

DATA ACQUISITION AND MICRO COMPUTER APPLICATION FOR VELOCITY MEASUREMENTS IN OPEN CHANNEL BENDS

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Abstract

The utilization and application of a desk-top micro-computer based system is described for data acquisition and control for use in the velocity measurements in open channel flow. The technique of measuring point velocities along three axes simultaneously is approached in two phases: Firstly, recording of the velocity data, and secondly reproducing the velocity data. The system involves utilization of voltage data recorder which can translate the flow velocities obtained by sensor probes picking up the acoustic interference. A data acquisition control unit, a desk-top computer and peripheral equipments which consist of distribution channels, printer and plotter terminals provide the necessary interpretation of the flow behaviour.

1.0 INTRODUCTION

When fluid flow through a curved open channel, there will be a steady redistribution of the velocities due to the interaction of the frictional, centrifugal and inertial forces. Secondary currents both in the lateral and vertical directions are pronounced than their existence in the straight channels, thus affecting the magnitude and direction of longstream velocities. A three dimensional flow exists which requires a specially designed instrument to be used for a speedy and efficient method of measurement.

The measurement of velocities at many points over one cross-section of a rectangular channel is required so that the total flow rate can be deduced from these velocities fairly accurately by a process of numerical and graphical integration. However, it is widely accepted that the measurement always poses several problems as the flow pattern is known to be spirally complicated.

Various forms of instruments were considered. The use of the hydrogen bubble technique was investigated but thought to be too elaborate and not so conveniently applied where a large number of measurements at a section were to be made. Similarly, the purchase of a laser doppler anemometer and its accessories were believed to be too massive for such a job, while the application of the salt-dilution technique was not practical in a self-contained water system.

Several tests were carried out on the conventional velocity meters available in the hydraulics laboratory. These were the Kent miniflo and the Ott current meters. Unfortunately, the former produced slow responses and the readings were unsteady showing dramatic fluctuations, while the latter was unable to record any effect of the secondary current. The application of an electromagnetic current meter was also investigated. However, most of the electro-magnetic current meters available in the market are two dimensional types, and run the risk of being affected by stray magnetic fields, particularly when the job is to be done in the laboratory.

2. Velocity Data Acquisition

Several pieces of equipment were involved in the recording and extracting the velocity data in the experimental channel. The functions of each equipment are described in the following sections:

2.1 'Minilab' Ultrasonic Current Meter

The 'MINILAB' is an ultrasonic laboratory current-meter specially designed for instantaneous vectorial measurement of current velocities. The instrument records the current velocity by transmitting acoustic signals between pairs of transducer probes in one, two or three-orthogonal directions. The

instrument consists of an electronic unit mounted in a standard 48 cm. rack (Plate 1.0), a probe cable and a probe (Plate 2.0).

The probe which is the sensing element of the ultrasonic current-meter, comprises three pairs of transducers which are excited sequentially. Each pair has two individual prongs mounted at a physical 'travel distance' from each other. On each tip of the prong is attached a miniature piezo-electric crystals. When excited from an electric impulse, the crystals will emit short burst of acoustic oscillations which propagate towards their respective opposite crystals with a resultant velocity $C \pm V_x$, where C is the sound speed in still water and V_x is the component of the fluid velocity which flows in the same direction as the acoustic signals. When hit by the incoming wave train, the crystals will respond by generating an analogue burst of electric oscillations which can be used to trigger the high speed timing circuit in the instrument.

The instrument is able to measure with a short response time, the sampling being represented at a very fast rate of approximately 150 times per second.

The standard three-axis probe for the MINILAB is designed as a reflector probe. The reflector is simultaneously used as the housing for the vertical z-axis. During the measurement, the reflector holder should be kept in the direction off the main flow.

The instrument responds to the current speed in all three directions and the output signals are presented as analogue voltage in the range of $0 \pm 10V$, where the positive and negative signs correspond to the directions respectively. Each channel has an individual output shown on the LED bar display on the front panel. The sensitivity in each direction is $1 \text{ mV. mm}^{-1} \text{ s}^{-1}$ or $10 \text{ mV. mm}^{-1} \text{ s}^{-1}$ (gain X 10). The output terminals can be connected to an analogue voltmeter, a plotter or any kind of recorder for any variation of output required.

The MINILAB is supplied with a 5 m long signal cable which should always be kept clean and dry to avoid any interference between adjacent channels.

2.2 TEAC R-61 Cassette Data Recorder

The TEAC R-61 cassette data recorder (Plate 3.0) is an instrument used for recording and reproducing four channel analogue signals using a compact cassette tape. It is a portable type of recorder with a steady tape travel in order to record and reproduce at a constant speed of 4.76 cm s^{-1} . The recorder can be used in broad range of outdoor as well as indoor applications.

The recorder has a direct (DR) as well as frequency modulation (FM) recording and reproducing mode. Four track-or four channel-recording can be done simultaneously on the normal 3.8 mm wide cassette tape. The unit can be connected directly to almost any measuring instrument which records voltage frequencies.

