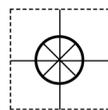


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# User's Guide



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## Series FD-400 Doppler Ultrasonic Flow Meter



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It is the policy of OMEGA Engineering, Inc. to comply with all worldwide safety and EMC/EMI regulations that apply. OMEGA is constantly pursuing certification of its products to the European New Approach Directives. OMEGA will add the CE mark to every appropriate device upon certification.

The information contained in this document is believed to be correct, but OMEGA accepts no liability for any errors it contains, and reserves the right to alter specifications without notice.

WARNING: These products are not designed for use in, and should not be used for, human applications.

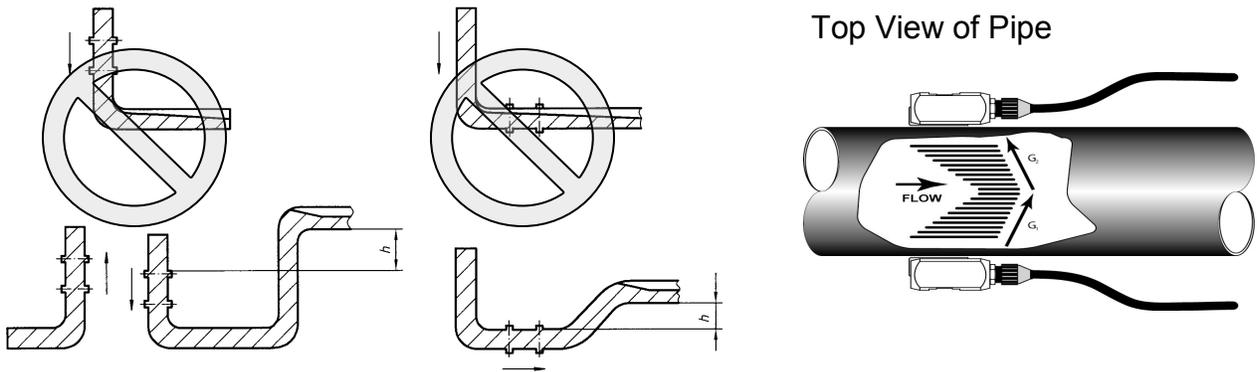
# QUICK-START OPERATING INSTRUCTIONS

This manual contains detailed operating instructions for all aspects of the FD-400 flow instrument. The following condensed instructions are provided to assist the operator in getting the instrument started up and running as quickly as possible. This pertains to basic operation of the clamp-on transducer only. If specific instrument features or an alternate transducer style are to be used or if the installer is unfamiliar with this type of instrument, refer to the appropriate section in the manual for complete details.

## Location

### 1. TRANSDUCER LOCATION

- A. Determine the appropriate mounting location for the transducers by referring to **Figure 1.1**. Pipe must be filled with liquid to ensure proper operation.



**Figure 1.1**  
**Transducer Locations**

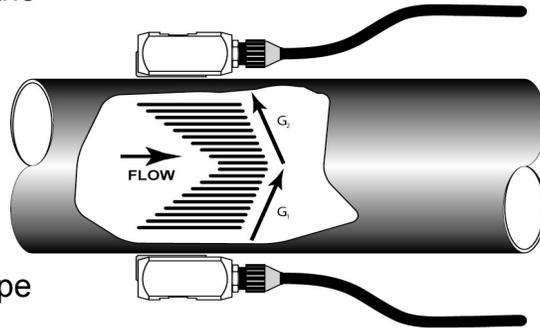
## Pipe Preparation and Mounting

### 2. PIPE PREPARATION AND TRANSDUCER MOUNTING

- A. The piping surface, where the transducers are to be mounted, needs to be clean and dry. Remove loose scale, rust and paint to ensure satisfactory acoustical bonds.
- B. Connect the mounting straps around the pipe. Leave the strap loose enough to slip the transducers underneath.
- C. Apply a liberal amount of silicone grease onto the transducer faces.
- D. Place each transducer under the mounting strap, 180° apart on the pipe. Ensure that the transducer cables are facing the same direction on the downstream side of the flow. See **Figure 1.2** on page 1.2.
- E. Route the transducer cable back to the FD-400 monitor, avoiding conduits that contain high voltage AC supply wires.

# QUICK-START OPERATING INSTRUCTIONS

Cables point in the direction of flow



Top View of Pipe

**Figure 1.2**  
**Transducer Direction**

## Connections

### 3. TRANSDUCER CONNECTIONS

- A. Mount FD-400 monitor within the length of the transducer cables. While transducer cable extension is not generally recommended, if additional transducer cable is required, utilize RG59 75 Ohm coaxial cable and 75 Ohm interconnections such as BNC.
- B. Route the transducer cables through the center conduit hole in the bottom of the FD-400 enclosure and connect to terminal block J4. The terminal blocks are a pluggable type and can be removed to simplify wiring access. A wiring diagram is located on the inner door for reference.

## Startup

### 4. INITIAL SETTINGS AND POWER UP

- A. Verify that the FD-400 power supply jumper settings are properly configured for the power supply that will be utilized. A wiring and jumper selection diagram is located on the inner door for reference.  
**NOTE:** Power supply selection is specified during order placement and appropriate jumpers are placed at the factory. If power is changed from AC to DC or vice versa, the fuse requirement will change. Fuse ratings are listed on the transmitter's door.
- B. Route power connections through the conduit hole farthest to the left and in the FD-400 enclosure. Then connect power to the J2 terminal block. See **Figure 3.2** on page 3.4.
- C. Apply power.
- D. On initial power-up, the FD-400 conducts a series of self-diagnostic tests and buffering operations that take approximately 30 seconds.
- E. Enter pipe internal diameter (Pipe ID), measuring units and output configuration.

# TABLE OF CONTENTS

	Page
<b>Quick-Start Operating Instructions</b>	1.1
<b>Introduction</b>	
<b>General</b>	1.5
<b>Applications</b>	1.5
<b>Product Specifications</b>	
<b>Transducer Installation</b>	
<b>Transducer Mounting Locations</b>	2.1
<b>Pipe Preparation</b>	2.3
<b>Clamp-On Transducer Mounting</b>	2.3
<b>Probe Transducer Mounting</b>	2.6
<b>Transmitter Installation</b>	
<b>Mounting Location</b>	3.1
<b>Dimensional Drawing</b>	3.2
<b>Transducer Wiring Connections</b>	3.3
<b>Power Supply Wiring Connections</b>	3.3
<b>Wiring Diagram</b>	3.4
<b>Multiple Meter Synchronization</b>	3.7
<b>ISO Modules—General Information</b>	3.8
<b>4-20 mA Module</b>	3.9

# TABLE OF CONTENTS

	Page
<b>Control Relay Module</b>	3.10
<b>Rate Pulse Output Module</b>	3.11
<b>Instrument Programming</b>	
<b>Keypad Operation</b>	4.1
<b>Totalizer Reset</b>	4.3
<b>Measurement Units Selection</b>	4.3
<b>Engineering Units Selection</b>	4.4
<b>4-20 mA Programming</b>	4.7
<b>Rate Pulse Programming</b>	4.9
<b>Dual Relay Configuration</b>	4.10
<b>Change Password</b>	4.12
<b>Advanced Set-up</b>	4.12
<b>Startup and Troubleshooting</b>	
<b>Startup Requirements</b>	5.1
<b>Troubleshooting</b>	5.2
<b>Appendix</b>	
<b>FD-400 Software Map—General Operations</b>	
<b>FD-400 Software Map—Output Configurations</b>	
<b>Specific Gravity / Fluid Sound Speed Chart</b>	
<b>Pipe Dimension Chart: ST, SS, PVC / Cast Iron / Ductile Iron</b>	
<b>FPS to GPM Conversion Chart</b>	

# PART 1 - INTRODUCTION

---

## General

The FD-400 ultrasonic flow meter is designed to measure volumetric flow of solids-bearing or aerated liquid within closed conduit. Transducers are available as non-contacting (FD-400C) or insertion probe (FD-400I) types. FD-400C non-contacting transducers are strapped to the outside of a pipe and are suitable for most installations where the pipe material supports the transmission of ultrasound. Some pipe materials, such as concrete pressure pipe and some plastic lined pipes do not allow ultrasound to penetrate to the liquid inside. For these applications, the FD-400I insertion probe will be needed.

The flow meter operates by transmitting an ultrasonic sound from its transmitting transducer through the pipe wall or from the probe tip into the moving liquid. The sound will be reflected by useful sonic reflectors<sup>1</sup> suspended within the liquid and recorded by the receiving transducer. If the sonic reflectors are moving within the sound transmission path, sound waves will be reflected at a frequency shifted (Doppler frequency) from the transmitted frequency. The shift in frequency will be directly related to the speed of the moving particle or bubble. This shift in frequency is interpreted by the instrument and converted to various user defined measuring units.

<sup>1</sup> What makes a good Doppler reflector? The four criteria are:

- The scattering material must have a sonic impedance (sound speed difference) at least 10% different from the fluid.
- There must be some particles large enough to cause longitudinal reflection – particles larger than 35 micron.
- For a given pipe size, the longitudinal reflection must have sufficient energy to overcome the Rayleigh (energy wasting) scattering caused by smaller particles.
- The reflecting material must travel at the same velocity as the fluid for good accuracy.

## Application Versatility

The FD-400 flow meter can be successfully applied on a wide range of metering applications. The easy to program transmitter allows the standard product to be used on pipe sizes ranging from 1 - 120 inch (25 - 3050 mm) pipe I.D. With the small pipe transducer option, the pipe size range is 0.25 - 1 inch (6 - 25 mm). A variety of liquid applications can be accommodated: raw sewage, river water, plant effluent, mining slurries, sludge, etc. Because the clamp-on transducers are non-contacting and have no moving parts, the flow meter is not affected by system pressure, fouling or wear. Standard transducers are rated to 250 °F (121 °C). Optional high temperature transducers are rated to operate to 400 °F (204 °C).

# PART 1 - INTRODUCTION

---

## **User Safety**

The FD-400 employs modular construction and provides electrical safety for the operator. The enclosure is constructed from rugged polycarbonate plastic with UV inhibitors. The enclosure does not contain any conductive materials that can become energized while the door is closed. The keypad is also manufactured from polycarbonate and is designed for outdoor use. The AC power transformer provides 4,000 Volts of isolation from the power supply mains. The display face contains voltages no greater than 24 Vdc. Output modules are optically isolated from external power supplies and provide a great degree of immunity to ground loops.

## **Data Storage**

The FD-400 product retains all user configuration data and totalizer accumulations in non-volatile FLASH memory indefinitely.

## **Product Identification**

The serial number and complete model number of each FD-400 is located on the inside of the monitor's front cover. Should technical assistance be required, please provide the Omega Customer Service Department with this information.

# PART 1 - INTRODUCTION

DESCRIPTION	SPECIFICATION
Measuring Principle	Doppler Ultrasonic
Flow Velocity Range	0.15-30 FPS (0.05-9 MPS); Minimum calibrated span 0.15 to 5 FPS (0.05 to 2 MPS)
Accuracy	±2% full scale, over calibrated span
Liquid Types	Liquids containing 100 ppm of useful sonic suspended reflectors greater than 35 micron size, and at least 25% of the overall particle volume is larger than 100 microns (See "Product Applications" page for details)

## MONITOR

DESCRIPTION	SPECIFICATION
Enclosure	NEMA 4X (IP-66), polycarbonate, stainless steel, brass, plated-steel mounting brackets 7.00H x 5.75W x 3.88D inches (178H x 146W x 99D mm)
Power Supply	115/230 VAC 50/60 Hz ±15% @ 5 VA Max; 12-28 VDC @ 2.5 VA Max
Display	2 line x 8 character LCD; LED backlighting; Top row 7-segment 0.7 inch (18 mm); Bottom row 14-segment 0.35 inch (9 mm); 8-digit rate 8-digit total (resettable)
Units	User configured - feet, gallons, ft <sup>3</sup> , Mil-gal, meters, liters, Mil ft <sup>3</sup> , m <sup>3</sup> , Mil-liters, acre-feet, oil barrels (42 gallon), liquor barrels (32.5 gallons), lbs., Kg
Rate Interval	Second, minute, hour, day. Totalizer exponent: E-2 to E+6
Response Time	User selectable: 6-60 seconds
Outputs	4-20mA: 800 ohms max; internal or external power supply; 12-bit resolution; optically isolated Dual Relay: independently configured; Form C, 200 VAC @ 0.5 A resistive; rate alarm, totalizer pulse, error Rate Pulse: two output types—500mV AC or open collector; 2,500 Hz max; 12-bit resolution; 500 mV AC into 2K ohm minimum; Open collector 1 A at 100 V max
Multiple Meters	Synchronization provision included—utilized for multiple meter, single pipe/manifold system. Up to four meters may be interconnected, up to 100 feet (30 meters) apart.
Keypad	Four keys, tactile
Ambient Conditions	-40 °F to +185 °F (-40 °C to +85 °C); 0-95% relative humidity, non-condensing
Approvals	CE approved

## TRANSDUCERS

DESCRIPTION	SPECIFICATION
Type	Compression-mode Ultrasonic; 625 kHz
Housing Material	Standard Clamp-On: NEMA 6P (IP-68) -40 °F to +194 °F (-40 °C to + 90 °C) CPVC, Ultem®, Nylon, PVC (Cable Jacket), Aluminum (small pipe) High Temp Clamp-On: NEMA 4 (IP-65) -40 °F to +400 °F (-40 °C to +200 °C) Vespel®, Anodized Aluminum, Nickel-plated brass, PTFE (Cable Jacket) Doppler Probe: NEMA 6 (IP-67) -40 °F to +210 °F (-40 °C to +100 °C); 700 PSI (48 Bar) Max. 316 Stainless Steel, Ultem®, FKM, Nylon, PVC (Cable Jacket) Optional Flexible Armored Conduit: Zinc-plated steel, PVC
Pipe Sizes	Standard Clamp-On Transducers: 1 inch (25 mm) and above Small Pipe Clamp-On Transducers: ¼ to 1 inch (6 to 25 mm) Probe Transducers: 4 to 120 inch (101 to 3050 mm)
Cable Length	Standard Lengths: 20, 50 and 100 Feet (6, 15, 30 m) Optional Lengths: to 990 Feet (300 m)
Installation	General Purpose

## PART 2 - TRANSDUCER INSTALLATION

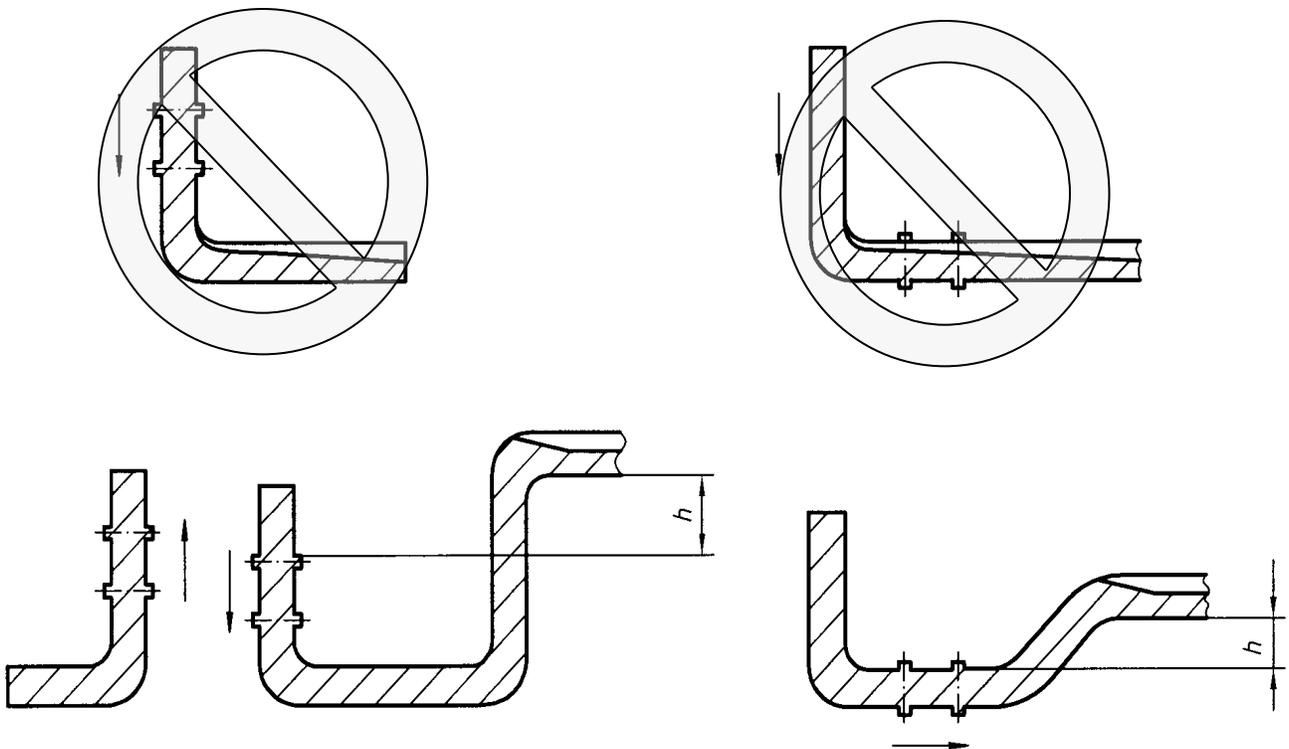
### Unpacking

After unpacking, it is recommended to save the shipping carton and packing materials in case the instrument is stored or re-shipped. Inspect the equipment and carton for damage. If there is evidence of shipping damage, notify the carrier immediately.

