrees/second limitation given in Appendix A.

11. Three calibration tests were conducted in the WES calibration facility (labeled tests A, B and C). Calibration tests B and C checked very closely to each other, but considerable difference was observed with Calibration Test A results. The meter was checked prior to testing each time to ensure there were no foreign matter in the moving parts that would hinder movement. There was almost no difference in air or water temperature

throughout the three tests that would indicate temperature effects. A count of 102 from Test A calibration data, yields a velocity of 0.426 fps (13.0 cm/sec). A similar count of 102 from Test B calibration data results in a velocity of 0.346 fps (10.5 cm/sec), a difference of 0.080 fps (2.5 cm/sec). This discrepancy between the two calibration data sets is about 19 percent. At 0.7 fps the difference is about 0.1 fps. We were unable to find a reason for the differences and attribute them to tiny pieces of debris binding the meter.

12. Test B calibration data were extended further (higher velocities) than either Test A or C. The percentage difference between maximum and minimum counts in the 10 sampling periods for the highest velocity tested during Test B was near 8 percent. At this setting, the maximum count was 483 and the minimum 447 or a difference of 36 counts.

PHASE II: Physical Model (in situ) Testing Program

13. Two models, the New York Harbor Physical Model and the Estuary Training Structures Facility (ETSF) were used for the NHRI meter in situ tests. The New York Harbor Model is constructed to length scales of 1:100 vertically and 1:1000 horizontally, which result in a velocity scale ratio, model to prototype, of 1:10. The brief testing conducted in the New York Harbor model were not conclusive, since during a large percentage of the tidal cycle, current speeds were below the threshold velocity of the NHRI meter. The NHRI meter satisfactorily measured current speed above 0.10 fps (3 cm/sec) (New York Harbor prototype velocity of 1.0 fps [30 cm/sec]). The meter's direction sensor operated very well until speeds fell below 0.10 fps (3 cm/sec) and in areas where the meter had sufficient room to turn.

14. Current speeds and directions in this model are normally collected on the prototype half-hour (18 seconds real time). Current directions in the New York Harbor model at most locations change over a period of 10-20 sec. Current speeds as they approach slack water (period when flow direction changes and current speed nears zero) are very small in magnitude. The NHRI meter was not capable of measuring these low speeds around slack water, nor was the direction sensor able to track or turn with the currents until a current speed near 0.10 fps (3 cm/sec) was reached.

15. In order that the NHRI meter be given a more complete in situ trial

test, it was decided to conduct further tests in the ETSF. This facility is a flume 20 ft (6.1 m) wide, by 160 ft (48.8 m) long, and 2.0 ft (0.6 m) high. The facility, at the time of the in situ tests, was set up for sediment entrainment studies. The test section was 6 ft (1.8 m) wide, by 110 ft (33.5 m) in length and the water depth was maintained at a depth of 1.0 ft (0.3 m). Water was pumped from a nearby sump using a 25 cfs (0.71 cm/sec) pump. Current speeds near 2.0 fps (61 cm/sec) were generated through the flume and were regulated by a system of valves and gates.

16. For the in situ tests in the ETSF, a 2 ft (0.61 m) long dike structure was placed in the flume perpendicular to flow. This obstruction created various current patterns and eddy formations in and around the dike structure. Dye was placed in the flume upstream of the structure and from visual observations of the currents, several stations were selected for sampling with the NHRI meter. The NHRI meter performed in a highly satisfactory manner at stations where the current speed was above 0.10 fps (3 cm/sec). The direction sensor was very accurate in determining current direction at almost all stations in the immediate vicinity of the structure. Erratic readings were encountered at stations where extremely turbulent flow was present. However, by monitoring the readout over a short period of time, an average direction could be easily determined.

PART III: CONCLUSIONS

17. The threshold speed of the meter (about 0.10 fps [3.0 cm/sec]) would be too high for the majority of WES estuarine physical models. Likewise, the direction sensor could not function at low speeds around slack periods. However, the meter when utilized in the ETSF performed very well in both measurements of current speeds and direction. The instrument would be a very valuable asset in model studies where the threshold velocity is above 0.10 fps (3 cm/sec) and channel width is great enough (at least 3.5 in. [8.9 cm]) to accommodate the meter.

18. In summary, the NHRI current meter will meet some of the needs of the WES estuarine physical model environment. The meter will be very useful in studies involving large scale physical models, flumes, and structural models.

Table 1

NHRI Meter Stability Tests

WES Calibration Facility

Time minutes	Counts per 30 sec.	Head		Velocity	
		Feet	Metres	fps	cms
0:00	159	0.177	0.054	0.525	16.0
0:15	155	0.177	0.054	0.525	16.0
0:30	142	0.177	0.054	0.525	16.0
0:45	143	0.177	0.054	0.525	16.0
1:00	136	0.177	0.054	0.525	16.0
1:15	140	0.177	0.054	0.525	16.0
1:30	156	0.177	0.054	0.525	16.0
1:45	154	0.177	0.054	0.525	16.0
2:00	149	0.177	0.054	0.525	16.0
2:15	162	0.177	0.054	0.525	16.0
2:30	152	0.177	0.054	0.525	16.0
2:45	155	0.177	0.054	0.525	16.0
3:00	148	0.177	0.054	0.525	16.0
3:15	148	0.177	0.054	0.525	16.0
3:30	140	0.177	0.054	0.525	16.0
3:45	162	0.177	0.054	0.525	16.0
4:00	160	0.177	0.054	0.525	16.0

Table 2

Nanjing Hydraulic Research Institute Current Meter

Calibration Tank Facility Tests

Test A

Head Feet*	Head Meters	Counts (30 sec)	Flow Speed in fps**	Flow Speed in cms	Counts Maximum	Counts Minimum
0.063	.019	0	—	—	—	—
0.073	.022	13	.085	2.59	14	12
0.082	.025	37	.106	3.23	40	34
0.086	.026	45	.117	3.57	49	41
0.090	.027	23	.128	3.90	24	22
0.100	.030	32	.154	4.69	33	31
0.115	.035	45	.202	6.16	49	41
0.134	.041	64	.280	8.54	68	60
0.162	.049	102	.426	12.98	108	96
0.178	.054	140	.527	16.06	148	132
0.210	.064	204	.766	23.34	216	193

