Thermo
ELECTRON CORPORATION

DCT7088

PORTABLE DIGITAL CORRELATION TRANSIT TIME ULTRASONIC FLOWMETER

USER MANUAL

Formerly

Thermo Polysonics

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Rev B (02/03)

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ELECTRON CORPORATION

USER MANUAL

DCT7088 PORTABLE TRANSIT TIME
ULTRASONIC FLOWMETER
FIRMWARE VERSIONS 6.00 ONWARD
FEBRUARY 2003
REV. B

NOTICE

Read this manual before working with the product. For personal and system safety and for optimum performance, make sure you thoroughly understand the contents before installing, using, or maintaining your transit time instrument.

For equipment service needs outside the United States contact your nearest Thermo representative. Within the United States, the Thermo Service Department is your single-point contact for all Thermo equipment service needs. If at any time you are not sure what to do, you have a question about using the product, or you have a service or support request, call the center at (713) 272-0404. This contact is your fastest link to quick and complete answers about any Thermo product or service.

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1. Product Overview

1.1 Introduction

The DCT7088 Digital Correlation Transit Time Flowmeter is manufactured by Thermo Electron Corporation. This microprocessor-based instrument measures the flow of clean, homogeneous liquids (liquids without large concentrations of suspended particles or gasses such as air bubbles). The flowmeter is noninvasive, which means that it measures flow from outside the pipe. Its transducers can be mounted to a pipe within a matter of minutes, and flow measurements may be made without interrupting the flow or modifying pipework.

The DCT7088 can be configured using an integral keypad for entering variables such as pipe size, pipe material, wall thickness, and fluid type (refer to Section 3, page 7). The flowmeter can also be remotely configured and monitored via the RS232 interface mode using the D-Link data link utility (refer to Appendix D, page 64). Another alternative to flowmeter configuration is to use the UltraScan utility which also graphically analyzes the signal in a Microsoft® Windows® environment (UltraScan manual provided on PolyCD).

1.2 Theory of Operation

Sound waves travel in fluids at a specific velocity depending on the type of fluid. If the fluid is moving, the sound wave travels at a velocity equal to the sum of the speed of sound in the fluid and the velocity of the fluid itself relative to the transducer. A sound wave traveling in the same direction as the fluid flow (downstream) will arrive sooner than a sound wave traveling against the flow (upstream). A transit time flowmeter operates by measuring both the absolute travel time of each sound wave and the difference in time required for the waves to travel between an externally mounted downstream and upstream transducer (Figure 1.2-A, below). Based on the transit time of the 2 sound waves, the flowmeter calculates the average fluid velocity.

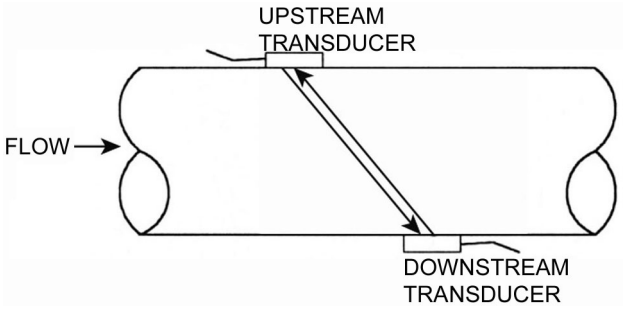


Figure 1.2-A: Typical Transit Time System

Once the differential transit time is calculated, several additional variables must be taken into consideration. The overall velocity of the fluid is actually made up of many individual local velocities that vary according to their distance from the pipe wall. The velocities in the center of the pipe are higher than the velocities near the pipe wall. The combination of these individual velocities for a specific type of fluid within a specific pipe yield a velocity distribution known as the flow profile (Figure 1.2-B, page 2), which is a function of the Reynolds number. By properly configuring the flowmeter, the effects of the flow profile are taken into consideration when calculating the mean fluid velocity. The flowmeter then multiplies this velocity by the pipe's cross-sectional area to obtain volumetric flow.

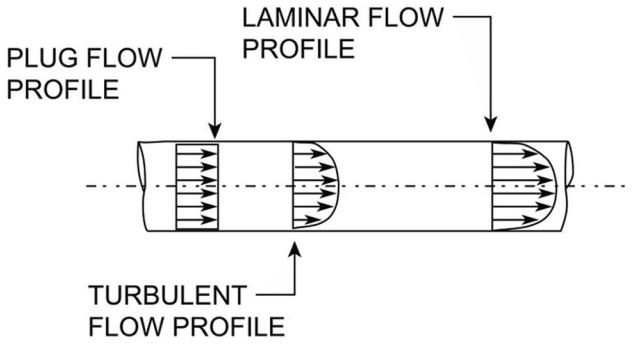


FIGURE 1.2-B: FLOW PROFILES

1.3 Transit Time Accuracy

Noninvasive ultrasonic measurements are subject to a variety of effects that can influence measurement accuracy. All ultrasonic instruments are velocity measuring devices and only infer volumetric flow from the operator-entered parameter of pipe inside diameter (ID). When this value is squared to get cross-sectional area, a 1% error yields a 2% error in volumetric flow. In practice, commercially fabricated pipe seldom has ID consistency much tighter than 1%, and unless the pipe to be measured has been accurately measured, this uncertainty is not reducible through instrument calibration.

The more sophisticated transit time flowmeters incorporate flow profile corrections to compensate for the pipe's cross-sectional velocity profile with a changing Reynolds number. However, this requires that the operator knows the inside roughness of the pipe to be measured. The instrument may infer a roughness if none is entered by the operator, but that is only an estimate based on the characteristics of new pipe. Pipes can, of course, accumulate deposits which may not only reduce the ID, but affect the roughness as well. Errors on the order of 2% as a result of this phenomenon are not uncommon.

While other factors may influence instrument accuracy to a lesser extent, the issues described above are the major elements of pipe dependency upon absolute instrument accuracy. While calibration on a reference flow loop under known conditions is a useful exercise to determine the accuracy potential of an instrument, it is not a guarantee of absolute accuracy on different pipes under field conditions.

1.4 Ordering

The table below describes ordering information for a standard DCT7088 flowmeter as well as available options.

MODEL NUMBER

Series: Digital Correlation Transit Time Flowmeters

DCT7088 = DCT7088, RS232 digital interface with UltraScan signal analysis and configuration program

Battery Duration

1 = 8 hours[1] **2** = 16 hours

Transducer Cable Length

16A = 16 ft (5 m)[1] **XXXXA** = increments of 10 ft (3 m) up to 1000 ft (305 m)

Additional Options

0704/0188 = Ultrasonic Thickness Gauge (UTG), English units
0704/0187 = UTG, metric units
22334-0001 = Thermal printer kit

Typical Model Number: DCT7088-1-B-16A

[1] standard

TABLE 1: ORDERING INFORMATION

1.5 Technical Specifications

1.5.1 Performance

Flow range:	0 to 40 ft/s (0 to 12 m/s)
Accuracy:	+/-1% of velocity or +/-0.05 ft/s (+/-0.0152 m/s), typical, digital output
Sensitivity:	0.001 ft/s (0.3 mm/s) at any flow rate, including zero
Linearity:	+/-0.1% of scale, digital output
Pipe size:	1 to 200 in (25 mm to 5 m)
Fluid:	homogeneous liquids without gas bubbles

1.5.2 Functional

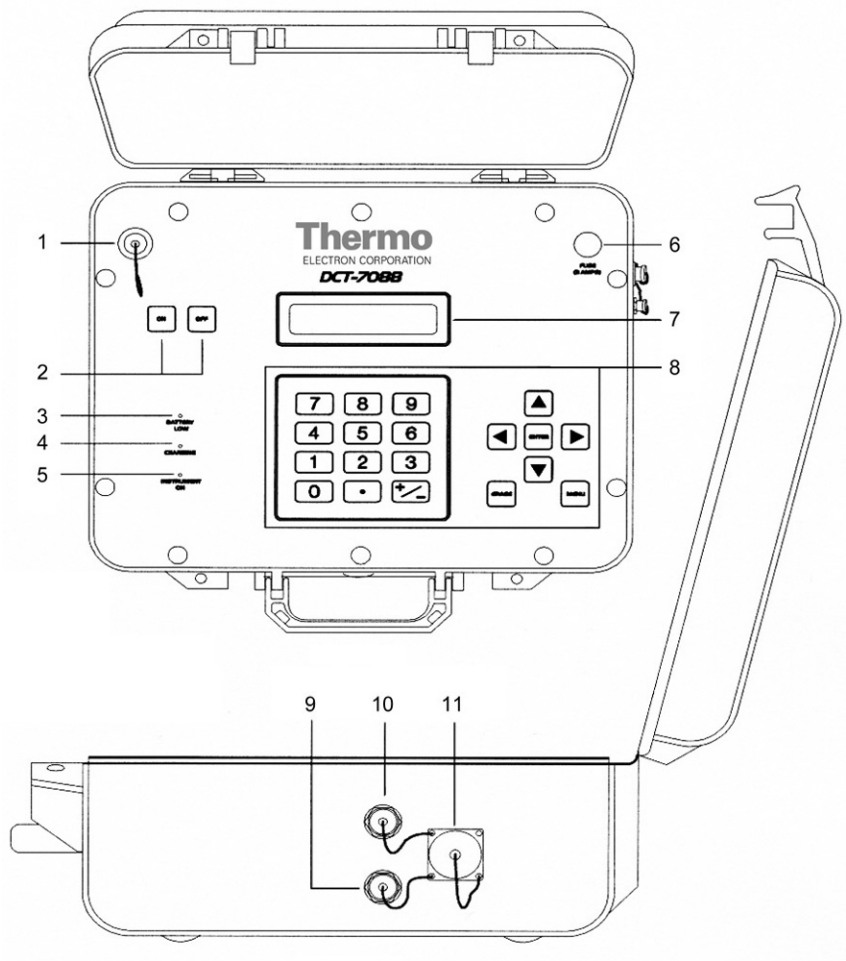
Outputs:	4-20 mA (into 1000 ohms), 12-bit, isolated, loop- or self- powered RS232 serial interface	
Power supply:	built-in lead acid gel battery providing 8 hours continuous operation (standard) OR 16 hours continuous operation (optional)	
Keypad:	19-key with tactile action	
Display:	40-character, 2-line, alphanumeric, backlit LCD	
Datalogger:	40,0000 points, time stamped; programmable in 1-second intervals	
Programming:	via UltraScan utility (supplied with flowmeter) OR integral keypad	
Temperature Range:	*Transducers:*	-40º to +212º F (-40º to +100º C) *optional high temperature transducers available*
	Transmitter:	-5º to +140º F (-20º to +60º C)

...1.5 Technical Specifications continued

1.5.3 Physical

Transmitter:	NEMA 6 (IP67), waterproof against accidental immersion; splashproof with lid open
Transducers:	encapsulated design with standard 16 ft (5 m) cable length
Weight:	approximately 11 lbs (4.9 kg) with 8-hour battery; approximately 15 lbs (6.8 kg) with 16-hour battery

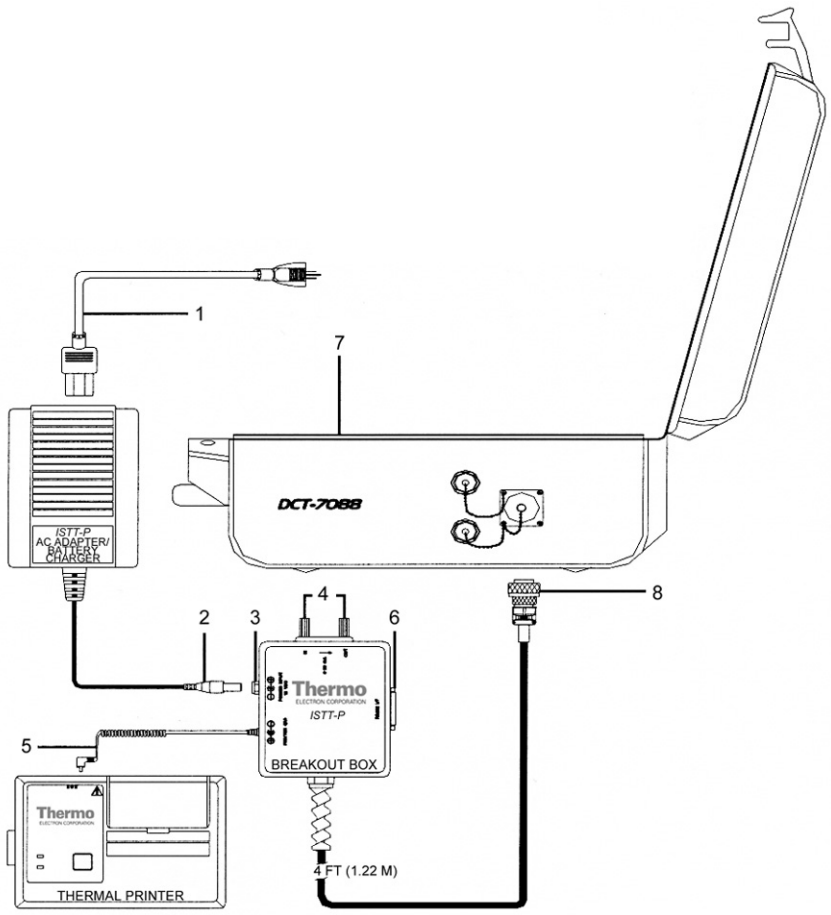
1.6 External Features



Components

#	**Description**
1	Printer port: provides output for optional external thermal printer; connects to special cable which has 3-pin round connector on flowmeter end and DB9 connector on printer end
2	ON/OFF keys
3	*Battery Low* light: activates approximately 7 or 14 hours of operation (depending on battery type); automatic shutdown after approximately 1 additional hour
4	*Charging* light
5	*Instrument on* light
6	Fuse: 3-A, 250 V; protects flowmeter from battery overcurrent or short circuits
7	Liquid crystal display (LCD): displays configuration selections, flow rate, totalized flow, etc.
8	Keypad: use to enter configuration parameters and control flowmeter functions
9	Downstream transducer connector
10	Upstream transducer connector
11	Breakout box interface connector: connects flowmeter to breakout box

1.7 Breakout Box Components



Components

#	Description
1	AC power cable
2	DC power output cable
3	DC power input connector: connects DC power output cable to flowmeter
4	4-20 mA output terminals
5	Printer charger cable
6	RS232 serial port
7	Breakout box interface connector: provides connections for DC power input from battery charger/AC adapter, for DC output cable for charging batter, for RS232 serial port, and for 4-20 mA current loop output terminals
8	7-pin circular connector: connects breakout box to flowmeter

2. Wiring the Current Loop

The 4-20 mA current loop module has an input terminal and an output terminal, which are indicated on a label on the inside of the flowmeter door. The current loop output is rated for a loop resistance of up to 1 k ohms and is isolated for up to 5 kV when loop-powered.

The 4-20 mA module is shipped with the current loop self-powered. Switch the module to loop power by moving a jumper on the module. Current loop modules which are loop-powered must be driven from an external power supply. In this case the flowmeter acts as a passive 2-wire transmitter.

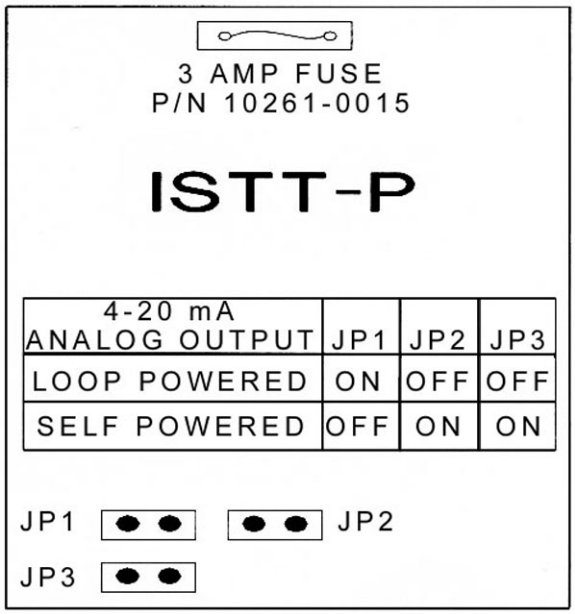
Prevent possible electrical shock and/or damage to the meter–disconnect power PRIOR to removing back cover of the breakout box and disconnect the breakout box from the flowmeter and battery charger/AC adapter.

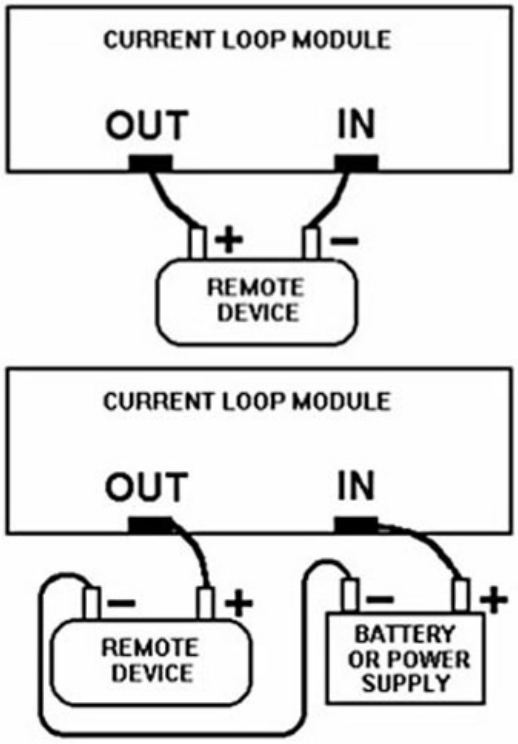
To connect the current loop:

1. Ensure the loop powering option is correct.

2. Locate the jumpers on the upper right corner of the module. Refer to Figure 2.1-A (below) to change the jumper settings.

3. Refer to Figure 2.1-B (below) for the self-powered option or Figure 2.1-C (below) for the loop-powered option.





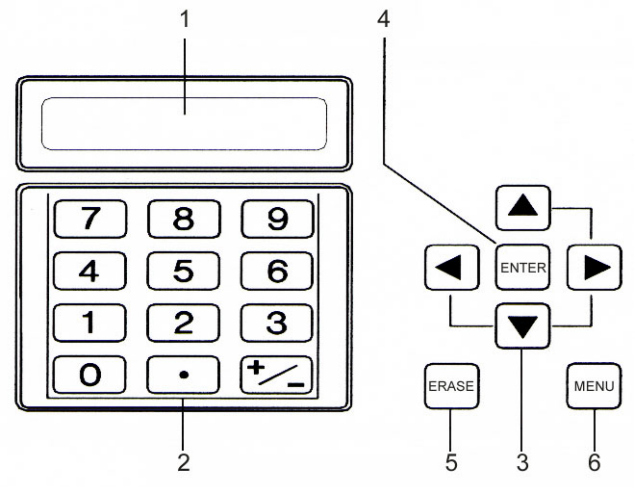
Figures 2.1-A (left), 2.1-B (right, top), 2.1-C (right, bottom)

3. Configuring & Operating the Flowmeter

3.1 The Keypad & Display

The keypad provides access to the microprocessor for flowmeter configuration. During operation, the instrument's 40-character LCD indicates flow rate and totalizer values.

3.1.1 Components



Components

#	Description
1	LCD
2	Numeric keys: **0** through **9** and decimal (**.**)
3	Arrow keys: for scrolling up, down, left, right
4	**ENTER** key: operates like the Return (Enter) key on a computer
5	**ERASE** key: deletes last value entered; in most setup and diagnostic menus, accesses Main Menu; accesses Menu 00 (flow rate and net totalizer display) if pressed twice
6	**MENU** key: provides access to setup and diagnostic menus

Figure 3: Keypad & Display Features

3.1.2 Display Contrast & Backlight

The display is backlit for ease of viewing in low-light conditions. In order to save battery life, the backlight shuts off automatically after several minutes have passed without a keypad entry. The display has a variable contrast setting, and you may need to adjust the contrast on the display as ambient temperature changes:

1. Press **MENU** followed by the **±** (plus/minus) key.
2. *LCD CONTRAST* appears on the display with a bar indicating current contrast setting.
3. Press **LEFT** or **RIGHT ARROW** keys to adjust the contrast.
4. Press **ENTER** when complete.

3.2 Direct Menu Access

The unique 2-digit address (reference Table 2, page 8) for each setup and diagnostic menu allows the user to directly access the desired menu:

1. Press **MENU**, and the letter ***M*** appears in the lower right corner of the display.
2. Enter the desired menu's 2-digit address.

The address must be entered while the ***M*** is displayed (within approximately 4 seconds). If the ***M*** is no longer displayed, press **MENU** again followed by the 2-digit address.

Table 2: Menu Addresses

Menu Type	Display	Menu
Primary	Flow/Net Totalizer	00
	Flow/Velocity	01
	Flow/Positive Totalizer	02
	Flow/Negative Totalizer	03
	Signal Strength/Low Signal Cutoff	04
Pipe	Pipe OD	10
	Pipe Wall Thickness	11
	Pipe ID	12
	Pipe Material	13
	Pipe Sound Speed	14
	Pipe Inside Roughness	15
Liner	Liner Material	16
	Liner Thickness	17
	Liner Sound Speed	18
	Liner Inside Roughness	19
Fluid	Fluid Type	20
	Fluid Sound Speed	21
	Fluid Viscosity	22
Transducer	Transducer Type	23
	Transducer Mounting	24
	Transducer Spacing	25
Flow	Flow Units	30
	Max Flow Range	31
	Min Flow Range	32
	Damping	33
	Low Flow Cutoff	34
	Low Signal Cutoff	35
Totalizer	Totalizer Units	36
	Totalizer Multiplier	37
	Net Totalizer	38
	Positive Totalizer	39
	Negative Totalizer	40
	Totalizer Reset	41

Menu Type	Display	Menu
Options	Measurement Units	42
	Site Parameters	43
	RS232 Configuration	46
	Change System Password	47
	Change Scale Factor Password	48
	Unit ID	49
Calibration		50
	Zero Set	51
	Scale Factor	52
	Sound Speed Compensation	53
	Date and Time	54
Current Loop		56
	Current Loop Span	57
	Current Loop Calibration	58
	Current Loop Test	59
Alarms		70
	Program Alarms	71
	View Alarms	72
Datalog	Datalog Setup	80
	Datalog Interval	81
Diagnostics	Signal Strength/Margin	90
	Delta Time/Fluid Sound Speed	91
	Reynolds #/Profile Factor	92
	Current Loop Output	93
	Software/Firmware Rev. Level	94
Print	Print Log Setup	96
	Print Settings	97
	Print Diagnostic	98
	Print Current Screen	99

3.3 Using the Arrow Keys to Access Menus

Another method of accessing the flowmeter's menus is to use the **LEFT** or **RIGHT ARROW** keys to scroll through the menu structure. Menus are organized into 3 basic levels: 1) Main menu, 2) submenus, and 3) primary displays, setup menus, diagnostic menus. The **Main** menu displays various **submenus**, which contain individual **setup** and **diagnostic** menus.

