AUTOMATED MOVING BOAT

MEASUREMENT SYSTEM

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1.0 INTRODUCTION

This manual covers the theory and practice of the moving boat method using the automated moving boat equipment package. The moving boat method of obtaining quick, accurate discharge measurements on medium to large rivers was originally developed by the United States Geological Survey and subsequently automated through microprocessor control by Water Resources Branch.

2.0 THEORY

Moving boat measurements are made by traversing a river with a suitable craft along a preselected path normal to the current whilst recording combined river and boat velocity and channel geometry. The combined river and boat velocities are then separated vectorally. Data is compiled at preselected sampling points to produce an average river velocity and a segment width. The average velocity, width, and average depth between sampling points are then combined to produce a segment discharge. These discharges are totaled and corrected for width and mean velocity to produce a total river discharge. Two persons are required to take a measurement: a boat operator and a instrument operator. The duties of the crew members are described under "Functions of Crew Members".

The metering equipment consists of a component current meter which provides combined boat and river velocity. This velocity is displayed on the current meter display in pulses per second and is used by the Measurement Processor to compute river velocity. The current meter is attached to an aluminum vane, which in turn is fixed to a stainless steel rod that rotates on two bearings within an aluminum tube mounted vertically at the front of or amidships of the boat. An electronic compass is attached to the top of the stainless steel rod. The compass during initialization is set to read zero degrees when the current meter vane is parallel to the section line. The resulting angle between the current meter and the section line is displayed and is used to determine sine and cosine values for determination of river velocity and segment width. An internal digital depth sounder provides the depth data required for the discharge computations. An optional analog strip chart or external depth connection is available.

The river velocity between sampling points is computed from the sine relationship between the average velocity from the current meter and the average angle of the current meter relative to the section line as recorded from the electronic compass. The sine relationship as shown in Figure 1 is

$$V = V_v \ \mathrm{SIN}\ \alpha$$

where V_v is the average combined boat and river velocity
α is the average angle of current meter relative to section line
and V is the average river velocity

The velocity is calculated from the current meter's equation whose constants are input to the system during initialization.

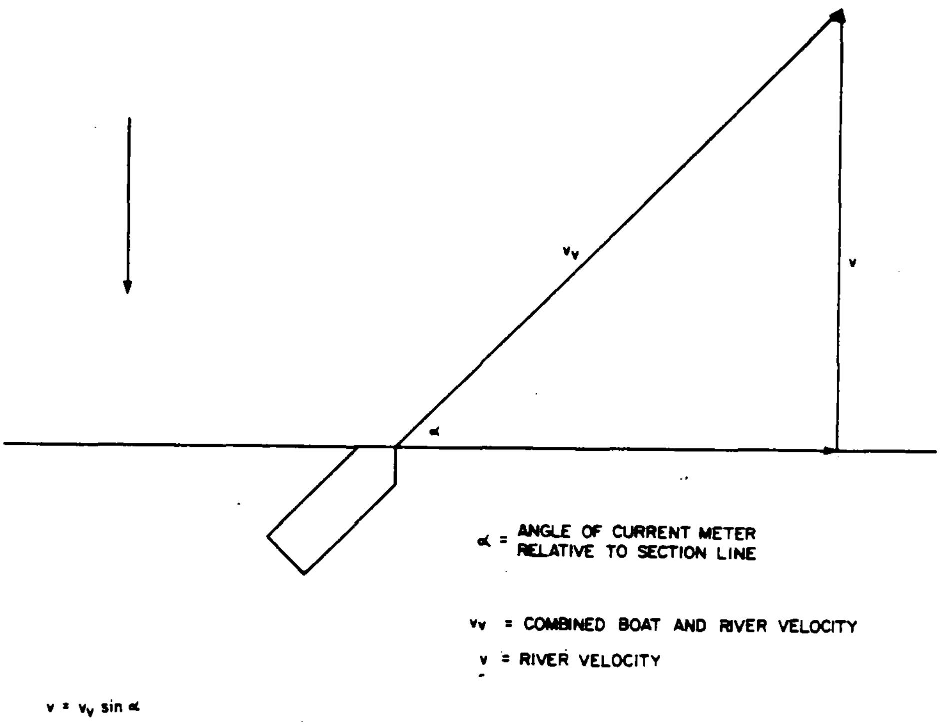

Figure 1. River velocity computation between sampling stations

The width between sampling points is computed using the cosine relationship as shown in Figure 2:

$$B = Bv \ COS\ \sigma$$

where Bv   is the relative distance of travel

α   is the average angle of current meter relative to the section line

and B   is the actual distance of travel.

The distance travelled before a sample is taken is controlled by the range setting which varies the number of current meter pulses counted.

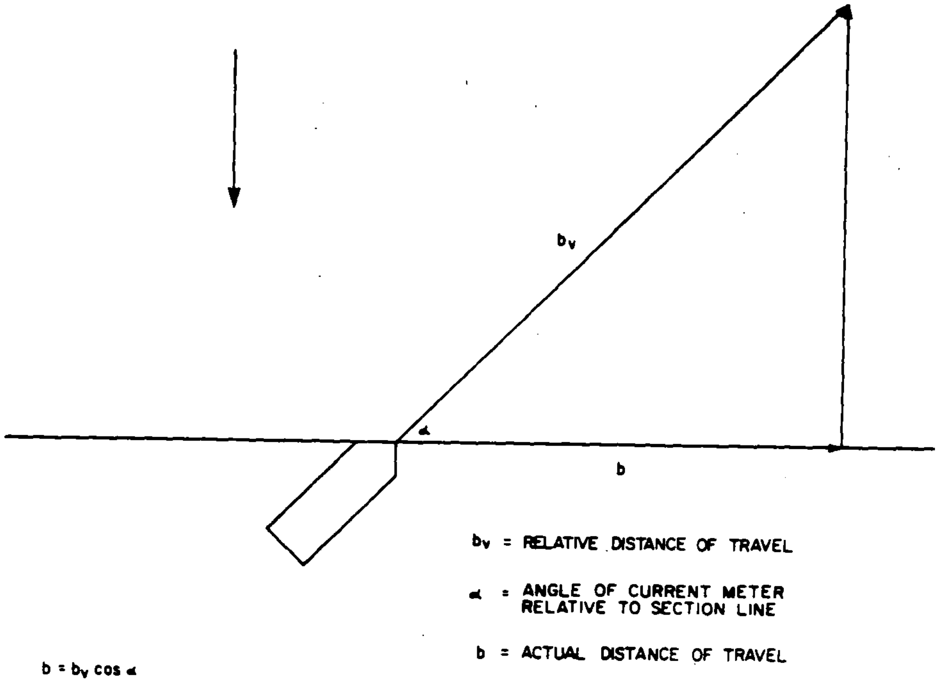

Figure 2. Computation of segment width between sampling stations

3.0 SELECTION AND PREPARATION OF MEASUREMENT SECTION

Site selection is very important to the success of a moving boat measurement. A poor site will affect the quality of data collected, as the technique is limited by the physical characteristics of a river. The following criteria should be met in selecting a measurement section.

1) River depths should be over 2 m in the traversing width. This minimum depth should extent at least 20 m upstream and downstream of the section line to avoid damage to subsurface equipment.

2) Minimum river velocities should be over 0.5 m/s. The boat is difficult to maintain on section line at river velocities below 0.5 m/s and errors due to excessive wandering offline are induced.

3) River sections with gently sloping banks should be chosen, as this will greatly assist section line targeting.

4) A uniform cross section is preferred because a river with deep and shallow sections will be difficult to traverse as a result of variable current speeds.

