Model 801 Flowmeter Operating Manual

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Table of Contents

1 Introduction

This manual covers the operation of the Teledyne ISCO Model 801 Electromagnetic Flow Meter with a Flat Type Transducer.

2 Equipment

604480210 Model 801 EM Flat transducer (single axis) | CDU (logging) | Wading Rod Set | 2m cable | PC Interface cable

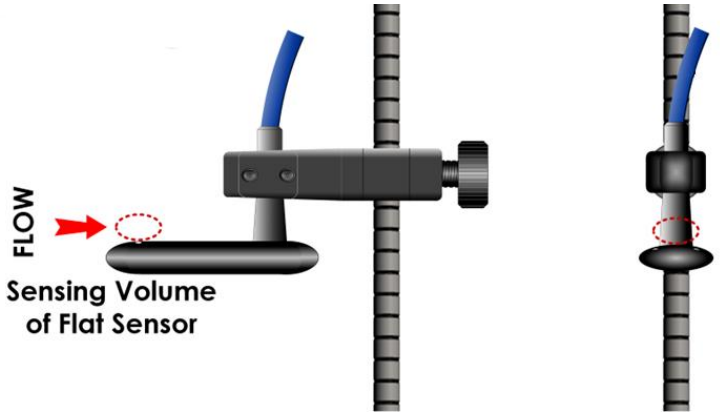
604480211 Model 801 EM Flat transducer (single axis) | CDU (logging) | Wading Rod Set | 6m cable | PC Interface cable

604480215 Set of 3 - 20" rods with 0.5" graduations with base and direction knob.

3 Description

The 801 electromagnetic flow meter uses the Faraday principle to measure the flow of water past the sensor.

The flat sensor has the sensing electrodes on one surface of the sensor; these should normally be facing uppermost. The volume of water whose flow is being sensed is a cylinder between the electrodes and extending to approximately 10mm above the sensor. Therefore, this sensor is also suited to shallow applications. Because of the small sensing volume, the real time readings of the flat sensor might appear variable if the water is turbulent.



The sensor should be aligned into the flow, and the calibration is determined for +ve flow (flow on to the sensor at the electrode end) with the sensor upstream of the wading rod.

The sensor will detect negative flow, and the same calibration is used, although there will normally be some interference caused by the turbulence from the wading rods. The unit is set to measure speeds up to 5 M/sec in both directions.

The system is calibrated as a combination of sensor with electronics in the Control Display Unit (CDU). The serial number of both the probe and the CDU are displayed on the display on startup.

The system will operate in any conducting fluid, and the conductivity does not affect calibration. At very low conductivities the signal will, however, become noisier. A simple check is to check the noise in still water.

The CDU has its own internal batteries and bulkhead connectors for the data interface to PC and the sensor. It also has a waterproof pressure equalising valve to compensate for changes in temperature and atmospheric pressure that would otherwise cause the display membrane to distort. The connectors have waterproof pro-caps for when not in use. The CDU is designed for operation in rain conditions and for temporary immersion in water to 0.3m for 10 seconds, provided all connectors or pro-caps are fitted.

The EM system measures the flow twice every second and calculates the real time flow every second as the average of the half second readings. The REAL TIME display is updated every second. The average speeds are computed as the average of the one second real time values over the averaging period which has been set (maximum period of 600 seconds). If an average period is terminated early, then the calculation is based on the time since the average was started.

The 2Hz data from the EM system has been digitally filtered from raw 96Hz data. The filter is a Digital FIR filter with a fixed time delay and no frequency dependent phase shift. The filter –3dB cutoff is 0.61Hz, and the delay time is 4.0 seconds.

The STANDARD DEVIATION (SD) is calculated from real time samples taken during the averaging period and gives an indication of the quality of the measurements. A high standard deviation indicates either a high variability in the flow or that the probe has not been held steady during the measurement.

There are 3 types of Averaging Modes:

Fixed Average:

The unit performs one average over the period set. At the end of the averaging period, the unit stops and displays the average and SD. It will commence another averaging period when requested by pressing START.

Free Running:

This is a fixed average with automatic restart of averaging period at the end of each period. The average and SD from the previous period are displayed and held during the subsequent period until updated.

Moving Average:

The average and SD are calculated over the averaging period set and is updated every second. When STOP is selected, the display is frozen at the last average.

