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CUSTOMER SPECIFIC DRAWINGS - FP-

Chapter 1 General System Description

The Accusonic Model 7510+P "Penstock Protection" System is designed for the detection of leaks in penstocks. In its standard configuration, the system consists of two multi-path ultrasonic flowmeters, one at each end of the penstock. One is designated the "Master" usually at the lower end, and the other the "Slave" at the upper end.

A serial digital communication link using modems and either a two-wire cable or pair of fibre-optic cables connects the two flowmeters. This is used to synchronize the flow measurements at the two ends of the penstock, send data from the "Slave" to the "Master" and enable interrogation of the parameters of the "Slave" from the "Master." The system may be configured to provide independent determinations of flow, analog outputs and alarm relays for two separate and dissimilar penstocks, providing the total number of paths shared between the two flowmeter sections at one end of the penstock does not exceed 8.

An alternative configuration for use on single short penstocks (under 300m long) uses only one "Master" electronic unit. This is directly connected by cables to both the upstream and downstream transducers.

The penstock is assumed always to be full, with the flowmeter configured in a "Pipe" mode. The water velocity is determined using the multi-path ultrasonic time-of-flight method. Either the "Gaussian" or "Chebyshev" multi-path integration methods can be implemented by setting the parameters describing path lengths, angles and weighting coefficients in accordance with ASME or IEC codes. The theory and operating principle of these flowmeters is described in Appendix A.

At the "Master" flowmeter, the flows in the pipe sections at the two ends of the penstock are compared, and alarms in the form of relay states are raised if the Master flow or the difference between the Master and Slave flows exceed specified thresholds for longer than specified times. Nine relays are provided for each penstock to indicate: minor Master section fault, Master section failure, Slave section failure, Master flow in excess of 1st threshold, Master flow in excess of 2nd threshold, flow difference in excess of 1st threshold, a minor leak and command to close the butterfly valve. A permanent visual display of the flows in the pipe sections at both ends of the penstock together with alarm conditions is provided on an LCD on the front of the console. Up to four independent isolated 4-20mA analog outputs are provided. These may be differently scaled to output flow or differential flow over any range from reverse to forward for the sections at both ends of the penstock.

At the "Slave" flowmeter, 5 relays are provided for each penstock to indicate: minor Slave section fault, Slave section failure, Slave flow in excess of 1st threshold, Slave flow in excess of 2nd threshold and command to close the butterfly valve. A permanent visual display of the flows in the pipe sections at the Slave end together with alarm conditions is provided on an LCD on the front of the console. Analog outputs of flow at the Slave end are also available.

Detailed displays of flow, velocities and diagnostic data are provided on a separate hand-held terminal, which is connected to a dedicated RS232 port. Under normal operating conditions this terminal is usually not connected. The site parameters are inserted into the flowmeter's non-volatile memory from the terminal, by way of a "user-friendly" menu. The parameters of the Slave may be interrogated from the terminal at the Master. Alternatively, a PC may be used in place of the hand-held terminal. Special software may be installed on the PC to provide a full screen display of the flowmeter's variables, including graphics showing trends from recent data, data to aid commissioning, acoustic signal waveform under "Oscilloscope" mode, and easier to use parameter entry.

Chapter 2 Technical Specifications

Transducers Models 7600.70

ls	7600, 7601and 7605		
	Temperature range:	operating	32° F to 105° F 0°C to 40° C
		storage	0° F to 150° F -18° C to 65° C
	Pressure range:	Model 7600 Special Models	0.5 to 150 bar absolute (2200 psi)
		7601	0.5 to 35 bar absolute (500 psi)
		7605	0.5 to 70 bar absolute (1000 psi)
	Water quality:	pH	3.5 to 10
		Solids loading	0 to 2000 parts/million
		Vapors of Ketones & Esters n	nust not be present
	Characteristic frequer	icy:	1 MHz
	Maximum voltage:		1500 V

Transducer Cable

RG108 Twin axial for lengths up to 300 ft (100m) RG 22 Twin-axial for lengths up to 1500 ft (450m)

Electronic Unit

Power supply:	Electronic unit	90 to 250 or 100 to	0v.a.c. 47 to 6 300 V d.c. v	53 Hz vithout adjustment
Power consumption:	Electronic unit	35 Watts	s, 70 VA MA	X
L L	Heater, a.c. power only	200 Wat	ts, 200 VA M	IAX
Temperature range:	operating	– 15°F to	o 140°F	-25°C to 60°C with heater
		+ 15°F to	o 140°F	-10° C to 60° C without heater
	storage	-20° F to	o 160°F	-30°C to 70°C
Dimensions:		20 x 20 x	x 9 inches	500 x 500 x 230mm
Weight:		54 LB		24.5 kg
Enclosure protection:		NEMA 4	4	IP65
Permanent Data Display		LCD 2	lines x 20 alp	bha-numeric characters
		Characte	er height	9mm
Alarm relays:		Form C of	contacts. 10A	A carrying capacity.
		Switchin	ng capacity: (0.5A, 110vdc, L/R = 40ms
		Isolation	1 2000 Vac	
Analog outputs: (up to 4)		4-20mA,	, Max load 75	50Ω , Isolation 1500Vrms
Safety & Electromagnetic C	ompatibility certification	Safety:	EN61010	
	- •	EMC:	EN61000-6	5-2: 2001, EN61000-6-4: 2001,
			Heavy Indu	strial

Communications Link

Systems using "Telephone" cable.

Full duplex on single pair cable, 120MHz carrier.1.5mW signal, into 120Ω transformer isolated.Recommended Cable typeRG108 Twin axial.Maximum length 2 km

Systems using Fibre Optic cable.

Two separate fibre optic cables, one for each direction. Cable size 62.5/125µm Maximum length 2 km Operating wavelength 850nm. Data rate 19200 baud. Connection is via 15 ft (5m) long pigtails, fitted with ST male connectors.

Hand-held Terminal

Type TT-8045 (Two 7	Technologies	s Inc.)	
Temperature range:	operating	32°F to 120°F	0° C to 50° C
	storage	0°F to 150°F	-18°C to 65°C
Dimensions:		4.1 x 7 x 1 inches	105 x 180 x 25mm
Weight:		0.5 lb.	0.23kg
Enclosure Protection:		Not NEMA rated,	IP41
Power supply:			5Volts d.c. from the 7510 unit, on pin 9 of the connector
RS232 signals:			19200 baud, 8 data bits, No parity, 1 Stop bit
Display			4 Lines x 20 Characters
	Type TT-8045 (Two T Temperature range: Dimensions: Weight: Enclosure Protection: Power supply: RS232 signals: Display	Type TT-8045 (Two Technologies Temperature range: operating storage Dimensions: Weight: Enclosure Protection: Power supply: RS232 signals: Display	Type TT-8045 (Two Technologies Inc.)Temperature range:operating storage32°F to 120°FDimensions:4.1 x 7 x 1 inchesWeight:0.5 lb.Enclosure Protection:Not NEMA rated,Power supply:RS232 signals:Display

Interface Specifications Analog Outputs

These are configured for 4-20mA. At the Master flowmeter, they may be separately allocated to give a linear representation of Master flows, Slave flows or Differential flows. At the Slave, they may only be allocated to output Slave flows. The outputs may be scaled individually to cover any range of flow from reverse, through zero, to forward: it is necessary only to define the extremes of the range (i.e., at 4mA and 20mA). (See parameter list.)

Under fault conditions, the outputs will go to	4.00mA	
Under conditions of under-range, an output will go to	4.00mA	
Under conditions of over-range, an output will go to	20.00mA	
When the flowmeter is taken out of measurement mode t	he output holds	the last value.
Resolution of the outputs:	0.005mA	15 bit
Linearity and stability:	±0.01mA.	0.06% of full scale
Maximum load:	1000 Ω	24 volts
Output isolation:	1500 V rms	Common Mode relative to ground
Output protection:	±50VDC	-

Data Display on Hand-held Terminal

In normal operation, 9 different display screens are available, one for each variable as follows: Signal Gain, Envelope Time, Travel Times, Time Differences, Velocities, Flow, Penstock 1, Penstock 2, and Volume. The first 5 are for diagnostic purposes concerned with the water velocity determinations; Flow and Volume are for observing flow data. All these displays refer to the local flowmeter. The "Penstock" screens show the upstream and downstream flows, differential flow and alarm states. For details of the displays, see the section on Data displays at the end of Chapter 5. For definitions of the variables, see the section on Variables at the end of Chapter 6.

Alarm Relays "Slave" End.