The TEAC R-61 cassette data recorder consists of the tape transport, recording/reproducing amplifier and battery case in one unit. All controls are concentrated on the front and right hand side panel and the recorder can be used either in a horizontal or vertical position or carried round the neck with a strap.

The tape drive mechanism employs the direct capstan system through the use of a low inertia motor. Independent control levers and push buttons are separately provided for steady tape travelling and fast rewinding.

However, the use of the recorder is restricted to good environment conditions as below:

- i) Ambient temperature within a range of $5 - 40$ degrees C;
- ii) Relative humidity within a range of $20 - 80$ percent.
- iii) No exposure to direct sunlight.

Several points are noted in the use of the recorder. These include:

- i) Input level adjuster

The input level adjuster is used to determine the appropriate value so that the input signal does



Plate 1—0: MINILAB Recorder

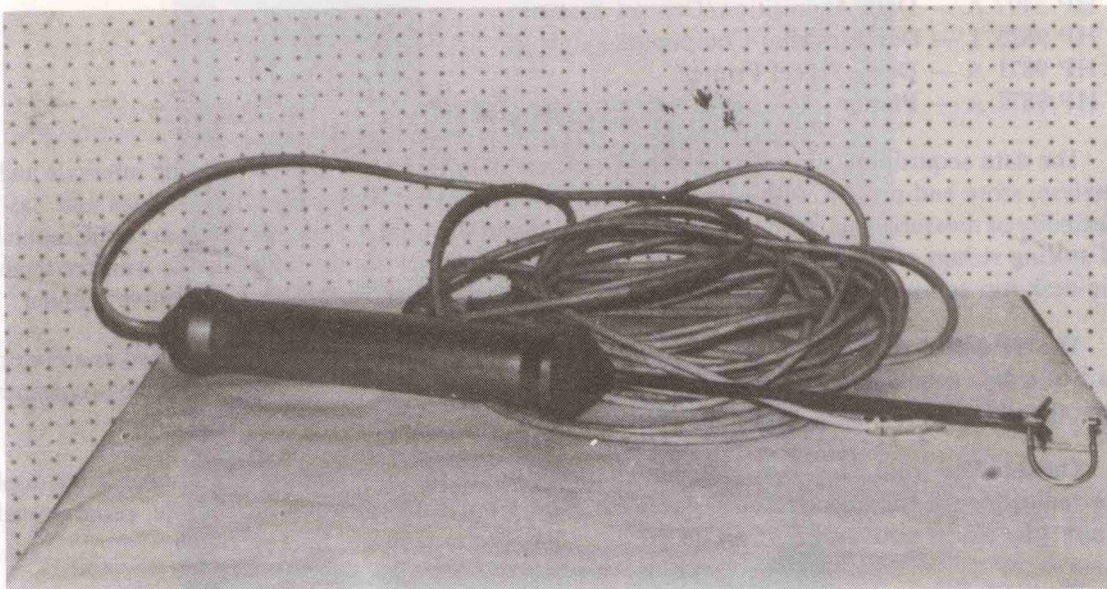


Plate 2—0: MINILAB Probe and Cable



Plate 3—0: TEAC R-61 Cassette Data Recorder

not exceed the specified level. In the case of FM mode recording, the input level is adjusted by using DC calibration voltage in the recorder. To set input at the sensitivity of 1.0V the input level is adjusted by the DC + 1.0V, the input level is adjusted by the DC calibration voltage so that the indicator shows + 100%. Under this condition, input sensitivity is guaranteed at a maximum voltage of + 1.5V (or + 150% on the indicator).

If the adjustment is made to indicate 33.3% at + 1.0V calibration voltage if the input voltage is expected at + 3.0V, the maximum input voltage that can be recorded is 4.5V.

ii) Input zero adjuster

This adjuster is used for setting the centre frequency in FM mode recording amplifier. Before recording data in the FM mode, an adjustment should be made so that the indicator shows zero (0.0%) against 0.0V calibration voltage. This zero point adjuster need not be further changed at the time of recording and reproducing.

2.3 Hewlett-Packard Computing Assemblies

The computing assemblies, which are used in the reproduction of stored velocity data, consist of the following instruments manufactured by the Hewlett-Packard Company.

- i) HP 3497 A — Data Acquisition/Control System
- ii) HP 9825 T — Desktop Mini-Computer
- iii) HP 9871 A — Daisy-Wheel Printer
- iv) HP 9872 A — Plotter

The data acquisition/control system has the capability to gather data at periodic intervals and to analyse, store and present data when required. It also offers a wide range of functions and has the flexibility of measurement, switching and control. Of particular interest in this research, is the capability of storing strings of velocity data from three different channel outputs and later to transfer them to the desk-top computer for analysis and then return for further storage in an iterative manner.

The HP 3497A data acquisition/control unit (referred to as the scanner) may be used as an integral part of a data acquisition system or as a stand alone scanner and control unit. It may be programmed remotely by a computer or programmed directly from the front panel.