If the measurement period is terminated prematurely (by pressing the STOP key), the average values and standard deviation will be calculated over the time since the start of the current averaging period. The data (speed, SD, averaging period) is available for direct interfacing to a PC in real time. (See Section 4.6.3 for interfacing information.):

- In **fixed average** mode, a data string of average data is outputted at the end of averaging period.
- In **moving average** mode, the last saved average is outputted when the STOP key is pressed.
- In **free running** mode, the data is outputted at the end of each fixed average period and also when the STOP key is pressed.

The CDU can log up to 999 averages for subsequent display and/or transfer to a PC.

The optional analogue output is +/-5volts for the speed range +/-5 M/sec, and the analogue signal is based on the latest average figure shown on the CDU. The analogue output connector also enables external DC to be applied.

4 System Operation

4.1 Setting Up

To prepare the system for use:

i. Clean the probe electrodes to remove any grease or dirt.

ii. Insert batteries (8 1.5v C type cells) if external power not being used. For maximum battery life, alkaline type cells are recommended.

iii. Connect cables for the particular combination of hardware being used.

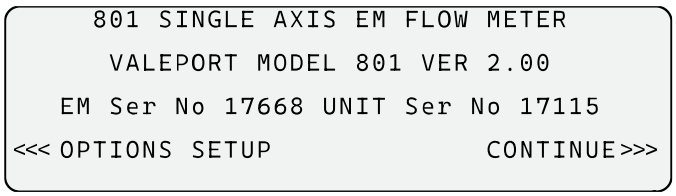
iv. If using with a probe fixed to wading rods, assemble the probe into the adaptor (clamping using the small grub screw) and fix to rods, base, and direction knob assembly.

v. If the probe is mounted by other means, note that the mounting may affect the flow characteristics and thus introduce an error into the measurement. You can, of course, adjust results by carrying out your own calibration.

Once the system's parts have been connected, it is ready for use. For testing purposes, all the CDU operations can be carried out without the sensor in water, but the real time data will be meaningless.

4.2 Switch On

ON Switch unit On using ON button. This is acknowledged by a beep from the unit. This key is also used to switch the unit Off at any point during operation. Switching the unit On causes the following display to appear:



CONTINUE Places the unit in Run Mode. See Section 4.3.

OPTIONS SET-UP This key selects the OPTIONS menu, where various hardware configurations (Logging On/Off, Beeper On/Off and Backlight On/Off) can be set up. This menu also allows access to the USER CALIBRATION menu and to the LOGGING menu. For further information, refer to Section 4.5.

4.3 Running the Unit

Pressing **CONTINUE** at the title screen or pressing **EXIT** at any of the **OPTION SET-UP** screens reveals one of the three possible displays shown below, depending on what mode the unit was in when it was last used. (Note that until START is pressed, no flow data is displayed.)

DISPLAY 1: FIXED AVERAGE

```
      FIXED AVERAGE 801  HH:MM:SS
                                STOP>>>
TTT    SSS SECS
                               SETUP>>>
 REAL  AVERAGE
 +X.XXX +X.XXX M/SEC  SD=X.XXX  START>>>
                                LOW BATT
```

DISPLAY 2: MOVING AVERAGE

```
   MOVING AVERAGE 801  HH:MM:SS
                                STOP>>>
SSS    SSS SECS
                               SETUP>>>
 REAL  AVERAGE
 +X.XXX +X.XXX M/SEC  SD=X.XXX  START>>>
```

DISPLAY 3: FREE RUNNING

```
    FREE RUNNING 801  HH:MM:SS
                                STOP>>>
TTT    SSS SECS
                               SETUP>>>
 REAL  AVERAGE
 +X.XXX +X.XXX M/SEC  SD=X.XXX  START>>>
```

An explanation of the different averaging modes can be found in the Description, Section 3.

SETUP Press this key to alter current sampling regime. See Section 4.4.

START After an initialisation period of about 10 seconds, during which the following display will appear, the unit will begin sampling in the mode which has been set. The real time data will be displayed at the bottom of the screen and updated every second. In Free Running and Fixed Average modes, the countdown within the average period is displayed. If the unit is in logging mode, the current record number will be displayed at the top right-hand side of the screen. If the data interface lead is connected, the end of average values will also be sent to the PC.