5) River widths should be at least 100 m. Smaller widths will result in insufficient sampling points and hence in lower accuracy.

The work done in preparing a river section for a moving boat measurement is dependent upon the permanency of the station. If only occasional measurements are to be made at various sites along a river, no extensive preparations are needed. Local features can serve as section line targets, and distance measurements to determine river widths can be made by stadia.

If a permanent moving boat discharge station is to be established, a thorough station survey should be made to attain maximum accuracy and continuity and to enable quick subsequent measurements.

The most suitable site can often be chosen, from a topographical map or air photos prior to an on-site survey. The on-site survey should be made with the same boat that will be used to take the measurements, to be certain that the boat is matched to the river conditions.

The first step in establishing a station is to ascertain that sufficient velocity and depth are available for the anticipated measurement period. The boat is run across the river by "crabbing" into the current. After one or two runs a judgement can be made whether the current is too fast or too slow. If the current is too slow at the desired measurement stage then a new site should be chosen. If the current is too fast then either a more suitable boat and motor should be chosen or a different site selected.

The river bed should be sounded by echo sounder to determine cross-section suitability. Sounding runs should also be made 20 m upstream and downstream to pinpoint shoals and other underwater hazards that might prove dangerous if the boat drifted off course during a measurement and also to establish the amount of manoeuvring room available prior to and after a measurement.

The exact section line should be established by theodolite. A decision must be made on the most suitable line that is normal to the current. The moving boat method can compensate for angular flow by averaging measurement runs in both directions along the section line, but it is a better practice to reduce this possible error to a minimum by choosing a section line as perpendicular to the current as possible. The section line should be extended up each river bank past the high-water mark at least 10% of the maximum river width. All brush and movable obstacles should be removed at least 10 m on each side of the section line for a clear view of the section line targets.

Permanent marker pins should be driven into the ground at the target locations and referenced to the surrounding physical features. Section line targets can be permanently installed if desired, as long as they do not create navigation hazards and are not subject to vandalism. If more than one measurement site is to be established in an area, it may be advantageous to carry a portable set of plywood targets that can be easily positioned at the marker pins. Figure 3 shows a typical layout.

The final step on the initial survey is to tie in all the marker pins by chainage and to record all data. Zero chainage should start at the rear marker pin on the left bank and then be carried across to the rear marker pin on the right bank with intermediate chainage to the front marker pins on each bank. The distance across the river between the two front marker pins should be measured accurately by triangulation or by electronic distance measuring devices.

The size and positions of the section line targets is very important, as they provide the boat operator with the only means of alignment along the section line. The targets on each river bank should be located 10% of the maximum river width apart (100 m apart if the maximum river width is 1000 m). Vertical separation of the target should allow coincidence from any position on the section line. Targets at least 1 m square painted in diagonal halves in contrasting colours such as red and yellow and mounted at the marker pins with the painted halves lined up vertically are recommended.

4.0 EQUIPMENT

4.1 Current Meter

The current meter used for the moving boat technique is an Ott Type A component propeller with a modified body that contains a pulse-generating gear. It is designed to be mounted on the front edge of the directional vane. The component type of propeller was chosen, as it is less susceptible to vertical velocities induced by the boat travelling over waves.

A 24-tooth Browning gear is mounted on the shaft of the current meter and is housed in the bronze meter body. The gear, when rotating in proximity to a magnetic field, generates 24 pulses per revolution. A magnetic transducer is attached to the top of the current meter less than 1 mm from the rotating gear. The transducer provides the magnetic field necessary for pulse generation and is attached by shielded cable to the measurement processor located in the boat. The transducer registers the pulses and feeds them into the processor. The velocity index is displayed digitally and is printed automatically for each discharge segment during a realtime run.

The current meter and transducer must be handled with great care, as they can be damaged with even minor impact. Minor changes in the shape of the propellor blades or slight bending of the propellor shaft will significantly change the current meter rating. The section on the assembly of the equipment describes the maintenance and assembly of the current meter and magnetic transducer.

4.2 Measurement Processor

The measurement processor is contained in a weather proof fibreglass carrying case. The front panel of the measurement system is illustrated in Figure 4 and has the following components:

1) ON/OFF power switch
2) Battery connector
3) START/STOP switch
4) Current Meter connector
5) Electronic compass connector
6) External depth connector
7) External terminal connector
8) Serial output connector
9) Analog chart recorder connector (optional)
10) Baseline reset switch
11) Sonalert alarm
12) Depth threshold POT
13) Echo return LED
14) 40 column printer
15) Full ASCII keyboard
16) 2 line, 40 character liquid crystal display
17) System fuses

Figure 4. Measurement Processor

The measurement processor inputs, displays, processes, stores, manipulates (edits) and plays back the data collected during each run. The system also has an operating system which allows auto-creation of new files, a file directory, copy and delete commands and the capability of interface to a bubble memory with a sophisticated bubble memory device driver and file handler software. The measurement processor also documents the following information: the data, the time, total run time, general run information, run number, run filename, ottmeter constants, LEW, REW, actual width, and the vertical velocity correction coefficient.

The measurement processor collects depth, crab angle and the velocity index readings from each of the sensors on a continual basis. Once each second the instantaneous velocity (pulses per second), the crab angle (degrees) and the depth (meters or feet) are displayed on the liquid crystal display in the following format:

RATE = xxx   CRAB ANGLE = xx   DEPTH = xx.x

The rate or velocity index component receives pulses from the current meter from a magnetic transducer. Each current meter has its own calibration constants. These constants are entered during initialization and are used to accurately compute velocity.

The angle component receives its data from an electronic compass. The processor allows the user to easily set the baseline with a push of a button and then instantaneously converts the compass co-ordinates into angle components.

Depth data is input from one of two sources, an external depth digitizer or an internal depth digitizer. The external depth data is input through a connector and updated from a data strobe pulse. The internal depth digitzer obtains its data from an internal digital depth sounder or an optional analog chart sounder system.

The automatic selection of sampling points within the river section at regular intervals of distance is controlled by range selection. Range selection is prompted by the processor. The user has a selection of 99 different ranges as shown below:

RANGE VALUES VERSUS DISTANCE

Range	Distance	Range	Distance	Range	Distance	Range	Distance
1	5.6	2	7.0	3	8.4	4	9.8
5	11.2	6	12.6	7	14.0	8	15.4
9	16.8	10	18.2	11	19.6	12	21.0
13	22.4	14	23.8	15	25.2	16	26.6
17	28.0	18	29.4	19	30.8	20	32.2
21	33.6	22	35.0	23	36.4	24	37.8
25	39.2	26	40.6	27	42.0	28	43.4

29	44.8	30	46.2	31	47.6	32	49.0
33	50.4	34	51.8	35	53.2	36	54.6
37	56.0	38	57.4	39	58.8	40	60.2
41	61.6	42	63.0	43	64.4	44	65.8
45	67.2	46	68.6	47	70.0	48	71.4
49	72.8	50	74.2	51	75.6	52	77.0
53	78.4	54	79.8	55	81.2	56	82.6
57	84.0	58	85.4	59	86.8	60	88.2
61	89.6	62	91.0	63	92.4	64	93.8
65	95.2	66	96.6	67	98.0	68	99.4
69	100.8	70	102.2	71	103.6	72	105.0
73	106.4	74	107.8	75	109.2	76	110.6
77	112.0	78	113.4	79	114.8	80	116.2
81	117.6	82	119.0	83	120.4	84	121.8
85	123.2	86	124.6	87	126.0	88	127.4
89	125.8	90	130.2	91	131.6	92	132.0
93	134.4	94	135.8	95	137.2	96	138.6
97	140.0	98	141.4	99	142.8		

For example if range 5 was selected the current meter travels through 11.2 meters of water before the next sample is taken.