For each penstock 5 relays are provided which are normally in the de-energized state. They are energized when the alarm state occurs, and de-energized again as soon as the alarm state ceases. The sense of this action can be inverted for individual relays if required. Form C contacts are also provided. The relay functions are:

K1.	Minor Section Fault	One or more paths have failed in that section, and flow is computed from the
		remaining good paths. (See Flow Computation Algorithm on page 3-1)
K2.	Section Fail	The flowmeter has been unable to compute flow in that section for a period in
		excess of a specified number of measurement cycles.
K3.	Flow Alarm level 1	The flow has exceeded the specified threshold Q_1 for more than the specified
		number T_1 measurement cycles.
K4	Flow Alarm level 2	The flow has exceeded the specified threshold Q_2 for more than the specified
		number T_2 measurement cycles.
K5.	Butterfly Valve Command	Flow Alarm level 2 is present.

Alarm Relays "Master" End

For each penstock, 9 relays are provided having the same logic as those in the "Slave" meter. The functions are:

K1.	Minor Section Fault	One or more paths have failed in that section, and flow is computed from the remaining good paths. (See Flow Computation Algorithm on page 3-1)
K2.	Section Fail	The flowmeter has been unable to compute flow in that section for a period in excess of a specified number of measurement cycles
K3.	Slave Section Fail	No flow data for that section from the Slave, for a period in excess of a specified number of measurement cycles, either because of a communications link failure or because the flowmater has been unable to compute flow in that
		section.
K4.	Flow Alarm level 1	The flow has exceeded the specified threshold Q_1 for more than the specified number T_1 measurement cycles.
K5.	Flow Alarm level 2	The flow has exceeded the specified threshold Q_2 for more than the specified number T_2 measurement cycles.
K6.	Differential Alarm level 3	The differential flow has exceeded the specified threshold Q_3 for more than the specified number T_3 measurement cycles.
K7.	Differential Alarm level 4	The differential flow has exceeded the specified threshold Q_4 for more than the specified number T_4 measurement cycles.
K8.	Leak Alarm level 5	The long time averaged differential flow has exceeded the specified threshold Ω_5 for more than the specified number T_5 measurement cycles
K9.	Butterfly Valve Command	Flow Alarm level 2 or Differential Alarm level 4 or both are present.

Parameter Insertion and Reading, Hand-held Terminal

Parameters describing the flowmeter configuration are inserted using seven different menus. These are: GLOBAL, SYSTEM, SECTION, PATH, ANALOG OUT, RELAY, SYSTEM STATS For instructions on how to insert the parameters, see Chapter 5. For details of the parameters, see the section on "User Defined Parameters" in Chapter 6.

There are two command menus:

SYSTEM ACTIONS: Under which any of the following three commands may be
STORE PARAMETERS: To store parameters once they have been entered corre
RESTORE PARAMETERS: To recall the parameters from memory.
TRANSMIT PARAMETERS: To transmit the complete parameter list to a data term

Connection of a PC

A PC or other terminal may be connected to the 9 pin RS232 socket marked Hand-held Communication.

RS232 signals:

19200 baud, 8 data bits, No parity, 1 Stop bit,

The connections on the 9 pin D socket are:

Pin 2	Data into the 7510 unit
Pin 3	Data out from the 7510 unit
Pin 3	Common, connected to ground in the 7510 unit
Pin 9	5vdc supply for the Hand-held terminal

The following keys are recognized by the flowmeter.

Numbers 0 through 9, Enter, Esc, -sign, Decimal point, #, Letters U, D, L, R, M, S, T, Z

The Enter key produces the characters CR/LF (^M ^J)

The letters U, D, L, R, are used as cursor controls, \uparrow , \downarrow , \leftarrow , \rightarrow . It is recommended that the key mapping of the communications software in the PC be set to assign these letters to the cursor keys.

A listing of parameters can be sent to the PC using the TRANSMIT PARAMETERS command.

An example of a listing is included at the end of Chapter 5.

Chapter 3 Technical System Description

General

The system is based on a Digital Signal Processor (DSP), which is used for the recognition of the acoustic signals and their timings, as well as for the sequencing of the transducer excitation, automatic gain control of the receiver, water velocity and flow determination, outputting of data, user interface and the command of alarm relays. Special software has been developed to avoid spurious operation of these alarms.

Each acoustic signal is digitized at a rate of 10 million readings per second. From this the software is able to search the received waveform for a signal having the appropriate shape of envelope, determine its amplitude for adjusting the receiver gain, and then to compute the exact time of arrival of the first zero crossing. By this means, true signals can be distinguished from spurious ones, thus reducing the incidence of both false and lost readings.

Flowmeter Configuration for each Conduit

Each Accusonic Model 7510+P Flowmeter may be configured with up to a maximum of eight acoustic paths in one conduit or "Section". Details of the configuration are defined by a set of parameters, the names of which appear in this document in *italics*. Each path is characterized by parameters describing *Length*, *Angle* and *Weight*, which are used for flow computation. Other path parameters are: *Max. Bad Measures, Signal delay* and *Transducer Frequency*

Flow Computation Algorithm

Path transducers are energized and measurements taken for all paths, which are configured. If a path fails to provide a good velocity value, because the signal is not found or the data fail to pass acceptability tests, then the last good velocity value is used for all flow calculations until the number of consecutive failures exceeds the parameter *Max. Bad Measures*. If the number of failures exceeds the parameter value, the path is declared to have failed, and its data are then not used for flow computation. The system continues to sample that path, and if it should recover from the fault condition, its data will be used after a brief delay, which ensures that they are reliable.

The velocity values for each path are averaged using an Infinite Impulse Response (IIR) digital filter, implemented in software. The resulting filtered velocity values are used for the calculation of the "instantaneous" flow. The period of the filter is fixed at 8 seconds.

The cross-section area is a fixed value defined by a single user-defined parameter, *Pipe area*. The other user-defined parameters are: *Flow scaling* and a *Weight* for each path W_n (n is the path number 1 to 8).

The flow = Flow scaling * Pipe area * $\sum W_n * V_n$ where Vn = velocity for path n.

In the event of one or more paths failing, a routine is implemented which enables the Flow to be computed from those paths, which remain good. The contributions towards the total pipe flow from the failed paths is replaced by a figure generated from the flow contribution from the remaining good paths, weighted as appropriate by the historic flow contribution ratios for all the paths. A table of time-averaged historic flow components $(V_n * W_n)$ is recorded during the flowmeter commissioning, involving about 1000 readings, taken at the pipe's normal flow (non-zero!). The record is made automatically by the flowmeter, frozen at the end of the "learning" run and stored in the meter's protected memory.

The "learning" routine is implemented by setting the section parameter *Learn Path Ratios* to 1, and then setting the flowmeter to run. At the end of 1000 readings, the *Learn Path Ratios* parameter will automatically reset to

zero. During the learning run, the letter C is displayed adjacent to the section Flow value. The learning run may be curtailed at any time by manually setting the *Learn Path Ratios* parameter to 0. Repeating the learning process will erase an old table and create a new one.

Mathematically, the routine can be represented as:

Flow = Current Flow from Good Paths * Historic Flow / Historic Flow from current good paths.

Current Flow from Good Paths = Pipe Area $\sum V_n W_n$ in which the velocity from any failed paths is set to zero.

Historic Flow is the long time-averaged flow recorded during flowmeter commissioning.

Historic Flow from current good paths is = Pipe Area \sum Historic V_n . W_n excluding those historic flow components, which apply to the paths, which are currently failed.

This formula applies under all conditions of number of paths, their configuration and the number failed, down to the number set in the parameter *Min Good Paths*. The minimum value of this parameter is one.

Measurement Sequence.

During each measurement cycle, usually about once per second, the Master sends a command to the Slave to make a flow measurement, and then the Master makes its own measurement. The Slave receives the command, makes its measurement, and sends the data to the Master. In this way the measurements at the two ends of the penstock are synchronized. The state of this process is indicated on the hand-held terminal (or PC) by the letters T, W or R on the fourth row, third column of the "Penstock" screen.

At the Master, "T" = Master Transmitting a command, "W" = Waiting for data, "R" = Receiving data. At the Slave, "T" = Slave Transmitting data, "W" = Waiting for a command, "R" = Receiving a command.

In the event of either the Master or the communications link failing, the Slave will make flow measurements in its own slightly slower time, and provide protection for the penstocks in the form of alarms for excessive flow.

Alarm Relay Operation.

To avoid the creation of false alarms, the delay sequences outlined below are employed.

