INNOVA-SONIC™ PORTABLE INSTRUCTION MANUAL

Model 210 Series- Innova-Sonic™ Portable

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1 Product Overview

1.1 Introduction

The INNOVA SONIC PORTABLE Ultrasonic Liquid Flow Meter consists of a flow sensor (two ultrasonic transducers), a flow transmitter and a Personal Digital Assistant (PDA).

The Model 210 INNOVA SONIC PORTABLE Ultrasonic Flowmeter is a state-of-the-art universal transit-time flowmeter designed using SLSI technology and low-voltage broadband pulse transmission. While principally designed for clean liquid applications, the instrument is tolerant of liquids with the small amounts of air bubbles or suspended solids found in most industrial environments. The 210 INNOVA SONIC PORTABLE features many advantages:

1. Designed using SLSI technology to offer you such advantages as minimized hardware, low operating voltage, multipulse transmission, low power consumption, high reliability, enhanced adaptability and reasonable protection against interference. Optimized intelligent signal self-adapting processing function eliminates the need for circuit adjustment
2. Easy data acquisition and processing. By using the PDA data acquisition and processing program of the 210 INNOVA SONIC PORTABLE, you can perform data acquisition and processing conveniently. Using the PDA, you can also perform such operations as browsing the collected data, making statistical analysis, displaying graphs, etc. The PC applications of the 210 INNOVA SONIC PORTABLE make it even easier to implement the above operations or print data tables.
3. Clear, user-friendly operating interface. The fully-windowed software supplied with this instrument allows users to set parameters or types easily, including British or Metric measurement units, pipe size, pipe material, wall thickness, fluid type, output signal, etc. The setup guide of the PDA makes it more convenient for users to configure the setup parameters, display settings and output settings. Instead of memorizing a large number of commands, you can complete these configurations simply by following the instructions on the screen. Different settings can be saved as different files that can be recalled easily.
4. Easy to install, small in size and easily portable. Plug in stereo-type connectors make cable connections easy. This product is small in size and light in weight supporting battery-powered operation. Its built-in and standby power supply can provide electricity for up to 24 hours.
5. Features 7-digit positive totalizer, negative totalizer and net flow totalizer working in parallel, each with a multiplier.
6. The 210 INNOVA SONIC PORTABLE uses a time measurement circuit with high resolution (up to 0.04nS), high linearity and high reliability that, together with its built-in 32 bit digital processor, ensures higher resolution and a wide measuring range. It can be used in various industries like water supply and treatment, power supply, district heating, mining, petroleum, chemistry, food processing and so forth. Its typical applications include:
    a) Flow measurement of any homogeneous liquid that is capable of transmitting sonic waves, such as water, sewage, sea water, acid and alkaline liquid, edible oil, diesel oil, crude oil, alcohol, beer, etc.
    b) Applications in power plants or thermal power, heating, metallurgy, mining, petroleum, chemistry, food, pharmaceutical, and other sections of the industry.
    c) Applications in energy efficiency testing, water management, flow tracking, computerized flow management, network system monitoring and so forth.

1.2 Theory of Operation

The transit time measurement theory applies to the 210 INNOVA SONIC PORTABLE Ultrasonic Liquid Flowmeter.

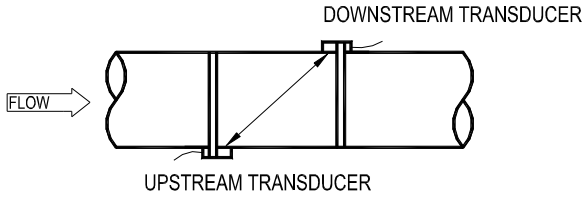


Figure 1-1 Typical Transit Time Schematic Diagram

The distribution of fluid velocity in a pipe varies with the cross-section, with the flow velocity at the center of the pipe faster than the velocity near the pipe wall. The distribution of fluid velocity in a pipe can be shown in as a velocity distribution cross-sectional diagram. Based on the mathematical model of the cross-sectional velocity distribution in the pipe and the settings of the flowmeter, average velocity can be calculated, and then the volumetric flow can be calculated according to the average velocity of the medium and the cross-sectional area of the pipeline.

1.3 External Features

The 210 INNOVA SONIC PORTABLE incorporates the following external features:

- ◆A PDA is connected with the transmitter via Bluetooth wireless communication. The PDA can serve as your personal digital assistant when not used for measurement.
- ◆Direct input/output terminal connections on the panel for easy operation.
- ◆Battery power supply with battery recharge port.
- ◆Die-cast aluminum chassis
- ◆Analog 4-20 mA output Cable

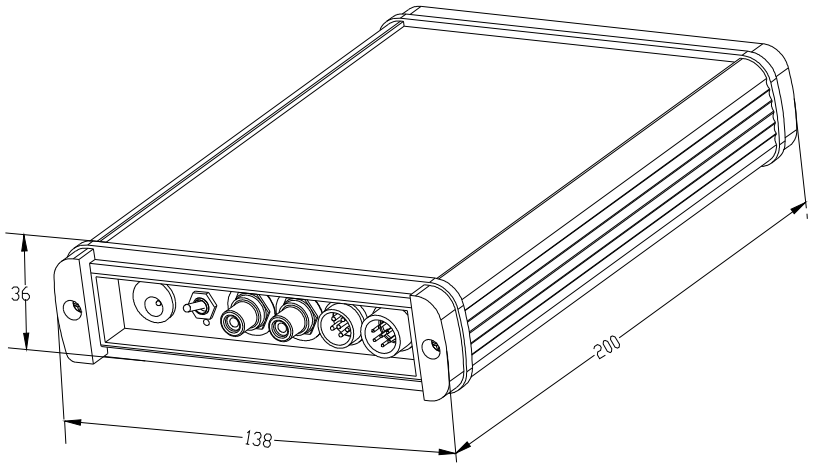


Figure 1-2 Outline Drawing of the Flowmeter (in mm)

1.4 Technical Specifications

Table 1-1 Technical Specifications of INNOVA SONIC PORTABLE Flow Meter

Performance	
Flow range	0~±12m/s (0~±40ft/s)
Accuracy	±1% of measuring value
Repeatability	0.2%
Pipe size	Clamp-on: 25~5000mm (1″ ~200″)
Functional	
Outputs	Analog output: 0/4~20mADC (max load 750Ω)
Power supply	12VDC (10~36VDC) Battery Power (continuous operation of main battery 8 hours + spare battery for 24 hours)
Display and Operation	PDA
Temperature	Transmitter: -40℃~60℃ Measuring medium: -40℃~80℃(standard); -40℃~150℃(high temp.)
Humidity	0~99%RH, non-condensing
Physical	
Transmitter	Aluminum case
Transducer	Encapsulated design Standard cable length: 5m
Weight	Transmitter +Transducer: approximately 2. 8kg

2 Components

The 210 Portable Innova Sonic Digital Correlation Transit Time Flow meter is comprised of 3 essential components; The Electronics unit, the Palm PDA Interface, and the Transducers.

Figure 2-1 INNOVA SONIC PORTABLE Panel and Connection Diagram

Shown in Figure 2-1 from left to right on the panel of the 210 INNOVA SONIC PORTABLE are the battery recharge port (charge the transmitter and connect to the standby power supply), power switch, power light (red), run indicator (green), upstream transducer connector, downstream transducer connector, 4~20mA output connector and a connector for function expansion. The unit is battery powered and when fully charged will have an operational life of 8 hours on the internal battery. An additional external battery may be connected to increase the life up to 24 hours. The 210 INNOVA SONIC PORTABLE Ultrasonic Liquid Flowmeters are powered by 12V batteries. Batteries can be recharged and standby power supply can be connected through the battery recharge port on the panel.