The discharge measurement processor is a user interactive system. Data is input through a full ASCII keyboard which supports both upper and lower case characters. The data is displayed and edited on the two line, forty character liquid crystal display. The raw and processed data is printed out on the 40 column dot matrix printer which provides hard copy of the data plus complete run documentation. The raw data is also stored in the internal non-volatile bubble memory system which can be used later. Editing of run information or transfer of data to another computer is possible.

Once initialization information is entered into the processor system, the run may begin by pressing the START/STOP button, The raw data and processed data is printed out at the end of each segment. The data print out is illustrated below:

RUN xx xx/xx/xx xx:xx:xx
SAMPLE RUN TITLE — INITIALIZATION DATA
.xxxxx .xxxxx (OTTMETER CONSTANTS)
LEW xx.x REW xx.x W xxxx.x V x.xxxx

SMP	FRD	CA	DA	ETIME	RATE	V_x	Q	
-01	xx.x	xx	xx.x	xxx.x	xxx	xx.xx	xxxx.x	
-02	xx.x	xx	xx.x	xxx.x	xxx	xx.xx	xxxx.x	REALTIME
-03	xx.x	xx	xx.x	xxx.x	xxx	xx.xx	xxxx.x	
-04	xx.x	xx	xx.x	xxx.x	xxx	xx.xx	xxxx.x	

```
      ***SUMMARY***
MEASURED DISCHARGE                              xxxxx
MEASURED AREA                                   xxxxx
MEASURED WIDTH                                  xxxx.x
WIDTH ADJUSTMENT FACTOR                         x.xxxx
WIDTH ADJUSTED DISCHARGE                        xxxxx
WIDTH ADJUSTED AREA                             xxxxx        SUMMARY
DEPTH ADJUSTED DISCHARGE                        xxxxx        DATA

TOTAL ELAPSED TIME                 xx:xx:xx
***START xx:xx:xx          END     xx:xx:xx
```

The initialization data consists of the following:

-blank line-	- blank line provide inter-run spacing
Run number	- SYSTEM assigned run number
Date	- USER provided date field
Time	- USER initialized, SYSTEM maintained time of day
Title	- USER provided 32 character title field
Ottfac info	- USER provied ottfac file image
LEW	- USER provided shore-to-first-marker distance
REW	- USER provided last-marker-to-shore distance
W	- USER provided true river width
V	- USER provided vertical velocity adjustment coefficient

The realtime data consists of the following for each segment measured:

subheading	- subheadings for use during EDIT MODE
SMP	- SYSTEM assigned sample number (0-99)
FRD	- flow resolution distance (distance between samples)
Ca	- average measured crab angle (degrees)
Da	- average measured depth (meters/feet)
etime	- elapsed time to traverse this segment (seconds)
rate	- measured water flow rate (meters/sec, feet/sec)
V_x	- flow velocity = Rate X sin (Ca) (meters/sec, feet/sec)
D	- calculated discharge (meters, feet 3/sec)

The SUMMARY DATA format field is described below.

1) The total discharge measured. This was totaled during the process function.

2) The total cross-sectional areas were totalled during the processing. It is the sum of all segment widths multiplied by the appropriate segment depths.

3) The total widths are summed during the process function.

4) The width adjustment factor is given as:

width adjustment = true width/measured width

5) The total discharge is multiplied by the width adjustment factor to derive the width adjusted discharge.

6) The calculated area totals are multiplied by the width adjustment factor to derive the width adjusted area.

7) The width adjusted discharge is multiplied by the user supplied vertical velocity adjustment coefficient to give the final discharge.

8) The total of all elapsed times as measured in each segment is printed in hours:minutes;seconds format.

9) The logged times that the START/STOP switch was pushed to START and pushed again to STOP the run.

The BUBBLE MEMORY provides 128K bytes of non-volatile memory storage. The bubble memory device driver and file handler interface the bubble memory to the Integral Operating System. The bubble memory is used to store all data collected during moving boat measurements. The data is stored in the bubble memory in the following format:

```
RUN xx xx/xx/xx  xx:xx:xx
SAMPLE RUN
.xxxxx .xxxxx (special device)
LEW xx.x REW xx.x W xxxx.x V x.xxxx
SMP Ca Da   etime rate
-01 xx xx.x xxx.x  xxx
-02 xx xx.x xxx.x  xxx
-03 xx xx.x xxx.x  xxx
-04 xx xx.x xxx.x  xxx
-05 xx xx.x xxx.x x.xx
***START:  xx:xx:xx  END:  xx:xx:xx
```

The information stored is the raw data from the real time run as described previously.

4.2.1 System Command Structure

Once the system has run through the initialization procedure, the system will prompt the user for a command by displaying the following prompt ">".

4.2.2 General Command Format

Commands consist of a command keyword followed by the specified operands. The operands may be separated by any number of spaces. In specifying the syntax of commands the following rules are used:

1) fields enclosed in < > are not optional
2) fields enclosed in [ ] are optional
3) and the actual brackets to not appear in the command.

Filenames are specified in the format :device:name.extension

where:	device	is any system device. If :device: is omitted, the :device: defaults to "BO" (the bubble). The :CI: (console input), :CO: (console output) do not require a file name.
	name	is any combination of ASCII characters (excluding space and special characters: i.e. A to Z, 0 to 9) starting with an alphabetic character up to 6 characters long.
	extension	is any combination of up to 3 ASCII characters (excluding space and special characters). This field may be omitted, in which case the . is also omitted.

Valid names are:	JOHN. DOE	
	A13.001	
	FF	
	filnam.12D	
Invalid names are:	1NO.DOC	(starts with number)
	F-3	(cannot have -)
	.doc	(name cannot be omitted)
	FILE.	(if no ext, omit .)
	MYFILES	(name too long)
	MYFILE.EXT1	(ext too long)

Commands available are: CATALOG, COPY, DELETE, EDIT, FORMAT, PLAYBACK, REALTIME, SETUP

4.2.3 CATALOG Command

The CATALOG command lists the entire directory contents of files stored in the bubble, giving the filename, attributes and size of each file.

4.2.4 COPY Command

The COPY command copies the contents of a file into another file. The source and destination files can reside on the same or on different media. The file from which the copy is made must be an input device (for example: the bubble - :BO:, or console - :CI:) and the file to which the copy is directed must be an output device (for example: the bubble - :BO:, or console - :CO:). The default device is the bubble. Any other device must be specified. This command can prompt for the source and output if the medium must be changed. The syntax of the COPY command is as follows:

COPY <sourcefile1>[,(sourcefile2>,...,<sourcefilen>] TO <destfile> [switch]

<sourcefile> is a file on any device capable of input. The contents of this file are not affected by the copy. If more than one <sourcefile> is specified they are concatenated in the order specificed when copied to <destfile>. The destination file name cannot be equal to any source file name; otherwise the results are unpredictable.

<destfile> is the name of the file to be created or recreated or the name of an output device. If the <destfile> already exists (and the P switch is not used), the current destfile will be overwritten. If the <destfile> already exists (and the P switch is used), the following message appears on the console:

FILE ALREADY EXISTS - DELETE(TYPE Y OR N):

If you respond to the message with "Y" followed by a carriage return, COPY deletes the existing file before making the copy. No action is performed if any other response is given.