- Following power-up of the unit or recovery of a failed section, a period of 16 measurement cycles elapses before data are presented. This is to allow time for the acoustic signals to be recognized reliably. A further period of 30 seconds must then elapse before any alarm relay is enabled. This is to ensure that the digital filtering of the data has settled, and the flow values at the two ends of the penstock are comparable.
- 2. If an alarm condition is present, it must remain for a number of consecutive measurement cycles (as defined in the Relay parameter list). If this number is exceeded the alarm relay is activated. If at any time before the number is exceeded the alarm condition ceases, the counter of consecutive exceedances is reset to zero. If after an alarm is activated, the alarm condition ceases, the alarm relay is immediately de-activated.
- 3. In the event of a loss of communication exceeding 8 cycles between the Master and Slave (but not a failure of the Slave flowmeter), the counter of any consecutive "Differential flow" or "Leak" exceedances is set to zero. Any Differential flow or Leak alarm relays, which are activated, will be de-activated. As soon as the communications link is re-established, the Differential flow or Leak alarm exceedance counters will be enabled.
- 4. For "Leak" detection, the flow data at both ends of the penstock are first averaged over a long period of time, so that small differential flows can be reliably detected. The averaging is done by Infinite Impulse Response digital filters. The period of the Leak filters is set in the Relay parameter list under *Leak Average* (values between 1 and 8 minutes can be selected).

Chapter 4 Unpacking and Installation

When the system arrives, inspect the packaging for signs of damage. If there is obvious external damage to the shipping container, request that the carrier's agent be present when the unit is unpacked. Be particularly careful not to destroy the shipping container during opening so that it may be used for future shipment of the unit.

Warning

Do not apply power to damaged components. Injury or further damage may occur.

Remove the system from the package and verify all parts against the packing list. Examine each of the components for physical damage. If a component is damaged, notify the carrier and follow the instructions for damage claims. Report any shipping problems immediately to Accusonic.

Physical Installation

Each console should be mounted in a location so the cable run from the transducers to the unit does not exceed 300 feet or 100 meters without the approval of Accusonic. In addition, the unit requires AC power connections for the electronics and heater, as well as connections to the communications link, the alarm relays and the analog outputs.

The instrument should be mounted vertically and should be attached to a wall or mounting panel capable of safely supporting 100 pounds (50kg). Use 3/8-inch (10mm) lag screws or carriage bolts.

Electrical Installation

All wiring is brought into the unit through customer-supplied conduit connectors.

- AC power supply mains. Separate connections for the flowmeter electronics and for the heater.
- Transducer cabling (may require more than one feedthrough)
- Communication cable
- Alarm relay cables
- 4-20mA Analog outputs

Caution

When drilling conduit holes, remove the circuit cards from the unit.

Power Wiring

Power consumption for the electronics is less than 70 VA. Power consumption for the heater is 200 Watts, a.c. only. Use #16 AWG or #14 AWG (1.5 mm² minimum).

The unit requires direct mains wiring and should be installed with a separate main power cutoff switch near the instrument, in compliance with the National Electrical Code (or IEC 60079-14 clauses).

Route power mains wiring into the unit through the appropriate feedthrough to the main terminal block, and connect as shown in Figure 4-1. Be sure to follow appropriate local codes and practices, and to attach a proper earth ground to instrument.

Wiring should be accommodated inside the enclosure so that positive strain relief is present at the connector terminals to avoid excessive stress on the terminal connections.

For d.c. power 100 to 300V d.c. the low potential side of the supply should be connected to the "-" terminal. For optional low voltage d.c. power, observe the correct polarity.

Safety Symbol and Icon Definitions



Caution: Refer to Accompanying Documents



LNG

Caution: Risk of Electric Shock

Transducer Ground / Shield Connection

L = Line (L1), N = Neutral (L2), G = Earth Ground

Earth (Ground) Terminal



Figure 4-1 Location of Power Connection

Transducer Wiring

Pull transducer cabling through the appropriate feedthrough and trim each line, leaving enough cable to reach the transducer terminal blocks at the bottom of the flowmeter console. Tag each cable with a path number and transducer letter according to the Accusonic numbering convention as shown in Figure 4-2. Trim the cables, strip back 2 inches of outer sheathing from each, pull inner conductors back from inside the outer braid, solder spade lugs to the conductor and shield of each cable as shown in Figure 4-3.

Do not connect the cables to the flowmeter yet. Leave the ends of the cables so that the conductors are not in contact with one another or with any metal parts on the flowmeter console.





Figure 4-2 Transducer Numbering - Simple Pipe



Figure 4-3 Stripping and Terminating the Transducer Cable





Figure 4-4A Transducer Wiring Connections - Balanced Cables



PATH-SELECTOR PANEL



Figure 4-4B Transducer Wiring Connections - Unbalanced Cables



Figure 4-5 Communication & Analog Connection

Transducer and Cabling Checkout

There are three steps to verify the transducer cabling and transducers:

- 1. Verify that there is infinite resistance across each transducer.
- 2. Verify that there are no internal shorts in any cable.
- 3. Verify continuity in the cabling.

Step 1 - Verify infinite resistance across each transducer

Measure the resistance across the transducer cable terminals using a Megohmmeter (high voltage ohmmeter) set to the highest resistance range. Each transducer should measure infinite resistance. Contact Accusonic if any transducer measures less than 20 M Ω resistance. Test transducer resistance at the unit, with the cabling detached, if possible. This can usually be performed easily when the transducers are pipe-mounted, where the outside of the pipe is accessible, and when the transducers are fitted with E/O connectors. Use a short test cable attached to an E/O connector. When the transducer is not accessible, or when the cable is permanently attached to the unit, do the best you can. Test the resistance at a wiring junction located as near as possible to the transducers. If it is not possible to detach the cabling back to the flowmeter console, be sure the console ends of the cables are detached from the unit and that they are not accidentally shorted together.

Step 2 - Verify that there are no internal shorts in any cable

With the free ends of all cables detached and isolated, test that the resistance across each cable is infinite. For twin-axial cable, test conductor to conductor, each conductor to shield, each conductor to ground, and shield to ground.

Step 3 - Verify Continuity

Work from either end of the cable and use a partner to connect pairs together, one at a time, at the far end of the cable. For each twin-axial cable, short each connector to shield and measure continuity.

Connecting Transducer Cabling

After verifying that all transducer cabling is sound, connect each line to the appropriate terminal on the flowmeter console, as shown in Figures 4-4A or 4-4B.

Twin Axial Cable (balanced cables)

Connect cables as shown in figure 4-4A. Configure jumpers on Path-Selector Backplane as shown in figure 4-4A.

Coaxial Cable (unbalanced cables)

Connect cables as shown in figure 4-4B Configure jumpers for on Path-Selector Backplane as shown in figure 4-4B.

Connecting the Communications Cable

Systems using "Telephone" cable.

Connect the single pair line to the appropriate terminals on the flowmeter console, as shown in Figure 4-5. The polarity of the connection is not important.

Systems using Fibre Optic cable.

Two separate fibre optic cables are required, one for each direction.

Connection is via 150 ft (46m) long, 62.5/125µm pigtails, fitted with ST male connectors.

The "Data Transmit" signal from the local Model 7510+ P flowmeter uses the red connector.

The "Data Receive" signal to the local Model 7510+ P flowmeter uses the blue connector.

Connecting to the Alarm Relays

Normally Open and Normally Closed contacts of each relay are available on the relay panel terminal strip, as shown in Figures 4-5 and 4-6. All relay contacts are isolated from each other. The function of each relay is shown in Figure 4-6.



Figure 4-6 Relay Configurations

Connecting the 4-20mA Isolated Analog Outputs

Connect to the output terminals on the flowmeter console, as shown in Figure 4-5. If it is desired to have one side of the 4-20mA signals grounded, a jumper is required between the adjacent COM terminal, and the LO side of the output to be grounded.

Connecting the Hand-held Terminal

Plug the 9 pin D plug on the lead from the terminal into the socket marked *Hand-held communication* (Figure 4.5) Connecting and disconnecting the terminal can be done at any time with the flowmeter powered or unpowered.

Connecting a PC

A PC can be connected to the socket marked *Hand-held communication*, and used instead of the hand-held terminal. Note that pin 9 of the 9-pin socket is internally connected to a low impedance 5V dc source.

Chapter 5 Initial Setup, User Operations

This Chapter describes setup and operation of the system via the Hand-held Terminal. (*Note: The instrument will not be damaged by entering incorrect parameters or otherwise manipulating the control panel.*)

Hand-held Terminal, Parameters and Variables

The hand-held terminal, which consists of a display and a keypad, is used to set up the system, start measurements, and observe the measured variables and status messages. Once the system starts taking measurements, it will continue to do so at a rate defined during setup. Flow measurements can be interrupted or halted from the terminal.