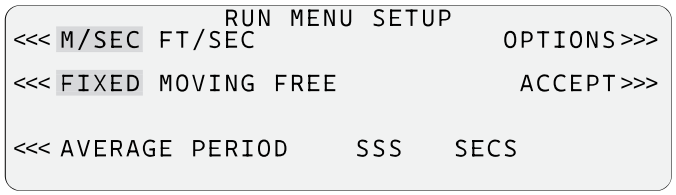
```
        INITIALISING EM
          PLEASE WAIT
```

STOP Press to cease sampling. This will force an early end to an averaging period at the next second.

LOW BATT When there is approximately 4 hours of battery life remaining (with backlight), this message will be displayed at the bottom right-hand corner of the screen. (See DISPLAY 1 for an example.) The message will remain until batteries are replaced. See Section 5 for more information on power consumption and battery life.

4.4 Setting Units, Averaging Mode, and Averaging Period

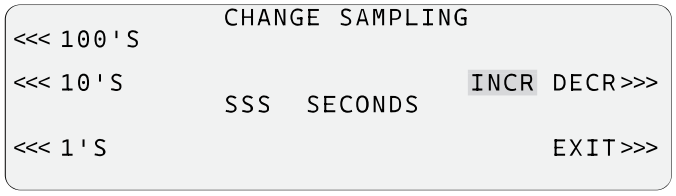
Selecting **SET-UP** in the Run Menu reveals the following display:



M/SEC FT/SEC	Toggles the Speed measurement between meters and feet per second.
FIXED MOVING FREE	Toggles the averaging mode between the three states. Refer to Section 3 for further details.
AVERAGING PERIOD	Displays the Averaging Period setting. To change this, press the key to move to the “Change Sampling” page. Refer to Section 4.4.1.
OPTIONS	Returns to the OPTIONS menu (Section 4.5).
ACCEPT	Returns to the RUN menu. Press this key after the sampling regime is correctly set up (Section 4.3).

4.4.1 Changing Averaging Period

Selecting **AVERAGING PERIOD** in the RUN SET UP screen reveals the following display:



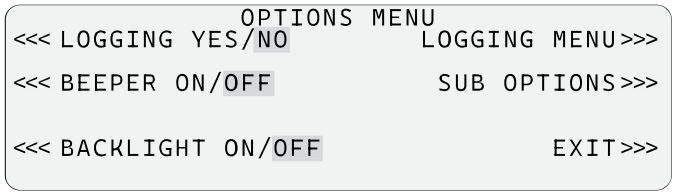
INCR DECR	Toggles between increasing and decreasing the number of seconds when the relevant key is pressed.
100'S	Changes the number of 100's of seconds in the averaging period.
10'S	Changes the number of 10's of seconds in the averaging period.
1's	Changes the number of 1's of seconds in the averaging period.
EXIT	Returns to the RUN MENU SETUP screen (Section 4.4).

"000" seconds cannot be set, and the maximum is 600 seconds.

4.5 Option Menu

(Logging, Beeper, Backlight, Sub Options)

Pressing **OPTIONS SET-UP** at the Title Screen or **OPTIONS** in the Run Menu Setup screens reveals the following display:



LOGGING YES/NO This key switches the logging facility On and Off. Up to 999 records may be stored.

BEEPER ON/OFF Toggles audible indication (once per second) that measurements are being made.

BACKLIGHT ON/OFF This key toggles the backlight On and Off. Refer to POWER CONSUMPTION, Section 5 for details regarding battery life with and without the backlight.

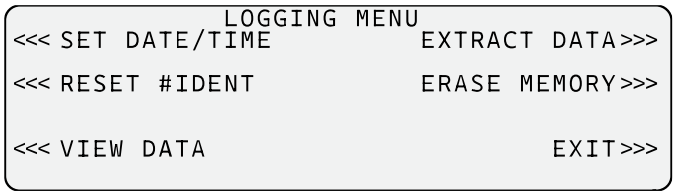
LOGGING MENU Allows access to LOGGING MENU, where stored data can be viewed, erased, or extracted to a PC (via data interface lead), and where the unit date and time is set. Refer to Section 4.6.

SUB OPTIONS This accesses the sub-options menu, which allows direct EM communications with a PC (via data interface lead) for viewing EM data and setting of the calibration coefficients. Refer to Section 6. This sub-options menu also allows, if the options are fitted, frequency outputs and alarms to be set.