If <destfile> is write protected, the following message is output:

WRITE PROTECTED

switch P is the pause switch, which allows files to be copied between two media on the same device. The system prompts for swaps with the following messages:

LOAD SOURCE MEDIUM, THEN TYPE (CR):
LOAD DESTINATION MEDIUM, THEY TYPE (CR):

When the COPY command is complete the following message is output on the console for each <sourcefile> specified in the command:

```
<sourcefile>      COPIED TO         <destfile>
```

Example 1: this example copies three files to one, overwriting its contents.

```
-COPY FILE1,PROG2.P80,MAIN TO SYSTEM.DOC
FILE1         COPIED TO        SYSTEM.DOC
PROG2.P80     COPIED TO        SYSTEM.DOC
MAIN          COPIED TO        SYSTEM.DOC
```

Example 2: This example displays a file on the console output device.

```
-COPY RDATA TO :CO:
RDATA         COPIES TO        :CO:
```

Exmaple 3: This example copies a file from one bubble to another, overwriting an existing file.

```
-COPY MVBV06 TO MVBV06.BAK P
LOAD SOURCE MEDIUM, THEN TYPE (CR):
LOAD DESTINATION MEDIUM, THEN TYPE (CR):

FILE ALREADY EXISTS - DELETE (TYPE Y OR N):  user types Y
LOAD SOURCE MEDIUM, THEN TYPE (CR):
LOAD DESTINATION MEDIUM, THEN TYPE (CR):
MVBV06        COPIED TO        MVBV06.BAK
```

4.2.5 DELETE Command

The DELETE command provides for erasure of specified directory entries. This command effectively delete the specified file from a disk, making the space it occupied available for reassignment. A file with the write-protect on cannot be deleted. The syntax of the DELETE command is as follows:

DELETE <filename> where <filename> is the name of the file to be deleted. If the write-protect is not set, the file is deleted and a confirming message is sent to the console.

```
***** DELETED ***** <filename>
```

If <filename> does not exist, the following message is sent to the console:

```
FILE NOT FOUND
```

If the file cannot be deleted because it is write-protected, the following message is sent to the console:

```
WRITE PROTECTED
```

4.2.6 EDIT Command

EDIT is a line oriented editor for use with the Moving Boat Package. The assumptions made are that each line is 35 characters long with a CR,LF at the end. MEDIT is the same as EDIT except that it is for use with the Tellurometer data files (42 characters long with a CR,LF at end). The editor maintains a pointer that marks a character in the file. All changes are made relative to the position of the pointer. Deleting a single character, for example, erases the character at the pointer; insertions are made immediately preceding the pointer. There are several commands to move the pointer. The editor is entered by the command EDIT <filename>.

Editor commands are entered from the keyboard whenever the asterisk (*) is displayed. Commands must end with a carriage return, and they will not execute unless one is entered. Only one editing command is permitted on a line. The general command format is as follows:

*command name (argument)
where: * is the editing command prompt (don't type it)
command name is a 1 or 2 character mnemonic in either upper or lower case

Commands can be divided into the following classes:

1) Pointer commands - Jump line (L) and Jump character (J)
2) Text commands - Print (P), Insert (I), Delete (D)
3) Search commands - Find (F), Substitute (S)

1) POINTER COMMANDS:

The pointer commands move the pointer any number of characters or lines forward or backward in the file, or the beginning or end of the file. The two pointer commands are the Line and Jump command. They have several common constraints. If the command tries to move the pointer beyond the end of the file, the pointer is positioned at the CRLF at the end of the file. If the command tries to move the pointer beyond the beginning of the file it is positioned at the beginning. If the command tries to move the pointer to the LF of the CRLF sequence, it is moved back to the CR position to prevent inadvertent insertion or deletion of one of these characters. A positive number moves the pointer towards the end of the file and a negative number moves the pointer towards the beginning of the file. The commands have formats as follows:

LN - where n is an integer in format 999 (plus) or -999 (minus) and specifies the number of lines the pointer should move. The pointer is always positioned at the start of the line moved to, unless the line command tries to move the pointer beyond the end of the file, in which case the

pointer is positioned at the CRLF at the end of the file (as stated in constraints above).
- LO moves the pointer to the beginning of the current line.
- L with no number, defaults to 1.

Jn - where n is an integer in the form 999 (plus) or -999 (minus) and specifies the number of characters the pointer should move. The CRLF at the end of each line counts as two characters.
- JO leaves the pointer in the original location
- J with no number, defaults to 1.

JT - a special case, moves the pointer to the beginning of the file

JE - a special case, moves the pointer to the end of the file.

2) TEXT COMMANDS

The text commands affect the text in a file by printing existing text, inserting new text or deleting existing text. The command formats are as follows:

PN - print command
where n is an integer in the form 999 (plus) or -999 (minus) and specifies the number of lines to be printed.
- A positive n specifies that n lines, beginning with the current line from the pointer to the end of the line and toward the end of the file are to be printed.
- A negative n causes the n lines preceding the current line and the current line to the pointer to be printed.
- PO causes current line from the beginning to the pointer to be printed.
- P1 causes current line from the pointer to the end to be printed.
- P with no number causes the whole current line to be printed.
The pointer always remains positioned at the same location.

I/text/ or I/text (CR) - Insert command
where text is one or more characters to be entered into the file. The characters must be ASCII characters entered from the keyboard and cannot incude CRLF or other control codes.

- / represents the delimiter and can be any ASCII character not found in the text.
- The command is terminated by either the delimiter (followed by CRLF, as with all commands) or by just the CRLF.
- The text is always inserted immediately before the pointer.
- If the I is terminated by the delimiter the insert is made only into the current line. As with all inserts there can be no overflow into the next line. The remaining characters are moved toward the end of the line and may be truncated. The pointer is positioned immediately following the text inserted.
- If the I is terminated by a CRLF only, the text is inserted into the current line, terminated by a CRLF and that line becomes the current line. The remainder of the former line becomes a new line. This command can be used to create new lines by first positioning the pointer either at the beginning of the line or before the CRLF. For example,

  Line: This is the old line. CRLF where the pointer is at 't' in 'the'
  Command: I/a new line to add (CRLF)
  Result: This is a new line to add the old line.

  The pointer is always positioned at the CRLF of the line inserted. (This makes multiple line insertions easy).

DLn or DCn

- The Delete command removes text from the edited file. There are two delete commands: one for deleting lines and one for deleting characters. With both commands the deletion starts at the pointer and deletes text either forward (positive number) or backward (negative number).
- Where n is an integer in the form 999 (plus) or -999 (minus) and specifies the number of lines/characters to be deleted.

DLn

- A position n specifies that n lines, beginning with the current line from the pointer to the end of the line and toward the end of the file are to be deleted.
- A negative n causes the n lines preceding the current line and the current line to the pointer to be deleted.
- DL0 causes no action.
- DL1 causes current line from the pointer to the end of the line to be deleted.

- DL with no number causes a default to DL1.
  The remainder of the lines are moved up in the file and nulls (0) are padded at the end of the file. These null lines have no effect.
  The pointer always remains positioned at the same location.

DCn

- A positive n specifies that n characters, beginning with the character at the pointer toward the end of the line are deleted (replaced with spaces). It is impossible to cross a line boundary with the character delete. It is also impossible to delete CRLF. The pointer remains positioned at the point of deletion.
- A negative n causes n characters from the pointer towards the beginning of the line to be deleted. The rest of the line is shifted left and spaces are padded at the end of the line. As with the positive delete, it is impossible to cross a line boundary or to delete the CRLF.
  The pointer moves to the point of deletion.
- DC0 causes the no action.
- DC with no number causes a default to DC1.