To access the **Main** menu from any screen:

1. Press **MENU** twice. The Main menu is displayed with the **Pipe** and **Liner** submenu options as shown in Figure 3.3-A.

FIGURE 3.3-A

2. To view the remaining submenus (Figure 3.3-B), press the **DOWN ARROW** key.

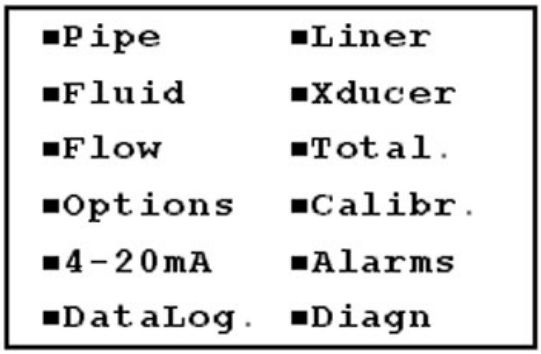


FIGURE 3.3-B

3. When the desired submenu is highlighted, press **ENTER** to display the first menu of the selected submenu. Figure 3.3-C is an example of when the **Flow** submenu is selected.

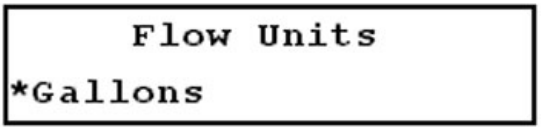


FIGURE 3.3-C

Use the **UP** or **DOWN ARROW** keys to view a Primary Display, setup menu, or diagnostic menu within the current submenu.

3.4 Flowmeter Configuration Using Setup Menus

Flowmeter configuration is accomplished using the setup menus. Some setup menus allow a numeric value to be entered, and others offer non-numeric selections. In non-numeric setup menus, an asterisk is displayed to the left of the selected currently entered in the flowmeter (Figure 3.4, below).

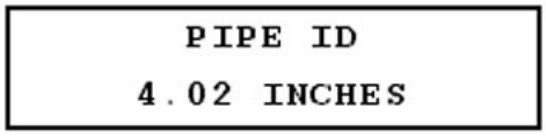


FIGURE 3.4

...3.4 Flowmeter Configuration Using Setup Menus continued

To configure the flowmeter:

1. Access the setup menus individually by pressing **MENU** and entering the 2-digit address OR by scrolling through the submenus and selecting the desired setup menu.

2. a. If the setup menu requires a numeric entry, use the numeric keys to enter the value and press **ENTER** to accept the value. If the numeric value is entered incorrectly, press **ERASE** to delete the entry.

   OR

   b. If the setup menu offers a non-numeric selection, press **ENTER**, and the asterisk changes to a flashing cursor. Use the arrow keys to scroll through the available selections. When the cursor is to the left of the desired selection, press **ENTER**.

3. Complete the configuration process by accessing a Primary Display (menus 00 through 04).

The flowmeter will not use the new parameters until accessing a Primary Display.

3.5 Quick Setup Configuration

The Quick Setup procedure contains the minimal steps required for flowmeter configuration. These steps enable the flowmeter to calculate transducer spacing, acquire ultrasonic signal, and measure flow. The number in parentheses after the required menu is the 2-digit address to directly access that menu.

1. Select a proper transducer site according to Section 4 (page 29).

2. Access the **Pipe** submenu. This submenu contains setup menus related to the pipe parameters such as pipe inside diameter (ID) and pipe outside diameter (OD).

Pipe Wall Thickness is an additional setup menu within the Pipe submenu. If parameters for any 2 of the following 3 setup menus are entered, the flowmeter calculates the remaining parameter automatically: Pipe OD (10), Pipe Wall Thickness (11), Pipe ID (12).

Accuracy is directly affected by the square of an error in pipe dimensions; actual measurements (not nominal) must be entered.

a. Select the **PIPE OD** menu (10). Figure 3.5-A is displayed. Enter the value for the pipe OD and press **ENTER**. Press the **DOWN ARROW**, and select **Actual.**

NOTE: If you know the pipe circumference but not the OD, enter the circumference value instead and press **ENTER**. Press the **DOWN ARROW**, and Figure 3.5-B is displayed. Select **Circum.** The flowmeter calculates the pipe OD automatically.

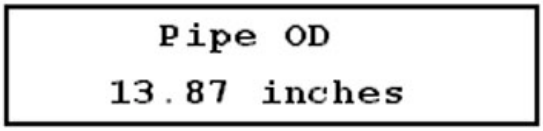


FIGURE 3.5-A

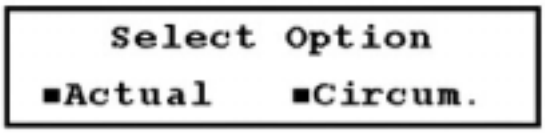


FIGURE 3.5-B

...3.5 Quick Setup Configuration continued

Step 2, **PIPE** setup menu continued:

b. Select the **Pipe ID** setup menu (12). Enter the pipe ID value, and press **ENTER.** (Figure 3.5-C)

c. Select the **Pipe Material** setup menu (13). Press the **UP** and **DOWN ARROWS** to scroll through the available options. (Figure 3.5-D)

NOTE: Select **OTHER** if the material is not listed. You must then enter then pipe sound speed (14) and pipe inside roughness (15).

3. If there is a liner:

   a. Access the **Liner Material** setup menu (16), and Figure 3.5-E is displayed. Press the **UP** and **DOWN ARROWS** to scroll through the available options.

   NOTE: Select **OTHER** if the material is not listed. You must then enter the liner sound speed (18) and liner inside roughness (19).

   b. Access the **Liner Thickness** setup menu (17), and enter the thickness. (Figure 3.5-F)

4. Access the **Fluid Type** setup menu (20), and scroll through the available options using the **UP** and **DOWN ARROWS.** (Figure 3.5-G)

   NOTE: Select **OTHER** if the fluid type is not listed. You must then enter the fluid sound speed (21) and fluid viscosity (22).

5. Within the **Transducer** submenu:

   a. Access the **Transducer Type** setup menu (23). Currently, the only selection available is **STANDARD**, which MUST be selected for all applications using clamp-on transducers, including high temperature transducers. (Figure 3.5-H)

   b. Access the **Transducer Mounting** setup menu (24), and select the desired mounting method. (Figure 3.5-I)

6. Access the **Transducer Spacing** view-only menu (25). Note the required spacing between transducers. (Figure 3.5-J)

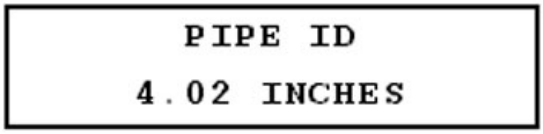


FIGURE 3.5-C

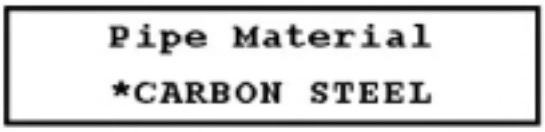


FIGURE 3.5-D

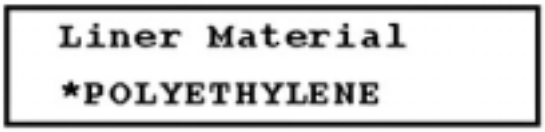


FIGURE 3.5-E

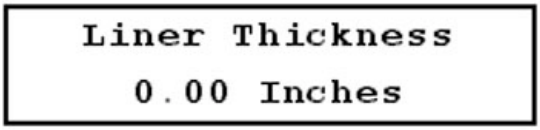


FIGURE 3.5-F

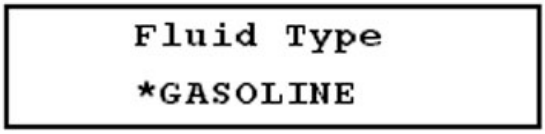


FIGURE 3.5-G

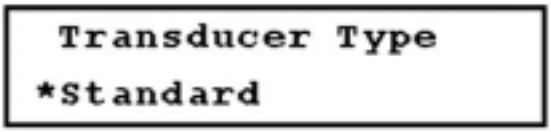


FIGURE 3.5-H

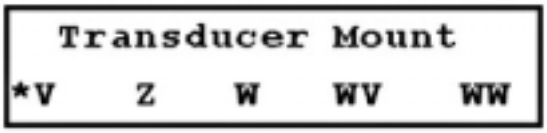


FIGURE 3.5-I

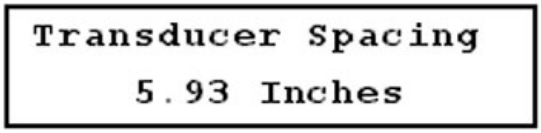


FIGURE 3.5-J

...3.5 Quick Setup Configuration continued

7. Access the **Flow Units** setup menu (30) within the **FLOW** submenu. Use this setup menu to select the flow rate units. Volumetric units are displayed first, followed by the associated time per units.

   a. Select one of the available volumetric units. (Figure 3.5-K)

   b. Press the **DOWN ARROW** and the time per unit options are displayed. Select the desired option. (Figure 3.5-L)

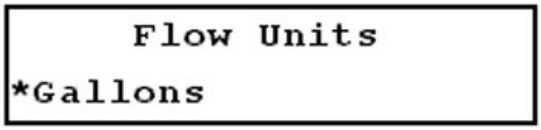


FIGURE 3.5-K

FIGURE 3.5-L

8. Install the transducers on the pipe using the spacing provided by the flowmeter, and connect the transducer cables to the flowmeter.
9. Access a **Primary Display** (00 through 04) to complete the configuration process.

If the flowmeter and transducers are properly installed and a steady flow is present, the flow and signal strength readings should be relatively stable.

If any of the above setup parameters are changed, the flowmeter stops measuring flow until the new value is entered and a Primary Display is accessed to accept the new value.

3.6 Primary Displays

The **Primary Displays** are for viewing only and cannot be configured. **Primary Displays** include displayed values for flow rate, totalizers, velocity, signal strength, or low signal cutoff (menus 00 through 04).

3.6.1 Flow/Net Totalizer (00)

The **Flow/Net Totalizer** is the standard display used under normal operating conditions. It displays the flow rate and net totalizer value. If the net totalizer is not currently enabled, the last net totalized value is displayed. (Figure 3.6-A)

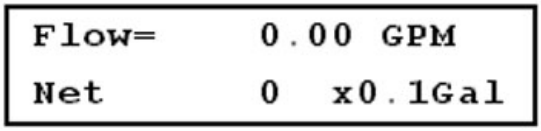


FIGURE 3.6-A

3.6.2 Flow/Velocity (01)

The **Flow/Velocity** display indicates the flow rate and fluid velocity. Velocity is displayed in feet per second (*FPS*) if ENGLISH is selected as the measurement unit in Menu 42 and in meters per second (*MPS*) if METRIC is selected. (Figure 3.6-B)

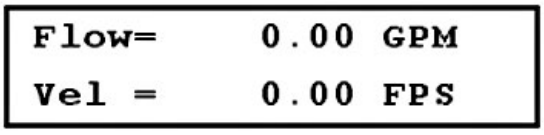


FIGURE 3.6-B

3.6.3 Flow/Positive Totalizer (02)

This display indicates the flow rate and the totalized flow in the positive flow direction. If the positive totalizer is not currently enabled, the last *net* totalized value is displayed. (Figure 3.6-C)

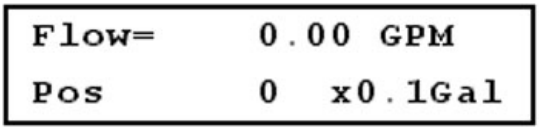


FIGURE 3.6-C

3.6.4 Flow/Negative Totalizer (03)

This display indicates the flow rate and the totalized flow in the negative flow direction. If the negative totalizer is not currently enabled, the last *net* totalized value is displayed. (Figure 3.6-D)

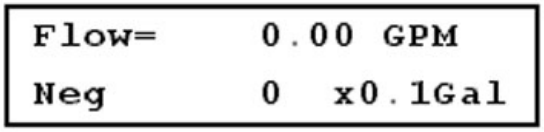


FIGURE 3.6-D

3.6.5 Signal Strength/Low Signal Cutoff (04)

This display indicates the values for signal strength and low signal cutoff. (Figure 3.6-E)

FIGURE 3.6-E

3.7 Additional Setup Menus Within the PIPE Submenu*

***Not included in the Quick Setup Configuration**

Following are **setup** menus not included in the Quick Setup Configuration detailed in Section 3.5 (page 10). **Setup** menus are used primarily to enter configuration data or to view the flowmeter's current configuration settings. The following setup menus are located within the **PIPE** submenu and are not required entries in the Quick Setup Configuration:

- **Pipe Wall Thickness** setup menu (11) (Figure 3.7-A)
- **Pipe Sound Speed** setup menu (14): This menu can only be configured if **OTHER** was selected as the pipe material in Menu 13. Enter the pipe sound speed. If **OTHER** was NOT selected as the pipe material, this menu is available by the direct access method only and functions as a view-only display to indicate the pipe sound speed as programmed in the flowmeter's database. (Figure 3.7-B)
- **Pipe Inside Roughness** setup menu (15): This menu can only be configured if **OTHER** was selected as the pipe material in Menu 13. Data on this parameter are available from the *Cameron Hydraulic Data Book* published by Ingersoll-Rand. Enter the inside roughness of the pipe. If **OTHER** was NOT selected as the pipe material, this menu is available by the direct access method only and functions as a view-only display to indicate the pipe inside roughness as programmed in the flowmeter's database. (Figure 3.7-C)

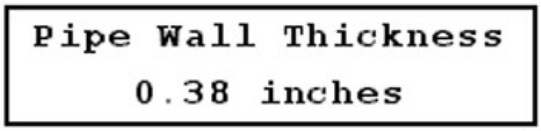


FIGURE 3.7-A

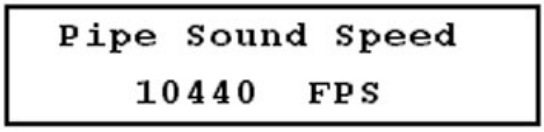


FIGURE 3.7-B

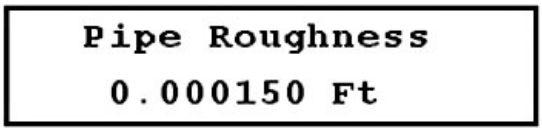


FIGURE 3.7-C

3.8 Additional Setup Menus Within the LINER Submenu*

***Not included in the Quick Setup Configuration**

- **Liner Sound Speed** setup menu (18): This menu can only be configured if **OTHER** was selected as the liner material in Menu 16. Enter the liner sound speed. If **OTHER** was NOT selected as the liner material, this menu is available by the direct access method only and functions as a view-only display to indicate the liner's sound speed as programmed in the flowmeter's database. (Figure 3.8-A)

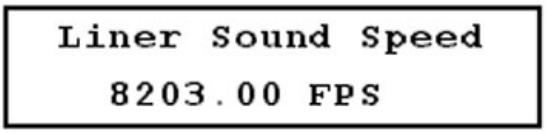


FIGURE 3.8-A

- **Liner Inside Roughness** setup menu (19): This menu can only be configured if **OTHER** was selected as the liner material in Menu 16. Enter the liner inside roughness. If **OTHER** was NOT selected as the liner material, this menu is available by the direct access method only and functions as a view-only display to indicate the inside roughness of the liner as programmed in the flowmeter's database. (Figure 3.8-B)

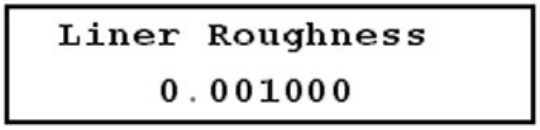


FIGURE 3.8-B

3.9 Additional Setup Menus Within the FLUID Submenu*

***Not included in the Quick Setup Configuration**

- **Fluid Sound Speed** setup menu (21): This menu can only be configured if **OTHER** was selected as the fluid type in Menu 20. Enter the fluid sound speed. If **OTHER** was NOT selected as the fluid type, this menu is available by the direct access method only and functions as a view-only display to indicate the fluid sound speed as programmed in the flowmeter's database. (Figure 3.9-A)

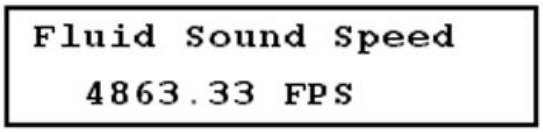


FIGURE 3.9-A

- **Fluid Viscosity** setup menu (22): This menu can only be configured if **OTHER** was selected as the fluid type in Menu 20. Enter the fluid viscosity. If **OTHER** was NOT selected as the fluid type, this menu is available by the direct access method only and functions as a view-only display to indicate the fluid viscosity as programmed in the flowmeter's database. (Figure 3.9-B)

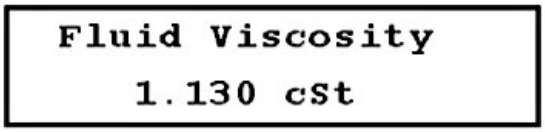


FIGURE 3.9-B

3.10 Additional Setup Menus Within the FLOW Submenu*

***Not included in the Quick Setup Configuration**

- **Max Flow Range** setup menu (31) and **Min Flow Range** setup menu (32): Use these menus to enter the minimum and maximum flow values for setting the volumetric flow range. Setting the optimum flow range generally improves the flowmeter's response time. (Figures 3.10-A and 3.10-B)

  NOTE: Whenever the pipe ID is changed, the flowmeter returns the volumetric flow range to its default settings. The default settings are the minimum and maximum flows for the new pipe ID that occur at +32 and -32 ft/s (+9.76 and -9.76 m/s).

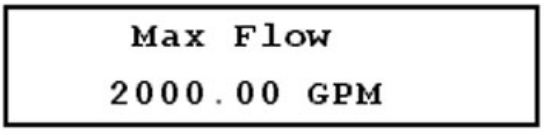


FIGURE 3.10-A

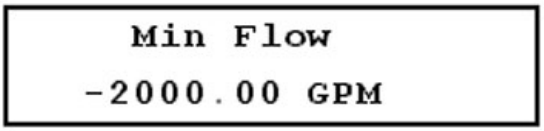


FIGURE 3.10-B

- **Damping** setup menu (33): Use this menu to enter the value for the damping coefficient, which suppresses short-term fluctuations in the indicated flow rate. The displayed flow rate and the 4-20 mA current loop output is a moving average of the last *n* seconds where *n* is the damping value. Increasing the coefficient increases the response time to changes. The coefficient is adjustable from 1 to 99 seconds in 1-second increments. Damping should be kept at a minimum unless the flow rate fluctuates wildly. If this is the case, increase the damping coefficient just enough to reduce the fluctuation to an acceptable degree. (Figure 3.10-C)

FIGURE 3.10-C

- **Low Flow Cutoff** setup menu (34): When a zero flow condition occurs (for example, as the result of a pump being shut off), internal sloshing, check valve leakage, and other fluid movement can prevent the flowmeter from reading total zero. This phenomenon can result in totalizer errors. Minimize these errors by entering a low flow cutoff, which drives the flowmeter to zero for flow rates at or below the specified value. If the flow rate falls below the low flow cutoff value, the indicated flow rate is driven to zero and the totalizers stop incrementing; this is the case regardless of flow direction. (Figure 3.10-D)

  For example, if you enter a low flow cutoff of 0.1 ft/s (.03 m/s), the flowmeter is driven to zero for flow rates less than 0.1 ft/s in the positive direction and greater than -0.1 ft/s in the negative direction. (Figure 3.10-E)

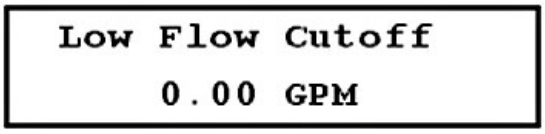


FIGURE 3.10-D

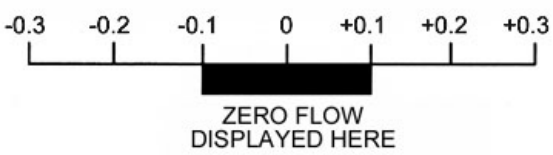


FIGURE 3.10-E

...3.10 Additional Setup Menus Within the FLOW Submenu* continued

***Not included in the Quick Setup Configuration**

- **Low Signal Cutoff** setup menu (35): Empty pipes or solids, bubbles, or voids in the flow stream may cause temporary drops in signal strength and erroneous readings. Minimize the effect of these dropouts by setting a low signal cutoff, which drives the flowmeter to the loss-of-signal (LOS) condition. The low signal cutoff should be set at the minimum acceptable signal amplitude.

  To set the low signal cutoff:

  a. Access the **Low Signal Cutoff** setup menu (35). (Figure 3.10-F)

  b. Enter the low signal cutoff and press **ENTER.**

  NOTE: The value for the low signal cutoff should usually be set at approximately one-half of the value of the signal strength present under flow conditions. Typically, signal strength is not significantly affected by flow rate.