EXIT Puts the unit into Run Mode using the hardware configurations selected (see Section 4.3).

4.6 Logging Menu

Selecting **LOGGING MENU** at the **OPTIONS MENU** reveals the following display.



SET DATE/TIME Allows access to the **CHANGE DATE/TIME** screen, where the unit's internal clock can be altered to correctly time stamp the recorded data. See Section 4.6.1.

RESET #IDENT Sets the memory pointer to record #1 and updates the series letter. For example, a second series of records would begin with record #001B.

VIEW DATA Displays logged data. See Section 4.6.2.

EXTRACT DATA Uploads stored data to a PC. See Section 4.6.3.

ERASE MEMORY Clears all stored data from the unit and resets data series identification to "A". This does not reset **#IDENT** to zero, which must be done by the **RESET #IDENT** key. Resetting **#IDENT** to zero should be done first; otherwise, the series B identification will be set. A screen will appear, requesting confirmation to erase the memory. Press YES to continue or EXIT to return to **LOGGING MENU**. If YES is pressed, a message will confirm that memory has been erased. Press **EXIT** to return to **LOGGING MENU**.

EXIT Returns to the OPTIONS MENU. Refer to Section 4.5.

4.6.1 Change Date/Time

Selecting **SET DATE/TIME** at the **LOGGING MENU** reveals the following display.

```
              CHANGE DATE/TIME
<<< NEXT                      INCREASE>>>

TIME: HH:MM                   DECREASE>>>
DATE: DD/MM/YYYY

                                  EXIT>>>
```

INCREASE Increases the currently selected number by 1.

DECREASE Decreases the currently selected number by 1.

NEXT Selects the next number in the time/date sequence.

EXIT Returns to the **LOGGING MENU**. Refer to Section 4.6.

4.6.2 Viewing Stored Data

Selecting **VIEW DATA** at the LOGGING MENU reveals a display similar to that shown below. If no data has been stored, the message NO DATA STORED will be displayed.

```
#IDENT FFFR
EM SER NO.XXXXX                 UP>>>
UNITS XXXXXX
RUN MODE XXXXXXXXXXXXX         DOWN>>>
DD/MM/YYYY HH:MM:SS

<<< VIEW                       EXIT>>>
```

The display shows the record number, serial number, units in which velocity is measured (meters or feet per second), run mode, and time at which the record was stored (i.e., the end of the averaging period).

UP Toggles the record to be viewed up by one.

DOWN Toggles the record to be viewed down by one.

VIEW Allows viewing of the currently selected record. A display of the format shown below will be seen. Press EXIT on this screen to return to the VIEW DATA screen, allowing another record to be seen.

EXIT Returns to the LOGGING MENU. Refer to Section 4.6.

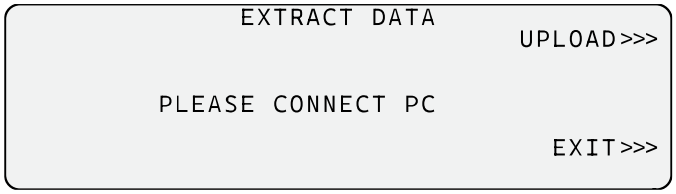
```
#IDENT FFFR

SPEED  +X.XXX
SD=     X.XXX

AV PERIOD SECS  SSS
                                  EXIT>>>
```

4.6.3 Extracting Data

Selecting **EXTRACT DATA** at the LOGGING MENU reveals the following display.



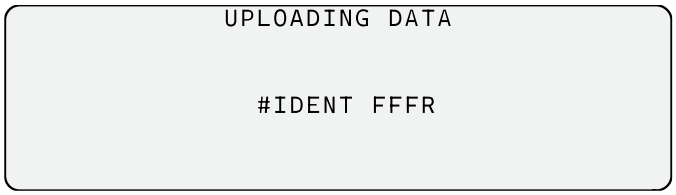
Connect the unit to a PC via the data interface lead supplied. Run a terminal emulation program on the PC, ensuring that communications are correctly set to 4800 baud, 8 data bits, 1 stop bit, no parity bits, flow control NONE. If the data is to be saved on the PC, make sure that the data is directed to a file name. It is uploaded as a text file with “Tab” delimiters, so it can be read into a word processor or spreadsheet application.