3) SEARCH COMMANDS

The search commands are the find and substitute commands. The command formats are as follows:

F/text/
or
F/text (CR))

- Find command searches for a character string. where text is one or more characters to be searched for. the characters must be ASCII characters entered from the keyboard and cannot include CRLF or other control codes.
- / represnts the delimiter and can be any ASCII character not found in the text.
- The command is terminated by either the delimiter (followed by CRLF, as with all commands) or by just the CRLF.
- The pointer is positioned to the character immediately following the string. If the string is not found, a "NOT FOUND" message is displayed and the pointer remains at its previous location.

S/text/new text/ or S/text/new text (CRLF)
(act same)

- Substitute command replaces a character string with another string. The search for the text acts exactly as the Find command. If the string is not found a message is displayed and the pointer remains at its previous location. If the

string is found it is replaced with the next text in the same manner as an insertion. The pointer is positioned at the end of the inserted text.
- Note a Substitute command with no new text acts as a simple delete of the text.

4) Exit command has the format: EX and is used to exit from the editor, closing the edited file.

At the end of an editing session the following message is sent to the console output device:

EDITED TO FILE: filename

4.2.7 FORMAT Command

The FORMAT command is used to reformat the bubble. Note that this commands DESTROYS ALL THE FORMER CONTENTS of the bubble and must be used with extreme caution. After the format command, only the DIOS system files will be present on the bubble. This command is used when a new bubble is received and the operator wishes to incorporate it into the system. A new bubble must be formatted before it can be used in the system.

4.2.8 PLAYBACK Command

The playback function is entered by typing P or PLAYBACK followed by a carriage return. The system then prompts the user for filename and run number. A complete playback of the filename selected will occur, recalculating all discharges and summary report. The playback function can be used for generating additional copies of desired runs or to recalculate the discahrge measurement when editing of data has occurred in a file.

4.2.9 REALTIME Command

The realtime function initiates a data collection run and is entered by typing R or REALTIME followed by a carriage return. The system then prompts the user for the filename and run number. The system then proceeds to collect and process data upon the push of the START/STOP switch. Data is printed out during the run and by pushing the START/STOP switch again, the system concludes the run by printing out the summary report. The system is then returned to the user's control by displaying a ">".

4.2.10 SETUP Command

The setup function is entered by typing SETUP followed by a carriage return. The setup function allows the user to re-enter initialization data, re-calibrate the depth digitizer, set the baseline bearing and re-enter OTTMETER constants. The format of SETUP is illustrated below:

```
ENTER DATE (00/00/00):
ENTER TIME (00:00:00):
ENTER LEW (00.0):
ENTER REW (00.0):
ENTER ACTUAL WIDTH (0000.0):
ENTER VELOCITY ADJUSTMENT FACTOR (1.0000):
SET BASELINE, PRESS CR TO CONTINUE:

ENTER SPEED OF SOUND (1500):
ENTER DEPTH METER DRAFT (00.0):

DISPLAY IN METERS OR FEET (M):

ENTER OTTMETER CONSTANTS FILENAME:
```

OTTMETER CONSTANTS FILENAME

The OTTMETER CONSTANTS file consists of a single line of text containing the OTTMETER coefficient followed by the offset and then followed by user desired text. The default values are shown below.

0.00541 0.02203 (Default values)

To create an Ottmeter file the following sequence of commands is used (assume the filename will be OTTFAC):

COPY :CI: TO OTTFAC (press carriage return)

0.00559 0.01667 A.38387 (press Control Z)

Press carriage return

If OTTFAC is entered as Ottmeter Constants filename during set-up, the values in the OTTFAC file will be used.

4.2.11 Velocity Adjustment Factor

A moving boat traverse is made with the current meter fixed 1 m below the water surface. This means that only one velocity sample is taken in the vertical. This one sample will in most cases not represent the mean velocity from river bed to surface and an adjustment must be made using representative vertical velocity profiles. As with the width-area adjustment, this correction is applied to the total discharge because it is not feasible to obtain a correction for each segment discharge.

A vertical velocity profile, such as that shown in Figure 5, is made by taking velocity samples at the 0.05 subsurface depth, at each 0.1 depth increment, and near the river bed at the 0.95 depth. The mean vertical velocity can be obtained by a number of proven mathematical or graphical methods. The most frequently used techniques are to add the incremental velocities, giving the 0.1 samples the full value and the 0.05 and 0.95 samples half value, and dividing the total by 10, or to plot the values, drawing a smooth curve through them. The graphical method, which permits the user to exercise judgement, is preferred. The vertical velocity coefficient is determined by the equation

$$Kv = \bar{v}/v$$

where Kv = vertical velocity coefficient,
$\bar{v}$ = mean velocity as computed from the velocity profile,
and v = velocity at the 1-m depth.

It is suggested that vertical velocity coefficients be computed from three representative stations along the measurement cross section. These stations should represent velocities which will produce approximately one-third of the river discharge. In this way the coefficients will be more indicative of the average river velocity. The mean of the three coefficients is determined and applied to the total discharge after the width-area adjustment has been made.

Velocity profiles are not required for each measurement, but should be made over a range of stage covering high, medium, and low discharges and obvious changes in the stage-discharge relation. In cases of heavy drift or where time is a factor and a number of measurement sites have to be covered in a day the following theoretical coefficients for a current meter set a 1 m depth can be used.

River depth D(m)	2	3	4	5	6	7	8	9	10
Coefficient	0.96	0.92	0.90	0.89	0.88	0.88	0.88	0.87	0.87

This is not a recommended practice, as each river will have a different coefficient due to its physical characteristics, and since the coefficient is applied directly to the total discharge it will have a significant bearing on the accuracy of the measurement. Vertical velocity profiles should be taken as soon after a measurement as circumstances permit.

The velocity adjustment factor is entered into the system during set-up. The system automatically prints the total velocity adjusted discharge in the summary.

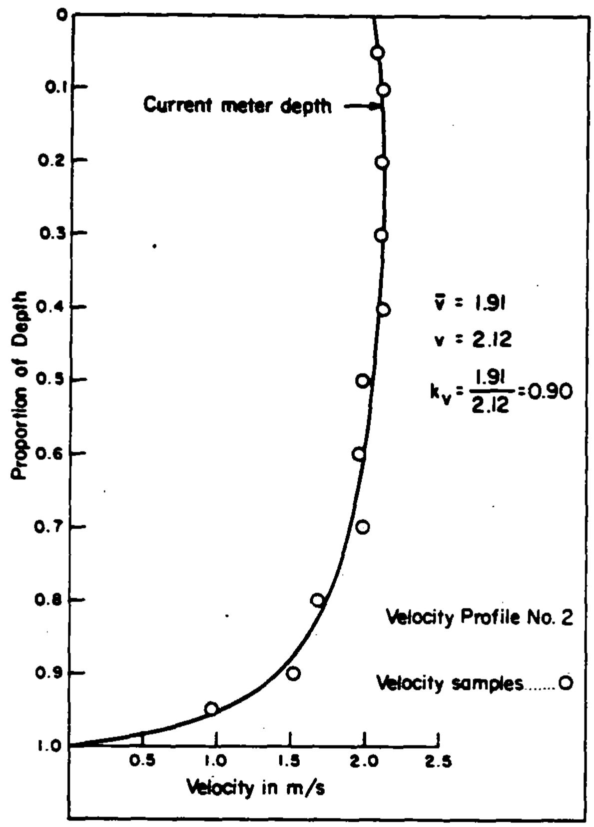

Figure 5. Computation of Velocity Adjustment Coefficient

4.2.12 Width Adjustment Factor

The incremental segment widths, determined from the cosine relation (preselected range setting multiplied by cos alpha), assumes that the river flow is normal to the metering section at every sampling point and a right-triangle relation exists for each segment. This is not the case for the average river because angular flows of varying degrees will be encountered. The oblique flow will have a horizontal component that acts with or against the boat travelling along the section line.

