



7510 IS Series Flowmeter
Technical Reference Manual

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Table of Contents

Chapter 1	1
Flowmeter Description	1
Chapter 2	1
General Specifications	1
Transducers, Model Nos 7657 and 7658 Intrinsically safe.	1
Electronic Unit	1
Transducer Cable	2
Hand-held Terminal	2
FCC Compliance	2
Part 68	3
Interface Specifications	4
Analog Level input	4
Level Arbitration	4
Analog Outputs	4
Relay Outputs	5
Data Display on Hand-held Terminal	5
Parameter Insertion and Reading, Hand-held Terminal	6
Connection of a PC in place of Hand-held Terminal	6
Connection of a PC for use with “Accuflow” 7510 Interface	7
Remote Access via a Telephone Line and Modem	7
Optional Integral Data Logger	7
Chapter 3	1
Flow Computation	1
Flow Computation Algorithms	2
Flow Computation Algorithms	2
In “Compound” Mode	2
In Manning mode	2
In Non-surcharged Single Path Trapezoidal Integration Mode	2
In Non-surcharged Multi-Path Trapezoidal Integration Mode	3
Alternative Crossed Path Configuration in Open Channels	4
In Surcharged Mode	4
Surcharged Trapezoidal Integration.	4
In “Pipe” Mode	5
Volume Calculation	5
Water Temperature Calculation	6
Chapter 4	1
Unpacking and Installation	1
Unpacking	3
Physical Installation	3
Electrical Installation	3
Cable Entry Locations and Installation	3
Power Wiring	5
Earth Ground Connections	5
Intrinsically Safe Transducer Wiring	7
Transducer and Cabling Checkout	10
Connecting Transducer Cabling	10
Connecting Intrinsically Safe Water Level Sensors	11
Connecting Non-intrinsically Safe Water Level Sensors	11
Connecting the Analog Outputs	14

Table of Contents

Connecting the Relay Outputs	14
Connecting the Hand-held Terminal	14
Connecting a PC	14
Connecting a Modem	14
Chapter 5	1
Initial Setup, General Operations	1
Hand-held Terminal, Parameters and Variables	1
Menus	1
Stepping through menus	1
Other key operations	2
Parameter Data Entry	5
Typical Parameter List	6
Typical Parameter List	6
Display of Variables	8
Display of Variables	8
Serial Data Formats on Optional RS232 Communication Port 3	11
Display of Variables on the Optional LCD	11
Operation of Optional Data Logging	12
Chapter 6	1
“Accuflow” Windows Interface	1
Application Overview	1
Wizard Interface	1
Receive Parameters from Flowmeter	1
Send Parameters to Flowmeter	1
Setup Wizard	1
Open Setup	4
Review Historical Data	4
Connect / Measure	4
File Menu	5
File Menu	5
File / New	5
File / Open	5
File / Save	5
File / Print	5
File / Exit	5
Configure Menu	5
Communications	5
Dial Modem	5
Hang Up Modem	6
Get Flowmeter Version	6
System	6
Section	6
Analog Outputs	6
Relay Setup	6
Operate Menu	6
Diagnostics Menu	7
Comm. Port Test	7
Path Variables	7
Scope Mode	8
Flowmeter Reset	9
DataLogging Menu	9
Data Log Setup	9
Retrieve Logged Data	10
Display Retrieved Log	12
Using Graphs	13

Chapter 7	1
User Defined Parameters	1
System Parameters	1
Section Parameters	3
Path Parameters	5
Level Input Parameters	7
Analog Output Parameters	7
Relay Parameters	9
System Stats	10
Baud Rate change	10
Logging to Flash	11
Variables	12
Variables	12
Special Configurations	14
Using Layer Boundary Parameters to Simulate a Round Pipe	14
Separating Forward and Reverse Flows, (for pump / generating plant)	14
Relay to indicate that a Section is Good	14
Appendix A:	15
Multipath Flowmeter Systems Theory and Operating Principle	15
Index	1

CUSTOMER SPECIFIC DRAWINGS - FP-

OPTIONAL INTERFACES SUPPLIED

- **Power Supply**

Voltage	90 to 250 V a.c. 47 to 65 Hz, or 100 to 300 V d.c.
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- **System Clock**

Programmable	For 10 MHz, 5 MHz, 2 MHz
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- **Acoustic Paths**

Number	4
Connection	Unbalanced

- **Signal Filters**

Transducer Frequency	1 MHz or 500 kHz
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- **Analog Inputs (Intrinsically Safe)**

Number	2
Load resistance	460 Ω plus 0.9V diode
Power supply	+24 V d.c.

- **Analog Inputs (Non-Intrinsically Safe)**

Number	2
Source resistance	100 Ω
Power supply	+24 V d.c.

- **Analog Outputs**

Number	4
Type	Isolated
Maximum load	750 Ω

- **Relays**

Number	up to 16
Type	SPDT

- **Heater**

Voltage	Not fitted.
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- **Internal Data Logging**

Memory	2 Mb
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Chapter 1

Flowmeter Description

The Accusonic Model 7510-I Intrinsically Safe “Compound” Flowmeter is specifically designed for accurate flow measurement in sewers, channels and pipes, in which the atmosphere may be potentially explosive. The cross section of the sewers, channels or pipes may be circular, rectangular, trapezoidal, “horseshoe” or other defined shape, ranging from 8 inches to 100 feet (0.2m to 30m) in width.

The Model 7510-I Flowmeter console is designed to be installed in a non-hazardous area, and connected by cables to the transducers in the hazardous area. When correctly installed, the system meets the requirements of the Class I, Division 1, Gas groups C & D, Hazardous Area Classification in USA and Canada, and the IEC codes EEx ia, for Zone 0 or Zone 1, Gas groups IIA & IIB.

Warning

For installations requiring intrinsic safety, the electronic console, cabling, transducers, and other electrical equipment in the sewer and associated with it, shall be installed in accordance with the appropriate National Electrical Codes. The work shall be carried out by experienced personnel, whose training has included formal instruction in the installation of electrical equipment in potentially explosive atmospheres, “intrinsically safe” protection and installation practices, the relevant rules and regulations, and the general principles of area classification.

The owner of the flowmeter shall establish a routine for regular inspection in accordance with National Safety Codes.

In USA installation shall follow NEC Article 504 for Intrinsically Safe protection.

Elsewhere IEC 60079-14 9 (for installation) and IEC 60079-17 (for regular inspection) shall be followed.

The depth of water above the invert or bottom of the conduit may vary from zero to surcharged. The flow may be in either direction, and generally there is no assumed relation between depth and flow. Under certain conditions of low water level, a Manning type of relation between level and flow may exist. To cope with all these three possible flow conditions, and the possible temporary loss of velocity measurements, “Compound” flowmeter logic is required.

The water may range in quality from clean to raw sewage, from natural or industrial sources, having a pH in the range 3.5 to 10, temperature between 32°F and 105°F (0°C and 40°C), and a solids loading from near zero to 2000 parts per million. It is assumed that the conduit does not contain vapors of ketones or esters which might eventually reduce the integrity of the plastic housing of the transducers. In addition, the water may contain floating weed, rag, paper and plastic debris, and may deposit grease on the walls and any devices attached to the walls, especially in the region around the dry weather flow level.

For those conduits which are always surcharged the flowmeter may be configured in the “Pipe” mode. In this mode the level inputs are ignored, and in some cases the flowmeter may be supplied from the factory without level input circuits. For the flow computation, 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.

For all other conduits the “Compound” mode should be used. The flowmeter is based on the “velocity-area” method for flow determination, generally described in ISO 6416 1992, and more specifically in Appendix A of this manual.

Flowmeter Description

The water velocity is determined using the multi-path ultrasonic time-of-flight method. The elevation of the water surface above the site datum is called the “Level,” and the variable component of this value is input to the flow computer in analog form from one or two sensors, (typically downlooker ultrasonic units or pressure transmitters). A single arbitrated value for Level is obtained from the two inputs. The wetted cross section area is computed from the Level and parameters stored in the computer defining the shape of the conduit. The integration technique for computing the flow from the velocity data is determined automatically from the water level and from the quality of the velocity data.

When the Level is too low for any acoustic paths to operate (or if they are submerged and have failed), flow may be computed using the Manning equation. When the level is higher and ultrasonic paths are operating, a “Trapezoidal” integration method is used. When the conduit is surcharged, either the same integration algorithm may be used (modified to allow for the friction effect of the top of the conduit), or alternatively the “Pipe” mode may be used.

The flowmeter may be configured to provide determinations of flow in up to four separate and dissimilar conduits or “Sections”, each with one or two analog Level inputs and a number of acoustic paths. The total number of Level inputs allocated among the Sections is limited to 4, and the total number of paths allocated among the Sections is limited to 8.

The electronic unit provides up to four independent outputs in a 4-20 mA analog form, which may be differently scaled to output separately forward and reverse flow, flow over any range from reverse to forward, mean velocity, level, water temperature or sum of section flows.

Up to a maximum of 16 relays may be fitted to the electronic unit to provide flow and level threshold alarms for each section or sum of sections, section status (fail) alarms, or totalizer pulses.

An alpha-numeric display of flow and diagnostic data is provided on a separate hand-held terminal, which is connected to the flowmeter via an RS232 serial data port. The site parameters may be inserted into the flowmeter’s non-volatile memory from this terminal, by way of a “user-friendly” menu. Alternatively, a PC with a communications software may be used in place of the hand-held terminal.

A second RS232 port is provided for use with a PC which has “Accuflow 7510 Flowmeter Interface” software installed. This provides a “Windows” based user friendly flowmeter configuration routine, as well as graphics showing trends from recent flow data, the received acoustic signal waveforms and other data to aid commissioning.

An internal data logger may be fitted, which stores any combination of the measured variables (Flows, Levels Velocities, Temperatures, Diagnostic data etc.) at a chosen interval, using non-volatile “Flash” memory technology.

The logger can be configured from the “Logging to Flash” menu.

The flowmeter may be fitted with an optional liquid crystal display (LCD), which can offer a range of flow data displays, depending on the configuration of the flowmeter.

Chapter 2

General Specifications

Transducers, Model Nos 7657 and 7658 Intrinsically safe.

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:		100 psi	7 bar.
Water quality:	pH	3.5 to 10	
	Solids loading	0 to 2000 parts/million	
	Vapors of Ketones & Esters must not be present		
Characteristic frequency:	1 MHz or 500 kHz.		
Intrinsically Safe Certification coding	Class I, Division 1, Gas groups C & D, EEx ia IIB T4		
Compliance Standards	IEC 60079-0, IEC 60079-11		
Maximum Transmit Voltage:	800 V peak.		

Electronic Unit

Standard Model

Power supply: Electronic Unit	90 to 250 V a.c. 47 to 65 Hz or 100 to 300 V d.c. without adjustment.	
Power consumption:		
Standard unit	26 Watts, 50 VA. (with a.c. power supply)	
With relays or power for level sensors	35 Watts, 70 VA. (with a.c. power supply)	
Heater a.c. power only,	200 Watts, Voltage as specified on equipment	
Contact Accusonic for details of Models suitable for 12 V, 24 V or 48 V d.c. power supply.		

Temperature range:	operating	+15°F to 140°F	-10°C to 60°C
	operating with heater	-15°F to 140°F	-25°C to 60°C
	storage	0°F to 150°F	-18°C to 65°C

Maximum Altitude for normal operation	6500 ft	2000 m
	For higher altitudes, contact Accusonic.	

Dimensions:	20 x 20 x 9 inches	500 x 500 x 230 mm
Weight:	60 lb	27 kg
Enclosure protection:	NEMA 4	IP65

Acoustic Paths (Up to 8 in total, allocated between all the Sections).

Length (Standard range)	0.7 to 100 ft	0.2 to 30 m
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Permanent Data Display (Optional)	LCD 2 lines x 20 alpha-numeric characters	
	Character height	9 mm

Level inputs (Optional up to 4)

useable input range with standard 100Ω load 4 -20 mA, (0.4 - 2.0 V)
 maximum voltage relative to ground for operation ± 20 V dc.

Intrinsically safe option

maximum withstand voltage relative to ground +28 V peak.
 Power supply for external level transmitter (per input) +24 V dc. 25 mA max
 All inputs and power supply are protected by intrinsically safe shunt diode barriers.
 Barrier series impedance 360Ω plus 0.9V diode.

Non-intrinsically safe option

maximum withstand voltage relative to ground 240 V rms
 Power supply for external transducers +24 V dc. 1.0 A max

Analog Outputs: (Optional up to 4)

Isolated	range	4-20 mA	
	maximum load	750Ω	15 Volts
	resolution	0.01 mA	(11 bit)
	linearity and stability	±0.02 mA	0.1% full scale
	isolation	1500 V rms. common mode relative to ground	
	protection	240 V rms. normal (or series) mode	

Alarm relays (Optional up to 16)

For Flow or Level exceedance, Faults or Totalizer.
 Normally open contacts. 10 A carrying capacity.
 Switching capacity: 0.5 A, 110 V d.c., L/R = 40 ms
 Isolation 2000 V a.c.

Optional Internal Data Logger

104 different variables selectable.
 Any interval selectable between 1 second and 24 hours
 Capacity of main memory: 192 K data points.

Transducer Cable

Unbalanced mode: Coaxial RG59 A/U.
 A special double jacketed version for underwater use is available.
 Approval from Accusonic should be obtained if the cables are expected to exceed 300 ft (100m)

Hand-held Terminal

Type TT-8045 (Two Technologies 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 25 mm
Weight:		0.5 lb.	0.23 kg
Enclosure Protection:		Not NEMA rated,	IP41
Power supply:		5 V d.c. from the 7510 unit, on pin 9 of D connector	
RS232 signals:	Factory setting	19200 baud, 8 data bits, No parity, 1 Stop bit	
Display		4 Lines x 20 Characters	

FCC Compliance

To comply with the Federal Communications Commission (FCC), Accusonic Technologies provides the following information concerning the 7510 flow meter installation and operation.

Part 68

This equipment complies with Part 68 of the FCC Rules and the requirements adopted by the ACTA. It bears a label displaying, among other information, a product identifier in the format US:AAAEQ##TXXXX. The user must provide this information to the telephone company if requested.

The REN identifies the number of devices that may be connected to the telephone line. Excessive RENs on the telephone line may prevent devices from ringing in response to an incoming call. In most areas, the sum of the RENs should not exceed five (5.0). To determine the number of devices you may connect to a line, as determined by the total RENs, contact your telephone company. For this product the REN is part of the product identifier, the digits represented by ## are the REN without the decimal point (e.g., 03 is a REN of 0.3).

The plug and jack used to connect this equipment to the telephone network must comply with the applicable FCC Part 68 rules and the requirements adopted by the ACTA. A compliant telephone cord and modular plug is provided with this product. It is designed to be connected to a compatible modular jack that is also compliant. See installation instruction for details.

The telephone company may make changes in its facilities, equipment, operations, or procedures that could affect the operation of this equipment. If this occurs, the telephone company will provide advance notice so you can make necessary modifications to maintain uninterrupted service.

In the unlikely event that this equipment harms the telephone network, the telephone company will notify you that temporarily discontinuing telephone service may be required. Notification will occur in advance of discontinuation, or as soon as practically possible. They will also inform you of your right to file a complaint with the FCC if necessary.

This equipment may not be used on public coin phone service provided by the telephone company. Connection to party line service is subject to state tariffs.

This equipment is not field repairable. If you experience trouble with it, please refer to this manual for troubleshooting, replacement, or warranty information, or contact:

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Interface Specifications

Analog Level input

Level is input in 4-20 mA analog form, from an external current loop source.

Both terminals at the flowmeter must be within 20 volts of ground for operation.

The external device should be configured to give increasing current for increasing water depth. If it is configured to give increasing current for decreasing water depth, the Level Arbitration will not operate correctly.

For Level sensors requiring d.c. power, 24 Volts dc (at a maximum current of 25 mA per input) is available from the Level input terminal block.

Configuration of the Level input is defined by user-defined parameters. A parameter makes allowance for alternative load resistances to be placed across the input terminals. Normally the input resistance is 100Ω.

For electrical characteristics see “Electronic Unit” Specifications, page 2-2.

- A Level input having an electric current (in mA) less than the value set by the parameter *Min mA Input*, or more than 21.0 mA is treated as being in a “fault” state.
- Level inputs between the value set by the parameter *Min mA Input* and 20.00 mA are interpreted as elevations in feet or metres, linearly interpolated in the range from 4.00 to 20.00 mA, between the values stored under the parameters *4mA Level Input* & *20mA Level Input*.

Level Arbitration

- Applies when two Level inputs are allocated to a Section. Both inputs must be configured to give increasing current for increasing water depth. Input #1 is the lower numbered input allocated to the section.
- If input #1 is between the value set by the parameter *Min mA Input* and 19.8 mA, the value scaled by the parameters *4mA Level* and *20mA Level* is used as the arbitrated value for Level. Input #2 is ignored.
- If input #1 is below the value set by the parameter *Min mA Input*, it is rejected. If at the same time, input #2 is between the value set by the parameter *Min mA Input* and 20.0 mA, the scaled value from input #2 is used as the arbitrated value for Level.
- If inputs #1 and #2 are both below their values set by the parameters *Min mA Input*, both are rejected, and no Level value is available. The flowmeter is declared failed.
- If input #1 is above 19.8 mA, and input #2 is not rejected, then the arbitrated level is the greater of that indicated by input #1 or input #2.
- If input #1 is above 19.8 mA, and input #2 is rejected, then Level is that indicated by input #1.
- Usually input #1 reading 20mA indicates pipe full. Input #2 is usually scaled for a larger range than #1.

Analog Outputs

These are configured for 4-20mA, and may be separately allocated to give a linear representation of the flow, level, average water velocity, water temperature or sum of section flows. If desired, the outputs may be scaled to cover any range of the variable from reverse, through zero, to forward: it is necessary only to define the output by the extremes of the range (i.e., at 4mA and 20mA).

Output allocation to flowmeter section, variable to be output, range and output under fault condition, are all defined under Analog Output parameters, (for definitions see Chapter 7)).

Under fault conditions, the outputs will go either to 4.00 mA or be held at the last good value, depending on the choice under the parameter *Hold on Error*.

Under conditions of under-range, an output will go to 4.00 mA

Under conditions of over-range, an output will go to 20.00 mA

When the flowmeter is taken out of measurement mode the output holds the last value.

For electrical characteristics see “Electronic Unit” Specifications, page 2-2.

Relay Outputs

The relays which have been installed can be allocated to any section and to any of the functions by setting the Relay Output parameters described in Chapter 7. The logical operation for the different functions is:

Threshold Exceedance	<p>The relay changes from its normal state when the value of the Flow or Level equals or exceeds the <i>Threshold</i> parameter for more than the number of consecutive measurement cycles defined by the <i>Delay</i> parameter.</p> <p>The relay returns to its normal state if the value of the Flow or Level falls below the <i>Threshold</i> for more than the number of consecutive measurement cycles defined by the <i>Delay</i>.</p> <p>If the section fails, the relay remains at, or immediately returns to its normal state.</p> <p>The Normal state (either energized or de-energized) can be selected by the parameter <i>Polarity</i>.</p> <p>The value of the <i>Threshold</i> can be positive or negative (-99999 to +999999).</p> <p>Note: In the logic, the value -6.00 is regarded as greater than -7.00.</p>
Status Alarms	<p>The relay changes from its normal state when the Fault state has been in existence for more than the number of consecutive measurement cycles defined by the <i>Delay</i> parameter.</p> <p>The relay returns to its normal state immediately if the Fault state ceases.</p> <p>The Normal state (either energized or de-energized) can be selected by the parameter <i>Polarity</i>.</p> <p>Note. A fault state due to a path failure is declared when the path has failed to provide data for more than a number of consecutive measurement cycles defined by the parameter <i>Max Bad Measures</i>. If the relay <i>Delay</i> is set to a value greater than zero, the relay will not operate until after that delay, even though the fault state will have already been in existence.</p> <p>The purpose of this routine is to hide short term faults which are known to occur, and only to give alarms for permanent faults.</p>
Totalizer Relays	<p>The relay changes from its normal state and returns 100 milli seconds later whenever the value for the Volume has increased by one complete unit.</p> <p>Only one operation of the relay can occur each measurement cycle.</p> <p>Only one relay can be allocated to each Section and only one to the Sum of Sections for totalizer pulses.</p> <p>In the event of power failure or the flowmeter being taken out of the Measure mode for less than one hour, the relay may operate at a rate of once per measurement cycle until the number of relay pulses has caught up with the Volume change which was computed to have occurred during the outage.</p>

Data Display on Hand-held Terminal

In normal operation, 11 different display screens are available, one for each variable as follows:

Envelope Times, Travel Times, Time Differences, Signal Gains, Velocities,
Flow, Volume, Level, Temperature, Sum of the Section Flows & Volumes, Analog in.

The first five are for diagnostic purposes concerned with the water velocity determinations, the next five for observing flow data, and the last for diagnostic purposes concerned with the various Level inputs.

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 7.

Parameter Insertion and Reading, Hand-held Terminal

Parameters describing the flowmeter configuration are inserted using 7 different parameter menus. These are: SYSTEM, SECTIONS, PATHS, LEVEL INPUTS, ANALOG OUTPUTS, RELAYS, LOGGING.

For instructions on how to insert the parameters, see Chapter 5.

For details on setting up the optional internal data logging, see Chapter 5.

For details of the parameters, see the section on “User Defined Parameters” in Chapter 7.

There are two command menus:

MEASURE: To put the flowmeter into the normal “Measure” mode.

SYSTEM ACTIONS. Under which any of the following three commands may be made.

STORE ALL PARS: To store parameters once they have been entered correctly.

RESTORE ALL PARS: To recall the stored parameters from non-volatile memory.

XMIT PARAMETERS: To transmit the complete parameter list to a data terminal.

In addition there is a list called SYSTEM STATS, which contains the software revision number, a parameter to change the data baud rate to the Hand-held terminal, and the facility to change the real time clock.

Connection of a PC in place of Hand-held Terminal

A PC or other terminal with ANSI emulation may be connected to the 9 pin “Hand-held Communications” socket, as an alternative to the Hand-held terminal usually supplied. The same logic of operation and functions will be available. A “Null Modem” cable or standard serial cable with a “Null Modem adapter” is required to interconnect between this socket and a PC’s serial port. Either the cable or adapter can be purchased at a PC supply or electronics store.

RS232 signals: 19200 baud, 8 data bits, No parity, and 1 Stop bit, No handshaking protocol
The baud rate may be changed using a parameter under SYSTEM STATS.

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 5 Common, connected to ground in the 7510 unit.
Pin 9 +5 volts dc. (for power to the Hand-held terminal).

The following ASCII characters are recognized by the flowmeter.