Warning

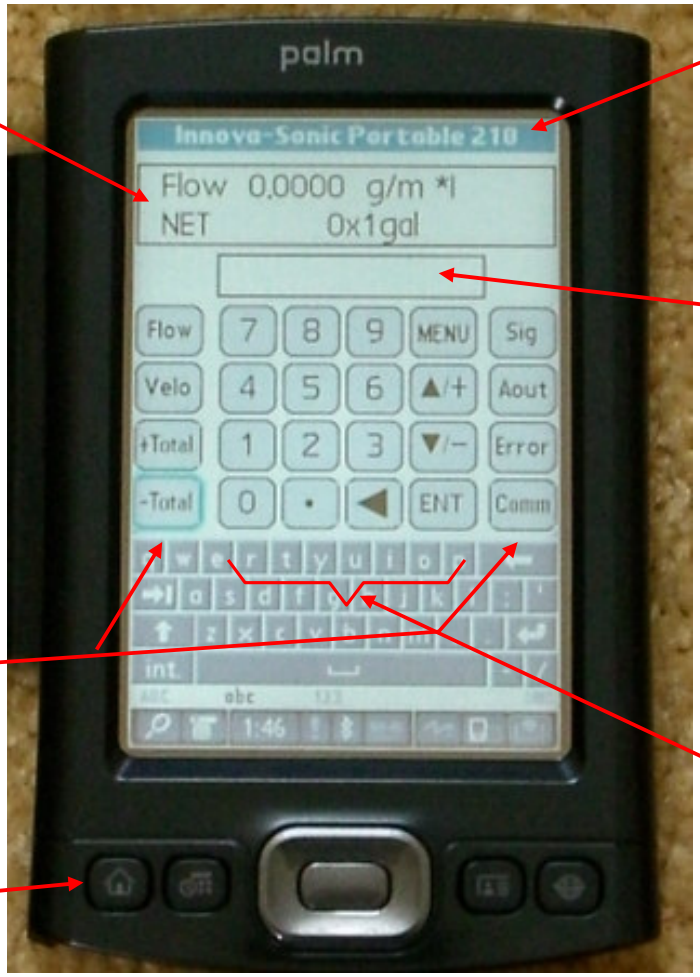
Only use the supplied charger to charge the batteries.

The Palm PDA Interface Unit

ID Area – Window Frame
For use with Data Acquisition mode and alternate setup mode

Information-Display Area

Displays Meter feedback info, Error Codes, and all Data Window information This area will be displayed in large-screen mode when running M00~M04 commands and Flow~Velo~+Total~-Total short cut keys. Press any point in this area to return to the normal display mode.



Input Display Area

Displays keypad operation information. Example: When MENU 1 1 is pressed, an "M11" will appear.

Shortcut Keys

Display the main information of the meter quickly.

Keypad area

Use the PDA stylus and the keypad for data entry, setup and all other keypad functions.

Home Button

Launches Palm Desktop

Figure2-3 Main Interface

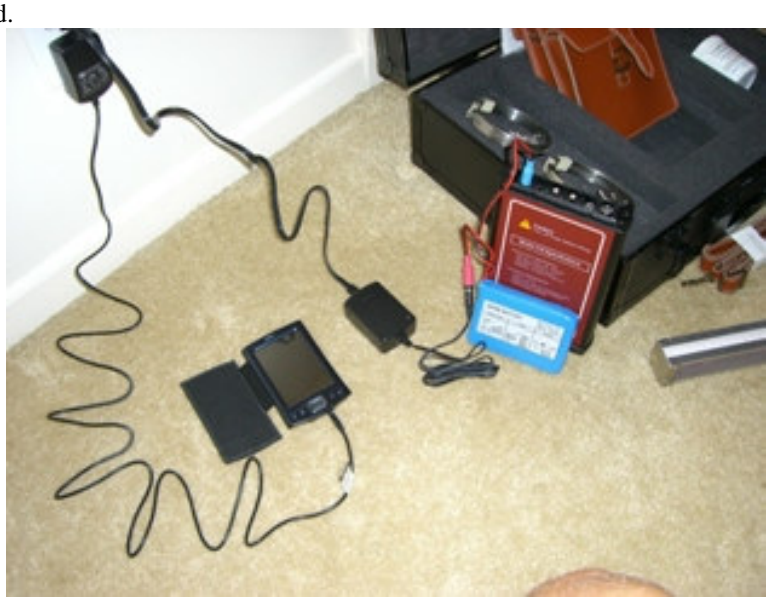
Figure 2-3 is the main interface of the 210 INNOVA SONIC PORTABLE. It can be divided into 5 parts: the ID area, Information Display area, Input Display area, Shortcut key and Keypad.

3 Installation / Commissioning

Check the packing list and contents to ensure that all necessary and ordered parts are on hand. Should any parts be missing or damaged, please contact Sierra Instruments as soon as possible.

3.1 Battery charging.

Once the instrument is determined to be complete, locate the chargers for both the Palm and the Electronics unit. Place both units on charge until the Palm Battery status indicates fully charged and the LED on the Charger for the Electronics unit glows green. If the Electronics Charger LED glows red, then it is not fully charged.



3.1.1 Turning the 210 Innova Sonic On

The 210 INNOVA SONIC PORTABLE runs a self-diagnostics program after a power up. If it detects any failure, the error message associated with the failure will be displayed (see Troubleshooting). Once the self-diagnostics process is completed, the instrument starts working automatically with the parameters that were entered during the last setup.

Since the 210 INNOVA SONIC PORTABLE uses overlap processing internally with time-sharing technology, operating the keypad (the keypad displayed on the PDA screen) will not affect the measurement process. Measurement, computing, keyboard input, displaying, printing, serial port operation and input/output are referred as "events", each of which works independently. For example, user's modification of date and time will not affect other tasks not related to date and time.
If the instrument is properly installed, it enters into normal operation mode when the power is turned on, and an "*R" is displayed on the top left-hand corner of the screen.

When using the instrument for the first time or installing it at a new location, parameters for the new location must be input. The instrument will permanently hold these parameters until the user modifies them.
When the transducer is removed or any parameter is changed, the instrument readjusts its settings automatically to work with the new parameters.

When in service, the instrument always completes its tasks simultaneously, regardless of the display window where the task is performed. Tasks including measurement and output are carried out normally. Each time the unit is powered on, the instrument enters into the display window it displayed when last powered off.

To ensure a faster communication setup, enter the Palm Home Desktop before powering off the Palm. When the Palm is turned on again, it will come back to the Desktop, allowing the user to select the Sierra Instruments 210 Innova Sonic Program.

3.2 Establishing Bluetooth communications.

Once the unit is fully charged, you are now ready to commence the configuration setup for your specific application. In order to accomplish this, you must first establish Bluetooth Communications between the Palm and the Electronics unit.

1. Turn the Electronics unit on. Observe the RED LED Power light illuminate. This must be in sequence, the Electronics SHALL be turned on FIRST, then the Palm. Failure to do so in this sequence could result in a lack of Blue Tooth Communications.

2. Turn on the Palm. Observe the PALM Boot up Sequence. The unit will then automatically launch the Sierra 210 Innova Sonics and search for BlueTooth devices. It may show a list of compatible devices to communicate with. Select the FLOXXX device if there are multiple devices listed. It will then establish communications and you should observe the Green/Amber Run light on the Electronics flashing while communicating…

3.2.1 IF COMMUNICATIONS FAIL. DO NOT BE ALARMED.

First, ENSURE the Electronics unit is turned on and the RED power LED is Illuminated.

In the event that a Data Window appears asking for a Password, enter the password of 1234. This will unlock the unit and allow communications to proceed.

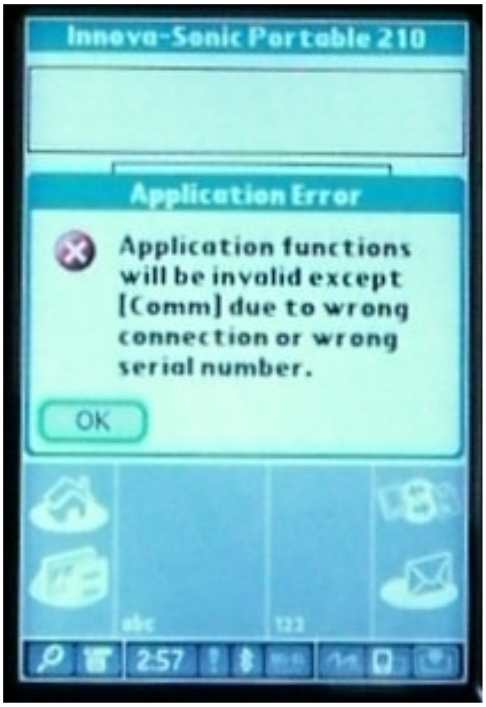
Should the Palm not discover the Electronics unit, you will see the following screens. Simply follow the steps below and you will be guided to re-establishing communications.

Note

The range of the Bluetooth Communications is a function of the level of battery life in both devices. Initially, with a fully charged Palm and Electronics, the Bluetooth with have a functioning range of approximately 30 feet. As the charge depletes, the range may also decrease.

On the Palm, you will see "Serial Number Error" Select OK.
Palm will search again for Bluetooth Devices.

If none are found, you will see "Application Error". Application Functions will be invalid due to wrong connection or wrong serial number. Select OK.