The true river width is entered into the system during set-up and is the distance from the water's edge of one shore to the water's edge of the opposite shore along the section line. As the system takes a measurement a computed total width is calculated from the sum of the panel widths. The correction factor that is applied to the total unadjusted area and total unadjusted discharge is computed as

$$Kb = Bm/Bc$$

where Kb = width-area adjustment coefficient
Bm = measured width of measurement section
and Bc = computed width.

Ideally the width correction should be applied to each segment width but this is impossible, as a measured width cannot be obtained for each segment.

Because the width corection is related to angular flow, it is important that the total river discharge is computed from a pair of measurement traverses originating from opposite sides of the river. In some cases oblique flow may predominate in one direction, and the total discharge may be artificially high or low if only a single run is used to compute river discharge.

The width adjustment also tends to compensate to some extent for errors introduced by discrepancies between the true course of the boat and the section line. The total width adjusted discharge is printed in the summary report at the end of each discharge measurement run.

4.2.13 System Generated Error Messages

The operating system will generate standard error messages, which are sent to the console output device. Some of these errors abort the current running program, and some just abort the current operation. The messages currently generated are as follows;

MESSAGE	DESCRIPTION	FUNCTION USED IN
********************	***************************	****************
BUFR LIMIT EXCEEDED	Limit of system buffers exceeded	System
AFTN NOT OPEN FILE	Trying to read/write non open file	Copy, Edit
ILLEGAL FILENAME	Filename not valid (see format)	All
NO DIRECTORY ROOM	No more room in directory	System
FILE NOT FOUND	No such file	All
WRITE PROTECTED	Attempt to write to or delete	All
NO NAME SPECIFIED	No filename specified in command	All
*** FATAL ERROR ***	Any error causing abort	All
STRING NOT FOUND :	String in Find or Substitue not found	Edit
IMPROPER OPERAND	Command argument invalid	Edit
TERMINATOR EXPECTED	Expecting CRLF - characters found	Edit
NO SUCH COMMAND	Invalid editor command	Edit
MISSING OPERAND	Expecting operand - not there	Edit
ILLEGAL VALUE	Value invalid format or size	Edit
SYSTEM ERROR		System
FILE ALREADY EXISTS	Attempt to create existing file	Copy
INVALID SWITCH	Expecting P - something else	Copy
CREATING NEW FILE	Edit creating new file	Edit
PATHNAMES NOT SAME	Pathnames do not specify same medium	System
CANT DELETE OPEN FL	Attempt to delete open file	System

4.3 Echo Sounders

The discharge measurement processor is available with an internal digital echo sounder or a analog strip chart sounder with a depth digitizer. Both systems operate with an 8 degree transducer operating at 192 KHZ.

When using the analog strip chart sounder and the depth digitizer, familiarization with the unit should be accomplished by the reading of its manual. The stylus must be tensioned properly to give a good trace. The operator must then adjust the sensitivity pot to obtain a good bottom trace with no surface noise. The threshold pot on the digitizer is adjusted until the echo LED flashes at a regular rate and depth readings appear. The digitizer, under software control tracks the bottom so that random noise echos are filtered out.

When using the digital sounder, no adjustments are necessary. The system automatically adjusts sensitivity and also tracks the bottom.

When using the external depth connector, familiarization with the analog sounder and depth digitizer are necessary. Appendix A contains the interconnect specifications for using the external depth port.

4.4 Angle-indicating Assembly

This component of the moving boat equipment package is used to determine the angle of the current meter relative to the section line. The variable angle is continually read by an electronic compass. The mean angle between sampling points is used in the vector analysis to determine segment discharges and widths.

The assembly consists of a 2-m-long aluminum tube which is fixed vertically at the front or side of the boat. Inside the tube is a stainless steel rod which rotates freely on a Teflon bearing at the bottom and top and extends from the tube 200 mm at the bottom and 30 mm at the top. An aluminum vane 300 mm high, 450 mm long and 2 mm thick is attached to the rod extension at the bottom, the electronic compass is attached to the top. The electronic compass is calibrated in four 90 degree segments in 1 degree intervals. The baseline is set during setup. A typical configuration is shown in Figure 6.

The current meter is attached to the leading edge of the directional vane. When a moving boat measurement run is made, the axis of the current meter assumes a position parallel to the water moving past the vane; this position corresponds to an angle transmitted by the electronic compass at the top of the assembly. The crab angle is computed and displayed in realtime and is dependent upon the combined velocity of the boat and the river.

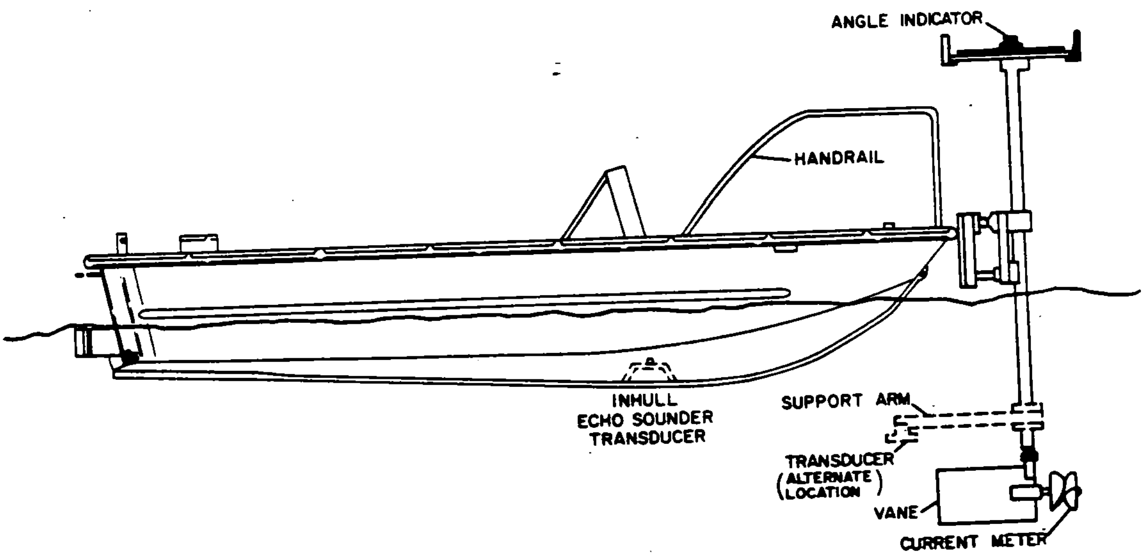

Figure 6. Typical Boat with Angle-indicating Assembly

4.5 Boats and Related Hardware

The safety of the crew is the prime consideration in the choice of a boat. It is very important that the boat chosen for moving boat measurements is suited to the river conditions.

Accessibility of the measurement site also plays a large role in the choice of a boat. If a site can be reached by road or is within reasonable boat travelling distance of a launching site, a hard-bottomed boat at least 5 m in length should be used. Sites that require the use of aircraft for access limit the size and weight of boat that may be used. In this case a 5-m high quality inflatable boat is recommended. The one boat that is definitely not recommended is a 3-m to 5-m car-top type aluminum boat, as these boats are very unstable when unbalanced.

Rivers that have high velocities should be measured using a boat of sufficient size and power. Fibreglass or aluminum boats having a cathedral type hull with an inboard engine or twin outboards are ideal. The boat should also have a walk-through type windshield to an open bow area. Modifications to the boat include a mounting bracket for the mast and vane assembly bolted securely to the bow.