The data lead connector information is:

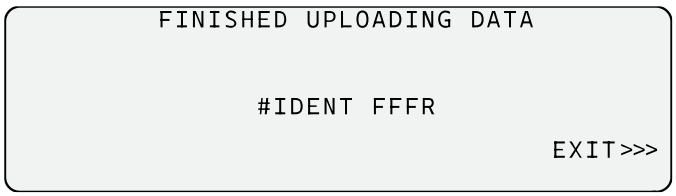
CDU end	Function	PC end
4 way in-line Male MilSpec connector [LMH06F 08 04 PN] [pins]		9 way “D” type female [sockets]
Pin A	RTS from PC [not used]	Socket 7
Pin B	Tx RS232 from PC to CDU	Socket 3
Pin C	Gnd	Socket 5
Pin D	Rx RS232C to PC	Socket 2

UPLOAD Begins to upload data to PC. Screens similar to those shown below will appear, and the #IDENT will increment during uploading.

EXIT Returns to LOGGING MENU. Refer to Section 4.6.



When data uploading is finished, the following screen appears, showing the **#IDENT** of the last record to be uploaded.

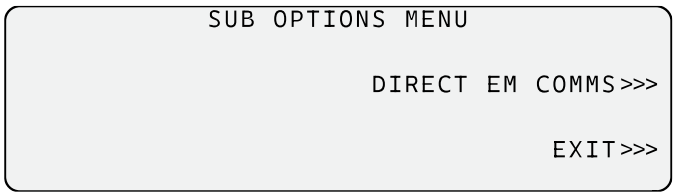


EXIT Returns to LOGGING MENU. Refer to Section 4.6.

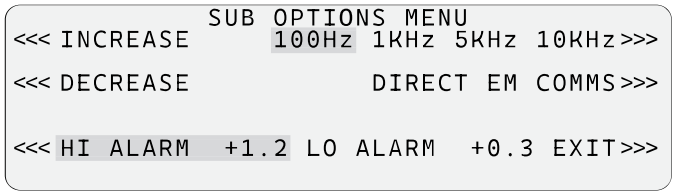
4.7 Sub Options Menu

Selecting **SUB OPTIONS** from the **OPTIONS MENU** reveals one of the following displays:

i. If Frequency or Alarm Outputs are not fitted:



ii. If Frequency or Alarm Outputs are fitted (Factory option):



4.8 Analogue Output (Factory Fit Option)

The analogue output is factory set to provide +/- 5v for the range +/- 5 m/s. The voltage is derived from a D/A from the last updated average velocity figure. Alternatives analogue outputs are available including 4-20mA, where the Control Display Unit provides the power for the 4-20mA. The wiring schedule for this is given in the second table.

The analogue output is made available from a data lead which has analogue out. A mating 6-way connector (LMH 06F 10 06 PN) is provided to enable users to terminate their own cable to this connector.

Connection details of the Y cable are:

CDU End	Function	Analogue Output
6-way female MilSpec bulkhead connector LMH 07A 10 06 SN [sockets]		6-way male Milspec connector LMH 06F 10 06 PN [pins]
Pin A	Signal Ground	Socket A
Pin B	Signal	Socket B

- These two are connected together in the mating connector. This “senses” that external DC is being applied.

Connection details of the 6-way bulkhead connector for a 4-20mA output:

CDU End	Function	Analogue Output
6-way female MilSpec bulkhead connector LMH 07A 10 06 SN [sockets]		6-way male Milspec connector LMH 06F 10 06 PN [pins]
Pin A	GROUND - 4/20 Ma OUTPUT	Pin A
Pin B	CURRENT SINK (SIGNAL OUT) - 4/20 Ma OUTPUT	Pin B
Pin C	+20VDC SUPPLY - 4/20 Ma OUTPUT	Pin C
Pin D	RS 232 IN TO UNIT	Pin D
Pin E	RS 232 SIG GND	Pin E
Pin F	RS 232 OUT FROM UNIT	Pin F

5 Power Supply

5.1 Changing Batteries

The 8 “C” cells are housed in the battery compartment in the bottom of the CDU. Access is gained by unscrewing the central retaining screw and pulling out the end cap and PCB assembly. The cells can then be removed. When putting in new cells, be careful to ensure they are inserted the correct way. Labels are located in the compartment to indicate the correct way. (Note that the large springs touch the -ve end on each cell, while the small springs touch the +ve end.)