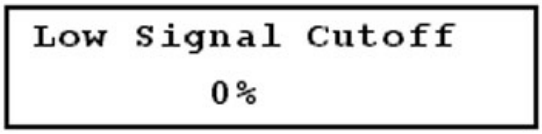


FIGURE 3.10-F

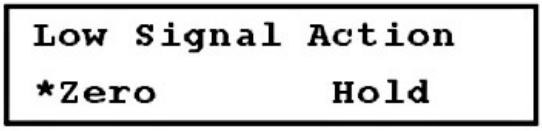


FIGURE 3.10-G

  c. Select one of the following:

  - **ZERO**: the flowmeter drops the reading to zero during LOS condition;
  - **HOLD**: the flowmeter holds the last valid reading during LOS condition for about 3 seconds. (Figure 3.10-G)

3.11 Additional Setup Menus Within the TOTAL Submenu*

***Not included in the Quick Setup Configuration**

- **Totalizer Units** setup menu (36): The flow unit selected for the totalizer display may be different from the flow unit selected for the flow rate display. (Figure 3.11-A)

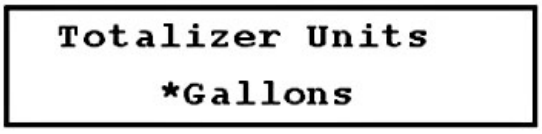


FIGURE 3.11-A

- **Totalizer Multiplier** setup menu (37): The totalizer value can be displayed with one of several multiplier values. For example, 700 liters can be displayed as *700* if the selected multiplier value is *X1*, or it can be displayed as *7* if selected multiplier value is *X100.* (Figure 3.11-B)

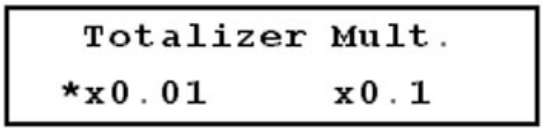


FIGURE 3.11-B

- **Net Totalizer** setup menu (38): Use this menu to enable or disable the net totalizer. The net totalizer provides the difference between the positive and negative flow values. For example, if there are 1000 gallons of flow in the negative direction and 3000 gallons of flow in the positive direction, the net totalizer indicates 2000 gallons of net flow. (Figure 3.11-C)

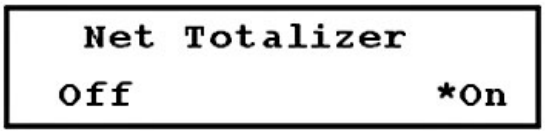


FIGURE 3.11-C

...3.11 Additional Setup Menus Within the TOTAL Submenu* continued

***Not included in the Quick Setup Configuration**

- **Positive Totalizer** setup menu (39): Use this menu to enable or disable the positive totalizer. The positive totalizer tracks the flow that moves in the positive direction, from upstream transducer to downstream transducer. It is NOT affected by flow in the opposite direction. (Figure 3.11-D)
- **Negative Totalizer** setup menu (40): Use this menu to enable or disable the negative totalizer. The negative totalizer tracks the flow that moves in the negative direction, from downstream transducer to upstream transducer. It is NOT affected by flow in the opposite direction. (Figure 3.11-E)
- **Totalizer Reset** setup menu (41): Use this menu to reset one or all of the totalizers. (Figure 3.11-F)

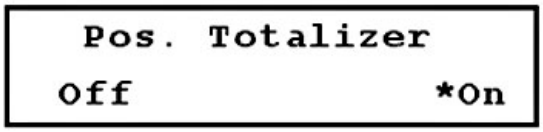


FIGURE 3.11-D

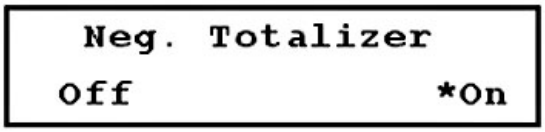


FIGURE 3.11-E

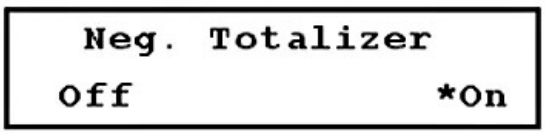


FIGURE 3.11-F

3.12 Additional Setup Menus Within the OPTIONS Submenu*

***Not included in the Quick Setup Configuration**

The **OPTIONS** submenu contains setup menus for several miscellaneous functions.

- **Measurement Units** setup menu (42): Use this menu to select **ENGLISH** (feet per second, *FPS*) or **METRIC** (meters per second, *MPS*) measurement units. (Figure 3.12-A)
- **Site Parameters** setup menu (43): This menu saves the parameters for the pipe, liner, fluid, transducer, and flow setup menus, allowing them to be recalled later for a specific measurement site. Several sites are available and are numbered. The site number is displayed in Menu 43 in the lower left corner of the screen and is followed by a colon. See Figure 3.12-B for an example of a site numbered 1.

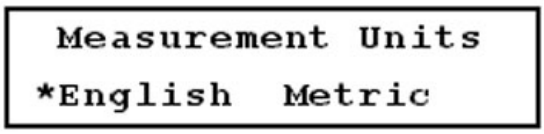


FIGURE 3.12-A

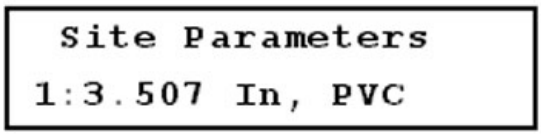


FIGURE 3.12-B

As the setup parameters are entered in their respective menus during normal configuration, the same parameters are saved simultaneously in the **Site Parameters** setup menu, in whichever site has the asterisk displayed.

Access a different site to automatically enter that site's stored parameters into the flowmeter for measuring flow. To access a different site, press **ENTER**, scroll to the desired site, and press **ENTER** again. **To avoid overwriting stored parameters and losing old data, ensure that the desired site is active prior to entering the new set of parameters.**

...3.12 Additional Setup Menus Within the OPTIONS Submenu* continued

***Not included in the Quick Setup Configuration**

- **RS232 Configuration** setup menu (46): Use this menu to configure the RS232 port which allows the flowmeter to connect to an IBM®-compatible PC using the UltraScan (refer to the UltraScan manual) or D-Link (refer to Appendix C, page 64) utilities. (Figure 3.12-C)

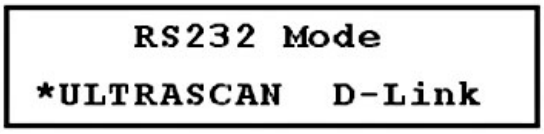


FIGURE 3.12-C

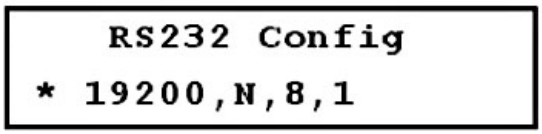


FIGURE 3.12-D

  a. Access the **RS232 Configuration** setup menu (46).

  b. Select **ULTRASCAN** or **D-LINK**.

  c. Press the **DOWN ARROW** to display the baud rate selections. The baud rate is the only RS232 parameter that can be selected. The remaining parameters are preset. (Figure 3.12-D)

  d. Access Menu 00.

- **Change System Password** setup menu (47): The flowmeter is shipped from the factory with the system password *disabled.* If a password is enabled, the flowmeter requests the password when a user attempts to enter any configuration data. Entering the correct password temporarily unlocks the system, allowing the user to make configuration changes.

  To change or disable the system password:

FIGURE 3.12-E

  a. Access Menu 47. (Figure 3.12-E)

  b. Enter the new system password and press **ENTER.** (Figure 3.12-F)

FIGURE 3.12-F

  NOTE: Disable the system password function by entering **0** (zero) as the system password. Enable the function by changing the password back to a non-zero number.

  c. Enter the old system password (Figure 3.12-G) and press **ENTER.** If the old system password is correctly entered, Figure 3.12-H is displayed. If the password is incorrectly entered, Figure 3.12-I is displayed.

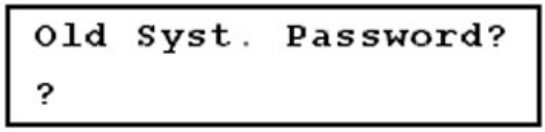


FIGURE 3.12-G

  NOTE: After the system password is accepted or rejected, Menu 48 is displayed, enabling the scale factor password to be changed.

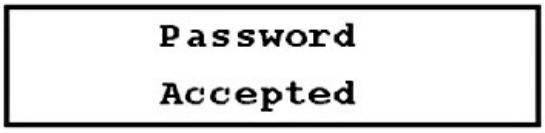


FIGURE 3.12-H

  d. Access Menu 00 to lock the system with the new password.

FIGURE 3.12-I

...3.12 Additional Setup Menus Within the OPTIONS Submenu* continued

***Not included in the Quick Setup Configuration**

- **Change Scale Factor Password** setup menu (48): Use this menu to change the scale factor password which is designed to protect the scale factor from unauthorized or accidental changes. The flowmeter ships from the factor with the scale factor password *disabled.* If the scale factor password is *enabled,* the flowmeter requests the password whenever a user attempts to change the scale factor.

  To change or disable the scale factor password:

  a. Access Menu 48. (Figure 3.12-J)

  b. Enter the new scale factor password and press **ENTER.** (Figure 3.12-K)

  NOTE: The system password function must be *disabled* to allow the scale factor to be changed without entering a password.

  c. Enter the old scale factor password and press **ENTER.** If entered correctly, Figure 3.12-L is displayed. If entered incorrectly, Figure 3.12-M is displayed.

  d. Access Menu 00.

- **Unit ID (identification) Number** setup menu (49): This number is determined by the operator to identify the specific instrument or site. Any whole number between 1 and 60,000 may be entered. (Figure 3.12-N)

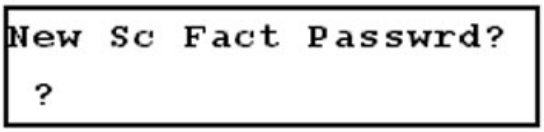


FIGURE 3.12-J

FIGURE 3.12-K

FIGURE 3.12-L

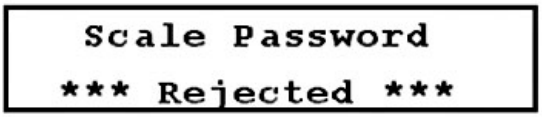


FIGURE 3.12-M

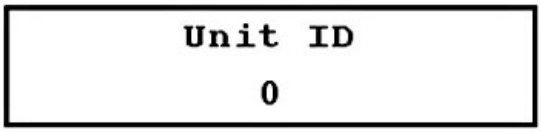


FIGURE 3.12-N

3.13 Additional Setup Menus Within the CALIBR Submenu*

***Not included in the Quick Setup Configuration**

Within the **CALIBR** submenu is the **Calibration Group** menu (50) (Figure 3.13-A), which contains 4 setup menus: **Zero Set, Scale, SS Comp, Date** (Menus 51 through 54).

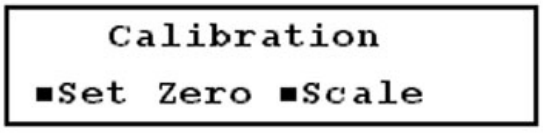


FIGURE 3.13-A

3.13.1 Zero Set Calibration

An important step in assuring accurate flow measurement is the proper calibration of the instrument and proper installation. The calibration methods must be performed for the particular pipe that is to be metered. Table 3 (below) provides guidelines for selecting a calibration method.

Calibration Method	Function	Application
Zero set calibration		
Zero flow set	Zeroes the instrument for an actual no flow condition	Installations where flow can be stopped
Manual zero set	Applies a manually entered offset to all flow readings	Where an offset is required
Scale factor	Compensates for manufacturing variations in the transducers	Set by the factory to the value imprinted on the transducers

TABLE 3

After installing the meter, you may find that a small adjustment to the zero point (zero set calibration) is required. Zero set calibration allows the meter to read very close to zero under zero flow conditions. There are 2 zero set calibration methods in Menu 51: the zero flow set method and the manual zero set method. View the zero point used by the flowmeter in either of these methods by selecting **Manual** in Menu 51.

After the instrument is properly zeroed, it should display a stable reading well below 0.05 ft/s (0.015 m/s) under zero flow conditions with the low flow cutoff disabled.

Prior to performing a zero set calibration, verify the following:

- transducers are connected to the pipe;
- instrument is reading flow;
- low flow cutoff is disabled to allow verification of calibration.

3.13.1.a Zero Flow Set Method

The best method of zeroing the instrument is to stop the flow and perform a zero flow set on the pipe. The purpose of the zero flow set is to zero the instrument for the individual application. This method is used *only* when flow in the pipe can be stopped. The flow rate displayed in Menu 01 must be between -0.25 and +0.25 ft/s (-0.076 and +0.076 m/s).

1. Ensure there is no flow in the pipe.
2. Access Menu 51. (Figure 3.13-B)
3. Select **No Flow.** If the zero flow set calibration is successful, Figure 3.13-C is displayed.

FIGURE 3.13-B

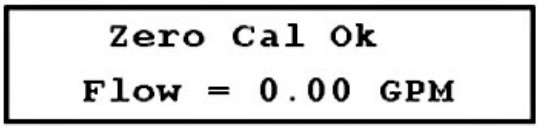


FIGURE 3.13-C

3.13.1.b Manual Zero Set

Use this method infrequently. Manual zero set applies a constant offset entered by the user to all readings. For example, if the flow reads 250 GPM and a 10 GPM offset is applied, the new reading becomes 240 GPM.

To zero the instrument using the manual zero set method:

1. Minimize flow occurring in the pipe.
2. Access Menu 51 and select **Manual.** Figure 3.13-D is displayed.
3. Enter the value of the required offset and press **ENTER.** If necessary, you can apply a negative offset by pressing **±** (plus/minus key).
4. The flowmeter is now calibrated with the manual zero set method, and the zero point offset is displayed. (Figure 3.13-E)

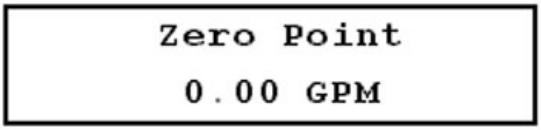


FIGURE 3.13-D

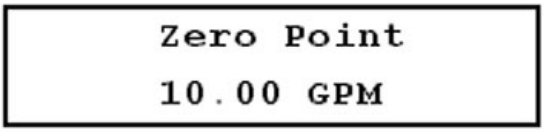


FIGURE 3.13-E

3.13.2 Scale Factor Calibration

After setting and verifying the instrument's zero point, you can set a scale factor to adjust the measured flow; the measured flow is multiplied by this scale factor. For example, if the displayed flow is twice the actual flow, you can enter a scale factor of 0.5 to divide the displayed flow by 2. The primary reason for setting the scale factor is to compensate for manufacturing variations in the transducers. The scale factor printed on the transducer set should be entered in Menu 52.

Observe the following precautions when setting the scale factor:

- Always determine the scale factor at the highest possible flow rate achievable in order to maximize accuracy of the scale factor.
- Use only the factory preset scale factor as marked on the transducers in the following situations: the flow cannot be stopped to verify or set the zero point; a reasonably high flow rate cannot be achieved; an accurate secondary flow standard is not available.

If an additional scale factor is required, the additional scale factor should be multiplied by the factory scale factor and the result should be entered. To enter a new scale factor:

1. Access Menu 52. (Figure 3.13-F)
2. Enter the new scale factor and press **ENTER.** Figure 3.13-G is displayed.
3. Enter the valid password and press **ENTER.**

   The new scale factor is displayed in Menu 52. To maximize security, enter a new scale factor password immediately.

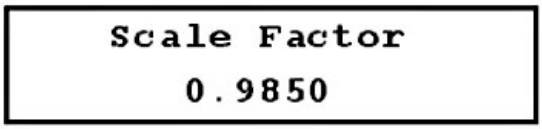


FIGURE 3.13-F

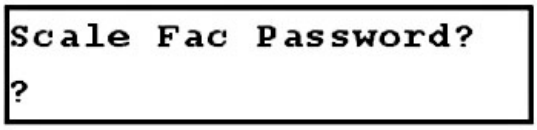


FIGURE 3.13-G

3.13.3 Other CALIBR Submenu Options

- **Sound Speed Compensation** setup menu (53): Enable or disable the flowmeter's sound speed compensation. Temperature variations in the fluid and other factors may cause variations in the fluid's sound speed. Typically, the flowmeter can determine sound speed more accurately when this feature is enabled. (Figure 3.13-H)

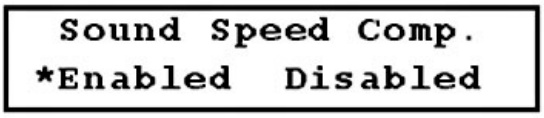


FIGURE 3.13-H

- **Date and Time** setup menu (54): Use this menu to set the date and time in the flowmeter's internal clock. The time is expressed in military time (24-hour format), and the date is in the month-day-year format (Figure 3.13-I). If you are NOT using UltraScan, set the time and date as follows:

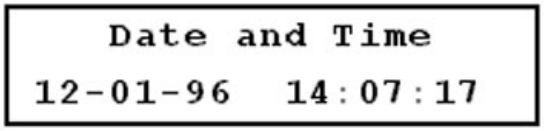


FIGURE 3.13-I

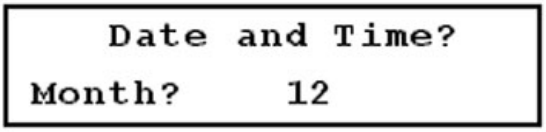


FIGURE 3.13-J

  a. Perform a Master Erase on the flowmeter according to Section 5.2 (page 40).

  b. Reconfigure the flowmeter, and access Menu 54.

  NOTE: Performing a Master Erase and reconfiguring the flowmeter prior to changing date or time prevents possible data corruption.

  c. Press **ENTER**, and prompts are displayed, requesting entries for month, day, year and hour, minute, second (Figure 3.13-J). Press **ENTER** after EACH entry.

  d. To keep the current values displayed in any screen, scroll to the next screen with the **DOWN ARROW** instead of pressing **ENTER.**

  e. Once all parameters are entered, the new programmed date and time is displayed.

3.14 Additional Setup Menus Within the 4-20mA Submenu*

***Not included in the Quick Setup Configuration**

Within the **4-20mA** submenu is the **Current Loop Group** menu (56), which contains 3 setup menus: **Span, Cal., Test** (menus 57 through 59). (Figure 3.14-A)

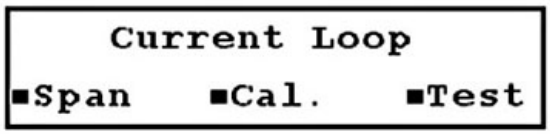


FIGURE 3.14-A

The 4-20 mA current loop is factory calibrated and should not require field calibration prior to use. If calibration and testing should become necessary, complete the following steps:

1. Connect a milliammeter to the input (IN) and output (OUT) terminals of the current loop module.
2. Access Menu 58. (Figure 3.14-B)

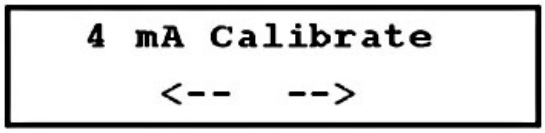


FIGURE 3.14-B

...3.14 Additional Setup Menus Within the 4-20mA Submenu* continued

***Not included in the Quick Setup Configuration**

3. Press the **RIGHT** or **LEFT ARROWS** to adjust the 4 mA set point until the value reads exactly 4.00 mA on the milliammeter. Every 2 presses of the arrow key adjusts the calibration approximately .01 mA.

4. Press **ENTER**.

5. Access Menu 58 again.

6. Press the **DOWN ARROW** to scroll to the **20 mA Calibrate** screen. (Figure 3.14-C)

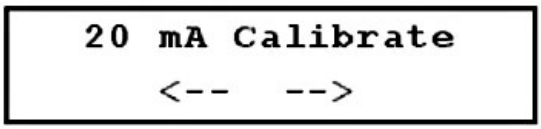


FIGURE 3.14-C

7. Repeat step 3 for entering the 20 mA set point.

8. Access Menu 00.

9. *Test* the current loop calibration by accessing Menu 59. (Figure 3.14-D)

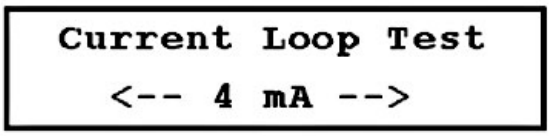


FIGURE 3.14-D

10. Change the current loop output in 1 mA increments using the **RIGHT** or **LEFT ARROWS**. The output indicated on the screen should be the same as the output on the milliammeter. If the values do not match, repeat steps 2 through 10.

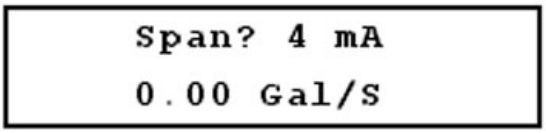


FIGURE 3.14-E

11. Set the current loop *span* by accessing Menu 57 (Figure 3.14-E). The current loop span is the span of flow versus current.

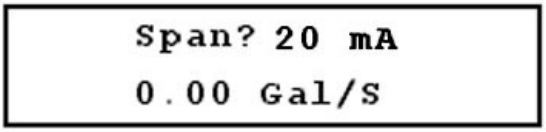


FIGURE 3.14-F

12. Enter a flow rate which equals the 4 mA (minimum anticipated) reading, and press **ENTER.**

13. Press the **DOWN ARROW**, and Figure 3.14-F is displayed.

14. Enter a flow rate which equals the 20 mA (maximum anticipated) reading, and press **ENTER.**

15. Access Menu 00 to complete the current loop calibration process.

3.15 Additional Setup Menus Within the ALARMS Submenu*

***Not included in the Quick Setup Configuration**

The **ALARMS** submenu (70) contains the setup menus for programming and viewing the flowmeter's alarm parameters. Up to 4 alarms may be independently programmed ON or OFF based on flow rate or signal strength values. If the measured value of the selected condition falls outside the specified parameters, the alarm activates and causes the printer (if purchased with flowmeter) to print the flow data and/or alarm status. (Figure 3.15-A)

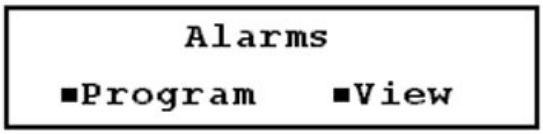


FIGURE 3.15-A

3.15.1 Programming the Alarm

1. Access Menu 71, and select and alarm to program. (Figure 3.15-B)

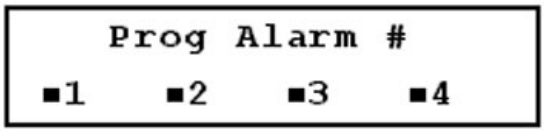


FIGURE 3.15-B

2. Figure 3.15-C is displayed. Select an alarm ON condition:

   - **NOT PROGRAMMED** (alarm OFF);
   - **FLOW >** : alarm activates when flow rate is greater than ON condition value;
   - **FLOW <** : alarm activates when flow rate is less than ON condition value;
   - **SIGNAL >** : alarm activates when signal strength value is greater than ON condition value;
   - **SIGNAL <** : alarm activates when signal strength value is less than ON condition value.