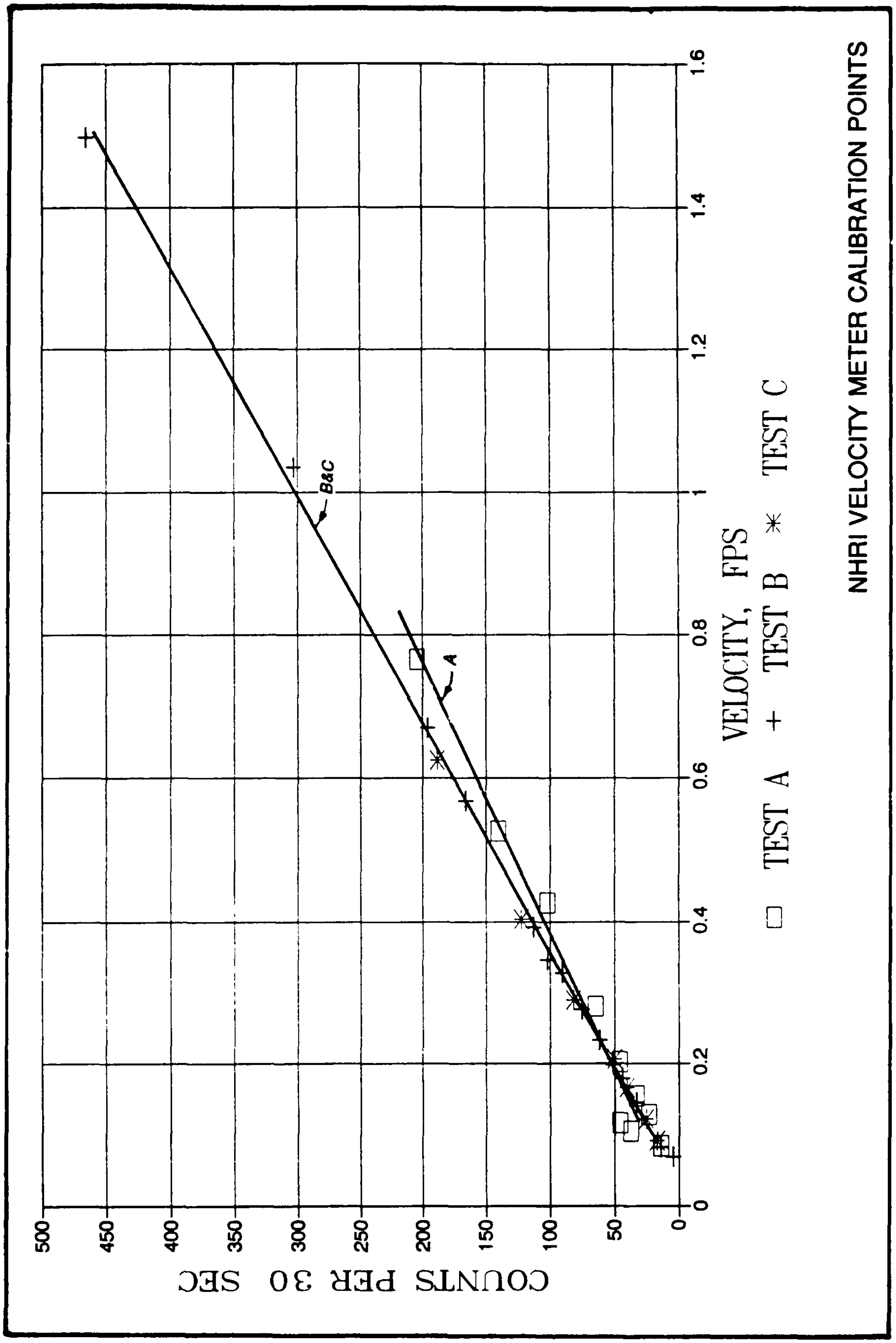
Test B

Head Feet*	Head Meters	Counts (30 sec)	Flow Speed in fps**	Flow Speed in cms	Counts Maximum	Counts Minimum
0.066	.020	4	.070	2.13	5	3
0.072	.022	13	.083	2.53	14	12
0.097	.030	32	.146	4.45	33	31
0.108	.033	43	.179	5.45	46	40
0.114	.035	51	.199	6.06	54	48
0.123	.037	61	.233	7.10	64	58
0.133	.041	75	.276	8.41	73	78
0.144	.044	90	.328	10.00	92	88
0.148	.045	102	.346	10.54	106	98
0.156	.048	112	.392	11.95	117	107
0.184	.056	165	.568	17.31	173	158
0.198	.060	195	.671	20.45	205	185
0.240	.073	303	1.035	31.54	318	288
0.283	.086	465	1.498	45.65	483	447

Test C

Head Feet*	Head Meters	Counts (30 sec)	Flow Speed in fps**	Flow Speed in cms	Counts Maximum	Counts Minimum
0.052	.016	0	—	—	—	—
0.076	.023	16	.092	2.80	17	15
0.088	.027	25	.122	3.72	27	22
0.104	.032	40	.166	5.06	42	38
0.116	.035	50	.206	6.28	53	47
0.136	.041	81	.289	8.81	83	79
0.158	.048	122	.403	12.28	128	116
0.192	.058	188	.625	19.05	198	178

* 1.0 ft = 0.3048 meters.
** 1.0 fps = 30.48 centimeters per second.



NHRI VELOCITY METER CALIBRATION POINTS

APPENDIX A

DESCRIPTION OF THE COMBINED CURRENT VELOCITY / DIRECTION METER

The combined current velocity/direction meter is mainly used for measuring the current velocity and direction varying slowly in the hydraulic tidal model and in hydraulic models of rivers, estuaries etc. in the laboratory.

This meter is composed of three parts:

1. Current velocity and direction sensors
2. Current direction servo-tracking and readout circuit
3. Current velocity readout circuit

CURRENT VELOCITY / DIRECTION SENSOR

A mini-servomotor and a piece of fibre optic rod are installed at the base. The rod is turned by the servomotor via the gears. A supporting frame is locked at the lower of the rod with lock nuts. A propeller is supported horizontally inside of the frame by a pair of agate bearings and a rudder of triangular wing is supported vertically outside of the frame by a pair of agate bearings, and a pair of poles is fixed just between the pair of wings.

When the axis of the frame is aimed at the current direction, the water resistances of the pair of poles are roughly the same, while the bridge in the circuit is balanced. When the rudder deflects with the changes of the current direction, the balance of bridge will be destroyed. The rod should be turned by the servomotor, which is driven by the amplifying circuit, until the axis of the frame is aimed at the current direction. Therefore, the axis of the propeller is always aimed at the current direction.

The current direction is read out with the help of the precision potentiometer fixed on the rod.

There are two sets of output sockets on the current velocity/direction sensor: 16-core socket are connected with the current direction servo tracking and readout circuit, while 4-core socket are connected with the current velocity readout circuit.

CURRENT DIRECTION SERVO TRACKING AND READOUT CIRCUIT

It is composed of bridge circuit, preamplifier, main amplifier, which connects with a pair of platinum poles and servomotor.

The current direction readout circuit is composed of D.C. voltage standard providing the precision potontiometer and A/D converter turning the output voltage of the potentiometer into numerical display.

CURRENT VELOCITY READOUT CIRCUIT

(See "Description of The Fibre-Optic Type Miniature Propeller Velocity Meter" for details)

THE OPERATION OF THE COMBINED CURRENT VELOCITY / DIRECTION METER

1. Plug the sensor, connect the power supply and switch on it. At this time, the LED nixie for current direction readout lights.

2. Push down the key "Motor". Adjust the balancing potentiometer to make the rod run in one direction slowly with the servomoter. At that time, the readout of current direction is increasing or decreasing continuously. It means the current direction readout system operates properly.

3. Place the sensor into static water. The rod may turn in one direction. Adjust the balancing potentiometer until the motor stop.