Set up the system by entering appropriate values for various parameters. Parameters define the geometry of each meter section and govern the operating modes of the system. All parameters are defined in Chapter 6.

Variables provide a view of measurements when the system is in normal "Measure" mode. At the end of this chapter typical display screens of the variables are shown. Chapter 6 contains definitions of the variables.

Menus

Refer to figure 5-1

After power-up, the system always returns to the "Measurement" mode, with the display screens on the console and on the terminal both showing "Penstock" data. Commands and control parameters are entered into the system using menus shown on the display. To cause the menus to appear, press the **Esc** key. Some menus display the available options, (e.g., "English" or "Metric" units), and you choose between them; in most cases you need to enter data. The next section describes how to access these options.

Stepping through menus

Seven keys are used to navigate through the various menu options and to move through lists of parameters. The keys are the four cursor keys, plus **Enter, Esc** and **Measure.** The shift key is not used. On the hand-held terminal, the cursor keys are:

1	or alternatively letter U on a PC	to move	Up
\downarrow	or alternatively letter D on a PC	to move	Down
←	or alternatively letter \mathbf{L} on a PC	to move	Left
\rightarrow	or alternatively letter R on a PC	to move	Right

The Up, Down, Left & Right keys enable you to select the required menu and to choose among the items within it.

- Pressing \uparrow or **U** displays the previous menu or item in the list
- Pressing \downarrow or **D** displays the next menu or item in the list
- Pressing \leftarrow or L displays the same parameter but for the previous path, or analog output
- Pressing \rightarrow or **R** displays the same parameter but for the next path, or analog output

The cursor keys do not cause a wraparound from top to bottom, or from left to right.

If the Up key is held, the highest menu or the top parameter in the list is selected.

If the **Down** key is held, the lowest menu or the lowest parameter in the list is selected.

If the **Left** key is held, the display to the extreme left, (Gains), or the parameter for section 1 is selected. If the **Right** key is held, the display to the extreme right, (Volume), or the parameter for section 4 is selected. The **Enter** key invokes the currently active selection. For example, if you have stepped through to SECTION PARAMETERS and press Enter, you enter the Section parameter list, at the topmost parameter, Sn PATH ENABLE {1:8}, where the first two characters "Sn" indicate the Section Number. If you type in a new value for a parameter and press enter, the new value is entered. If you have stepped through to MEASURE and press Enter, you command the system to enter "Measure" mode.

The **Esc** key (or Z) steps you out of Measure mode or out of a current list to the top of the menu. It may be pressed from anywhere in the list.

The Measure (or M) key returns the flowmeter to the Measure mode, from the top of any menu.

Pressing Esc and then Measure when in any menu list, returns the flowmeter to the Measure mode. Any changed parameters will be stored in non-volatile memory (provided that the parameter *Parameter Store* in the System menu is set to 1). A message "STORING PARAMETERS" appears briefly on the terminal screen to confirm that the storing has been done.

If the parameter, *Parameter Store*, in the System menu is set to 0, a separate "STORE" command is required to save the parameters to non-volatile memory if this is desired.

If the system is left at the top of any menu, (i.e. the **Esc** key has been pressed), the system will automatically return to the Measure mode and store any changed parameters, after a delay of 30 seconds.

Other key operations

- **Reset** (#) causes a system reset. Loses any changed parameters, and reasserts those in non-volatile memory.
- \leftarrow (L) and \rightarrow (R) keys in "Measure" mode enable you to select alternative display screens.
- **Display** or **T** while viewing Variables stops the updating of the terminal display. Press again to restore updating. This feature omits screen data from appearing on the RS232 output.
- **Pause** (**P**) in "Measure" mode causes the flowmeter to "pause." This enables the user to compare data such as travel times, difference times and velocities, which have been computed from the same measurement cycle. The system automatically returns to the Measure mode after 60 cycles or if **Pause** is pressed again.

The Menus and Commands are:	
GLOBAL PARAMETERS:	One list of parameters designating the meter as Master or Slave.
SYSTEM PARAMETERS:	One list of basic system parameters defining flow computation.
SECTION PARAMETERS:	Two parallel lists, one for each section at the end monitored by the meter.
PATH PARAMETERS:	Eight parallel lists, one for each path.
ANALOG OUT PAR's:	Four parallel lists, one for each analog output.
RELAY PARAMETERS:	Two parallel lists of alarm thresholds, one for each section.
MEASURE:	A "Command" to put the system into the normal "Measure" mode.
SYSTEM ACTIONS:	
STORE PARAMETERS:	To store parameters to non-volatile memory.
RESTORE PARAMETERS:	To recall the parameters from non-volatile memory. (i.e. lose non-stored ones)
TRANSMIT PARAMETERS:	To transmit the complete parameter list to a data terminal.
SYSTEM STATS:	Data on the software revision, for information only.
	Facility to set data baud rate for communications link and to set the real-time
	clock.



Figure 5-1 7510 Plus Penstock Protections General Menu

Parameter Data Entry in the Local Flowmeter

All parameters are entered using the same method. If the current value of the displayed parameter is correct, then step on to the next (either down or to the right, as desired).

The keys on the terminal used for data are:

Numbers 0 through 9, \uparrow , \downarrow , \leftarrow , \rightarrow , (U, D, L, R,) – sign (F), decimal point (x)

An example of the method of data entry follows, starting from the normal "Measure" mode, when it is desired to access the SECTION PARAMETER menu:

Action	Terminal display shows	Comments
Press Esc	The menu last used	Measurements cease.
Press \uparrow or \downarrow (U or D) un	til you get:	
	SECTION PARAMETERS	Step up or down past other lists.
	SLAVE -> LOCAL	You have access to the Local flowmeter.
	01 - 19 - 96	Date. Month - Day - Year
	15: 25: 48 **	Time. Hrs: Mins: Secs $** = 24$ hr clock
Press Enter	SECTION PARAMETERS	
	S1 PATH ENABLE {1:8}	First parameter in Section 1 (Local).
	CUR = 00000000	Current value, no path enabled.
	ENT =	Place to enter a new value.
Press 11 Enter	SECTION PARAMETERS	
	S1 PATH ENABLE {1:8}	First parameter in Section 1.
	CUR = 11	Current value, paths 1 & 2 enabled.
	ENT = 11	The new value.
Press↓ twice	SECTION PARAMETERS	
	S1 PIPE AREA	Fourth parameter in Section 1.
	CUR = 25.732	Current value.
	ENT =	Place to enter a new value.

If you return to look at the Path Enable parameter of section 1, the display will be:

	SECTION PARAMETERS S1 PATH ENABLE {1:8} CUR = 11000000 ENT =	First parameter in Section 1. Current value, paths 1 & 2 enabled. Place to enter a new value.
To return to the "Measure" mode: Press Esc then Measure	FLOW 1 47.54 1 SECT 2 SECTION FAIL	Flow in Section 1. Flow in Section 2, No good data.
	2 W	Path being read, Wait state.

Parameter Data Entry in the Slave Flowmeter from the Master End

To access the parameters in the Slave flowmeter, its parameters are first copied via the communications link to a block of memory in the Master flowmeter. All parameters are entered or amended using the same method as for the Local Flowmeter. Once they have been updated, and the **Esc** key pressed, the amended parameters are then transmitted back to the Slave flowmeter via the communications link. An example of the method of data entry follows, starting from the normal "Measure" mode:

Action	Terminal display shows	Comments
Press Esc	The menu last used	Measurements cease at Master.
Press \uparrow (or U) until you see	GLOBAL PARAMETERS	Step up to top list
× , , ,	MASTER -> LOCAL	Now you have access to Local meter
	01 - 19 - 96	Date. Month - Day - Year
	15: 25: 48 **	Time. Hrs: Mins: Secs ** = 24 hr clock
Press Enter	GLOBAL PARAMETERS	
	LOCAL / REMOTE 0 / 1	First parameter in Global menu
(CUR = 0	Current value, Terminal accesses local
E	ENT =	Place to enter a new value.
Press 1 Enter	GLOBAL PARAMETERS	
	LOCAL / REMOTE 0 / 1	First parameter in Global menu
(CUR = 1	New value, Terminal accesses remote
E	ENT = 1	Place to enter a new value.
Press Esc	GLOBAL PARAMETERS	
	MASTER -> REMOTE	You have access to Remote meter (Slave)
	01 - 19 - 96	Date. Month - Day - Year
	15: 25: 48 **	Time. Hrs: Mins: Secs ** = 24 hr clock
You may now access the other me for the Local parameter access	enus of the Slave flowmeter by J	pressing \downarrow (or D) keys, in the same manner as
	SYSTEM PARAMETERS	You have stepped down to System menu.
	MASTER -> REMOTE	You have access to Slave meter
	01 - 19 - 96	Date. Month - Day - Year
	15: 25: 49 **	Time. Hrs: Mins: Secs $** = 24$ hr clock
When you press Enter , messages sending its data. When the data ar	"T" and "W" appear briefly on	the screen indicating that the Slave flowmeter is
senteng its data. When the data at	SYSTEM PARAMETERS	First parameter in Slave System menu

SYSTEM PARAMETERS
FLOW SCALINGFirst parameter in Slave System men
Current valueCUR = 1.0000Place to enter a new value.ENT =Place to enter a new value.