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

The letters **U, D, L, R**, are used as cursor controls, **↑, ↓, ←, →**

or **S** is used to cause a system Reset,

P to put the system in Pause,

T to prevent updating of the Terminal display

M to put the system in the Measure mode.

Z as an alternative for Esc.

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

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

Connection of a PC for use with “Accuflow” 7510 Interface

A PC may be connected to the 9 pin “RS232” socket, for use with special Accusonic PC based programs. A “Null Modem” cable or standard serial cable with a “Null Modem adapter” is required to interconnect between this socket and a PC’s serial port. The cable or adapter can be purchased at a PC supply or electronics store.

RS232 signals: 19200 baud, 8 data bits, No parity, 1 Stop bit, No hand-shaking protocol.

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 5	Common, connected to ground in the 7510 unit.

Remote Access via a Telephone Line and Modem

For remote access to the flowmeter from an office, via a telephone and modem link, the modem should be connected to the socket of the flowmeter marked “RS232”.

Note that the flowmeter RS232 port does not support any hardware or software flow control protocol.

The cable linking the modem and flowmeter is an industry standard configuration, but will require either the interchange of pins 2 & 3 or a “null modem” to be inserted in the line.

The modem must be capable of communicating with the flowmeter at 19200 baud, 8 data bits, no parity, and be set up to auto answer. The modem must contain a data buffer of at least 1.5 k bytes, as well as support error detection and retransmission protocols.

The equipment required at the office consists of a suitable telephone connection, modem (supporting the same error detection and retransmission protocols as the one at the flowmeter) and a PC running the Accusonic program “Accuflow 7510 Flowmeter Interface”.

Optional Integral Data Logger

The internal data logger can be configured to log any combination of the measured variables (Flows, Levels Velocities, Temperatures, Diagnostic data etc.) at a chosen interval, using non-volatile “Flash” memory technology.

The memory part of the data logger resides on one circuit card which is mounted next to the DSP card in the flowmeter console. The flowmeter processor (DSP) carries out all the house keeping functions necessary to format data and store them on the memory card. The DSP also formats the data when requested to upload them to a PC.

The user interfaces with the logger for setting up, either using the Hand-held terminal (see Chapter 5 & 7), or via the RS232 serial port using a PC running under the Accuflow Interface. (see Chapter 6)

Reading the logged data can only be achieved using the Accuflow Interface.

If the logger is not installed in the flowmeter, the menu for setting it up is inoperative, and any parameters set in it are ignored.

The logger is fully protected against data loss in the event of power failure.

Chapter 3

Flow Computation

The Accusonic Model 7510 Flowmeter may be configured with up to a maximum of eight acoustic paths and two inputs for Level (or water depth) 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* and *Angle*. For “Pipe” mode integration, a *Weight* parameter is added: for “Compound” mode *Elevation* is added. Paths are numbered in order of elevation, with the lower path numbers having lower elevations. In Compound flowmeters, pairs of “Crossed Paths” in a section are indicated by having the same elevation. Other Path parameters include:

Max. Bad Measures, Max Velocity Change, Max Path Velocity, Signal Delay and Transducer Frequency

In “Pipe” mode, path transducers are energized and measurements taken for all paths which are configured. In “Compound” mode, only those transducers submerged by an amount greater than the parameter *Min. submersion* are energized.

If a path fails to provide a good velocity value, because the signal is not found, or the velocity appears to exceed the *Max Path Velocity* parameter, then the last good velocity value is used for flow calculations until the number of consecutive failures exceeds the parameter *Max. Bad Measures*. 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. If the change in velocity appears to exceed the *Max Velocity Change* parameter, the computed velocity is incremented or decremented by an amount equal to the *Max Velocity Change*.

In “Pipe” mode, all *Manning, Level* and *Layer* parameters indicated by the letter “C” after their names are ignored. The conduit geometry and velocity integration are defined in terms only of *Pipe Area* and *Path weights*.

In “Compound” mode instantaneous values for velocity are averaged for paths having identical elevations, and the averaged velocity is used as the velocity at that elevation. If one of the paths has failed for more than the parameter *Max. Bad Measures*, the good path will be used alone for providing the velocity at that elevation. Paths which do not have identical elevations will be treated as separate paths in the Trapezoidal Integration. The velocities displayed and the velocities sent to the “Com 1” port will be the individual velocities for each path.

The conduit cross-section is defined in terms of up to 8 “Layers,” each layer being described by an elevation and a width. The width of the conduit at any elevation is computed by linear interpolation between the layer widths above and below.

The elevation and width of the channel bottom are defined by Layer #1. The layer elevations are independent of the path elevations. For a rectangular or trapezoidal conduit, only two layers need be defined, the first describing the channel bottom, and the second describing the top of the channel. For a closed conduit, the top-most layer elevation must be equal to or greater than the elevation of the soffit or top of the conduit (or the *Surcharge Level* parameter). For an open channel, the top-most layer elevation must be set above the highest possible level. The other Section parameters required for Compound Integration are: *Bottom friction, Top weight* and the Surcharged Integration method to be used (*Surch Trap/Pipe*).

If “Trapezoidal” integration is chosen for the surcharged condition, certain “Pipe” mode parameters are ignored by the system, and these are indicated in Chapter 7.

Flow Computation Algorithms

In “Compound” Mode

The flowmeter automatically chooses one of 5 integration methods, depending on the value of the Level, and on the status of any of the acoustic paths which are sufficiently submerged to operate, (i.e. those whose elevations are defined to be less than [Level - *Min. submersion*]). The 5 methods are:

1. Zero flow if the Level (or depth of water) is below a user defined value.
2. Manning Equation when the depth of water is too low for acoustic paths to operate, or, within-user defined limits, if none of the acoustic paths yields valid data.
3. Single Path Trapezoidal Integration, when the conduit is not surcharged and only one path (or one pair of crossed paths) is submerged, or when only one path (or one pair of crossed paths) is able to yield valid data.
4. Multi-path Trapezoidal Integration, when the conduit is not surcharged and at least two acoustic paths at different elevations (any of which may be pairs of crossed paths) yield valid data.
5. Surcharged Integration, when the pipe is surcharged. A user-selectable choice of two methods is available:
 “Pipe” as described for “Pipe” mode involving parameters of path weights and pipe area;
 “Surcharged Trapezoidal” where the pipe geometry and velocity integration are defined by methods similar to those used for non-surcharged trapezoidal integration.

Note

*If none of the above conditions is satisfied, the flowmeter is declared to be in a “fault” state.
 On sites where the Manning equation is not appropriate, the facility can be inhibited by setting the parameter Manning max lvl. to a value equal to or below the parameter Layer elevation 1.*

In Manning mode

The flow is computed from the variable Level and fixed parameters of channel roughness, channel slope, and dimensions of the conduit.

$$\text{The flow} = \text{Flow scaling} * \text{Area} * C * n^{-1} * R^{0.667} * \sqrt{s}$$

- where:
- Area = the cross-section area of fluid at the current Level, computed using layer data.
 - C = Manning Constant = 1.49 if English units are used, 1.00 if metric units are used.
 - n = the Manning coefficient of roughness.
 - R = Hydraulic radius, which is the Area/Wetted Perimeter.
 - s = Slope of the energy line. For a long pipe, the pipe slope.

In Non-surcharged Single Path Trapezoidal Integration Mode

The flow is computed from the variables Level and Water Velocity, and fixed parameters describing the conduit.

$$\text{The flow} = \text{Flow scaling} * \text{Area} * \text{Velocity} * \text{Path position coefficient.}$$

where: Area = the cross-section area of fluid at the current Level, computed using layer data.

Path position coefficient is obtained by interpolation from the following look-up table (from ISO 6416).

Ratio of path depth below surface to depth of water above bottom.	Ratio of point velocity to mean velocity in the vertical.
0.1	0.846
0.2	0.863
0.3	0.882
0.4	0.908
0.5	0.937
0.6	0.979
0.7	1.039
0.8	1.154
0.9	1.424
0.95	1.65 (extrapolation).

In Non-surcharged Multi-Path Trapezoidal Integration Mode

The flow computation in this mode is performed in a series of steps, following the principles set out in ISO 6416 for the “mid-section” method. Each step consists of determining the flow over a smaller cross-sectional area or panel. The total flowrate in the conduit then becomes the sum of the individual panel flows.

There are three basic types of panel:

1. Bottom panel which is bounded on the bottom by the bottom or bed of the conduit and on the top by the lowest operating path.
2. Intermediate panel bounded on the top and bottom by consecutive operating paths that are not at the same elevation.
3. Top panel bounded on the bottom by the highest operating path and on the top by the surface of the water.

Each of these panels is bounded on either side by the walls of the conduit, whose dimensions and shape are defined by the layer parameters. The actual area for each panel can therefore be a complicated computation involving the calculation of the conduit widths at the paths which bound the panel (from interpolation between the nearest layer widths), the calculation of the areas between these paths and the layer nearest them (or between the paths if there is no layer between them), and the calculation of the areas between any other layers which may lie between these paths.

The flow computation in the bottom panel is:

$$Q_{\text{Bottom}} = \text{Area}_{\text{Bottom}} * \text{Vel}_A * (1 + \text{Bottom friction}) / 2$$

where: $\text{Area}_{\text{Bottom}}$ = conduit area between the bottom (Layer #1) and the lowest good path
(or pair of crossed paths)

Vel_A = Water velocity as computed from the lowest good path or pair of crossed paths

The flow in the intermediate panel above the bottom panel is:

$$Q_{\text{Int}} = \text{Area}_{\text{Int}} * (\text{Vel}_A + \text{Vel}_B) / 2$$

where: Area_{Int} = conduit area between good path A and the next good path B

Vel_B = water velocity as computed from the next good path or pair of crossed paths

The flows in all the intermediate panels is computed similarly

The flow in the uppermost panel bounded by the surface is:

$$Q_{\text{Top}} = \text{Area}_{\text{Top}} * (\text{Vel}_N + \text{Top Weight} * \text{Vel}_{\text{Surface}}) / (1 + \text{Top Weight})$$

where: Area_{Top} = conduit area between the uppermost good path (or pair of crossed paths) and the water surface.

Vel_N = water velocity computed from the uppermost good path or pair of crossed paths

$\text{Vel}_{\text{Surface}}$ = an estimated water velocity at the surface from a limited algebraic extrapolation of the velocities from the uppermost good path (or pair of crossed paths) and the next good path (or pair of crossed paths) below it.

If the difference in elevation between the water surface and the uppermost good path is less than the difference in elevations between the uppermost and next lower good paths, then:

$$\text{Vel}_{\text{Surface}} = \text{Vel}_N + (\text{Vel}_N - \text{Vel}_M) * (\text{Level} - \text{Elevation}_N) / (\text{Elevation}_N - \text{Elevation}_M)$$

where Elevation_N and Elevation_M are the elevations of the uppermost good path and of the next lower good path.

and Vel_N and Vel_M are the water velocities from the uppermost good path (or pair of crossed paths) and of the next lower good path (or pair of crossed paths)

If the difference in elevation between the water surface and the uppermost good path is greater than the difference in elevations between the uppermost and next lower good paths, then:

$$Vel_{Surface} = Vel_N + (Vel_N - Vel_M)$$

The total Flow in the conduit is the sum of the flows in all the panels.

$$Flow = Flow\ scaling * (Q_{Bottom} + \sum Q_{Int} + Q_{Top})$$

Alternative Crossed Path Configuration in Open Channels

When crossed paths are installed, the flowmeter may be configured as two separate sections having identical geometry and the same level inputs. Section #1 is configured for the paths in one plane, and section #2 for those in the other plane. The *Flow Scaling* parameter is set to 0.5, and the channel flow is the sum of the section flows. Analog outputs should be allocated to section #1 to give Level, temperature and velocity, and to SF (Sum of Flows) for Flow.

In Surcharged Mode

A choice of two possible integration methods is available -- “Pipe” and “Surcharged Trapezoidal.”

Surcharged Pipe Integration.

See description on page 3-5 for “Pipe Mode.”

Surcharged Trapezoidal Integration.

The flow is computed from the path velocities and the cross-section area (which is computed from the layer parameters and the *Surcharge Level* parameter).

When paths at more than one elevation are good, the Flow is computed in the same manner as for non-surcharged trapezoidal integration, except that the flow in the panel between the uppermost good path (or pair of crossed paths) and the top of the conduit or soffit is set to:

$$Q_{Top} = Area\ between\ uppermost\ good\ path\ and\ soffit * Vel_N * (1 + Bottom\ Friction)/2$$

When only one path (or pair of crossed paths) is good, the total section Flow calculation simplifies to:

$$The\ Flow = Flow\ scaling * Area * Vel_A * (1 + Bottom\ Friction)/2$$

where: Area = the surcharged cross section area of conduit computed from the Layer data and the *Surcharge Level* parameter.

For multi-path installations, the value of *Bottom Friction* is usually set between 0.5 and 0.8. The lower value is used when the lowest path is very close to the bottom of the channel.

For single path installations with the path located near to the bed, the value for *Bottom Friction* should be set according to:

Channel shape	Path elevation / Surcharge Level	Bottom Friction.
Rectangular	10%	1.6
Rectangular	20%	1.4
Round	10%	1.3
Round	20%	1.1

In “Pipe” Mode

In “Pipe” mode, the conduit is surcharged, and flow is computed by the product of average water velocity and the conduit cross-section area. The average water velocity is obtained from the sum of the path velocities, each weighted according to its position in the conduit.

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 *Weight* for each path W_n (n is the path number 1 to 8)

$$\begin{aligned} \text{The flow} &= \text{Flow scaling} * \text{Pipe area} * \sum W_n * V_n \\ \text{where } V_n &= \text{velocity for path } n. \end{aligned}$$

Details of the method, including path configurations and weights to be used in special formulae for different pipe shapes, are described in the ASME PTC 18 or IEC Pub 41 codes for hydraulic turbine efficiency testing. The formulae and the weighting factors used in the codes differ from the more general formula used in the flowmeter. Examples of weights to be inserted in the flowmeter are given in Chapter 7, under Path Parameters.

In the event of one or more paths failing, the flowmeter is capable of calculating Flow by invoking a “Path substitution” routine. The Flow continues to be computed from those paths which remain good, however the uncertainty increases with the number of paths failed. For this routine to operate, the following two conditions must be met:

1. The number of good paths must be equal to or greater than the Section parameter *Min good Paths*.
2. The flowmeter must have completed the “Learn” routine.

During the “Learn” routine, which must be implemented at the pipe’s normal flow (non-zero!), a table of time-averaged historic flow components ($V_n * W_n$) is recorded and stored in the flowmeter’s protected memory. The “learn” 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 “L” 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.

In the “Path Substitution” routine, 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. Mathematically, the routine can be represented as:

$$\text{Flow} = \text{Current Flow from Good Paths} * \text{Historic Flow} / \text{Historic Flow from current good paths.}$$

The Current Flow from Good Paths is = Pipe Area * $\sum V_n \cdot W_n$
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 $V_n \cdot W_n$ excluding those historic flow components which apply to the paths which are currently failed.

Volume Calculation

Volume is the totalized flow and is computed as:

$$\text{Volume} = \text{Flow in the displayed units} * \text{Time elapsed in seconds} / \text{Volume Scaling}$$

If the flow is positive, the count will rise to a maximum of 99 999 999, and then reset to zero and start again. The Volume figure will be incremented or decremented depending on whether the flow is positive or negative. If the count is small, the Volume figure will be displayed as a number with up to 4 decimal places.

The volume counts transmitted by relay closures to an external counter are designed to maintain agreement between the displayed Volume (in the flowmeter) and the count as registered by the counter.

General Specifications

When the flow is positive, a count is usually transmitted by the relay whenever the Volume increases by one complete unit. However, if there is a period during which the flow is negative, the Volume figure displayed in the flowmeter will decrement, but there will be no counts transmitted by the relay. If the flow should then return positive, no further counts will be transmitted until the Volume figure exceeds the value which it attained prior to the negative flow period.

In the event of the flowmeter being taken out of the Measure Mode or powered down for a period not exceeding one hour, the Volume count will be made up for the missing period. The count made up will be given by:

$$\text{Make-up Count} = \text{Flow existing at time of Flowmeter recovery} * \text{Down time in Seconds} / \text{Volume Scaling}.$$

Water Temperature Calculation

Water temperature for a section is computed from the average speed of sound in water, as determined from the measurements made by all the good working paths in the section.

The result is in °F if the System Parameter *English / Metric* is set to “English”, and in °C if it is set to “Metric”.

The calculated temperature is:

$$\text{Temperature } ^\circ\text{F} = 1.129 * 10^{-7} * c^3 - 1.46827 * 10^{-3} * c^2 + 6.450118 * c - 9559.7 + \text{Temp Correction}$$

$$\text{Temperature } ^\circ\text{C} = 5.0822 * 10^{-6} * c^3 - 2.127056 * 10^{-2} * c^2 + 29.88592 * c - 14096 + \text{Temp Correction}$$

where *c* is the average speed of sound in water, and *Temp Correction* is a Section Parameter.

These formulae apply only to fresh water at low pressure.

At 10 bar pressure, the flowmeter will indicate 0.6°F (0.3°C) high at near freezing,
and 1.4°F (0.8°C) high at 90°F (30°C)

At a salinity of sea water (35 parts / thousand), the flowmeter will indicate
19°F (10°C) high at near freezing,
and 30°F (17°C) high at 90°F (30°C)

Chapter 4

Unpacking and Installation

Warnings

1. After unpacking the equipment, inspect it for signs of physical or water damage. Do not apply power to damaged components. Injury or further damage may occur.
2. If this equipment is being installed in a wastewater environment, or where corrosive gases (e.g. chlorine, H₂S, SO₂) are present, these gases or other condensing vapors shall be prevented from entering the flow meter enclosure; otherwise permanent damage to the electronics will occur.

To prevent such entrance all conduits and cables entering the enclosure shall be sealed with poured seals in accordance with the National (USA) or Canadian Electrical Safety Codes. If permanent seals are not being installed at this time, temporary seals shall be made using “electricians putty” or similar material.

Note: Do not use RTV sealant; it gives off acetic acid vapors.

Special Notes for Installations in Potentially Flammable Atmospheres

1. General
 - a. For installations requiring intrinsic safety, the electronic console, cabling, transducers, and other electrical equipment in the sewer and associated with it, shall be installed in accordance with the appropriate regional or national electrical codes or standards. The work shall be carried out by experienced personnel whose training has included formal instruction in the installation of electrical equipment in potentially explosive atmospheres. They shall be knowledgeable of the relevant rules and regulations for such installations with particular emphasis on “intrinsically safe” protection and installation practices.

In the USA installation should follow National Electrical Code (NEC) Article 504 for Intrinsically Safe protection.

In Canada installation should follow the Canadian Electrical Code (CEC) Part 1, CSA C22.1. In the European Economic Community (EEC) and elsewhere, IEC 60079-14 (for installation) should be consulted.

- b. Alteration or repairs to the flow meter shall be carried out only with appropriate authorization and only by adequately trained personnel who are fully aware of the safety issues associated with the apparatus. Following replacement, repair, modification or adjustment, the items concerned shall be inspected in accordance with manufacturer’s documentation and relevant regional or national safety codes, such as IEC 60079-17 (Table 2).

2. North American Installations

In addition to the material provided in the General section above, the following items apply in North American Installations.

This flow meter has cable and transducer connections approved by Factory Mutual Approvals and the Canadian Standards Association for use in Class I, Division 1, Groups C & D hazardous locations. The installation interconnections shall be accomplished as described in Control Drawing 7510-BE-0118 that is included with every product shipment.

3. EEC Installations

In addition to the items covered in the General section above, the following items apply in EEC installations.

This flow meter has cable and transducer connections certified by Sira as meeting the criteria of the EEC ATEX Directive 94/9/EC effective 30 June 2003 for use in flammable gases and vapors with apparatus groups IIA and IIB and temperature classes from T1 through T6. The apparatus qualifies for an ambient temperature range from -20C to +50C. The IEC Codes EEx ia, Zones 0 and 1, Groups IIA and IIB, Temperature Code T6 apply.

The marking of transducer Models 7601P, 7657, and 7658 are given on drawings 7601AE0196, 7657AE0004, and 7658AE0004 that fully describe the products and their range of applicability including the certificate number Sira 03ATEX2471X.

Since the enclosures are of polymeric material, the user shall take precaution to assure that conditions that would promote the generation of static charge on the enclosure surface be avoided. A caution is provided on the product marking advising to clean with a damp cloth in order to prevent static accumulation.

The manufacturer's local distribution centers will supply operating/installation instructions in English and any other appropriate language in use where the equipment will be installed in the EEC.

The owner of the flow meter should establish a routine for regular inspection in accordance with any relevant National Safety Codes, such as IEC 60079-17.

4. Installations elsewhere

For installations outside of North America and the EEC, the criteria given in the General section and for the EEC above may be used.

Unpacking

When the flowmeter 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.

Remove the flowmeter 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

The flowmeter should be mounted on 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 a power connection, as well as connections to any pressure transmitters and to the site process control system.

The instrument should be mounted vertically and should be attached to a wall or mounting panel capable of safely supporting 100 pounds. (50 kg). Use 3/8 inch (10 mm) lag screws or carriage bolts. If an external PC is used, provide a suitable table or shelf.

If the cabinet is to be mounted out-doors, it should be protected by a sun shield on the top and the south facing side.

Electrical Installation

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

Cable Entry Locations and Installation

All wiring should be brought into the unit through customer-supplied conduit connectors. The cable entries shall be in conformity with the National Electrical Codes for Intrinsically Safe Systems.

Note. In order to reduce the possibility of malfunction of the processor, due to electro-magnetic interference radiated from the various cables, all wiring brought into the unit should be routed to its terminals by the shortest reasonable route. **Spare cable should be looped in the conduit and trunking outside the flowmeter console.**

Recommended cable entries are shown in Figure 4-1. These cable entries will provide for the most direct point to point wiring and provide the required separation between the intrinsically safe and non-intrinsically safe wiring. (2 inches or 50mm). **Do not run intrinsically safe cables with non-intrinsically safe cables in the same conduit.**

The following connections may be required:

- ◆ a.c. or d.c. power supply mains to the electronic unit.
- ◆ a.c. power supply mains for the heater if fitted.
- ◆ Transducer cabling (may require more than one feedthrough)
- ◆ Level sensor inputs if required.
- ◆ 4-20mA Analog outputs
- ◆ Alarm and Totalizer relay outputs.
- ◆ Serial Data. (RS232) to Modem, PC or terminal.

Check that the voltage ratings for the electronics and heater (if fitted) as specified on the label on the connector panel Fig 4-1, are appropriate for the supplies.