4. Stir the rudder in the static water lightly with a piece of fine filament, the rod will turn agilely with the deflection of the rudder. If the tracking rate in the clockwise direction is not as same as in the counter clockwise direction, it is necessary to adjust the balancing potentiometer until these two rates are basically same.

5. The poles operate with the help of the water resistance, so it is related to water temperature, water quality, the oxidized level of the pole surfaces. pay attention to the cleaning of the pole surfaces.

6. The adjustment of the sensitivity potentiometer can change the tracking rate of servomotor.

7. The reference angle of current direction is specified artificially. The angle of current direction readout is relative to the artificially reference angle.

8. There is a current direction output socket on the rear panel which is used for self-balancing potentiometer to draw the process of current direction changes automatically of data acquisition.

The full output range is 0-3.5v (using 1° as 0.01v)

9. When installing the sensor, the rod must be vertical.

TECHNICAL PERFORMANCES

1. Operating medium: water
2. Diameter of propeller: 15mm
3. Size of the rudder: triangular wing with an included angle of 30° (length 30 mm, height 15mm)
4. Minimum current velocity of propeller starting and current direction tracking: 3cm/sec.
5. Maximum angular speed of current direction tracking: 30° /sec
6. Minimum depth to be measured: 4 cm
7. Maximum depth to be measured: 50 cm
8. Current direction readout:
   LED nixie display
   Mechanical range—360°
   Electrical range—350±1°
   Output signal—3.5v/350°
   Resolution—1°

Note: Because of the development history, the current direction tracking and read-out circuit, and current velocity readout circuit are placed in two cabinets respectively. They are going to be merged into one in the future. so the portion of the current velocity sensor, the current velocity readout circu it and their technical performances see "Description of The Fibre-Optic Type Miniature propeller Velocity Meter" for details.

Front Panel:

流向读出(度) Current Direction Readout (Degree)
灵敏度 Sensitivity Potentiometer
平衡 Balancing Potentiometer
电机 Servo Motor
电源 Switch of Power Supply

Rear Panel：

0.5A	Fuse
电源	Socket of power supply
流向输出	Current Direction Output
传感器	Socket of Sensor—Core

DESCRIPTION OF THE FIBRE-OPTIC TYPE MINIATURE PROPELLER VELOCITY METER

This meter is mainly used in laboratory to measure the velocity of current in ducts, in hydraulic engineering models and in hydraulic models of rivers, estuaries, etc.

The meter consistes of a sensor of the fibre-optic type miniature propeller and a read-out cicuit of velocity.

THE SENSOR OF FIBRE-OPTIC TYPE MINIATURE PROPELLER

With the miniature propeller as the first stage sensor and the optical fibre as the second stage sensor, the velocity is made to be changed into the output of pulse frequency.

The sensor is composed of a Y-shaped fibre-optic beam rod, a bulb, a phototransistor, a miniature propeller and a suspporting frame. The propeller is supported on a pair of shaft tips of the frame by a pair of agate bearings, the frame is locked on the rod by nuts.

Prior to use the sensor, one should strictly examine:

1. If the supporting system of the propeller is overtight or overloose.
2. If there is filament dirt tangled around the agate bearings or shaft tips.
3. If the frame is locked tightly with the rod.

The light source emitting from the bulb through the transmitting fibre-optic beam and transmits to the rod end. Whenever the plated reflecting edge of the propeller sweeps past the front of rod end, a light-reflecting signal is received by the phototransistor through the receiving fibre optic beam.

Thus, the light pulse intensity received from the optic transistor is not only related to the properties of optical fibre, but also to the following three factors:

1. The intensity of the light source.
2. The gap between the rod end and the reflecting edge of the propeller.
3. The quality of the reflecting face of the propeller.

Taking the lifetime of bulb into account, the operating voltage is better limited within 1.6v to 1.8v. On using the sensor, the gap (typically 1-2mm) between the rod end and the reflecting edge of the propeller is adjusted according to the turbidity of the measured water object. It is also very important to check on the quality of the plated reflecting face of the propeller after the use of long duration.

VELOCITY REOD-OUT CIRCUIT

The circuit can regularly register the output pulse of the sensor and enables the accumulated pulses, via an interface circuit, automatically to feed into the BL-818 programmable calculator. ——The velocity can directly be read out following the calibrated relationship.

The circuit comprises six parts; an input circuit, a control unit, a counter and display, and interface unit, operation and read-out devices and a power supply.

The operating procedures are as follows:

1. Programming———From the calibrated results, there exists a certain relationship between the rotating speed of the propeller and the velocity of water flow. The task of programming is to pre-programm this relationship to the programmable calculator; therefore, based on the input accumulated pulses the calculation can automatically be conducted and read out the value of velocity. (The method is detailed in the part of "A Programming Method")

2. As the power supply is connected and switch on, the second signal display flickers by a second interval and the LED nixie for counting and displaying lights.

3. As the selective switch is set to the 'Count' position, the testing meter displays the output voltage of the light source. Adjust the light-source voltage-regulating potentiometer on the left side of the casing, so that the terminal voltage of bulb falls in the allowable operating range——typically 1.4v to 1.8v (non including the voltage drop dissipation of the cable)

4. Connect the sensor and set the selective switch to the 'Test' position. Then gently rotate the propeller with hand to have the plated reflecting face remain at the better position of the front of the rod end; thus the testing meter indicates the output signal intensity of the sensor.

5. As the output signal intensity reaches 40μA, the instrument can work normally and reliably. Then set the selective switch to the 'Count' position and rotate the propeller lightly to have the plated reflecting face sweep back and forth the front of the rod end, thus LED nixie displays the accumulated values number by number.

6. Only when the output signal intensity reaches 40μA, the instrument runs normally, which refers to the slow rotating speed of the propeller. If the ins-

trument is employed to a higher velocity of water, the intensity should increaes 1 to 2 times.

7. When the sensor is placed in the flow water to be measured, the LED nixie indicates the accumulated values by sequent numbers, with the rotating of the propeller. As soon as the sampling time ends, the LED nixie displays the final accumulated values.(the halting time of the values is one second)

8. After one secon elapses, reset and count again. In accordance with the value of velocity and the condition of flow, the meaurement is considered to be reliable if the mean square deviation of counting of many times is limited to a certain range.

9. According to the value of velocity, the condition of flow and measuring requirements, the sampling time is chosen within 1-99 seconds. The user can set at his own requirement with the use of code switch.

10. The programmable calculator is "ON". As soon as the sampling time ends, the final accumulated figure paused displaying on the LED nixie feeds into the BL-818 programmable calculator through the interface circuit. Consequently, the accumulated figure immediately appears on the BL-818 LCD: Following that , the BL-818 programmable calculator goes into operation in the light of pre-set programme and indicates the calculated result——the value of velocity —— on the LCD. The above procedures are accomplished in one-second after the sampling pause.

11. After one-second paused sampling time has passed, the counter displays Zero again and re-count, whereas, on the BL-818 LCD stands the calculated result which does not vanish until the second new figure feed in. Therefore, the display time of the velocity on the BL-818 LCD is equal to the sampling time.