If the data have not been received, the screen will not change. If a data transfer does occur, the Slave flowmeter will stop measuring. It will return to Measure mode either when the Master is returned to Measure, or automatically after a delay of 2 minutes. This will not affect parameter entry. You may now change parameters as required and exit the routine in the same way as for the "Local" flowmeter. The Master flowmeter will always return to the "MASTER –> LOCAL" state when you return to Measure mode.

Typical Parameter List

** GLOBAL PARAMETERS **

LOCAL/REMOTE 0/1 MASTER/SLAVE 0/1 SYSTEM ADDRESS MESSAGE MODE STAND ALONE	0 0 1 0 0	The terminal reads data from this flowmeter This flowmeter is a "Master" Factory setting, not changeable. Normal operation. Not in message mode Normal configuration with two electronic units.
** SYSTEM PARAMETERS **		One list for the whole flowmeter.
FLOW SCALING VOLUME SCALING NUMBER of ACCUM's REPETITION TIME ENGLISH / METRIC 0/1 SYSTEM CLOCK MHz ANALOG OUT SCALING DATA LOGGING PARAMETER STORE	$ \begin{array}{r} 1.0000\\ 1000\\ 4\\ 1.0000\\ 0\\ 10.000\\ 0.5000\\ 0\\ 1\end{array} $	Not sending data. Always store changed parameters in non-volatile memory
** SECTION PARAMETERS ** ** SECTION 1 **		Separate list for each section.
S PATH ENABLE {1: 8} S ANALOG OUT ENABLE S PIPE AREA S MIN GOOD PATHS S VOLUME INIT VALUE S LEARN PATH RATIOS	11000000 1100 42.00 1 0 0	Paths 1 & 2 enabled for this section.
** PATH PARAMETERS ** ** PATH 1 **		Separate list for each Path.
PLENGTHPANGLEdg'sPWEIGHTusPSIGNAL DELAYusPMAX BAD MEASURESPFREQUENCYkHz	$\begin{array}{c} 12.000 \\ 45.000 \\ 0.5000 \\ 12.000 \\ 20 \\ 1000.00 \end{array}$	
** ANALOG OUTPUT PARAMETERS ** ANALOG OUT 1 **	**	Separate list for each output.
A LQ/RQ/DQ 0/1/2 A 4mA OUTPUT A 20mA OUTPUT A OVERIDE OUTPUT ? A MAN OUTPUT VALUE A 4mA FINE ADJUST A 20mA FINE ADJUST	$\begin{array}{c} 0 \\ 0.0000 \\ 1000.0 \\ 0 \\ 0.0000 \\ 10892 \\ 54546 \end{array}$	Output is of Flow for the Local end. 4mA for zero flow. 20mA for 1000 units of flow.

** RELAY PARAMETERS **

S	FLOW THRESHOLD Q1	25.000	
S	FLOW THRESHOLD Q2	27.000	
S	DIFF THRESHOLD Q3	1.500	
S	DIFF THRESHOLD Q4	2.500	
S	LEAK THRESHOLD Q5	0.500	
S	FLOW DELAY T1	7	
S	FLOW DELAY T2	10	
S	DIFF DELAY T3	7	
S	DIFF DELAY T4	10	
S	LEAK DELAY T5	50	
S	LEAK AVE 0 - 8 MINS	4	
S	LOCAL Q AUTO / MAN	0	Normal mode. Actual flows used.
S	LOCAL Q MANUAL	27.100	
S	REMOTE Q AUTO / MAN	1	The manually entered figure is used.
S	REMOTE Q MANUAL	25.500	
S	RELAY SENSE {1:8}	00000000	All relays normally de-energized.

** SYSTEM STATS **

SOFTWARE VERSION		95112001	
SP BAUD RATE $\{2:7\}$		19200	Normal value, can be changed
DATA BITS	*	8	
STOP BITS	*	1	
PARITY	*	0	
485/232 SEL 0 / 1	*	1	
YEAR		97	
MONTH		04	
DATE		03	
DAY $(SUN = 0)$		4	
AM / PM 0/1		0	
24 /12 HOUR CLOCK	0/1	0	
HOUR		14	
MINUTE		28	
SECOND		56	

Permanent Display of Variables on the Built-in LCD

For both ends of the penstock, the display is:

7
() () () ()
$\bigcirc \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc$

Figure 5-2 Penstock Display

Note: If no flowmeters are configured in one penstock (no paths enabled), the display for that penstock is blank. At the Slave flowmeter, the displays for Downstream Flows are blank.

Display of Alarm States

The failure of any section is indicated by the word FAIL in the display position for that flow. The Alarm codes refer to the relay states at the local flowmeter. The meanings of each of the four bits of the code from left to right are:

Minor Section Fault Alarm Relay # 1	Flow Alarms Relays # 4 & 5	Differential Flow Alarms Relays # 6 & 7	Leak Alarm Relay # 8
0 = All paths good	0 = No alarm	0 = No alarm	0 = No alarm
1 = One or more paths failed	l = Flow > Ql 2 = Flow > Q2	1 = Diff Flow > Q3 2 = Diff Flow > Q4	1 = Leak > Q5
	2 = Flow > Q2 3 = Flow > Q1 & Q2	2 = Diff Flow > Q4 3 = Diff Flow > Q3 & Q4	

Display of Variables on a Terminal

Variables are displayed only when the flowmeter is in "Measure" mode. Immediately after power up, the flowmeter will enter the "Measure" mode and will display the "Penstock" screen for penstock # 1.

The format for the "Penstock" screens is:

FLOW (the variable)	S (Slave)	Instantaneous Slave flow	Averaged Slave flow
I , A (instantaneous, average)	M (Master)	Instantaneous Master	Averaged Master flow
		flow	
P 1 (Penstock # 1)	S - M (Slave- Master)	Differential flow	Leak flow
Path being read, Com link status	RY (Relays)	Relay states for 8 relays	Cycle counter 0 to 9999

The characters in **Bold** indicate the variable, the end of the penstock (Master or Slave), and the Penstock number. The bottom line shows the individual relay states for relays #1 to #8. (#1 is Minor Fault, #8 is Leak alarm): 0 = relay de-energized. 1 = relay energized

The cycle counter is a number which increments for every measurement cycle. Its use is for checking relay delay times.

All the other display screens for the Variables except "Penstock" have the following general format.

Variable being displayed	Path or Section #	Data for path # 1 or Section # 1
Units of the Variable	Path or Section #	Data for path # 2 or Section # 2
Note on which column of data is which	Path #	Data for path # 3
Path being read, Com link status	Path #	Data for path # 4

When displaying variables concerning Path data (GAIN, TENV, TRAV, DELT, VEL), the \uparrow and \downarrow cursor keys enable the screens for the higher numbered paths (5 through 8) to be displayed.