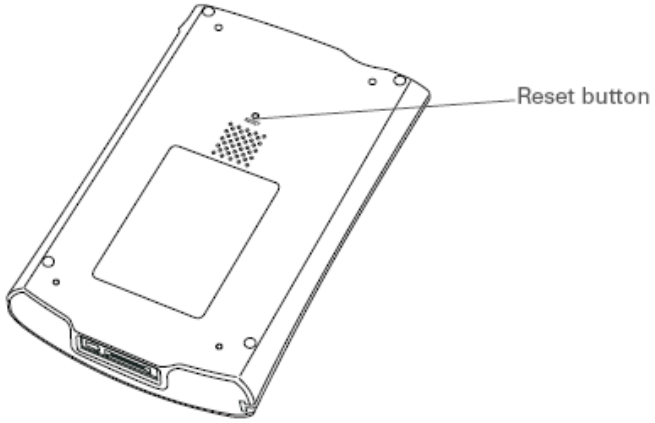


You will now be back to a regular Innova Sonic Portable 210 screen, but the data windows will be blank. At this point select the HOME button on the lower left corner of the Palm, as shown in Fig 2-3 Main Interface. This will take you to the main Palm Desktop screen.

Under the APPLICATIONS ICON select the Sierra 210 program and re-launch it. If this still fails to communicate, repeat the above, but after selecting the Home Button, cycle power to the Palm unit. This will force the Palm into a re-boot sequence. Select the OK button on the screen until the 210 program appears stating that some functions will be unavailable until communications are restored.

If you are still unable to communicate, activate the Reset function on the back of the Palm. This will force a reboot and recycle the Palm software, again, once the Palm software is completely booted up, the 210 will automatically launch.

To do a soft reset, use the tip of the stylus to gently press the reset button inside the hole on the back panel of your handheld.



If your handheld does not respond after a soft reset, you need to do a hard reset.

If further attempts to establish Bluetooth communications fail, contact Sierra Instruments for assistance.

3.3 Configuring for your application. "The 8 Steps to successful flow measurement."

Once you are communicating with the electronics, the unit will have the last programmed information. You will need to enter the parameters for your new application, (assuming they are different from the last measured location). The following information is required to be programmed into the unit in order to successfully measure the flow in a given application.

MENU 11: Pipe Outer Diameter
MENU 12: Pipe Wall Thickness
MENU 13: Pipe Inner Diameter (if you enter the OD and Wall, the ID will self compute)
MENU 14: Pipe Material
MENU 16: Liner Material (if any)
MENU 20: Fluid Type
MENU 23: Transducer Type (for the 210 Portable, it will either be Standard, or High Temp depending on which you have in your kit)
MENU 24: Transducer Mounting Style (Z, V, N, or W mounting configuration, see section XXX below)
MENU 25: READ Transducer Spacing

Once these values are programmed in, you may mount the transducers, connect the cables and select Menu 00 and begin reading flow! We will discuss basic data entry here, and then detail the mounting styles. See Section 4 Entering Data in the Palm Menu for details on exactly how to accomplish this.

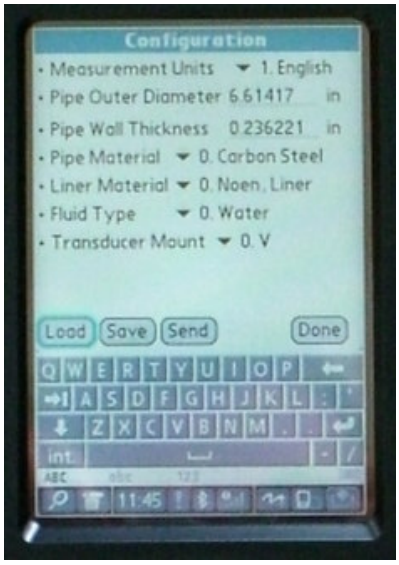
3.3.1 Alternative Method for Application Programming.

On the ID Area – Window Frame (See Fig 2-3 Main Interface above) if you tap once in the Blue Window frame, two selectable tabs appear.

Utility and Options.

Under the Utility Tab, you will see the choices for the following;

Data Acquisition
Table & Graph
Configuration
Display
Output



Selecting the Configuration Option will bring up a 1 page synopsis of the currently entered data. You may change the data here, rather than entering each separate menu section. Simply tap a data section and it will either activate a cursor in that label or display a selection box with choices to enter. IMPORTANT! ONCE YOU ENTER THIS DATA, YOU MUST SELECT THE SEND BUTTON, OR THE PALM WILL NOT UPLOAD IT TO THE ELECTRONICS. Once complete, you will still need to enter MENU 25 to read the transducer spacing prior to mounting them on the pipe.

Selecting the OPTIONS Tab will provide you with the Instrument Serial Number and Software Version Data.

The other options under the Utility Tab will be discussed in detail later in this manual.

3.4 ENTERING DATA IN THE PALM MENU

In order to input the required data, you must navigate to that data window. Page 35 has all the data windows outlined in a chart format. So, to enter the Pipe Outer Diameter, we need Menu 11. Navigate to Menu 11 by pressing the MENU and "1", "1" keys on the Palm.

Observe the data window with the existing Pipe Outer Diameter Displayed in the Display section on the Palm. To change this data and input the new pipe dimensions, press the ENT Key. {This is the enter key and will be referred to as the Enter key from this point in the manual.} When you select the enter key, you will see a cursor that looks like this >. At this point, simply type in the data and press the enter key again. This will over write the existing information in the Palm and save the new data.

For example, to input a pipe outer diameter of 12.85, perform the following steps: press MENU 1 1 to enter Window No.11 where the last held Pipe Outer Diameter value will be displayed, then press ENT. A ">" Symbol will appear. Then type the new data

1 2 . 8 5 then press ENT

Pipe Outer Diameter >

Once complete with the new Pipe Outer Diameter, select the Down Arrow key. This will take you to the next sequential Data Window, Pipe Wall Thickness…

Using the same procedure as above, with the Wall Thickness data, enter the Pipe Wall thickness and then continue with the Down Arrow until you have reached the Transducer spacing data window. At this point you are ready to install the transducers. Ensure that you have entered the correct data for each of these data windows;

- MENU 11: Pipe Outer Diameter
- MENU 12: Pipe Wall Thickness
- MENU 13: Pipe Inner Diameter (if you enter the OD and Wall, the ID will self compute)
- MENU 14: Pipe Material
- MENU 16: Liner Material (if any)
- MENU 20: Fluid Type
- MENU 23: Transducer Type (for the 210 Portable, it will either be Standard, or High Temp depending on which you have in your kit)
- MENU 24: Transducer Mounting Style (Z, V, N, or W mounting configuration, see section XXX below)
- MENU 25: READ Transducer Spacing

3.5 Transducer Mounting Methods

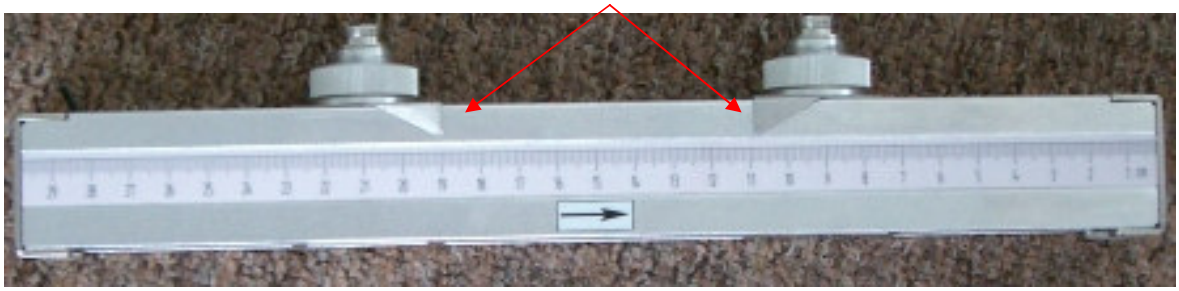
Four transducer-mounting methods are available. They are respectively: V method, Z method, N method and W method. The V method is primarily used on small diameter pipes (DN100~300mm, 4”~12”). The Z method is used in applications where the V method cannot work due to poor signal or no signal detected. In addition, the Z method generally works better on larger diameter pipes (over DN300mm, 12”) or cast iron pipes.

The N and W methods are not commonly used. They are used on smaller diameter pipes (< DN50mm, 2”).

3.5.1Transducer Spacing

The space between the front edges of the two transducers is considered as the standard transducer spacing. After entering the required parameters, check the data displayed in Window No.25 and space the transducers accordingly. There are two small pointers on the sides of the transducer racks. The spacing is from point to point as shown below.

Spacing Pointers



3.5.2 Transducer Mounting Inspection

Check to see if the transducer is installed properly and if there is an accurate and strong enough ultrasonic signal to ensure proper operation and high reliability of the transducer. It can be confirmed by checking the detected signal strength, total transit time, delta time as well as transit time ratio.