### Mounting Locations

The transducers that are utilized by the FD-400 contain piezoelectric crystals for transmitting and receiving ultrasonic sound energy through the pipe wall in the case of the Series FD-400C transducer and from the probe tip of the Series FD-400I. Placement of the ultrasonic transducer is the most critical step in achieving an accurate and reliable flow reading. All flow meters of this type rely on a full-pipe of fluid that is flowing symmetrically (evenly) in the pipe. Flow in partially filled pipes and immediately downstream of elbows, valves and pumps is unstable and will lead to unstable readings and non-linearity.

**Figure 2.1** illustrates five possible pipe configurations and recommends installation only in locations where it can be guaranteed that the pipe will be filled at all times when flow measurements are required. The two locations illustrated in the top two drawings may allow the meter to operate, but it is unlikely that stable and accurate

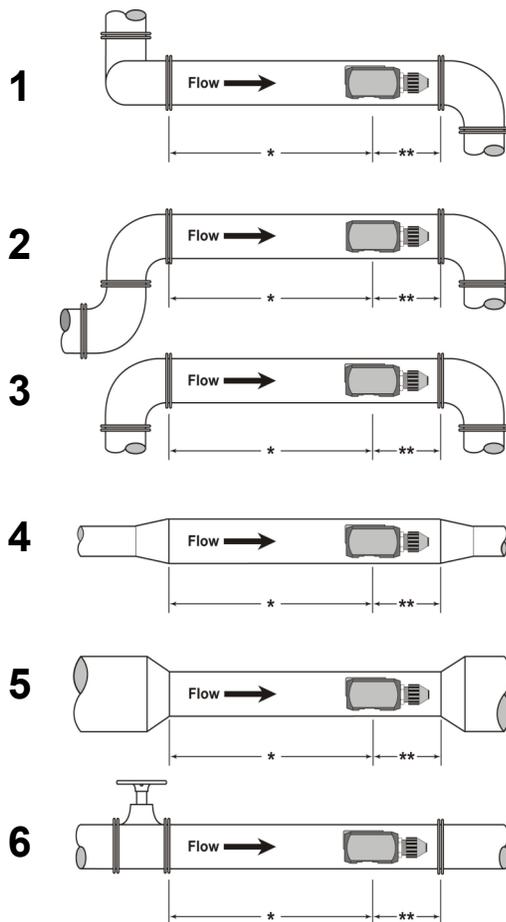


**Figure 2.1**  
**Pipe Configurations and Installation Recommendations**

## PART 2 - TRANSDUCER INSTALLATION

flow readings will be realized over a very large range of flow. Since products like the FD-400 have software algorithms that assume a full-pipe of liquid, partially-filled pipes can lead to very large flow measurement errors and should be avoided.

Select a transducer mounting location with adequate straight runs of pipe, both upstream and downstream, to achieve stable readings<sup>1</sup>. Examples of minimum upstream and downstream requirements are included in **Figure 2.2**.



Example	* Upstream Pipe Diameters	** Downstream Pipe Diameters
1	24	5
2	14	5
3	10	5
4	10	5
5	10	5
6	24	5

**Figure 2.2**  
**Upstream/Downstream Pipe Requirements**

<sup>1</sup> The FD-400 system will provide repeatable measurements on piping systems that do not meet these requirements, but the accuracy may be influenced to various degrees.

# PART 2 - TRANSDUCER INSTALLATION

---

## Pipe Preparation

Before the transducer heads are mounted to the pipe surface, an area slightly larger than the flat surface of the transducer face must be prepared. If pipe insulation is present, it must be peeled back to expose the pipe surface. Typical preparation involves wire brush removal of loose paint, rust, scale or dirt. Paint, if bonded well to the pipe surface, does not need to be removed. The bumps present on ductile iron pipe do not need to be removed. Thoroughly dry the mounting surfaces so that the couplant grease will properly bond to the surface.

**NOTE:** Small pits in the piping surface typically do not significantly impact ultrasonic transmission or signal reception.

## Couplant

To assure an acoustically conductive path between the transducer face and the prepared piping surface, a coupling compound is employed. Clamp-on ultrasonic meters will not operate without coupling compound mounted between the pipe wall and the transducer face. Enclosed with the FD-400 system is a tube of coupling compound that is adequate for general purpose applications. Omega prefers silicone-based valve grease or RTV (Room Temperature Vulcanizing) products or grease for Doppler installations as they operate over a very wide temperature range. In some installations, such as automotive, silicone is not permitted. Alternate petroleum-based products can be utilized, but verify that the grease is rated not to flow at the maximum surface temperature anticipated on the pipe.

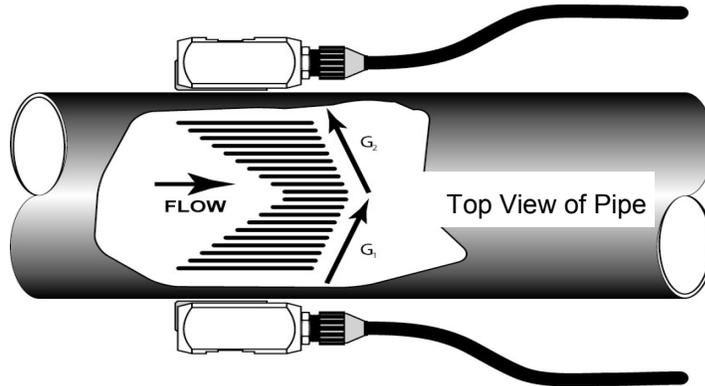
In general, utilize the following couplants with these transducers:

FD-400C	Dow 732 or Dow 111 (or equivalent)
FD-400C-HT	Dow 112 or Pyrogel Grade 100
FD-400I	Not applicable

## FD-400C Clamp-On Transducer Mounting

Clamp-on transducers should be mounted on the pipe 180° apart and facing each other on the pipe, with the cables on the downstream side of the transducers. If the pipe is horizontal, the preferred mounting orientation is 3 and 9 o'clock, with 12 o'clock being the top of the pipe. See **Figure 2.3** on page 2.4. Orientation on vertical pipes does not matter. FD-400I insertion probe transducer installation starts on page 2.6.

## PART 2 - TRANSDUCER INSTALLATION



**Figure 2.3**  
**Transducer Placement**

### **PROCEDURE:**

1. Large pipe installations utilize stainless steel straps to secure the transducers to the outside of the pipe. The FD-400 system is shipped with four 36 inch (900 mm) straps, which are suitable for pipes up to 39 inches (1000 mm) diameter. Select the proper number of transducer straps to allow a complete strap to go around the circumference of the pipe. If a pipe is larger than 39 inches (1000 mm), it is recommended that a single strap/buckle arrangement be utilized to reduce the number of strap connections. See **Figure 2.4**. The straps can be connected together to make a continuous length. Small pipe installations do not utilize straps, but use an integral clamping mechanism built into the transducer.
2. Wrap the strap around the pipe in the area where the

<b>Pipe Sizes</b>		<b>Straps Required</b>
1" to 9"	25 to 225 mm	1
10" to 19"	250 to 480 mm	2
20" to 29"	500 to 740 mm	3
30" to 39"	760 to 1000 mm	4

**Figure 2.4**  
**Straps Required vs. Pipe Size**

## PART 2 - TRANSDUCER INSTALLATION

---

transducers are to be mounted. Leave the strap loose enough to allow the transducers to be placed underneath. If multiple straps are being used, it can be beneficial to wrap electrical tape around all but one strap connection to secure the strap worm screws in place.

3. Spread an even layer of coupling compound, approximately  $\frac{1}{8}$  inch (3mm) thick, to the prepared transducer mounting areas of the pipe.
4. Spread an even layer of coupling compound, approximately  $\frac{1}{8}$  inch (3mm) thick, to the flat face of the two transducers.
5. Place each transducer under the strap with the flat face – amber plastic window – positioned towards the pipe. The notch on the back of the transducer will provide a mounting surface for the strap. The transducer cables must be facing in the same direction and downstream of the transducers for proper operation.

**NOTE:** Large pipes may require two people for this procedure.

6. Tighten the strap strong enough to hold the transducers in place, but not so tight that all of the couplant squeezes out of the gap between the transducer face and pipe. Ensure that the transducers are squarely aligned on the pipe and 180° apart. If RTV is utilized, avoid moving the transducers during the curing time – typically 24 hours – as bubbles may form between the transducer and pipe that can reduce ultrasonic signal transmission to unsatisfactory levels.
7. Route the transducer cables back to the area where the transmitter will be mounted, avoiding high voltage cable trays and conduits. Failure to use proper cables can lead to improper operation of the FD-400 flow meter. Excess cable may be coiled to take up extra length or cutoff.
8. If the transducers are to be permanently mounted using Dow 732, the RTV must be completely cured before proceeding to Instrument Start-up. Ensure that no relative motion between the transducer and pipe occurs during the 24 hour curing process. If Dow 111 grease was used for temporary operation of the FD-400 system, proceed with the Instrument Start-up procedures.

## PART 2 - TRANSDUCER INSTALLATION

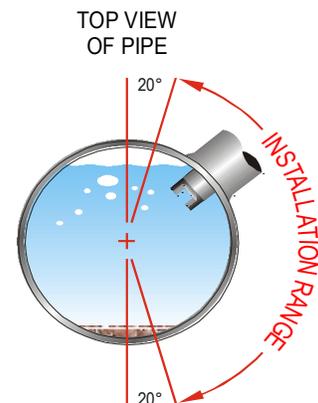
### FD-400I Probe Transducer Mounting

The FD-400I insertion transducer that is utilized by the FD-400 contains piezoelectric crystals for transmitting and receiving ultrasonic sound energy. The black Ultem<sup>®</sup> plastic tip of the FD-400I contains these crystals, which are designed to be inserted just into the path of the flowing liquid.

Select a transducer mounting location that will be completely filled with liquid when flow measurements are to be made – See **Figure 2.1** on page 2.1 – and with adequate straight runs (without disturbances) of pipe, both upstream and downstream, to achieve stable and accurate readings. Examples of minimum upstream and downstream requirements are included in **Figure 2.2** on page 2.2. Note that if adequate straight piping cannot be provided, the FD-400 system will operate repeatably, but will probably not achieve ideal accuracy.

When installing the FD-400I transducer in a horizontal pipe, the preferred orientation is at least 20 degrees from the top or bottom of the pipe – See **Figure 2.5**. Ensure that the mounting location allows for adequate clearance to install and retract the probe fully from the pipe.

**Figure 2.5**  
**Acceptable**  
**Installation Locations**

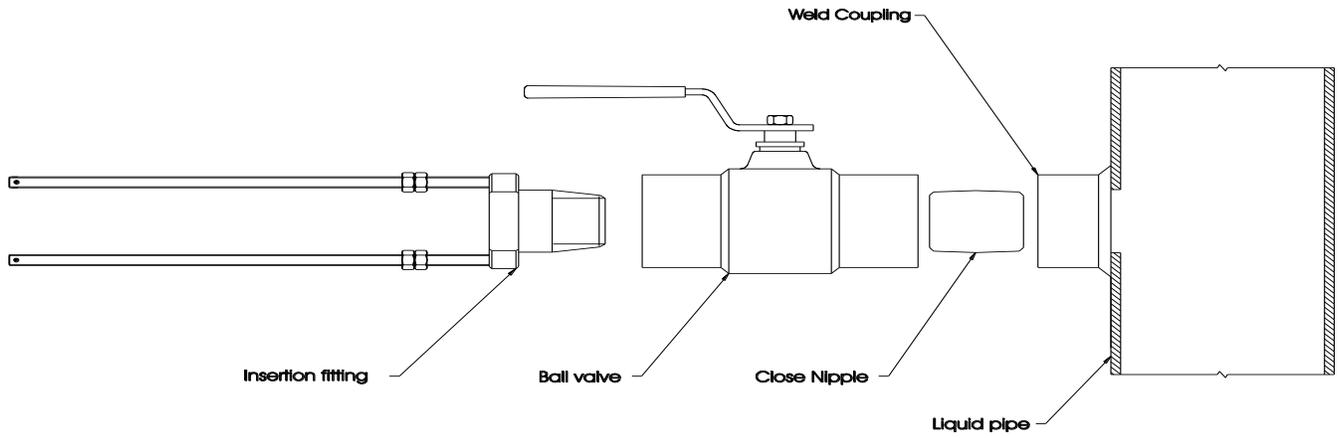


Install Doppler Probe between 1 o'clock  
and 5 o'clock on the pipe

The instructions cover hot tapped installations (installations where it is required to install or remove the transducer probe without shutting down the process pressure). If the product is being installed without an isolation valve, ignore the steps that pertain to its installation. **Figure 2.6** on page 2.7 illustrates an exploded view of an isolation valve assembly and names the various components.