The standard front panel has an alphanumeric keyboard for programming the scanner and a display for indicating measurement results, status etc. This front panel also has an audible, programmable alarm (the alarm also sounds if an illegal entry has been made on the keyboard).

There are sixteen distributing channels available for the data acquisition/control system, but only three channels are used since the velocity measurements are carried out in three-dimensions.

The HP 9825 T desk-top mini-computer, with a 62K bytes of user read/write memory (RWM), uses a high level programming language (HPL), which is a powerful formula orientated language and is most effective for the data acquisition programs. The computer can be used as on its own or as a system controller for industrial and scientific application. It has the advantage of a fast programme execution times while efficiently using the program storage space in memory. The computer has a single tape cartridge drive facility which allows for data storage for processing off-line or in retaining programs for future use. The display is, however, of the single line 32 character LED but allows for fast and easy editing with its speed of 180 lines per minute. It has a 16 character wide thermal printer which provide an economical mean of listing data and informations. The keyboard is featured similar to a typewriter having both upper and lower alphanumerics.

Other features include the live keyboard facility which means that the calculation may be performed and subroutines executed during a program run. An interrupt facility is also provided which allow signal from other peripheral to execute a higher priority program or input information while suspending the main operations, these operations resuming of at a later stage.

The HP 9825 T and HP 3497 A are linked to the 9871 A Printer and 9872 A plotter. Results are tabulated and plotted at the respective machines by controlling the program specially created for the study (Appendix 1).

Plate 4.0 illustrates the Hewlett-Packard computing units HP3497A and HP 9828T.

The Hewlett-Packard HPL language is more powerful and efficient than the more commonly used BASIC applied in most micro-computers. Various statements are abbreviated mnemonics using the lower case alphanumeric keyboards e.g., "lbl" to label, or "dsp" to display. It allows for multistatements or expressions to be written on the same line provided each statement is separated by a semi-colon. Equal sign may be implied by assignment operator \rightarrow .

The variables used in the programming language can be of simple variables and array variables. The simple variable consist of alphanumeric characters of the upper case A to Z and are assigned values by using the assignment operators e.g., $1 \rightarrow K$ i.e., let the variable K equals 1.).