The “mounting” condition directly influences the flow value accuracy and system reliability. In most instances, applying a wide bead of sonic coupling compound lengthwise on the face of the transducer and sticking it to the outside pipe wall will give good measurement results. However, the following inspections still need to be carried out in order to ensure high reliability of the measurement.

3.5.3 V Method

The V method is considered as the standard method. It usually gives a more accurate reading and is used on pipe diameters ranging from 25mm to 400mm (1~16") approximately. Also, it is convenient to use, but still requires proper installation of the transducer, contact on the pipe at the pipe's centerline and equal spacing on either side of the pipe.

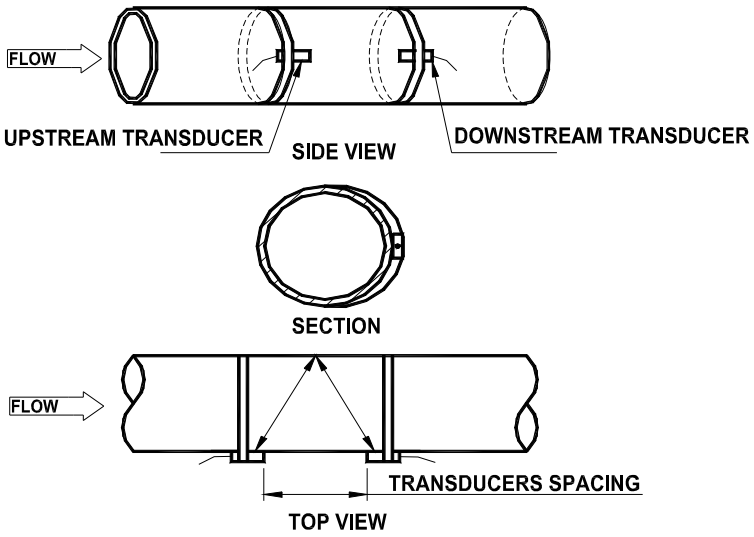


Figure 2-6 V Method

3.5.4. Z Method

Z method is preferable when normal operation with V method is not possible due to poor signal reception caused by large diameter pipe, heavy scale deposits on the inner pipe wall and the liner, or the presence of suspended solids in the fluid. When Z method is used, sound is transmitted directly through the pipeline without any traverse (also referred to as single beam path distance), and signal loss is minimized.

Z method is used on pipe diameters over 200mm (8"), Z method is recommended for actual installation.

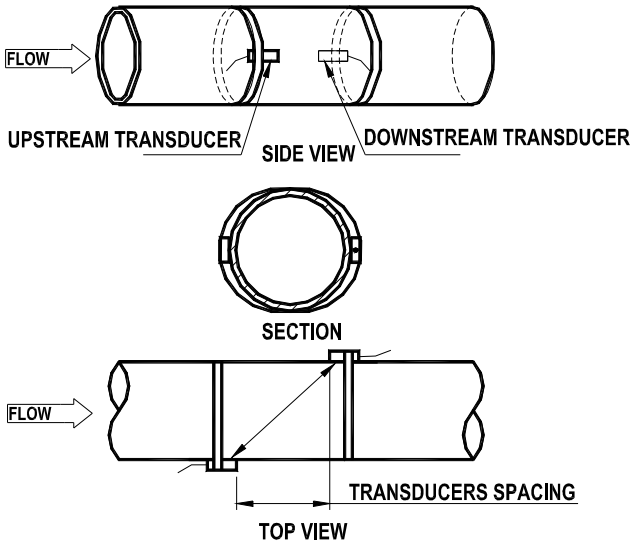


Figure 2-7 Z Method

3.5.5 N Method (not commonly used)

With the N method, the sound waves traverse the fluid three times and bounce twice off the pipe walls (three beam path distance). It is suitable for small pipe diameter measurement. The measurement accuracy can be improved by extending the transit distance with the N method (uncommonly used).

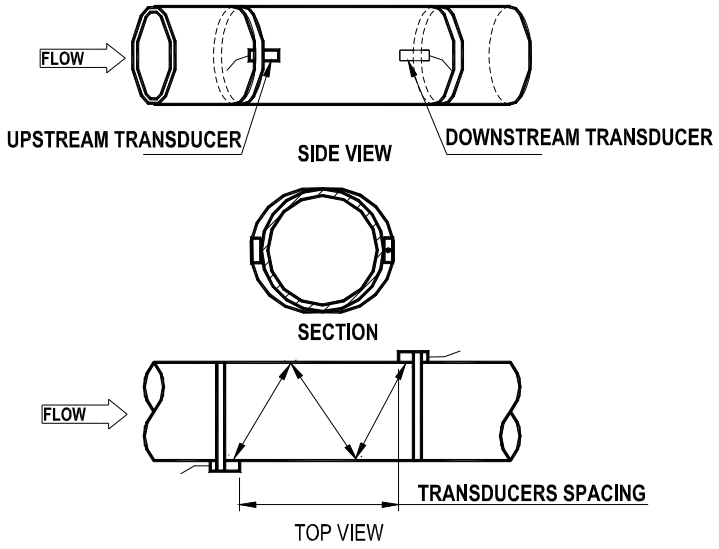


Figure 2-8 N Method

3.5.6 W Method (Rarely Used)

As with the N method, the measurement accuracy can also be improved by extending the transit distance with the W method. The sound wave traverses the fluid four times (four beam path distance) and bounces three times off the pipe walls. It is suitable for very small pipe (diameters less than 50mm, 2").

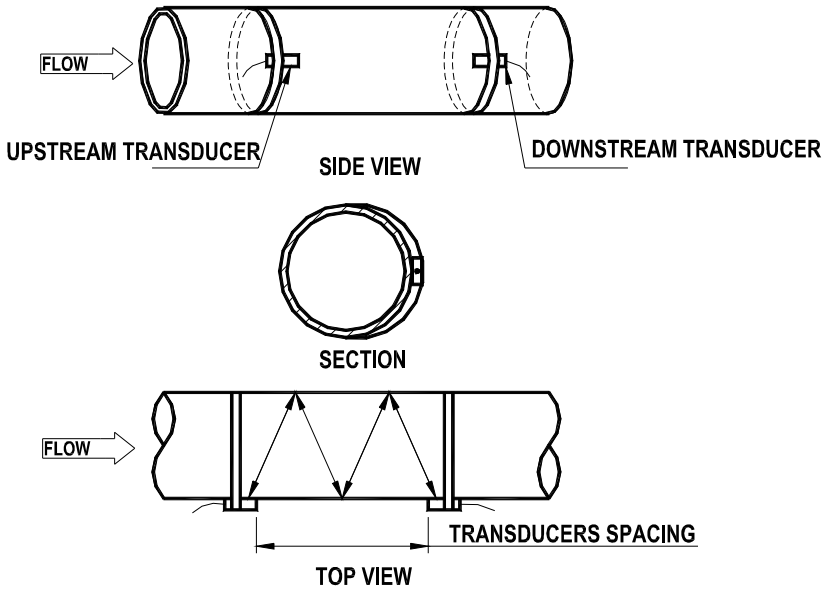


Figure 2-9 W Method

3.6 Measuring point Selection

Of all flowmeter types, installing an ultrasonic flowmeter is the most convenient. You can start measuring simply by selecting an appropriate measuring point, inputting the pipe parameters at the measuring point to the flowmeter and attaching the transducer onto the pipeline.

To guarantee highly accurate measurement results, it is necessary to select a pipe section where the fluid flow is evenly distributed. When selecting a measuring point, follow the guidelines below:

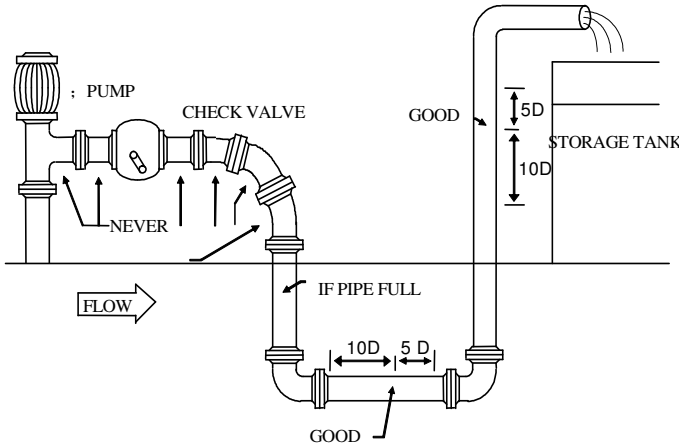


Figure 2-10 Measuring Point Selection

- Choose a section of pipe, which is always full of liquid, such as a vertical pipe with flow in the upward direction or a full horizontal pipe.
- Generally, the measuring point should have a straight pipe run length equal to at least 10 pipe diameters upstream and 5 pipe diameters downstream. If there is a pump, a pipe tee, adjusting valve, throttling orifice, expansion of the pipe section or any other flow disturbance producing elements above the measuring point, the straight pipe section upstream should be longer. For a horizontal pipe, transducers are usually fixed at the 9 and 3-o'clock position of the pipe.
- Avoid attaching the transducers at the 6 and 12 o'clock position to prevent signal attenuation caused by deposition at the bottom of the pipe or air bubbles and air pockets in the top of the pipeline.
- Ensure that the pipe surface temperature at the measuring point is within the transducer temperature limits.
- Scale formation of inner pipe should be taken into account. If possible, select a section of pipe free of scale inside. When such a section cannot be located, you must consider the scale as liner for better measuring accuracy.
- Choose a section of pipe where the pipe material is homogeneously and compactly formed and the ultrasonic signal can be easily transmitted. Measuring point selection is illustrated in Figure.2-10 and Figure.2-11.