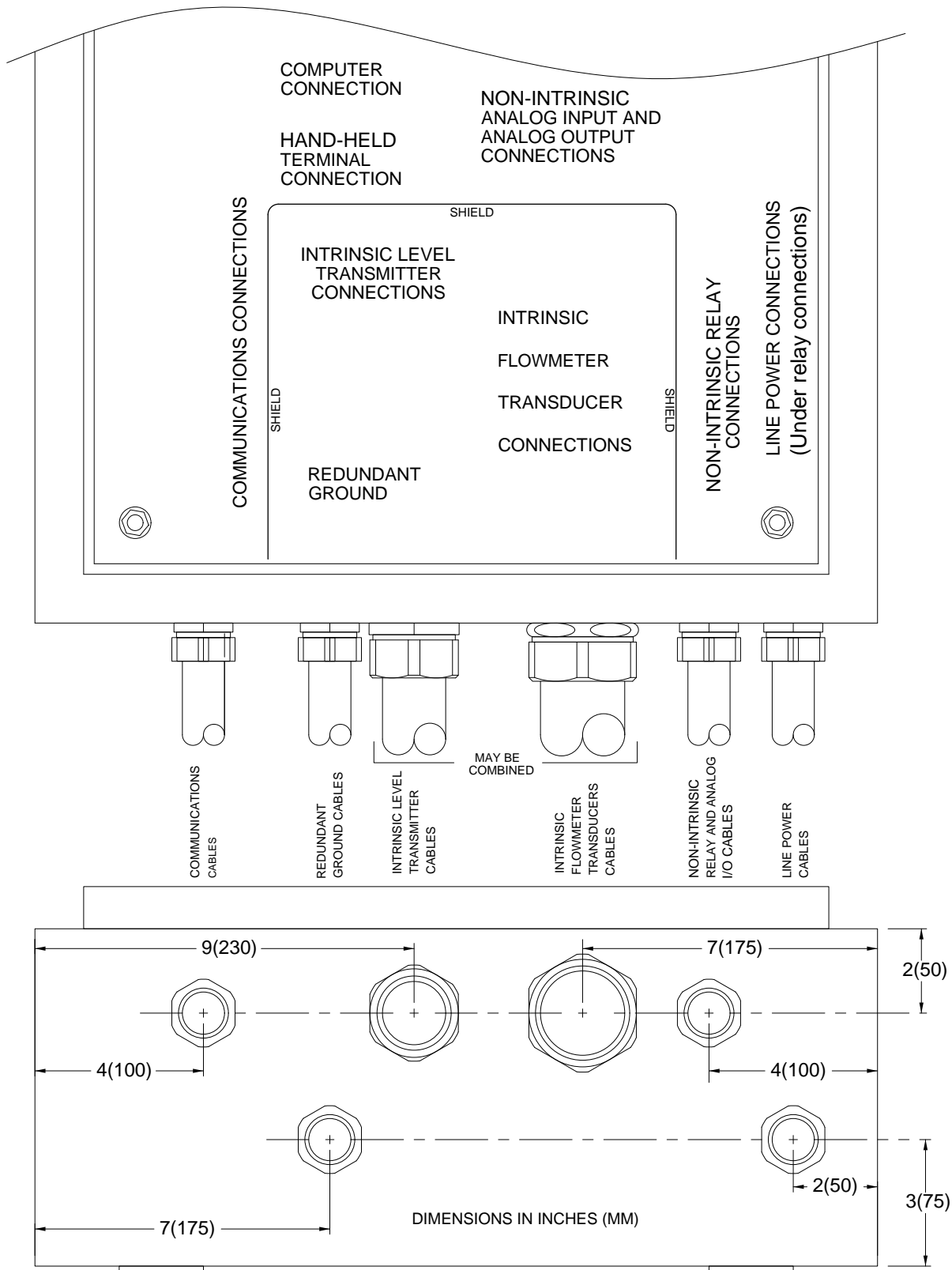


Figure 4-1 Cable Entry Locations

NOTE : DO NOT RUN INTRINSIC SAFE CABLES WITH NON-INTRINSIC SAFE CABLES IN SAME CONDUIT.

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. (1.5mm² minimum)

The unit requires direct mains wiring and should be installed with a separate main power isolator switch near the instrument, in compliance with the National Electrical Code. (or IEC 60079-14 Clause 8)

Power connections are made to two terminal blocks (for electronic unit and for heater if required). The cables shall enter in the bottom of the cabinet at the right hand side towards the rear. To gain access to the terminals it may be necessary to remove temporarily the relay assembly. Connect as shown in Figure 4-2.

For low voltage d.c. power, observe the correct polarity.

For d.c. power 100 to 300 V d.c., the low potential side of the supply should be connected to the “N” terminal.

The “Service Outlet” socket is directly connected to the supply to the electronics, through the fuse and switch. It is for use with low power test equipment such as a PC, oscilloscope or small soldering iron.

See Figure 4.8

Line Fuse Rating: 250V/ 5A.

Earth Ground Connections

Caution. Connection to Earth Ground must be made and tested BEFORE any other connections (other than power) are made. Make sure all signal, computer, transducer, sensor, relay, input or output connections are disconnected at this time. Connections other than ground may result in a false ground impedance measurement. (See Figure 4-3)

Redundant ground connections are made to the various intrinsic safety ground terminal lugs. These wires are not considered intrinsically safe themselves, but rather an intrinsic safety guard. The ground wires may enter through the center of the cabinet if space permits. If space does not permit, move the ground entry point towards the left of the cabinet. Each ground circuit must be connected in such a way that disconnection of one ground circuit does not result in loss of ground to the other ground circuits.

All grounding must meet the wiring requirements of National Electrical Codes for intrinsically safe equipment.

Redundant ground cables must be insulated stranded cables #12 AWG (American Wire Gauge), or 4mm² or larger. Each cable must be individually connected from a redundant ground lug to a point on the site's ground grid network.

The flowmeter transducer redundant ground lug is located next to the power supply indicators on the lower edge of the path selector module. Be sure the cable is squeezed between the compressing copper lug plates, and NOT directly under the screw. (See figure 4-7)

The barrier block redundant ground lug for the water level inputs (if supplied) is located next to the barrier blocks in the upper left corner of the path selector module. If barrier blocks are not installed, then there may not be a barrier block redundant ground lug.

Be sure the cable is squeezed between the compressing copper lug plates, and NOT directly under the screw. (See figure 4-7)

Each ground connection shall be tested to assure a ground impedance in accordance with National Electrical codes for Intrinsically Safe Circuits. When testing a ground connection, other grounds must be disconnected. Refer to figure 4-3 for measurement details.

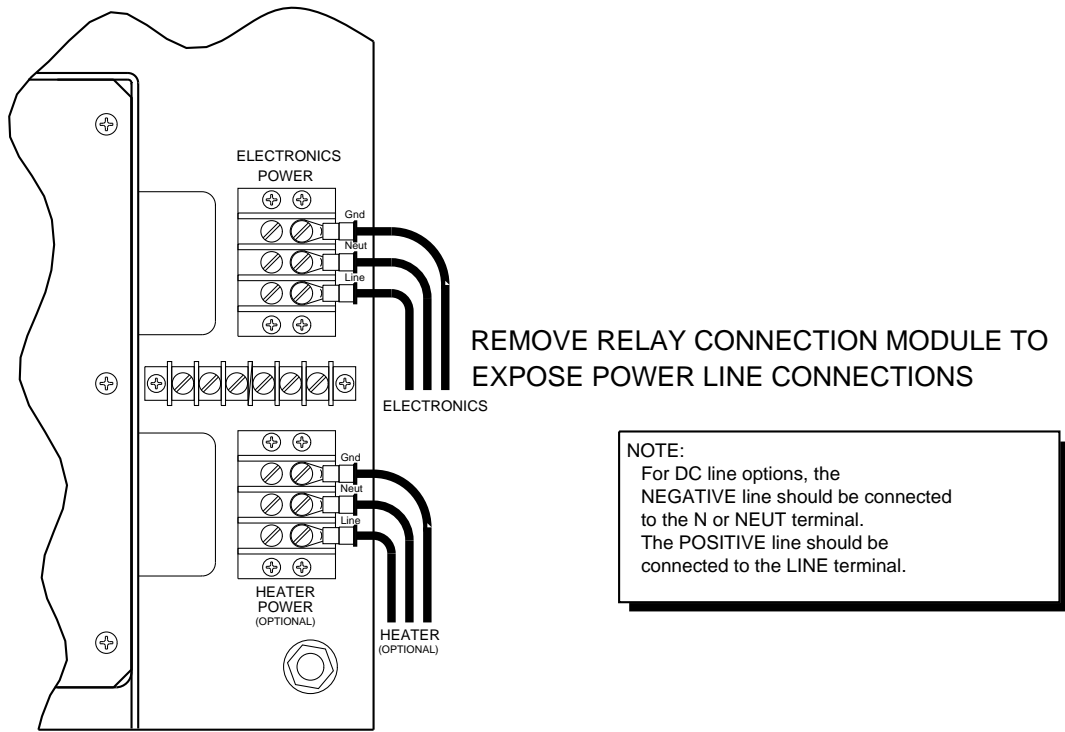


Figure 4-2 Power Line Connections

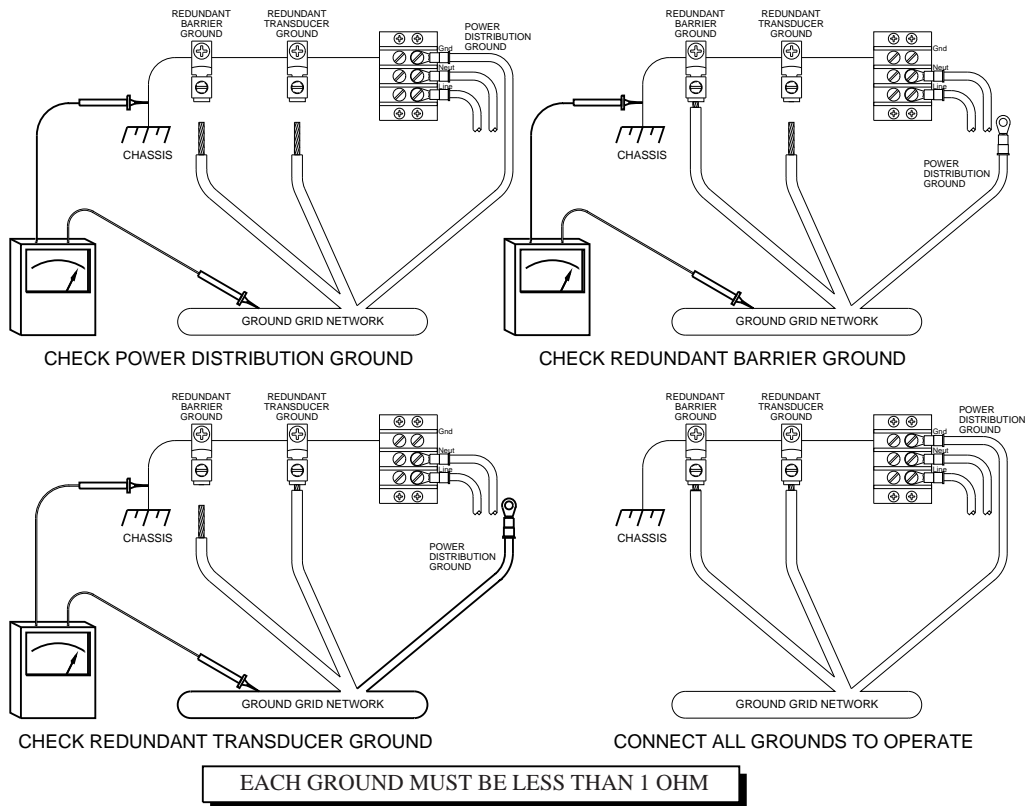


Figure 4-3 Earth Ground Connections

1. Disconnect transducer and barrier grounds. Check the power distribution ground(s).
2. Disconnect barrier and power distribution grounds. Check the transducer ground.
3. Disconnect transducer and power distribution grounds. Check the barrier ground.
4. CONNECT ALL GROUNDS PRIOR TO SYSTEM OPERATION.

Replace the relay connection assembly using three (3) screws.

Intrinsically Safe Transducer Wiring

Both intrinsically safe (IS) flowmeter transducer cables and intrinsically safe (IS) level sensor cables should enter the cabinet in the center directly under the shielded area. IS flowmeter transducer cables may occupy a common entry provided that the cable type is as specified in control drawing 7510-BE-0118

IS level sensor (pressure transmitter) cables may also occupy the same entry as the IS flowmeter transducer cables, or a separate common entry.

(Note: Accusonic Technologies flowmeter transducer cables meet the requirements of drawing 7510-BE-0118.)

DO NOT RUN INTRINSICALLY SAFE CABLES WITH NON-INTRINSICALLY SAFE CABLES IN THE SAME CONDUIT.

Intrinsically safe wiring from the flowmeter cabinet shall be enclosed in bonded conduit and sealed in conformity with National Electrical codes for intrinsically safe equipment.

The number of conduits installed for IS flowmeter transducer cables and IS level sensor cables is determined by the number and size of the cables. When selecting conduit, consider any future plans to upgrade the number of IS flowmeter transducers or IS level sensors.

Large systems may use 16 to 20 flowmeter transducer cables. When calculating conduit size, the Accusonic Technologies jacketed and non-jacketed transducer cables have outside diameters of 0.325 inches and 0.250 inches (8mm and 6.5mm) respectively.

Prior to pulling cables through the conduit, it is best to label each IS flowmeter transducer cable and IS level sensor cable for identification later. Refer to Figure 4-5 or the customer specific drawings at the back of this manual. Label each IS transducer cable with a path number (1-8) and position (A, B).

Note that transducer "A" is the **downstream** transducer and transducer "B" is the **upstream** transducer.

Caution

Double-check the cable numbering and verify sufficient reach before trimming.

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 4-5. 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 4-6.

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 nor with any metal parts on the flowmeter console.

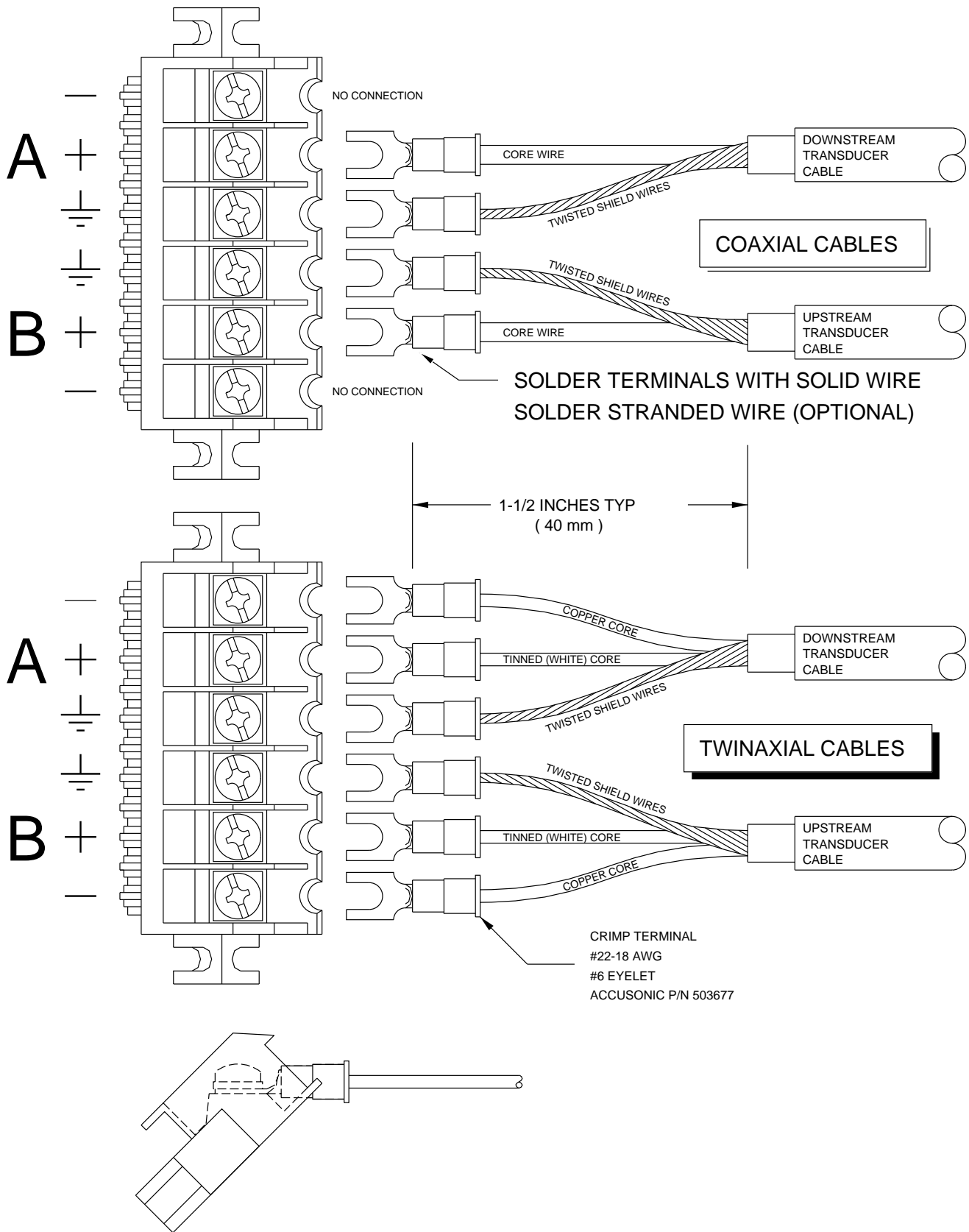


Figure 4-4 Transducer Connections

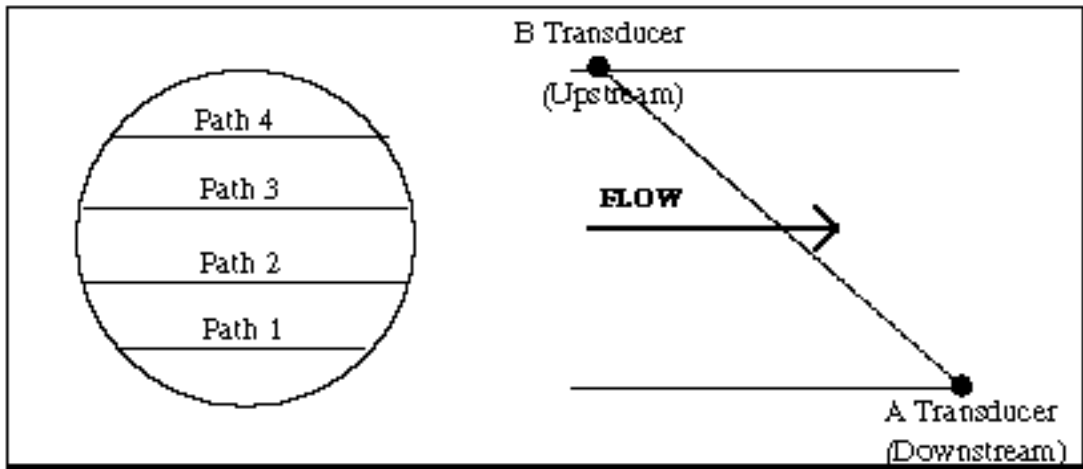


Figure 4-5 Transducer Numbering - Simple Pipe

1. Strip outer sheath back 2 inches (50mm), exposing braided shield.



2. Pierce the braid, snake inner conductors and insulation out.



3. Twist braid tightly, trim to 1.5 inches (35mm), attach forked lug, crimp a
4. Trim inner conductors to 1.5 inches (35mm), strip 3/8 inch(10 mm) of ins
5. Attach lugs, crimp and solder.

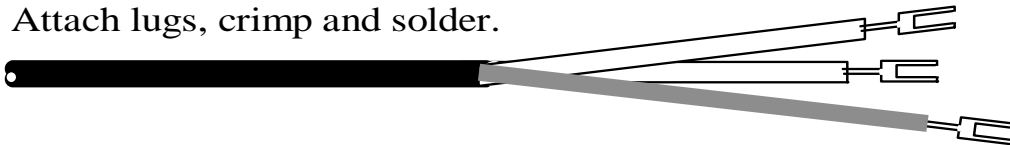


Figure 4-6 Stripping and Terminating the Transducer Cable

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 coaxial cable, test conductor to shield, conductor to ground and shield to ground. For twin-axial cable, test conductor to conductor, each conductor to shield, each conductor to ground, and shield to ground.

Step 3 - Verify Continuity and Cable Identification.

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 coaxial cable, short the connector to shield and measure continuity. 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 Figure 4-4.

Using the thumbscrews, remove the four (4) hold-down clamps, and unplug the terminal blocks. Attach the terminated cables to the terminal blocks as shown in Figure 4-4. Plug the terminal blocks into their respective slots, and refasten the hold-down clamps.

Intrinsically safe wiring shall be routed to stay clear of non-intrinsically safe wiring (i.e. all cables excluding grounds outside the shielded area) by a separation of 2 inches (50 mm).

In addition all intrinsically safe wiring shall stay within the shielded area. Route the cabling to assure that these separation and shielding requirements are met. Use cable ties if necessary. Refer to NEC ANSI/NFPA 70 Article 504, Par 504-30 or other applicable National Electrical codes for intrinsically safe circuits.

Connecting Intrinsically Safe Water Level Sensors

Warning

Only intrinsically safe water level transmitters may be connected to these inputs. Inputs from non-intrinsically safe circuits (such as 4-20mA signals from an electronic unit mounted in the “safe” area shall be connected to the “Non-intrinsic Analog I/O” see Figure 4-9)

The integral barrier blocks (if fitted), provide two terminals for connection to intrinsically safe current loop (4-20 ma) pressure transmitters. Connection of the pressure transmitters to these barrier blocks ensures that the electrical signals emanating from the flowmeter are restricted to intrinsically safe levels.

The signals emanating from the water level transmitter will be limited by the design of that transmitter, and certified accordingly.

No wire preparation is necessary other than stripping back the insulation, and attaching using the screw terminals provided, as shown in Figure 4-8.

Connect the POSITIVE (+) wire to terminal 3; connect the NEGATIVE (-) wire to terminal 4.

Connecting Non-intrinsically Safe Water Level Sensors

Any level sensor providing a 4-20 mA process loop signal can be used by the flowmeter.

After installing the external level sensor according to the manufacturer’s instructions, use a twin-axial, shielded cable to connect the input to the appropriate terminals. See Figures 4-7

On most systems the terminals for the level inputs are located in the right hand upper section of the cabinet as shown in Figure 4-9. The exact layout of the terminals will vary depending on the options provided on the individual flowmeter. The labeling on the flowmeter and the customer specific drawings located at the back of this manual will indicate the terminals to be used. Input impedance for each channel is 100 ohms.