Examples of typical screens from left (Gain) to right (Volume) are:

GAIN dB-% S/NdB n W	1 2 3 4	10 40	97 53	38 12	Path 1 Amplifier gain in dB, signal in % of max. signal / noise in dB Path 2 Amplifier gain in dB, signal in % of max. signal / noise in dB Indication of units of display. Blanks indicate Paths 3 & 4 not enabled. Changing number "n" indicates which paths are operating, letter "W" indicates that the system is waiting for data from Slave.
TENV us F_R n W	1 2 3 4	1087 SIG NF		1089	Envelope times for path 1 in μ s. Indication of units of display μ s, and envelope times for path 2. Indicates that first value is Forward time, second is Reverse time. blanks indicate paths 3 & 4 are not enabled.
TRAV us F_R n W	1 2 3 4	1079 SIG NF		1081	Signal travel time through water for path 1. Signal Not Found. Path failed. As for TENV. As for TENV.
DELT ns I_A n W	1 2 3 4	2107 SIG NF		2215	Travel time difference for path 1, in nano seconds. Signal Not Found. Path failed Indicates first value is instantaneous, second value is averaged for 8 secs As for TENV
VEL n W	1 2 3 4	10.006 SIG NF		1450	Water velocity on Path 1, Velocity of sound in water, Path 1. Signal Not Found. Path failed Path 3 not enabled Path 4 not enabled
FLOW SECT	1 2	25.234 16.750	S		Flow in section 1, one or more paths failed. Flow in section 2 (Its paths are in group 5 to 8)

n W

PENSTOCK SCREENS

FLOWS25.58325.510FLOWM25.23425.500P1(S-R)0.34900.0100nWRY100100002345	Slave end of penstock 1,	Instantaneous flow,	Time averaged flow.
	Master end of penstock 1,	Instantaneous flow,	Time averaged flow.
	Indicates Penstock number 1,	Differential flow,	Leak flow
	Path being read, Wait state,	Relay states, counter	with range 0 to 9999
FLOWS16.71916.850FLOWM16.75016.825P1(S-R)-0.031-0.025nWRY000000002345	Slave end of penstock 2,	Instantaneous flow,	Time averaged flow.
	Master end of penstock 2,	Instantaneous flow,	Time averaged flow.
	Indicates Penstock number 2,	Differential flow,	Leak flow
	Path being read, Wait state,	Relay states, counter	with range 0 to 9999
VOL 1 67854 SECT 2 3786	Volume for section 1 Volume for section 2 Path being read. Communi	cations link in Wait state	

Data Logging Format on RS232 Port

Data are output each measurement cycle, when Data Logging is enabled. See System Parameter Menu.

RS232 signals 19200 baud, 8 data bits, no parity, 1 stop bit, no handshaking protocol.

Typical data string for a dual penstock system, with Terminal Display OFF (F1 pressed).

LDF125234#LDF216750#LDR125583#LDR216719#LDA125500#LDA216825#LDH125510#LDH216850# LDM110#LDM2–25#LDV110006#LDV20#LDV59756#LDV69542#LDG110# LDG240 #LDG524#2DG628# LDB197#LDB25#LDB599#LDB6105

LDF125234#	Log Data	Flow,	Local Section 1	=	25.234	
LDF216750#	Log Data	Flow,	Local Section 2	=	16.750	
LDR125583#	Log Data	Flow,	Remote Section 1	=	25.583	
LDR216719#	Log Data	Flow,	Remote Section 2	=	16.719	
LDA125500#	Log Data	Average Flow,	Local Section 1	=	25.500	
LDA216825#	Log Data	Average Flow,	Local Section 2	=	16.825	
LDH125510#	Log Data	Average Flow,	Remote Section 1	=	25.510	
LDH216850#	Log Data	Average Flow,	Remote Section 2	=	16.850	
LDM110#	Log Data	Leak Flow,	Penstock 1	=	0.010	
LDM2-25#	Log Data	Leak Flow,	Penstock 2	=	-0.025	
LDV110006#	Log Data	Velocity	Path 1	=	10.006	
LDV20#	Log Data	Velocity	Path 2	=	Failed	
LDV59756#	Log Data	Velocity	Path 5	=	9.756	
LDV69542#	Log Data	Velocity	Path 6	=	9.542	
LDG110#	Log Data	Gain in dB	Path 1	=	10	
LDG240#	Log Data	Gain in dB	Path 2	=	40	Path failed
LDG524#	Log Data	Gain in dB	Path 5	=	24	
2DG628#	Log Data	Gain in dB	Path 6	=	28	
LDB197#	Log Data	Gain in %	Path 1	=	97	
LDB25#	Log Data	Gain in %	Path 2	=	5	No signal
LDB599#	Log Data	Gain in %	Path 5	=	99	-
LDB6105#	Log Data	Gain in %	Path 6	=	105	
	-					

Notes:

- 1. Data for sections or paths, which are not enabled, are omitted from the log data string.
- 2. The log from a Slave Flowmeter has the same format, except that all data for a "Remote" flowmeter and for "Leak" are given zero values.
- 3. If the terminal display is left on, extra characters are inserted in between logs. The extra characters are those that are changed on the screen, therefore, the format is not fixed.

Chapter 6 User Defined Parameters

Global Parameters

These parameters define whether this flowmeter is a "Master" or a "Slave," and to which flowmeter the hand-held terminal is communicating. Alternatively, whether the system is configured as a "Stand-alone."

LOCAL / REMOTE 0/1	Applicable only to a Master Flowmeter. Determines whether the Hand-held terminal or PC is accessing parameters from this (the local) flowmeter or via the communications link from the Remote Slave. Set to 0 to access parameters from the Master. Set to 1 access parameters from the Remote Slave. Flowmeter automatically reverts to "Local" when it returns to Measure mode.
MASTER / SLAVE 0/1	Selects whether this flowmeter is a Master or a Slave. Set to 0 to configure it as a "Master". Set to 1 to configure it as a "Slave".
SYSTEM ADDRESS *	A fixed value for the communications, not changeable. Set to 1 at the factory.
MESSAGE MODE	Enables simple messages to be typed in to the terminal at one meter and appear on the terminal screen at the other meter. This is an aid to commissioning. Set to 0 for normal operation. Set to 1 to enable this facility. Automatically reverts to 0 when the system returns to Measure mode.
STAND ALONE	Selects whether the system is configured using only one electronic unit.

Set to 0 for normal operation. Set to 1 for "Stand-alone" configuration.

System Parameters

These parameters define the overall configuration of the flowmeter:

FLOW SCALING	The flowmeter calcu parameter below. If alternative units, the This scaled flow is o For English units	culates flow in either English or Metric units defined by If English is chosen, flow will be in ft^3/s ; if Metric, in n is value for Flow may be multiplied by <i>FLOW SCALIN</i> output to the display, the analog outputs and the RS232 Flow in ft^3/s : set to 1.0 Flow in Millions of gallons/day: (MGD) set to 0.0		
	For Metric units	Flow in m ³ /s		set to 1.0
		Flow in Mega litres/day (MLD)		set to 86.4
		Flow in m ³ / hour	-	set to 3600
VOLUME SCALING	Sets the scaling of th	the totalized flow.		
	For English units,	Flow in ft ³ /s:	Volume in 1000 ft ³	set to 1000
	-	Flow in ft ³ /s:	Acre feet	set to 43560
		Flow in MGD:	Million gals	set to 86400
	For Metric units	Flow in m^3/s :	1000m^3	set to 1000
		Flow in MLD:	Mega litres	set to 86400
		Flow in m ³ / hour:	1000m3	set to 3600000

User Defined Parameters	
NUMBER OF ACCUM's	Number of accumulations of signal waveform for each velocity measurement. Range: 1 to 16. This facility can be useful for increasing the signal: noise ratio. In high velocity applications, (>10 ft/s, 3m/s), set to 1.
REPETITION TIME	The time interval in seconds between measurements. For normal operation set to 1.0. Useful range 0 to 8.0.
ENGLISH / METRIC	Selects the units of length used by the flowmeter. For English units, (feet) set to 0. For metric units, (metres) set to 1.
SYSTEM CLOCK MHz	Sets the sampling rate of the digitizer. Normally set to 10.0. On flowmeters configured at the factory for long paths (>50ft) set to 5.00.
ANALOG OUT SCALING	A factory-set parameter, to suit the 4-20mA output device. Normally set to 0.25.
DATA LOGGING	Selects whether or not to output data to the RS232 port. To select the outputting, set to 1, otherwise set to 0.
AUTO STORE PARAMETER	Set to 1 normally, so that changed parameters are stored in non-volatile memory whenever the system is returned to the Measure mode. If set to 0, changed parameters are used by the system but not stored. The changed parameters will be lost and the old ones asserted if the # key is pressed, or if there is a temporary loss of power.

Section Parameters

These parameters describe each conduit and the method of flow computation. For "dual" flowmeters, two complete lists are required. All lengths are limited to five figures. For "Stand-alone" systems, Section 1 is allocated to the downstream end, and Section 2 to the upstream end.

PATH ENABLE {1:8}	For each section, an 8 bit binary number has to be defined. e.g., For path 3 to be used, the number is set to 00100000. For paths 1,2,3,4 to be used, set to 1110000. When entering the value, the zeros after the last selected path need not be entered. If no paths are enabled, the section is not enabled.
ANALOG OUT ENABLE	For each section, a 4 bit binary number has to be defined. e.g., For Analog Outputs 1 & 2 to be used for this section, the number is set to 1100.
PIPE AREA	The cross-section area of the conduit in ft^2 or m^2 .
MIN GOOD PATHS	The minimum number of good paths, which must be present to calculate flow in pipe mode. The contribution to the Flow from any failed paths will be provided by the replacement routine.
VOLUME INIT VALUE	The current value of the Totalized Flow or Volume. This value may be reset to any value as required, Range 0 to 999 999
LEARN PATH RATIOS	If set to 1, a new path ratio table will be created automatically. The parameter will reset to 0, and the table will be frozen after 1000 readings.