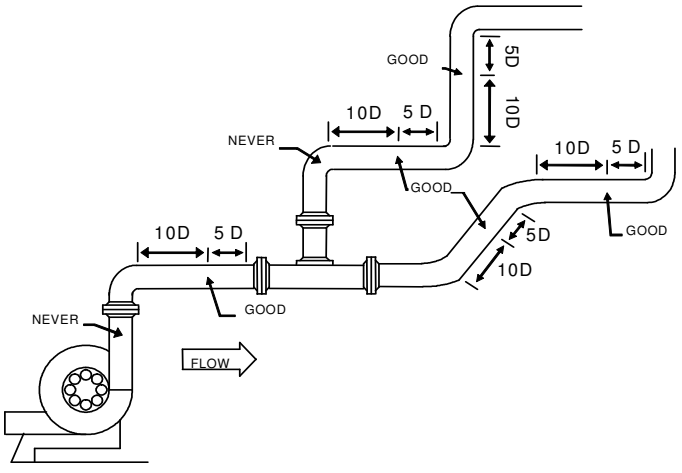


Figure 2-11 Installing the Transducers (example)

Note

If these guidelines are not followed, signal strength and quality will be affected, and measurement accuracy degraded.

3.7 Mounting the Transducers

As shown in figure 2-12, the transducers of the INNOVA SONIC PORTABLE are integral within a convenient slide ruler. Magnets are built in the slide ruler. For magnetically conductive pipe materials (such as carbon steel), you can stick the slide ruler directly onto the pipe outside wall to fix it as shown in figure 2-13. For non-magnetic conductive pipe materials, you can attach the slide ruler onto the pipe by using pipe clamps.

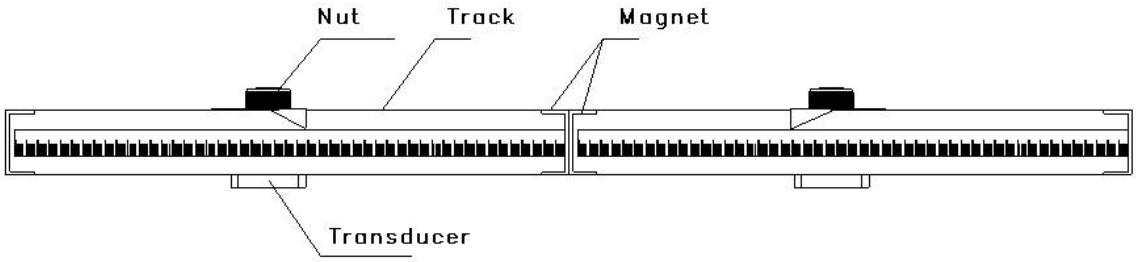


Figure 2-12 Slider Ruler with Integrated Transducers

Prior to installing the transducers, clean up the pipe surface where the transducers are to be mounted. Remove any rust, scale or loose paint and choose a section of sound conducting pipe for installing the transducers. Any pipe insulation materials must be removed so that the transducers may have a direct connection to the pipe surface. Apply a wide bead of sonic coupling compound down the center of the face of each transducer. To install the transducers, if both transducers are in a single mounting rack, {see figures 2-14 through 2-18 below} set the established spacing from Menu 25 between the transducers. Tighten the locking ring on top of each transducer. Using the magnetic racks, place the transducers on the pipe surface. Gently loosen the transducer locking rings so that the self contained springs push the transducers tightly against the pipe surface. If the transducers are in separate individual racks, set one rack on the pipe, measure the required spacing from the pointer on the rack and place the 2nd rack in position such that the distance between pointers meets the MENU 25 spacing dimension.

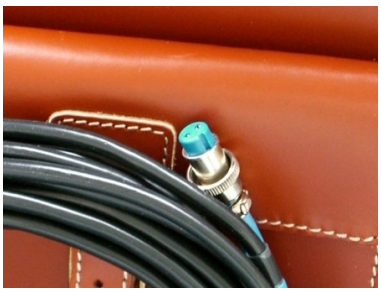
For Nonmetallic pipes, use the same procedure as above, however, secure the mounting racks to the pipe surface with the included pipe straps. Alternative methods to secure the racks to the pipe surface could include Cable Tie Wraps or even Elastic Bungee Cords. Any device used to hold the racks to the pipe surface should ensure that the racks are held securely, and the transducers are tight against the pipe surface.

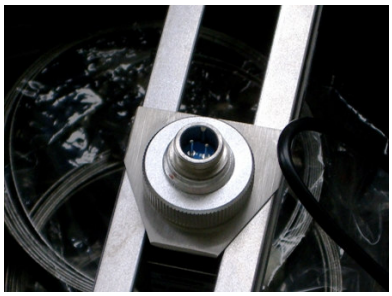
Note

The 2 transducers must be fixed at the front position (i.e. 3 or 9 o'clock position of the pipe) to prevent signal loss which can be caused by sediment along the bottom of the pipe or air bubbles and air pockets along the upper part in the pipe.

3.8 Connecting the Transmitter

Once the transducers are securely mounted on the pipe, connect the cables to each transducer and then to the Electronics box. Care should be taken here as the transducer cable ends are keyed to fit into the transducers wiring connection and then fastened with a threaded connector. The opposite end is a stereo type plug that simply inserts into the corresponding Upstream and Downstream connection point. Once these 2 cables are securely connected, you are ready to read the flow.





The upstream transducer cable has red terminal ends and downstream transducer cable has blue terminal ends. See Figure 2-2.

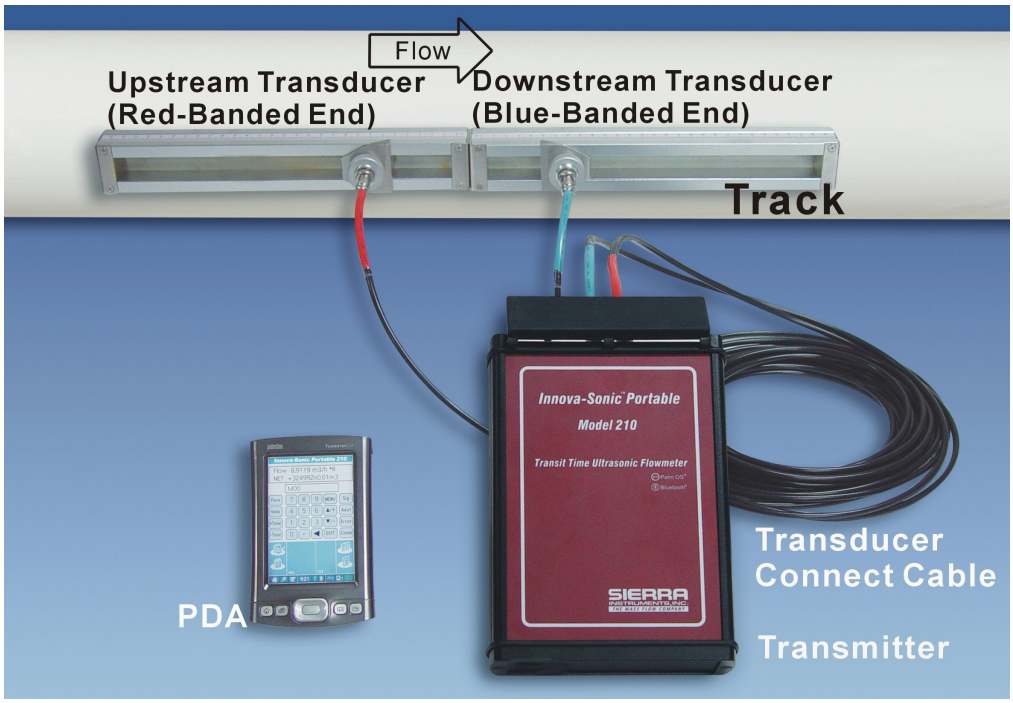


Figure 2-2 Transducer Connection

When installing transducers to relatively small pipes {sizes under 8" in most applications}, the transducer spacing displayed in MENU25 may be less than 7.5" (190mm), then we can install the transducers in single slide ruler track. The installation method is unscrewing a transducer off the track at first, as is shown in figure 2-14, then install the two transducers to one track face-to-face as shown in figure 2-15. Accordingly, as shown in figure 2-16, the flow meter works as usual. Exercise caution during this procedure as the transducers are spring loaded in the racks.