The inflatable boat is ideal for measurement sites that are considerable distances apart, as the boat can easily be transported in a vehicle or aircraft. These boats operate very well in high velocities, are very stable even in rough water conditions, and are easily adaptable to the equipment package.

5.0 FUNCTIONS OF CREW MEMBERS

The accuracy of the measurement technique is largely dependent upon the boat operator's skill and experience. Two persons are required to conduct a measurement, the boat operator and a instrument operator. All crew members must wear life jackets while in the boat.

5.1 The Boat Operator

The boat operator has the responsibility for the safety of the crew and equipment and must check the boat, motor and mechanical equipment prior to leaving shore. Before the mast and vane assembly is lowered, the metering section should be checked for debris or underwater hazards. The boat operator determines where the end-of-run floats are positioned so that there is sufficient room to manoeuvre at the beginning and end of each measurement run. When the floats have been positioned, a practice run should be made in each direction to give the operator a "feel" for the river. Fluctuations in current speed and direction can then be anticipated and the boat manoeuvred accordingly.

When the equipment has been checked out and the crew is ready, the boat operator positions the boat into the current approximately 5 m outside the float marker on the section line. The bow of the boat is swung slowly sideways towards the far shore. The boat will start to slide sideways and sufficient power must be applied to keep the boat on the line. Power must be applied gradually to prevent surges on the current meter. A proper combination of power and alignment of the boat into the current will result in a smooth well-controlled measurement run. Too much side area into the current will result in the boat slipping downstream, and to much power will result in the boat advancing upstream.

The shore targets are a visual guide to keep the boat on the section line as the measurement run is made. The boat operator continues to "crab" the boat into the current, maintaining as close as possible a 45 degree angle with the current. The operator must not be distracted during the measurement run, as the boat must be kept as close as possible on the section line at an acceptable angle of approach. Also a watch must be kept for floating debris that could damage the metering gear or capsize the boat. The angle of approach to the current, as monitored by the instrument operator is very important, as it can greatly affect the measurement result. Too small an angle (less than 20 degrees) means that the boat is travelling too fast and that the current meter is mainly monitoring boat speed. Small angle readings, if read incorrectly, create larger errors in calculation of segment discharges than do incorrect readings at about the 45 degree position. Large angles (over 70 degrees) mean that the boat is moving too slowly and an excessive number of samples will be taken. An experienced boat operator will be able to judge from the angle display if the boat is manoeuvring properly.

If the readings are poor or the boat slides a considerable distance off the shore target, it is advisable to return to the marker float and start again. The measurement run is complete when the bow of the boat passes the opposite shore marker float. As one moving boat measurement usually consists of a measurement run in each direction, the return run should be made as quickly as possible before river conditions change. The summary report typically takes 15 seconds.

5.2 The Instrument Operator

The instrument operator maintains the measurement processor. This crew member is responsible for system set-up and keeping track of the files created on each measurement run. It is very important not to overwrite or lose data by carelessness. The instrument operator also watches for floating debris and other safety hazards and constantly monitors the crab angle and depth reading. The boat operator should be informed when critical crab angles are being reached. The instrument operator makes echo sounder adjustments and insures that sufficient paper is installed in the system and that the battery to power the system is fully charged.

6.0 ASSEMBLY AND CARE OF EQUIPMENT

The individual components which make up the moving boat measurement package have been described in detail in the section on equipment. This section explains the assembly routine prior to a measurement and the care and maintenance required to keep equipment in good working order. As the equipment can be used on a variety of boats with either a bow or gunwale mounting, it is assumed that the boat has a suitable sturdy mounting arrangement that will accept the mast and vane assembly.

The current meter, begin a delicate instrument in a vulnerable position, requires special care in maintenance and assembly. Instructions are as follows:

1) Unscrew the propellor from the current meter body. When the propellor is completely free of the threads, carefully slide the propellor off the bearing assembly.

2) Inspect the hub of the propellor and clean out any dirt or water that may be present in the oil cup and sleeve.

3) Inspect the bearing assembly and shaft for dirt.

4) Fill the oil cup within the propellor to the top with Ott propellor oil, as shown in Figure 7.

5) With the meter body held vertically, bearing assembly facing down, carefully slide the propellor onto the bearing assembly until the threads are engaged. Hand tighten the propellor onto the bearing assembly.

6) Spin the propellor and watch and listen for any irregularities which may retard the movement of the propellor. Grit in the bearings or a bent shaft will result in measurement errors. If the meter is suspect it should be dissembled and any damaged parts replaced and the meter recalibrated. (It is advisable to carry two current meters in case one becomes inoperative.) A damaged meter, if used because of lack of a replacement, must be recalibrated in "as is" condition prior to computing the measurement.

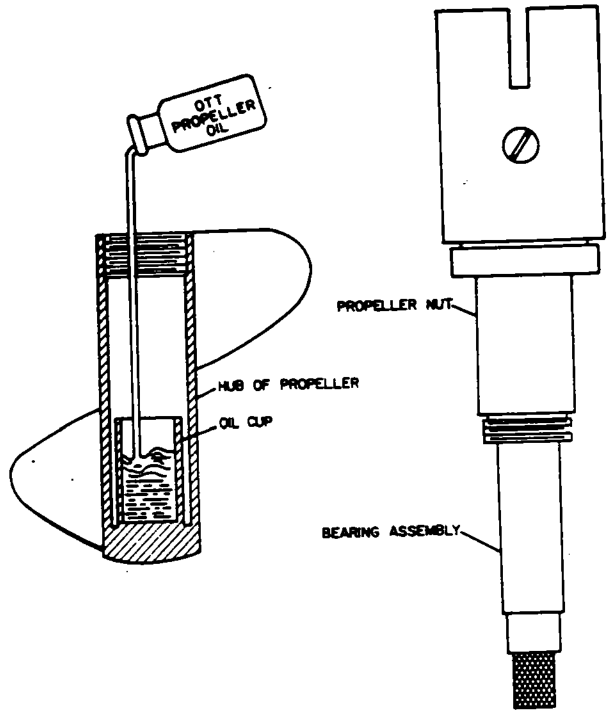

Figure 7. Component Current Meter

7) When the meter has been reassembled and checked, the magnetic transducer is inserted. Adjustment of the probe position should be done with care to prevent damage to the probe tip. The procedure is as follows:

a) Screw the transducer into the threaded opening on the meter body until slight contact is made with the top of a gear tooth.

b) Back the probe off one half turn to provide minimum clearance with the tooth. Secure the lock nut gently, and slowly rotate the propellor. (Care must be taken, as the probe may have been positioned between two gear teeth, and turning the propellor would damage the probe.)

c) If the probe clears the gear and the meter spins freely, plug the cable from the probe into the measurement processor and check for output on the LCD display. If no output appears or if the output is erratic when the meter is rotated at a moderate speed, the probe adjustment procedure must be repeated.

d) When the proper probe adjustment has been made carefully tighten the lock nut. Only slight pressure should be applied to the lock nut, as the threads on the probe are paper thin and can easily be broken.

8) The meter is now ready for mounting on the direction vane. This is done after the vane and mast are assembled.

9) Upon completion of the last measurement for the day remove the meter from the vane, unscrew the probe, empty the oil wiping all parts clean, and store in the meter box.

The aluminum vane is placed in the slot of the rotating stainless steel shaft and fastened with two cap screws. The current meter is attached to the front edge of the vane. A bolt is passed through one side of the meter and the mounting hole in the vane and tightly threaded into the other side of the meter. Two small screws on the side opposite the bolt are tightened into the aluminum vane after the meter has been aligned parallel to the vane. The depth sounder transducer is then attached in its mount at the rear of the vane. The cable from the magnetic probe and the depth sounder transducer is taped to the mast at approximately 400-mm intervals, allowing enough slack at the vane for rotation.