Path Parameters

The paths are numbered in sequence, 1 through 8, any of which can be allocated to any section. The individual paths are each described by:

LENGTH	The length between the transducer faces which are in contact with the water. Standard range: 1.0 to 50.ft. or 0.3 to 15m. Extended range 100ft or 30m.		
ANGLE dg's	The angle in degrees between the acoustic path and the centerline of the conduit. Range of values: 10.00° to 80.00°.		
WEIGHT	The weighting constant for the path. R For a multipath pipe, the sum of all the For 2-path Chebyshev integration: set For 4-path Chebyshev integration: set For 8 path Chebyshev integration: set	ange: 0.000 to 1.000 weights should be equal Both Paths: Outer Paths (1 & 4): Inner Paths (2 & 3): Outer Paths: Inner Paths:	to near unity. 0.5000 0.1382 0.3618 0.0691 0.1809
SIG DELAY μs	The part of the signal travel time in μ s, total cable delay, and the signal travel ti either end of the path. Range: 0 to 20 μ For Model 7617 or 7656 transducers, see For Model 7600, 7601, 7630, 7634, 761 For model 7605 and 7625 transducers, s	which is due to the elect me through the two tran us et to 12µs. 6 transducers, set to 8µs set to 18µs.	cronic circuits, the asducer windows at s.
MAX BAD MEASURES	The maximum number of consecutive measurement cycles in which no valid value of velocity on a particular path is obtained. If this value is not exceeded, the last good velocity value from that path is used for the Flow computation. If this value is exceeded, the path is declared to have failed, and its data are then not used for Flow computation, unless and until new valid data are obtained. Range: 1 to 100. Usually set to: 10.		
FREQUENCY kHz	The characteristic frequency of the trans	sducers. Usually 1000k	Hz.

Analog Output Parameters

Any number up to four analog outputs can be allocated to a section. The variable to be output and the scaling for each individual analog output are defined by the following parameters.

LQ / RQ / DQ 0/1/2	Selects the variable to be represented by the analog output. Set to 0 to output the flow for the section at this end of the penstock (Local). Set to 1 to output flow for the section at the Remote Slave end of the penstock. Set to 2 to output the differential flow between the ends of the penstock.
4mA OUTPUT	The value of the flow, in the units specified, for which an output of 4.00mA is required.
20mA OUTPUT	The value of the flow in the units specified, for which an output of 20.00mA is required.

OVERRIDE OUTPUT ?	Selects whether the output is to be derived from the variable or from a mentered fixed value. Normally only used during system commissioning. To select the chosen Variable set to 0 To select the manually entered <i>MAN OUTPUT VALUE</i> : set to 1	
MAN OUTPUT VALUE	The manual figure, in the scaled units used by the flowmeter	er.
4 mA FINE ADJUST	The binary value sent to the digital-to-analog converter that This typically is used to adjust the "zero" or 4 mA output.	t represents 4.00 mA. Nominal value 10,922.
20 mA FINE ADJUST	The binary value sent to the digital-to-analog converter that represents 20.00 mA This typically is used to adjust the "span" or 20 mA output. Nominal value 54,6	

Relay Parameters

These parameters set the alarm levels for each relay. For "dual" flowmeters, two complete lists are required. All flow and differential flow figures are in the same units as are displayed on the terminal and LCD.

FLOW THRESHOLD Q1	The flow at or above which alarm relay #4 will eventually operate. The relay will operate if the flow remains in this state for a number of consecutive measurement cycles in excess of the value set in the parameter <i>Flow Delay T1</i> .
FLOW THRESHOLD Q2	The flow at or above which alarm relay #5 will eventually operate.
DIFF THRESHOLD Q3	The differential flow at or above which alarm relay #6 will eventually operate.
DIFF THRESHOLD Q4	The differential flow at or above which alarm relay #7 will eventually operate.
<i>LEAK THRESHOLD Q5</i> NOTE. For all differential	The differential averaged flow at or above which alarm relay # 8 will operate. alarms, the sign of the difference is ignored; only the magnitude is considered.
FLOW DELAY TI	The number of consecutive flow measurement cycles for which flow must exceed <i>Flow Threshold Q1</i> before relay #4 operates.
FLOW DELAY T2	The number of consecutive flow measurement cycles for which flow must exceed <i>Flow Threshold Q2</i> before relay #5 operates.
DIFF DELAY T3	The number of consecutive flow measurement cycles for which differential flow must exceed <i>Diff Threshold Q3</i> before relay #6 operates.
DIFF DELAY T4	The number of consecutive flow measurement cycles for which differential flow must exceed <i>Diff Threshold Q4</i> before relay #7 operates.
LEAK DELAY T5	The number of consecutive flow measurement cycles for which time averaged differential flow must exceed the <i>Leak Threshold Q5</i> before relay #8 operates.
LEAK AVE 0-8 MINS	The averaging time in minutes for the determination of leaks.
LOCAL Q AUTO / MAN	Selects whether the flow value for this flowmeter is to be derived automatically from measurements by the acoustic paths or from a manually entered fixed value. Set to 0 for automatically determined flows. The usual setting except for testing. Set to 1 for a manually entered value defined by the parameter <i>Local Q Manual</i> .

LOCAL Q MANUAL	The manually entered value for flow for this flowmeter, used for test purposes.
<i>REMOTE Q AUTO / MAN</i>	Used by a "Master" meter only. Selects whether the flow value attributed to the "Slave" flowmeter is to be derived automatically from the "Slave" meter via the communications link, or from a fixed value manually entered at this meter. Set to 0 for automatically determined flows received via the communications link. Set to 1 for a manually entered value defined by the parameter <i>Remote Q Manual</i> .
REMOTE Q MANUAL	The manually entered value for flow for the remote "Slave" flowmeter.
RELAY SENSE {1:8}	An 8 bit binary number defining the logical sense of each relay numbered 1 to 8. 0 = relay normally de-energized, $1 =$ relay normally energized

System Stats This list contains general information on the system, as well as facilities for altering the communications link baud rate and the clock date and time.

SOFTWARE VERSION	A serial number defining the version of the software (for information only)		
SP1 BAUD RATE (2:7)	User selectable baud rate of the communication ports (Com 1,2,and 3)Set to2for1200 baudSet to3for2400 baudSet to4for4800 baudSet to5for9600 baudSet to6for19200 baudSet to7for38400 baud		
DATA BITS *	Character length. Fixed value of 8.		
STOP BITS *	Fixed value of 1.		
PARITY *	Fixed value. No parity.		
485/232 SEL 0 / 1 *	Defines whether RS485 or RS232 signals are used for the communications link modem. Fixed value. Set to 1 for RS232.		
YEAR	Calendar year. For the year 2000 set to 00.		
MONTH	Calendar month.		
DATE	Calendar date.		
DAY (SUN = 0)	Day of the week.		
AM / PM 0 / 1	Defines period of day if 12-hour clock is used.		
24 / 12 HOUR CLK 0 /1	Defines whether 24 or 12-hour clock is used.		
HOUR	Time.		
MINUTE	Time.		

SECOND Time.

Variables

All variables are available to be displayed on the screen of the hand-held terminal, as live data with the flowmeter operating in the "Measure" mode. A separate screen has to be selected for each type of variable. The variables are:

GAIN	The value of the Receiver gain, nominally in dB units. Maximum value 40 equal to: $20 \times \log_{10}$ [Ratio of signal voltage at A/D converter: Transducer output] 0dB indicates a signal level of 1 Volt peak to peak at the transducer terminals of the unit. The second figure is the amplitude of the latest instantaneous signal, after amplification, expressed as a % of full signal at the detector. The third figure is the Signal / Noise ratio expressed in dB. Maximum value 40, indicating no significant noise. A figure less than 20 indicates that noise is present, and that operation of the flowmeter may be impaired.	
TENV	The travel times of the overall signal envelopes (used for diagnostic purposes).	
TRAV	The signal travel times in micro seconds (μ s), Forward and Reverse. The values are the total times less the Signal Delays and are used for the computation of water velocity.	
DELT	The time difference, in nano seconds (ns), between the forward and reverse signal travel times. A negative figure indicates reverse flow. The first figure is the latest instantaneous value; the second is an 8 second filtered average.	
VEL	The first figure is the value of the individual measured water velocity for the path in feet/second or metres/second. A negative figure indicates reverse flow. The second figure is the velocity of sound in water for the path. If the path fails or is out of the water, the message <i>SIG NF</i> (Signal Not Found) is displayed.	
FLOW	 The value of the water flow, scaled in the required units. If the parameter <i>Flow Scaling</i> is set to 1, the units will be cubic ft/s or cubic metres/s. The letters S or C following the flow value indicate warnings: S Indicates that one or more paths have failed, and that flow is being computed from the remaining good paths. C Indicates that the flowmeter is in the <i>Learn Path Ratios</i> mode. Under fault conditions, a message is substituted for the flow value. SECTION FAIL Indicates that there are too few good paths to compute flow 	
VOL	Scaling parameter. These values can be individually set or reset from the Section menus. The maximum displayed value is 999 999, after which the display goes to zero and restarts.	