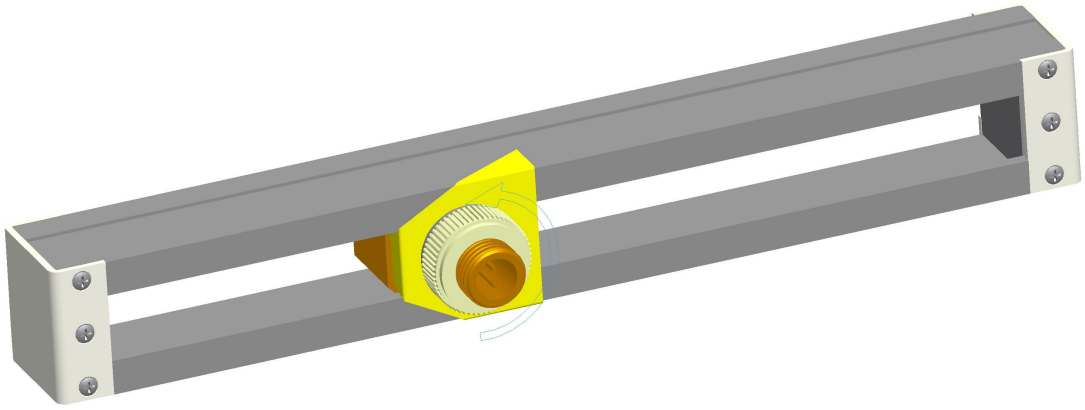


Figure2-14 Unscrewing transducer from the track

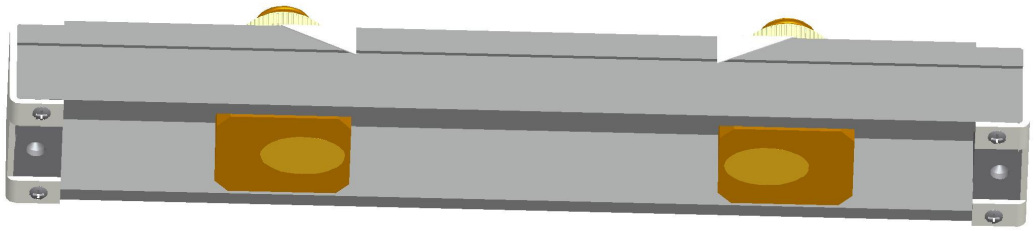


Figure 2-15 install the two transducers to one track

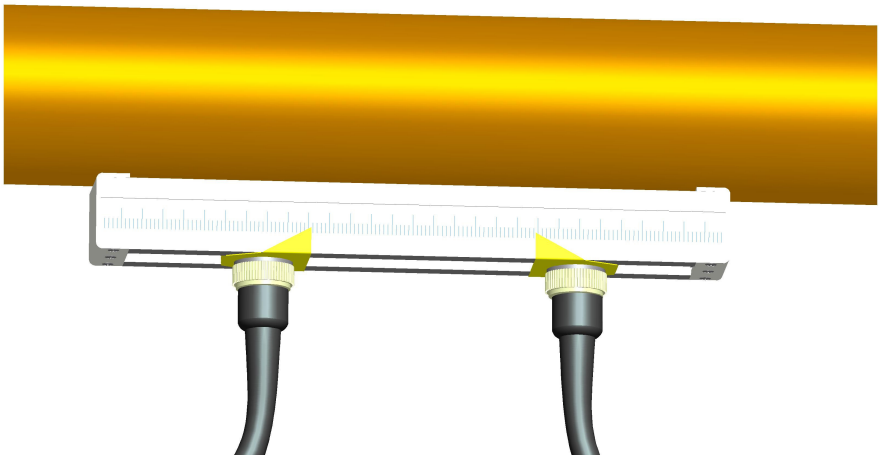


Figure 2-16 installing the transducers to one track for measuring

When finished installing both transducers in a single rack, they should appear as shown in the photo below, Figure 2-17. The oval transducer crystals should be facing each other. They are designed to send signals back and forth to one another, and if they are installed backwards, they will not function.

Figure 2-17 both transducers in one rack

Each transducer has a flow direction arrow or an Upstream / Downstream Identification. See Figure 2-18. Additionally, each rack has the flow direction arrow depicted on it. Ensure the arrows point in the correct direction to ensure proper operation.

Figure 2-18 Up stream transducer label

Note

The 2 transducers must be fixed at the front position (i.e. 3 or 9 o'clock position of the pipe) to prevent signal loss which can be caused by sediment along the bottom of the pipe or air bubbles and air pockets along the upper part in the pipe.

Once the cables are connected, simply select MENU 0 0 and you will display the flow rate. You can then use the shortcut keys for additional flow information as desired.

3.9 Ensuring a Quality Flow Measurement

Once the cable are connected, if you select Menu 0 0 you will be taken to the main flow display. If all is correct, you will see the flow rate, total and a Status Code of *R on the display area. At this point you may select MENU 9 0 to enter the Diagnostics portion of the data windows.

3.9.1 SIGNAL STRENGTH & QUALITY

Menu 9 0 will provide the Signal Strength and Quality readings. You want the SS to be above 60 and the Q to be above 50. If these values are above those limits, you have a good reliable and accurate flow reading. The Signal Strength is a measure of how much transmitted signal is being received by the alternate transducer. The display will show both the Upstream and Downstream signals. The Quality is a measure of the electronics processing the information, and distinguishing between noise and true flow signal. See Figure 6-1.

Figure 6-1 Menu 90

Figure 6-2 Menu 91

3.9.2 TRANSIT TIME RATIO

Menu 9 1 will provide a display of TOM / TOS ratio. See Figure 6-2. This is a measurement of the actual VS the Calculated Time of Flight for the flow signal. TOM is the Time of Flight Measured, TOS is the Time of Flight Selected. The "Calculated" or "Selected" Time of Flight is what the instruments expects to see based on the application you programmed it for. For example, you program a 6" SCH 40 carbon steel pipe with water as a fluid, it expects to see a certain value for the time of flight. The instrument compares this expected value to the actual measured value and displays it as a ratio in %. As long as you are within 3%, (100 +/-3) then you will be with in published accuracy specifications'. If TOM/TOS varies by greater than 3%, something is incorrect in the programming or transducer placement.

3.9.3 Total Time and Delta Time

Menu 93 will provide "Total Time and Delta Time" which indicates the condition of the installation. The measurement calculations in the flowmeter are based on the two parameters. Therefore, when "Delta Time" fluctuates widely, the flow and velocities fluctuate accordingly. This means that the signal quality detected is too poor. It may be the result of poor pipe-installation conditions, inadequate transducer installation or incorrect parameter input.

Generally, "Delta Time" fluctuation should be less than ±20. Only when the pipe diameter is too small or velocity is too low can the fluctuation be wider.

3.9.4 Warnings

1. Pipe parameters entered must be accurate; otherwise the flowmeter will not work properly.
2. During the installation, apply enough coupling compound to stick the transducer onto the pipe wall. While checking the signal strength and Q value, move the transducer slowly around the mounting point until the strongest signal and maximum Q value can be obtained.
3. Check to be sure if the mounting spacing is in accordance with the one displayed in Window M25.
4. If the signal strength is always displayed as 0.00, there is no signal detected. Thus, it is necessary to check that the pipeline related parameters have been entered accurately. Check to be sure the transducer mounting method has been selected properly, the pipe is not worn-out, and the liner is not too thick. Make sure there is there is indeed fluid in the pipe or that the transducer is not very close to a valve or elbow, and there are not too many air bubbles in the fluid, etc.
5. ENSURE THAT THERE IS INDEED FLUID IN THE PIPE. This has been stated earlier, but on numerous occasions, the instrument is installed, the indications are poor Quality and low Signal Strength, only to have the use begin to suspect the instrument as malfunctioning. After further review, it was determined that the pipe was actually EMPTY…

3.9.5 4-20mA Current Output

The 4~20mA current output connects to the 5-pin din jack on the panel. With an accuracy of 0.1%, The current output of the 210 INNOVA SONIC PORTABLE is fully programmable and can be set to various output modes such as 4~20mA or 0~20mA. Use Window M55 to select the output mode.
The max load of 4-20mA DC is 750Ω. Exercise care on polarity when connecting.