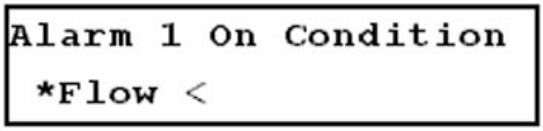


FIGURE 3.15-C

3. Press the **DOWN ARROW**, and Figure 3.15-D is displayed.

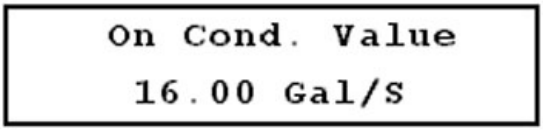


FIGURE 3.15-D

4. Enter the value for the alarm ON condition, and press **ENTER.**

   NOTE: Flow units used for alarms are the same as flow units selected for measuring flow in Menu 30.

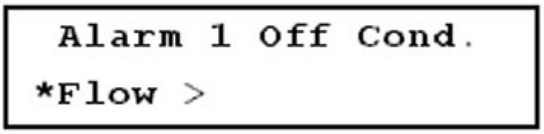


FIGURE 3.15-E

5. Press the **DOWN ARROW**, and Figure 3.15-E is displayed.

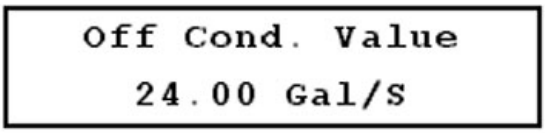


FIGURE 3.15-F

6. Select an alarm OFF condition: Selections available are the same as those for the ON condition. The OFF condition value should be entered in conjunction with the ON condition value to establish as “dead band” which prevents the alarm from continuously cycling on and off when flow is close to the ON or OFF value.

   For example, if the ON condition is **FLOW > 250 GPM**, the OFF condition may be set as **FLOW < 240 GPM**. With these settings, the alarm turns on when flow exceeds 250 GPM and does not turn off until flow falls below 240 GPM.

7. Press the **DOWN ARROW**, and Figure 3.15-F is displayed.

8. Enter a value for the alarm OFF condition, and press **ENTER.**

9. Repeat steps 1-8 for each alarm you want to program.

3.15.2 Viewing Alarms

To view the ON/OFF status of the alarms:
1. Access Menu 72. (Figure 3.15-G)

2. Select an alarm to view, and the ON and OFF conditions are displayed for the selected alarm. (Figure 3.15-H)

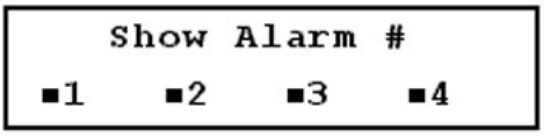


FIGURE 3.15-G

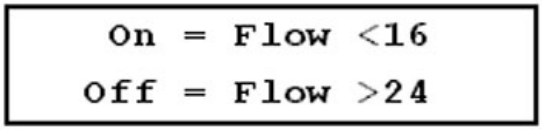


FIGURE 3.15-H

3.16 Additional Setup Menus Within the DATA LOG Submenu*

***Not included in the Quick Setup Configuration**

The **DATA LOG** submenu contains the **Log Menu** (80) and the **Log Interval** menu (81). The datalogger provides the ability of continuously recording flow data at a preset interval. The flowmeter has a single datalog file with approximately 40,000 data points available. This allows considerable data to be collected. The datalogger is always recording data. When all points are recorded, the datalogger records over the previous data points one at a time in a continuous loop, starting with the oldest data points first. The logger can be started and stopped manually or can be programmed to run automatically at a future start and stop time.

The flowmeter stores completed datalog files and assigns a unique file number to each log. This allows datalogs to be recorded and retrieved. Additionally, files can be viewed, deleted, or transferred in ASCII format to an IBM®-compatible PC for record keeping or analysis. Log files are transferred using the D-Link flowmeter data link utility (Appendix D, page 64).

- **Log** menu (80): There are 4 selections available (Figure 3.16-A):

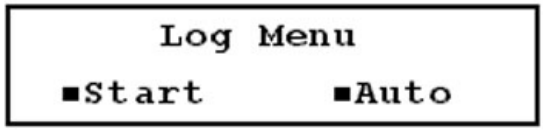


FIGURE 3.16-A

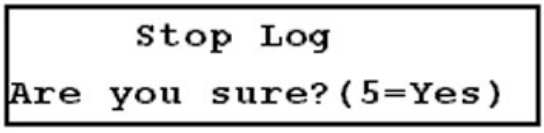


FIGURE 3.16-B

  a. **Start** (or stop) log–This option provides control for manually starting/stopping the datalogger. The appropriate option (start or stop) is displayed depending on whether the logger is currently recording.

     To stop the log:

     1. Access Menu 80, and select **Stop.**
     2. Figure 3.16-B is displayed; press **5.**

  b. **Auto**–This option allows the user to program the logger for a future start and stop time. To use this function:

     1. Access Menu 80, and select **Auto.**

     2. The current programmed start/stop times are displayed. (Figure 3.16-C, page 26)

     3. Press **ENTER.** Prompts are displayed requesting day, hour, minute, and second information for the start/stop times (Figure 3.16-D, page 26). Press **ENTER** after EACH entry.

3.16 Additional Setup Menus Within the DATA LOG Submenu* continued

***Not included in the Quick Setup Configuration**

Once the start/stop times are entered, the new times are displayed. (Figure 3.16-E).

The datalogger will now start and stop automatically at the preset times. If the logger is running, the user can manually stop the logging by selecting **Stop** in Menu 80.

Ensure that flow measurement units, time, and date are correct on the flowmeter PRIOR to beginning the log. Do not change any of these parameters while the logger is actively or before transferring the data.

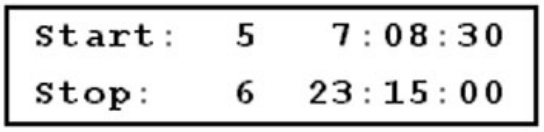


FIGURE 3.16-C

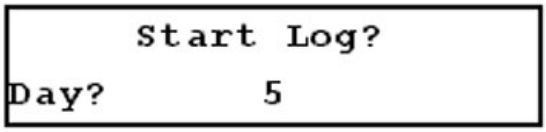


FIGURE 3.16-D

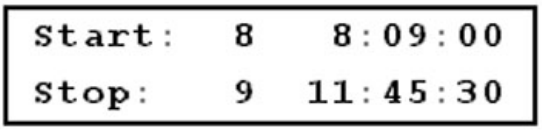


FIGURE 3.16-E

- **Interval** menu (81): Datalog intervals must be entered in whole seconds, with a minimum interval of 1 second. (Figure 3.16-F)
- **View** menu: Use this menu to view which log files are stored in memory, the file sizes, and amount of log memory still available. Additionally, use this menu to delete log files:

  1. Access Menu 80, and select **View.**
  2. Scroll through the log file with the **UP/DOWN ARROWS** to locate the file you want to delete.
  3. Press **ENTER**, and Figure 3.16-G is displayed.
  4. Press **5**, and Figure 3.16-H is displayed.
  5. Press **.** (decimal point), and Figure 3.16-I is displayed informing you the log is deleted.

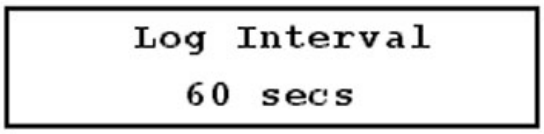


FIGURE 3.16-F

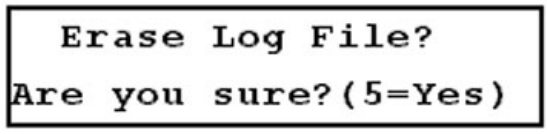


FIGURE 3.16-G

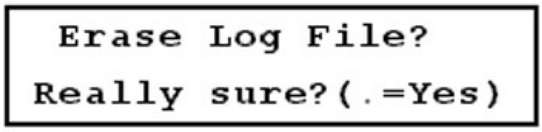


FIGURE 3.16-H

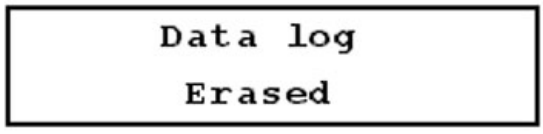


FIGURE 3.16-I

3.17 Additional Setup Menus Within DIAGNOSTICS Submenu*

***Not included in the Quick Setup Configuration**

The **DIAGNOSTICS** submenu contains various view-only menus which display important diagnostic parameters that are currently used or calculated by the flowmeter. These parameters are helpful when configuring or troubleshooting the flowmeter.

- **Signal Strength/Margin** display (90): Displays the signal strength in percentage and the margin. The signal strength value displayed is the average of the signal strengths for the upstream and downstream transducers. Margin is an indicator of signal quality and is generally greater than 5%. Signal strength is generally greater than 3% under good measurement conditions. (Figure 3.17-A)

FIGURE 3.17-A

- **Delta Time/Fluid Sound Speed** display (91): Displays the value for DeltaT and the fluid sound speed as measured by the flowmeter. DeltaT is the difference between the upstream and downstream travel times, expressed in nanoseconds (ns). (Figure 3.17-B)

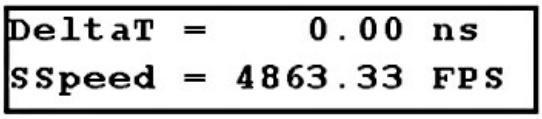


FIGURE 3.17-B

- **Reynolds Number/Profile Factor** display (92): Displays the Reynolds number and flow profile factor currently being used by the flowmeter. The flow profile factor is calculated by the flowmeter and used to determine the effect of the flow profile on mean measured fluid velocity. (Figure 3.17-C)

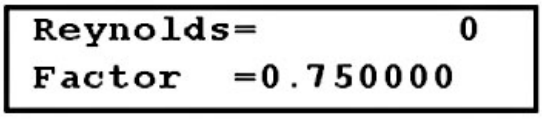


FIGURE 3.17-C

- **Current Loop Output** display (93): Displays values of the current in mA that the flowmeter is presently providing to the current loop output. (Figure 3.17-D)

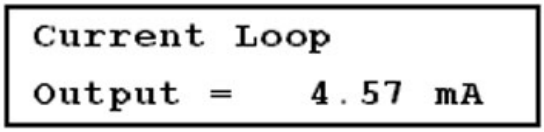


FIGURE 3.17-D

- **Software/Firmware Revision Level** display (94): Displays the software (*SOFT VERS.*) and firmware (*FPGA VERS.*) versions installed in the flowmeter. (Figure 3.17-E)

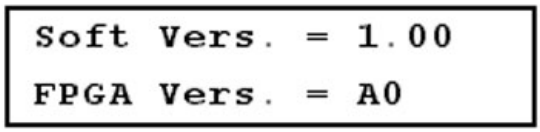


FIGURE 3.17-E

3.18 Additional Setup Menus Within PRINT Submenu*

***Not included in the Quick Setup Configuration**

Following are instructions on how to configure the optional external thermal printer. To begin, ensure the printer cable is connected to the printer port on the upper left of the flowmeter's control panel.

- **Print Log Setup** menu (96): Use this menu to configure the printer to print out flow data at a preset interval and/or whenever an alarm activates. Printed flow data include data from all enabled totalizers. Flow data are printed in minimum, maximum, and average flow rates. Minimum and maximum flow rates automatically reset at the end of each print period. The average flow rate is the average over the print interval.

3.18 Additional Setup Menus Within PRINT Submenu* continued

***Not included in the Quick Setup Configuration**

- **Print Log Setup** menu continued: To configure the printer:

  1. Access Menu 96. (Figure 3.18-A)
  2. Select an option from the following:
     a. **NONE**: disable printer;
     b. **FLOW**: print flow data at a preset log interval,
     c. **ALARM**: print flow data when an alarm activates,
     d. **BOTH**: print flow data at a preset log interval *and* when an alarm activates.
  3. If you select **FLOW** or **BOTH**, press the **DOWN ARROW** to set the print interval. (Figure 3.18-B)
  4. Enter the print interval in whole seconds, and press **ENTER.**

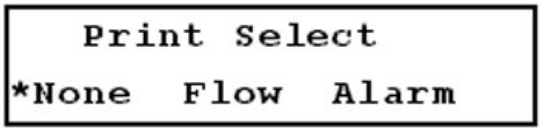


FIGURE 3.18-A

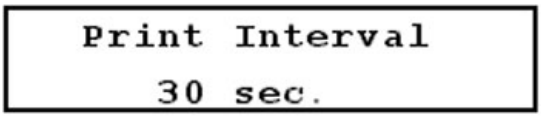


FIGURE 3.18-B

Operation errors may occur if the log interval is too short to allow the selected data to be printed. If the print interval is interrupted by a power loss, the printer resumes at the specified interval after power is restored.

- **Print Settings** menu (97): Print all parameters associated with the pipe, liner, fluid, transducer, and flow menus (10-35) by pressing **MENU** followed by **97**.

- **Print Diagnostics** menu (98): Print all parameters associated with the **DIAGNOSTICS** submenu (90-94) by pressing **MENU** followed by **98**.

- **Print Current Screen** menu (99): Print the current display by pressing **MENU** followed by **99**.

4. Wiring & Installing the Transducers

4.1 Wiring

The transducer terminals and cables are arranged in pairs and are labeled *DN STREAM* and *UP STREAM*. The downstream transducer cable has blue-banded ends; the upstream transducer has red-banded ends.

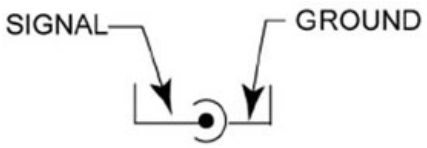


Figure 4.1

Locate the symbol seen in Figure 4.1. This symbol is on both pairs of terminals and indicate which terminals should connect to the center wire conductors and which should connect to the coaxial shields.

4.2 Site Selection & Preparation

Prior to installing the transducers, a proper site must be selected to ensure accurate measurement. Examples of site recommendations are illustrated in Figures 4.2-A (below) and 4.2-B (page 30).

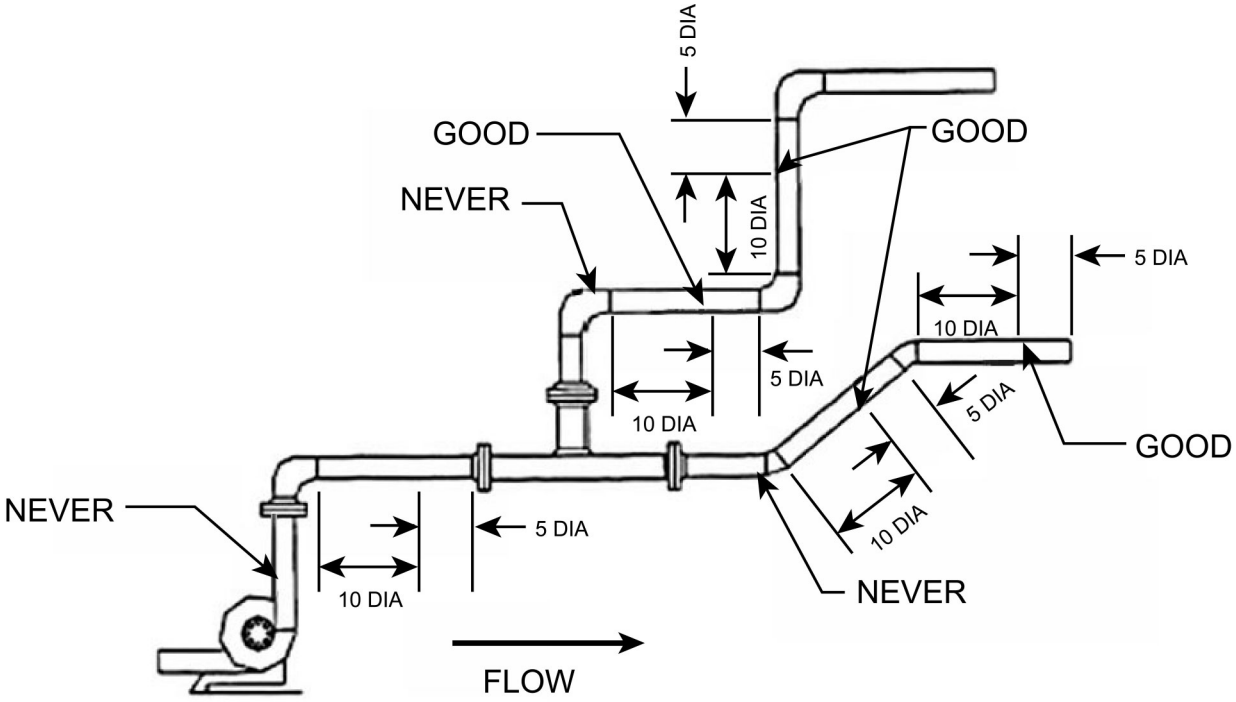


Figure 4.2-A

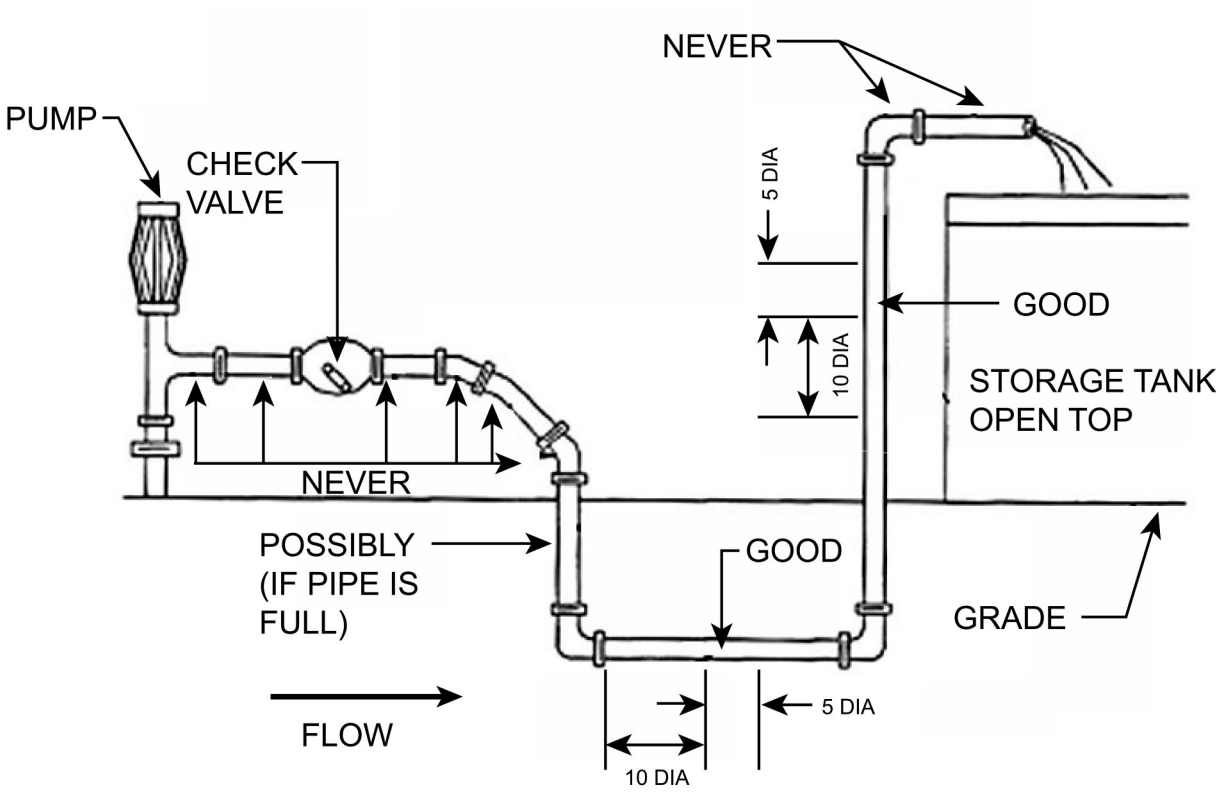


FIGURE 4.2-B

Use the following guidelines when selecting the transducer site:

- Choose a section of pipe which is always full of liquid, such as a vertical pipe with up flow or a full horizontal pipe.

- The site should have a **straight run equivalent to at least 10 pipe diameters upstream and 5 pipe diameters downstream** from any elbows, tees, throttling valves, orifices, reduced sections, or other flow disturbances.

- Up to 30 diameters of straight run may be required upstream from the flowmeter after a pump, control valve, or double piping bend for greater accuracy. A distance of 5 diameters downstream is *usually* sufficient under all circumstances.

- Always mount the transducers on the sides of the pipe in the 3 o'clock or 9 o'clock positions on horizontal pipes. Positioning the transducers in this manner prevents signal loss which can be caused by sediment along the bottom of the pipe or gas bubbles and air pockets along the top of the pipe.

- Ensure that the pipe skin temperature is within the transducer temperature rating. The transducers are rated for -40º to +212º F (-40º to +100º C). Temperature ratings up to 392º F (200º C) are available with optional high temperature transducers.

- Pipes with excessive corrosion or scaling create conditions which can make accurate measurement difficult or impossible; if possible, avoid selecting these sections of pipe as mounting locations.