5.2 Battery Life

The current consumption of the units is as follows (all measured at 10vDC):

	Backlight On	**Backlight Off**
Standby	92 mA	33 mA
Run	229 mA	171 mA

The battery life, based on good quality alkaline cells operating at approximately 15 °C (note that performance can be reduced with low temperatures) and working on a duty cycle of 5 minutes On / 1 minute Standby, is as follows:

	Elapsed Time (Hours)	**Elapsed time Low Battery to Stop (Hours)**	**Actual On Time (Hours)**	**On Time LB to Stop (Hours)**	**% Duration to Low Battery**
Backlight off		3.50		2.91	91%
Duration to low battery	34.00		28.33		
Duration to stop	37.50		31.25		
Backlight on		7.00		5.82	75%
Duration to low battery	20.50		17.08		
Duration to stop	27.50		22.92		

If the unit is left in Standby, and if no button has been pressed for 5 minutes, the beeper emits 5 beeps as a reminder that the unit is still switched on. This feature does not operate when the CDU is connected to a PC for communications such as downloading data.

5.3 External Power (Factory Fit Option)

The unit will operate on an input voltage range of 7 to 15 vDC. The optional External DC power cable has 4mm plugs (Red +ve, Black -ve). If these are connected using the wrong polarity, an internal fuse will blow. Refer to factory for instructions for repair.

The External DC power cable connection details are:

CDU end	Function	Free End
3 way in-line Male MilSpec connector [LMH06F 08 33 SN] [sockets]		4mm “banana” plugs
Pin A	+ve	Red
Pin B+C	-ve	Black

6 Calibration

Selecting **DIRECT EM COMMS** at the OPTIONS MENU enables the user, using a PC in terminal mode via the optional DC data lead, to read and alter the EM calibration.

Connect the unit to a PC via the data interface lead supplied. Connection details are given in Section 4.6.3.

Run a terminal emulation program on the PC, ensuring that communications are correctly set to 4800 baud, 8 data bits, 1 stop bit, no parity bits, flow control NONE.

The EM calibration has 3 parts to it:

HYDRO CAL This is the “shape” of the calibration curve, and for normal routine calibrations the same calibration is used for all units of the same type.

SYSTEM GAIN FACTOR The Gain Factor is specific to a combination of sensor and CDU and is the factor by which all raw data from the electronics are multiplied to normalise the data to a standard counts per meter/sec.

SYSTEM ZERO OFFSET The Zero Offset is specific to a combination of sensor and CDU and is the number of counts which the unit outputs at zero flow. See section 6.1 below for details on re-setting zero offset.

Having connected the CDU and PC and entered DIRECT EM COMMS, the unit will output EM data at a rate of 2 Hz. Calibrated data from the EM electronics is in mm/sec. To communicate to the unit and interrupt it, press and hold the “#” key on the PC. When the unit responds with a §, enter a single # and press <cr>. The unit will respond with a “«”and then await a command. (The “«” may not be visible in all terminal programs if that character is not available in the font.) These commands are a series of “#” codes.

Code	Followed By space and	Operation
#007	Output_Format<cr>	Sets the output format of the unit to CAL or NOCAL. CAL is data in calibrated units, NOCAL is raw counts and is used for calibrating purposes.
#030	Nothing<cr>	Reads the output format CAL or NOCAL
#028	Nothing<cr>	Sets the unit into run mode. Data is outputted at the 2Hz rate.
#170	Zero_offset<cr>	Sets the zero offset in counts.
#172	Nothing<cr>	Reads the zero offset which has been set.
#174	Gain_Factor<cr>	Sets the GAIN_FACTOR.
#176	Nothing<cr>	Reads the GAIN_FACTOR which has been set.
#190	Nothing<cr>	Reads the Hydro Calibration which has been set.
#192	Calibration<cr>	Sets the Hydro Calibration.

To alter the calibration from the factory setting, the calibration coefficients must be entered. These coefficients are stored within the micro-controller in an ASCII text string. The format of this string depends on the type of calibration (line fit or polynomial fit). The first part of the string will be the calibration function number, selected from the table below, which defines the type of fit.