# PART 2 - TRANSDUCER INSTALLATION

---



**Figure 2.6**  
**Hot Tap Installation**

## **PART 2 - TRANSDUCER INSTALLATION**

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## **PART 2 - TRANSDUCER INSTALLATION**

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# PART 2 - TRANSDUCER INSTALLATION

## TO CALCULATE INSERTION DEPTH

Measure and record the following linear distances:

E = PROBE LENGTH = \_\_\_\_\_

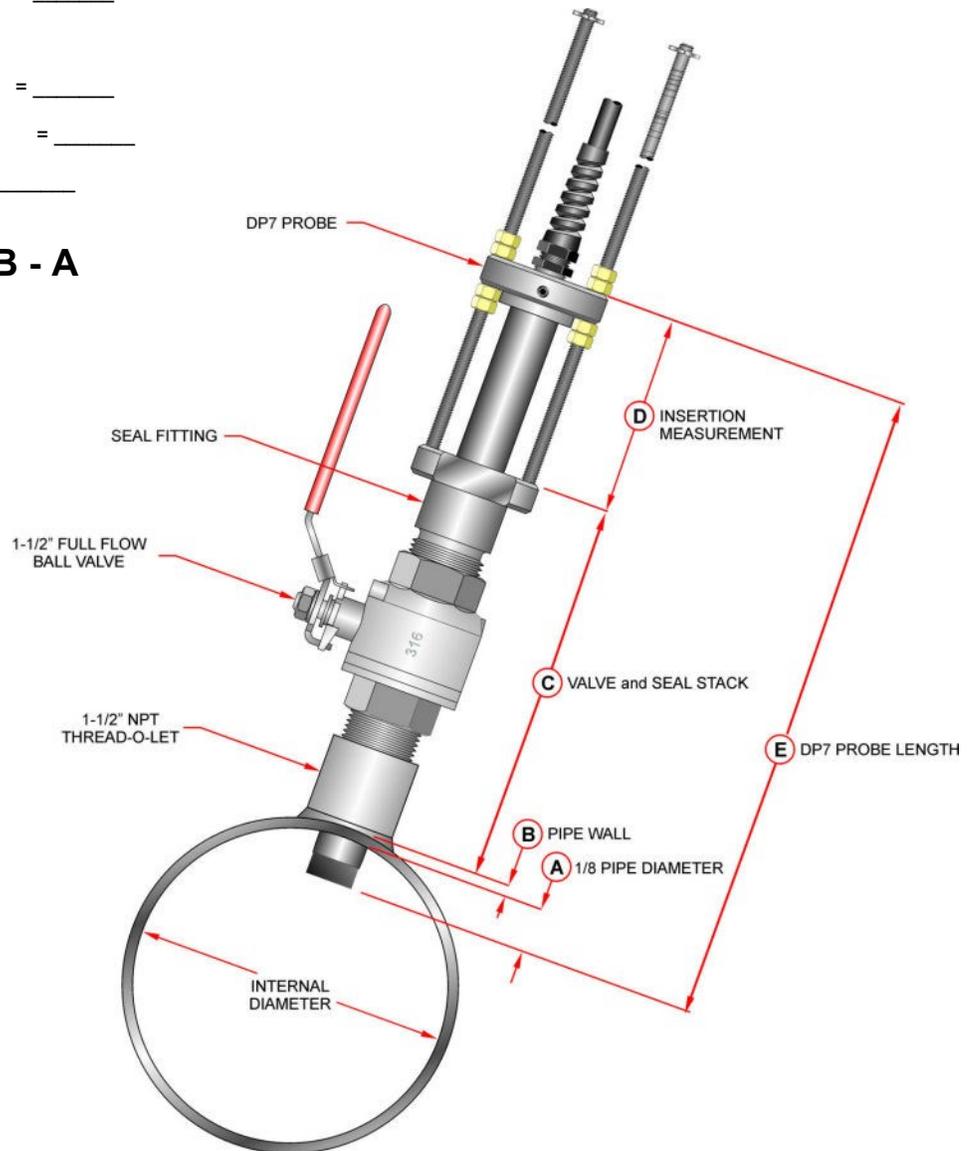
C = SEAL FITTING TO PIPE WALL  
= \_\_\_\_\_

B = PIPE WALL THICKNESS  
= \_\_\_\_\_

A =  $0.125 \times$  PIPE ID = \_\_\_\_\_

D = INSERTION DEPTH = \_\_\_\_\_

$$D = E - C - B - A$$



**Figure 2.7**  
**Installation Measurements**

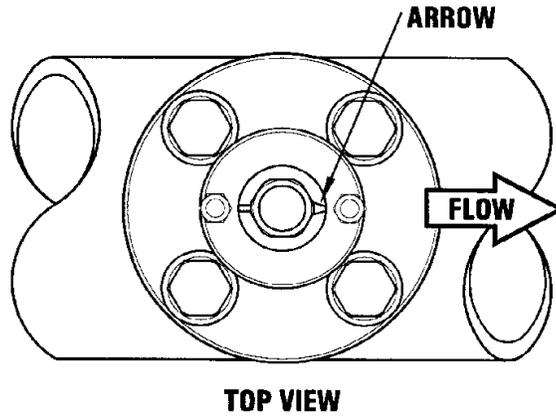
## **PART 2 - TRANSDUCER INSTALLATION**

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## PART 2 - TRANSDUCER INSTALLATION

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**Figure 2.8**  
**Flow Direction**  
**Arrow**

## PART 3 - TRANSMITTER INSTALLATION

---

### Mounting Location

After unpacking, it is recommended to save the shipping carton and packing materials in case the instrument is stored or re-shipped. Inspect the equipment and carton for damage. If there is evidence of shipping damage, notify the carrier immediately.

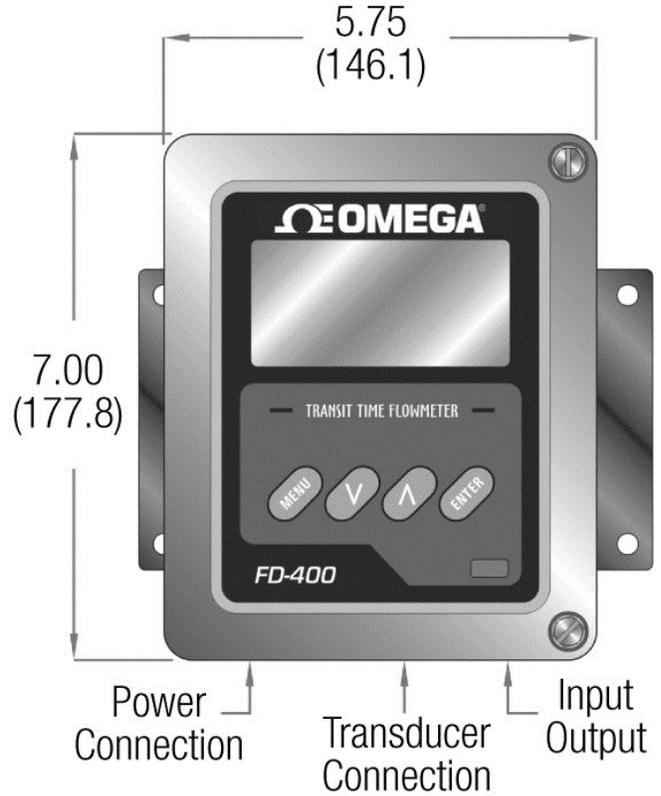
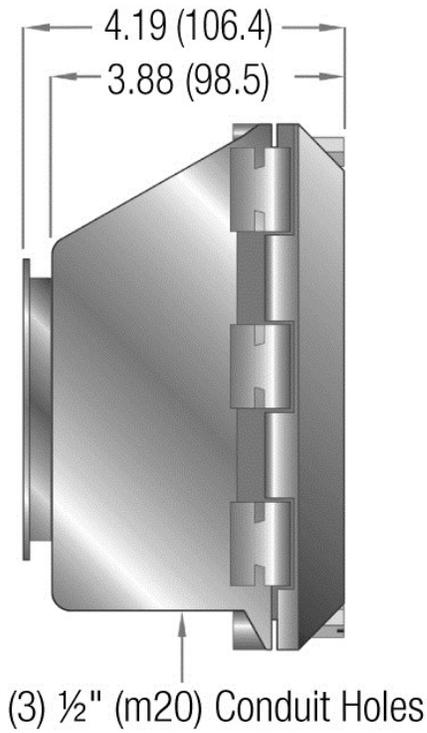
The enclosure should be mounted in an area that is convenient for servicing, calibration and for observation of the LCD readout.

1. Locate the transmitter within the length of transducer cable that was supplied with the FD-400 system. If this is not possible, it is recommended that the cable be exchanged for one that is of proper length. While transducer cable extension is not generally recommended, if additional transducer cable is required, use RG59 75 Ohm coaxial cable and 75 Ohm interconnections such as BNC terminations. Transducer cables that are up to 990 feet (300 meters) may be accommodated.
2. Mount the FD-400 transmitter in a location that is:
  - ◆ Where little vibration exists
  - ◆ Protected from falling corrosive fluids
  - ◆ Within ambient temperature limits -40 to +185°F (-40 to +85°C)
  - ◆ Out of direct sunlight. Direct sunlight may increase transmitter temperature to above the maximum limit
3. Mounting: Refer to **Figure 3.1** on page 3.2 for enclosure and mounting dimension details. Ensure that enough room is available to allow for door swing, maintenance and conduit entrances. Secure the enclosure to a flat surface with four appropriate fasteners.
4. Conduit holes: Conduit hubs should be used where cables enter the enclosure. Holes not used for cable entry should be sealed with plugs.

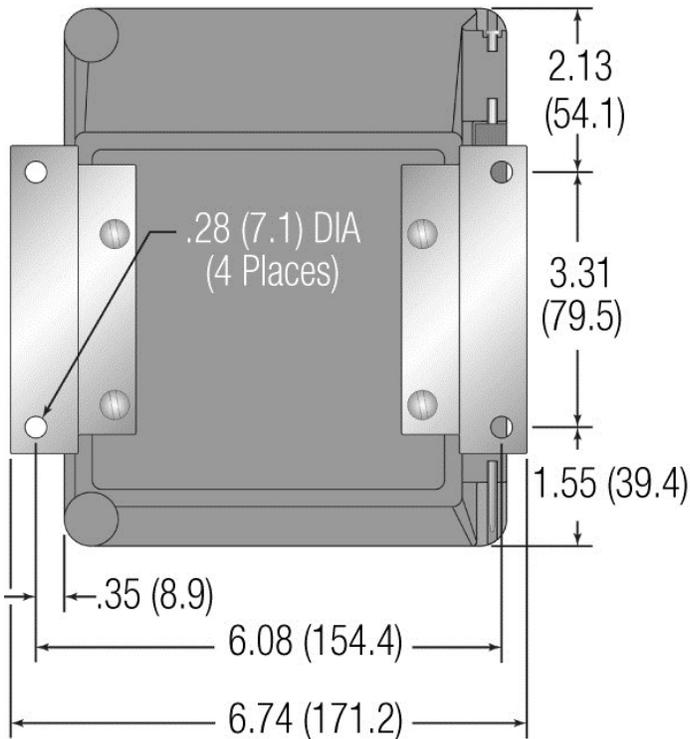
**NOTE:** Use NEMA 4 (IP-65) rated fittings/plugs to maintain the watertight integrity of the enclosure. Generally, the left conduit hole (viewed from front) is used for line power, the center conduit hole for transducer connections and the right hole is utilized for ISO-MOD I/O wiring.

5. If additional holes are required, drill the appropriate size hole in the enclosure's bottom. Use extreme care not to run the drill bit into the wiring or circuit cards.

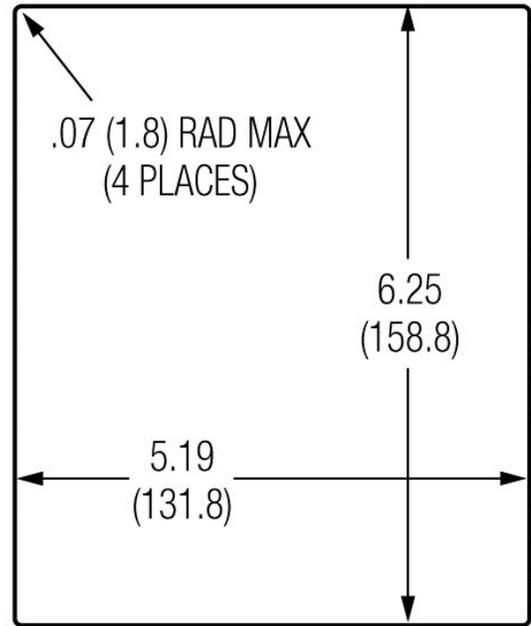
# PART 3 - TRANSMITTER INSTALLATION



## Wall Mount



## Panel Mount (optional)



## Panel cut-out

Panel thickness: 0.5" (12 mm) MAX

## PART 3 - TRANSMITTER INSTALLATION

---

### Transducer Wiring Connections

To access terminal strips for electronic connectors, loosen the two screws in the enclosure door and open the door.

1. Guide the transducer terminations through the transmitter conduit hole located in the bottom-center of the enclosure. Secure the transducer cable with the supplied conduit nut (if flexible conduit was ordered with the transducer).
2. The terminals within the FD-400 are a pluggable type – they can be removed, wired and then plugged back in. Connect the appropriate wires to J4 at the corresponding screw terminals in the transmitter. See **Figure 3.2** on page 3.4 or the Wiring Diagram located on the inner door of the transmitter.

**NOTE:** The transducer cable carries low level high frequency signals. While transducer cable extension is not generally recommended, if additional transducer cable is required, utilize RG59 75 Ohm coaxial cable and 75 Ohm interconnections such as BNC terminations. Cables to 990 feet (300 meters) are available.

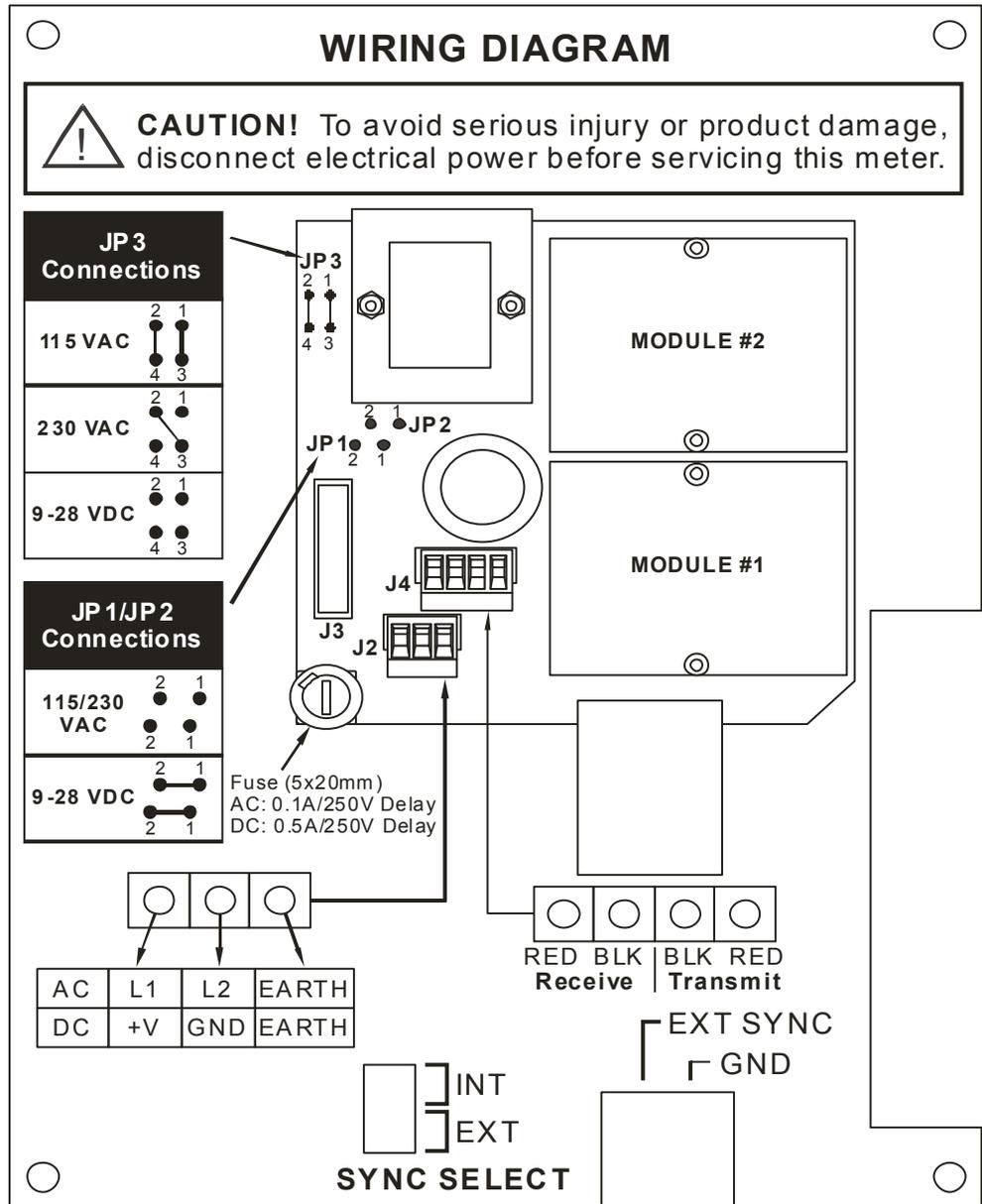
### Power Supply Wiring Connections

Connect power to the screw terminal block marked J2 in the FD-400 transmitter. See **Figure 3.3** on page 3.5 for AC power supplies and **Figure 3.4** on page 3.6 for DC power supplies. Utilize the conduit hole on the left side of the enclosure for this purpose. Use wiring practices that conform to local and national codes (e.g., The National Electric Code Handbook in the U.S.).