- Remove any dirt, grease, rust, loose paint, or scale from the pipe surface prior to mounting the transducers. To obtain best results on aging and rough pipes, a file or grinder may be required to clean the pipe down to bare metal.

If your application cannot follow these guidelines completely, meaningful flow measurements (with some loss in accuracy and stability) may still be obtained, depending on signal quality.

4.3 Spacing & Mounting the Transducers

Once you have selected a proper transducer site, you must ensure proper transducer spacing and mounting in order to maximize signal strength and accuracy:

1. Determine which mounting method is appropriate for your application: V, W, Z, VV, WV.

2. Refer to Section 3 (page 7) to configure the flowmeter via the keypad or to the UltraScan manual to configure with UltraScan, and note the value required for the transducer spacing (value calculated by and displayed on flowmeter LCD or in UltraScan).

3. Clean the area of the pipe designated as the mounting location. Remove any rust, scale, or loose paint; well-bonded paint does not need to be removed.

On horizontal pipes, the transducers should be mounted in the 3 o'clock and 9 o'clock positions in order to avoid situations which can cause signal loss, i.e., sediment along the bottom of the pipe, gas bubbles or air pockets along the top of the pipe.

4. Refer to one of the following sections to mount the transducers according to the selected mounting method:

   - the V method: Section 4.4.1 (page 33),
   - the W method: Section 4.4.2 (page 34),
   - the Z method: Section 4.4.3 (page 34),
   - the VV and VW methods: Section 4.4.4 (page 37).

5. Install the portable slide rack:

   a. Extend the chain hooks by unscrewing the chain adjustment knobs to their fullest extent. The knobs will stop at the end of the adjustment and should not be removed.

   b. Place the rack against the pipe and wrap the chains around the pipe.

   c. With excess slack removed from the chain, connect the chains to the chain hooks.

   d. Tighten the chain hooks by screwing down both chain adjustment knobs.

6. Install the portable transducers:

   a. Position the slides according to the calculated spacing. The top rail of the rack is marked in inches and the bottom rail is marked in millimeters.

   b. Apply sonic coupling compound to a transducer face, and with the cable connector end of the transducer towards the outside of the rack, install the transducer beneath one of the slides. The inside face of the transducer should align with the inside edge of the slide.

   d. Tighten the knobs on the slide evenly to hold the transducer in place.

   e. Repeat this procedure with remaining transducer.

...4.3 Spacing & Mounting the Transducers continued

7. Ensure the transducer face is aligned normal to the pipe (Figure 4.3-A, below). The transducer face alignment is particularly critical on small pipes due to pipe curvature. Notice that the properly installed transducer contacts the pipe at the pipe's centerline and that the gaps on either side of the centerline are equal. The notches on both ends of the portable transducer rack allow the assembly to self-align to the curvature of the pipe. Check the contacts of the notches to the pipe, and adjust as necessary.

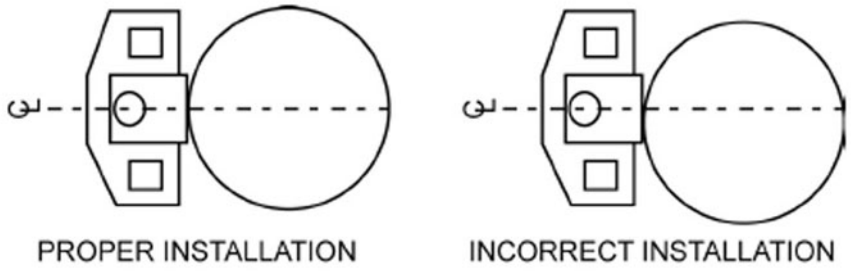


FIGURE 4.3-A

8. Connect the transducer cables to the flowmeter.

The transducers should be mounted on the pipe in relation to the direction of flow, as shown in Figure 4.3-B (below). Reversing the position of the upstream and downstream transducers or reversing the transducer cable connections to the instrument results in negative flow readings.

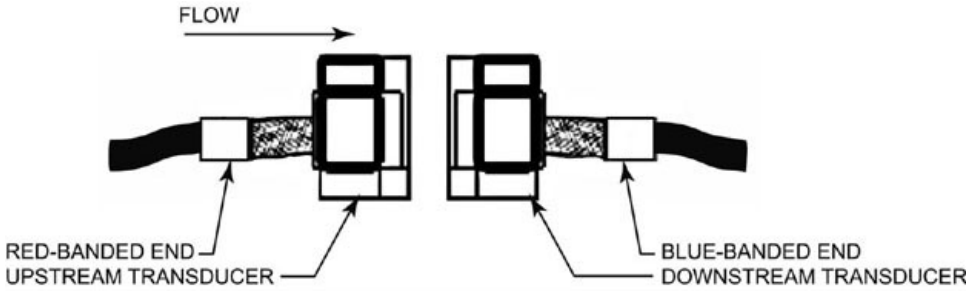


FIGURE 4.3-B

- Refer to Figure 1.6 (page 4) to locate the upstream and downstream connectors on the side of the meter.

- The upstream transducer cable has red-banded ends, and the downstream transducer cable has blue-banded ends (Figure 4.3-B, above).

9. If maximum accuracy at low flow rates is important, calibrate the flowmeter according to Section 3.13 (page 19).

   The flowmeter is now capable of accurately measuring velocity and flow.

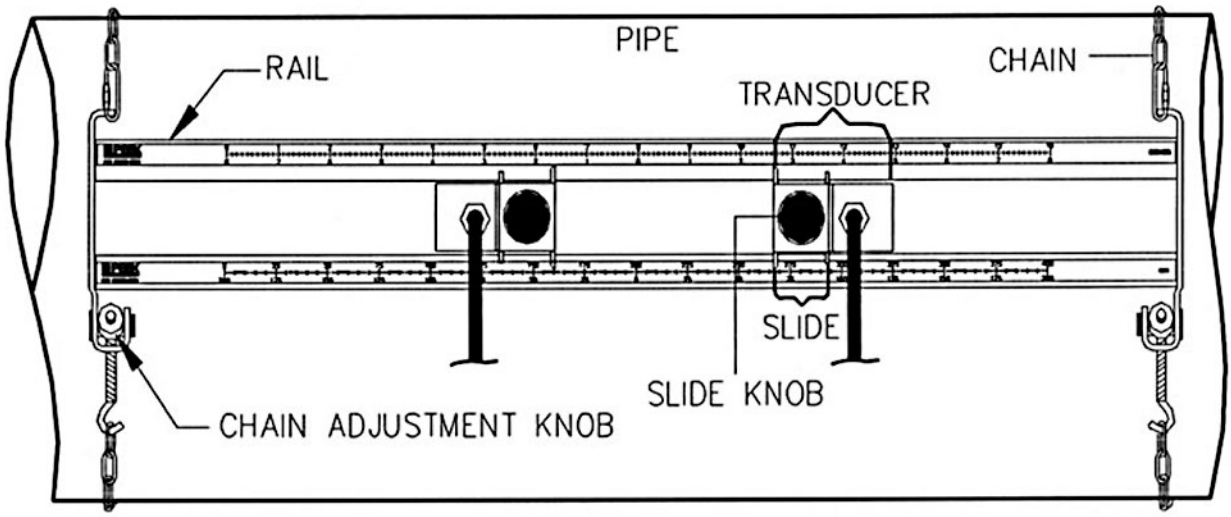


FIGURE 4.3-C: PORTABLE TRANSDUCER RACK INSTALLATION

4.4 Transducer Mounting Methods

There are several methods of mounting the transducers. The best method is determined by the specific application. Complete steps 1-5 in Section 4.3 (page 31), and refer to the following sections for instructions on how to properly mount the transducers with one of the available mounting methods.

4.4.1 V Method

The V method (Figure 4.4-A, below) is considered the standard method for pipes with 4- to 16-in (101.6 to 406.4 mm) diameters. This method typically yields a more accurate reading than the Z method since it utilizes a longer measurement path.

Ensure V is the selected mounting method.

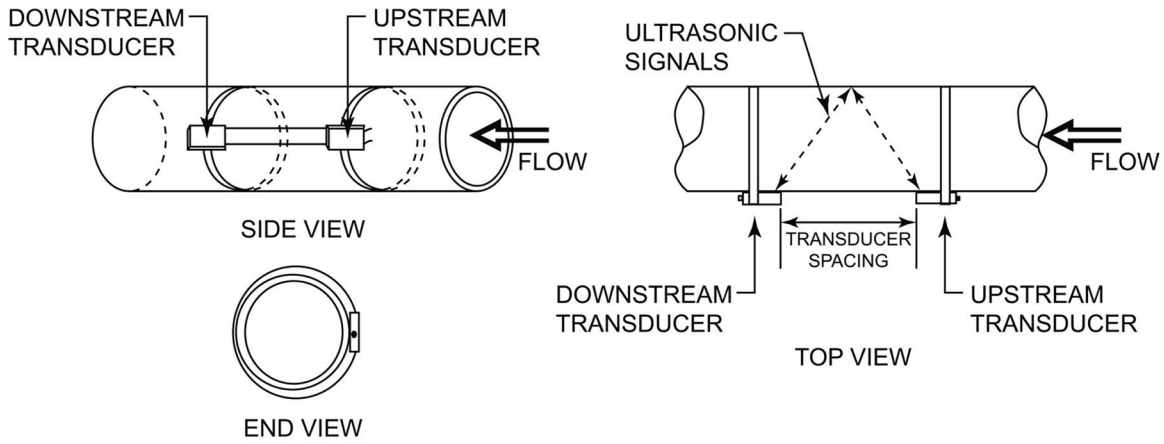


FIGURE 4.4-A: V MOUNT

4.4.2 W Method

In many instances, flowmeter performance on small metallic pipes with outer diameters of 4 inches (100 millimeters) or less can be improved by using the W mounting method (Figure 4.4-B, below). With the W method, the sound wave traverses the fluid 4 times and bounces off the pipe walls 3 times. Like the V method, both transducers are mounted on the same side of the pipe.

Ensure W is the selected mounting method.

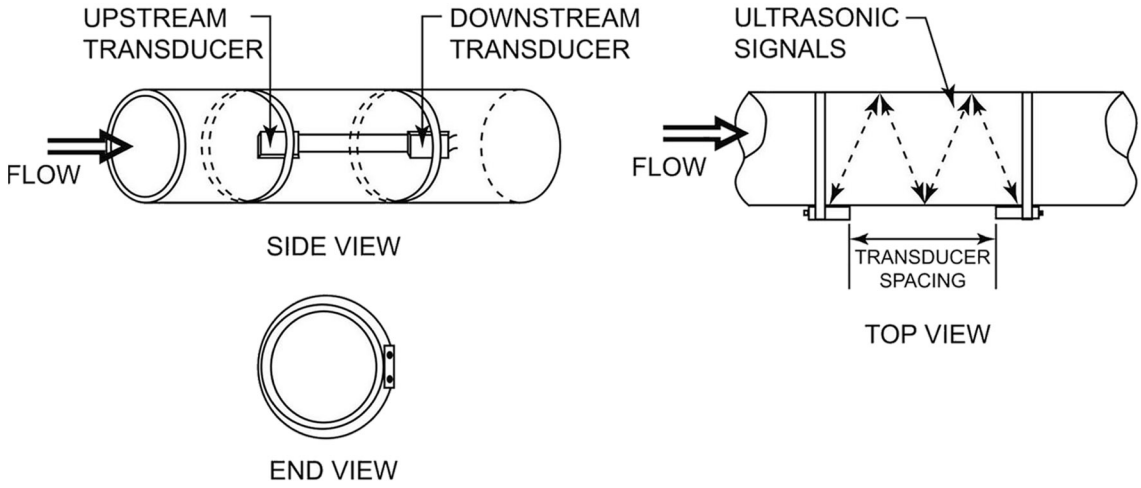


FIGURE 4.4-B: W MOUNT

4.4.3 Z Method

The signal transmitted in a Z method installation has less attenuation than a signal transmitted with the V method. This is because the Z method utilizes a directly transmitted (rather than reflected) signal which transverses the liquid only once. The Z method (Figure 4.4-C, below) is used primarily in applications where the V method cannot work due to signal attenuation from excessive air or solids in the liquid, thick scale, poorly bonded linings, or very large pipes. In addition, the Z method generally works better on larger diameter pipes where less pipe length is required for mounting.

Ensure Z is the selected mounting method.

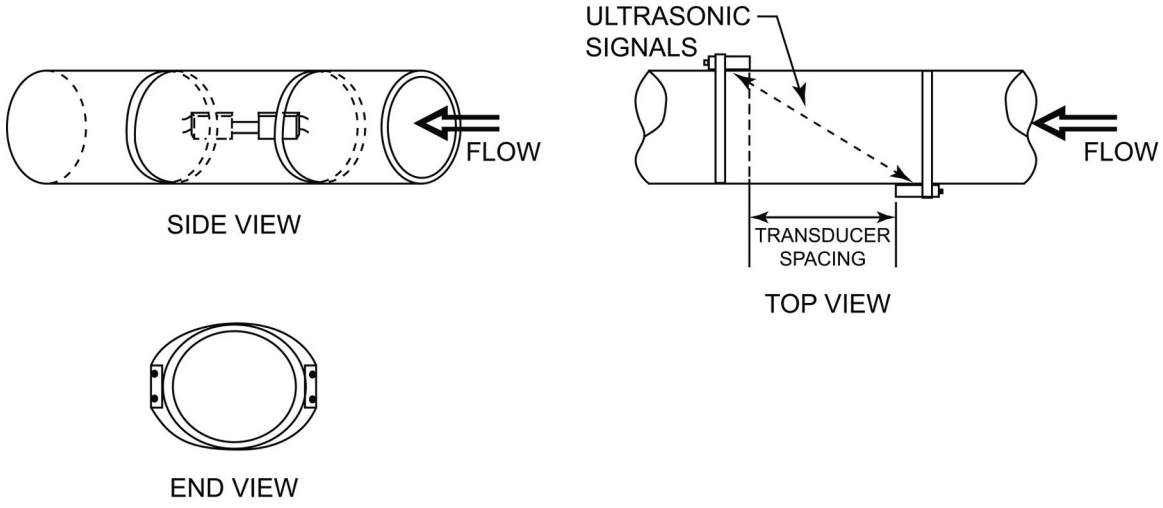


FIGURE 4.4-C: Z MOUNT

...4.4.3 Z Method continued

1. Establish a reference at both the 3 o'clock and 9 o'clock positions on the pipe. (Figure 4.4-D)

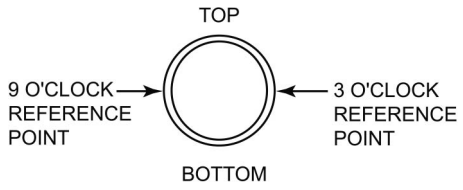


Figure 4.4-D: Z Mount, step 1

2. Place a transdducer at the 3 o'clock position.

3. Trace the shape of the 3 o'clock transducer along its inside edge (opposite the cable connection). Draw a horizontal line at its center. Remove the transducer.

   (Figure 4.4-E)

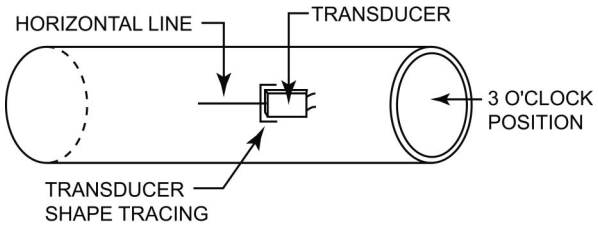


Figure 4.4-E: Z Mount, steps 2-3

4. Obtain a continuous sheet of paper longer than the circumference of the pipe. Calculator paper tape or thermal printer paper works well for this.

5. Fold one end of the paper across the pipe's width to produce a clean, straight edge.

6. Line the fold of the paper up with the horizontal centerline of the 3 o'clock transducer.

   (Figure 4.4-F)

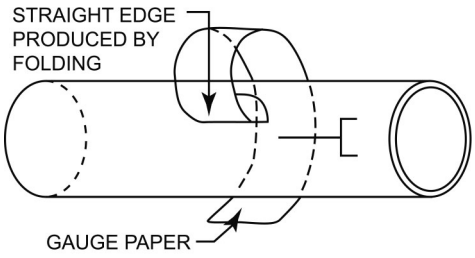


Figure 4.4-F: Z Mount, steps 4-6

7. Wrap the paper firmly around the pipe, and mark the intersection point where the fold comes in contact with the rest of the paper. (Figure 4.4-G)

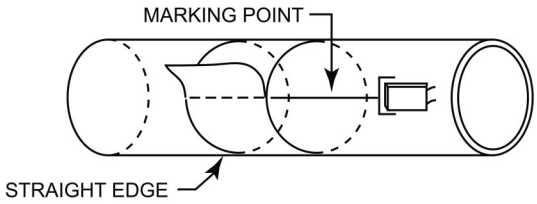


Figure 4.4-G: Z Mount, step 7

8. Remove the paper from the pipe. Place the fold and intersection mark together again, and fold the paper exactly in half. (Figure 4.4-H)

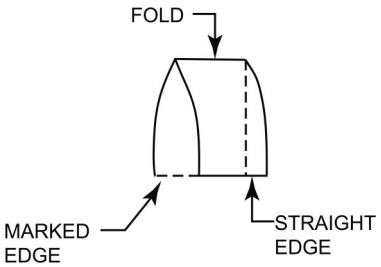


Figure 4.4-H: Z Mount, step 8

...4.4.3 Z Method continued

9. Mark along the new fold. (Figure 4.4-I)

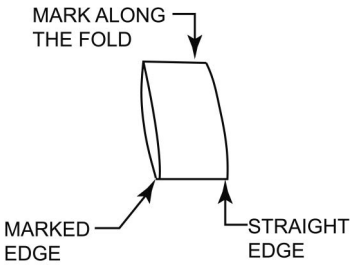


FIGURE 4.4-I: Z MOUNT, STEP 9

10. Draw a horizontal line along the pipe from the centerline of the 3 o'clock transducer position. Use a level to ensure that the line is level with the top of the pipe. The line should be at least 3 inches (76 millimeters) longer than the transducer spacing calculated by UltraScan or via Menu 25.

    For example, if UltraScan calculates the spacing as 14 inches (356 millimeters), draw a line 17 inches (432 millimeters) long. (Figure 4.4-J)

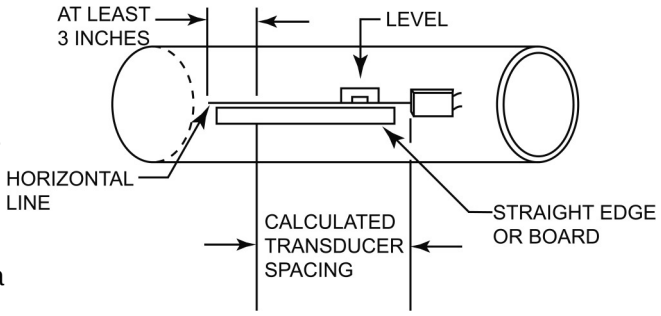


FIGURE 4.4-J: Z MOUNT, STEP 10

11. Measure the spacing from the inside edge of the 3 o'clock transducer, and mark this on the pipe. (Figure 4.4-K)

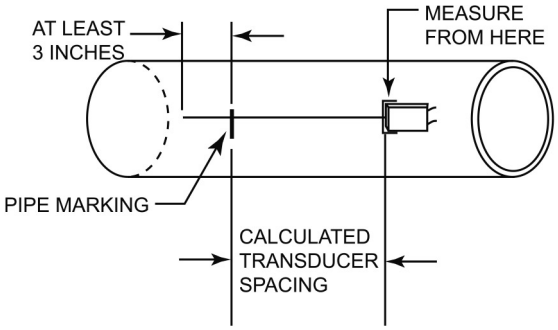


FIGURE 4.4-K: Z MOUNT, STEP 11

12. Wrap the paper firmly back on the pipe. Have the point where the ends of the paper come together line up with the horizontal line on the 3 o'clock side of the pipe. Ensure that the inside corner of the straight edge of the paper is aligned with the mark made for the transducer spacing. Tape the paper down, or have someone hold the paper in place. (Figure 4.4-L)

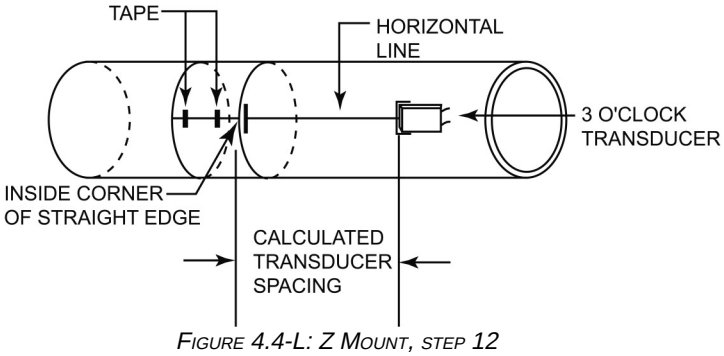


FIGURE 4.4-L: Z MOUNT, STEP 12

...4.4.3 Z Method continued

13. Go to the other side of the pipe (9 o'clock position), and mark the pipe at the point where the marked fold and the inside edge of the paper length intersect. (Figure 4.4-M)

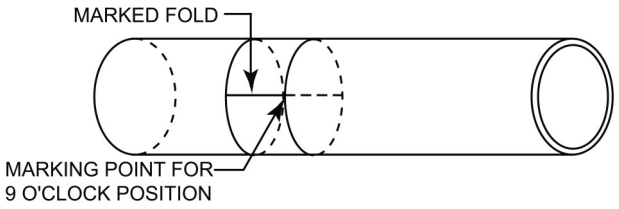


FIGURE 4.4-M: Z MOUNT, STEP 13

14. Remove the paper from the pipe and trace the shape of the 9 o'clock transducer in the same manner you did for the 3 o'clock transducer. Ensure that the inside edge of the transducer (opposite the cable connection) is even with the point just marked on the 9 o'clock side of the pipe. (Figure 4.4-N)

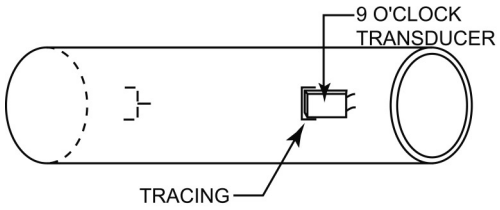


FIGURE 4.4-N: Z MOUNT, STEP 14

15. Mount the transducers by following steps in Section 6.7 (page 32). (Figure 4.4-O)

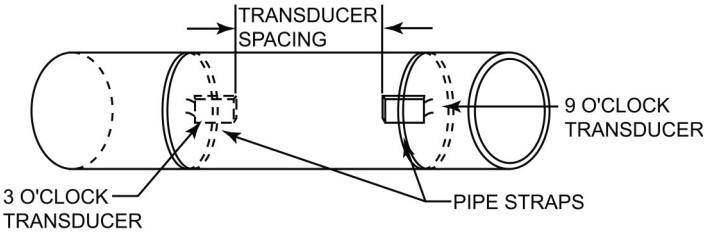


FIGURE 4.4-O: Z MOUNT, STEP 15

The figure below illustrates the final Z method installation.