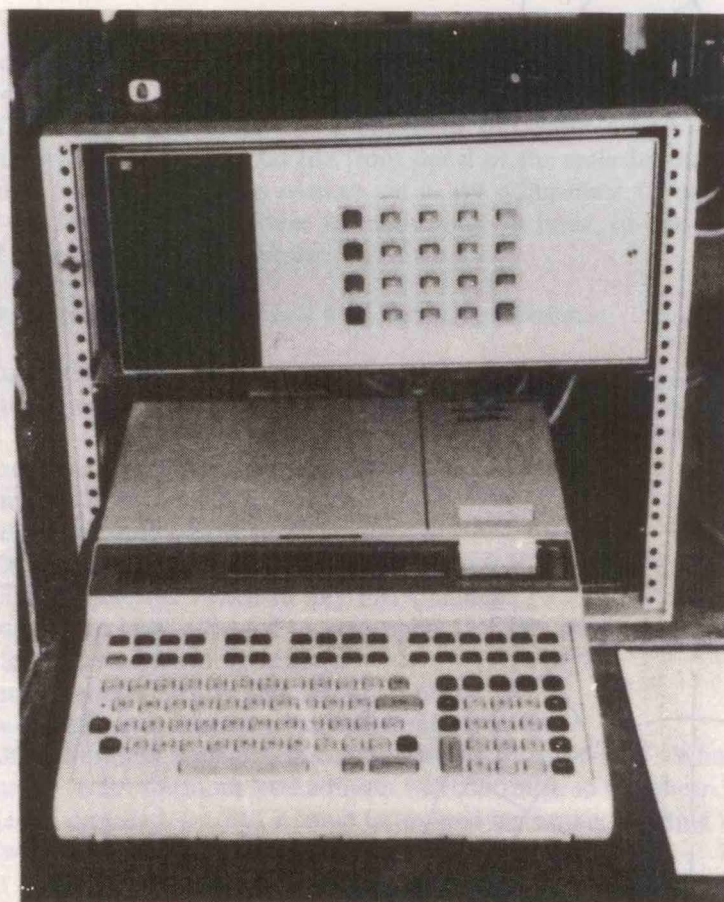


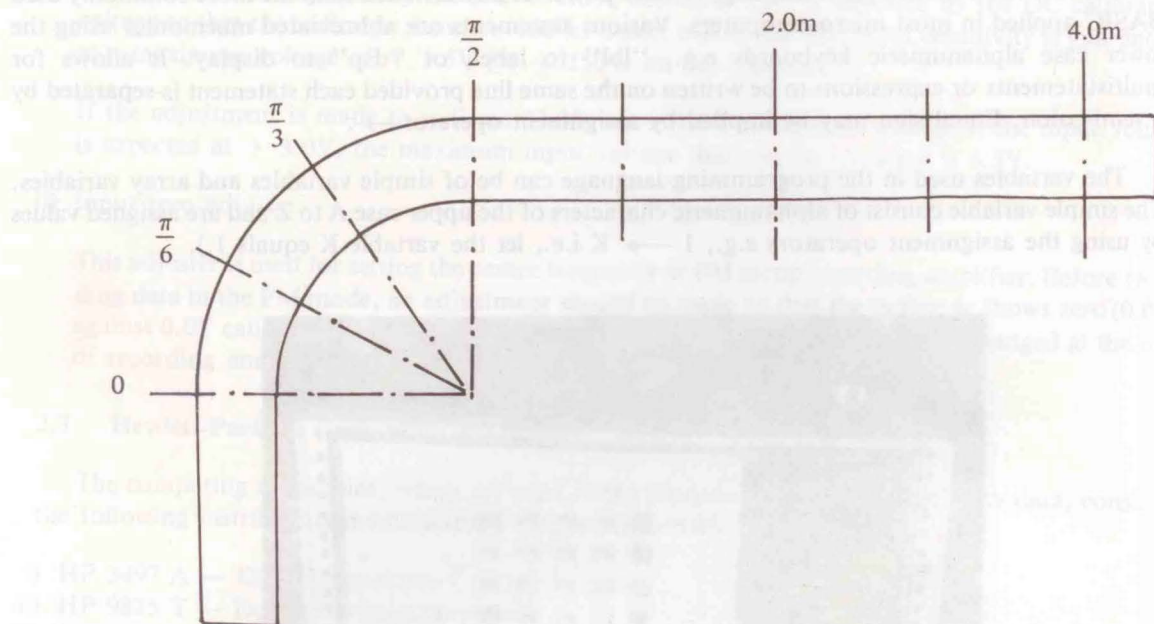
Plate 4-0: HP Data Acquisition/Control Unit and Mini-Computer

3. Experimental Method

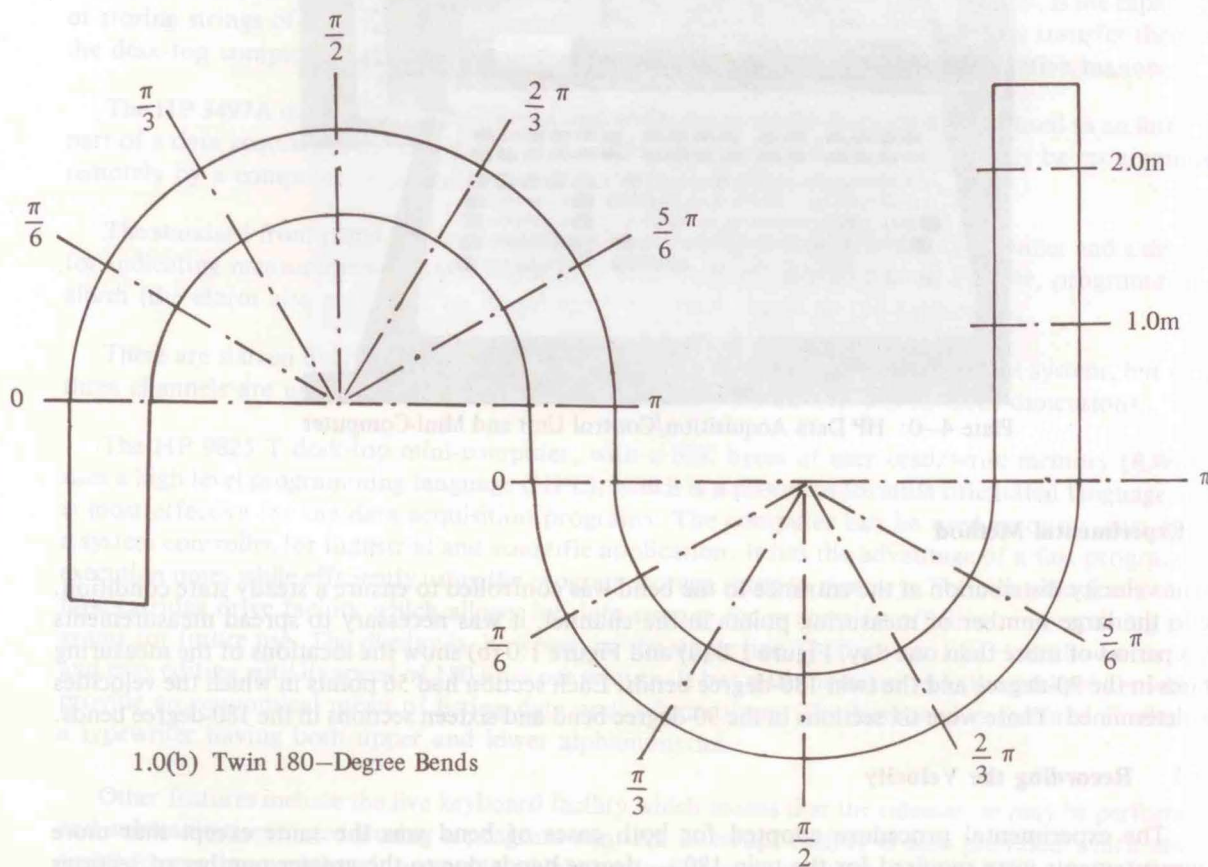
The velocity distribution at the entrance to the bend was controlled to ensure a steady state condition. Due to the large number of measuring points in the channel, it was necessary to spread measurements over a period of more than one day. Figure 1.0 (a) and Figure 1.0 (b) show the locations of the measuring sections in the 90-degree and the twin 180-degree bends. Each section had 56 points in which the velocities were determined. There were six sections in the 90-degree bend and sixteen sections in the 180-degree bends.