TECHNICAL PERFORMANCES

1. Operating medium: water and other liquid
2. Diameter of propeller: 11mm, 4-blade
3. Material: plastic ABS
4. Starting velocity: 3cm/sec
5. Voltage of light source: 1.4v-1.8v
6. Output signal of sensor: greater than 80μ(at 1.6v of light source voltage)
7. Sampling time: 1-99 sec arbitrarily chosen with code switch
8. Test of output signal of sensor: testing meter
9. Rotating monitoring of propeller: ramdomly displayed by a LED nixie
10. Operational Civcuit: using a BL-818 programmable calculator

11. Calibrated coefficient setting: BL-818 key board
12. Flow velocity readout: BL-818 LCD
13. Length of optical fibre rod: There are five different length of the rod, that is 40, 50, 60, 80, 100 cm.
14. Power requirement: 220v AC 50/60Hz.

A PROGRAMMING METHOD

1. Take the calibrated relation $V = an + b = a\frac{N}{T} + b$ for an example.

Where, V— flow velocity (cm/sec)

n— rotation speed of the propeller (rev/sec)

T— setting sampling time (sec)

N— the number of turns of the propeller within the sampling time

a, b— Calibrated Coefficients

Programming procedures: The sequen y is as follows:

ON/C F Comp F K_1 $\frac{a}{T}$ x

K_1 + b = F Comp

The main power supply must be switched off while programming.

The programming remain permanetly when the main power supply is switched off; It is un-necessary to re-programming whenever it is switched on.

2. The read-out value from the instrument is the velocity of the model. If the velocity of the prototype is required to read-out directly, a velocity scaling can be incorporated into the programmed coefficients.

3. An example

Set sampling time: T=10 sec

Calibrated coefficients: a=4.2, b=2.5

Velocity scaling: $\lambda_v = 5$

Unit of the prototype velocity: m/sec

In this case, the programmed coefficients $\frac{a}{T}$ should be changed into $\frac{a}{T} \times \frac{\lambda_v}{100} =$ 0.021 and b into $b \times \frac{\lambda_v}{100} = 0.125$

Programming procedures: The sequency is the following:

ON/C F COMP F K_1 0.021 x

K_1 + 0.125 = F COMP

When the programming is completed, test must be conducted in such a way that following the push of N COMP , the indicated value is the velocity

$$V=\frac{4.2}{10}\cdot\frac{5}{100}\cdot N+2.5\cdot\frac{5}{100}(M/sec)$$

If N=20, V=0.545 M/Sec

PRODUCTS SERIES

The sensor of fibre optic type miniature propeller:

1. There are three different diameters of propeller, that is, 6, 11, 15mm for different space-resolution.

2. There are three different numbers of the plated reflecting face of the propeller, that is, 1, 2, 4 for different velocity-resolution.

3. There are two kind of rod —— straight rod and bent rod —— for measuring the horizontal flow and vertical flow velocity.

Velocity read-out and registeration:

Model I: The LED display real-time-displays the accumulated rotating turns of the propeller, The LCD of the BL-818 programmable calculator indicates the value of velocity.

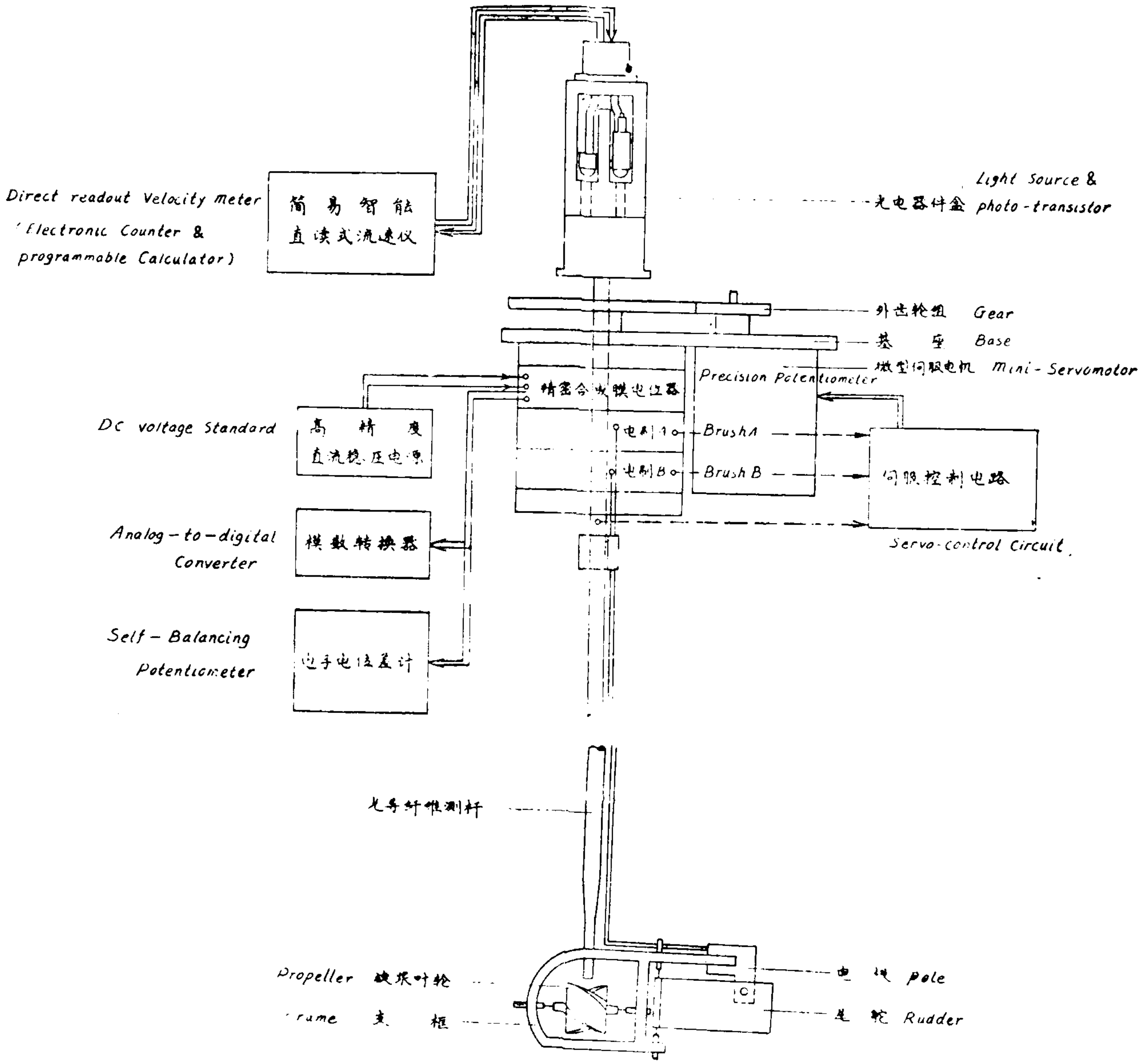
Model II: The LED display real-time-displays the accumulated rotating turns of the propeller. The LCD of the HR-8 pocket calculator indicates the value of velocity, with a printer attached.

Model III: Synchro-acqusition of 8 channel flow velocity LED simultaneously indicate the rotating state of 8 channel propeller sensors. A HR-7 pocket calculator prints and outputs the 8 channel velocity values.