4.0 Functional Technical Data Information

4.1 Key Functions of the Keypad

The keypad has the following functions:

Table 2-1 Key functions

Key	Function
0	Numeric key: 0
1	Numeric key: 1
2	Numeric key: 2
3	Numeric key: 3
4	Numeric key: 4
5	Numeric key: 5
6	Numeric key: 6
7	Numeric key: 7
8	Numeric key: 8
9	Numeric key: 9
•	Value key: decimal point
◀	Delete key: Clears the last character on the Input Display
MENU	Menu key: pressing this key displays “M” on the Input Display
ENT	Enter key
▲/+	Double function key: page up or positive sign
▼/-	Double function key: page down or negative sign

4.2 Shortcut Key Operation and Display

The shortcut keys provide for a quick display of the main information of the ultrasonic flowmeter. You can get the corresponding information by pressing the key directly.

4.3 Keypad Operation

The 210 INNOVA SONIC PORTABLE flowmeter is windows-based. All parameter inputs, instrument setup and displayed measurement results are subdivided into more than 100 independent windows. Users can input parameters, change settings and display measurement results by “visiting” the specific windows. Windows are numbered in double digit format (including the ”+”) from 00 to 94, then +0, +1, etc. Each window number, or window address code, has a specific meaning. For example, Window No.11 displays Pipe Outer Diameter parameters; Window no.25 displays Transducer Mounting Spacing. See “Window Description” for further information.

The shortcut method to access a window is to press MENU with the stylus in any mode and then press the double-digit window address code. For example, to input or check Pipe Outer Diameter parameters (Window

no.11), you can simply press MENU 1 1.

There are three types of windows:

1） Data，e.g. M11, M12 ;

2） Options，e.g. M14；

3） Display only，e.g. M00, M01.

To check the corresponding parameters, visit the data window. To change the numerical value of that window, first press the ENTER key to activate the cursor >, enter the new data value, then press ENT to confirm.

4.4 Serial Number of the Program

The INNOVA SONIC PORTABLE ultrasonic liquid flowmeter is equipped with a PDA exclusively designed for this flowmeter. Every time the PDA is started, it runs the INNOVA SONIC PORTABLE first. If the PDA is not properly connected to the flowmeter transmitter or the software is unauthorized (the serial number on the “about” menu is not identical to that of the transmitter), the software will ask the user to make a proper connection or install the correct serial number (the so-called correct serial number is the serial number of the flowmeter that is identical to the serial number listed in the “About” menu of the supplied PDA). A wrong serial number prohibits normal use. Connecting with an incorrect serial number will cause all functions except “comm” key to be disabled. If you want to exit INNOVA SONIC PORTABLE, press ”OK” and then press the ”HOME” icon (located at the lower left corner of the PDA) to return to the main interface of the PDA operating system. You may then use all PDA functions as available.
If you press “About” in the ID area with the stylus, the system will display the serial number of the software and related copyright, version information. While measuring, you can display the display-only data in full screen by press the corresponding information display area (This operation is limited to M00~M04 and shortcut keys Flow, Velo, Total, -Total). Press any point on the screen to return to the normal display.

4.5 Window Descriptions

Window keys and their display contents are listed below:

M00~M09 Display windows: Used to display flow rate, positive total, negative total, net total, velocity, date & time, analog inputs for present flow, present operation and flow results today.

M10~M29 Initial parameter setup windows: Used to enter pipe outer diameter, pipe wall thickness, fluid type, transducer type, transducer mounting and spacing, etc.

M30~M38 Flow units selection and totalizer option operating windows: Used to select a system of units of measurement. You can choose from flowmeter units such as gallons and cubic feet, or turn on/off each totalizer as well as performing ”reset” for them.

M40~M49 Include: Flow correction operating window and Network IDN window (No.46), System Lock window (No.47), Keypad Lock window (No.48), etc.

M55~M83 Input and output setup windows: Current Loop Mode Select, 4mA or 0 mA Output Value, RS-232C Setup, Low FO Frequency, LCD Contrast Adjustment, etc.

M90~M94 Diagnoses: Signal Strength Quality (Window No.90), TOM/TOS*100 (Window No.91), Flow Sound Velocity estimated by measurement (Window No.92), Total Time and Delta Time of the measured signal (Window No.93), Reynolds Number and K Factor of the Instrument (Window No.94).

M+0~M-0 Appendix: Power On/Off Time, Total Working Hours, On/Off Times etc.

4.6 Pipe Parameter Entry Shortcuts

The following parameters should be entered for normal measurement:

1. Pipe outer diameter
2. Pipe wall thickness
3. Pipe material
4. Liner material parameters (including thickness and sound velocity, if needed)
5. Fluid type
6. Transducer type
7. Transducer mounting methods

Follow the procedure below to enter the above-mentioned parameters by keypad shortcuts:

1. Press MENU 1 1 to enter Window No.11, then enter the pipe outer diameter and press the ENT key.
2. Press MENU 1 2 to enter Window No.12, then input pipe wall thickness and press ENT key to conform.
3. Press MENU 1 4 to enter Window No.14, then press ENT key, scroll the ▲/+ or ▼/- key to select pipe material, and press the ENT key.
4. Press MENU 1 6 to enter Window No.16, then press ENT key, scroll the ▲/+ or ▼/- key to select liner material, and press the ENT key.
5. Press MENU 2 0 to enter Window No.20, then press ENT key, scroll the ▲/+ or ▼/- key to select a fluid type, and press the ENT key.
6. Press MENU 2 3 to enter Window No.23, then press ENT key, scroll the ▲/+ or ▼/- key to select a transducer type, and press the ENT key.
7. Press MENU 2 4 to enter Window No.24, then press ENT key, scroll the ▲/+ or ▼/- key to select a transducer-mounting method, and press the ENT key.
8. Press MENU 2 5 to enter Window No.25, then accurately install the transducer according to displayed transducer mounting spacing and selected mounting method (Refer to *Installing the Transducers* in this chapter).
9. Press MENU 0 1 to enter Window No.01 to display measurement result.

5. INNOVA SONIC PORTABLE Software Usage

The INNOVA SONIC PORTABLE software contains two parts: INNOVA SONIC PORTABLE.prc that runs on the PDA and UFMData data processing program working under Microsoft Windows operating system.

Under normal conditions, to complete all measurement tasks and data acquisition, data browsing and setup guide operations, only the PDA software INNOVA SONIC PORTABLE.prc is needed. If you need further data processing, copy the data from PDA to your PC and carry out statistical analysis, graphic display, printing and other operations on the data using UFMData (UFMData will be provided and will need to be installed in your PC).

INNOVA SONIC PORTABLE.prc exploits the powerful computing capabilities of PDA, offering the following functions in addition to normal measurement:

Data Acquisition: Collects data from the flowmeter and stores it in the memory of the PDA. The collected data

can be browsed in a table or graph on the PDA and simple analysis can be conducted.
Setup Guide: Allows the meter to be configured in steps with a setup wizard. Users can save the settings in a file, which can be recalled directly later on to simplify the setup process. The setup guide greatly simplifies the operation of the meter, allowing personnel who are unfamiliar with the flowmeter to configure its settings easily.
Full Screen Display: The program has the ability to display MENU00~04 and shortcut keys Flow, Velo, +Total, -Total in full screen view. Operators can check the data easily.

5.1 Data Acquisition and Analysis

5.1.1 PDA Data Acquisition and Analysis Program

This program stores the collected data into the PDA's Flash memory in the form of files.
For 210 Series Portable kits equipped with the Palm TX, the data is stored on the SD card. The Data Files may be accessed by starting the "Card Reader" program while attached to your PC. This will allow you to transfer the data files to your PC for use with the UFM Data program.

For those 210 kits Equipped with the Palm Tungsten T5 model PDA, the data files are stored in the following directory. Press the "file" icon in the PDA window and go to the following directory: ***palm\programs\210***. You can see four directories: INNOVA SONIC PORTABLE, Display, Output, and Setup. The "INNOVA SONIC PORTABLE" directory is used for storing the collected flowmeter data, "Output" for storing output setup files of the flowmeter, "Display" for storing the display setup files of the flowmeter and "Setup" for storing setup and configuration files of the flowmeter.
During data acquisition, 1800 data points can be collected each hour (i.e. each data point requires 2 seconds). Data amount for each hour is 144K. Assuming the data storage of the PDA is 128M, each extension card is able to store over 900 hours of data or 160000 data points. If needed, users can choose extension cards with more storage.