Appendix A:

Multipath Flowmeter Systems Theory and Operating Principle

MULTIPATH FLOWMETER SYSTEMS THEORY AND OPERATING PRINCIPLE







Description

Accusonic flowmeters utilize the multiple parallel path transit time flwo measurement technique which is designed for accurate flow measurement (±0.5% of actual flowrate) in large pipes and open channels. The systems can be configured to measure flow in fully surcharged pipes and conduits, pipes and conduits ranging from partially full to surcharged (compound configuration), and open channels. Depending upon accuracy requirements, the flowmeters can be set up to operate 1-8 acoustic paths with cross path (cross flow) correctionh available on flowmeters with 2 or more paths.

A single console can be used to handle flow measurements in multiple pipes.





2. For open channels and partially full pipes:

When more than one path is submerged

$$Q = [A_{Bottom}, V_{A^*}(1 + F_{Bottom}) / 2] + [\sum_{i,i+1} (V_i + V_{i+1}) / 2]$$

$$i = 1$$

+ $[A_{Top^*}(V_n + W_{Top^*}V_{Surface}) / 1 + W_{Top}]$

Where: А

= Flowrate 0

= Cross sectional area (determined as a function of depth and channel/pipe dimention)

= Velocity of lowest path of lowest pair of crossed

V, paths

- FBottom = FBottom friction coefficient
 - = FVelocity of the i path or pair of crossed paths = FWeight for the surface velocity to correct for friction
- Ŵ_{т₀р} at the surface = FSurface velocity extrapolated from the top two
- V_{Surface} measured path velocities

For pipes and channels where only one path is submerged:

Q = V * C * A

Where:

- = 🗖 (depth)
- С = A correction factor to correct velocity measured as a function of the path height to depth. The correction factor is based on USGS developed velocity/depth relationships.

In cases where there is a very short (less than 5 x width or diameter) straight channel or pipe run upstream of the meter section, it is likely that the direction of flow will not be parallel to the centerline. If this is the case, a second "crossed path" at each elevation will be required to eliminate the cross-flow error (Figure 5).

3. For pipes and conduits that range from partially full to surcharged:

For compound applications, Accusonic meters are designed to automatically change mode of operation from open channel to full pipe as the conduit surcharges. The method of flow calculation used is as appropriate for the depth, number of paths submerged and path locations

From the above, it can be seen that to calibrate or set up an acoustic flowmeter, all that is required is to measure the distance between the transducers, the angle of the transducers with respect to the centerline of the pipe or channel, and the physical dimensions of the pipe or channel. The multiple parallel path acoustic method is an absolute flow measurement method that does not require calibration by comparision to another flow measurement method.

System Accuracy/ Measurement Uncertainty

For pipeline flow measurement using a 4-path flowmeter, the accuracy of the rate indication and totalization of flow is specified to be plus or minus 0.5 percent of actual flow for all flows with velocity above 1 foot per second and up to maximum flow, provided the flowmeter is installed according to Accusonic specifications in a section of pipe with a minimum of ten diameters of upstream straight pipe. For installations having between four and ten diameters of straight pipe upstream of the meter section, four crossed paths (eight paths total) are required to maintain an accuracy of plus or minus 0.5 percent of flowrate.

To assure the specified accuracy, the flowmeter integrates the four velocities for each measurement plane (one for four path, two for four crossed paths) to calculate flowrate. Where crossed paths are used, the flowmeter software is designed to utilize velocity information from each plane of transducers to quantify and correct for crossflow.

System accuracy is determined by assigning an expected error to each componenet of flow measurement and then defining the total system uncertainty (accuracy) as the square root of the sum of the squared values of the individual errors. Sources of error for pipeline flow measurement are:

- Path Length Measurement
- Path Angle Measurement
- Travel Time Measurement
- Radius Measurement (or area for non-circular conduits)
- Velocity Profile Integration Error

Numerically, the analysis is as follows:

1. Path length measurement is typically done with the pipe dewatered. Using steel tape measures in larger pipes and calipers or micrometers in smaller pipes, individual path length uncertaintl is less than 0.15% (e.g., a 1/16-in (1.5mm) error in a 4-ft (1.2m) path length would result in a 0.13% error in velocity calculation). However, since there are 4 paths and the error is random, overall flow measurement uncerainty due to path length measurement error would be:

E, = 1/4 (4 x 0.0015)1/2 = 0.00075 or 0.075%

2. Path angle measurement is typically done with the pipe dewatered using a theodolite. The theodolite is capable of measuring angles to within ±20"; however, the primary source of error is the ablility to set the theodolite up on the pipe centerline. Careful set-up, according to Accusonic procedures, will assure that the theodolite is within ±0.1° (±6') of the true centerline.

(CONTINUED ⇔)



MULTIPATH FLOWMETER SYSTEMS THEORY AND OPERATING PRINCIPLE



So for paths nominally at 45°, the flow measurement uncertainty due to path angle measurement error would be:

E_a = (1-(cos 45.10/cos 45.00)) = 0.0017 or .017%

The above analysis assumes that there is no cross flow in the pipe (due to upstream disturbances such as elbows). This assumption is good for applications wehre there are at least 10 diametes of upstream straight pipe. For less available straight pipe, cross paths may maintain accuracy see Operating Principle).

For cross path installations, the above error is reduced to the theodolite resolution.

3. Travel Time Measurement is dependent on the digital oscillator accuracy, oscillator frequency, the ability of the received circuitry to consistently recognized the same point (leading edge on each received pulse, and the accurate subtraction of transducer, cable and system time delays. A precision oscillator (typically 160 MHz), accurate to within ±0.01%, is used for timing. Delay times are calculated and verified in the laboratory. The patented Accusonic Signal Quality Monitory (SQM) system ensures that the first negative edge of the received pulse will be considered to be the received point, for timing purposes. The flow measurement uncertainty from all timing errors is to calculated to be:

E₊ = 0.001 or .01%

4. Radius measurement is typically done from the inside with the pipe dewatered. The radius is measured at several sections to account for normal pipe out-of-roundness and give an average radius through the meter section. When done according to Accusonic procedures, the radius measurement can be completed to within ±0.02% (e.g., for a 6-foot (1.8m)-diameter pipe, the radius is measured to within1/16 in (1.5mm) or for a 10-foot (3m)-diameter pipe, the radius is measured to within 1/8 inch (3mm)).

The flow measurement uncertainty due to radius measurement error is:

E_R = (1 - (1/1.002)²) = 0.004 or 0.4%

 Velocity profile uncertainty is estimated by numerical analysis of the ability of a 4-path integration to fit simulated velocity profiles. The uncertainty due to profile integration error is determined to be less than:

 $E_1 = (E_1^2 + E_q^2 + E_T^2 + E_R^2 + E_L^2)^{1/2}$

= 0.0049 @ 0.005 or 0.5%

For other situations such as open channel systems, 2-path systems, compound meters, etc., the accuracy would be determined through an error analysis similar to the above, with the additional sources of error considered. For example, for an open channel system, there would be additional uncertainties due to level measurement and surface velocity deterination.

Typical system uncertainties for various meter applications are presented in Table 1.

Table 1 Uncertainty Values for Various Flowmeter Configurations

Description	Typical Uncertainty
4- or 8- path pipeline system	±0.5% of actual flowrate
2-path pipeline system	±1.5% of actual flowrate
4-path open channel system	±2.0% of actual flowrate
2-path open channel system	±5.0% of actual flowrate

The accuracy of Accusonic multipath flwometers has been well proven in numerous independent laboratory and field tests conducted by the EPRI and others on a variety of large-diameter pipes..



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