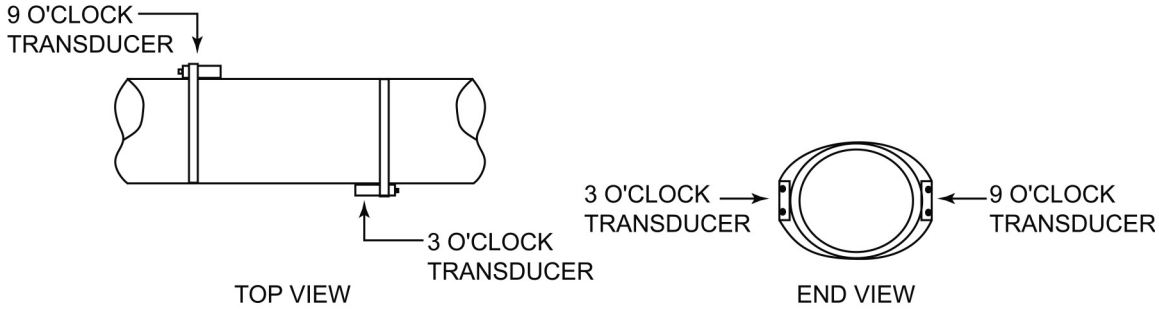


FIGURE 4.4-P

4.4.4 WV and WW Methods

For applications with pipe diameters smaller than 2 inches (50 millimeters), the WV and WW methods are options to achieve higher accuracy and stability when reasonable signal strength can be obtained (10% or higher).

4.5 Small Pipe Applications

In this section, small pipe applications refer to the following pipe sizes:

- stainless steel or brass: 1.0 to 3.5 in (25.4 to 88.9 mm)
- PVC, carbon steel, or other: 1.0 to 2.5 in (25.4 to 63.5 mm).

If signal strength is greater than 10%, we recommend the W mounting method for pipe sizes 3.5 in (63.5 mm) or smaller and the WW mounting method for pipe sizes 2.0 in (50.8 mm) or smaller.

The pipe curve effect on small pipe applications can cause multipath signals and measurement uncertainty. Removing extra compound along the transducer sides can eliminate the side wave paths as seen in Figure 4.5-A (below). Follow these steps to eliminate these side wave paths:

1. Apply coupling compound as usual on to the coupling surfaces, and clamp the transducers onto the pipe.

2. Use a pen-sized, standard screwdriver to remove the extra grease between the transducers and the pipe (Figure 4.5-A, below).

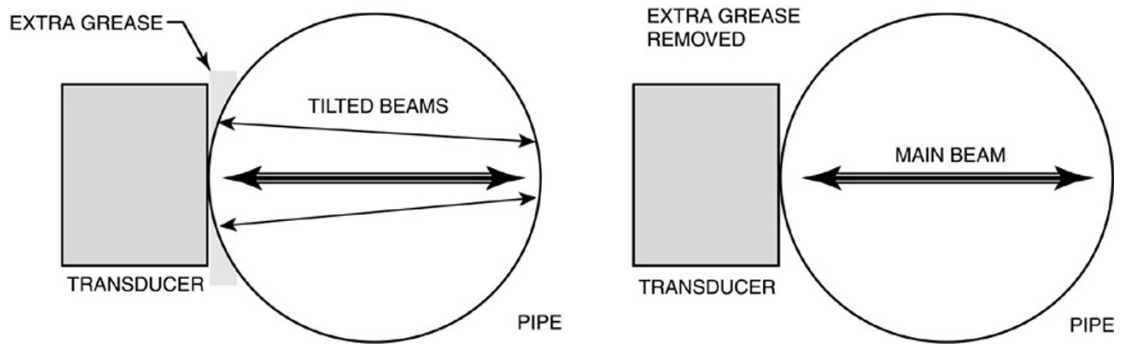


FIGURE 4.5-A

For high temperature or outdoor small pipe applications, use the foam tape strips shipped with the flowmeter to block the side wave paths. **Other tape materials generally do not satisfy performance or safety specifications.** Please contact the Thermo Customer Service Department when more tape strips are needed.

1. Wipe grease off the coupling surfaces of both transducers. Clean the surfaces with detergent and let dry. (Figure 4.5-B)

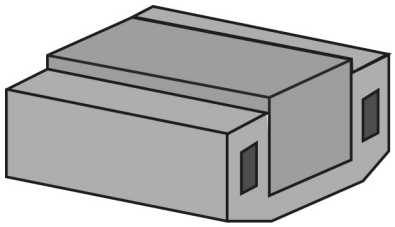


FIGURE 4.5-B: APPLYING FOAM TAPE STRIPS, STEP 1

2. Draw 2 lines on each transducer surface with a pencil so that the band defined by the lines is in the middle of the surface. The spacing between the 2 lines should be as follows:

- 3.0 to 3.5 in pipes: 0.50 in (76.2 to 88.9 mm pipes: 12.7 mm);
- 2.5 to 3.0 in pipes: 0.44 in (63.5 to 76.2 mm pipes: 11.2 mm);
- 2.0 to 2.5 in pipes: 0.38 in (50.8 to 63.5 mm pipes: 9.7 mm);
- 1.5 to 2.0 in pipes: 0.32 in (38.1 to 50.8 mm pipes: 8.13 mm);
- 1.5 in and smaller pipes: 0.25 in (38.1 mm and smaller pipes: 6.35 mm). (Figure 4.5-C)

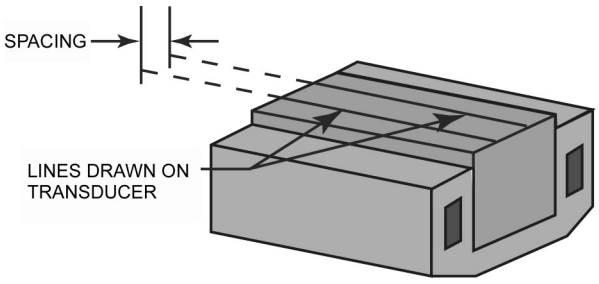


Figure 4.5-C: Applying foam tape strips, step 2

3. Remove the adhesive protection paper to expose the tape strips. Place a strip on each side of the surface along the line. Press the strips down to ensure good adhesion. (Figure 4.5-D)

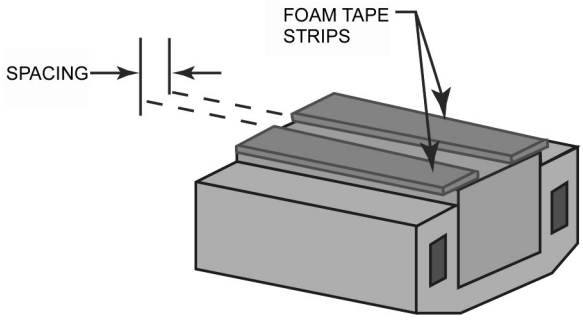


Figure 4.5-D: Applying foam tape strips, step 3

4. Apply coupling compound to the space between the tape strips. The optimum height of the compound layer is approximately one-half the height of the tape strips. (Figure 4.5-E)

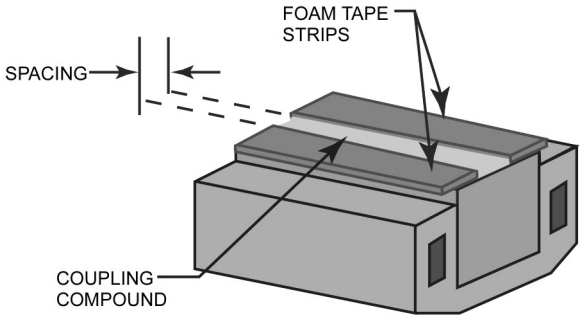


Figure 4.5-E: Applying foam tape strips, step 4

5. Emergency Overrides & Master Erase

Since these 2 procedures allow critical data to be accessed and changed, this page may be removed from the instruction manual to prevent unauthorized use of these features.

5.1 Emergency Overrides

In the event that a user-entered password is forgotten, the following emergency override passwords may be used: **42** for the system password and **43** for the scale factor password. These override passwords may not be changed or disabled.

5.2 Performing a Master Erase

This function erases all user-entered data AND data in the datalogger. Note all configuration settings and download the datalog file if a record is desired prior to performing a Master Erase.

1. Turn the flowmeter off and back on again.
2. When the message **INITIALIZING...** is displayed, press **ERASE** within 3 seconds.
3. The **Master Erase** screen is displayed (Figure 5-A). To continue with the Master Erase, press the **5** key within 3 seconds, and Figure 5-B is displayed.
4. Press the **.** (decimal) key within 3 seconds to continue.
5. If the Master Erase function is completed, Figure 5-C is displayed. If the function is not completed, Figure 5-D is displayed.
6. Enter all configuration data.

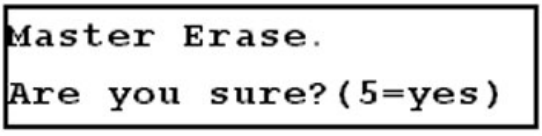


Figure 5-A

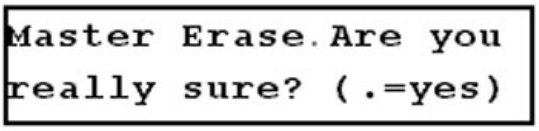


Figure 5-B

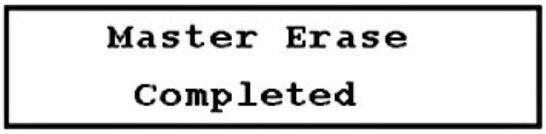


Figure 5-C

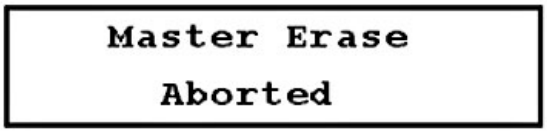


Figure 5-D

6. FLOWMETER MAINTENANCE & TROUBLESHOOTING

6.1 Replacing the Fuse

Prevent possible electrical shock and/or damage to the meter–disconnect power to the meter PRIOR to wiring.

6.1.1 Flowmeter Fuse

The fuse located on the front panel of the flowmeter (upper right corner) protects the instrument from overcurrent or short circuits from the internal battery. It is rated at 3 A, 250 V. The sheetmetal access cover does not need to be removed since it has a hole for accessing the fuse. To replace the fuse:

1. Disconnect power from the flowmeter, and determine the cause of the fuse failure; correct if known.

2. Open the door of the flowmeter, and use a small, flat-bladed screwdriver to remove the fuse and replace it with another fuse of the same rating.

3. Reconnect power to the flowmeter and verify that the unit operates properly, e.g. the newly-installed fuse does not blow.

6.1.2 Breakout Box Fuse

The fuse located in the breakout box protects the instrument from overcurrent from the battery charger/AC adapter output. To replace the fuse:

1. Disconnect power from the flowmeter and disconnect the breakout box from the flowmeter and battery charger/AC adapter.

2. Remove the 4 screws from the cover of the breakout box, and use a small, flat-bladed screwdriver, to remove the fuse and replace it with another fuse of the same rating.

3. Reconnect power to the flowmeter and the breakout box to the battery charger/AC adapter, and verify that the unit operates properly.

6.2 Charging the Printer Battery

Charging the printer battery is a simple procedure. Connect the printer to the printer power cable on the breakout box (if battery charger/AC adapter is connected). Note the following cautions PRIOR to charging the printer battery:

- **If the battery is fully discharged, the battery charge time is 15 hours. DO NOT charge for more than 24 hours.**

- **Do not connect the battery charger/AC adapter directly to the printer. The voltage and polarity output of the charger do not match required input of the printer. If they are directly connected, the printer battery can explode or the printer can be seriously damaged.**

6.3 Charging the Flowmeter

The DCT7088 is a DC-powered instrument that normally operates from the internal 12-V battery supplied with the unit. It may also be powered by one of the following sources which connect to the 12-15 Vdc input on the breakout box:

- battery charger/AC adapter, which converts a 90 to 64 Vac, 50/60 Hz, 15-W input to a 15 Vdc output;
- automobile cigarette lighter adapter, which provides a 12 Vdc output.

If the battery charger/AC adapter is connected, it simultaneously powers the flowmeter and recharges or maintains the charge on the internal battery. The battery charges at a slower rate when the charger/ adapter is used to power the unit and charge the battery.

6.4 Replacing Sonic Coupling Compound

Any voids or air gaps that exist in the coupling compound beneath the transducers can reduce the signal and render the flowmeter inoperative. Coupling compound should be protected from washout and replaced as required. Annual replacement is recommended for most applications to maintain optimal performance.

To replace the coupling compound:

1. Remove the transducers from the pipe.

2. Clean the old compound from the transducers and the pipe.

3. Apply a wide bead of compound lengthwise down the center of each transducer face.

4. Remount the transducers, verifying that the compound is squeezing out from underneath all sides of the transducers and forming a bead along the edges.

We recommend the following sonic coupling compounds:

- Sil-Glyde® (American Grease Stick Company): made from a silicon base and suited for most transducer installations; rated for pip skin temperatures from -40º to +212º F (-40º to +100º C);

- Dow Corning® 111 or similar high temperature couplant: can be used for applications with pipe skin temperatures up to 300º F (150º C);

- General Electric RTV-108 or similar silicon RTV: should be used for underground or submerged transducer sites or sites where a more permanent bond is required; RTV should be completely cured prior to covering up the transducer site or taking readings;

- Krautkramer® Hitempco (Thermo P/N 22861-0001): good high temperature couplant; should be used with optional high temperature transducers rated up to 392º F (200º C).

The transducers should not be bonded with epoxy.

6.5 Troubleshooting & Support

6.5.1 General

If the unit does not perform satisfactorily, complete the following steps until the problem is resolved:

1. Verify that the flowmeter is properly installed and that the installation site is suitable.
2. Verify that the flowmeter is properly configured.
3. Perform a Master Erase.
4. Contact the installation contractor or representative through whom the flowmeter was purchased.
5. Contact Thermo to attempt to resolve the problem over the phone.
6. If we determine the problem cannot be resolved over the phone, return the entire unit to the factory.

6.5.2 Local Representative Support

The local Thermo representative is the first contact for support and is well equipped to answer questions and provide application assistance. Your representative has access to product information and current software revisions.

6.5.3 Service & Returns

If it becomes necessary to contact the Thermo Service Center with software or hardware problems, please have the following information available:

- signal strength
- pipe orientation
- pipe ID
- fluid type
- liner thickness
- transducer type and mounting configuration
- pipe OD
- pipe material
- liner material
- model and serial numbers.

To return an instrument:

1. Contact the Thermo Service Center for an RMA number (issued by the service representative). **The receiving dock does not accept shipments without the RMA number.**

   You can contact the us at any of the following:
   - phone: (713) 272-0404
   - fax: (713) 272-5388
   - web: www.thermo.com
   - address: listed below

2. Ensure the instrument is well packed, in its original shipping box if available.

3. Include a letter fully explaining the symptoms of the failure as well as detail describing the application where the unit was being operated (type of fluid, pipe size, pipe material, fluid velocity, etc.).

4. Write the RMA number on the **outside** of the shipping box.

5. Send the unit freight-paid to:

   Thermo Electron Corporation
   Process Instruments Division
   9303 W. Sam Houston Parkway S.
   Houston, TX 77099
   USA

6.5.4 Upgrades

Thermo provides the most current software for your meter at time of shipment. Find out about upgrades by contacting Thermo via mail, fax, phone, or web. Upgrades are available using the RS232 port and a remote terminal.

6.6 Warranty Statement

Thermo products are warranted to be free from defects in material and workmanship at the time of shipment and for one year thereafter. Any claimed defects in Thermo products must be reported within the warranty period. Thermo shall have the right to inspect such products at Buyer's plant or to require Buyer to return such products to Thermo plant.

In the event Thermo requests return of its products, Buyer shall ship with transportation charges paid by the Buyer to Thermo plant. Shipment of repaired or replacement goods from Thermo plant shall be F.O.B. Thermo plant. A shop charge may apply for alignment and calibration services. Thermo shall be liable only to replace or repair, at its option, free of charge, products which are found by Thermo to be defective in material or workmanship, and which are reported to Thermo within the warranty period as provided above. This right to replacement shall be Buyer's exclusive remedy against Thermo.

Thermo shall not be liable for labor charges or other losses or damages of any kind or description, including but not limited to, incidental, special or consequential damages caused by defective products. This warranty shall be void if recommendations provided by Thermo or its Sales Representatives are not followed concerning methods of operation, usage and storage or exposure to corrosive conditions.

Materials and/or products furnished to Thermo by other suppliers shall carry no warranty except such suppliers' warranties as to materials and workmanship. Thermo disclaims all warranties, expressed or implied, with respect to such products.

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APPENDIX A: PIPE SCHEDULES

This appendix provides pipe schedules as a convenient reference for the following pipe materials: steel, stainless steel, and PVC (Table A-1); cast iron (Table A-2); ductile iron (Table A-3).

The inside diameters (IDs) listed in the following tables are calculated from the outside diameter (OD) and minimum wall thicknesses as specified in applicable standards. The actual pipe ID may vary from the dimension listed in the tables by as much as 25% of the pipe minimum wall thickness. The accuracy of flow rate measurement is enhanced if the pipe ID is actually measured.

Table A-1
Steel, Stainless Steel and PVC Pipe Standard Schedules
Inside Diameter (ID) and Outside Diameter (OD) in Inches

Nominal Pipe Size ( )	Outside Diameter (OD)	Sched. 5	Sched. 10 (Light Wall)	Sched. 20	Sched. 30	Sched. 40	Sched. 60	Sched. 80	Sched. 100	Sched. 120	Sched. 140	Sched. 160	Std. Wall	X STG
1	1.315	1.185	1.097			1.049		0.957				0.815	1.049	0.957
1.25	1.660	1.530	1.442			1.380		1.278				1.160	1.380	1.278
1.5	1.900	1.770	1.682			1.610		1.500				1.338	1.610	1.500
2	2.375	2.245	2.157			2.067		1.939				1.687	2.067	1.939
2.5	2.875	2.709	2.635			2.469		2.323				2.125	2.469	2.323
3	3.500	3.334	3.260			3.068		2.900				2.624	3.068	2.900
3.5	4.000	3.834	3.760			3.548		3.364					3.548	3.364
4	4.500	4.334	4.260			4.026		3.826		3.624		3.438	4.026	3.826
5	5.563	5.345	5.295			5.047		4.813		4.563		4.313	5.047	4.813
6	6.625	6.407	6.357			6.065		5.761		5.501		5.187	6.065	5.761
8	8.625	8.407	8.329	8.125	8.071	7.981	7.813	7.625	7.437	7.187	7.001	6.813	7.981	7.625
10	10.750	10.482	10.420	10.250	10.136	10.020	9.750	9.562	9.312	9.062	8.750	8.500	10.020	9.750
12	12.750	12.438	12.390	12.250	12.090	11.938	11.626	11.374	11.062	10.750	10.500	10.126	12.000	11.750
14	14.000		13.500	13.376	13.250	13.124	12.812	12.500	12.124	11.876	11.500	11.188	13.250	13.000
16	16.000	15.670	15.500	15.376	15.250	15.000	14.688	14.312	13.938	13.562	13.124	12.812	15.250	15.000
18	18.000	17.670	17.500	17.376	17.124	16.876	16.500	16.124	15.688	15.255	14.876	14.438	17.250	17.000
20	20.000	19.634	19.500	19.250	19.000	18.812	18.376	17.938	17.438	17.000	16.500	16.062	19.250	19.000
24	24.000	23.564	23.500	23.250	22.876	22.624	22.062	21.562	20.938	20.376	19.876	19.312	23.250	23.000
30	30.000	29.500	29.376	29.000	28.750	28.500							29.250	29.000
36	36.000		35.376	35.000	34.750	34.500					31.876	31.312	35.250	35.000
42	42.000			41.000	40.750	40.500							41.250	41.000
48	48.000					47.250							47.250	47.000

Table A-2
Cast Iron Pipe Standard Classes
Inside Diameter (ID) and Outside Diameter (OD) in Inches

Nominal Pipe Size ( )	Class A		Class B		Class C		Class D		Class E		Class F		Class G		Class H	
	OD	ID	OD	ID	OD	ID	OD	ID	OD	ID	OD	ID	OD	ID	OD	ID
3	3.80	3.02	3.96	3.12	3.96	3.06	3.96	3.00								
4	4.80	3.96	5.00	4.10	5.00	4.04	5.00	3.96								
6	6.90	6.02	7.10	6.14	7.10	6.08	7.10	6.00	7.22	6.06	7.22	6.00	7.38	6.08	7.38	6.00
8	9.05	8.13	9.05	8.03	9.30	8.18	9.30	8.10	9.42	8.10	9.42	8.10	9.60	8.10	9.60	8.00
10	11.10	10.10	11.10	9.96	11.40	10.16	11.40	10.04	11.60	10.12	11.60	10.00	11.84	10.12	11.84	10.00
12	13.20	12.12	13.20	11.96	13.50	12.14	13.50	12.00	13.78	12.14	13.78	12.00	14.08	12.14	14.08	12.00
14	15.30	14.16	15.30	13.98	15.65	14.17	15.65	14.01	15.98	14.18	15.98	14.00	16.32	14.18	16.32	14.00
16	17.40	16.20	17.40	16.00	17.80	16.20	17.80	16.02	18.16	16.20	18.16	16.00	18.54	16.18	18.54	16.00
18	19.50	18.22	19.50	18.00	19.92	18.18	19.92	18.00	20.34	18.20	20.34	18.00	20.78	18.22	20.78	18.00
20	21.60	20.26	21.60	20.00	22.06	20.22	22.06	20.00	22.54	20.24	22.54	20.00	23.02	20.24	23.02	20.00
24	25.80	24.28	25.80	24.02	26.32	24.22	26.32	24.00	26.90	24.28	26.90	24.00	27.76	24.26	27.76	24.00
30	31.74	28.98	32.00	29.94	32.40	30.00	32.74	30.00	33.10	30.00	33.46	30.00				
36	37.96	35.98	38.30	36.00	38.70	35.98	39.16	36.00	39.60	36.00	40.04	36.00				
42	44.20	42.00	44.50	41.94	45.10	42.02	45.58	42.02								
48	50.50	47.98	50.80	47.96	51.40	47.98	51.98	48.00								
54	56.66	53.96	57.10	54.00	57.80	54.00	58.40	53.94								
60	62.80	60.02	63.40	60.06	64.20	60.20	64.82	60.06								
72	75.34	72.10	76.00	72.10	76.88	72.10										
84	87.54	84.10	88.54	84.10												

NOTE: For pipes with cement linings, reduce the pipe inside diameter by two times the lining thickness. Standard and double cement lining thicknesses are listed in Table A-3.