**CAUTION:** Any other wiring method may be unsafe or cause improper operation of the instrument.

**NOTE:** This instrument requires clean electrical line power. Do not operate this unit on circuits with noisy components (i.e., fluorescent lights, relays, compressors or variable frequency drives). It is recommended not to run line power with other signal wires within the same wiring tray or conduit.

# PART 3 - TRANSMITTER INSTALLATION



**Figure 3.2**  
**FD-400 Wiring Diagram**

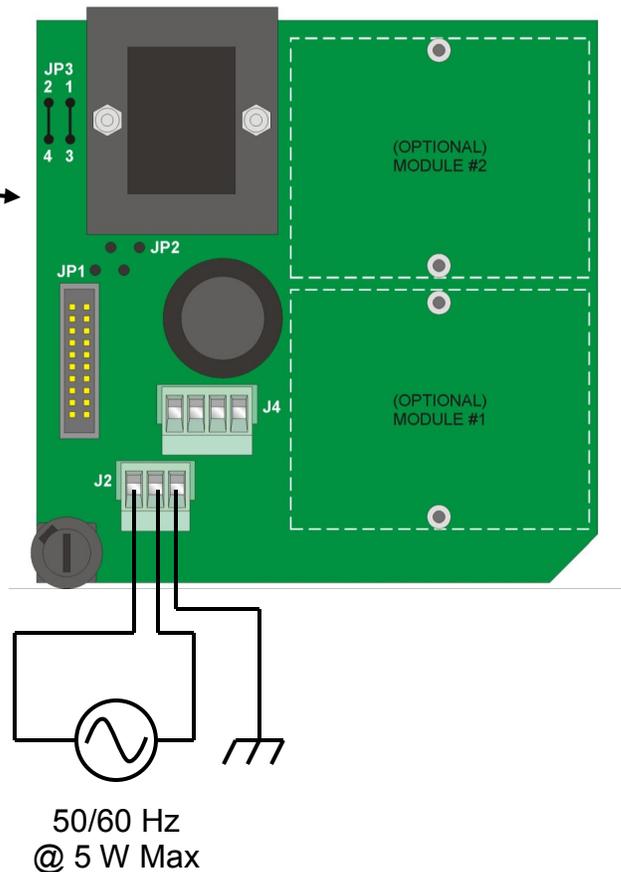
# PART 3 - TRANSMITTER INSTALLATION

## AC Power Supply

### AC POWER CONNECTIONS

1. Verify that the jumpers at JP3 are properly oriented for the power supply. See **Figure 3.2** on page 3.4. Verify that the jumpers at JP1 and JP2 are not present.
2. Connect L1, L2 and EARTH to the terminals referenced in **Figure 3.2**. Phase and neutral connections to L1 and L2 are not polarized. Do not operate without an earth ground connection.
3. See **Figure 3.3** for AC connection schematic. Wire gauges up to 14 AWG can be accommodated in the FD-400 terminal blocks.

**NOTE:** Jumpers positioned for 115 VAC operation. 230 VAC operation requires an alternate position.



**Figure 3.3**  
**AC Power Connection**

# PART 3 - TRANSMITTER INSTALLATION

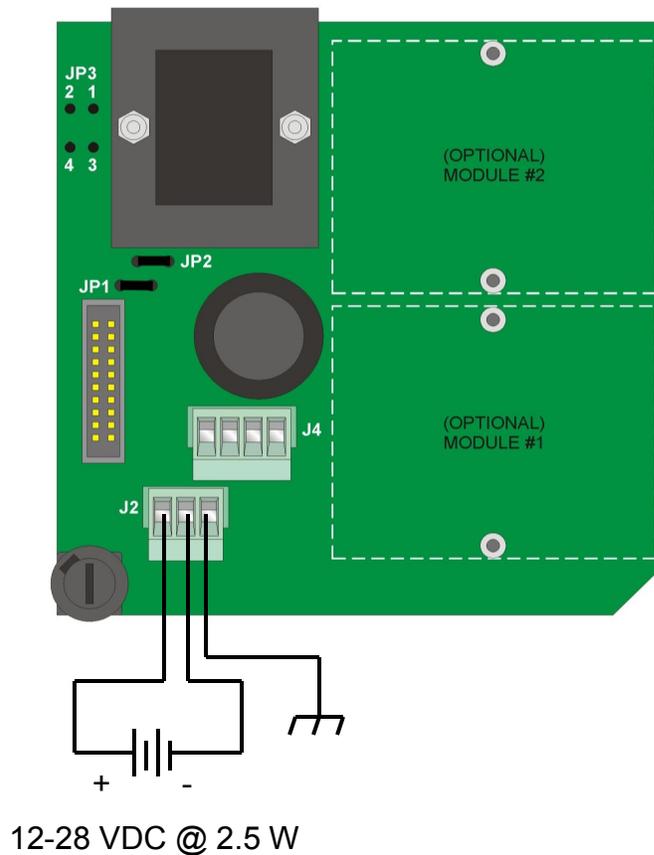
## DC Power Supply

### DC POWER CONNECTIONS

The FD-400 may be operated from a 12-28 VDC source, as long as the source is capable of supplying a minimum of 2.5 Watts.

12 VDC Supply @ 208 mA minimum  
24 VDC Supply @ 104 mA minimum

1. Verify that the jumpers are properly placed. See the Wiring Diagram located on the inside door of the FD-400 enclosure or see **Figure 3.2** on page 3.4. The jumpers at JP3 should not be present and the jumpers at JP1 and JP2 will be in place.
2. Connect the DC power source as illustrated in the schematic in **Figure 3.4**. Wire up to 14 AWG can be accommodated in the FD-400 terminal blocks.



**Figure 3.4**  
**DC Power Connection**

# PART 3 - TRANSMITTER INSTALLATION

## Multiple Meter Synchronization

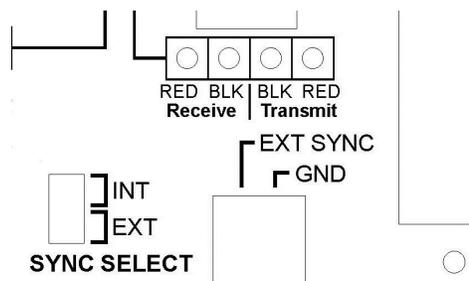
### Multiple Meter Installations

The FD-400 flow meter contains a provision for synchronizing multiple FD-400 flow meters together. Synchronization is required when more than one FD-400 flow meter is mounted on a common pipe or header system. If meters are not synchronized, a phenomena called “cross-talk” can occur between meters, which can lead to erroneous readings and inoperability. Cross-talk results from the small differences in transmitted frequency generated from two or more different ultrasonic flow meters. By synchronizing the transmitted ultrasonic energy, cross-talk caused by differences in transmitted frequency is eliminated.

The FD-400 synchronization circuit is designed to interconnect up to four FD-400 flow meters over a cable length of 100 feet (30 meters). Utilize 20-22 AWG twisted-pair shielded interconnection wire for this purpose. See **Figure 3.5**.

To synchronize multiple meters:

1. Remove power from the FD-400 flow meters.
2. Daisy-chain connect the EXT SYNC and GND terminal blocks together between the meters to be synchronized, utilizing the twisted-pair cable described previously. The terminal block is located on the circuit board that is mounted on the door of the FD-400 monitor. See Wiring Diagram on page 3.4, the decal on the inner door of the FD-400 monitor or schematic below.
3. At a single point, connect the shield drain wire from the interconnection cable to earth ground.
4. Configure the SYNC SELECT jumpers on the FD-400 flow meters. One FD-400 should be configured for INT and the remaining units configured for EXT (see below).
5. Apply power to the FD-400 system.



**Figure 3.5**  
**FD-400 Synchronization Connections**

# PART 3 - TRANSMITTER INSTALLATION

---

## ISO Modules

The FD-400 utilizes ISO-MODs for input and output functions. ISO-MODs are epoxy encapsulated electronic input/output modules that are simple to install and replace in the field. See **Figure 3.6**. All modules are 2,500 V optically isolated from FD-400 power and earth grounds. This eliminates the potential for ground loops and reduces the chance of severe damage in the event of an electrical surge.

Three ISO-MOD options are available, including: 4-20 mA, dual-relay and rate pulse. The FD-400 supports any two ISO-MOD input/output modules. All modules are field configurable by utilizing the keyboard interface. Field wiring connections to ISO-MODs are quick and easy using pluggable terminals. Configuration and connection of the various ISO-MODs are described on the following pages.



**Figure 3.6**  
**Two ISO-MOD I/O Modules Installed**

## ISO-MOD Replacement

To remove an ISO-MOD, remove the two machine screws that secure the module in place and pull the module straight out of the enclosure. A 10-pin connection is on the bottom of the module that mates with the circuit board underneath. Installation of a module is simply the reverse operation of removal. 4-20 mA modules will require calibration parameters to be entered if the module is replaced. See Part 4 of this manual for instructions on entry of calibration parameters.

# PART 3 - TRANSMITTER INSTALLATION

## 4-20 mA Output Module

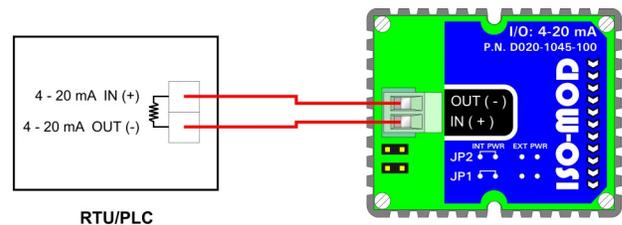
The 4-20 mA Output Module interfaces with most recording and logging systems by transmitting an analog current signal that is proportional to system flow rate. The 4-20 mA ISO-MOD may be configured via jumper selections for either an internally powered (**Figure 3.7A**) or externally powered (**Figure 3.7B**) mode.

**Internal Power Configuration:** Ensure that jumpers are in place at JP1 and JP2 on the module – reference **Figure 3.7A**. In this configuration, the 4-20 mA output is driven from a +24 VDC source located within the FD-400 flow meter. The 24 VDC source is isolated from DC ground and earth ground connections within the FD-400 instrument. The module can accommodate loop loads up to 800 Ohms in this configuration.

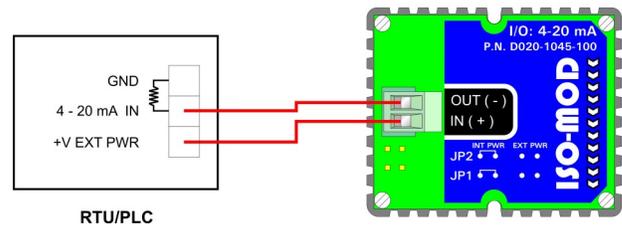
**NOTE:** The +24 internal supply, if configured to power the 4-20 mA output, shares a common ground with another ISO-MOD (if installed). If another module is connected to earth ground, a ground loop may occur. The solution to this problem is to configure the 4-20 mA module for external power and utilize an external isolated supply to power the 4-20 mA loop.

**External Power Configuration:** Remove the two jumpers located at JP1 and JP2 on the module – reference **Figure 3.7B**. In this configuration the 4-20 mA module requires power from an external DC power supply. The voltage of the external power source must be sufficient to power the module and drive the loop load. The loop loss attributed to the ISO-MOD is 7 VDC, so the minimum voltage required to power a loop can be calculated using the following formula:  
**Loop voltage (min) = (loop load Ohms × 0.02) + 7**

**Figure 3.7A**  
Internally Powered  
4-20mA



**Figure 3.7B**  
Externally Powered  
4-20mA



# PART 3 - TRANSMITTER INSTALLATION

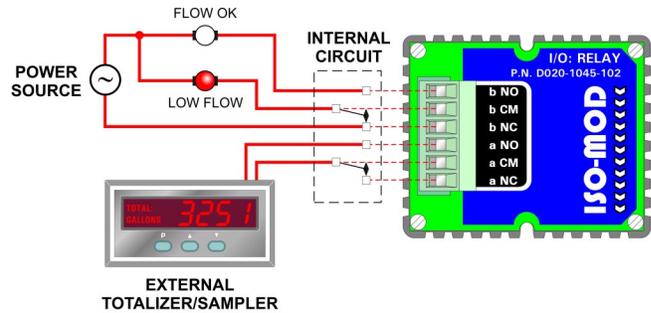
## Control Relay Output Module

Two independent SPDT (single-pole, double-throw, Form C) relays are contained in this module. The relay operations are user configured via the front panel to act in either a flow rate alarm, error alarm or totalizing pulse. The relays are rated for 200 VAC maximum and have a current rating of 0.5 A resistive load (175 VDC @ 0.25 A resistive). It is highly recommended that a secondary relay be utilized whenever the Control Relay ISO-MOD is used to control inductive loads such as solenoids and motors.

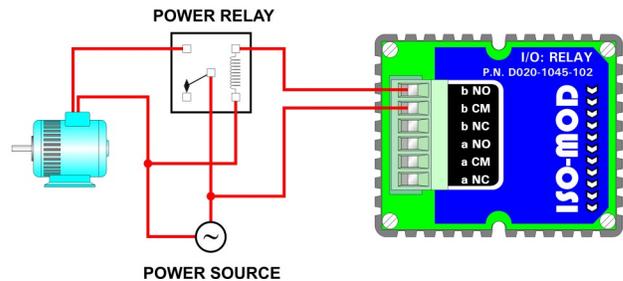
Typical relay connections are illustrated in **Figure 3.8A**. The reed relays located within the relay module can interface directly with small pilot lights, PLCs, electronic counters and SCADA systems.

**Figure 3.8B** describes the connection of an external power relay to the Relay ISO-MOD. It is recommended that external power relays are utilized whenever the load to be switched exceeds the switch rating of the reed relays, or if the load is inductive in nature.

**Figure 3.8A**  
Typical Relay Connections



**Figure 3.8B**  
External Relay Connections



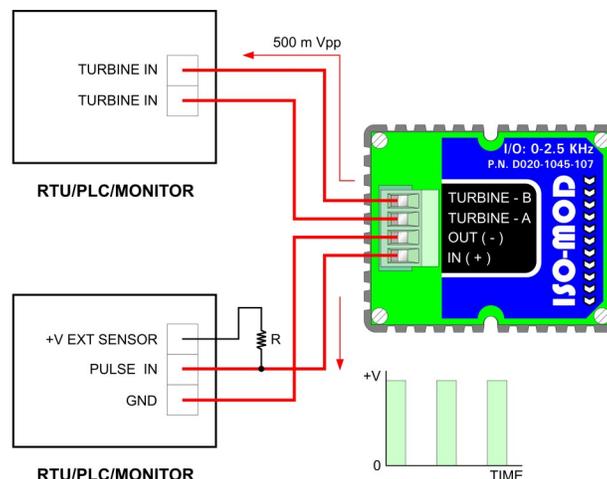
## PART 3 - TRANSMITTER INSTALLATION

### Rate Pulse Output Module

The Rate Pulse Output Module is utilized to transmit information to external counters and PID systems via a frequency output that is proportional to system flow rate. The frequency output range of the Rate Pulse Module is 0-2,500 Hz. This module has two types of outputs: one simulates the output of the coil of a turbine flow meter and the other is an open-collector type that does not source voltage at its output. Both outputs may be connected simultaneously.