NON-INTRINSIC LEVEL INPUT CONNECTIONS

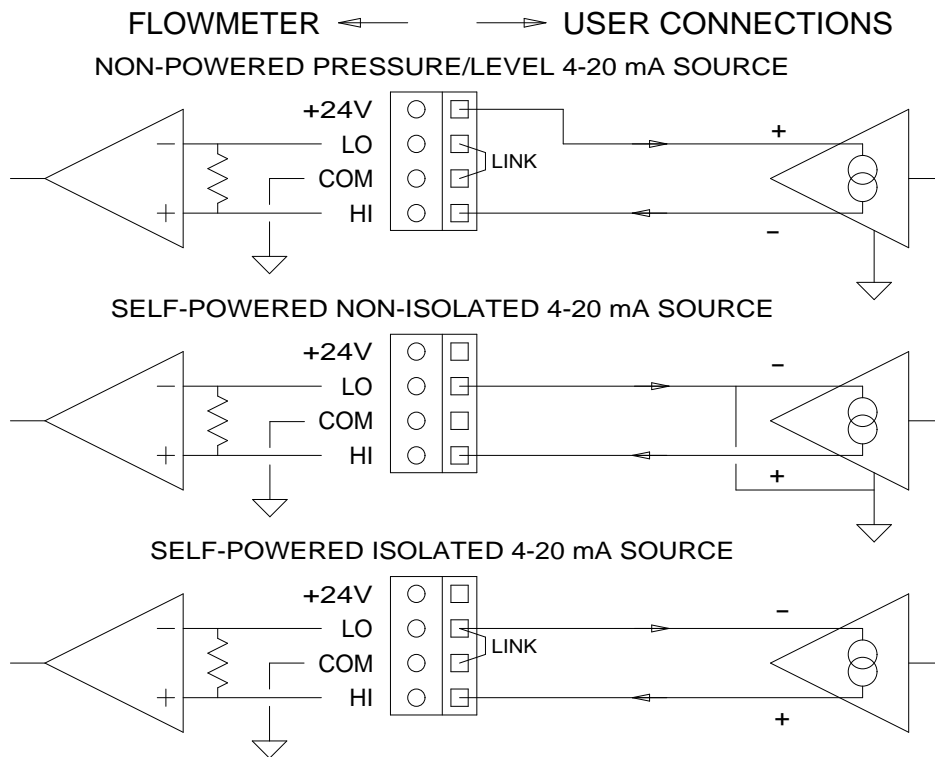


Figure 4-7

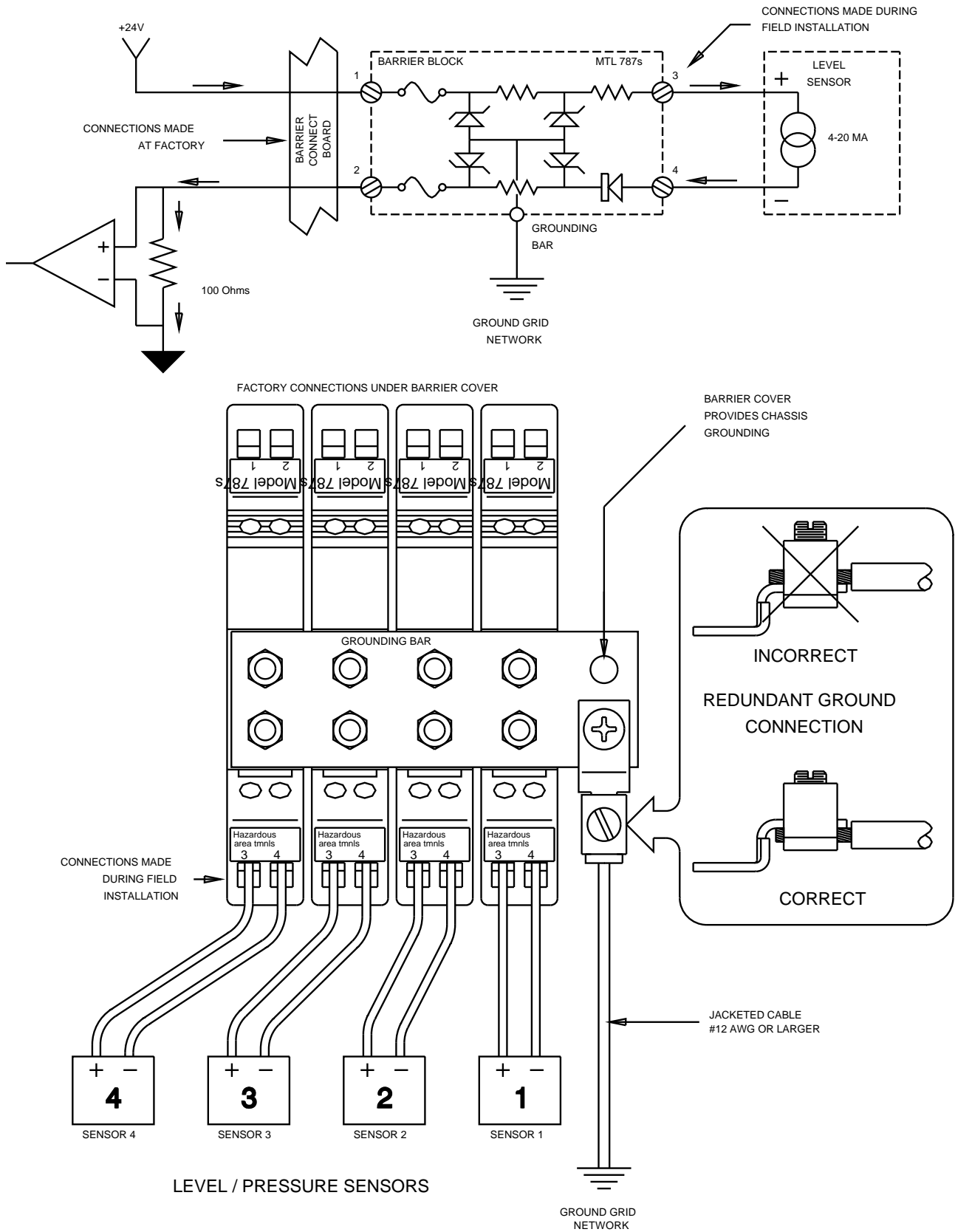


Figure 4-8 Intrinsically Safe Water Level Sensor Connections

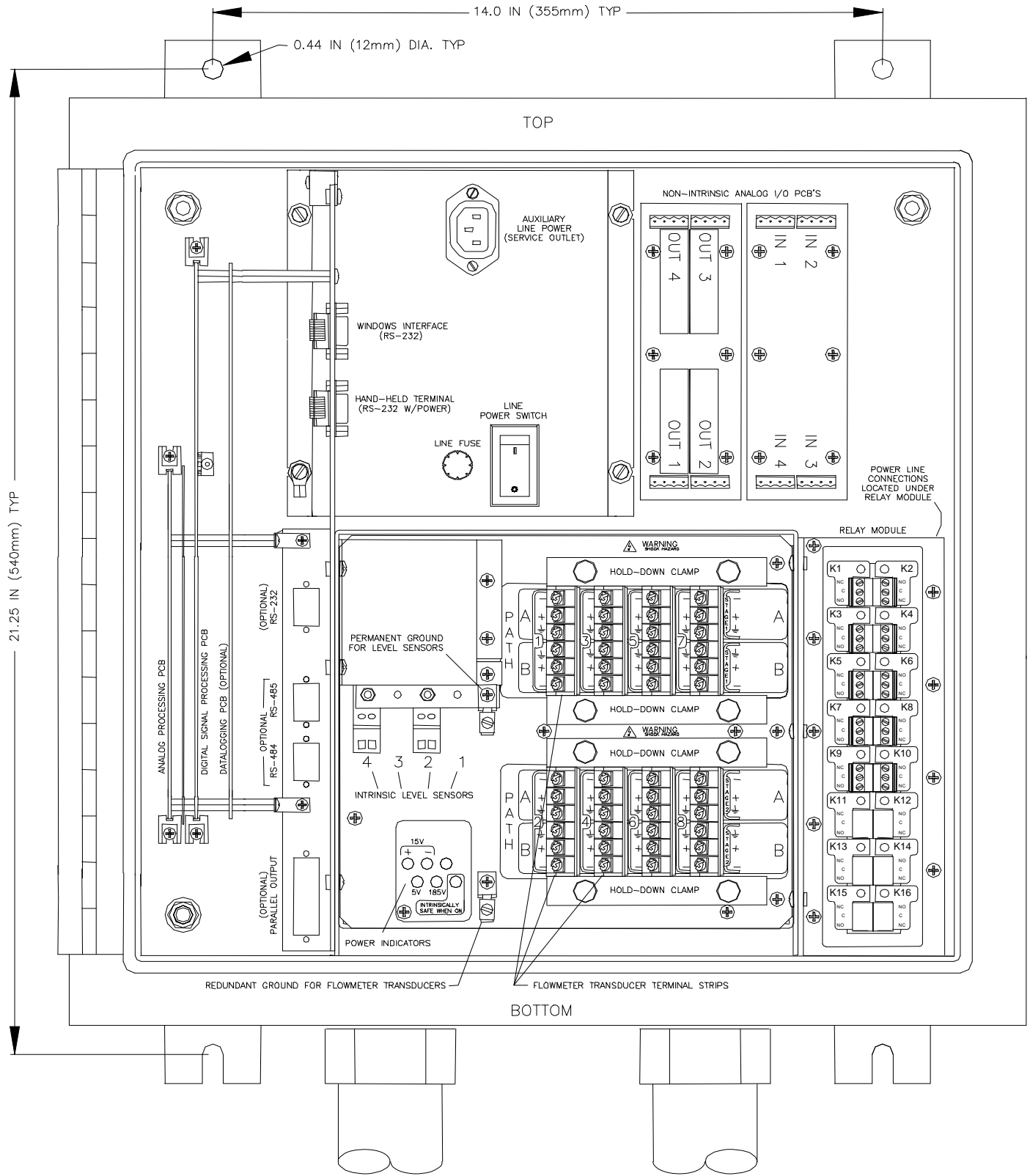


Figure 4-9 Flowmeter Layout

Connecting the Analog Outputs

Connect to the 4-20mA terminals as indicated in Figure 4-8 and any customer specific drawings at the back of this manual.

Connecting the Relay Outputs

The terminals for the relays are located on the extreme right hand end of the console as shown in Figure 4-9. The exact layout of the terminals will vary depending on the options provided on the individual flowmeter. See the Customer Specific drawings at the back of this manual for any custom configurations.

Connecting the Hand-held Terminal

To connect the Hand-held terminal, plug the 9 pin D plug on the lead from the terminal into the socket marked "*Hand-held Terminal.*" Connecting and disconnecting the terminal can be done at any time with the flowmeter powered or unpowered.

On initial power up during the commissioning of the flowmeter, it may be necessary to ensure that the default baud rate of 19200 has been selected. To do this, switch off the power, connect together pins 2 & 3 of the 9-pin D socket marked "*Hand-held Terminal,*" and switch the power back on.

Connecting a PC

A PC can be connected to the socket marked "*Hand-held Terminal*" and used instead of the hand-held terminal. The PC should be running under either a Terminal emulation or a Communications program. A "Null Modem" cable or standard serial cable with a "Null Modem adapter" is required to interconnect between this socket and a PC's serial port. The cable or adapter can be purchased at a PC supply or electronics store.

Alternatively, a PC may be connected to the socket marked "*Windows Interface (RS232)*" for use with special Accusonic programs such as "*Accuflow 7510 Flowmeter Interface*".

Connecting a Modem

For remote access to the flowmeter from an office, via a telephone and modem link, the modem should be connected to the socket marked "*Windows Interface (RS232)*".

A "Null Modem" cable or standard serial cable with a "Null Modem adapter" is required to interconnect between this socket and a PC's serial port. The cable or adapter can be purchased at a PC supply or electronics store.

Note that the flowmeter RS232 port does not support any hardware or software flow control protocol.

The modem must be capable of communicating with the flowmeter at 19200 baud, 8 data bits, no parity, and be set up to auto answer. The modem must contain a data buffer of at least 1.5 k bytes, as well as support error detection and retransmission protocols.

The equipment required at the office consists of a suitable telephone connection, modem (supporting the same error detection and retransmission protocols as the one at the flowmeter) and a PC running the Accusonic program "*Accuflow 7510 Flowmeter Interface*".

Chapter 5

Initial Setup, General Operations

This Chapter describes setup and operation of the flowmeter using the Hand-held Terminal. The alternative method using a PC with “Accuflow” is described in Chapter 6.

(Note: The instrument will not be damaged by entering incorrect parameters.)

Hand-held Terminal, Parameters and Variables

The hand-held terminal, which consists of a display and a keypad, is used to set up the flowmeter, start measurements, and observe the measured variables and status messages. Once the flowmeter 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 flowmeter by entering appropriate values for various parameters. Parameters define the geometry of each meter section and govern the operating modes of the flowmeter. All parameters are defined in Chapter 7.

Variables provide a view of measurements when the flowmeter is in normal “Measure” mode. At the end of this chapter typical display screens of the variables are shown. Chapter 7 contains definitions of the variables.

Menus

Refer to figures 5-1 and 5-2.

After power-up, the flowmeter always returns to the “Measurement” mode, with the display showing Flow. Commands and control parameters are entered into the flowmeter using menus shown on the display. To cause the menus to appear, press the **Esc** key. Some menus display the available options, (e.g., “Pipe” or “Open Channel” mode), 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 **M** (or **Measure**). The shift key is not used. On the hand-held terminal, the cursor keys are:

↑,	or alternatively U on a PC	to move Up.
↓,	or alternatively D	to move Down.
←,	or alternatively L	to move Left.
→,	or alternatively R	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 ↑, **U** displays the previous menu or item in the list
- Pressing ↓, **D** displays the next menu or item in the list
- Pressing ←, **L** displays the same parameter but for the previous path, level or analog output.
- Pressing →, **R** displays the same parameter but for the next path, level 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, (TENV), or the parameter for section 1 is selected.

If the **Right** key is held, the display to the extreme right (Level Input), 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, where the 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, the system will 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.

Pressing the **Measure** key (or **M**) 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 flowmeter is left in any menu, it will automatically return to the Measure mode and store any changed parameters, after a delay of about 60 seconds.

Other key operations

- **Reset** (or # or **S**) causes a system reset. Deletes all parameter changes unless they have been stored.
- In “Measure” mode, the **Left** and **Right** keys 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 is done to omit screen data from appearing on the hand-held RS232 output.
- **Pause** (or **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 flowmeter automatically returns to the Measure mode after 60 seconds or if **P** is pressed again.

The Menus and Commands are:

SYSTEM PAR's:	One list of basic system parameters.
SECTION PAR's:	Up to four parallel lists, one for each flowmeter section.
PATH PAR's:	Up to ten parallel lists, one for each path.
LEVEL INPUT PAR's	Up to four parallel lists, one for each analog Level input.
ANALOG OUT PAR's	Up to eight parallel lists, two for each analog output.
RELAY PAR's	Up to 16 parallel lists, one for each Relay.

Then there are two command menus:

1. MEASURE: To put the flowmeter into the normal “Measure” mode.
2. SYSTEM ACTIONS:
 - STORE ALL PARS: To store parameters once they have been entered correctly.
 - RESTORE ALL PARS: To recall the stored parameters from non-volatile memory.
 - XMIT PARAMETERS: To transmit the complete parameter list to a data terminal.

SYSTEM STATS: Data on the software revision for information only.
Facility to set the real-time clock and baud rate for the Hand-held terminal port..

LOGGING TO FLASH Facility to set the Variables to be logged and the interval between logs.

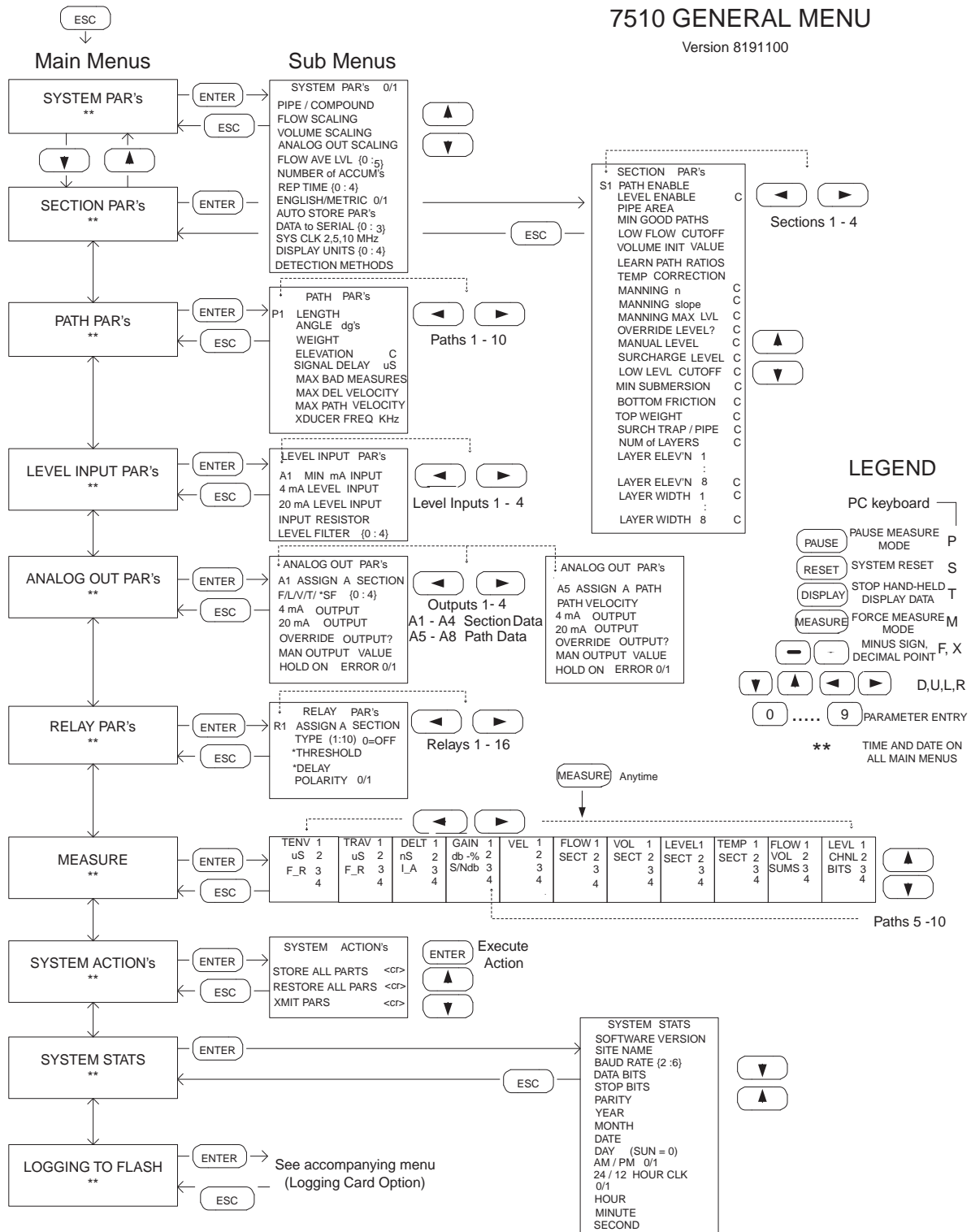


Figure 5-1

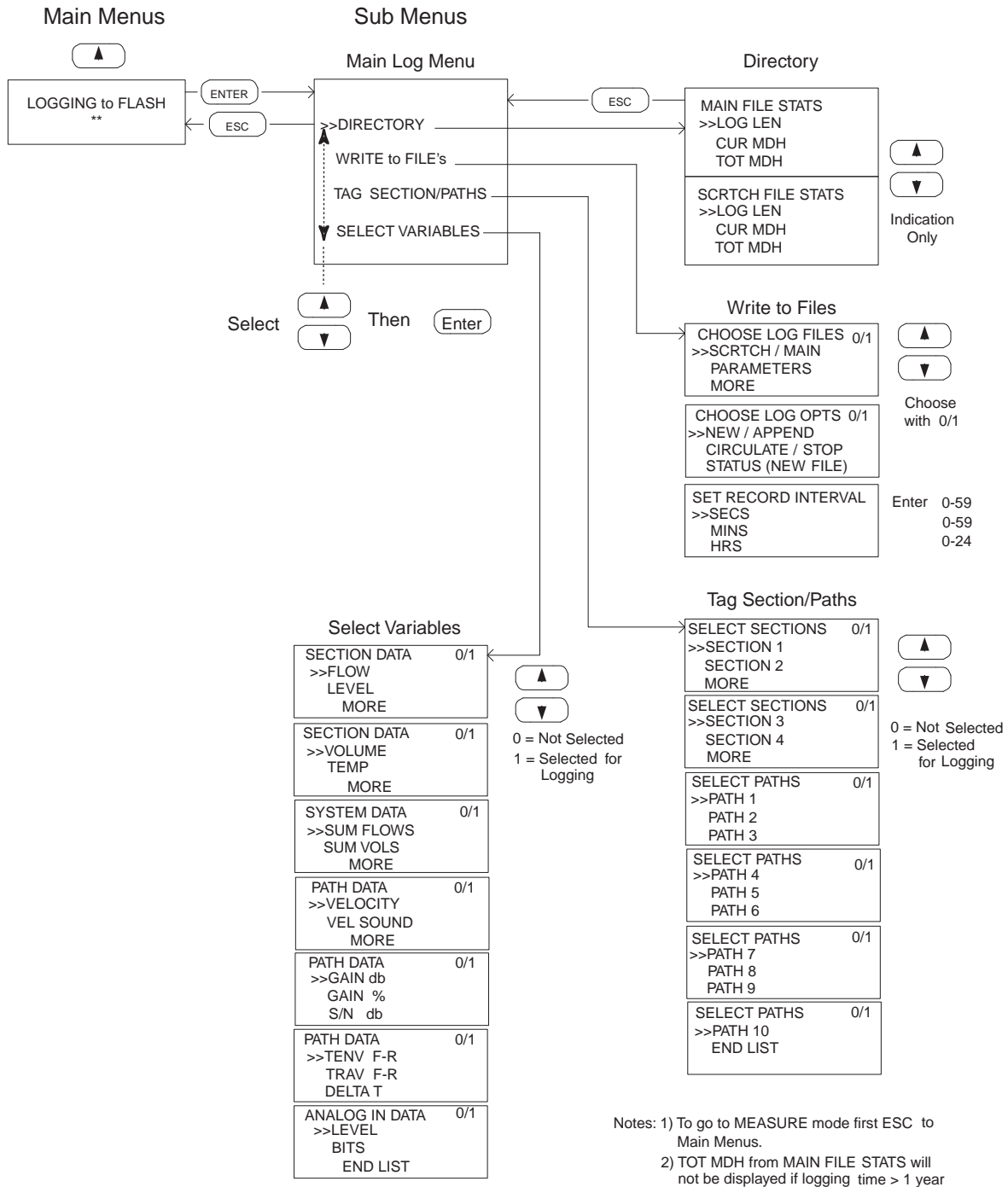


Figure 5-2

Parameter Data Entry

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, or as desired).