Table A-3
Ductile Iron Pipe Standard Classes
Inside Diameter (ID) and Outside Diameter (OD) in Inches

Nominal Pipe Size	Outside Diameter (OD)	Inside Diameter							Cement Lining (See Note)	
		Class 50	Class 51	Class 52	Class 53	Class 54	Class 55	Class 56	Standard Thickness	Double Thickness
3	3.96		3.46	3.40	3.34	3.28	3.22	3.16		
4	4.80		4.28	4.22	4.16	4.10	4.04	3.98		
6	6.90	6.40	6.34	6.28	6.22	6.16	6.10	6.04	0.125	0.250
8	9.05	8.51	8.45	8.39	8.33	8.27	8.21	8.15		
10	11.10	10.52	10.46	10.40	10.34	10.28	10.22	10.16		
12	13.20	12.58	12.52	12.46	12.40	12.34	12.28	12.22		
14	15.30	14.64	14.58	14.52	14.46	14.40	14.34	14.28		
16	17.40	16.72	16.66	16.60	16.54	16.48	16.42	16.36		
18	19.50	18.80	18.74	18.68	18.62	18.56	18.50	18.44	0.1875	0.375
20	21.60	20.88	20.82	20.76	20.70	20.64	20.58	20.52		
24	25.80	25.04	24.98	24.92	24.86	24.80	24.74	24.68		
30	32.00	31.22	31.14	31.06	30.98	30.90	30.82	30.74		
36	38.30	37.44	37.34	37.06	37.14	37.04	36.94	36.84		
42	44.50	43.56	43.44	43.32	43.20	43.08	42.96	42.84	0.250	0.500
48	50.80	49.78	49.64	49.50	49.36	49.22	49.08	48.94		
54	57.10	55.96	55.80	55.64	55.48	55.32	55.16	55.00		

Note: For pipes with cement linings, reduce the pipe inside diameter by two times the lining thickness listed above.

APPENDIX B: FLUID PROPERTIES

B.1 Fluid Sound Velocities & Kinematic Viscosities

This section provides a table of fluid sound speeds and kinematic viscosities. The information is based on material from the *Cameron Hydraulic Data Book* (17th ed., Ingersoll-Rand, 1988) and *Table of Physical and Chemical Constants* (13th ed., Longmans, 1966).

Note that viscosity does not have as significant an effect on flow accuracy as sound speed since viscosity is only used to calculate flow profile. Even a comparatively large error in viscosity results in a change of only 2 to 5 percent.

LIQUID	t°C	c(m/s)	t° F	c(ft/s)	cSt
Acetaldehyde CH_3CHO	16.1 20	--- ---	61 68	--- ---	0.305 0.295
Acetic acid	50	1584	122	5196	---
10%.....	15	---	59	---	1.35
50%.....	15	---	59	---	2.27
80%.....	15	---	59	---	2.85
Conc.-glacial.....	15	---	59	---	1.34
Acetic anhydride	24 15	1384 ---	75 59	4540 ---	--- 0.88
Acetone CH_3COCH_3	20	1190	68	3903	0.41
Acetylene tetrabromide	28	1007	82	3303	---
Acetylene tetrachloride	28	1155	82	3788	---
Alcohol					
allyl.....	20 40	--- ---	68 104	--- ---	1.60 0.90
butyl-n.....	20 70	--- ---	68 158	--- ---	3.64 1.17
ethyl (grain) C_2H_5OH.....	20 37.8	--- ---	68 100	--- ---	1.52 1.2
methyl (wood) CH_3OH	15 0	--- ---	59 32	--- ---	0.74 1.04
propyl.....	20 50	--- ---	68 122	--- ---	2.8 1.4
Ammonia	-17.8	---	0	---	0.30

LIQUID	T°C	c(m/s)	t°F	c(ft/s)	cSt
Amyl acetate	29.2	1173	85	3847	---
n-Amyl alcohol	28.6	1224	83	4015	---
iso-Amyl ether	26	1153	79	3782	---
Aniline	20 10	1656 ---	68 50	5432 ---	4.37 6.4
Argon	-183.0	816.7	-297	2679	---
Asphalt, blended					
RC-0, MC-0, SC-0	25 37.8	--- ---	77 100	--- ---	159 - 324 60 - 108
RC-1, MC-1, SC-1	37.8 50	--- ---	100 122	--- ---	518 - 1080 159 - 324
RC-2, MC-2, SC-2	50 60	--- ---	122 140	--- ---	518 - 1080 215 - 430
RC-3, MC-3, SC-3	50 60	--- ---	122 140	--- ---	1295 - 2805 540 - 1080
RC-4, MC-4, SC-4	60 82.8	--- ---	140 180	--- ---	1725 - 4315 270 - 540
RC-5, MC-5, SC-5	60 82.8	--- ---	140 180	--- ---	6040 - 18340 647 - 1295
RS-1, MS-1, SS-1	25 37.8	--- ---	77 100	--- ---	33 - 216 19 - 75
Asphalt emulsions					
Fed #1.....	25 37.8	--- ---	77 100	--- ---	215 - 1510 75 - 367
Fed #2, V, VI.....	25 37.8	--- ---	77 100	--- ---	33 - 216 19 - 75

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Automotive crankcase oils					
SAE-5W	-17.8	---	0	---	1295 max
SAE-10W	-17.8	---	0	---	1295 - 2590
SAE-20W	-17.8	---	0	---	2590 - 10350
SAE-20	98.9	---	210	---	5.7 - 9.6
SAE-30	98.9	---	210	---	9.6 - 12.9
SAE-40	98.9	---	210	---	12.9 - 16.8
SAE-50	98.9	---	210	---	16.8 - 22.7
Automotive gear oils					
SAE-75W	98.9	---	210	---	4.2 min
SAE-80W	98.9	---	210	---	7.0 min
SAE-85W	98.9	---	210	---	11.0 min
SAE-90	98.9	---	210	---	14 - 25
SAE-14Q	98.9	---	210	---	25 - 43
SAE 150	98.9	---	210	---	43 min
Beer	20	---	68	---	1.8
Benzene (Benzol) C_6H_6	20 0	1321 ---	68 32	4333 ---	0.744 1.00
Benzophenone	100	1316	212	4316	---
Bismuth	285	1663	545	5455	---
Bone Oil	54.4 100	--- ---	130 212	--- ---	47.5 11.6
Bromine	20	---	68	---	0.34
Bromobenzene	50	1074	122	3523	---
Bromoform	25	908	77	2978	---
Butane-n	-1.1 ---	--- ---	-50 30	--- ---	0.52 0.35
Butyl acetate	30	1172	86	3844	---
n-Butyl alcohol	20	1257.7	68	4125	---
iso-Butyl bromide	-104	1450	-155	4756	---
Butyric acid n	20 0	--- ---	68 32	--- ---	1.61 2.3cp
Cadmium	360	2150	680	7052	---

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Caesium	130	967	266	3172	---
Calcium chloride					
5%	18.3	---	65	---	1.156
25%	15.6	---	60	---	4.0
Carbolic acid (phenol)	18.3	---	65	---	11.83
Carbon tetrachloride CCl_4	20	---	68	---	0.612
	37.8	---	100	---	0.53
Carbon disulphide CS_2	25	1149	77	3769	---
	0	---	32	---	0.33
	20	---	68	---	0.298
Carbon tetrachloride	20	938	68	3077	---
Castor oil	18.6	1500	65	4920	---
	37.8	---	100	---	259-325
	54.4	---	130	---	98-130
China wood oil	20.6	---	69	---	308.5
	37.8	---	100	---	125.5
Chlorine	20	850	68	2788	---
m-Chlornitrobenzene	40	1368	104	4487	---
Chlorobenzene	25	1302	77	4271	---
Chloroform	20	---	68	---	0.38
	25	995	77	3264	---
	60	---	140	---	0.35
Cocoanut oil	37.8	---	100	---	29.8 - 31.6
	54.4	---	130	---	14.7 - 15.7
Cod oil	37.8	---	100	---	32.1
	54.4	---	130	---	19.4
Corn oil	54.4	---	130	---	28.7
	100	---	212	---	8.6
Corn starch solutions					
22 Baume	21.1	---	70	---	32.1
	37.8	---	100	---	27.5
24 Baume	21.1	---	70	---	129.8
	37.8	---	100	---	95.2
25 Baume	21.1	---	70	---	303
	37.8	---	100	---	173.2

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Cotton seed oil	37.8 54.4	--- ---	100 130	--- ---	37.9 20.6
Crude Oil 48°API	15.6 54.4	--- ---	60 130	--- ---	3.8 1.6
40°API	15.6 54.4	--- ---	60 130	--- ---	9.7 3.5
35.6 API	15.6 54.4	--- ---	60 130	--- ---	17.8 4.9
32.6 API	15.6 54.4	--- ---	60 130	--- ---	23.2 7.1
Salt Creek	15.6 54.4	--- ---	60 130	--- ---	77 6.1
Cyclohexane	20	1278	68	4192	---
Cyclohexanol	30	1622	86	5320	---
Decane-n	-17.8 37.8	--- ---	0 100	--- ---	2.36 1.001
l-Decene	20	1250	68	4100	---
Deuterium oxide	20	1381	68	4530	---
Diesel fuel oils 2D	37.8 54.4	--- ---	100 130	--- ---	2 - 6 1 - 3.97
3D	37.8 54.4	--- ---	100 130	--- ---	6 - 11.75 3.97 - 6.78
4D	37.8 54.4	--- ---	100 130	--- ---	29.8 max 13.1 max
5D	50 71.1	--- ---	122 160	--- ---	86.6 max 35.2 max
Diethyl Ether	20	---	68	---	0.32
Diethylene glycol	21.1 30	--- 1533	70 86	--- 5028	32 ---
Diethylene glycol monoethyl ether	30	1296	86	4251	---
Dimethyl siloxane (Dow Corning® 200 fluid)	20	912.3	68	2992	---

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Diphenyl	100	1271	212	4169	---
Diphenyl ether	30	1462	86	4795	---
Ethanol	20	1156	68	3792	---
Ethanol amide	25	1724	77	5655	---
Ether (diethyl)	25	985	77	3231	---
Ethyl acetate $CH_3COOC_2H_5$	15 20	--- 1133	59 68	--- 3716	0.4 0.49
Ethyl alcohol	20	1161.8	68	3811	---
Ethyl bromide C_2H_5Br	10 20	932 ---	50 68	3057 ---	--- 0.27
Ethyl glycol	30	1606	86	5268	---
Ethyl iodide	20	876	68	2873	---
Ethylene bromide	20	---	68	---	0.787
Ethylene chloride	20	---	68	---	0.668
Ethylene dibromide	24	1014	75	3326	---
Ethylene dichloride	23	1240	73	4067	---
Ethylene glycol	21.1 30	--- 1616	70 86	--- 5300	17.8 ---
Ethylene glycol monoethyl ether	30	1279	86	4195	---
Ethylene glycol monomethyl ether	30	1339	86	4392	---
Formaldehyde	25	1587	77	5205	---
Formamide	25	1610	77	5281	---
Formic acid 10%	20 20	1299 ---	68 68	4261 ---	--- 1.04
50%	20	---	68	---	1.2
80%	20	---	68	---	1.4
Conc.	20	---	68	---	1.48

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Freon					
-11	21.1	---	70	---	0.21
-12	21.1	---	70	---	0.27
-21	21.1	---	70	---	1.45
Fuel Oils					
1	21.1	---	70	---	2.39 - 4.28
	37.8	---	100	---	2.69
2	21.1	---	70	---	3.0 - 7.4
	37.8	---	100	---	2.11 - 4.28
3	21.1	---	70	---	2.69 - 5.84
	37.8	---	100	---	2.06 - 3.97
5A	21.1	---	70	---	7.4 - 26.4
	37.8	---	100	---	4.91 - 13.7
5B	21.1	---	70	---	26.4-
	37.8	---	100	---	13.6 - 67.1
6	50	---	122	---	97.4 - 660
	71.1	---	160	---	37.5 - 172
Gallium	50	2740	122	8987	---
Gas oils	21.1	---	70	---	13.9
	37.8	---	100	---	7.4
Gasolines					
a	15.6	---	60	---	0.88
	37.8	---	100	---	0.71
b	15.6	---	60	---	0.64
c	15.6	---	60	---	0.46
	37.8	---	100	---	0.40
Glycerine	30	1923	86	6307	---
100%	20.3	---	69	---	648
	37.8	---	100	---	176
50% Water	20	---	68	---	5.29
	60	---	140	---	1.85cp
Glucose	37.8	---	100	---	7.7M - 22M
	65.6	---	150	---	880 - 2420
Guaicol	100	1252	212	4107	---
Helium	-268.8	179.8	-452	590	---

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
n-Heptane	-17.8	---	0	---	0.928
	22.4	1150	72	3772	---
	37.8	---	100	---	0.511
Heptene	30	1082	86	3549	---
Heptyne	30	1159	86	3802	---
Hexane	20	1203	68	3946	---
n-Hexane	-17.8	---	0	---	0.683
	21.2	1085	70	3559	---
	37.8	---	100	---	0.401
Honey	37.8	---	100	---	73.6
Hydrogen	-256	1187	-429	3893	---
Industrial lubricants					
Turbine oils					
685	15.6	---	60	---	647
SSU at 100°F	93.3	---	200	---	14.5
420	15.6	---	60	---	367
SSU	93.3	---	200	---	11
315	15.6	---	60	---	259
SSU	93.3	---	200	---	8
215	15.6	---	60	---	151
SSU	93.3	---	200	---	7.3
150	15.6	---	60	---	99
SSU	93.3	---	200	---	6
Machine lubricants					
#8	37.8	---	100	---	23 - 34
	54.4	---	130	---	13 - 18
#10	37.8	---	100	---	34 - 72
	54.4	---	130	---	18 - 25
#20	37.8	---	100	---	72 - 83
	54.4	---	130	---	25 - 39
#30	37.8	---	100	---	75 - 119
	54.4	---	130	---	39 - 55

LIQUID	t° C	c(m/s)	t° C	c(ft/s)	cSt
Machine lubricants, cont					
Cutting oils					
#1.....	37.8	---	100	---	30 - 40
	54.4	---	130	---	17 - 23
#2.....	37.8	---	100	---	40 - 46
	54.4	---	130	---	23 - 26
Indium	260	2215	500	7265	---
Ink, printers	37.8	---	100	---	550 - 2200
	54.4	---	130	---	238 - 660
Insulating oil	21.1	---	70	---	24.1 max
	37.8	---	100	---	11.75 max
Kerosene	20	---	68	---	2.71
	25	1315	77	4313	---
Jet Fuel (av)	-34.4	---	-30	---	7.9
Lard	37.8	---	100	---	62.1
	54.4	---	130	---	34.3
Lard oil	37.8	---	100	---	41 - 47.5
	54.4	---	130	---	23.4 - 27.1
Lead	340	1760	644	5773	----
Linseed oil	37.8	---	100	---	30.5
	54.4	---	130	---	18.94
Menhadden oil	37.8	---	100	---	29.8
	54.4	---	130	---	18.2
Menthol	50	1271	122	4169	---
Merck	20.2	1482.3	68	4862	---
Mercury	20	1454	68	4769	---
	21.1	---	70	---	0.118
	37.8	---	100	---	0.11
Methanol	20	1118	68	3667	---
Methyl acetate	20	---	68	---	0.44
	30	1131	86	3710	---
Methyl alcohol	20	1121.2	68	3678	---
Methyl bromide	2	905	36	2968	---

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Methylene chloride	23.5	1064	74	3490	---
Methylene iodide	24	977.7	75	3207	---
Milk	20	---	68	---	1.13
Molasses					
A, first.....	37.8	---	100	---	281 - 5070
	54.4	---	130	---	151 - 1760
B, second.....	37.8	---	100	---	1410 - 13.2M
	54.4	---	130	---	660 - 3.3M
C, blackstrap.....	37.8	---	100	---	2630 - 55M
	54.4	---	130	---	1320 - 16.5M
Naphthalene	80	---	176	---	0.9
Naptha	25	1225	77	4018	---
Neatsfoot oil	37.8	---	100	---	49.7
	54.4	---	130	---	27.5
Nitrobenzene	20	---	68	---	1.67
	23.8	1462	75	4795	---
Nitrogen	-188.9	744.7	-308	2443	---
Nonane	20	1248	68	4093	---
l-Nonene	20	1218	68	3995	---
Nonene-n	-17.8	---	0	---	1.728
	37.8	---	100	---	0.807
n-Octane	-17.8	---	0	---	1.266
	20	1192	68	3910	---
	37.8	---	100	---	0.645
Oil (lubricating)	10	1625	50	5330	---
Oil of camphor	25	1390	77	4559	---
Oleic acid	20	1442	68	4730	---
Olive oil	21.7	1440	71	4723	---
	37.8	---	100	---	43.2
	54.4	---	130	---	24.1
Oxygen	-182.9	912	-297	2991	---
Palm oil	37.8	---	100	---	47.8
	54.4	---	130	---	26.4

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Paraldehyde	28	1197	82	3926	---
Peanut oil	37.8 54.4	--- ---	100 130	--- ---	42 23.4
l-Pentadecene	20	1351	68	4431	---
Pentane	20	1008	68	3306	---
iso-Pentane	25	985	77	3231	---
n-Pentane	-17.8 20 26.7	--- 1044 ---	0 68 80	--- 3424 ---	0.508 --- 0.342
Petrolatum	54.4 71.1	--- ---	130 160	--- ---	20.5 15
Petroleum ether	15.6	---	60	---	31(est)
Phenol	100	1274	212	4179	---
Potassium	150	1840	302	6035	---
n-Propanol	20	1220	68	4002	---
Propionic acid	20	---	68	---	1.13
n-Propyl acetate	26	1182	79	3877	---
n-Propyl alcohol	20	1223.2	68	4012	---
Propylene glycol	21.1	---	70	---	52
Pyridine	20	1445	68	4740	---
Quenching oil (typical)	---	---	---	---	100 - 120
Rapeseed oil	37.8 54.4	--- ---	100 130	--- ---	54.1 31
Rosin oil	37.8 54.4	--- ---	100 130	--- ---	324.7 129.9
Rosin (wood)	37.8 93.3	--- ---	100 200	--- ---	216 - 11M 108 - 4400
Rubidium	160	1260	320	4133	---
Sesame seed oil	37.8 54.4	--- ---	100 130	--- ---	39.6 23
Silicon tetrachloride	30	766.2	86	2513	---