The turbine meter output creates a 500 mV peak-to-peak saw-tooth waveform that is not referenced to ground. This output can be run to electronic monitors that are compatible with variable reluctance outputs from coils, such as those found in turbine and paddle-wheel flow meters. The input impedance of the receiving device should not be smaller than 2,000 Ohms.

The standard pulse output does not output a voltage, but acts as an “open-collector” output requiring an external power source and pull-up resistor. See **Figure 3.9**. The MOSFET in the Rate Pulse Module can support loads of 100 V @ 1 A. Resistor selection is based on the input impedance of the receiving device. Select a resistor that is a maximum of 10% of the input impedance of the receiving device, but does not exceed 10k Ohms.



**Figure 3.9**  
**Rate Pulse Module**

# PART 4 - INSTRUMENT PROGRAMMING

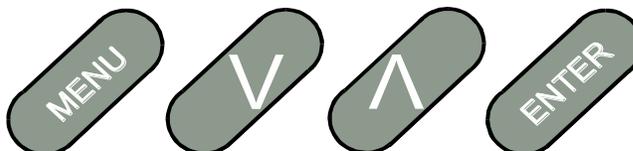
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## General

The FD-400 is configured through the keypad interface. All entries are saved in non-volatile FLASH memory and will be retained indefinitely in the event of power loss.

## Keypad Operation

The FD-400 contains a four-key tactile feedback keypad interface that allows the user to view and change configuration parameters used by the FD-400 operating system.



**Figure 4.1**  
**Keypad Layout**

The FD-400 allows two basic sets of programming procedures: list item selection and numeric value entry.

**NOTE:** While in RUN mode, pressing both the UP and DOWN arrow keys will display the current firmware version installed in the meter.

### List Item Selection Procedure

**NOTE:** If you are already in PROGRAM mode and the selection to be viewed or changed is already displayed, proceed to step 3 below. If you are in PROGRAM mode and the selection to be viewed or changed is not displayed, press the UP or DOWN arrow keys and repeat pressing until the desired selection appears. Proceed to step 3.

1. Press MENU. PROGRAM appears in the lower left-hand corner and ID UNITS appears on the lower line of the display.
2. Press the DOWN arrow key to move to the desired selection.
3. Press ENTER to view the current selection.
4. If the current selection is desired, press ENTER to confirm. The unit will automatically advance to the next selection.
5. If the current selection must change, press the UP arrow key and repeat pressing to scroll through the available choices. Press ENTER to confirm your selection. The unit will automatically advance to the next selection.

## PART 4 - INSTRUMENT PROGRAMMING

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6. To exit programming mode, press the MENU key. Depending on your position in the programming mode, up to three MENU key presses may be required to exit. The display will change to RUN mode.

**NOTE:** The FD-400 firmware revision can be displayed by pressing both arrow keys simultaneously.

### Numeric Value Entry Procedure

**NOTE:** If you are already in PROGRAM mode and the selection to be viewed or changed is already displayed, proceed to step 3 below. If you are in PROGRAM mode and the selection to be viewed or changed is not displayed, press the UP or DOWN arrow keys and repeat pressing until the desired selection appears. Proceed to step 3.

1. Press MENU. PROGRAM appears in the lower left-hand corner and ID UNITS appears on the lower line of the display.
2. Press the DOWN arrow key until the desired selection displays. The current numeric value for this selection appears on the upper line of the display.
3. If the current value is desired, press ENTER. The left most programmable number begins to flash. Press ENTER again to confirm and keep the current numeric value. The unit will automatically advance to the next menu selection.
4. If the current selection must be changed, press ENTER. The left most programmable number begins to flash. Use the UP arrow key to scroll through the digits 0-9 and change the flashing digit to the desired value. Use the DOWN arrow key to move the active digit to the right. Continue using the UP and DOWN arrow keys until all digits are selected.
5. Press ENTER to confirm your selection. The unit will automatically advance to the next selection.
6. To exit programming mode, press the MENU key. Depending on your position in the programming mode, up to three MENU key presses may be required to exit. The display will change to RUN mode.

# PART 4 - INSTRUMENT PROGRAMMING

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## Menu Structure

The FD-400 software is structured using menus. A menu map of the user interface is included in the **Appendix** of this manual. The map provides a visual path to the configuration parameters that users can access. This tool should be employed each time configuration parameters are accessed or revised.

## Totalizer Reset

Press both the ENTER and the MENU keys when in the RUN mode to reset the totalizer. The message TOTAL RST will be displayed for a few seconds to indicate that the totalizer had been cleared. If a password has been set, the user must enter the correct password for the totalizer to be cleared.

The following sections define the configuration parameters accessible in the program mode.

## Measurement UNITS Selection

### ID UNITS

*INCH*  
*MM*

Selects unit of measure for pipe ID entry. The choices are either inches (English) or millimeters (Metric) units.

## Pipe Inside Diameter

### PIPE ID – Pipe Inside Diameter Entry

*ENGLISH (Inches)*  
*METRIC (Millimeters)*

Enter the pipe inside diameter in inches if INCH was selected as ID UNITS; in millimeters if MM was selected.

## Flow Display Mode

### DISPLAY – Display Mode Selection

*RATE*  
*TOTAL*  
*BOTH*  
*DIAG*

# PART 4 - INSTRUMENT PROGRAMMING

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To display only the Flow Rate, select RATE. To display only the Flow Total, select TOTAL. To alternately display the Flow Rate and the Total, select BOTH. By selecting BOTH, the display will switch between RATE and TOTAL every 7 seconds.

The DIAG selection places the display in the diagnostics mode. When selected, the display will show the measured frequency, the gain setting and the signal strength.

## Engineering Units RATE

### RATE UNT – Engineering Units for Flow Rate

*VEL FEET* - Velocity in Linear Feet  
*VEL MTRS* - Velocity in Linear Meters  
*GALLONS* - U.S. Gallons  
*LITERS* - Metric Liters  
*MGAL* - Millions of U.S. Gallons  
*CUBIC FT* - Cubic Feet  
*M CU FT* - Millions of Cubic Feet  
*CUBIC ME* - Cubic Meters  
*MEGLTRS* - Millions of Metric Liters  
*ACRE FT* - Acre Feet  
*OIL BARR* - Oil Barrels (42 U.S. Gallons)  
*LIQ BARR* - Liquid Barrels (31.5 U.S. Gallons)  
*LBS* - Pounds  
*KGS* - Kilograms

Select a desired engineering unit for flow rate measurements.

When Pounds (LBS) or Kilograms (KGS) is selected, the specific gravity for the fluid type must be entered for the SP GRAV setup parameter.

## Engineering Units RATE INTERVAL

### RATE INT – Time Interval for Flow Rate

*MIN* - Minutes  
*HOURL* - Hours  
*DAY* - Days  
*SEC* - Seconds

Select a desired engineering unit for flow rate measurements.

# PART 4 - INSTRUMENT PROGRAMMING

## Engineering Units TOTALIZER

### TOTL UNT – Engineering Units for Flow Totalizer

*GALLONS* - U.S. Gallons  
*LITERS* - Metric Liters  
*MGAL* - Millions of U.S. Gallons  
*CUBIC FT* - Cubic Feet  
*M CU FT* - Millions of Cubic Feet  
*CUBIC ME* - Cubic Meters  
*MEGLTRS* - Millions of Metric Liters  
*ACRE FT* - Acre Feet  
*OIL BARR* - Oil Barrels (42 U.S. Gallons)  
*LIQ BARR* - Liquid Barrels (31.5 U.S. Gallons)  
*LBS* - Pounds  
*KGS* - Kilograms

Select a desired engineering unit for flow accumulator (totalizer) measurements.

## Engineering Units TOTAL Exponent

### TOTL MUL – Flow Totalizer Multiplier

*0.01 to 1,000,000*

Utilized for setting the flow totalizer exponent. This feature is useful for accommodating a very large accumulated flow. The exponent is a  $\times 10^n$  multiplier, where “n” can be from  $-2$  ( $\times 0.01$ ) to  $+6$  ( $\times 1,000,000$ ). **Table 4.1** should be referenced for valid entries and their influence on the FD-400 display.

Exponent	Display Multiplier
<b>× PT 01</b>	× 0.01
<b>× PT 1</b>	× 0.1
<b>×1</b>	× 1
<b>×10</b>	× 10
<b>×100</b>	× 100
<b>×1000</b>	× 1,000
<b>×10000</b>	× 10,000
<b>×100000</b>	× 100,000
<b>×1000000</b>	× 1,000,000

**Table 4.1 — Totalizer Exponent Values**

# PART 4 - INSTRUMENT PROGRAMMING

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## Fluid Specific Gravity

### SP GRAV – Fluid Specific Gravity Entry

*unitless*

Allows adjustments to be made to the specific gravity (density) of the liquid.

If Pounds (LBS) or Kilograms (KGS) is selected for either the RATE UNT or the TOTL UNT, a specific gravity must be entered for the correct mass flow to be calculated. A list of fluids and their associated specific gravities is located in the **Appendix** of this manual.

## Low Flow Cut-off

### FL C-OFF – Low Flow Cut-off

A **Low Flow Cut-off** entry is provided to allow very low flow rates (that can be present when pumps are off and valves are closed) to be displayed as Zero flow. The value entered is in **actual rate units**.

## Scale Factor

### SCALE F – Scale Factor

This function can be used to make the FD-400 system agree with a different or reference flow meter, or to compensate for an installation where there is inadequate straight pipe to obtain a laminar flow profile, by applying a correction factor/multiplier to the readings and outputs. A factory calibrated system should be set to 1.000. The range of settings for this entry is 0.500 to 5.000. The following example describes using the SCALE F entry.

- The FD-400 meter is indicating a flow rate that is 4% higher than another flow meter located in the same pipe line. To make the FD-400 indicate the same flow rate as the other meter, enter a COR FTR of 0.960, to lower the readings by 4%.

# PART 4 - INSTRUMENT PROGRAMMING

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## System Damping

### DAMPING – System Damping

*Relative Percent Entry: 0-99%*

**Flow Filter Damping** establishes a maximum adaptive filter value. Under stable flow conditions (flow varies less than 10% of reading), this adaptive filter will increase the number of successive flow readings that are averaged together up to this maximum value. If flow changes outside of the **10%** window, the Flow Filter adapts by decreasing and allows the meter to react faster. Increasing this value tends to provide smoother steady-state flow readings and outputs.

## Configure I/O Module 1

### CFG MOD1 – Configure I/O Module 1

This prompt allows access to the setup parameters associated with installation of the optional **ISO-MOD** interface modules. If NO is selected, the unit will skip ahead to CFG MOD2. If YES is selected, configuration and calibration of the module installed in the first position is accessible.

## Module Type

### MOD TYPE – Module Type

*NONE* - No Module Installed  
*4-20MA* - 4-20mA Analog Output  
*RATE* - Rate Pulse Output  
*RELAY* - Relay Output

Select the type of module installed from the list.

## 4-20 mA Programming

### **ISO-MOD** 4-20 mA

*FLOW 4MA*  
*FLOW 20MA*  
*CAL 4MA*  
*CAL 20MA*  
*4-20 TEST*

## PART 4 - INSTRUMENT PROGRAMMING

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Configured via jumper selections for either a passive (current sinking) or active (current sourcing) transmission mode (see **Part 3** for details), the 4-20 mA Output Module interfaces with virtually all recording and logging systems by transmitting an analog current signal that is proportional to system flow rate. Independent 4 mA and 20 mA span settings are established in memory using the flow measuring range entries. These entries can be set anywhere in the measuring range of the instrument. Output resolution of the module is 12-bits (4096 discrete points) and the module can drive up to 800 Ohms of load with its internal 24V isolated power source.

### 4-20 mA Span

The FLOW 4MA and FLOW 20MA entries are used to set the span of the 4-20 mA analog output. These entries are volumetric rate units that are equal to the volumetric units configured as Engineering Rate Units and Engineering Units Rate Interval.

For example, to span the 4-20 mA output from 0 GPM to +100 GPM, with 12 mA being 50 GPM, set the FLOW 4MA and FLOW 20MA values as follows:

FLOW 4MA = 0.0  
FLOW 20MA = 100.0

### 4-20mA Calibration

The 4-20 mA **ISO-MOD** is factory calibrated and should not require adjustment unless it is replaced.

**NOTE:** The CAL 4MA and CAL 20MA entries should not be used in an attempt to set the 4-20 mA range. Utilize FLOW 4MA and FLOW 20MA, detailed above, for this purpose.

### CAL 4MA

The 4-20CAL? entry allows fine adjustments to be made to the “zero” and span of the 4-20 mA output. Select YES to access adjustment. To adjust the 4 mA output, a milliammeter or reliable reference must be connected to the 4-20 mA output.

Procedure:

1. Disconnect one side of the current loop and connect the milliammeter in series (disconnect either wire at the terminals labeled +/- on the **ISO-MOD** 4-20 mA module).

# PART 4 - INSTRUMENT PROGRAMMING

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2. Using the arrow keys, increase the numerical value to increase the current in the loop to 4 mA. Decrease the value to decrease the current in the loop to 4 mA. Typical values range between 40-80 counts.
3. Re-connect the 4-20 mA output circuitry as required.

## **CAL 20MA**

Calibration of the 20 mA setting is conducted much the same way as the 4 mA adjustments.

Procedure:

1. Disconnect one side of the current loop and connect the milliammeter in series (disconnect either wire at the terminals labeled +/- on the **ISO-MOD** 4-20 mA module).
2. Using the arrow keys, increase the numerical value to increase the current in the loop to 20 mA. Decrease the value to decrease the current in the loop to 20 mA. Typical values range between 3700-3900 counts.
3. Re-connect the 4-20mA output circuitry as required.

## **4-20mA Test**

### **4-20TEST – 4-20mA Output Test**

Allows a simulated value to be output from the 4-20 mA output. By incrementing this value, the 4-20 mA output will transmit the indicated current value.

## **Rate Pulse Programming**

### **ISO-MOD RATE PULSE**

*FLOW OHZ  
FL MAXHZ  
RATE TST*

The Rate Pulse Output Module is utilized to transmit information to external counters and PID systems via a frequency output that is proportional to system flow rate. Independent Zero and Span settings are established in memory using the flow measuring range entries. Output resolution of the module is 12-bits (4096 discrete points) and the maximum output frequency setting is 2,500 Hz. The module has two output modes, turbine meter simulation and “open

# PART 4 - INSTRUMENT PROGRAMMING

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collector". The turbine meter simulation sources a non-ground referenced saw-tooth waveform with a maximum peak amplitude of approximately 500 mV p-p. The open-collector output utilizes a 0.21 Ohm MOSFET output that is rated to operate at 100 V and 1 A maximum. If the open-collector output type is utilized, an external voltage source and limit resistor must be present. See **Part 1** of this manual for connection information.

## Rate Pulse Span

The FLOW 0HZ and FL MAXHZ entries are used to set the span of the 0-2.5 kHz frequency output. These entries are volumetric rate units that are equal to the volumetric units configured as Engineering Rate Units and Engineering Units Rate Interval.