The keys on the terminal used for data are:

Numbers 0 through 9, - sign (with F), decimal point (with x)

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.
Press ↑, (U) until you get	SECTION PAR's 09-16-96 14 : 28 : 56	Step up past other lists This is the Section menu heading. Date: Month - Date - Year. Time: Hrs : Mins : Secs.
Press Enter	SECTION PAR's S1 PATH ENABLE CUR = 000000000 ENT =	First parameter in Section 1 Current value, no path enabled Place to enter a new value.
Press 11	SECTION PAR's S1 PATH ENABLE CUR = 000000000 ENT = 11	First parameter in Section 1 Current value, no path enabled The new value. Paths 1 & 2 enable
Press Enter	SECTION PAR's S1 PATH ENABLE CUR = 11 ENT = 11	First parameter in Section 1 Current value, paths 1 & 2 enabled The new value.
Press ↓, (D) twice	SECTION PAR's S1 PIPE AREA CUR = 25.732 ENT =	Third parameter in Section 1 Current value, Place to enter a new value.

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

SECTION PAR's S1 PATH ENABLE CUR = 110000000 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 (M)	FLOW 1 47.54 MN 1 SECT 2 LEVEL<CUTOFF 3 2 4	Flow in Section 1, in Manning mode Flow in Section 2, Level too low. Section 3 not enabled. Section 4 not enabled
--	--	--

Typical Parameter List

(for a circular conduit, 10 ft. diameter)

Note: The parameters for configuring the Data Logger are not included in this listing.

** SYSTEM PARAMETERS **

One list for the whole flowmeter.

PIPE / COMPOUND	0/1	1	
FLOW SCALING		1.0000	
VOLUME SCALING		1000	
ANALOG OUT SCALING		1.0000	Factory setting depending on output module.
FLOW AVE LVL {0 : 5}		3	5 minute averaging for flow.
NUMBER of ACCUM's		1	
REP TIME {0 : 4}		1	1 second
ENGLISH / METRIC	0/1	0	English units (feet)
AUTO STORE PAR's		1	
DATA to SERIAL {0 : 3}		0	
SYSClk 2, 5, 10 MHz		10.000	Paths less than 50 ft (15m)
DISPLAY UNITS {0 : 5}		5	No units displayed.
DETECTION METHODS		0	Automatic

** SECTION PARAMETERS **

Separate list for each section.

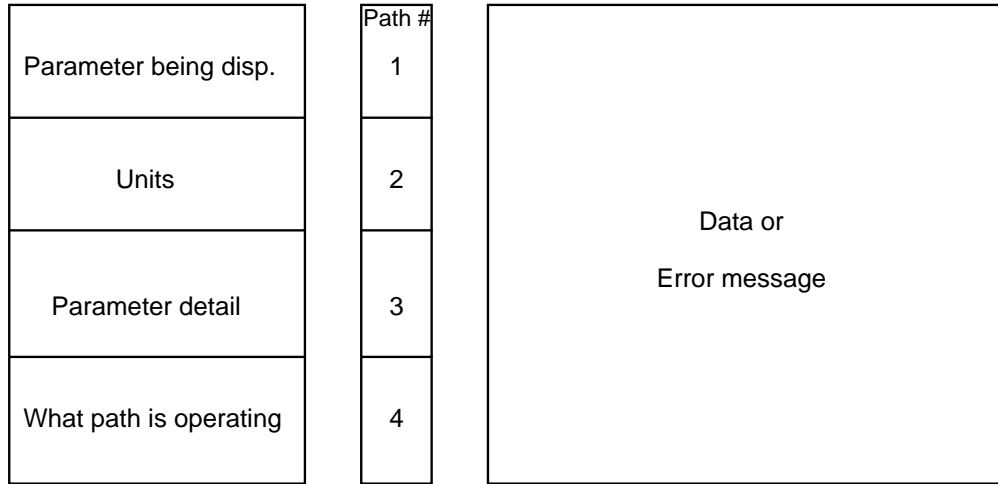
** SECTION 1 **

S PATH ENABLE		1111000000	(Shows a four-path configuration.)
S LEVEL ENABLE	C	1100	Two level inputs are available for use.
S PIPE AREA		78.5	Used only under surcharged pipe mode conditions.
S MIN GOOD PATHS		1	Used only under surcharged pipe mode conditions.
S LOW FLOW CUTOFF		0.1000	
S VOLUME INIT VALUE		0	
S LEARN PATH RATIOS		0	
S TEMP CORRECTION		0	
S MANNING n	C	0.013	
S MANNING slope	C	0.010	
S MANNING MAX LVL	C	4.0000	Manning not used above this level.
S OVERRIDE LEVEL?	C	0	Level obtained from the analog inputs.
S MANUAL LEVEL	C	6.0000	
S SURCHARGE LEVEL	C	10.0000	
S LOW LEVL CUTOFF	C	0.4000	
S MIN SUBMERSION	C	0.3000	
S BOTTOM FRICT'N	C	0.8000	
S TOP WEIGHT	C	0.1	
S SURCH TRAP / PIPE	C	1	Switches to Pipe mode when surcharged
S NUM of LAYERS	C	8	
S LAYER ELEV'N 1	C	0.0000	Note: This set of layer parameters gives a good representation of a circular conduit or pipe of 10 ft. diameter. For a different diameter, multiply each <i>LAYER ELEV'N.</i> and <i>LAYER WIDTH</i> by diameter/10.
S LAYER ELEV'N 2	C	0.5000	
S LAYER ELEV'N 3	C	2.0000	
S LAYER ELEV'N 4	C	4.0000	
S LAYER ELEV'N 5	C	6.0000	
S LAYER ELEV'N 6	C	8.0000	
S LAYER ELEV'N 7	C	9.5000	
S LAYER ELEV'N 8	C	10.0000	
S LAYER WIDTH 1	C	1.1600	
S LAYER WIDTH 2	C	4.7200	
S LAYER WIDTH 3	C	8.2300	
S LAYER WIDTH 4	C	9.9300	
S LAYER WIDTH 5	C	9.9300	
S LAYER WIDTH 6	C	8.2300	
S LAYER WIDTH 7	C	4.7200	
S LAYER WIDTH 8	C	1.1600	

** PATH PARAMETERS **		Separate list for each Path.
** PATH 1 **		
P LENGTH	12.000	
P ANGLE	dg's 45.000	
P WEIGHT	0.1382	Used in surcharged pipe mode conditions
P ELEVATION	C 0.95	Elevation used in non-surcharged conditions
P SIGNAL DELAY	us 12.000	
P MAX BAD MEASURES	10	
P MAX VEL CHANGE	1.0000	
P MAX PATH VELOCITY	10.000	
P XDUCER FREQU	kHz 500.00	
** LEVEL INPUT PARAMETERS **		Separate list for each input. Not used in "Pipe" mode.
** LEVEL 1 **		
A MIN mA INPUT	4.100	
A 4mA LEVEL INPUT	0.0000	
A 20mA LEVEL INPUT	12.000	
A INPUT RESISTOR	100.00	
A LEVEL FILTER {0:4}	2	
** ANALOG OUTPUT PARAMETERS **		Separate list for each output.
** ANALOG OUT 1 **		A1 - A4 Section data for outputs 1 - 4
A ASSIGN A SECTION	1	A5 - A8 Section data for outputs 1 - 4
A F/L/V/T/*SF {0-4}	0	Only one type of data can be assigned to each output
A 4mA OUTPUT	0.0000	I.E. If A1 assign a section = 1, then A5 assign A path
A 20mA OUTPUT	1000.0	must be = 0.
A OVERRIDE OUTPUT	0	
A MAN OUTPUT VALUE	0	
A HOLD ON ERROR 0/1	0	
A 4/0 mA ERROR 0/1	0	
** RELAY PARAMETERS **		Separate list for each output.
** RELAY 1 **		
R ASSIGN A SECTION	2	
R TYPE (1 : 10) 0 = OFF	1	Section Flow > Max 1
R * THRESHOLD	160	
R * DELAY	5	
R POLARITY 0/1	0	
** SYSTEM STATS **		
SOFTWARE VERSION	8191100	
SITE NAME	Special	A name enterable only via Accuflow
BAUD RATE	6	19200 baud
DATA BITS	8	
STOP BITS	1	
PARITY	0	
YEAR	98	
MONTH	07	
DATE	20	
DAY (SUN=0)	1	
AM / PM 0/1	1	
24/12 HOUR CLOCK 0/1	0	
HOUR	14	
MINUTE	28	
SECOND	56	

Display of Variables

All the display screens for the Variables have the following format.



Variables are displayed only when the flowmeter is in “Measure” mode. Immediately after power up, the flowmeter will enter the “Measure” mode, and display whichever display had been selected when the flowmeter was last put into “Measure” mode..

When displaying variables concerning Path data (TENV, TRAV, DELT, GAIN, VEL), the Up and Down cursor keys enable the screens for the higher numbered paths (4 through 8) to be displayed.

Examples of typical screens from the most left (TENV) to most right (Level) are:

<p>TENV 1 1087 1089 us 2 1135 1138 F_R 3 2 4</p>	<p>Forward and Reverse Envelope times for path 1 in μs Indication of units of display μs, Envelope times for path 2 Indicates that first value is Forward time, second is Reverse time blanks indicate path 3 and path 4 are not enabled</p>
<p>TRAV 1 1079 1081 us 2 1128 1031 F_R 3 2 4</p>	<p>Forward and Reverse Signal travel time through water for path 1 in μs Forward and Reverse Signal travel time through water for path 2 in μs As for TENV As for TENV</p>
<p>DELT 1 2107 2215 ns 2 3471 3385 I_A 3 2 4</p>	<p>Instantaneous and averaged Travel time difference for path 1, in ns. Indication of units of display, nano secs. Travel time difference path 2, Indicates first value is instantaneous, second value is averaged. As for TENV</p>
<p>GAIN 1 10 97 38 dB-% 2 27 103 22 S/NdB 3 2 4</p>	<p>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 after P, indicates which paths are operating,</p>

VEL	1	8.7543	4765	E	Water velocity path 1, Velocity of sound path 1. Detection method.
	2	9.7564	4768	Z	Water velocity path 2, Velocity of sound path 2. Detection method.
					Path 3 not enabled
2					Path 4 not enabled
FLOW	1	25.583	MN	1	Flow in section 1, Manning formula in use, Level #1 value used
SECT	2	157.48	SP	F 4	Flow in section 2, Single Path Integration, Pipe Full, Level #4 used
					Section 3 not configured
2					Section 4 not configured
VOL	1	2367854.			Volume Section 1.
SECT	2	985.3731			Volume Section 2.
					Section 3 not configured
2					Section 4 not configured
LEVEL	1	3.8682	MN	1	Arbitrated Level value for section 1, using Level input # 1.
SECT	2	16.793	SP	F 4	Arbitrated Level value for section 2, using Level input # 4.
		3 0.0000		4094	Section 3 Level not configured
2		4 0.0000		4094	Section 4 Level not configured
TEMP	1	56.789	MN	1	Water temperature in Section 1
SECT	2	57.234	SP	F 4	Water temperature in Section 2
FLOW		183.06			The sum of the Flows in Section 1 & 2
VOL		2368839.			The sum of the Volumes in Section 1 & 2
SUMS					Indicates that this display is for the sum of the section data.
LEVEL	1	3.8682		750	Level input #1 value, Analog input = $750/4095*50 = 9.157$ mA
CHNL	2	0.0000		217	Level input #2 value, Analog input = $217/4095*50 = 2.65$ mA
BITS	3	10.005		4094	Level input #3 value, Analog input ? 50 mA
2		4 16.793		1437	Level input #4 value, Analog input = $1437/4095*20 = 17.54$ mA

Note

*The figures for Analog Input assume an input load of 100Ω
In "Pipe" mode, the Level displays have no meaning*

Serial Data Format on RS232 Hand-held Communication Port

When the System Parameter *Data to Serial* is set to 1, the data stream is output each measurement cycle. Data are only output for sections, stages or paths which are configured.

A typical data string for a dual section flowmeter with Terminal Display Off (**Display** or **T** pressed).

Note: 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.

LDF125583#LDF2157480#LDO1183435#LD02746400#LDS14538#LDS20#LDS310005#LDS614793#LDT12-
#LDT24#LDE153#LDE248#LDV110006#LDV2263#LDG116#LDG227#LDC14798#LD4796#LDB194#LDB2-
98#

where

LDF125583#	Log Data Flow Section 1	= 25.583	
LDF2157480#	Log Data Flow Section 2	= 157.480	
LDO1183435#	Log Data Flow Section 1	= 183435	
LDO02746400#	Log Data Flow Section 2	= 746400	
LDS14538#	Log Data Level #1	= 4.538	
LDS20#	Log Data Level #2	= 0	
LDS310005#	Log Data Level #3	= 10.005	
LDS416793#	Log Data Level #4	= 16.793	
LDT12#	Log Data Integration Type Section 1	= 2	See below
LDT24#	Log Data Integration Type Section 2	= 4	See below
LDE153#	Log Data Temperature Section 1	= 53	
LDE248#	Log Data Temperature Section 2	= 48	
LDV110006#	Log Data Velocity Path 1	= 10.006	
LDV2-263#	Log Data Velocity Path 2	= - 0.263	Reverse flow.
LDG116#	Log Data Gain Path 1	= 16dB	
LDG227#	Log Data Gain Path 2	= 27dB	
LDC14798#	Log Data Velocity SND Section 1	= 4798	
LDC24796#	Log Data Velocity SND Section 2	= 4796	
LDB194#	Log Data Gain Path 1	= 94%	
LDB298#	Log Data Gain Path 2	= 98%	

The types of Integration are:

- 0 = No integration, section failed
- 1 = "Pipe"
- 2 = Manning
- 3 = Single path
- 4 = Full
- 5 = Multi-path.

RS232 signals 19200 baud, 8 data bits, no parity, 1 stop bit, no handshaking protocol.
The baud rate may be changed by changing a parameter under SYSTEM STATS.

Serial Data Formats on Optional RS232 Communication Port 3

When the System Parameter *Data to Serial* is set to 2, the following data stream (called “Argus”) is output every 30 measurement cycles.

T ±FFFFF SSSS TTTT UUUU EEEE + 00000 00

Where ±FFFFF is the flow x 100, SSSS arbitrated level x 1000, TTTT is Level one x 1000, UUUU is Level two x 1000.

When the System Parameter *Data to Serial* is set to 3, the following data stream (called “Drax”) is output every measurement cycle.

±vvvv ±www ±xxxx ±yyyy aaaa bbbb cccc dddd

Where the first four fields are the water velocities x 1000, and the second four are the velocities of sound for paths 1 to 4. All the values are instantaneous, with no filtering.

Display of Variables on the Optional LCD

Depending on the number of sections which have been configured, different display formats are provided.

If only one section is configured in “Compound” mode, the display format can be chosen to be either:

FLOW	25.583	l/s
VOL	2367854.	Cm

or:

FLOW	25.583	l/s
LEVEL	3.8682	m

The selection is made depending on the display screen chosen for the Hand-held terminal, when the measure mode is entered.

To select “Flow and Volume” to be displayed, from Measure mode, select any of the Hand-held terminal screens, then press **Esc** then **Measure**.

To select “Flow and Level” to be displayed, from Measure mode, select the “Level” screen on the Hand-held terminal, then press **Esc** then **Measure**.

If only one section is configured in “Pipe” mode, the display format is always of Flow and Volume.:

The units of Flow and Level are selected by the parameter *DISPLAY UNITS* in the System menu.

If two sections are configured in “Compound” mode, the display format is:

FW	25.583	157.48	l/s
LV	3.8682	16.793	m

If two sections are configured in “Pipe” mode, the display format is:

FW	56.987	157.48	l/s
VL	67854.	985.37	Ml

If three or four sections are configured in either “Compound” or “Pipe” mode, the display shows the variable selected for display on the Hand-held terminal. (Flow, Volume, Level or Temperature).

The variable and units are shown to the left of the screen.

The values of the variables for sections 1 & 2 are on the top row, for sections 3 & 4 on the bottom row.

FW1	25.583	2	157.48
1/s 3	67.543	4	98.765

Operation of Optional Data Logging

The integral Data Logger may be configured to store any of the flowmeter variables. It can be setup through the hand-held terminal, or the AccuFlow Windows® interface. The data may be retrieved only through use of AccuFlow.

Operation through AccuFlow is described in Chapter 6, while the hand-held terminal parameters for the Data Logger are described in Chapter 7.

The method of setting the Data Logger parameters using the Hand-held terminal differs from that for setting most other flowmeter parameters, in that all the settings (except the time interval) are choices of whether to select or not to select a particular option. To select an option, simply press the **1** key; to omit the option, press the **0** key.

To configure the logger, escape from Measure mode and go down through the various menus using the ↓ key to the last menu “Logging to Flash”. Press **Enter**.

Four menus will be presented:

DIRECTORY	Gives information on the length of the log and the time before the log file is full.
WRITE TO FILEs	Offers choices of which file to use (Scratch or main), other options and the “ <i>RECORD INTERVAL</i> ” or period between logs.
TAG SECTION / PATHS	Offers choices of which Sections and Paths are in use and for which data are required to be logged.
SELECT VARIABLES	Offers choices of the variables to be logged for the previously selected Sections and Paths.

To select a particular menu, use the ↑ or ↓ keys to move the cursor (>>) to the desired menu, and press **Enter**.

To select a particular item, use the ↑ or ↓ keys to move the cursor (>>) to the desired item, and press **1**.

To set the *RECORD INTERVAL*, set the time in seconds, minutes and hours by typing in the required figures for the units of time pointed to by the cursor.

Notes: The **Enter** key is not used for these submenus.

The flowmeter will not automatically return to the Measure mode from the LOGGING TO FLASH menu.

To return to Measure and (if set) to log data, first exit to the main menu by pressing **ESC**, and then press **Measure** or the **M** key

Chapter 6

“Accuflow” Windows Interface

This Chapter describes the alternative method of setting-up and operating the flowmeter using the Windows interface.

(Note: The instrument will not be damaged by entering incorrect parameters.)

Application Overview

The Accusonic 7510 Flowmeter Windows application provides a user friendly interface to the flowmeter. From the application, the user can enter and examine flowmeter parameters, control the flowmeter measurement cycle, graph real time or historical data, and conduct diagnostic tests.

A wizard interface is provided to make common tasks easier by providing step-by-step instructions. From the wizard the user can load in the last used configuration, open an existing configuration, look at previously logged data graphically, connect to a flowmeter and begin measurements, or setup flowmeter parameters through use of the setup wizard.

The main application window provides the user with the ability to setup system and flowmeter parameters, control the flowmeter measurement mode, display graphical data, manage data logging operations, and use a variety of flowmeter diagnostics.

Wizard Interface

The wizard interface provides step-by-step instructions to the user to accomplish ordinary tasks. Each step will consist of a dialog window that will “ask” the user for information about what is required, or about setup parameter information. Every step has an available help button, and pressing F1 will bring up context sensitive help on the specific step. The main wizard interface provides buttons for the following tasks:

Receive Parameters from Flowmeter

When this button is selected, the application in the PC will connect with the flowmeter and request its parameters. After having successfully received the parameters, the user is given the option of saving them in a file.

Send Parameters to Flowmeter

When this button is selected, the application in the PC will send the parameters contained in the PC to the flowmeter. The parameters may have been from a file that was opened or a configuration that was created using the wizard. Any parameters the flowmeter had stored will be overwritten.

Setup Wizard

The setup wizard provides step-by-step instructions to setup all the parameters necessary to operate a flowmeter. The setup procedure is broken down into the following steps, each of which has its own dialog window:

Firmware Version Window

In this setup wizard window, the user inputs the firmware version of the flowmeter that is being interfaced. Inputting the correct firmware version will ensure proper parameter transfer.

Sections Window

In this setup wizard window the user enters the number of sections that the flowmeter will be measuring. A section is any single pipe, conduit, channel, river, etc. where flow is to be measured. So if there are two pipes,

there are two sections. In addition, the user will enter the type of section, open channel, pipe, or compound. An open channel is a section that is never full, a river or canal, for example. A pipe is a section that is always full, like a water main. A compound section can be full at some times, but not full at others. Sewers are usually compound sections.

Units of Measure

In the measurement wizard window, the user selects the units in which flow and volume are to be measured and reported. Standard choices are provided for flow and volume, but the define buttons give the user the option of defining units that are not on the list. After selecting the define button, the user is asked for a unit name, and a scale factor. The unit name will be displayed on graphs and future menu choices, and is added to the list of standard units. The scale factor is a value by which the flow or volume measurements are to be multiplied in order to convert the measurements to the desired units. The flowmeter measures flow in cubic feet per second (CFS) and volume in cubic feet when English units are chosen, and measures flow in m^3/s and volume in m^3 when metric units are chosen. The scale factors must be chosen to convert from these units. For example, To convert the flow measurement units to m^3/hour , the scale factor is 3600. This factor essentially converts seconds to hours.

In addition, the flow averaging period is entered. The flow averaging period is the amount of time that the flow measurements will be averaged over.

Path Enable Window

In the path enable wizard window, the user will assign paths to a section by using the path checkboxes. At least one path must be enabled to move on. Then the low flow cutoff may be entered. If the absolute value of the computed flowrate is below the low flow cutoff, the flow is set to zero.

If the section always runs full (pipe mode), then the window will also ask for the section's shape and size, as well as the minimum number of good paths and whether learn path ratios should be on. The minimum number of good paths is the number of good path measurements which must be present to calculate flow. The contribution to the flow calculation from any failed paths will be provided by the replacement routine. The default is 4.

Learn path ratios enables a "learning" run that records information that is used in the case of path failures. In the event of one or more paths failing, a routine is implemented which enables flow to be computed from the remaining good paths. The contributions towards the flow measurement from the failed paths is replaced by a figure generated from the remaining good paths, weighted by the historic flow contribution ratios for all the paths. A table of time-averaged historic flow components is recorded during commissioning, involving about 1000 readings. The record is made automatically by the flowmeter in what is termed a "learning" run. The "learning" routine is implemented by checking the Learn Path Ratios checkbox. The learning run may be stopped by unchecking the checkbox, or allowing the flowmeter to complete the 1000 readings.

If the section does not always run full (open channel or compound), bottom friction and top weighting coefficients are to be entered. The bottom weighting and top weighting coefficients are used to extrapolate the velocities from the lowest and highest paths to the section bottom and/or top (or water surface).

Section Shape

For sections that do not always run full (open channel or compound), the section shape is requested. The section shape window gives two choices, round and other. Round is for circular pipes (they are assumed to be perfectly circular). Other is for sections that cannot be described so easily.