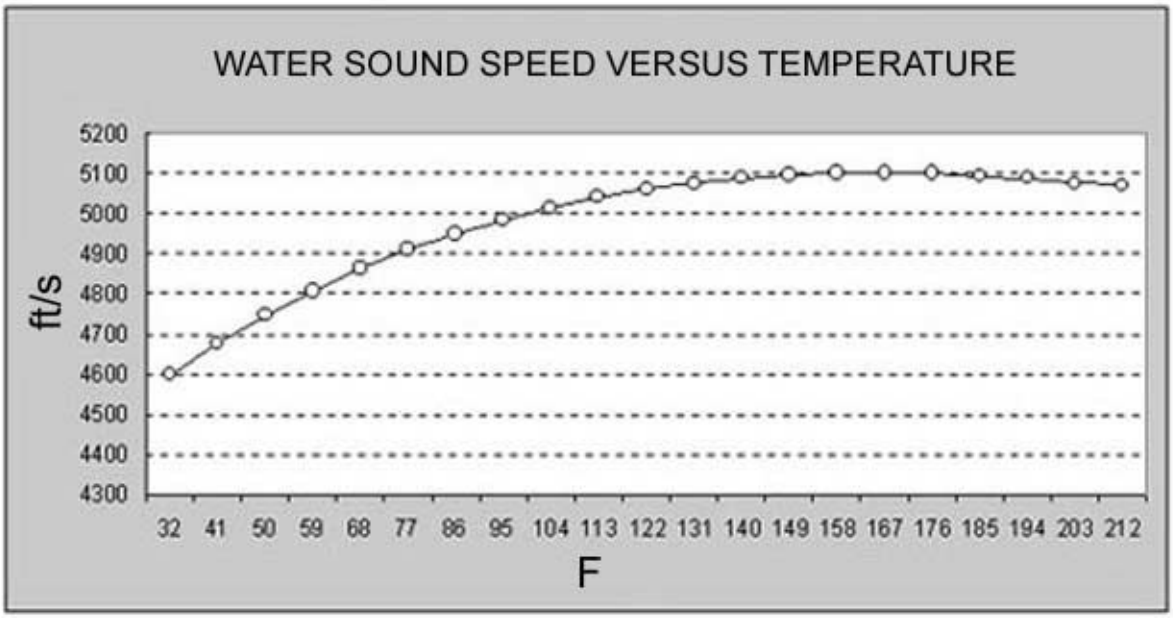
LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Sodium	150	2500	302	8200	---
Sodium chloride (fused)	850	1991	1562	6530	---
5%.....	20	---	68	---	1.097
25%.....	15.6	---	60	---	2.4
Sodium hydroxide (caustic soda) 20%.....	18.3	---	65	---	4.0
30%.....	18.3	---	65	---	10.0
Soya bean oil	37.8 54.4	--- ---	100 130	--- ---	35.4 19.64
Sperm oil	37.8 54.4	--- ---	100 130	--- ---	21 - 23 15.2
Sugar solutions Corn syrup 86.4 Brix	37.8 82.2	--- ---	100 180	--- ---	180Mcp 1750cp
84.4 Brix	37.8 82.2	--- ---	100 180	--- ---	48Mcp 800cp
82.3 Brix	37.8 82.2	--- ---	100 180	--- ---	17Mcp 380cp
80.3 Brix	37.8 82.2	--- ---	100 180	--- ---	6900cp 230cp
78.4 Brix	37.8 82.2	--- ---	100 180	--- ---	3200cp 160cp
Sugar solutions Sucrose 60 Brix	21.1 37.8	--- ---	70 100	--- ---	49.7 18.7
64 Brix	21.1 37.8	--- ---	70 100	--- ---	95.2 31.6
68 Brix	21.1 37.8	--- ---	70 100	--- ---	216.4 59.5
72 Brix	21.1 37.8	--- ---	70 100	--- ---	595 138.6
74 Brix	21.1 37.8	--- ---	70 100	--- ---	1210 238

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Sugar solutions, cont Sucrose 76 Brix	 21.1 37.8	 --- ---	 70 100	 --- ---	 2200 440
Sulphur	130	1332	266	4369	---
Sulphuric acid 100%	20	---	68	---	14.6
95%	20	---	68	---	14.5
60%	20	---	68	---	4.4
Tar, coke oven	21.1 37.8	--- ---	70 100	--- ---	600 - 1760 141 - 308
Tar, gas house	21.1 37.8	--- ---	70 100	--- ---	3300 - 66M 440 - 4400
Tar, pine	37.8 55.6	--- ---	100 132	--- ---	559 108.2
Tar, road - RT-2.....	 50 100	 --- ---	 122 212	 --- ---	 43.2 - 64.9 8.88 - 10.2
RT-4.....	50 100	--- ---	122 212	--- ---	86.6 - 154 11.6 - 14.3
RT-6.....	50 100	--- ---	122 212	--- ---	216 - 440 16.8 - 26.2
RT-8.....	50 100	--- ---	122 212	--- ---	660 - 1760 31.8 - 48.3
RT-10.....	50 100	--- ---	122 212	--- ---	4.4M - 13.2M 53.7 - 86.6
RT-12.....	50 100	--- ---	122 212	--- ---	25M - 75M 108 - 173
Tetralin	20	1484	68	4868	---
Tin (molten)	240	2470	464	8102	---
Toluene	20 30	--- 1275	68 86	--- 4182	0.68 ---
o-Toluidine	22.5	1669	73	5474	---
l-Tridecene	20	1313	68	4307	---

LIQUID	t° C	c(m/s)	t° F	c(ft/s)	cSt
Trielhylene glycol	21.1	---	70	---	40
Triethylamine	0	1189	32	3900	---
Turpentine	25 37.8 54.4	1225 --- ---	77 100 130	4018 --- ---	--- 86.6 - 95.2 39.9 - 44.3
l-Undecene	20	1275	68	4182	---
Varnish, spar	20 37.8	--- ---	68 100	--- ---	313 143
Water distilled.....	20	1482.9	68	4864	1.0038
fresh.....	15.6 54.4	--- ---	60 130	--- ---	1.13 0.55
sea.....	---	---	---	---	1.15
Water (sea) (surface, 3.5% salinity)	15	1507.4	59	4944	---
Whale oil	37.8 54.4	--- ---	100 130	--- ---	35 - 39.6 19.9 - 23.4
Xylene hexafluoride	25	879	77	2883	---
o-Xylene	20 22	--- 1352	68 72	--- 4435	0.93 ---
Zinc	450	2700	842	8856	---

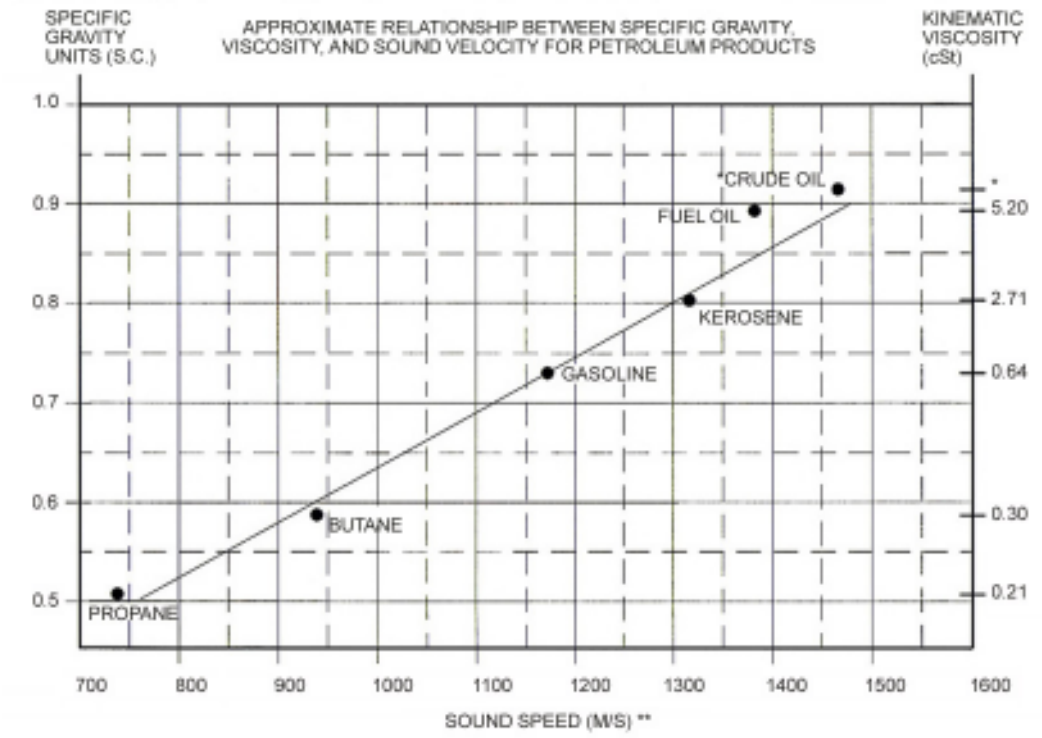
B.2 Clean Water Sound Speed Versus Temperature

Fº	Cº	ft/s	m/s	Fº	Cº	ft/s	m/s
32	0	4599.8	1402.019	131	55	5075.4	1546.982
41	5	4677.8	1425.793	140	60	5087.2	1550.579
50	10	4747	1446.886	149	65	5095.3	1553.047
59	15	4808.3	1465.57	158	70	5099.7	1554.389
68	20	4862.1	1481.968	167	75	5100.8	1554.724
77	25	4909.1	1496.294	176	80	5098.7	1554.084
86	30	4949.9	1508.73	185	85	5093.6	1552.529
95	35	4985	1519.428	194	90	5085.6	1550.091
104	40	5014.7	1528.481	203	95	5074.8	1546.799
113	45	5039.4	1536.009	212	100	5068.4	1544.848
122	50	5059.6	1542.166	*see next page for graphical representation			



B.3 Relationship Between Specific Gravity, Viscosity, & Sound Velocity for Petroleum Products

This figure is a graph showing the approximate relationship between specific gravity, viscosity and sound velocities for aliphatic hydrocarbons (petroleum products).



*SEE TABLE FOR VISCOSITY OF VARIOUS TYPES OF CRUDE OIL
** MULTIPLY M/S BY 3.28 TO OBTAIN FT/S IF ENGLISH UNITS ARE REQUIRED

NOTE:
VISCOSITIES ARE APPROXIMATE. THIS NOMOGRAPH SHOULD BE APPLIED TO ALIPHATIC HYDROCARBONS AND MIXTURES THEREOF ONLY

APPENDIX C: MONITORING & DOWNLOADING DATALOGS USING D-LINK

D-Link is PC-based user interface software that can communicate with DCT6088 and DCT7088 flowmeters to monitor and download datalog information.

C.1 Installing D-Link

Start the PolyCD and select D-Link in Communication Software. Follow the instructions to install D-Link.

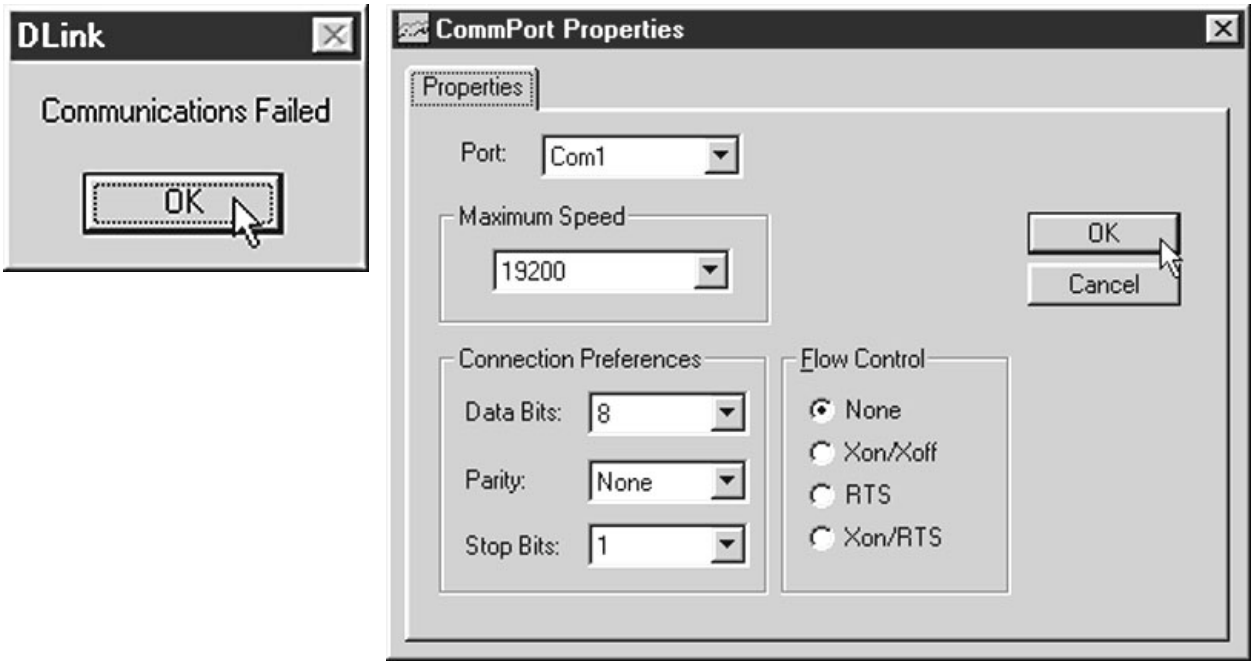
C.2 Establishing Communications with a Flowmeter

1. Go to the **Options Group** menu (42) and select *D-Link* in the communication options.

2. Connect a RS232 cable from the PC to the flowmeter.

3. Open the D-Link utility.

If a *Communication Failed* dialogue opens as shown in Figure C.2-A, click *OK*. Make necessary adjustments according to your PC setup (Figure C.2-B) and click *OK*.



FIGURES C.2-A & C.2-B

If communications still do not establish check the following and correct any errors:

- D-Link is selected in communication Options Menu;
- RS232 cable is connected correctly between the meter and your PC;
- no other software program in your PC is using the COM port you selected.

C.3 Monitoring Datalogs

Once communications between the PC and the meter establish, the program opens as shown in Figure C.3-A (below). Click the arrow below *Get Log*, and select the log file you want to check. Click *Get Log*. The log information downloads and displays as seen in Figure C.3-B (page 77). Log information can be downloaded from the meter when the log is still running, so you can monitor the flow data without stop the log. Refer to Section 4.16 (page 28) for instructions on setting up the datalogger.

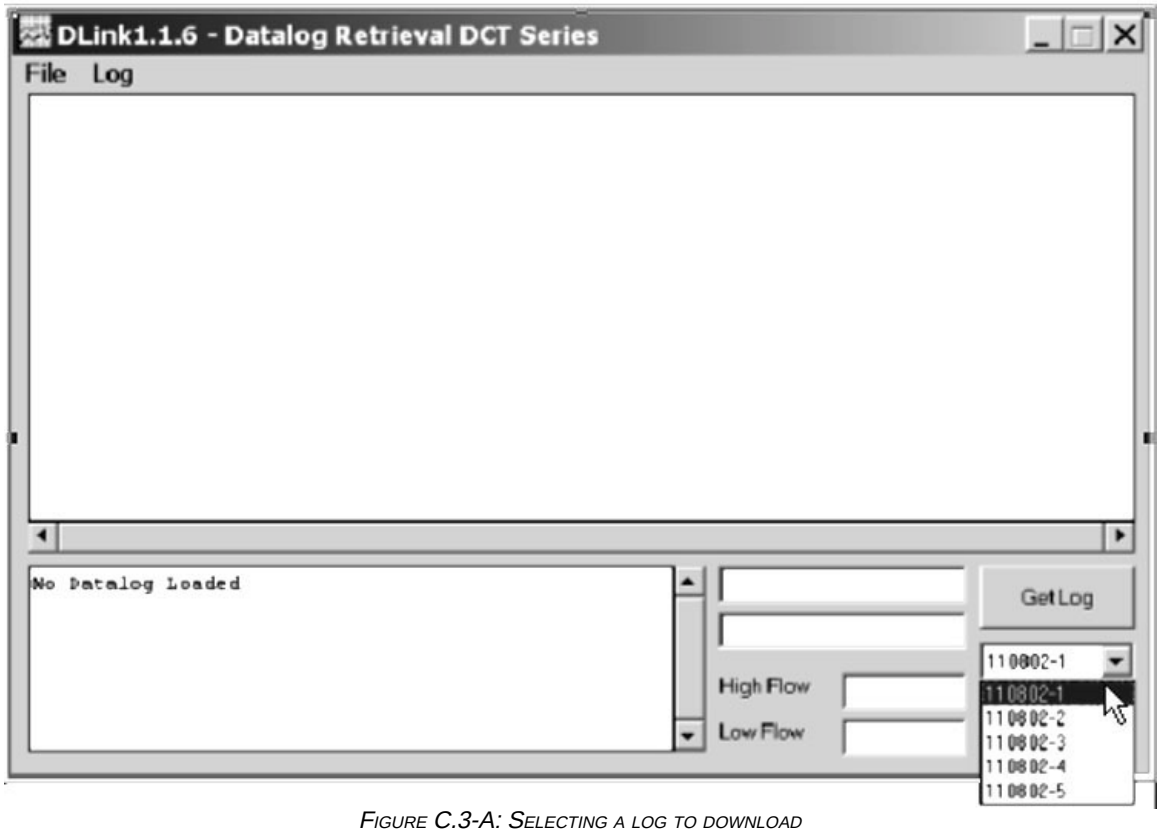


FIGURE C.3-A: SELECTING A LOG TO DOWNLOAD

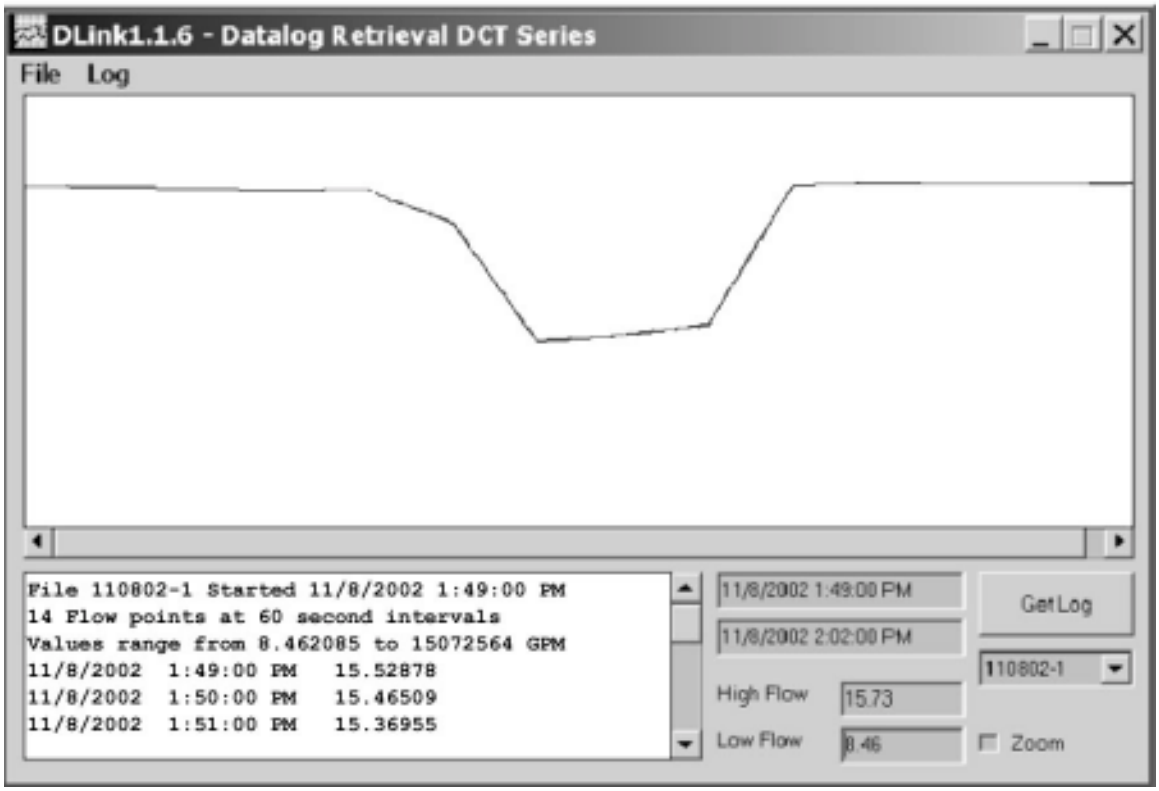


FIGURE C.3-B: DISPLAYED LOG

C.4 Saving & Loading Datalogs

To save the current displayed datalog to a file, go to *File* and select *Save Log.* The file can then be opened in data processing software such as Excel® for Windows®.

To load a previously saved log file, go to *File* and select *Load Log* (refer to Figure C.4, page 78).

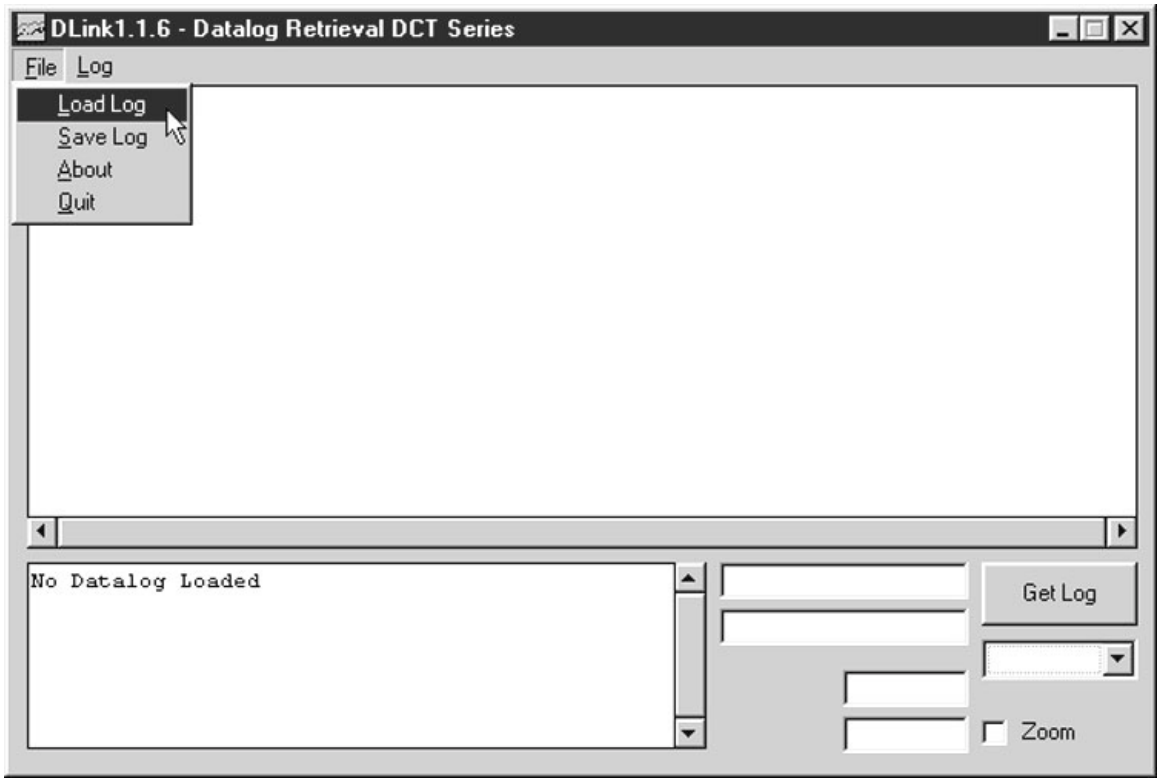

DLink1.1.6 - Datalog Retrieval DCT Series
File
Log
Load Log
Save Log
About
Quit
No Datalog Loaded
Get Log
Zoom

FIGURE C.4