For example, to span the 0-2.5 kHz output from 0 GPM to +100 GPM, with 1.25 kHz being 50 GPM, set the FLOW 0HZ and FL MAXHZ values as follows:

FLOW 0HZ = 0  
FL MAXHZ = 100.0

## Rate Pulse Test

### RATE TST – Rate Pulse Output Test

Allows a simulated value to be output from the rate pulse output. By incrementing this value, the rate pulse output will transmit the indicated frequency in terms of percentage of the maximum output frequency.

For example, if the maximum output frequency is 2500 Hz, increment the displayed value to 50 to output a test frequency of 1250 Hz.

## Dual Relay Configuration

### ISO-MOD Dual Relay

RELAY 1 AND RELAY 2

NONE  
TOTAL  
FLOW  
    OFF  
    ON  
ERRORS

## PART 4 - INSTRUMENT PROGRAMMING

Two independent SPDT (single-pole, double-throw, Form C) relays are contained in this module. The relay operations are user configured via the keypad to act in either a total pulse output, flow rate alarm or error alarm mode. The relays are rated for 200 VAC maximum and a have current rating of 0.5A resistive load (175 VDC @ 0.25A resistive). It is highly recommended that a secondary relay be utilized whenever the Control Relay **ISO-MOD** is used to control inductive loads such as solenoids and motors.

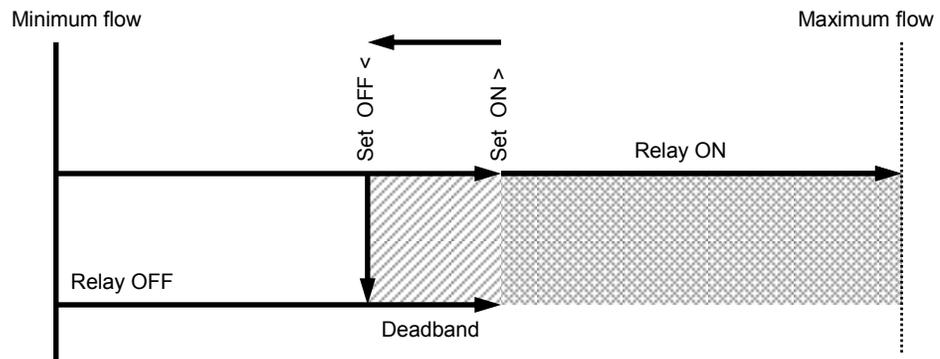
### Totalizer Relay

**TOTAL** mode configures the relay to output a 50 mSec pulse (contact changeover) each time the display totalizer increments.

### Flow Rate Relay

**Flow Rate Relay** configuration permits relay changeover at two separate flow rates allowing operation with an adjustable switch deadband. **Figure 4.2** illustrates how the setting of the two set points influences Rate Alarm operation.

A single-point flow rate alarm would place the ON> setting slightly higher than the OFF< setting – allowing a switch deadband to be established. If a deadband is not established, switch chatter (rapid switching) may result if the flow rate is very close to the switch point.



**Figure 4.2**  
**Single Point Alarm Operation**

### Error Alarm Relay

When a relay is set to **ERROR** mode, the relay will activate when any error occurs in the flow meter that has caused the meter to stop measuring reliably. See the **Appendix** of this manual for a list of potential error codes.

# PART 4 - INSTRUMENT PROGRAMMING

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## Configure I/O Module 2

### CFG MOD2 – Configure I/O Module 2

The I/O configurations for CFG MOD2 are identical to those detailed in CFG MOD1.

## Change Password

### PASSWORD – Change the Security Password

0-9999

By changing the Security Password from 0000 to some other value (any value between 0001-9999), configuration parameters will not be accessible without first entering that value when prompted. If the value is left at 0000, no security is invoked and unauthorized changes could be made. Access to resetting of the Totalizer is also protected by this password.

## Advanced Setup

### AD SETUP – Advance Setup Mode

Advance setup mode allows access to the following parameters. Select YES to access these parameters.

*AGC MODE* - Automatic Gain Control  
*GAIN POT* - Digital Gain Control  
*FILTER* - Hardware Filter Control  
*LINEAR* - 10 Point Linearization

## AGC Mode

### AGC MODE – Automatic Gain Control Mode of Operation

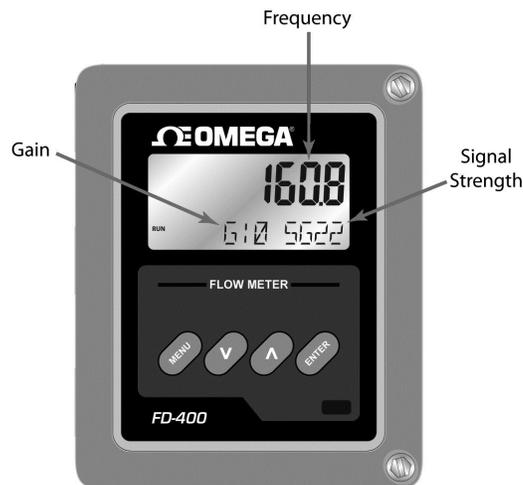
*NORMAL* - Standard Configuration  
*HIGH* - Used for low signal strength  
*MANUAL* - AGC disabled  
*GAIN POT* - Digital Gain Control  
*FILTER* - Hardware Filter Control

Select the desired mode of operation. A basic understanding of the AGC logic is required in order to know when to use any selection other than NORMAL.

## PART 4 - INSTRUMENT PROGRAMMING

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When the unit is powered up, there is a delay before the unit begins transmitting sound into the pipe. During this time, the signal strength is measured and a base signal level is obtained. Typically this is a value of about 20. The unit measures flow by measuring the Doppler frequency shift. The frequency shift is approximately 70Hz per foot per second. For every foot per second increase in velocity, the signal strength should increase by 1. The unit automatically adjusts the gain and selects the proper hardware filter for the measured velocity. The control can be observed when the DISPLAY mode is set to DIAG. See **Figure 4.3**.



**Figure 4.3**  
**Diagnostic Display**

### Manual Operations

When NORMAL is selected, the unit will automatically control the gain and front end hardware filter for optimum measurement of the Doppler signal.

Select HIGH for applications where the unit reads flow rates consistently, but much lower than the actual flow rate. This may be required when sound is not getting through the pipe as well. Selecting HIGH will cause the unit to look for the signal strength to increase by 2 for every foot per second increase in flow rate. Basically, the gain is doubled, but still automatically controlled.

For applications where the flow is constant, but you may need to tune the unit to filter out extraneous noise, select the MANUAL mode. Typically, this would only be required at very low flow rates. When MANUAL mode is selected, the GAIN POT and FILTER settings are manually set. Automatic control is disabled.

# PART 4 - INSTRUMENT PROGRAMMING

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## Gain Control

### GAIN POT – Digital Gain Pot

0-64

Using the arrow keys, increase or decrease the numerical value to set the signal gain level. Typically, optimum flow measurement is made when this value is between 10 and 50. Use the lowest value that provides an accurate and stable flow reading. This adjustment must be made in conjunction with the FILTER setting, and may be an iterative process.

## Hardware Filter

### FILTER – Hardware Filter Selection

*NONE* - No Filter

*LOW* - (1600Hz Cutoff)

*MEDIUM* - (350Hz Cutoff)

*HIGH* - (250Hz Cutoff)

Select the hardware filter with a cutoff frequency that is above the Doppler shift frequency to be measured. The Doppler shift frequency is found by multiplying the flow velocity (in FPS) by 80.

For example, if the flow velocity is 4 FPS then the cutoff frequency is  $4 \times 80$  or 320 Hz. The filter with the next highest frequency would be 350 Hz.

## Transducer Type

### XDCR TYPE – Transducer Type

*DT9* - Clamp-on Transducers

*PROBE* - Insertion Probe Transducer

Select the appropriate transducer type to be connected to the FD-400 transmitter. The selection invokes optimum hardware and software settings unique to the transducer architecture.

## PART 4 - INSTRUMENT PROGRAMMING

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### Linearization

#### LINEAR – Entry of Linearization Data

The Linearization feature allows for correction of flow readings caused by non-linear flow measurement. This typically occurs when there is insufficient straight piping before or after the location where the transducers are mounted.

Up to 10 linearization points may be entered. The microprocessor will perform a linear interpolation between data points entered in the linearization table and apply the associated correction factor to the measured flow rate.

Start by entering the number of linearization points to be entered at the NUM PTS prompt. If a value of 00 is entered, linearization is disabled.

The unit will then prompt for FREQ 1 to be entered. Enter the measured frequency corresponding to the flow rate for the first point. This can be obtained by running actual flow with the DISPLAY mode set to DIAG and reading the measured frequency, or by calculating the frequency if the flow rate in feet per second is known using the following formulas:

**FD-400C** Clamp-On Transducer:

$$\text{Freq} = \text{Velocity (FPS)} \times 80 \text{ Hz}$$

**FD-400I** Insertion Probe Transducer:

$$\text{Freq} = \text{Velocity (FPS)} \times 80 \text{ Hz}$$

The unit will then prompt for COEFF 1 to be entered. This is the value that the measured flow rate will be multiplied by at this point. Enter the coefficient or correction factor to be applied. The value entered must be between 0.5 and 1.5.

Repeat this procedure for all of the linearization points. When all of the points have been entered, the unit will return to the NUM PTS prompt. Press the Menu key to return to the main menu LINEAR prompt. Then using the arrow keys, move to the next setup parameter.

# PART 5 - STARTUP AND TROUBLESHOOTING

---

## FD-400 Startup Requirements

**NOTE:** The FD-400 flow meter system requires a full pipe of flowing liquid before a successful startup evaluation can be completed. Do not attempt to make adjustments or make Manual configuration changes until a full pipe of flowing liquid is verified.

**NOTE:** If an RTV sealant was utilized to couple the transducers to the pipe, the sealant must fully cure before power is applied to the instrument. Most RTVs require 24 hours to cure satisfactorily. It is very important that the transducers are not moved during the curing process – air bubbles can form between the transducer and the pipe wall and influence performance. If silicone grease was utilized as a couplant, the curing time is not required.

### Procedure:

1. Verify that the FD-400C or FD-400I transducer has been properly installed and wired – See **Part 2**.
2. Verify that the FD-400 power supply jumper settings are properly configured for the power supply that will be utilized – See **Part 3**.
3. Verify that the FD-400 is properly programmed – See **Part 4**.
4. Apply power.
5. On initial power-up, the FD-400 microprocessor conducts a series of self-diagnostic tests, base-line measurements and begins to buffer liquid velocity data. During this start-up, approximately 30 seconds, flow rate readings and outputs will be inhibited.
6. After the start-up routine has completed running, the meter will begin to display flow rate and/or total as configured.
7. If an ERROR appears on the FD-400 lower display, please refer to the following Troubleshooting pages for resolution.

# PART 5 - STARTUP AND TROUBLESHOOTING

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## Troubleshooting

Symptom	Resolution
Display does not light up	<ol style="list-style-type: none"><li>1. Insufficient power to FD-400 monitor – measure voltage at J2</li><li>2. Power supply not properly wired to J2 – See <b>Part 3</b></li><li>3. Fuse F1 is open or not installed</li><li>4. Power supply jumpers are not installed properly – See <b>Part 3</b></li><li>5. Ribbon cable between the door and enclosure back is not fully engaged into the two sockets</li></ol>
ERROR on the FD-400 Display	<ol style="list-style-type: none"><li>1. Transducers not properly coupled to the pipe – couplant not present or pipe not properly prepared</li><li>2. Transducer not properly wired to the J4 Terminal block inside the FD-400 – review the Wiring Diagram on the inside door of the FD-400</li><li>3. More than one FD-400 installed on the piping system – See <b>Part 3: Multiple Unit Installation</b></li><li>4. Insufficient particles over 35 microns – inject air upstream of the transducers</li><li>5. Too many particles that are smaller than 35 micron – ultrasonic meters likely will not operate</li><li>6. Transducer failure – unplug transducer cable from J4, measure capacitance between red/black Receive and Transmit. Verify that the capacitance on each set is approximately 2 nF (nano Farads) – and within 0.02 nF of each other</li></ol>
Unstable Flow Reading	<ol style="list-style-type: none"><li>1. Relocate transducer to a pipe position with less hydraulic disturbance</li><li>2. Increase Damping value</li></ol>
Inaccurate Flow Reading	<ol style="list-style-type: none"><li>1. Verify that pipe ID is entered correctly</li><li>2. Verify that an erroneous Scale Factor has not been entered</li><li>3. Verify that erroneous Linearization values have not been entered</li><li>4. Verify that AGC is set to Normal</li><li>5. Verify that the transducers are mounted square and 180 degrees apart on the pipe</li><li>6. Relocate transducer to a pipe position with greater straight run length</li><li>7. DP7 Probe not aligned in the pipe</li></ol>

# PART 5 - STARTUP AND TROUBLESHOOTING

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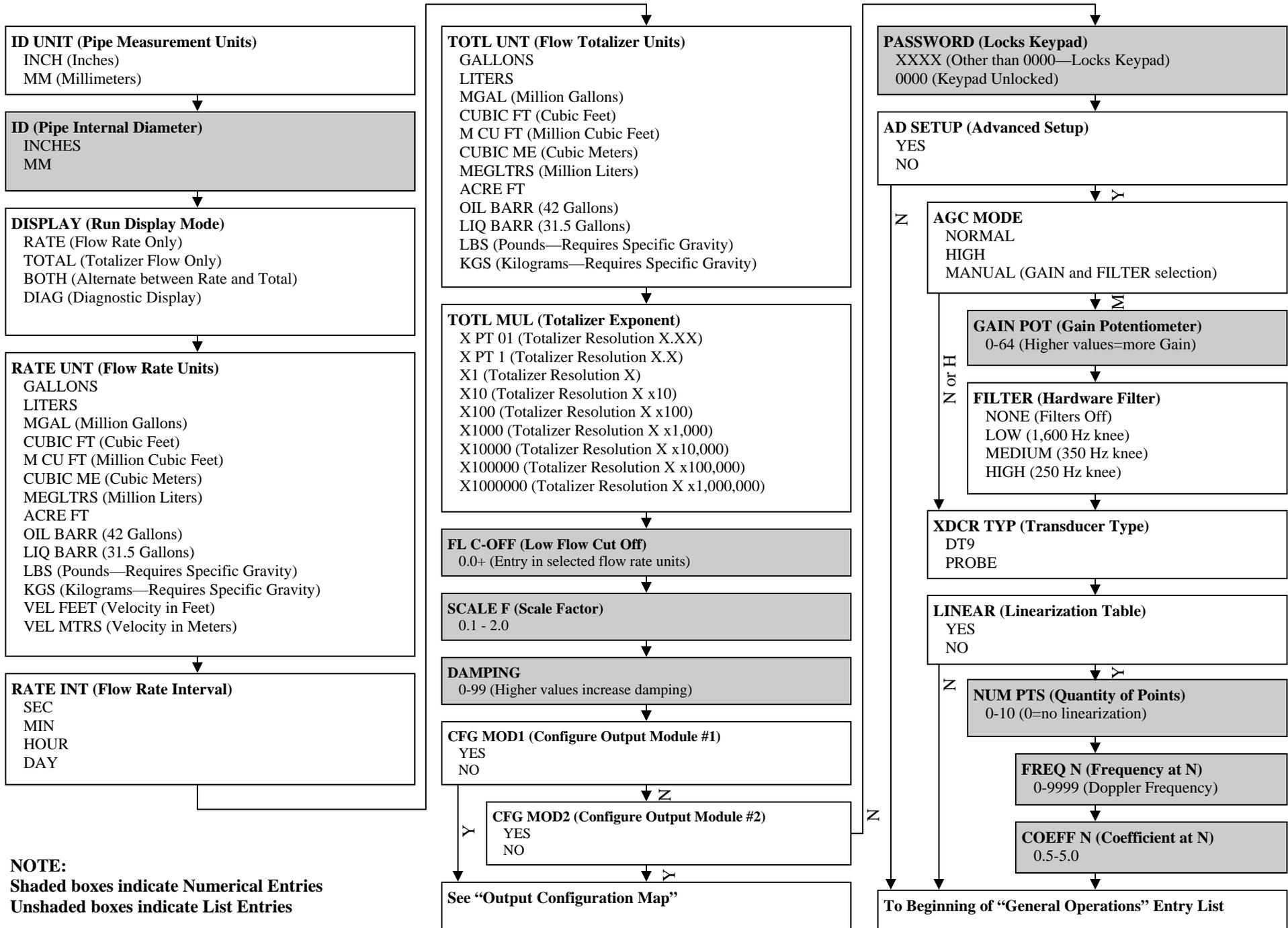
## Troubleshooting