3.1 Recording the Velocity

The experimental procedure adopted for both cases of bend was the same except that more measurements were required for the twin 180 — degree bends due to the greater number of sections that existed. Eight verticals were chosen in each section two of which were closed to the walls, while six others were spread at equal intervals between the two. Measurements were taken at seven different depths along each vertical. Their positions were respectively at 0.95 H, 0.8 H, 0.6 H, 0.5 H, 0.4 H, 0.2 H and 0.01 H, where H is the total depth of flow.



1.0(a) 90-Degree Bend



1.0(b) Twin 180-Degree Bends

Fig. 1.0. Measuring Sections in the Experimental Flume

Allowing the water to run into the channel, the overflow weir was raised so that the required water level could be achieved and kept constant during the run. Any turbulence that occurred at entry to the straight channel before the bend was controlled by the meshes at the stilling so that only steady uniform flow resulted. The uniformity was observed by using potassium permanganate indicator and then checked by using the Kent-Miniflo Current Meter Type 265-4. The depth of the water was determined by the point gauge mounted on the instrument carriage and the respective point depths were calculated for the verticals.

Before any velocity measurement commenced, the MINILAB current meter and TEAC cassette recorder were checked for drift and calibrated. This was achieved by the following procedures:

(a) Drift check for the MINILAB current meter

- (i) The probe cable was plugged to the MINILAB recorder, and the recorder was connected to the power switch.
- (ii) The MINILAB probe was placed into a bucket of still water.
- (iii) The zero dial was then adjusted on the front panel of the recorder until all LED only shone in the middle. A multi-meter was used to aid in the adjustment for greater accuracy.
- (iv) The probe was left in the calm water for about half an hour, so that a stability plateau was reached. If necessary (iii) was repeated.

(b) Calibration procedure for the TEAC R-61 cassette recorder.

- (i) On switching on the power, the indicator lamp was noted to show the supply voltage. The cassette tape was then inserted into the holder ensuring that the visible side of the tape faced towards the front.
- (ii) The input zero point was adjusted by setting:
 - (a) the input selector switch to CAL.
 - (b) the level indicator switch to DC.
 - (c) the DC calibration voltage selector switch to 0 V.
 - (d) the channel selector switch to any FM Channel.
 - (e) the input zero level adjusted to zero point i.e., 0% on the indicator.
- (iii) The input level was adjusted by setting:
 - (a) the input selector switch maintained at CAL.
 - (b) the level indicator selector switch maintained at DC.
 - (c) the DC calibration voltage selector switch to 1.0V or -1.0V. When the input level was less than + 1.5V, the input level adjuster was controlled so that the indicator showed 100%. If the level exceeded + 1.5V, it could be lowered by turning the input level adjuster counter-clockwise.

The calibrated input for both positive and negative deflections was then recorded. When all the checks and calibrations for the instrument has been carried out, measurements could be taken. The following procedures were conducted.

- (i) The output channels of the MINILAB recorder were connected to the input channel of the TEAC cassette recorder. The general layout of the connection is shown in Figure 2.0.
- (ii) The probe head was cleaned by using a soft brush to break any bubble forming on its surface and then lowered into position in the section selected.
- (iii) The input selector switch of the cassette recorder was turned to USE position.
- (iv) Velocity frequencies were then recorded for the change in the cassette recorder counter reading of two digits. The pause button was then pressed at the end of the measurement to stop temporarily. When required to continue, the button could be released and further measurement obtained.
- (v) The MINILAB probe was then moved to the next measuring point and (iv) was repeated.
- (vi) When the measurement was completed for the section, the probe was then lifted and placed back in still water to check if there was any drift. If any drift had occurred, the calibration was adjusted and measurement at the section was repeated.
- (vii) The carriage was towed to the next section for subsequent measurements to be carried out, until all the sections along the channel were completed.