Note: The sensor of fibre optic type miniature propeller can provide a stronger output pulse signal which makes it possible to directly link with a microcomputer so as to realize the synchro-acquisition of multi-point flow velocity.

Front Panel:

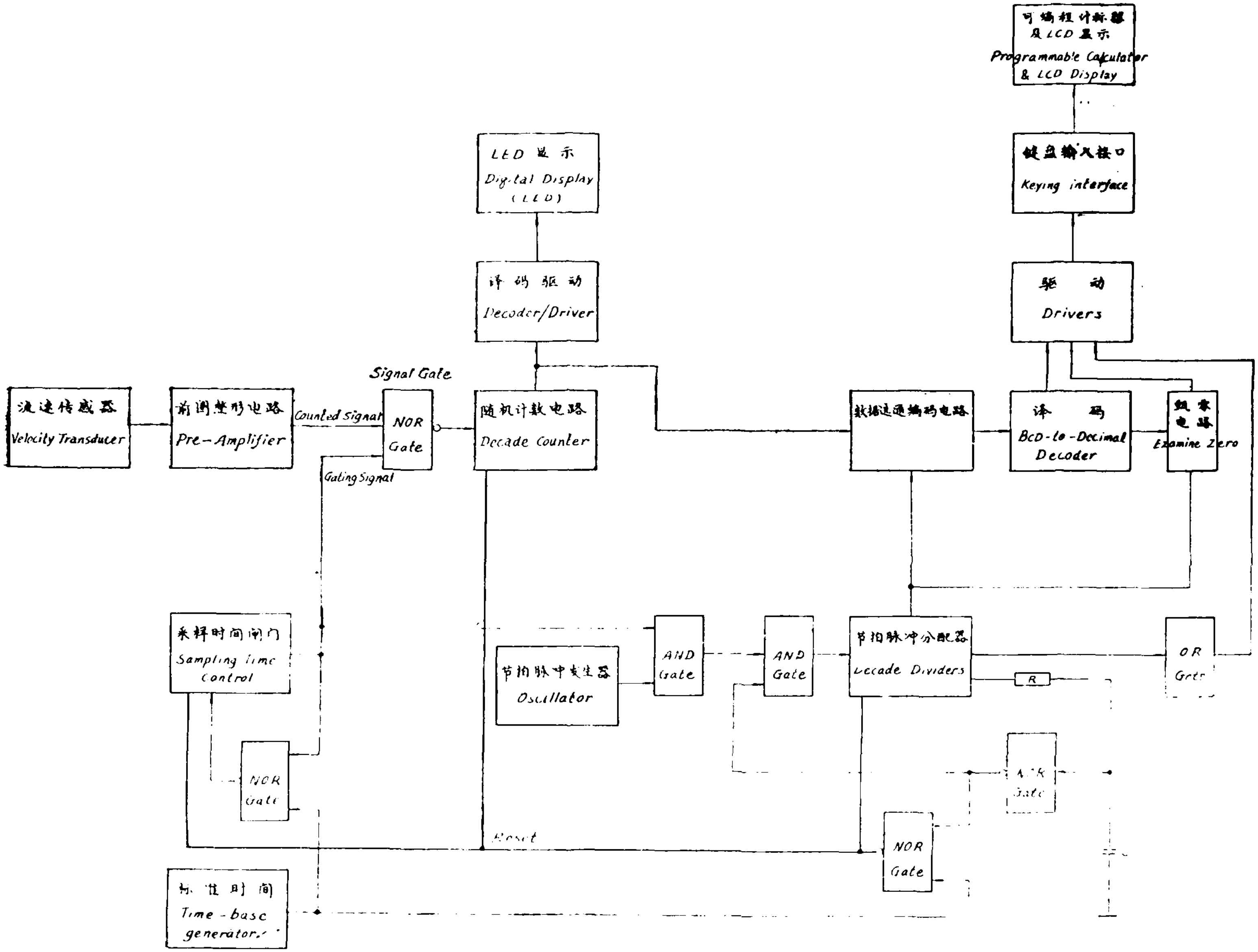
检　测	Test
计　数	Count
电　源	Switch of power supply
计数显示	LED Display
运　算	Calculate
采样时间(秒)	Sampling Time (sec)



跟踪式流速流向仪示意框图

Block diagram

the Combined Current - Velocity / Direction Meter (Servo-type)



直读式流速仪电路方框图

Block diagram of the direct readout velocity meter

APPENDIX B

Current Meter Calibration Facility

1. This memorandum gives a description of and instructions for the use of the laboratory current meter calibration facility located in Estuaries Shelter No. 8, Building 6006.

Description of Facility

2. The facility consists of a two-chamber calibration tank, a constant head tank, and associated piping as shown in Figure 1. The calibration tank is divided into upper and lower chambers by a partition containing a 2.5-inch plastic Verein Deutscher Ingeneiure (Streeter, 1962) nozzle. Water introduced into the upper chamber flows through the nozzle into the lower chamber and over a brass 45° V-notch weir into a waste pit. Discharge and thus nozzle flow velocity is determined by measuring head over the weir. Current meters are calibrated by placing them in the nozzle jet on the lower chamber side of the partition. The calibration tank is that designed by Brown (1970) but has been modified in several minor ways.

3. The constant head tank (Figure 2) consists of concentric cylindrical barrels on a stand above the calibration tank. Water flows into the center barrel from an overhead freshwater supply line. The lip of the center barrel acts as a long (6.3 feet) sharp-crested weir and maintains a nearly constant water level in the barrel for a given flow. Water flowing over the lip falls into the outer barrel and is wasted. Water for the calibration tank is withdrawn through a tap in the bottom of the inner barrel, where it flows through either or both of two flow meter/valve assemblies and then into the calibration tank's upper chamber.

Use of the Facility

4. Scheduling and maintenance of the calibration facility is performed by personnel of the Harbor Entrance Branch, Estuaries Division. It is recommended that first-time users request assistance in use of the facility.

5. Flow into the calibration facility is controlled by the 1 1/2-inch

valve located just inside and to the right of the east personnel entrance to Estuaries Shelter No. 8. Opening this valve introduces flow into the constant head tank. The user at this point should be certain that the overflow line from the constant head tank is open to prevent the tank from overflowing and drowning the user. The supply line flow should be adjusted until the desired flow into the constant head tank results in a steady discharge through the tank overflow line. Water must be freely flowing over the lip of the inside barrel during all measurements. The constant head tank situation may be monitored by observing the convex mirror above the tank and the plastic tube that shows the water elevation in the overflow tank.

6. Flow to the calibration chambers from the constant head tank is controlled by the two valves feeding flow meters A and B. Approximate flow rates may be set using these flow meters, but actual flow must be determined by measuring the head over the V-notch weir in the lower chamber (Figure 3). The point gage should be positioned to measure water elevation at a point 1.11 feet from the weir in the center of the tank. Zero water surface elevation is defined as being 0.084 foot below the engraved cross on the top surface of the aluminum reference bar. The reference bar must be securely clamped into the proper position before zeroing the point gage. The relationship between head over the weir and nozzle velocity is shown in Figure 4 and Table 1.