Round

After selecting round for the section shape, the wizard asks for the radius of the pipe. This should be the inner radius. When "Round" is selected, all layer data are automatically computed by the wizard.

Other

After selecting “other” for the section shape, the wizard asks for the number of layers, their elevations and widths. The layers describe the size and shape of the section. These should be available from the survey data taken at installation.

Flow Calculation When Level is Surcharged

For compound sections only, the flow calculation method when the level is surcharged is requested. In this wizard window, the user selects the integration method to be used when the section is surcharged (running full). For more information about integration methods, please see Chapter 3. The default for round pipes is pipe integration. For other shapes, the default is trapezoidal integration.

Level Input Enable Window

For sections that do not always run full (open channel or compound), the level input enable window is displayed. In this wizard window, the user enables the analog inputs for level (stage) measurements by selecting the appropriate checkbox for the section. For pipe and compound sections, the user is also asked for the level at which the section is surcharged (full). The user should also enter the level below which flow is defined as zero. There is also an option to enter a manual value for the level input, overriding the analog inputs. If override analog level input is checked, an entry box becomes visible for a manually entered value. The value entered will override all flowmeter calculated level values, and the flowrate will be calculated on the basis of the manually entered level. This option may be used for testing purposes.

Level Input Setup

For sections that do not always run full (open channel or compound), the level input setup is requested. In this window the user enters the level values for 4 and 20 mA. For these values the user should enter the elevation of the water surface at which the analog input is 4.0 or 20.0 mA. For example, if at 10.0 feet, the analog input is 20.0 mA, enter 10.0 for “Level at 20 mA”. This value may be in the range of -50 to 50. Also the level filtering period should be entered. This is the period, in measurement cycles, that the level inputs will be averaged over. For example, if the measurement update rate (repetition rate) is 2 seconds, and the level filtering period is 15 cycles, then the averaging period is approximately 30 seconds. The tabs at the top of the “notebook” window can be clicked to switch from one input to another.

Manning Parameters

For sections that do not always run full (open channel or compound), the Manning equation parameters are requested. In this wizard window, the user is asked if they wish to use the Manning formula, and if so, for the parameters necessary. For more information on the Manning formula, see Chapter 3 .

Path Setup

This window prompts the user for path parameters. The path length, angle, and elevation should be available from the survey data. The transducer model number should also be available in the as built data. If a new transducer model number needs to be added, select the “add to list” button. After that, a transducer model number, frequency, and signal delay must be entered. Elevations are not required for sections that always run full, and are not displayed.

Output Setup

In the output setup window, the user can define what section a given 4- 20 mA analog output is assigned to, what type of data is output, the output range and the output under error conditions. An output can be assigned to any active section, and can reflect flow, level, average velocity, temperature, or total flow data. In the 4 mA boxes the user should enter the value of the variable chosen for the analog output for which an output of 4.0 mA is desired. For example, if flow has been chosen for output, and the units are m^3/s , enter -1.5 if it desired to have a 4.0 mA output at $-1.5 m^3/s$. 4.0 mA is the lowest valid output. A similar procedure should be used for the 20 mA entry. It is acceptable for the 4 mA output to represent a variable value that is either greater than or less than that of the 20 mA output

Under conditions where the chosen variable is below the selected range, 4 mA will be output. Under conditions where the chosen variable is over the selected range, 20 mA will be output. If a fault occurs, the output will either be held at the last known good value, or be set to 4 mA, depending on the choice made in the “On Error” box.

There is also an option to enter a manual value for the analog output, overriding the calculated outputs. If override analog output is checked, an entry box becomes visible for a manually entered value. The value entered will override all flowmeter calculated values, and the output current will be calculated on the basis of the manually entered value. This option may be used for testing purposes.

Relay Setup

In the relay setup window, the user can define what section a given relay is assigned to, what function the relay has, the threshold value, the polarity, and the delay before operation. Relays can be used as indicators that the section flow is over a threshold value, the section level is over a threshold, the sum of all the section flows is over a threshold, the section has failed, path substitution is active (pipe mode only), or as a section or sum of sections volume totalizer. For those functions that require it, the threshold value is entered in the appropriate units. The user can also define what polarity the relay is to be when operated. The delay before operation is in measurement cycles, so that if the measurement update rate (repetition rate) is 2 seconds, and the delay is 3 cycles, then the delay is approximately 6 seconds.

Open Setup

This choice allows the user to open a previously saved configuration file. A standard open file dialog box is shown, from which the user can select the desired file. Once the file is loaded, it can be used for flowmeter measurements, or can be modified.

Review Historical Data

The review historical data option allows the user to view graphs of previously logged data. When the button is selected, a flowmeter ID and data range window is displayed. In this window, the user selects the ID of the desired flowmeter. The start and stop date calendars will automatically update to show the full range of logged data for that flowmeter. The user can use the calendars to select a smaller range by clicking the arrows at the top of the calendars to change the month, and by clicking the desired date. The time is selected by using the list boxes below the calendars.

Once the ID and date/time range are selected, the user can choose which graph to be viewed. The *view data by variable* graph will display either flow or level for multiple sections. For example, in the view by variable graph, the user can graph flow for sections 1 through 4. Then they can select level for those sections. Flow and level cannot be graphed together on this view, however. The *view data by section* graph allows the user to look at flow, level and velocity for an individual section. Because there can be up to 10 velocity data curves in a section, the velocity graph is separate from the *flow/level* graph. If only one graph is selected, it will appear as a full page. If both flow/level and velocity are selected, they will share the screen. Please see “using graphs” for more information about their features.

Connect / Measure

If Connect / Measure is chosen, the application will connect to the flowmeter, and upload its parameters. The uploaded parameters will be used in building the graph. After parameter loading, measurements will begin, and the graph will start to display data. Initially, there is a delay in acquiring the data, and graph options are disabled. They are re-enabled when the initial acquire period is complete. Please see “using graphs” for more information about their features.

File Menu

The file menu provides access to basic file management operations.

File / New

File / New starts the setup wizard in order to allow the user to create a new configuration file. The configuration initially contains only the default values.

File / Open

Choosing File / Open opens an existing configuration file. When this menu choice is selected, the standard windows *open file* dialog box will appear with the current directory and *.cfg configuration files selected as defaults. Making a selection in this dialog and selecting OK will load in the selected configuration file. This will overwrite any previously loaded configuration. Once the file is loaded, it can be used for flowmeter measurements, or can be modified.

File / Save

This allows the user to save the currently loaded configuration file, while giving it a new name. An existing file name may be chosen, or a new name created. Choosing File / Save As opens the standard *save file* dialog box which is similar to the *open file* box described above.

File / Print

The File Print item allows the user to print the contents of the configuration file. This can be useful for record keeping. The print uses the Windows default printer, unless it is changed using the Setup button.

File / Exit

This item exits the flowmeter program.

Configure Menu

The configure menu allows the user to make modifications to the currently loaded configuration. The configure menu has the following choices:

Communications

The communications configure menu allows the user to make modifications to the communications setup. The flowmeter has particular communications formats, which are reflected in the defaults provided here. In most cases, the only two parameters that should require modification are the Comm. port number and the maximum consecutive communication errors.

Comm. Port

The user chooses the communications port that is connected to the flowmeter.

Maximum Consecutive Communication Errors

This allows the user to enter the maximum consecutive number of communication errors that are to be tolerated without declaring a failure. The default is 3. A single communication error may take up to 10 seconds to confirm.

Dial Modem

The dial modem selection allows the user to choose a modem and a phone number, and establish a modem connection. After dial modem is selected, the user must choose a modem to use from the provided list. If “None” is chosen, that serial comm. port will be used directly with no modem, otherwise, the selected modem will be used. If a modem is selected, the next dialog requests a phone number to dial. The user can select a number from the list, or add one by clicking on “Add phone number”. If the user wishes to configure the modem, click on “Set up modem”. This will display the standard Windows95 modem properties dialog. Beware that these settings apply to all programs, not just AccuFlow. Once the phone number is entered, the modem will attempt a connection. It will retry 3 times, waiting one minute in between attempts. The connection attempt can be canceled at any time.

Hang Up Modem

The hang-up modem selection allows the user to break the existing modem connection and hang up the phone.

Get Flowmeter Version

When get flowmeter version is chosen, the application will attempt to connect with the flowmeter, and will ask for its version number. It will be reported to the user and stored in the current configuration. Versions previous to 837991 do not support this option, and communication failures may occur.

System

The system configure menu allows the user to make modifications to the currently loaded configuration in the areas of section type, number of sections, measurement units, flowmeter RS-232 enabling, and other general parameters. For definitions of these parameters, please see the parameter definition section in Chapter 7.

Section

The Section configure menu allows the user to make modifications to the currently loaded configuration in the section parameter area. For definitions of section parameters, please see the parameter definition section in Chapter 7. From the section menu, the path, level, and relay setup windows can be accessed.

Path

The path setup window allows the user to make modifications to the currently loaded configuration in the path parameter area. For definitions of path parameters, please see the parameter definition section of this manual in Chapter 7.

Level Inputs

The level inputs setup window allows the user to make modifications to the currently loaded configuration in the level analog input area. For definitions of level parameters, please see the parameter definition section of this manual in Chapter 7.

Analog Outputs

The analog outputs configure menu allows the user to make modifications to the currently loaded configuration in the analog output area. For definitions of analog output parameters, please see the parameter definition section of this manual in Chapter 7.

Relay Setup

The relay setup configure menu allows the user to make modifications to the currently loaded configuration in the relay area. For definitions of relay parameters, please see the parameter definition section of this manual in Chapter 7.

Operate Menu

The operate menu provides the ability to connect to the flowmeter and send or receive parameters, to begin measurements, or to review historical data.

When *receive parameters* is selected, the application in the PC will connect with the flowmeter and request its parameters. After having successfully received the parameters, the user is given the option of saving them in a file.

When *send parameters* is selected, the application in the PC will send the parameters contained in the PC to the flowmeter. The parameters may have been from a file that was opened or a configuration that was created using the wizard. Any parameters the flowmeter had stored will be overwritten.

When *Connect / Measure* is chosen, the application will connect to the flowmeter, and upload its parameters. The uploaded parameters will be used in building the graph. After parameter loading, measurements will begin, and the graph will start to display data. Initially, there is a delay in acquiring the data, and graph options are disabled. They are re-enabled when the initial acquire period is complete. Please see using graphs for more information about their features.

When *Set Flowmeter Clock* is selected, a dialog will appear for the user to enter in the desired date and time to be sent to the flowmeter. It will default to the current time according to the PC clock. After making the desired entries, click on Set Meter Clock to send it to the flowmeter. If you wish to see the date and time according to the flowmeter, click on Get Flowmeter Clock.

Show Differences can be used to verify that the configuration sent to the flowmeter has been received and stored properly. When show differences is chosen, the application connects with the flowmeter and requests its parameters. When they are received, they are compared to the configuration currently loaded in the PC. The parameters in the PC are shown on the left as “Local Configuration”, while the parameters on the right are the “Flowmeter Configuration”. Only those parameters that are different are shown, so that if the configurations are identical, both lists will be blank. It is common for the section volume parameters to be different, as they are updated with every measurement. Clicking on the Re-Transmit Parameters button sends the PC configuration to the flowmeter. After it has been sent, it is read back and any differences are shown again.

The *Review Historical Data* option allows the user to view graphs of previously logged data. This function is the same as described in the wizard interface section.

Diagnostics Menu

The diagnostics menu allows the user to test the flowmeter system, and to view detailed path variables that are not ordinarily used. The diagnostics menu has the following choices:

Comm. Port Test

If the Comm. port item is chosen, a window to test the Comm. port is opened. The comm. port test tests the function of the port on the PC. It does not test the flowmeter communications. Before testing the port, the user must put a wrap-around connector that connects the transmit and receive lines on the desired port. When the test port button is selected, the port will output patterns and read them back. It will compare the patterns to make sure that they are the same. If they are, it will display a good status in the memo box. If they do not match, it will display the expected pattern, and the actual pattern received. If there is no response in one second, it will display a “no response” message.

The port menu item in the Comm. port test window can be used to configure and open the port. The Configure menu choice allows the user to set the desired port, the baud rate, number of data bits, parity, stop bits and flow control. These are set up initially to work with the flowmeter, and usually should not require modification. The *Open menu* choice opens the desired port for communications. This must be done or a “no response” error will occur.

Path Variables

The path variables window allows the user to look at all the data coming from the flowmeter in tabular form. It is displayed as a multiple tab notebook. Each tab contains the variables for a given section. In addition, there is a settings tab that allows the user to choose only those variables and paths required. The user may choose to have the table continuously updated, or to pause the updates.

Before beginning measurements, the user is asked if the data are required to be logged. If so, the data logging menu is displayed. The data logging menu allows the user to enable and setup data logging to the PC. Checking enabled will allow data to be saved to the PC. The name of the data to be saved can have a maximum of 8 characters. This name is actually the sub-directory name where the data files will be stored. The data can be scheduled for every reading (about one every three seconds), or a set interval. The data recorded at the set interval, i.e. 15 minutes, will be the current value of the data, not an average. Once the setup is complete, clicking OK, will cause the measurements to begin.

This window is also used to display data log data. All of the variables below remain the same, but the PC is not connected to the flowmeter. The pause and resume buttons are replaced by record number and choose a new log controls.

The variables displayed are section, path and level variables, and are as follow:

Section

Section variables are flow, average level, section volume, average velocity, temperature, integration method, and section status. The status indicates if the section is full, has failed, has invoked path substitution because a path has failed, or is on a “learning” run.

Path

Path variables are velocity, gain (dB or %), signal-to-noise ratio, travel time, time difference, envelope time, path status (out of the water, failed, velocity error), and path detection method.

Level

Level variables are level and level status (good, greater than maximum layer height, below minimum level).

Scope Mode

Scope mode allows the user to look at the received transducer waveforms in a window that looks much like an oscilloscope. Scope mode will put the flowmeter into pipe mode, so that any selected paths will be active without regard to the water level, and will freeze the 4-20 mA analog outputs at their current values. The window displays the forward waveform in the top graph, and the reverse in the bottom graph. One path at a time may be displayed. The path to be traced may be set by using the Path Number spin control. There are a number of controls available. They are described below.

Single Sweep

When this button is clicked, the “oscilloscope” contacts the flowmeter and obtains the waveform to be displayed. Because of the volume of data, this process usually takes 3 to 4 seconds. Only one trace is taken in single sweep mode.

Continuous

When this button is clicked, the “oscilloscope” continuously contacts the flowmeter and obtains waveforms.

Pause

Clicking on the pause button stops the “oscilloscope” from acquiring data after the latest waveform is taken. It is most commonly used to stop the continuous mode.

Mouse Control

When the mouse is moved into a graph that has a waveform displayed, a sidebar appears. It will follow the mouse until the mouse is clicked or the mouse exits the graph area. When the sidebar is visible, its coordinates are displayed on the panel above the graph in engineering units (time and volts). Each graph can have its sidebar moved and set independently.

Zoom Level

Zoom level allows the user to control the length of the time period to be displayed. A value of 1 displays the smallest time period (usually 50 μ S), or the maximum “zoom”. A value of 8 displays the longest period (usually 400 μ S). After the zoom level is selected, a new waveform must be obtained by clicking either single sweep or continuous.

Display Variables

If display variables is checked, velocity, gain, time difference, and travel time will be obtained in addition to the waveform.

Waveform/Envelope

This control is used to select what kind of waveform is displayed. Waveform displays the actual received signal. Envelope displays the envelope of the received waveform as computed by the flowmeter.

Build History

Normally, an old waveform is erased every time a new waveform is obtained and displayed. Build history allows the waveforms to display on top of each other. This can show any differences from measurement to measurement.

Restore Paths

Clicking restore paths will set the path enables and the pipe/open channel mode back to the state they were in prior to entering scope mode. The analog outputs will also become active.

Open File

A previously saved file can be opened and displayed. The variables are not active.

Save File

The currently displayed waveform is saved as a *.dat file.

Erase

Clicking the erase button clears both graphs.

Print

Print prints a copy of the scope mode window.

Flowmeter Reset

If flowmeter reset is selected, the application will attempt to connect to the flowmeter and send its reset command. A reset is the software equivalent of flipping the on/off switch.

DataLogging Menu

The DataLogging menu allows the user to set up and retrieve data logs stored in the flowmeter. The DataLogging menu has the following choices:

Data Log Setup

Choosing DataLogging/Data Log Setup from the main menu allows the user to set up the parameters for data logging at the flowmeter. This capability is optional, and requires the flowmeter to have the data logging memory card.

First choose the kind of log file you desire, main or temporary. The main file provides 192k of capacity, while the temporary provides only 16k. Typically, the temporary memory is used only for short term debugging. In addition, a measurement status can be logged with every measurement by checking “Log Status”. The parameters in use may also be recorded by checking “Log Parameters”. Normally, the log will overwrite memory when the logging memory is completely full, always keeping the most recent data. To prevent any overwriting, check “Stop

logging when memory is full". Next, choose a logging interval in hours, minutes and seconds. The maximum interval is 24 hours.

Finally, choose the sections, paths and variables you wish to log. When complete, click on "Send Setup to Meter", and the parameters will be sent to the meter, and logging will begin. This action will start a new logging file, so any previous data will be overwritten. You can also view the flowmeter setup by clicking "Get Meter Setup", Note that the meter must be in measure mode for successful setup, transfer.

As changes are made to the setup, the amount of memory capacity in terms of logging hours is displayed. For example, if you log section 1 flow at 1 hour intervals, the memory capacity is 98,280 hours (about 11 years). The message will say you have chosen 2 parameters because time is always logged.

Retrieve Logged Data

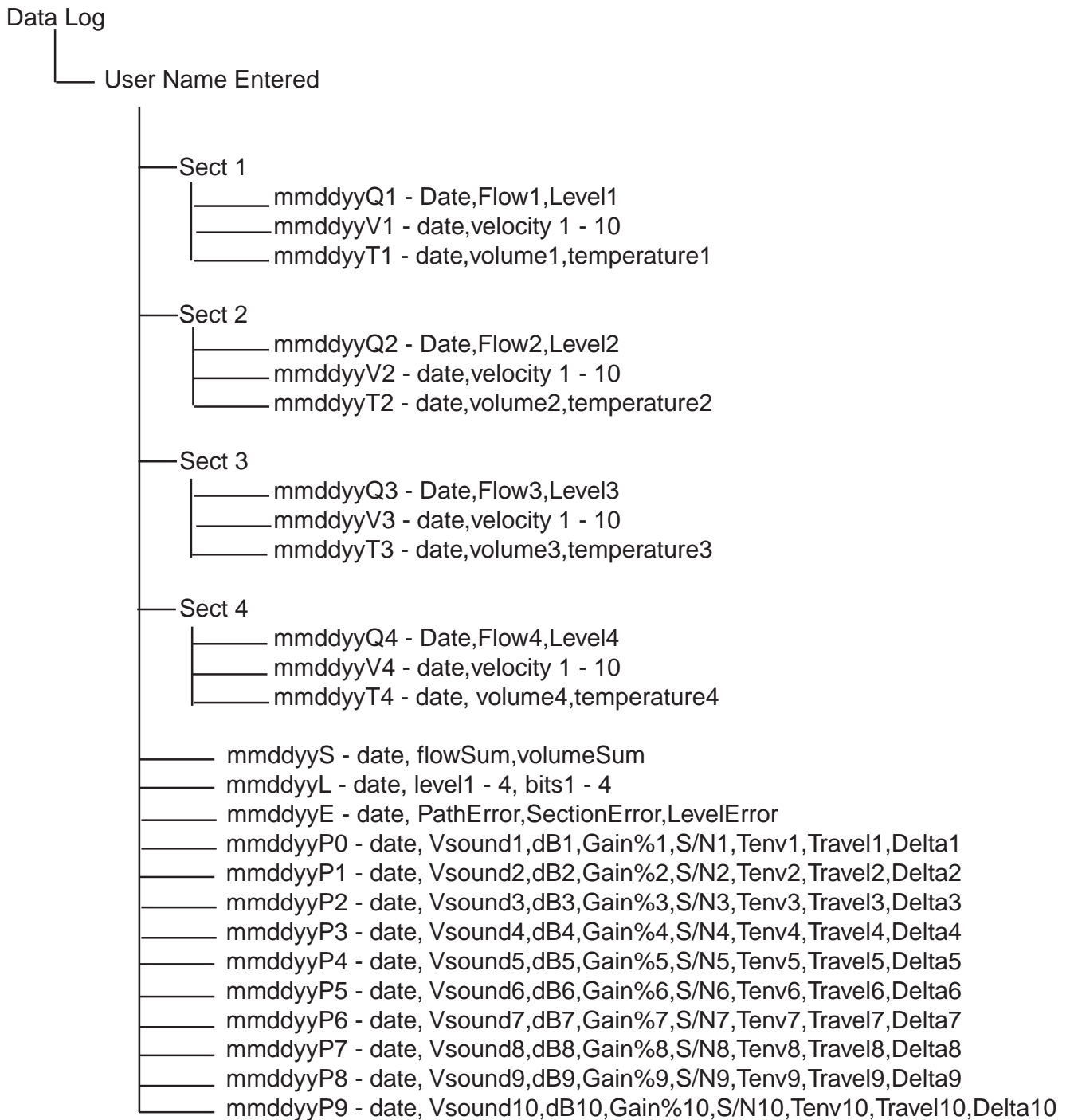
Choosing DataLogging/Retrieve Logged Data from the main menu allows the user to retrieve data that has been logged at the flowmeter. This capability is optional, and requires the flowmeter to have the data logging memory card.

First, choose how much data to retrieve, the "most recent", or "all data". If you choose most recent, you must click on the "Retrieve Directory" button. This will provide you with the number of "blocks" available, and the number of hours of data stored in a block. Choose the number of blocks you wish to retrieve. For example, if 8 blocks are available, each with 1 week of data, and you wish to retrieve 2 weeks of data, select 2 blocks.

Next, choose a data name. This name has a maximum of 8 characters, and cannot have spaces or special characters. Now click on "Retrieve Data". Each data block takes about 45 seconds to retrieve. If the data is corrupted, this time can be longer. If you check for confirmations, you will be given the option of not retrieving a particular block.

Once the data is retrieved, it is stored in the data_log directory in a sub-directory with the name you provided. Flow, level and velocity are stored in section sub-directories, and can be viewed in "Review Historical Data." Section volume and temperature are also stored in the section sub-directories. The sum of flows and sum of volumes are stored in the "S" file, path data is stored in "P" files, and level data is stored in the "L" file. The file names will contain the date and the above code. For example, if the data log began on May 25, 1997, the data for path 1 (VSound, gains, times) will be stored in a file named "05297P0". All files are comma delimited text that can be imported into spreadsheets.