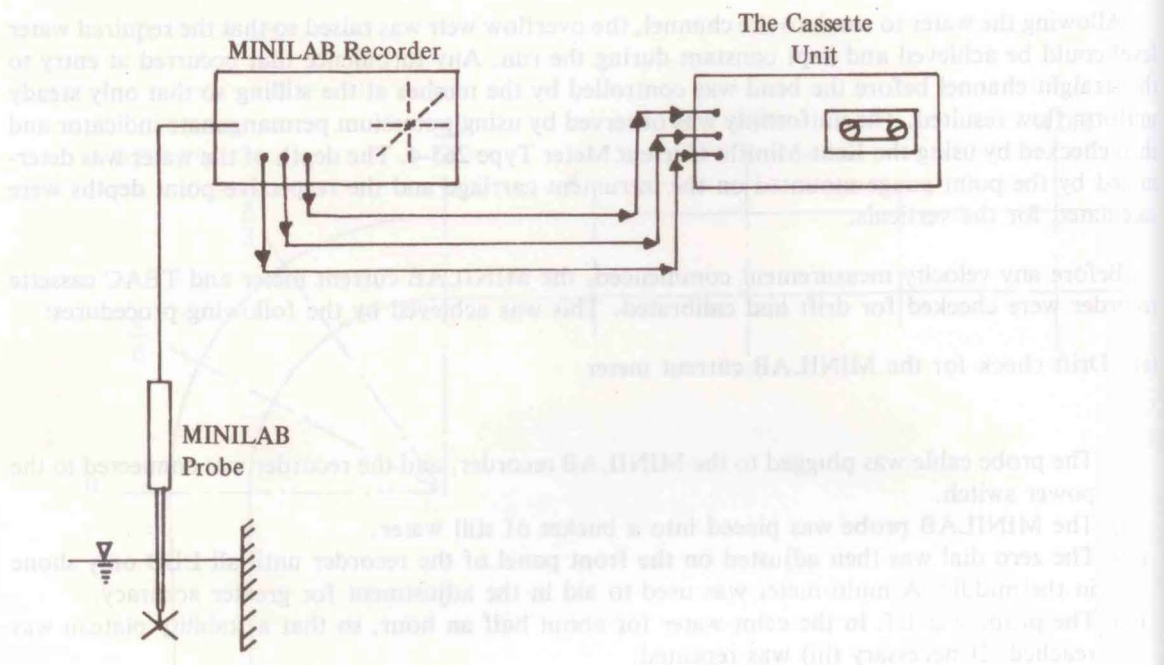


Fig. 2.0. Schematisation of Recording the Velocity Data

3.2 Reproducing the Velocity Data

The advantage of recording the velocity using the cassette recorder was that all the data could be stored conveniently and could be reproduced at a later stage when required. However, the technique of reproducing the results needed the use of a mini computer, a data acquisition control unit, and a printer or a plotter. Figure 3.0 shows the general layout of the instruments employed in reproducing the data stored in the cassette tape.

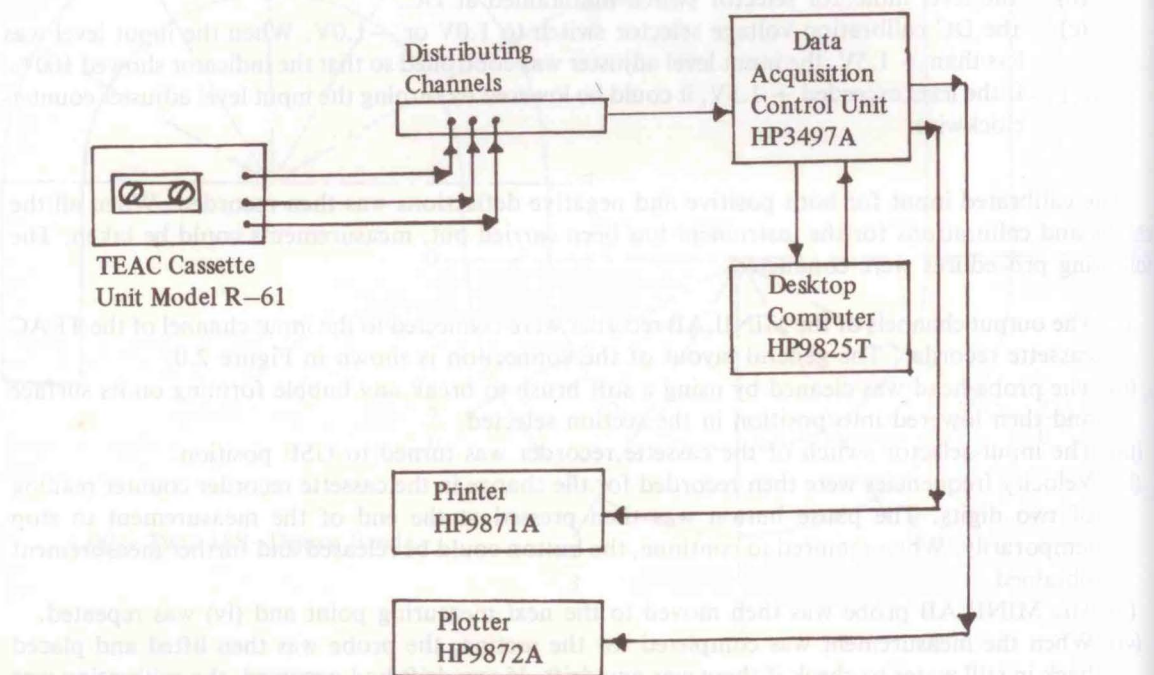


Fig. 3.0. Schematisation of Reproducing the Velocity Data

The three output terminals of the cassette recorder were connected to the first three distribution channels of the Hewlett-Packard data acquisition control unit. The prepared program was then loaded into the desktop mini computer.