The mast, vane, and meter assembly is now ready for attachment to the boat. The mast is aligned vertically by adjusting the spacing bolts at the base of the pivot plate. The final alignment is made after a practice run, as the speed of the current will determine the horizontal plane of the boat, which in turn affects the position of the mast with respect to vertical. The mast is adjusted so that it is perpendicular to the water surface for most of the measurement run.

The mast is fastened to the pivot plate with a clamping block which will allow vertical adjustment of the meter below the water surface. The mast is graduated in 0.5-m increments, which can easily be seen from the boat. Ajdustment is made by loosening the clamp bolts on the pivot plate and sliding the mast up or down to the desired position. This adjustment should also be made after a practice run, as the current will cause the bow to rise out of the water. A current meter setting of 1 m below the water surface has been found to be the most suitable position for a combination of accuracy and stress on the mast. The cables from the magnetic probe and depth sounder transducer are run to the vicinity of the measurement processor. The electronic compass unit is then fastened to the top of the mast and its cable is also run to the measurement processor.

The current meter and electronic compass are then connected to the measurement processor. The power cable is then connected to a 12 volt source making sure the polarity is correct. The unit is then turned on, the LCD display should display current rate, crab angle and depth. Set-up data may now be entered via the keyboard.

The baseline zeroing is set when the command "PRESS BASELINE SET WHEN READY" appears on the LCD or printer. The initial press of the push button sets the crab angle to zero, a second press sets the angle to 90 degrees, the third to zero and so on. This allows the operator to set the baseline by aligning the current meter vane either parallel or perpendicular to the baseline. Once set the baseline doesn't require resetting unless a system reset has occurred by either pressing the reset button or a power disconnect.

The depth sounder attached to the measurement processor whether external or internal must be calibrated for speed of sound and draft adjustment. The internal calibration is done during set up and the procedure is described in the echo sounder section. The recommended calibration technique for an echo sounder is the bar check or, where a solid flat river bed is available, a check against accurate soundings. As soundings will vary with salinity and water temperature, it is imperative that calibraton checks be made on a daily basis.

The bar check is the more accurate but takes more time and requires calm water of at least half the maximum river depth. An aluminum rod with at least 100 mm of surface width and as long as the boat is wide is lowered beneath the transducer to a fixed depth by measured cables or ropes attached at each end. The sounder is turned on and calibrated to obtain a chart reading that corresponds with the depth of the bar. This procedure is then repeated at a lower depth. When the chart reads the bar at the proper depth for both bar settings, then the sounder is properly calibrated.

The simpler method, while not as accurate, is most often used because of river conditions, as it is difficult to find an area of calm water with sufficient depth for proper positioning of the bar. The sounding technique simply requires a level rod for shallow streams or a weighted surveyor's tape for deeper streams. The boat is positioned near shore and held by its own power or anchored. The measuring rod or tape is lowered on each side of the boat in line with the transducer. The mean of the two depth readings if recorded and the echo sounder is calibrated to this mean depth. If this technique is used, a calibration should be made at the beginning and end of each day and the echo sounder display adjusted as necessary.

It is imperative that an accurate measurement for the calibration depth is made. In 1 meter of water a discrepancy of .1 meter will change the speed of sound by 10 percent or 150 meters/sec. This is → why, if an accurate measurement of depth is not possible, the deeper the water the more accurate the calibration.

If the assembly and set-up is now complete, preparations to take the first measurement requires only the inputting of filename, run number and range setting.

7.0 TYPICAL MEASUREMENT PROCEDURE

The choice of boats, instrument settings, and site preparation is related to the particular physical characteristics of the river but the basic measurement technique is the same regardless of river width, depth, or current velocity. Figure 3 shows a typical site set-up. If care is taken in all phases of the technique, an accurate measurement can be obtained in a very short period of time. The following guidelines should be closely followed from the arrival on the site to the completion of the measurement.

1) On an initial measurement establish a safe operating area. This is accomplished by sounding the river above and below the section line and noting potentially hazardous areas.

2) Establish start and end marker floats. The floats are positioned approximately 5 m upstream of the section line to avoid interference with the boat. Plastic containers make ideal floats, as they create little drag and a light line at least twice the river depth attached to a 2-kg Danforth type anchor will hold them in position. Before positioning the float the boatman must sound the immediate area to be certain that there is enough room to manoeuvre the boat with the mast attached.

3) Make all required width measurements and input IO data into the measurement processor during setup. When the stage fluctuates rapidly, the river width must be determined before and after each set of measurements. If targets are not permanent, they must be positioned prior to the measurement and any brush or debris that may interfere with the line of sight must be removed.

4) Calibrate the echo sounder using either the bar check or the manual sounding technique (see page).

5) Assemble all the equipment at the shore but do not lower and secure the vane and mast assembly until a safe water depth is reached. Check all instrumentation to be certain that it is functioning properly before leaving shore.

6) Proceed to the vicinity of the nearest marker float, lower and secure the mast and vane assembly. Turn on the measurement processor. Press the start button and run the boat slowly along the section line, keeping on line as closely as possible. This practice run determines the range setting to be used to obtain 25 to 40 sampling points and also allows the boat operator to obtain a "feel" for the river that will assist in anticipating current fluctuations.

7) Return to the initial marker float and prepare for the first measurement run.

The instrument operator enters the data required by the system (filename, run number and range) and checks that all instruments are functioning.

The boat operator starts manoeuvring the boat from approximately 10 m below the section line and 5 m outside (shoreside) of the marker float. As the bow of the boat slowly reaches the section line, he turns the bow slightly towards the marker float. The boat should now be slowly drifting towards the float, and power adjustments must be made to keep the boat on line. As the bow of the boat reaches the float, the boat operator gives a signal upon which the instrument operator activates the system by pressing the start/stop button.

An audible signal is heard when the start and stop buttons are pressed and at all intermediate sampling points. At each audible signal all the raw data, the river velocity and panel discharge are printed out. As the bow of the boat passes the end float, the boat operator gives a signal and the stop button is pushed. The system then prints the summary of the measurement.

8) A moving boat measurement consists of a pair of runs originating from opposite banks, so it is important that the return run be completed as soon as possible. Typically a return run should start within two minutes of the run just completed.

8.0 TREATMENT OF DATA

Moving boat measurements can be made on most large rivers that meet the minimum requirements of depth and velocity. Because a large number of measurements can be made in a relatively short period of time, care must be taken in analyzing the computed data.

In the case of a river with a rapidly rising or falling stage, individual measurement pairs are related to the mean river stage during the time of measurement. A significant segment of a stage-discharge relationship can be determined from a one-day series of measurements if the stage is changing rapidly. Effects of backwater or slope variations will also be apparent on a rapidly changing river if the measurement pairs are treated individually.

A river that maintains a constant elevation over the period of measurement can be measured to a greater degree of accuracy by obtaining the mean of three measurement pairs. The three measurement pairs taken at a constant river elevation will reduce errors due to data collection, angular flow variation and discharge fluctuations. If, during steady flow conditions measurement results are consistently higher in one direction that the other, it is an indication that the section line is not perpendicular to the current. The section line should be adjusted if this situation occurs at all stages.

at a constant river elevation will reduce errors due to data collection, angular flow variation and discharge fluctuations. If, during steady flow conditions measurement results are consistently higher in one direction that the other, it is an indication that the section line is not perpendicular to the current. The section line should be adjusted if this situation occurs at all stages.

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