Calibration Function No.	OPERATION
0	Not defined
1	One straight line fit
2	Two straight line fit
3	Three straight line fit
4	Four straight line fit
5	Five straight line fit

The calibration takes the A/D counts and calculates the engineering value from calibration coefficients. In all cases it is assumed that the –ve and +ve flow characteristics are the same.

Thus, for example, a three-line fit calibration will be entered in the format shown below. (Note the single space between each value.)

3 Coefficient1 Offset1 Max_lt1 Coefficient2 Offset2 Max_lt2 Coefficient3 Offset3 Max_limit3<cr>

- The **Offset** is the y axis (engineering value output) intercept at zero counts for the straight-line segment.
- The **Coefficien**t is the slope of the straight line in engineering units per count.
- The **limit** is the number of counts up to which the straight line is to be used (must be a positive number).

Where Max_lt is the range up to—but not including—that which the straight line operates over.

- The first straight line starts from 0 up to Max_lt1 in A/D counts (WHOLE numbers).
- The second straight line starts from Max_lt1 and including it up to Max_lt2 but not including it.
- The third straight line starts from Max_lt2 and including it, up to Max_lt3 but not including it.

The last line limit (e.g. Max_lt3 in the example above) must be set to more than the maximum number of counts. Teledyne usually sets this to 40000.

6.1 Adjusting Zero Offset

If the zero offset requires adjusting from the factory set calibration, this can be adjusted using the following procedure:

6.1.1 Determining the Updated Offset

6.1.1.1 Method 1 - Using Data Displayed at Zero Flow

- Note the zero reading (Zr) in still water in mm/sec. (And note the display reading is in M/sec.) Great care should be taken to ensure that the water is still.
- From the calibration sheet, note the zero-offset figure (in counts) defined for the unit (Zc1). This figure can also be read from the unit by the **#172<cr>** command (see above).
- Calculate the new zero offset counts, Zc2, from the equation:

  Zc2 = Zc1 - (Zr * (Counts per mm/sec))

  The calibration is approximately 1mm/sec is 1 count, so the equation becomes:

  Zc2 = Zc1 – (Zr * (Counts per mm\sec))

  For example:

Original zero offset in counts,	Zc1	=	- 6.45
Zero reading in still water,	Zr	=	- 0.005 m/sec
		=	- 5 mm/sec
New zero offset in counts,	Zc2	=	- 6.45 – (-5)
		=	- 6.45 + 5
		=	- 1.45 counts

It is important to use the correct signs.

6.1.1.2 Method 2 – Reading Raw Real Time Counts

- Interrupt the unit using the **#<cr>** command detailed above.
- Put the EM unit into NOCAL mode (i.e. to output data in raw counts) by entering **#007** “space” **NOCAL <cr>**. Note that each time the unit is interrupted, it automatically goes back into CAL output mode, so the **#007 NOCAL<cr>** command must be re-entered.
- The output mode can be checked by entering **#030<cr>**, and the unit will respond with CAL or NOCAL as appropriate.
- Make the unit go into RUN mode by entering **#028<cr>**.
- The unit will output data at 2Hz, and with the sensor in still water, the counts for zero flow can be observed. Using the terminal emulation program, the data can be captured as a text file for averaging, etc.

6.1.1.3 Setting the New Zero Offset

The new zero offset is entered by the command

#170 “space” **zero offset<cr>**

in the example above **#170 –1.45<cr>**

and is checked by **#172**

7 Care and Maintenance

While the instrument has been designed for field use, it is not indestructible, and care should be taken not to damage either the sensor, cable, or Control Display Unit.

In principle, the calibration is for life, but—as with most instruments—it is advisable that check calibrations should be carried out on an annual basis.

7.1 Storage

Between uses, the Model 801 and CDU should be stored securely in their transit cases with the CDU batteries removed to prevent the possibility of battery leaks. See section 5.1 for instructions on removing batteries, but do not fit new batteries until the instrument/CDU is taken out of storage.

7.2 Servicing and repair

If your instrument(s) require regular servicing or need to be returned to Teledyne ISCO for repairs, please ensure that you contact iscowatersupport@Teledyne.com, requesting an RMA. Any return without an RMA (which has been issued and accepted by Teledyne ISCO Water) will not be accepted and could be subject to storage charges.

8 Certifications

FCC

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at their own expense.

Canada

Caution: This equipment is not intended for use in residential environments and may not provide adequate protection to radio reception in such environments.