7. Flows should be allowed to stabilize before readings are taken. Head should then be measured before and after each meter calibration to insure that the flow rate has not changed. Under normal conditions the flow rate will fluctuate very little once stability has been reached.

8. The current meter to be calibrated is mounted on a point gage and placed in front of the nozzle in the lower chamber. The meter should be plumb, not more than 2 inches away from the end of the nozzle, and as near as possible to the center line.

9. The chamber should be allowed to flush itself for a short period prior to testing to remove any dust or foreign particles that may have collected in the tank between uses. If the equipment is in need of cleaning, personnel of the Harbor Entrance Branch should be notified. The user should not attempt to clean the equipment himself as improper cleaning could cause the calibration to be altered. Lines draining both upper and lower chambers must be closed during use.

10. Conversion tables for calibrated meters at different model scales may be generated by using a curve fitting technique such as program FLSFIT and program VTABLE, available from Mr. John Shingler, Estuaries Division.

Calibration of the Facility

11. The facility is calibrated or checked at least annually. Calibration consists of measuring the time required to fill a 1.01-cubic foot plastic box from the V-notch weir overflow at a given head. The resulting volumetric flow rate is converted to an average velocity through the nozzle and then to an actual velocity that corrects for the velocity profile near the nozzle boundary. The correction factor is that given by Brown (1970).

12. Two quadratic equations are fit to the calibration data points by the least squares method. Separate equations are fit to the upper and lower portions of the curve with the dividing point being a head of 0.09 foot—the point at which the weir nappe losses aeration. The curve on Figure 4 and the values in Table 1 represent the best-fit quadratic equation.

Accuracy

13. The point gage used to measure head on the weir is read directly to the nearest 0.001 foot and can be interpolated to ±0.0005 foot. An error of 0.001 foot due to miszeroing or misreading the point gage will result in a current speed error of 0.002 fps at 0.05 fps and 0.01 fps at 1.0 fps.

14. Volume of the calibration cube has been computed from measurements of inside dimensions to be 1.011 cubic feet. Measuring the volume of water required to fill it showed a volume of 1.014 cubic feet. For volumetric computations it is assumed to have a volume of 1.01 cubic feet. Variation of ±0.005 cubic foot in actual volume would result in an error of 0.5 percent in the flow rate and calculated flow speed.

15. The most significant source of error in calibrating the flume is measuring the time required to fill the calibration cube. Time is measured with a stopwatch graduated to 0.1 second. Tests of several individuals timing the duration of a timed light has shown variations of up to 0.5 second under optimum conditions. If 1.0 second is taken to be the maximum error in time

measurement, the resultant flow speed error is about 0.2 percent at 0.05 fps and about 4 percent at 1.0 fps.

16. The correction factor used to compute a center-line speed from the average flow speed is a function of the flow Reynolds number. The calibration curve (Figure 4) is based on a water temperature of 70°F, but the error due to change in viscosity for a temperature range of 60°–90°F is about 0.002 fps at 0.1 fps and less for higher flow speeds. The correction factor has not been measured for flow speeds of less than about 0.5 fps and must therefore be extrapolated. From the data presented by Brown (1970), the error in the factor could be as much as 3 percent at 0.02 fps, or ±0.0006 fps, well within the other errors.

REFERENCES

Streeter, V. L., 1962, Fluid Mechanics, McGraw-Hill, New York, NY.

Brown, B. J., 1970, Memorandum for Record, Subject: Calibration Facility for Laboratory Current Meters, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