Logged Data Directory Structure



Shown above is the sub-directory tree structure that is created to store the data downloaded from the datalog board. The number and types of files may differ slightly from site to site depending on the current system configuration. The top of the tree (Data_Log) is found in the sub-directory where the Accuflow software has been installed. The first branch below Data_Log (labeled ID above) will be the name entered as part of the download process. The file naming convention used is based on the start date of the specific data that is downloaded. For example if the datalog operation began on April 1, 1999 the mmddyy portion of the names shown above will be

replaced with "040199". Note that the name is based on when the data collection started and not when it is downloaded. The last one or two characters in each filename (shown above in bold) indicate the type of data stored in each file.

The data type designators indicate the following:

- **Qn** indicates flowrate and level data for section n where n indicates the section number 1 through 4.
- **Vn** indicates the velocity data for section n. the velocity data file will store the velocity data for all paths in the system and not just the section. For example a 4- section system with 2 paths in each section (total of 8 paths) will store the velocity data for all 8 paths in each section meter sub-directory.
- **Tn** indicates the volume and temperature data for section n
- **S** indicates the system flowrate and volume that is simply the sum of the section flowrate and volume data.
- **L** indicates the level measurement data for each of the active level measurement inputs. This data consists of two parts, the first part contains the level data for each of the active level inputs scaled in engineering units (feet, meters, ...). The second part contains the raw binary value as read from the A/D for each of the active level inputs.
- **E** contains the path error, section error and level error values. These values are the decimal equivalents of system
- **Pn** contains the path data for path n. This data consists of:
 - the velocity of sound determined by the velocity measurement travel times
 - the gain required to obtain a useable signal level
 - the percentage of the full scale A/D resolution that the received signal achieved
 - the signal to noise ratio measured
 - average of the forward and reverse travel times measured when the path is operating in the envelope detect mode
 - average of the forward and reverse travel times measured when the path is operating in the zero crossing detect mode
 - difference between the forward and reverse travel time measurements, calculated as $T_{rev} - T_{fwd}$

Display Retrieved Log

Choosing DataLogging/Display Retrieved Log from the main menu allows the user to display data log data that has been retrieved from the flowmeter. The data will be displayed in a tabular format, one measurement, or record, at a time.

Initially, a dialog to choose the data log ID and desired date/time appears. Once you have chosen an ID, the data log is scanned to determine its range. You can then choose a record to begin with, by entering a date and time. The default is the first record.

After choosing OK, the data is displayed in a table. To change to different records, use the record number spinner at the bottom of the screen.

Using Graphs

On the *view by variable* graph, the user can select which variable by selecting either the flow or the level button, and then select the section number(s) by using the buttons numbered 1 through 4. Multiple sections may be selected. The numbers below the section number buttons reflect the value of flow or level at the sidebar. The sidebar is the yellow vertical line that can be used as a marker for data points. It can be moved left or right by clicking and dragging the circular “knob” at the top of the sidebar. Notice that the numeric data changes as the sidebar is moved.

On the *view by section* graph, the user can select the section by clicking the radio buttons in the bottom right corner. Flow, level and velocity 1 through 10 are selected with the buttons on the bottom of the window. Sidebar operation is the same as in the *view by variable* graph, except that both graph panes are updated. If just velocities are selected, that graph will be expanded to the full window. Likewise, if only flow and/or level are selected their graph will be expanded. Otherwise, the window is split into two graph panes.

On the *settings* notebook tab, the user can select scaling options. They are normally automatically scaled based on the input value for historical data, or the maximum expected input for real-time data.

Set up the flowmeter by entering appropriate values for various parameters. Parameters define the geometry of each meter section and govern the operating modes of the flowmeter. All parameters are defined in Chapter 7.

Variables provide a view of measurements when the flowmeter is in normal “Measure” mode. Chapter 7 contains definitions of the variables.

Chapter 7

User Defined Parameters

System Parameters

These parameters define the overall configuration of the flowmeter.

PIPE / COMPOUND 0 / 1 Set to 0 (zero). to select “Pipe” mode. for all sections.
set to 1. to select “Open Channel/Compound” mode

FLOW SCALING The flowmeter calculates flow in either English or Metric units defined by the parameter below. If English is chosen, flow will be in ft³/s: if Metric in m³/s. To express flow in alternative units, the value for the Flow may be multiplied by the *FLOW SCALING* parameter.
This scaled flow is output to the display, the analog outputs and RS232 ports,
For English units, Flow in ft³/s: set to 1.0
Flow in Millions of gallons/day: (MGD) set to 0.646
For Metric units Flow in m³/s set to 1.0
Flow in Mega litres/day (MLD) set to 86.4
Flow in l/s set to 1000
Flow in m³/ hour set to 3600

VOLUME SCALING Sets the scaling of the totalized flow.
For English units, Flow in ft³/s: Volume in 1000 ft³ set to 1000
Flow in ft³/s: Acre feet set to 43560
Flow in MGD: Million gals set to 86400
For Metric units Flow in m³/s 1000m³ set to 1000
Flow in MLD Mega litres set to 86400
Flow in l/s m³ set to 1000
Flow in m³/ hour 1000m³ set to 3600000

ANALOG OUT SCALING A factory set parameter. Set to 1.0 for non-isolated, or 0.5 for isolated outputs.

FLOWAVE LVL {0 : 5} The time over which the Flow data are averaged.
Applies to the data displayed, logged and output on the analog output.
Set to 0, No time-averaging of the flow data
set to 1, the flow data are averaged over a period of 1 minute.
set to 2, the flow data are averaged over a period of 2 minutes.
set to 3, the flow data are averaged over a period of 5 minutes.
set to 4, the flow data are averaged over a period of 10 minutes.
set to 5, the flow data are averaged over a period of 15 minutes.

<i>NUMBER OF ACCUM's</i>	<p>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)) this parameter should be set to 1, otherwise signal cancellation can occur.</p> <p>If the acoustic signal quality is very good, a low value may be used, (1 to 4). Under adverse noise conditions, set to 8 or more.</p> <p>The advantage of using a low value is that the measurement cycle is shorter, and a better “snap-shot” of the flow in the conduit is taken.</p>
<i>REP TIME {0 : 4}</i>	<p>Sets the time interval between measurements.</p> <p>set to 0, the flowmeter meter will run at its maximum rate.</p> <p>set to 1, the flowmeter will take readings at 1 second intervals.</p> <p>set to 2, the flowmeter will take readings at 2 second intervals.</p> <p>set to 3, the flowmeter will take readings at 5 second intervals.</p> <p>set to 4, the flowmeter will take readings at 10 second intervals.</p> <p>Note. If the flowmeter is unable to complete the reading in the time selected, (because the path lengths are long or too many paths are selected) then the flowmeter will take the readings as quickly as possible without attempting to synchronize to any real time.</p>
<i>ENGLISH / METRIC 0/1</i>	<p>Selects the units of the Parameters and Variables of the flowmeter.</p> <p>For English units, (feet) set to 0. For metric units, (metres) set to 1.</p>
<i>AUTO STORE PAR's</i>	<p>Set to 1 normally, so that changed parameters are stored in non-volatile memory whenever the system is returned to the Measure mode.</p> <p>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 Esc then the Reset (or #) key is pressed, or if there is a temporary loss of power.</p>
<i>DATA to SERIAL {0 : 3}</i>	<p>To select the outputting of data to RS232 serial ports.</p> <p>set to 0, for no serial data outputs.</p> <p>set to 1, for data output to the “Hand-held terminal” port, see page 5-8.</p> <p>set to 2, for data output to the optional Com 3 RS232 port in “Argus” format</p> <p>set to 3, for data output to the optional Com 3 RS232 port in “Drax” format</p>
<i>SYSCLK 2, 5, 10 MHz</i>	<p>Sets the sampling rate of the digitizer.</p> <p>For 1MHz transducers or path lengths less than 50 ft (15m): set to 10.0</p> <p>For path lengths up to 100ft, (30m) and 500 kHz transducers set to 5.00.</p> <p>For path lengths up to 300ft, (90m) and 200 kHz transducers set to 2.00.</p> <p>Note. For the 10MHz setting, link JP50 on the DSP card must be towards the center of the card. For other settings, the link must be away from center.</p>
<i>DISPLAY UNITS 0 : 4</i>	<p>Selects the characters to indicate the units of the variables displayed on the optional Liquid Crystal Display.</p> <p>Set to 0 to display flow in “l/s”, level in “m”, Volume in Cm, Temp in °C.</p> <p>set to 1 to display flow in “MLD”, level in “m”, Volume in ML, Temp in °C.</p> <p>set to 2 to display flow in “CMS”, level in “m”, Volume in Cm, Temp in °C.</p> <p>set to 3 to display flow in “CFS”, level in “ft”, Volume in CF, Temp in °F.</p> <p>set to 4 to display flow in “MGD”, level in “ft”, Volume in MG, Temp in °F.</p> <p>set to 5 to omit the units in the display.</p>
<i>DETECTION METHODS</i>	<p>Set to 0, “AUTOMATIC” to enable the flowmeter to use the optimum signal detection method for the conditions. The normal setting.</p>

Set to 1, "FIRST NEG" to force the flowmeter to use only detection of the "first negative" edge of the received signal. (Use only if the water known to be clean and without aeration)

Set to 2, "ENVELOPE" to force the flowmeter to use only detection of the "envelope" of the received signal. (For use if water is always aerated)

Section Parameters

These parameters describe each conduit and the method of flow computation. Separate lists are required for each section. For all unused sections, the parameters *Path Enable* and *Volume Init Value* must be set to zero. All other parameters for unused sections can be ignored; their values are not used by the system.

All lengths and elevations are limited to five figures.

Parameters with the letters C after their names are used only in Open Channel or Compound mode.

<i>PATH ENABLE</i>		<p>For each section, a 10 bit binary number has to be set in order to define which paths are to be allocated to the section. e.g. For path 3 to be used, the number is set to 0010000000. For paths 1,2,3,4 to be used, set to 1111000000. When entering a value, the zeros after the last selected path need not be entered. If no paths are enabled, the section is not enabled.</p>
<i>LEVEL ENABLE</i>	C	<p>This parameter is ignored if the system is in "Pipe" mode. For each section, a 4 bit binary number has to be set in order to define which of the analog level inputs apply to the section. A maximum of two inputs can be allocated to any section. e.g. For analog level input #1 only to be used, the number is set to 1000. For analog level inputs #1 & #2 to be used, the number is set to 1100. For analog level inputs #3 & #4 to be used, the number is set to 0011. A particular level input can be allocated to one or more sections.</p>
<i>PIPE AREA</i>		<p>"Pipe" mode only. The cross-section area of the conduit in ft² or m². This parameter is ignored in "Open Channel" or "Compound" mode.</p>
<i>MIN GOOD PATHS</i>		<p>In pipe mode, the minimum number of good paths that must be present to calculate flow. The contribution to the Flow from any failed paths can be provided by the Path Substitution routine, providing that the "Learn path Ratios" routine has been correctly implemented. See page 3-5. If the "Learn" routine can not be implemented, because at the time of commissioning there is insufficient flow, this parameter must be set equal to the number of paths installed. Range 1 to number of paths installed. If set to number of paths installed, the flow will cease to be computed and the section fail, if any path fails.</p> <p>In compound mode, setting this parameter to "1" will force single path integration to be the result of path velocity times the area times the flow scaling constant. When set to any other value the flowmeter will adjust the measured velocity and calculate flow as outlined on page 3-2.</p>

<i>LOW FLOW CUTOFF</i>		<p>Defines the range of flows which the flowmeter will declare to be zero. If set to 0.00, the flowmeter will be bi-directional, with no minimum flow. If set to a +ve value, all negative flows and positive flows up to the set value will be declared to be zero. If set to a -ve value, all positive flows and negative flows down to the set value will be declared to be zero. Any flow which is declared to be zero will be output on the displays and analog outputs as zero, and treated as zero flow for the computation of Volume and the computation of Sum of Section Flows.</p>
<i>VOLUME INIT VALUE</i>		<p>The current value of the Totalized Flow or Volume. The volume may be reset to any value as required, Range 0 to 999 999 For unused sections, this parameter should be set to zero, otherwise it will contribute to the <i>Sum of Volumes</i>.</p>
<i>LEARN PATH RATIOS</i>		<p>“Pipe” mode only. If set to 1, the “Learning” routine will be invoked, and a new path ratio table will be created automatically. (See page 3-5 Pipe Mode). The parameter will reset to 0, and the table frozen after 1000 readings. Warning: all paths must be good & flow non zero if this routine is invoked.</p>
<i>TEMP CORRECTION</i>		<p>A constant in °F or °C which is added to the computed temperature to correct for minor variations in the water quality. Range -30 to +30. Normally set to 0.</p>
<i>MANNING n</i>	C	<p>The Manning coefficient of roughness. Usually between 0.01 & 0.03.</p>
<i>MANNING slope</i>	C	<p>The slope of the energy line in the conduit: a dimensionless number: Usually between 0.0 to 0.010</p>
<i>MANNING MAX LVL</i>	C	<p>The maximum value of Level for which the Manning Formula is valid. Range: -5000 to +5000</p>
<i>OVERRIDE LEVEL?</i>	C	<p>Selects whether the level is to be derived from the 4-20 mA analog level input or from a manually entered fixed value. To select the analog input: set to 0 To select the manually entered Level value: <i>LEVEL MANUAL</i>: set to 1.</p>
<i>MANUAL LEVEL</i>	C	<p>A fixed Level value, representing the elevation of the water surface above the site datum. Range: -5000 to +5000</p>
<i>SURCHARGE LEVEL</i>	C	<p>The value of Level at and above which the section is surcharged. For an open channel site, this must be set above the highest possible Level. For a closed conduit, it is set equal to the elevation of the top of the conduit or soffit. Range: -5000 to +5000</p>
<i>LOW LEVL CUTOFF</i>	C	<p>Elevation of the water surface, above the site datum, below which the flowmeter will regard the flow as zero. Range -5000 to +5000</p>

<i>MIN SUBMERSION</i>	C	The minimum submersion is the minimum distance which the water surface must be above a path for the path to be energized and used by the system to compute flow. Range: 0.0 to 5.0. Usually set to a value at least equal to the surface wave amplitude, or if the surface is smooth, set in accordance with the following: for 1 MHz transducers, $0.05\sqrt{\text{Path Length in ft}}$, or $0.03\sqrt{\text{Path Length in m}}$. for 500 kHz transducers, $0.07\sqrt{\text{Path Length in ft}}$, or $0.04\sqrt{\text{Path Length in m}}$. for 200 kHz transducers, $0.11\sqrt{\text{Path Length in ft}}$, or $0.06\sqrt{\text{Path Length in m}}$.
<i>BOTTOM FRICT'N</i>	C	The ratio between the assumed velocity at the conduit bottom and that at the elevation of the first good path above the bottom. Also used to compute the assumed velocity at the top of the conduit under surcharged conditions. Range: 0.0 to 2.0 Usually set to: 0.8 for multi-path open channels. A lower value, (0.5 min.), if the bottom path is very near the bed. A value of 1.2 to 1.8 may be appropriate for single path installations. See p 3-4
<i>TOP WEIGHT</i>	C	The weighting coefficient used to correct the extrapolated surface velocity Usually set to 0.1. In narrow conduits set to 0.
<i>SURCH TRAP / PIPE</i>	C	Selects the integration method to be used when the conduit is surcharged. Set to 0 if surcharged trapezoidal mode is to be used. Set to 1 if "Pipe" mode is to be used.
<i>NUM of LAYERS</i>	C	Number of layers used for defining the conduit cross-section area Any number between 2 and 8 layers may be defined.
<i>LAYER ELEV'N 1</i>	C	The elevation of the conduit bottom or invert relative to the site datum. Range -5000 to +5000.
<i>LAYER ELEV'N 2</i>	C	The elevation of the next layer above the bottom relative to the site datum.
<i>LAYER ELEV'N 3</i>	C	The elevation of the next layer, if required. Note that if the conduit is closed, the elevation of the highest layer must be equal to or greater than that of the soffit or top of the conduit. If the conduit is an open channel, the elevation of the highest layer must be greater than that of the highest possible Level.
<i>LAYER WIDTH 1</i>	C	The effective width of the conduit at the bottom or invert of the conduit. Range 0.0 to 300
<i>LAYER WIDTH 2</i>	C	The width of the next layer above the bottom.
<i>LAYER WIDTH 3</i>	C	The width of the next layer, if required.

Notes

1. The layer elevations must be in strict height order.
2. Two layers cannot be given the same elevation.
3. Data entered in layers having numbers higher than the parameter *NUM of LAYERS* will be ignored
4. For a Round Pipe, the layer configuration given on pages 5-4 or 7-14 is recommended
5. If, during operation of the flowmeter, the water level should exceed the elevation of the highest layer, without the conduit being surcharged, a warning *LVL > MX LY HT* will be displayed.

Path Parameters

The paths are numbered in sequence, 1 through 8, any of which can be allocated to any section.

For Model 7616, 7617, 7618, 7634, 7656, 7658, set to	500kHz.
For Model 7612, set to	200kHz

Level Input Parameters

Either one or two can be allocated to a section. The allocation is defined in the Section menu.

Level parameters are ignored by the system when in “Pipe” mode.

Scaling for each individual analog level input is defined by the following parameters.

<i>MIN mA INPUT</i>	The value of the input in mA below which it is declared to be in a fault state. The value may be in the range 0.0 to 19.0 mA.
<i>4mA LEVEL INPUT</i>	Elevation of the water surface above the site datum, at which the Level input is 4.0 mA. The value may be in the range -5000 to +5000.
<i>20mA LEVEL INPUT</i>	Elevation of the water surface, above the site datum, at which the Level input is 20.0 mA. The value may be in the range -5000 to +5000.
<i>LEVEL RESISTOR</i>	The value of the input resistance of the 4-20 mA Level input. The value may be in the range 250Ω to 50Ω. Nominal value 100Ω. This parameter is set at the factory to calibrate the input. The value should not require changing.
<i>LEVEL FILTER 0-4</i>	The approximate time in units of 15 measurement cycles, over which the Level data are averaged. e.g.: if set to 0 no averaging if set to 4 (max) averaged over 60 measurement cycles. Applies to the data displayed, used in the computation of flow, logged and output on the analog output.

Analog Output Parameters

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

<i>ASSIGN A SECTION</i>	Defines which section the output responds to. For “sum of section” flow, set to 0. For Section 1, set to 1, etc.
<i>F / L / V / T / *SF {0-4}</i>	Selects the variable to be represented by the analog output. Set to 0 to output flow for the section. Set to 1 to output the arbitrated value of the level for the section. Set to 2 to output the average velocity for the section. Set to 3 to output Temperature, in °F for <i>English</i> or °C for <i>metric</i> units. Set to 4 to output the Sum of the Section Flows. Note. The units of velocity are either ft/s or m/s depending on the parameter <i>English/metric</i> . Velocity output is not affected by the <i>Flow Scaling</i> . The velocity is equal to the flow divided by the wetted cross section area.
<i>4mA OUTPUT</i>	The value of the variable, in the units specified, for which an output of 4.00 mA is required.

<i>20mA OUTPUT</i>	The value of the variable, in the units specified, for which an output of 20.00 mA is required.
<i>OVERRIDE OUTPUT?</i>	Selects whether the output is to be derived from the variable or from a manually entered fixed value. Normally only used during system commissioning. To select the chosen Variable, (Flow, Level, Temperature etc.) set to 0 To select the manually entered <i>MAN OUTPUT VALUE</i> : set to 1.
<i>MAN OUTPUT VALUE</i>	The manual figure, in the scaled units used by the flowmeter.
<i>HOLD ON ERROR 0/1</i>	Set to 0 to cause the output to go to 4mA in the event of failure. Set to 1 to cause the output to hold the last good value in the event of failure.

Four analog output channels are dedicated to the task of outputting path velocity. In the parameter list these output channels are defined as Channel 5 to Channel 8 (A5 to A8). Since there are only four hardware analog channels in the 7510 flowmeter the velocity output channels are mapped to hardware channels 1 through 4. The actual analog outputs are found as follows;

- Channel 1 and Channel 5 will be output on hardware channel 1
- Channel 2 and Channel 6 will be output on hardware channel 2
- Channel 3 and Channel 7 will be output on hardware channel 3
- Channel 4 and Channel 8 will be output on hardware channel 4

NOTE: Care must be taken when assigning analog outputs. If channel 1 (A1) has been turned on with the intent of outputting a section variable (F/L/V/T) then channel 5 (A5) should not be used for path velocity. The result of enabling a section output channel (A1 to A4) and the matching velocity output channel (A5 to A8) will be that both outputs will be written to the same output each time the outputs are updated.

Relay Parameters

There are 16 separate lists, one for each relay. These describe the function, section allocation and behavior of each individual relay, if supplied.

ASSIGN A SECTION Defines which section the relay responds to.
For “sum of section” functions, set to 0.

TYPE (1 : 10) 0 = OFF Defines the function of the relay. When a selection has been made, a code giving an indication of the function appears on the screen.

Value	Display Code	Function
Set to 0	**OFF**	if the relay is not used.
Set to 1	<i>SEC Q MX 1</i>	for the relay to operate when the section flow exceeds the threshold value in this relay’s list.
Set to 2	<i>SEC L MX 1</i>	for the relay to operate when the section level exceeds the threshold value in this relay’s list.
Set to 3	<i>PATH SUB</i>	for the relay to operate when Path Substitution is in operation in the section. (Pipe mode only).
Set to 4	<i>SECT FAIL</i>	for the relay to operate when the section fails.
Set to 5	<i>SECT VOL</i>	for the relay to transmit section totalizer pulses.
Note Only one relay may be allocated to each section for this function.		
Set to 6	<i>SUM Q MX 1</i>	for the relay to operate when the sum of section flows exceeds the threshold value in this list.
Set to 7	<i>SUM VOL</i>	For the relay to transmit totalizer pulses for the sum of the sections.

THRESHOLD The value of the variable (flow or level), above which the relay will eventually operate. Range -99999 to +999999

DELAY The number of consecutive measurement cycles for which the variable exceeds or falls below the threshold, before the relay operates.
When used for Section Fail or Path Substitution alarms, the relay operation is delayed by a number of measurement cycles, after the onset of the alarm state. If an alarm state ceases, the relay returns to its normal state immediately.
Range 1 to 999 measurement cycles.

POLARITY 0 / 1 Defines whether the relay is energized or de-energized when it operates as a result of the event

Set to 0 for the relay to be normally de-energized.

Set to 1 for the relay to be normally energized.

Note. All relays are de-energized when the electronic unit is without power.

Examples:

To configure a relay to close when the flow in section #1 is negative, set:

TYPE = 1, ASSIGN A SECTION = 1, THRESHOLD = 0, DELAY = 5, POLARITY = 0

To configure a relay to indicate if section #3 fails, or if the power is off, set:

TYPE = 6, ASSIGN A SECTION = 3, THRESHOLD = 0, DELAY = 0, POLARITY = 1

System Stats

This list contains general information on the system, as well as facilities for altering the baud rate for the *Hand-held Communication* port and for setting the clock date and time.