Symptom	Resolution
Analog output does not match data collection system	<ol style="list-style-type: none"><li>1. Verify 4-20 mA calibration</li><li>2. Verify 4 mA and 20 mA flow settings</li><li>3. Verify that the loop load is within the supply voltage range</li><li>4. Run 4-20mA TEST feature – verify that mA outputs coincide with expected data collection system readings</li></ol>
Rate Pulse output does not match data collection system	<ol style="list-style-type: none"><li>1. Verify 0 Hz and MAX Hz flow settings</li><li>2. Place oscilloscope or frequency counter on the Rate Pulse module outputs and verify frequency output</li><li>3. Run output TEST feature – verify that the Hz output coincides with expected data collection system readings</li><li>4. Verify that “K-factor” has been calculated correctly: K-factor = Hz/(flow/second) <b>Example:</b> Max Hz (2,500 Hz) = 10,000 Gallons/Minute K-factor = 2,500 Hz / 166.7 Gallons/Second K-factor = 15 pulses/gallon</li><li>5. Verify that the data collection system is accepting the pulses from the FD-400 – connect to Turbine out or OUT/IN as required</li></ol>
FD-400 does not capture short flow pulses	When run in AUTO mode, the FD-400 utilizes a series of filters that optimize readings for a particular flow range. The flow meter will take several seconds to adjust to a step change in flow. To make the flow meter respond quickly to changes in flow, decrease DAMPING, place the meter into MANUAL AGC and lock the FILTER at NONE.

# **A P P E N D I X**

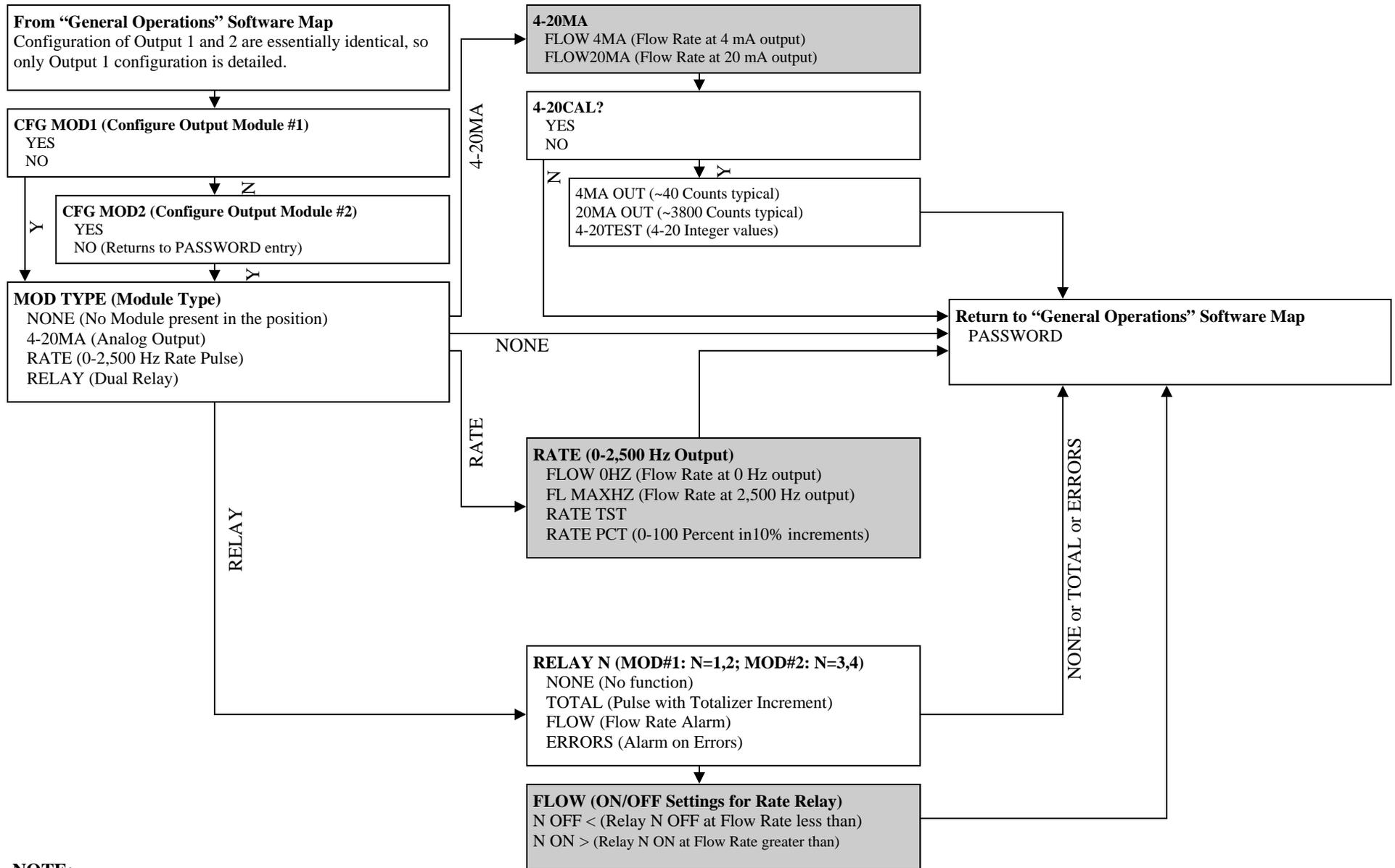
# SERIES HF/622 SOFTWARE MAP - General Operations

VER 1.04-1.05



# SERIES HF/622 SOFTWARE - Output Configuration Map

VER 1.04-1.05



**NOTE:**  
 Shaded boxes indicate Numerical Entries  
 Unshaded boxes indicate List Entries

## Fluid Properties

Original Date: 7/30/1999  
 Revision: A  
 Revision Date: 9/10/2003  
 Å

Fluid	Specific Gravity 20 degrees C	Sound Speed m/s	ft/s	delta-v/degree C m/s/degree C	Kinematic Viscosity Centistokes	Absolute Viscosity Centipoise
Acetate, Butyl		1270	4163.9			
Acetate, Ethyl	0.901	1085	3559.7	4.4	0.489	0.441
Acetate, Methyl	0.934	1211	3973.1		0.407	0.380
Acetate, Propyl		1280	4196.7			
Acetone	0.79	1174	3851.7	4.5	0.399	0.316
Alcohol	0.79	1207	3960.0	4.0	1.396	1.101
Alcohol, Butyl	0.83	1270	4163.9	3.3	3.239	2.688
Alcohol, Ethyl	0.83	1180	3868.9	4	1.396	1.159
Alcohol, Methyl	0.791	1120	3672.1	2.92	0.695	0.550
Alcohol, Propyl		1170	3836.1			
Alcohol, Propyl	0.78	1222	4009.2		2.549	1.988
Ammonia	0.77	1729	5672.6	6.7	0.292	0.225
Aniline	1.02	1639	5377.3	4.0	3.630	3.710
Benzene	0.88	1306	4284.8	4.7	0.711	0.625
Benzol, Ethyl	0.867	1338	4389.8		0.797	0.691
Bromine	2.93	889	2916.7	3.0	0.323	0.946
n-Butane	0.60	1085	3559.7	5.8		
Butyrate, Ethyl		1170	3836.1			
Carbon dioxide	1.10	839	2752.6	7.7	0.137	0.151
Carbon tetrachloride	1.60	926	3038.1	2.5	0.607	0.968
Chloro-benezene	1.11	1273	4176.5	3.6	0.722	0.799
Chloroform	1.49	979	3211.9	3.4	0.550	0.819
Diethyl ether	0.71	985	3231.6	4.9	0.311	0.222
Diethyl Ketone		1310	4295.1			
Diethylene glycol	1.12	1586	5203.4	2.4		
Ethanol	0.79	1207	3960.0	4.0	1.390	1.097
Ethyl alcohol	0.79	1207	3960.0	4.0	1.396	1.101
Ether	0.71	985	3231.6	4.9	0.311	0.222
Ethyl ether	0.71	985	3231.6	4.9	0.311	0.222
Ethylene glycol	1.11	1658	5439.6	2.1	17.208	19.153
Freon R12		774.2	2540			
Gasoline	0.7	1250	4098.4			
Glycerin	1.26	1904	6246.7	2.2	757.100	953.946
Glycol	1.11	1658	5439.6	2.1		
Isobutanol	0.81	1212	3976.4			
Iso-Butane		1219.8	4002			
Isopentane	0.62	980	3215.2	4.8	0.340	0.211
Isopropanol	0.79	1170	3838.6		2.718	2.134
Isopropyl alcohol	0.79	1170	3838.6		2.718	2.134
Kerosene	0.81	1324	4343.8	3.6		
Linalool		1400	4590.2			
Linseed Oil	.925-.939	1770	5803.3			
Methanol	0.79	1076	3530.2	2.92	0.695	0.550
Methyl alcohol	0.79	1076	3530.2	2.92	0.695	0.550
Methylene chloride	1.33	1070	3510.5	3.94	0.310	0.411
Methylethyl Ketone		1210	3967.2			
Motor Oil (SAE 20/30)	.88-.935	1487	4875.4			
Octane	0.70	1172	3845.1	4.14	0.730	0.513

Oil, Castor	0.97	1477	4845.8	3.6	0.670	0.649
Oil, Diesel	0.80	1250	4101			
Oil (Lubricating X200)		1530	5019.9			
Oil (Olive)	0.91	1431	4694.9	2.75	100.000	91.200
Oil (Peanut)	0.94	1458	4783.5			
Paraffin Oil		1420	4655.7			
Pentane	0.626	1020	3346.5		0.363	0.227
Petroleum	0.876	1290	4229.5			
1-Propanol	0.78	1222	4009.2			
Refrigerant 11	1.49	828.3	2717.5	3.56		
Refrigerant 12	1.52	774.1	2539.7	4.24		
Refrigerant 14	1.75	875.24	2871.5	6.61		
Refrigerant 21	1.43	891	2923.2	3.97		
Refrigerant 22	1.49	893.9	2932.7	4.79		
Refrigerant 113	1.56	783.7	2571.2	3.44		
Refrigerant 114	1.46	665.3	2182.7	3.73		
Refrigerant 115		656.4	2153.5	4.42		
Refrigerant C318	1.62	574	1883.2	3.88		
Silicone (30 cp)	0.99	990	3248		30.000	29.790
Toluene	0.87	1328	4357	4.27	0.644	0.558
Transformer Oil		1390	4557.4			
Trichlorethylene		1050	3442.6			
1,1,1-Trichloro-ethane	1.33	985	3231.6		0.902	1.200
Turpentine	0.88	1255	4117.5		1.400	1.232
Water, distilled	0.996	1498	4914.7	-2.4	1.000	0.996
Water, heavy	1	1400	4593			
Water, sea	1.025	1531	5023	-2.4	1.000	1.025
Wood Alcohol	0.791	1076	3530.2	2.92	0.695	0.550
m-Xylene	0.868	1343	4406.2		0.749	0.650
o-Xylene	0.897	1331.5	4368.4	4.1	0.903	0.810
p-Xylene		1334	4376.8		0.662	

## Steel, Stainless Steel, P.V.C.

### Standard Schedules

Nominal Pipe Size Inches	OUTSIDE DIAMETER	SCH. 5		SCH. 10 (LTWALL)		SCH. 20		SCH. 30		STD.		SCH. 40		SCH. 60		X STG.		SCH. 80		SCH. 100		SCH. 120		SCH. 140		SCH. 180			
		ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall	ID	Wall		
1	1.315	1.185	0.065	1.097	0.109					1.049		1.049	0.133			0.957	0.179	0.957	0.179									0.815	0.250
1.25	1.660	1.530	0.065	1.442	0.109					1.380		1.380	0.140			1.278	0.191	1.278	0.191									1.160	0.250
1.5	1.900	1.770	0.065	1.682	0.109					1.610		1.610	0.145			1.500	0.200	1.500	0.200									1.338	0.281
2	2.375	2.245	0.065	2.157	0.109					2.067		2.067	0.154			1.939	0.218	1.939	0.218									1.687	0.344
2.5	2.875	2.709	0.083	2.635	0.120					2.469		2.469	0.203			2.323	0.276	2.323	0.276									2.125	0.375
3	3.500	3.334	0.083	3.260	0.120					3.068		3.068	0.216			2.900	0.300	2.900	0.300									2.624	0.438
3.5	4.000	3.834	0.083	3.760	0.120					3.548		3.548	0.226			3.364	0.318	3.364	0.318										
4	4.500	4.334	0.083	4.260	0.120					4.026	0.237	4.026	0.237			3.826	0.337	3.826	0.337				3.624	0.438	3.624	0.438	3.438	0.531	
5	5.563	5.345	0.109	5.295	0.134					5.047	0.258	5.047	0.258			4.813	0.375	4.813	0.375				4.563	0.500	4.563	0.500	4.313	0.625	
6	6.625	6.407	0.109	6.357	0.134					6.065	0.280	6.065	0.280			5.761	0.432	5.761	0.432				5.501	0.562	5.501	0.562	5.187	0.719	
8	8.625	8.407	0.109	8.329	0.148	8.125	0.250	8.071	0.277	7.981	0.322	7.981	0.322	7.813	0.406	7.625	0.500	7.625	0.500	7.437	0.594	7.187	0.719	7.187	0.719	6.183	1.221		
10	10.750	10.482	0.134	10.42	0.165	10.25	0.250	10.13	0.310	10.02	0.365	10.020	0.365	9.750	0.500	9.750	0.500	9.562	0.594	9.312	0.719	9.062	0.844	9.062	0.844	8.500	1.125		
12	12.750	12.420	0.165	12.39	0.180	12.25	0.250	12.09	0.330	12.00	0.375	11.938	0.406	11.626	0.562	11.750	0.500	11.370	0.690	11.060	0.845	10.750	1.000	10.750	1.000	10.120	1.315		
14	14.000			13.50	0.250	13.37	0.315	13.25	0.375	13.25	0.375	13.124	0.438	12.814	0.593	13.000	0.500	12.500	0.750	12.310	0.845	11.810	1.095	11.810	1.095	11.180	1.410		
16	16.000			15.50	0.250	15.37	0.315	15.25	0.375	15.25	0.375	15.000	0.500	14.688	0.656	15.000	0.500	14.310	0.845	13.930	1.035	13.560	1.220	13.560	1.220	12.810	1.595		
18	18.000			17.50	0.250	17.37	0.315	17.12	0.440	17.25	0.375	16.876	0.562	16.564	0.718	17.000	0.500	16.120	0.940	15.680	1.160	15.250	1.375	15.250	1.375	14.430	1.785		
20	20.000			19.50	0.250	19.25	0.375	19.25	0.375	19.25	0.375	18.814	0.593	18.376	0.812	19.000	0.500	17.930	1.035	17.430	1.285	17.000	1.500	17.000	1.500	16.060	1.970		
24	24.000			23.50	0.250	23.25	0.375	23.25	0.375	23.25	0.375	22.626	0.687	22.126	0.937	23.000	0.500	21.560	1.220	20.930	1.535	20.930	1.535	20.930	1.535	19.310	2.345		
30	30.000			29.37	0.315	29.00	0.500	29.00	0.500	29.25	0.375	29.250	0.375			29.000	0.500												
36	36.000			35.37	0.315	35.00	0.500	35.00	0.500	35.25	0.375	35.250	0.375			35.000	0.500												
42	42.000									41.25	0.375	41.250	0.375			41.000	0.500												
48	48.000									47.25	0.375	47.250	0.375			47.000	0.500												