Following the instruction displayed on the computer, all the velocity data were then relayed through the data acquisition control unit, computed accordingly and then printed or plotted on the respective machines. The CONTINUE button on the computer was pressed whenever the cassette recorder counter indicator showed periods at which measurements were taken. This ensured that only the data at those points represented the correct velocities.

4. Conclusion

The success achieved from the combination of an acoustic currentmeter with various voltage calibrating devices suggest the flexibility now existing in the technique of velocity measurement in open channels. The data scanner unit is considered most useful in storing and relaying records when needed. However, creating a program requires much concentration to avoid error messages which can be very obscure and leave many inexperienced operator wandering. Once a program has been compiled properly in the computer memory results can be produced either on a printer, plotter or a CRT display as desired.

References

1. GYTRE, T. (1980) 'Acoustic Travel Time Current Meters', Air Sea Interaction, Ed. Dobson, F., Hasse L. and Davies, R., Plenum Publishing Corp., New York.
2. SALLEH, M. NOOR (1985) 'Numerical and Experimental Investigations of Flow Around Bends in Open Channels', a thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Civil Engineering, University of Strathclyde, Glasgow, Scotland.

APPENDIX ONE.

PROGRAM USED TO EXTRACT THE DATA STORED IN THE CASSETTE AND TO PRINT AND PLOT THE LONGITUDINAL, TRANSVERSE AND VERTICAL VELOCITIES BY USING HEWLETT-PACKARD MINI-COMPUTER SYSTEM.

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0: dim X[56], Y[56], Z[56], A[50], U[3], L[3], M[3], C[3], D[7], R[9]
1: dim F$[30]; fxd 4
2: ent "Job Reference", F$
3: wrt 709, "VR3SO1VF1"
4: dsp "Set Cal at +1V"; stp
5: for K = 1 to 3
6: if K = 1; wrt 709, "AC0"
7: if K = 2; wrt 709, "AC1"
8: if K = 3; wrt 709, "AC2"
9: gsb "read"
10: S → U[K]; wrt 702, U[K]; next K
11: dsp "Set Cal at -1V"; stp
12: for K = 1 to 3
13: if K = 1; wrt 709, "AC0"
14: if K = 2; wrt 709, "AC1"
15: if K = 3; wrt 709, "AC2"
16: gsb "read"
17: S → L[K]; wrt 702, L[K]; next K
18: for K = 1 to 3
19: 2/(U[K] - L[K]) → M[K]
20: U[K] * M[K] - 1 → C[K]; wrt 702, M[K], C[K]
21: next K
22: ent "Discharge of Water", Q
23: ent "Depth of Water", D
24: ent "Location in Channel", L
25: ent "No of Readings", N
26: wrt 709, "AFOAL2"
27: for K = 1 to N; dsp "Prepare Reading"; stp
28: wrt 709, "AS"
29: gsb "read"
30: (S*M[1] + C[1])/10 → X[K]; wrt 709, "AS"
31: gsb "read"
32: (S*M[2] + C[2])/10 → Y[K]; wrt 709, "AS"
33: gsb "read"
34: (S*M[3] + C[3])/10 → Z[K]; wrt 702, X[K], Y[K], Z[K]; next K
35: fmt /, /, 20x, "Values of Coefficients", /, /, 35x, "M", 10x, "C", /; wrt 702
36: fmt 28x, 2f10.3, /
37: for K = 1 to 3
38: wrt 702, M[K], C[K]
39: next K
40: 1 → D[1]; .8 → D[2]; .6 → D[3]; .5 → D[4]; .4 → D[5]; .2 → D[6]; .01 → D[7]
41: 2.05 → R[1]; 2.15 → R[2]; 2.25 → R[3]; 2.35 → R[4]
42: 2.45 → R[5]; 2.55 → R[6]; 2.65 → R[7]; 2.75 → R[8]
43: fmt /, /, 20x, "Primary and Secondary Velocities in a 90-Deg. Bend"; wrt 702
44: fmt /, /, 30x, "Discharge =", f7.3, " cumecs"; wrt 702, Q
45: fmt /, /, 30x, "Depth of Water =", f7.3, " metres"; wrt 702, D
46: fmt /, /, 30x, "Location =", f6.2, " metres before bend"; wrt 702, L
47: /, /, /, 35x, " Longitudinal velocities", /, /; wrt 702
48: fmt 2x, "Zeta/Rad", 5x, 8f11.3, /
49: wrt 702, R[1], R[2], R[3], R[4], R[5], R[6], R[7], R[8]
50: fmt /, 2x, f4.2, 10x, 8f11.4
51: 1 → K; for J = 1 to 49 by 8