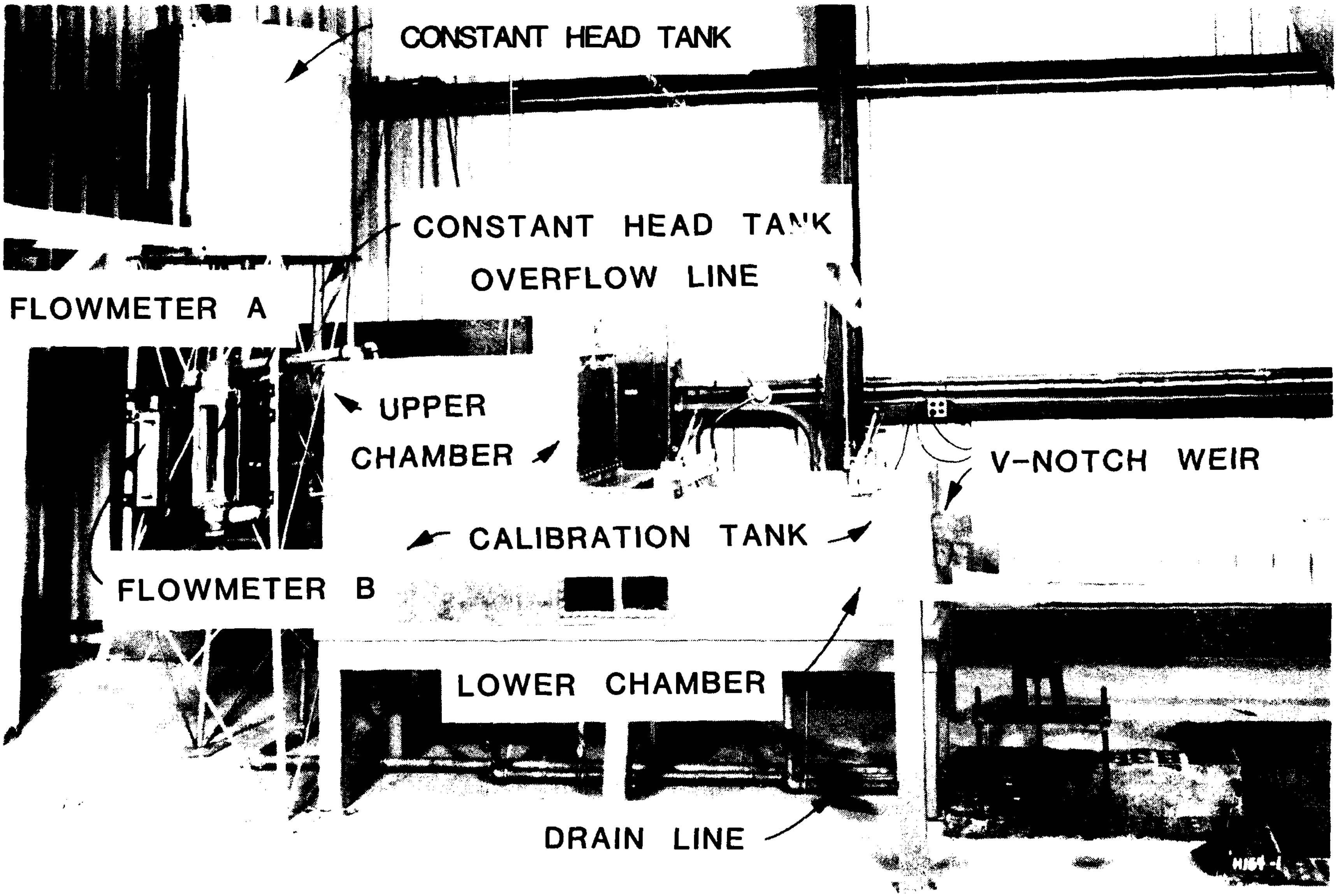


Figure 1. Calibration facility

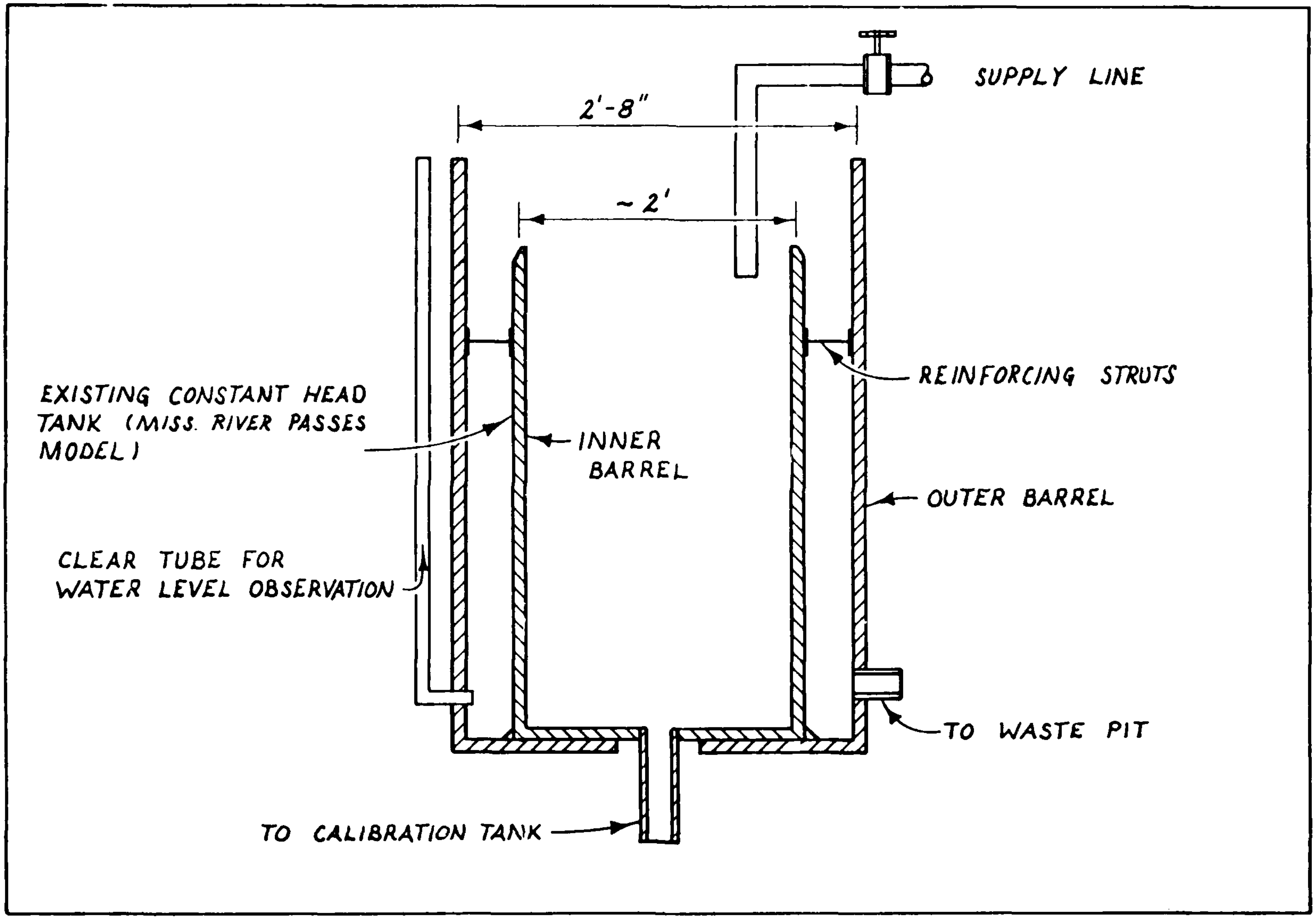


Figure 2. Constant head tank

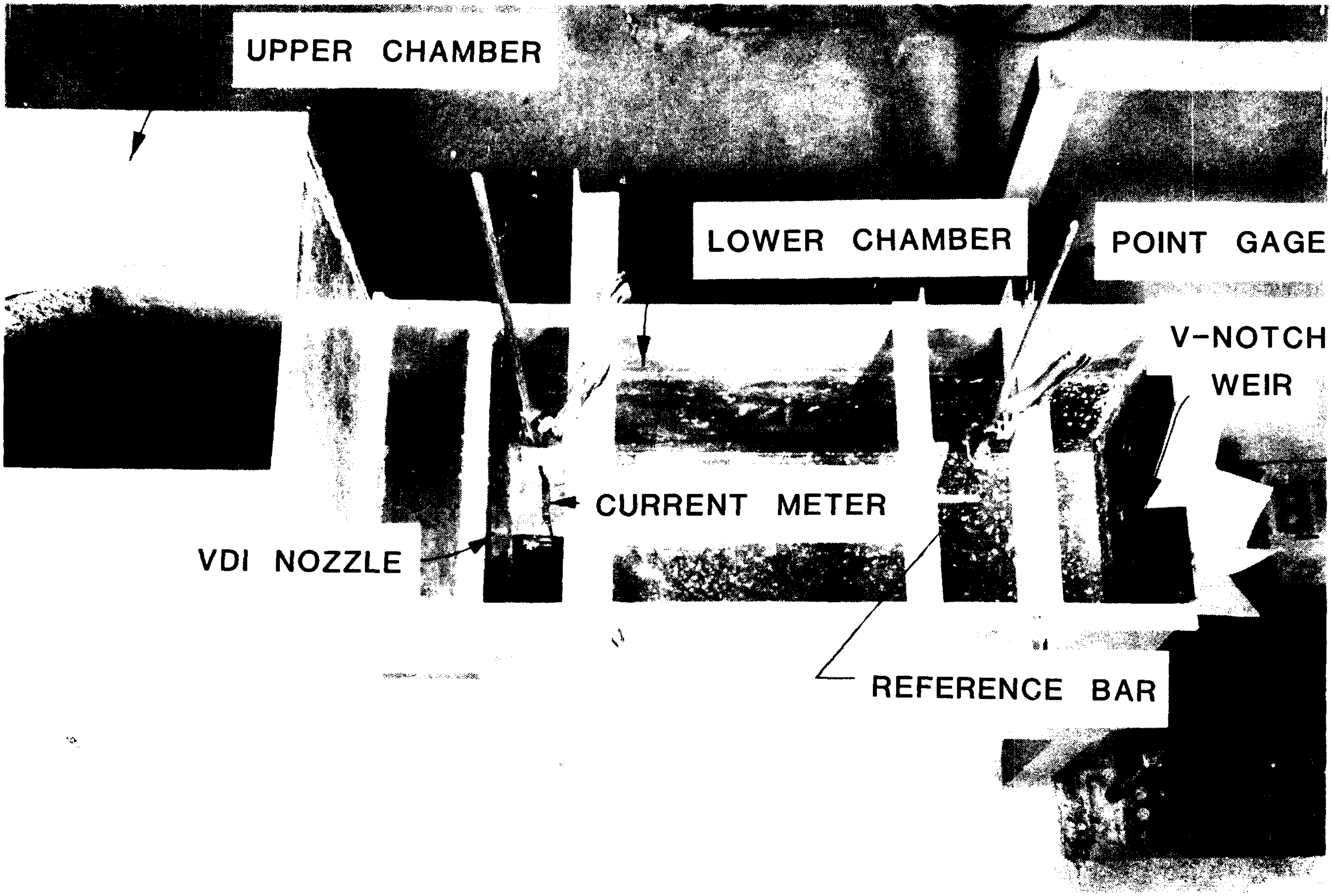


Figure 3. Calibration tank

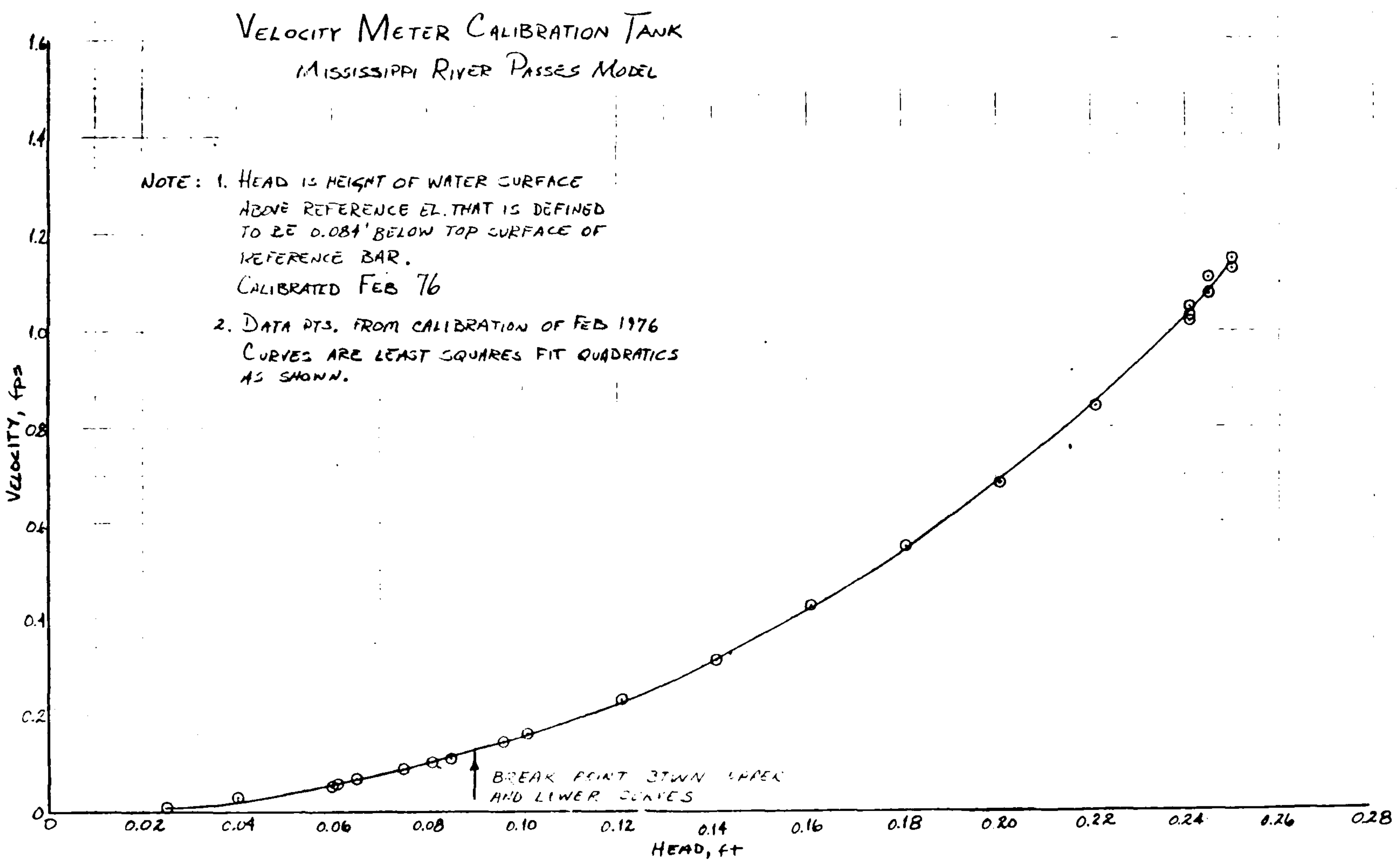


Figure 4. Calibration curve

Table 1

Head (ft) on Weir vs Flow Velocity (fps) through Nozzle

MRPM Calibration Facility

Calibration of 2-76

Head	Velocity	Head	Velocity	Head	Velocity
0.030	0.015	0.104	0.166	0.178	0.527
0.032	0.017	0.106	0.172	0.180	0.541
0.034	0.019	0.108	0.179	0.182	0.554
0.036	0.022	0.110	0.185	0.184	0.568
0.038	0.024	0.112	0.192	0.186	0.582
0.040	0.027	0.114	0.199	0.188	0.596
0.042	0.029	0.116	0.206	0.190	0.611
0.044	0.032	0.118	0.214	0.192	0.625
0.046	0.035	0.120	0.221	0.194	0.640
0.048	0.038	0.122	0.229	0.196	0.655
0.050	0.041	0.124	0.237	0.198	0.671
0.052	0.044	0.126	0.245	0.200	0.686