The method of changing the values of those which are not fixed is the same as for the other parameters.

<i>SOFTWARE VERSION</i>		A serial number defining the version of the software (for information only)
<i>SITE NAME</i>		An alpha / numeric name which can be entered only by using Accuflow Maximum number of characters: 9. Spaces are permitted.
<i>BAUD RATE (2-6)</i>		User selectable baud rate of the Hand-held terminal . See notes below for special instructions. Set to 2 for 1200 baud 3 " 2400 4 " 4800 5 " 9600 6 " 19200 Normal value
<i>DATA BITS</i>	*	Character length. Fixed value of 8.
<i>STOP BITS</i>	*	Fixed value of 1.
<i>PARITY</i>	*	Fixed value. No parity.
<i>YEAR</i>		Calendar year For the year 2000 set to 00.
<i>MONTH</i>		Calendar month.
<i>DATE</i>		Calendar date.
<i>DAY (SUN = 0)</i>		Day of the week.
<i>AM / PM 0 / 1</i>		Defines period of day if 12 hour clock is used.
<i>24 / 12 HOUR CLK 0 / 1</i>		Defines whether 24 or 12 hour clock is used.
<i>HOUR</i>		Time.
<i>MINUTE</i>		Time.
<i>SECOND</i>		Time.

Baud Rate change

The baud rate of the communication to the hand-held terminal port can be selected.

To reduce the risk of changing the baud rate and then finding that re-entry to the flowmeter menu is impossible, the newly selected baud rate will not be implemented until the system has been reset.

To select a new baud rate, enter the code number of the desired rate in the menu, then press **Esc** and **Measure (M)** to return the system to the Measure mode. Then, to reset the system and implement the new baud rate:

either, turn the power off and back on,

or, exit the measure mode by pressing **Esc**, then press the **Reset (#)** key.

To return the system to the default baud rate of 19200, switch off the power, connect together pins 2 & 3 of the 9-pin D socket marked "Hand-held communication," and switch the power back on.

Logging to Flash

The various menus for setting up the logging of data to flash memory are:

<i>DIRECTORY</i>	Provides a directory of the current log files. There are two, the “Main, (capacity 192k values) and the “Scratch”, (capacity 16k values)
<i>LOG LEN</i>	Indicates the number of storage locations used so far in the current log.
<i>CUR MDH</i>	Indicates the time in months, days, hours, for which the current log has been recording.
<i>TOT MDH</i>	Indicates the total log time in months, days, hours, remaining before the memory is full. The value for this is automatically calculated by the computer, and can be used as a guide to the maximum duration of a log, for a particular chosen set of variables and logging frequency.

****NOTE:** *CUR MDH and TOT MDH will not be displayed. If programmed logging time exceeds 1 year.*

<i>WRITE TO FILE</i>	Selects a log file, its characteristics, and its frequency.
<i>SCRATCH / MAIN</i>	Choose which file to log into. Enter 0, to select “Scratch”, 1 to select “Main”
<i>PARAMETERS</i>	Enable logging of parameters (not currently implemented)
<i>NEW / APPEND</i>	Enter 0, to Open new file, Enter 1, to append new data to existing file.
<i>CIRCULATE / STOP</i>	Enter 0, to circulate to beginning on file full. Enter 1, to stop when file full.
<i>STATUS</i>	Enter 1, to log the status of flowmeter with each log. Enter 0, to omit status.
<i>SET LOG INTERVAL</i>	Enter logging frequency in seconds, hours, and minutes. (24 hours maximum)

****NOTE:** *Appending will not occur if any other logging parameter is changed.*

<i>TAG SECTION / PATHS</i>	Select sections and paths for which the selected variables will be logged.
<i>SECTION 1- 4</i>	Enter a 0 to select “No logging for that section”, a 1 to select “Logging”
<i>PATHS 1-10</i>	Enter a 0 to select “No logging for that path”, a 1 to select “Logging”

<i>TAG VARIABLES</i>	Select the variables to be logged. Entering a 0 selects “off”, a 1 selects “on”
<i>FLOW</i>	Section flow
<i>LEVEL</i>	Section level (averaged)
<i>VOL</i>	Section volume
<i>TEMP</i>	Section temperature
<i>SUM of FLOWS</i>	Sum of section flows
<i>SUM of VOLS</i>	Sum of section volumes
<i>VELOCITY</i>	Path velocity
<i>VSND</i>	Path calculated velocity of sound
<i>GAIN dB</i>	Path gain in dB
<i>GAINS %</i>	Path gain in percent
<i>S / N dB</i>	Path signal to noise ratio
<i>TENV F-R</i>	Path forward and reverse envelope times
<i>TRAV F-R</i>	Path forward and reverse travel times
<i>DELTA T</i>	Path delta time
<i>LEVEL</i>	Input level
<i>BITS</i>	Input level in bits

Variables

All variables except average velocity 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:

- 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 represent the travel times of the signals through the water.
- 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 average taken over 8 readings.
- 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.
The second figure is the amplitude of the latest instantaneous signal, after amplification, expressed as a % of full signal at the detector. Normally this value will be between 95 and 105.
The third figure is the Signal to Noise ratio expressed in dB. Less than 12dB indicates a serious noise problem, and that the data for that path will be rejected.
- VEL** If the path is not enabled or is out of the water, the display for that velocity is blank.
The first figure is the value of the individual water velocity in feet/second or metres/second, averaged over 8 readings. A negative figure indicates reverse flow.
The second figure is the computed velocity of sound for that path, (used for diagnostic purposes).
The letter E or Z indicates the signal detection method, either “Envelope” or “First Negative”.
The letter H indicates that the velocity reading has been “Held” The latest acoustic signal is unacceptable, and the previous value for water velocity is being used for the computation of flow.
PATH FAILED indicates that consecutive acoustic signals for that path have been rejected for a period greater than the parameter *Max Bad Measures*. The path has failed.
VEL > MAX indicates path failure due to computed velocity greater than *Max Path Velocity*
- FLOW** The time-averaged value of the water flow, scaled in the required units.
SECT If the parameter *Flow Scaling* is set to 1, the units will be cubic ft/s or cubic metres/s.
The averaging is carried out using an Infinite Impulse Response (IIR) digital filter, whose time is set by the System parameter *FLOW AVE 0 - 4 MINS*.

The letters and number following the value indicate the method of flow determination selected by the flowmeter, whether the conduit is Full (surcharged), and which of the possible level inputs (Manual, #1 or #2) has been selected. Typical examples of these codes are:

In Pipe Mode:

- | | | |
|----|---|--|
| PI | | indicates that the system is configured for “Pipe” mode. |
| PI | L | indicates that the Learn Path Ratio routine is in progress. |
| PI | S | indicates that the Path Substitution routine is in use.
(i.e. one or more paths have failed). |

In Compound Mode:

MN 1	indicates Manning mode, non surcharged, level #1 used.
SP 1	indicates Single Path Trapezoidal Integration, non surcharged, level #1.
MP 1	indicates Multi Path Trapezoidal Integration, non-surcharged, level #1.
MP F 2	indicates Multi Path Trapezoidal Integration, surcharged (Full), level #2.
PI S 4	indicates Pipe Integration, surcharged. Path Substitution, level #4.
PI F 0	indicates Pipe Integration, surcharged. Manual Level selected.

Under low flow or fault conditions, a message is substituted for the section flow value.

LVL > MX LY HT	indicates that the Level exceeds the elevation of the uppermost layer.
LEVEL<>Limits	indicates failure due to the Level input being below <i>Min mA Input</i> or above 21 mA.
LEVEL < CUTOFF	indicates that the flow is zero, due to valid but low Level.
NO GOOD PATHS	indicates failure of all paths, and Level too high for Manning to be valid.
SECTION FAIL	indicates that there are too few good paths to compute flow in “Pipe” mode. i.e. Number of good paths is less than <i>Min Good Paths</i> .

VOL SECT The totalized flow for each section, scaled according to the *Volume 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.

LEVEL SECT The arbitrated time-averaged value of the Level in each section, which is used for the calculation of flow. The averaging is carried out using an Infinite Impulse Response (IIR) digital filter, whose time is set by the parameter *LEVEL FILTER*. The messages following are the same as are displayed on the “Flow” screen.

TEMP SECT The water temperature in each section, computed from the average velocity of sound for each good working path in that section. It is computed using the relationship for distilled water, corrected if necessary by a user defined offset; the section parameter *TEMP CORRECTION*

FLOW VOL SUMS The sum of all the section flows. If a section has failed, its contribution is deemed to be zero. The sum of all the section volumes. If a section has failed, the value for its Volume accumulated up to the time of failure will be used for calculating the sum of all section volumes.

LEVEL CHNL BITS The time-averaged value of each individual Level input, in terms of the elevation of the water surface above the site datum. The second 4-digit number after the Level value is the instantaneous value of analog input. It is scaled so that an input of 0.00 volts is displayed as 0, and 5.00 volts as 4094.

If the input resistor fitted is the nominal 100Ω, the 4 digit number will be scaled so that: 0 mA is displayed as 0, 4 mA as 328, 20 mA as 1638 and 50 mA as 4095.

Special Configurations

Occasionally, it may be necessary to configure the meter in a “non-standard” mode to meet a particular requirement. This section contains special configurations.

Using Layer Boundary Parameters to Simulate a Round Pipe

When a “compound flowmeter” is set up in a pipe, the shape of the pipe has to be described using the Layer Boundary parameters. If the pipe is round, a large number of possible ways of describing its shape in terms of trapezoidal layers can be devised.

The table below gives one possibility, which has the merits of giving very close approximations to the wetted area, with only 11 numbers to be calculated. The maximum errors occur when the stage is below 0.1 x Pipe Diameter. This is below the lowest layer and likely to be below the lowest path, and so of no relevance. At a stage of 0.05 x Pipe Diameter, the error is 4.5% of actual area. For stages between 0.1 and 0.2 x Pipe Diameter, the errors are less than 0.2%. Above 0.2 x Pipe Diameter, the errors are small.

<u>Layer Boundary Elevation</u>	<u>Layer Boundary Width</u>
Zero x Diameter	0.116 x Diameter
0.05 x Diameter	0.472 x Diameter
0.20 x Diameter	0.823 x Diameter
0.40 x Diameter	0.993 x Diameter
0.60 x Diameter	0.993 x Diameter
0.80 x Diameter	0.823 x Diameter
0.95 x Diameter	0.472 x Diameter
1.00 x Diameter	0.116 x Diameter

All Path Elevations in terms of measured distance above the channel bottom.

Separating Forward and Reverse Flows, (for pump / generating plant)

For some full pipe systems, it may be desired to compute separate totalizer counts (from relay closures) and volumes for forward and reverse flows.

To achieve this, two sections should be configured, using the same paths, but with slightly different section parameters. In this example, Section #1 is for forward flow, and section #2 for reverse.

<u>Parameter</u>	<u>Section #1</u>	<u>Section #2</u>	<u>Comment</u>
<i>Path Enable</i>	1111000000	1111000000	both the same
<i>Pipe Area</i>	Actual value	- Actual value	Section #2 will read negative.
<i>Low Flow Cutoff</i>	0.0001 or more	- 0.0001 or less	See description on page 7-4

With this configuration, Section #1 will give a positive value for all forward flows, and zero for reverse flows.
Section #2 will give a positive value for all reverse flows, and zero for forward flows.

For Compound or open channel situations, contact Accusonic.

Relay to indicate that a Section is Good

For flowmeters which are used for automatic plant control, it is often desirable to have a relay to indicate “Section Good”, rather than “Section Failed”. The difference being that “Section Good” should be energized only when the section is “good”, be de-energized immediately it is “bad”, and allow for a delay between the section recovering and the relay becoming energized. The “Section Failed” concept does not provide this logic.

To provide this: Enable a dummy path in the section, (e.g. Path #10), to which nothing is connected.

Set Section parameter *Min Good Paths* to the minimum number required for flow calculation.

Set “dummy” path *Length* to 1.0, *Weight* to 0, Other parameters to 1 or ignore.

Set Relay parameter for desired Section, *Type* to 3 (Path Sub), *Delay* as required, *Polarity* to 0.

Appendix A:

Multipath Flowmeter Systems Theory and Operating Principle

ACCUSONIC
TECHNOLOGIES



Description

Accusonic flowmeters utilize the multiple parallel path transit time flow measurement technique which is designed for accurate flow measurement ($\pm 0.5\%$ 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.



Theory and Operating Principle

The Accusonic flowmeter is connected via signal cables to multiple pairs of transducers mounted in a pipe or channel at specific elevations. Velocity at each elevation is determined using the differential travel time method in which an acoustic pulse travels downstream faster than a pulse travels upstream. A pulse of sound travelling diagonally across the flow in a downstream direction will be accelerated with the velocity component of the water and, conversely, a pulse travelling diagonally upstream will be decelerated by the water velocity. This method of measurement is described as follows:

$$T1 = \frac{L}{C - V \cos \emptyset} \quad T2 = \frac{L}{C + V \cos \emptyset}$$

Where:

T1 = Travel time of the acoustic pulse between transducer B and transducer A (Figure 1)

T2 = Travel time of the acoustic pulse between transducer A and transducer B

C = Speed of sound in water

V = Velocity of the water

\emptyset = Angle between the acoustic path and the direction of water flow

The above equations are solved for V, independent of C, yielding:

$$V = \frac{(T_1 - T_2)}{(T_1 + T_2)} \times \frac{L}{2 \cos \emptyset}$$

Therefore, the velocity of the water at the acoustic path can be calculated by knowing the path length (L) and path angle (\emptyset), and measuring the time for the acoustic pulse to travel between the transducers in the upstream and downstream directions.

Typically, four pairs of transducers are spaced in the pipe or channel to give four parallel acoustic paths (see Figures 3 & 4). Velocities for these paths are then integrated so that flow is measured according to the following equations:

1. For Pipes:

$$Q = 2R^2 \sum_{i=1}^4 w_i v_i$$

Where:

Q = Flowrate

R = Pipe radius

w_i = Integration weighting constant for the ith path (defined by the path location)

v_i = Velocity determined by the ith path

i = Number of acoustic paths

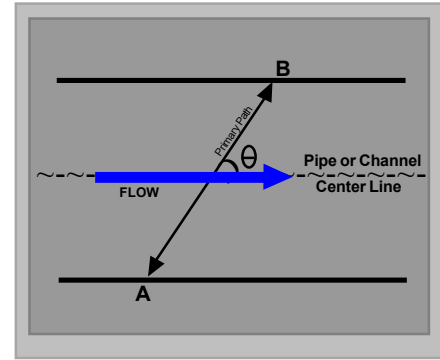


Figure 1 Acoustic Path Layout

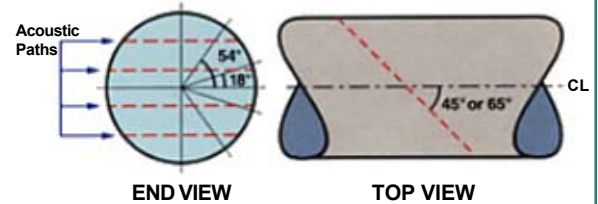


Figure 2 Typical full-pipe pipeline placement (using the Gauss-Chebyshev integration method)

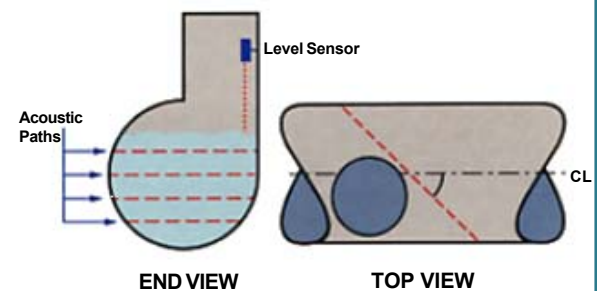


Figure 3 Typical partially full pipe

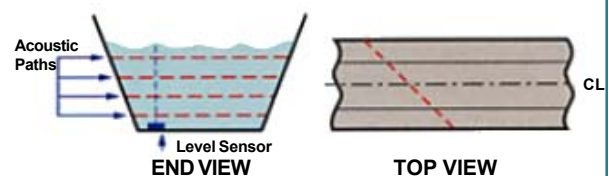


Figure 4 Typical open channel path placement

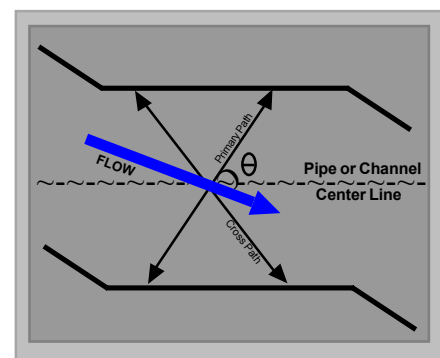


Figure 5 Cross Path Configuration

2. For open channels and partially full pipes:

When more than one path is submerged

$$Q = [A_{\text{Bottom}} \cdot V_A \cdot (1 + F_{\text{Bottom}}) / 2] + [\sum_{i=1}^n A_{i+i+1} \cdot (V_i + V_{i+1}) / 2] + [A_{\text{Top}} \cdot (V_n + W_{\text{Top}} \cdot V_{\text{Surface}}) / (1 + W_{\text{Top}})]$$

Where:

- Q = Flowrate
- A = Cross sectional area (determined as a function of depth and channel/pipe dimension)
- V_A = Velocity of lowest path of lowest pair of crossed paths
- F_{Bottom} = FBottom friction coefficient
- V_i = FVelocity of the i path or pair of crossed paths
- W_{Top} = FWeight for the surface velocity to correct for friction at the surface
- V_{Surface} = FSurface velocity extrapolated from the top two measured path velocities

For pipes and channels where only one path is submerged:

$$Q = V * C * A$$

Where:

- A = \square (depth)
- C = 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 comparison 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 component 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 uncertainty 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 uncertainty due to path length measurement error would be:

$$E_L = \frac{1}{4} (4 \times 0.0015)^{1/2} = 0.00075 \text{ or } 0.075\%$$

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

(CONTINUED \Rightarrow)



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

$$E_{\theta} = (1 - (\cos 45.10 / \cos 45.00)) = 0.0017 \text{ or } .017\%$$

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 where there are at least 10 diameters 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.

- Travel Time Measurement is dependent on the digital oscillator accuracy, oscillator frequency, the ability of the received circuitry to consistently recognize 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 Monitor (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 be calculated to be:

$$E_T = 0.001 \text{ or } .01\%$$

- 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 within 1/16 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:

$$E_R = (1 - (1/1.002)^2) = 0.004 \text{ or } 0.4\%$$

- 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:

$$E_I = (E_L^2 + E_q^2 + E_T^2 + E_R^2 + E_{\theta}^2)^{1/2}$$

$$= 0.0049 \text{ @ } 0.005 \text{ or } 0.5\%$$

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 determination.

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



INDEX

~A~
 Accuflow Interface 2-6 to 2-7, 4-13, Ch-6
 Analog Output
 Connections 4-13
 Electrical Specification..... 2-
 General Specification 2-4
 Parameters 5-5, 7-7

~B~
 Baud Rate, Hand-held term & RS 232 2-6
 To change 7-10

~C~
 Cables (transducer) 2-2, 4-6
 Crossed Paths..... 3-1, 3-4
 Clock Setting 7-10
 Compound Mode 3-1 to 3-4

~D~
 Data Logging 2-2, 2-7, 5-10, 6-9, 7-11
 Data Output
 Analog 4-20 mA 2-2, 2-4
 on Hand-held terminal 5-6
 LCD 5-9
 Serial on hand-held terminal port 5-8
 Special formats on Com 3 port
 DELT 5-6, 7-12
 Display
 on Hand-held terminal 2-5, 5-6
 on LCD 5-9

~E~
 Earth Connections..... 4-4
 Electrical Specifications 2-1
 EMC Conformity 2-3
 Error Messages 7-12, 7-13

~F~
 Fault Messages 7-12, 7-13
 Flow
 Computation 3-1 to 3-5
 Compound choices 3-2
 Manning..... 3-2
 Non surcharged single path 3-2
 Non surcharged multi path 3-3
 Surcharged..... 3-4
 Pipe..... 3-5

~G~
 Gain 5-6, 7-12
 Ground Connections 4-4

~H~
 Hand-held Terminal
 Connections 2-6, 4-13
 Displays 5-6
 Specification 2-2
 Heater
 Specification 2-1
 Connection 4-4

~K~
 Key Functions on Terminal 5-1, 5-2

~L~
 Layer data
 Round pipe 7-14
 Level Input
 Arbitration 2-4
 Connection 4-10, 4-13
 Electrical specification 2-2, 2-4
 Fault conditions 2-4
 Parameters 5-5, 7-7
 Logging to Flash..... 2-2, 2-7, 5-10, 6-10, 7-11

~M~
 Menus 5-1
 Manning..... 3-2
 Modem for Accuflow remote access 2-7, 4-12
 Multi-path integration..... 3-1 to 3-5

~P~
 Parameters
 Descriptions..... 7-1 to 7-11
 Entry 5-3
 List Typical..... 5-4
 Transmit to PC..... 5-2
 Paths
 Allocation to sections 1-2, 3-1, 7-3
 Connections 4-6
 Crossed 3-1, 3-4
 Elevation order 3-1, 7-6
 Length range..... 2-1, 7-6
 Parameter 5-5, 7-6
 Substitution (pipe only)..... 3-5
 Variables..... 7-12

PC
 In place of terminal..... 4-13, 2-6
 With Accuflow 2-6 to 2-7, 4-12, Ch 6

Power
 Connection 4-4
 Specification..... 2-1
 Outlet 4-4
 Pump / Turbine systems 7-14

~R~
 Relays
 Connection 4-13, Cust. Spec. Drawings

Index

Electrical specification 2-2
Functions & Logic 2-5
Section “Good” 7-14
Parameters 5-5, 7-9
Remote Access via Modem 2-7, 4-12
Retrieve Logged Data 6-10
Round Pipe, Layer data 7-14
RS232 Serial Data Outputs 5-8

~S~

Section “Good” relay 7-14
Section Parameters 5-4, 7-3
Serial data outputs 5-8
Status Indication 7-12, 7-13
System Parameters 5-4, 7-1
Statistics 5-5, 7-10

~T~

Temperature of Water
Calculation 3-6
Correction factor 7-3
Display 7-13
TENV 5-6, 7-12
TRAV 5-6, 7-12
Transducers
Cables 2-2, 4-8
Connections 4-6
Specification 2-1

~V~

Variables, Definitions 7-12
Volume
Calculations 3-5
Display 5-7, 5-9
Relay pulses logic 3-5
Resetting initial value 7-3