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52: wrt 702, D[K], X[J], X[J + 1], X[J + 2], X[J + 3], X[J + 4], X[J + 5], X[J + 6], X[J + 7]
53: 1 + K → K; next J
54: fmt /,/ /, /, 35x, "Transverse Velocities", /,/ /; wrt 702
55: fmt /, 2x, "Zeta/Rad", 5x, 8f11.3, /
56: wrt 702, R[1], R[2], R[3], R[4], R[5], R[6], R[7], R[8]
57: fmt /, 2x, f4, 2, 10x, 8f11.4
58: 1 → K; for J = 1 to 49 by 8
59: wrt 702, D[K], Y[J], Y[J + 1], Y[J + 2], Y[J + 3], Y[J + 4], Y[J + 5], Y[J + 6], Y[J + 7]
60: 1 + K → K; next J
61: fmt /,/ /, /, 35x, "Vertical Velocities", /,/ /; wrt 702
62: fmt 2x, "Zeta/Rad", 5x, 8f11.3, /
63: wrt 702, R[1], R[2], R[3], R[4], R[5], R[6], R[7]
64: fmt /, 2x, f4.2, 10x, 8f11.4
65: 1 → K; for J = 1 to 49 by 8
66: wrt 702, D[K], Z[J], Z[J + 1], Z[J + 2], Z[J + 3], Z[J + 4], Z[J + 5], Z[J + 6], Z[J + 7]
67: 1 + K → K; next J
68: psc 705; pen #
69: ent "pen Number", J
70: pen # J; fxd 2
71: 1 → K
72: gsb "scale"
73: gsb "axpl"
74: gsb "plotx"
75: for K = 2 to 8
76: gsb "scale"
77: gsb "axplot"
78: gsb "plotx"
79: next K
80: pclr:csiz 1, 1.7; pen 3; plt -4.5, 1.5; lbl F\$
81: plt -4.5, 1.3; lbl "Longitudinal Velocities"
82: gsb "borders"
83: gsb "Radius"
84: dsp "Change Paper", stp
85: ent "pen number", J
86: pen # J
87: 1 → K
88: gsb "scale"
89: gsb "axpl"
90: gsb "ploty"
91: for K = 2 to 8
92: gsb "scale"
93: gsb "axplot"
94: gsb "ploty"
95: next K
96: pclr:csiz 1, 1.7; pen # 3; plt -4.5, 1.5; lbl F\$
97: plt -4.5, 1.3; lbl "Transverse Velocities"
98: gsb "borders"
99: gsb "Radius"
100: dsp "Change Paper"; stp
101: ent "pen number", J
102: pen # J
103: 1 → K
104: gsb "scale"
105: gsb "axpl"
106: gsb "plotz"
107: for K = 2 to B

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108: gsb "scale"
109: gsb "axplot"
110: gsb "plotz"
111: next K
112: pclr; csiz 1, 1.7; pen # 3; plt —4.5, 1.5; lbl F$
113: plt —4.5, 1.3; lbl "Vertical Velocities"
114: gsb "borders"
115: gsb "Radius"
116: pen #
117: end
118: "read": wrt 709, "VN20VS1VT3VS"
119: 0 → S; for I = 1 to 20; red 709, A[I]
120: A[I] + S → S; next I
121: S/20 → S; ret
122: "scale":
123: scl —2 —.9*K, 8.4 —.9*K, —1, 2
124: ret
125: "axpl"
126: pclr; pen # 1
127: csiz .6, 1, 1, 0
128: xax 0, 2, —.2, .4, 1
129: xax 1, 2, —.2, .4
130: yax 0, .1, 0, 1, 2
131: pen # ; ret
132: "plotx":
133: pen # 4
134: for J = 1 to 7
135: plt X[(.125*K + J — 1)/.125], D[J]
136: next J
137: pen # ; ret
138: "ploty":
139: pen # 4
140: for J = 1 to 7
141: plt Y[(.125*K + J — 1)/.125], D[J]
142: next J
143: pen # ; ret
144: "plotz":
145: pen # 4
146: for J = 1 to 7
147: plt Z[(.125*K + J — 1)/.125], D[J]
148: next J
149: pen # , ret
150: "axplot":
151: pclr; pen # 1; csiz .6, 1, 1, 0
152: xax 0, .2, —.2, .4, 1
153: xax 1, .2, —.2, .4
154: yax 0, .1, 0, 1
155: pen # ; ret
156: "borders":
157: plt —7.6, 2
158: iplt 8.14, 0
159: iplt 0, —2.52
160: iplt —8.14, 0
161: iplt 0, 2.52
162: pclr; csiz 1, 1.8, 1, 90
163: pen # 2; plt —7.1, .3; lbl "Depth Ratio"
164: csiz 1, 1.8; plt —3.9, —.4; lbl "Velocities m/s"
165: pen # ; ret
166: "Radius"

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*9539