0.054	0.048	0.128	0.254	0.202	0.702
0.056	0.051	0.130	0.262	0.204	0.717
0.058	0.055	0.132	0.271	0.206	0.733
0.060	0.059	0.134	0.280	0.208	0.750
0.062	0.062	0.136	0.289	0.210	0.766
0.064	0.066	0.138	0.299	0.212	0.783
0.066	0.070	0.140	0.308	0.214	0.799
0.068	0.074	0.142	0.318	0.216	0.816
0.070	0.079	0.144	0.328	0.218	0.833
0.072	0.083	0.146	0.338	0.220	0.851
0.074	0.088	0.148	0.349	0.222	0.868
0.076	0.092	0.150	0.359	0.224	0.886
0.078	0.097	0.152	0.370	0.226	0.904
0.080	0.102	0.154	0.381	0.228	0.922
0.082	0.106	0.156	0.392	0.230	0.940
0.084	0.111	0.158	0.403	0.232	0.959
0.086	0.117	0.160	0.415	0.234	0.978
0.088	0.122	0.162	0.426	0.236	0.997
0.090	0.128	0.164	0.438	0.238	1.016
0.092	0.132	0.166	0.450	0.240	1.035
0.094	0.138	0.168	0.463	0.242	1.055
0.096	0.143	0.170	0.475	0.244	1.074
0.098	0.148	0.172	0.488	0.246	1.094
0.100	0.154	0.174	0.501	0.248	1.114
0.102	0.160	0.176	0.514		