# Cast Iron Pipe

## Standard Classes

	CLASS A			CLASS B			CLASS C			CLASS D			CLASS E			CLASS F			CLASS G			CLASS H			
Size (Inches)	O.D. Inch	I.D. Inch	Wall																						
3	3.80	3.02	0.39	3.96	3.12	0.42	3.96	3.06	0.45	3.96	3.00	0.48													
4	4.80	3.96	0.42	5.00	4.10	0.45	5.00	4.04	0.48	5.00	3.96	0.52													
6	6.90	6.02	0.44	7.10	6.14	0.48	7.10	6.08	0.51	7.10	6.00	0.55	7.22	6.06	0.58	7.22	6.00	0.61	7.38	6.08	0.65	7.38	6.00	0.69	
8	9.05	8.13	0.46	9.05	8.03	0.51	9.30	8.18	0.56	9.30	8.10	0.60	9.42	8.10	0.66	9.42	8.10	0.66	9.60	8.10	0.75	9.60	8.00	0.8	
10	11.10	10.10	0.50	11.10	9.96	0.57	11.40	10.16	0.62	11.40	10.04	0.68	11.60	10.12	0.74	11.60	10.00	0.80	11.84	10.12	0.86	11.84	10.00	0.92	
12	13.20	12.12	0.54	13.20	11.96	0.62	13.50	12.14	0.68	13.50	12.00	0.75	13.78	12.14	0.82	13.78	12.00	0.89	14.08	12.14	0.97	14.08	12.00	1.04	
14	15.30	14.16	0.57	15.30	13.98	0.66	15.65	14.17	0.74	15.65	14.01	0.82	15.98	14.18	0.90	15.98	14.00	0.99	16.32	14.18	1.07	16.32	14.00	1.16	
16	17.40	16.20	0.60	17.40	16.00	0.70	17.80	16.20	0.80	17.80	16.02	0.89	18.16	16.20	0.98	18.16	16.00	1.08	18.54	16.18	1.18	18.54	16.00	1.27	
18	19.50	18.22	0.64	19.50	18.00	0.75	19.92	18.18	0.87	19.92	18.00	0.96	20.34	18.20	1.07	20.34	18.00	1.17	20.78	18.22	1.28	20.78	18.00	1.39	
20	21.60	20.26	0.67	21.60	20.00	0.80	22.06	20.22	0.92	22.06	20.00	1.03	22.54	20.24	1.15	22.54	20.00	1.27	23.02	20.24	1.39	23.02	20.00	1.51	
24	25.80	24.28	0.76	25.80	24.02	0.89	26.32	24.22	1.05	26.32	24.00	1.16	26.90	24.28	1.31	26.90	24.00	1.45	27.76	24.26	1.75	27.76	24.00	1.88	
30	31.74	29.98	0.88	32.00	29.94	1.03	32.40	30.00	1.20	32.74	30.00	1.37	33.10	30.00	1.55	33.46	30.00	1.73							
36	37.96	35.98	0.99	38.30	36.00	1.15	38.70	35.98	1.36	39.16	36.00	1.58	39.60	36.00	1.80	40.04	36.00	2.02							
42	44.20	42.00	1.10	44.50	41.94	1.28	45.10	42.02	1.54	45.58	42.02	1.78													
48	50.50	47.98	1.26	50.80	47.96	1.42	51.40	47.98	1.71	51.98	48.00	1.99													
54	56.66	53.96	1.35	57.10	54.00	1.55	57.80	54.00	1.90	58.40	53.94	2.23													
60	62.80	60.02	1.39	63.40	60.06	1.67	64.20	60.20	2.00	64.82	60.06	2.38													
72	75.34	72.10	1.62	76.00	72.10	1.95	76.88	72.10	2.39																
84	87.54	84.10	1.72	88.54	84.10	2.22																			

## Ductile Iron Pipe

### Standard Classes

Pipe Size (inches)	Outside Diameter (inches)	Class 50		Class 51		Class 52		Class 53		Class 54		Class 55		Class 56		Cement Lining Std./Double Thickness
		ID	Wall													
3	3.96			3.46	0.25	3.40	0.28	3.34	0.31	3.28	0.34	3.22	0.37	3.14	0.41	.123/.250
4	4.80			4.28	0.26	4.22	0.29	4.16	0.32	4.10	0.35	4.04	0.38	3.93	0.44	
6	6.90	6.40	0.25	6.34	0.28	6.28	0.31	6.22	0.34	6.16	0.37	6.10	0.40	6.04	0.43	
8	9.05	8.51	0.27	8.45	0.30	8.39	0.33	8.33	0.36	8.27	0.39	8.21	0.42	8.15	0.45	
10	11.10	10.32	0.39	10.46	0.32	10.40	0.35	10.34	0.38	10.28	0.41	10.22	0.44	10.16	0.47	
12	13.20	12.58	0.31	12.52	0.34	12.46	0.37	12.40	0.40	12.34	0.43	12.28	0.46	12.22	0.49	
14	15.30	14.64	0.33	14.58	0.36	14.52	0.39	14.46	0.42	14.40	0.45	14.34	0.48	14.28	0.51	.1875/.375
16	17.40	16.72	0.34	16.66	0.37	16.60	0.40	16.54	0.43	16.48	0.46	16.42	0.49	16.36	0.52	
18	19.50	18.80	0.35	18.74	0.38	18.68	0.41	18.62	0.44	18.56	0.47	18.50	0.50	18.44	0.53	
20	21.60	20.88	0.36	20.82	0.39	20.76	0.42	20.70	0.45	20.64	0.48	20.58	0.51	20.52	0.54	
24	25.80	25.04	0.38	24.98	0.41	24.92	0.44	24.86	0.47	24.80	0.50	24.74	0.53	24.68	0.56	
30	32.00	31.22	0.39	31.14	0.43	31.06	0.47	30.98	0.51	30.90	0.55	30.82	0.59	30.74	0.63	.250/.500
36	38.30	37.44	0.43	37.34	0.48	37.06	0.62	37.14	0.58	37.40	0.45	36.94	0.68	36.84	0.73	
42	44.50	43.56	0.47	43.44	0.53	43.32	0.59	43.20	0.65	43.08	0.71	42.96	0.77	42.84	0.83	
48	50.80	49.78	0.51	49.64	0.58	49.50	0.65	49.36	0.72	49.22	0.79	49.08	0.86	48.94	0.93	
54	57.10	55.96	0.57	55.80	0.65	55.64	0.73	55.48	0.81	55.32	0.89	55.16	0.97	55.00	1.05	

## FPS TO GPM CROSS - REFERENCE (Schedule 40)

Nominal Pipe (Inches)	I.D. INCH	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9
1	1.05	2.6989	4.0484	5.3978	6.7473	8.097	9.4462	10.796	12.145	13.490	14.844	16.190	17.540	18.890	20.240	21.590	22.941	24.290
1.25	1.38	4.6620	6.9929	9.3239	11.655	13.99	16.317	18.648	20.979	23.310	25.641	27.970	30.300	32.630	34.960	37.300	39.627	41.958
1.5	1.61	6.3454	9.5182	12.691	15.864	19.04	22.209	25.382	28.555	31.730	34.900	38.070	41.250	44.420	47.590	50.760	53.936	57.109
2	2.07	10.489	15.734	20.979	26.224	31.47	36.713	41.958	47.202	52.450	57.692	62.940	68.180	73.430	78.670	83.920	89.160	94.405
2.5	2.47	14.935	22.402	29.870	37.337	44.80	52.272	59.740	67.207	74.670	82.142	89.610	97.080	104.50	112.00	119.50	126.95	134.41
3	3.07	23.072	34.608	46.144	57.680	69.22	80.752	92.288	103.82	115.40	126.90	138.40	150.00	161.50	173.00	184.60	196.11	207.65
3.5	3.55	30.851	46.276	61.702	77.127	92.55	107.98	123.40	138.83	154.30	169.68	185.10	200.50	216.00	231.40	246.80	262.23	277.66
4	4.03	39.758	59.636	79.515	99.394	119.3	139.15	159.03	178.91	198.80	218.67	238.50	258.40	278.30	298.20	318.10	337.94	357.82
5	5.05	62.430	93.645	124.86	156.07	187.3	218.50	249.72	280.93	312.10	343.36	374.60	405.80	437.00	468.20	499.40	530.65	561.87
6	6.06	89.899	134.85	179.80	224.75	269.7	314.65	359.60	404.55	449.50	494.45	539.40	584.30	629.30	674.20	719.20	764.14	809.09
8	7.98	155.89	233.83	311.78	389.72	467.7	545.61	623.56	701.50	779.40	857.39	935.30	1013.0	1091.0	1169.0	1247.0	1325.1	1403.0
10	10.02	245.78	368.67	491.56	614.45	737.3	860.23	983.12	1106.0	1229.0	1351.8	1475.0	1598.0	1720.0	1843.0	1966.0	2089.1	2212.0
12	11.94	348.99	523.49	697.99	872.49	1047.0	1221.5	1396.0	1570.5	1745.0	1919.5	2094.0	2268.0	2443.0	2617.0	2792.0	2966.5	3141.0
14	13.13	422.03	633.04	844.05	1055.1	1266.0	1477.1	1688.1	1899.1	2110.0	2321.1	2532.0	2743.0	2954.0	3165.0	3376.0	3587.2	3798.2
16	15.00	550.80	826.20	1101.6	1377.0	1652.0	1927.8	2203.2	2478.6	2754.0	3029.4	3305.0	3580.0	3856.0	4131.0	4406.0	4681.8	4957.2

FPS TO GPM:  $GPM = (PIPE\ ID)^2 \times VELOCITY\ IN\ FPS \times 2.45$

GPM TO FPS:  $FPS = \frac{GPM}{(ID)^2 \times 2.45}$

FPS X .3048 = MPS

GPM X .0007 = GPD

GPM X 3.7878 = LPM

## FPS TO GPM CROSS - REFERENCE (Schedule 40)

Nominal Pipe (Inches)	I.D. INCH	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9
18	16.88	697.52	1046.3	1395.0	1743.8	2093.0	2441.3	2790.1	3138.8	3488.0	3836.3	4185.0	4534.0	4883.0	5231.0	5580.0	5928.9	6277.7
20	18.81	866.14	1299.0	1732.0	2165.3	2598.4	3031.5	3464.6	3897.6	4330.7	4763.8	5196.8	5629.9	6063.0	6496.0	6929.1	7362.2	7795.3
24	22.63	1253.7	1880.0	2507.0	3134.1	3761.0	4387.8	5014.6	5641.5	6268.3	6895.1	7522.0	8148.8	8775.6	9402.4	10029	10656	11283
26	25.25	1560.7	2341.0	3121.0	3901.9	4682.2	5462.6	6243.0	7023.4	7803.7	8584.1	9364.5	10145	10925	11706	12486	13266	14047
28	27.25	1817.8	2727.0	3636.0	4544.5	5453.4	6362.3	7271.2	8180.0	9088.9	9997.8	10907	11816	12725	13633	14542	15451	16360
30	29.25	2094.4	3142.0	4189.0	5236.0	6283.2	7330.4	8377.6	9424.9	10472	11519	12566	13614	14661	15708	16755	17803	18850
32	31.25	2390.6	3586.0	4781.0	5976.5	7171.9	8367.2	9562.5	10758	11953	13148	14344	15539	16734	17930	19125	20320	21516
34	33.25	2706.4	4060.0	5413.0	6766.0	8119.2	9472.4	10826	12179	13532	14885	16238	17592	18945	20298	21651	23004	24358
36	35.25	3041.8	4563.0	6084.0	7604.5	9125.4	10646	12167	13688	15209	16730	18251	19772	21292	22813	24334	25855	27376
42	41.25	4165.4	6248.0	8331.0	10414	12496	14579	16662	18744	20827	22910	24992	27075	29158	31241	33323	35406	37489
48	47.99	5637.8	8457.0	11276	14095	16913	19732	22551	25370	28189	31008	33827	36646	39465	42284	45103	47922	50740
54	53.98	7133.1	10700	14266	17833	21399	24966	28532	32099	35665	39232	42798	46365	49931	53498	57065	60631	64198
60	60.09	8839.2	13259	17678	22098	26518	30937	35357	39777	44196	48616	53035	57455	61875	66294	70714	75134	79553
72	72.10	12726	19089	25451	31814	38177	44540	50903	57266	63628	69991	76354	82717	89080	95443	101805	108168	114531
84	84.10	17314	25971	34628	43285	51943	60600	69257	77914	86571	95228	103885	112542	121199	129856	138514	147171	155828

FPS TO GPM:  $GPM = (PIPE\ ID)^2 \times VELOCITY\ IN\ FPS \times 2.45$

GPM TO FPS:  $FPS = \frac{GPM}{(ID)^2 \times 2.45}$

FPS X .3048 = MPS

GPM X .0007 = GPD

GPM X 3.7878 = LPM

## WARRANTY/DISCLAIMER

OMEGA ENGINEERING, INC. warrants this unit to be free of defects in materials and workmanship for a period of **13 months** from date of purchase. OMEGA's WARRANTY adds an additional one (1) month grace period to the normal **one (1) year product warranty** to cover handling and shipping time. This ensures that OMEGA's customers receive maximum coverage on each product.

If the unit malfunctions, it must be returned to the factory for evaluation. OMEGA's Customer Service Department will issue an Authorized Return (AR) number immediately upon phone or written request. Upon examination by OMEGA, if the unit is found to be defective, it will be repaired or replaced at no charge. OMEGA's WARRANTY does not apply to defects resulting from any action of the purchaser, including but not limited to mishandling, improper interfacing, operation outside of design limits, improper repair, or unauthorized modification. This WARRANTY is VOID if the unit shows evidence of having been tampered with or shows evidence of having been damaged as a result of excessive corrosion; or current, heat, moisture or vibration; improper specification; misapplication; misuse or other operating conditions outside of OMEGA's control. Components in which wear is not warranted, include but are not limited to contact points, fuses, and triacs.

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Direct all warranty and repair requests/inquiries to the OMEGA Customer Service Department. BEFORE RETURNING ANY PRODUCT(S) TO OMEGA, PURCHASER MUST OBTAIN AN AUTHORIZED RETURN (AR) NUMBER FROM OMEGA'S CUSTOMER SERVICE DEPARTMENT (IN ORDER TO AVOID PROCESSING DELAYS). The assigned AR number should then be marked on the outside of the return package and on any correspondence.

The purchaser is responsible for shipping charges, freight, insurance and proper packaging to prevent breakage in transit.

FOR **WARRANTY** RETURNS, please have the following information available BEFORE contacting OMEGA:

1. Purchase Order number under which the product was PURCHASED,
2. Model and serial number of the product under warranty, and
3. Repair instructions and/or specific problems relative to the product.

FOR **NON-WARRANTY** REPAIRS, consult OMEGA for current repair charges. Have the following information available BEFORE contacting OMEGA:

1. Purchase Order number to cover the COST of the repair,
2. Model and serial number of the product, and
3. Repair instructions and/or specific problems relative to the product.

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