5.1.2 Main Interface

The main interface is illustrated in Figure 3-1. The main menu is divided into two items: Utility and Options. Submenus under Utility are further classified into two modules: Data Acquisition and Table & Graph are menus used to perform data acquisition and display data table and graph, while Configuration, Display and Output are menus used for flowmeter setup. Options menu is used to display software copyright and version information.

Figure 3-1 Main Menu

5.1.3 Data Acquisition

To collect data, click “Data Acquisition” menu to enter Data Acquisition mode as shown in Figure 3-2. After inputting the File Name and Time of Acquisition, operators can click the “start” button to enter data acquisition mode. The Data that can be collected include: date & time, flow rate, flow velocity, net total flow, positive Total flow, negative total flow, Electronic Serial Number, pipe inner diameter, pipe outer diameter, pipe material, liner material and fluid type. Collected data will be stored under the “INNOVA SONIC PORTABLE” directory of the PDA extension card. Acquisition of each data point requires 2 seconds.

During data acquisition, graphs and data values of the flow rate and flow velocity are displayed on the screen in real time, each of them distinguished by different colors. If a curve exceeds the display range of the coordinate, it will be readjusted to be within the optimal display area. If necessary, you can also adjust it manually using a multiplier.

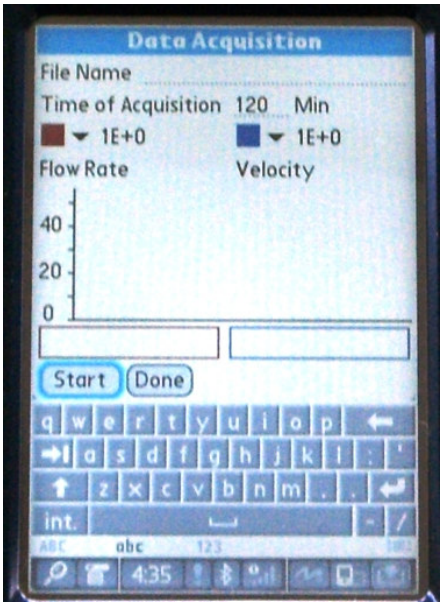


Figure 3-2 Data Acquisition

File Name: Give a name for the collected data. Input the name above the line manually, otherwise the name will be generated automatically.

Time of Acquisition: A period of time in which the data is collected. Input the time manually in minutes. The default time is 120 min.

Start Button: Click to start acquisition. During acquisition, this button becomes a “stop” button. If clicked, “stop” can stop the acquisition.

Done Button: Click to exit this page.

Coordinate: Curves that display Flow Rate and Flow Velocity during data acquisition.

Red Box: Displays the value of the Flow Rate.

Blue Box: Displays the value of the Flow Velocity.

5.1.4 Data Analysis and Graph

Select “Table & Graph” from the “Utility” menu to enter the data analysis mode as shown in Figure 3-3. This page is presented as a table where the date & time, flow rate, flow velocity, net totalizer, positive total flow, negative total flow of the collected data are shown in the form of a data table. To view the data more easily, you can adjust the display time interval by pressing different Time buttons. Press Left/Right/Up/Down arrow buttons to turn page.

Figure 3-3 Data Processing Table Screen

There are 4 buttons below the main page: “Load”, “Analyze”, “Graph” and “Done”. These buttons are used for loading data file, data analysis, graph display and exiting respectively.

“Load” page: Press “Load” button to enter the Load page as shown in Figure 3-4. After clicking a file and pressing the “OK” button, the contents of the selected file are displayed in a table. You can delete data files from this page by selecting a file and pressing the “Delete” button.

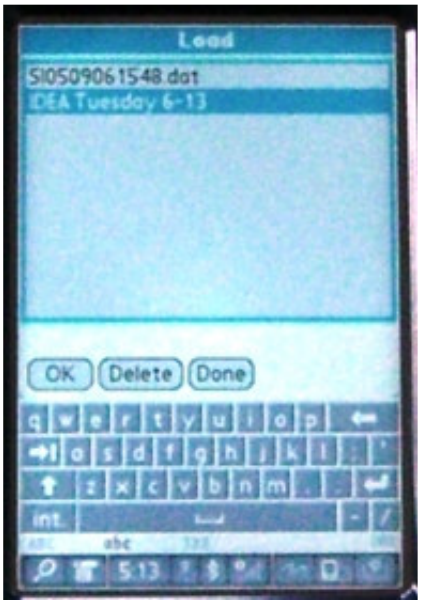


Figure 3-4 Load Data

“Analyze” page: Click “Analyze” button to enter Data Analyze page as shown in Figure 3-5. This table shows

the analysis results of the flow rate and flow velocity in the “Data Table”.

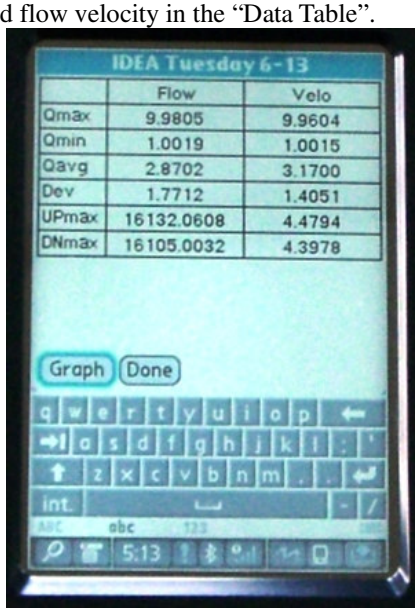


Figure 3-5 Data Analyze

Qmax: Maximum values of flow rate and flow velocity;

Qmin: Minimum values of flow rate and flow velocity;

Qavg: Average values of flow rate and flow velocity;

Dev: Deviation of flow rate and flow velocity;

UPmax: Maximum upwards variable rate of flow rate and flow velocity;

DPmax: Maximum downwards variable rate of flow rate and flow velocity;

“Graph” Page: Click “Graph” button to enter Data Curve Graph page as shown in Figure 3-6.

Data Curve Graph page displays curves of flow rate, flow velocity, net totalizer for the current file. Different curves are shown in different colors, which are indicated by the boxes with filled-in colors. Below the boxes are curve names that the boxes indicate. You can adjust the display area of a curve by using a multiplier. The time below the coordinate shows the time range of the curve currently displayed on the screen. You can browse through the page using Left/Right arrow button, or move data points using Left/Right triangle button.

When clicking a point within the graph display area, a cursor intersecting with the curve appears. At the same time, the value of the curve at the intersection point is displayed.

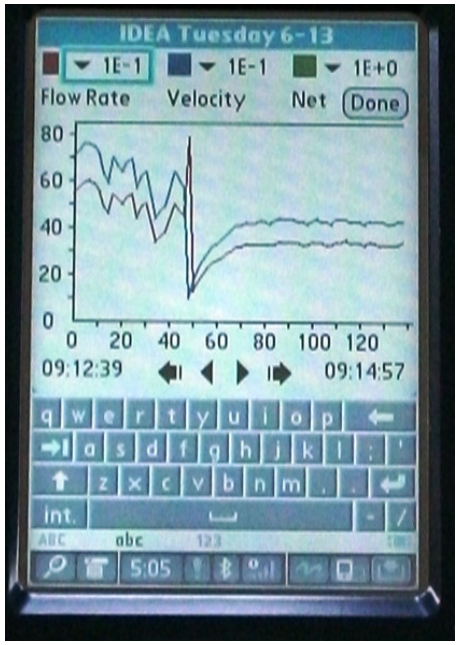


Figure 3-6 Data Curve Graph

5.2 UFMData Data Analysis and Printing Program

Note

Skip this section if you will not use a PC to process the collected data.

Running under the Windows operating system (Windows98 or above) at a PC terminal, the UFMData data analysis and printing program is used to process the ultrasonic flowmeter data collected by the PDA. The purpose of this program is to supplement the data processing function of the PDA. This program allows users to display graphs, print or save the files in Excel format, or browse and analyze the collected data in a table, enabling users to manage the flowmeter data more conveniently.

Flowmeter data are stored under the INNOVA SONIC PORTABLE directory of the PDA. You can set the PDA to “Driver Mode” and connect it with your PC.

Note

For information about how to connect the PDA with your PC, see TungstenT5_handbook_CS.pdf in the PDA CD-ROM.

The main window of this program is divided up into 4 pages: Data page, Graph page, Analyze page, Configuration page.

5.2.1 Data Browsing and Printing

After the program starts, the data browsing page will be displayed as shown in figure 3-7. This page allows you to browse and print the loaded data in a table, or adjust the display time of the data.

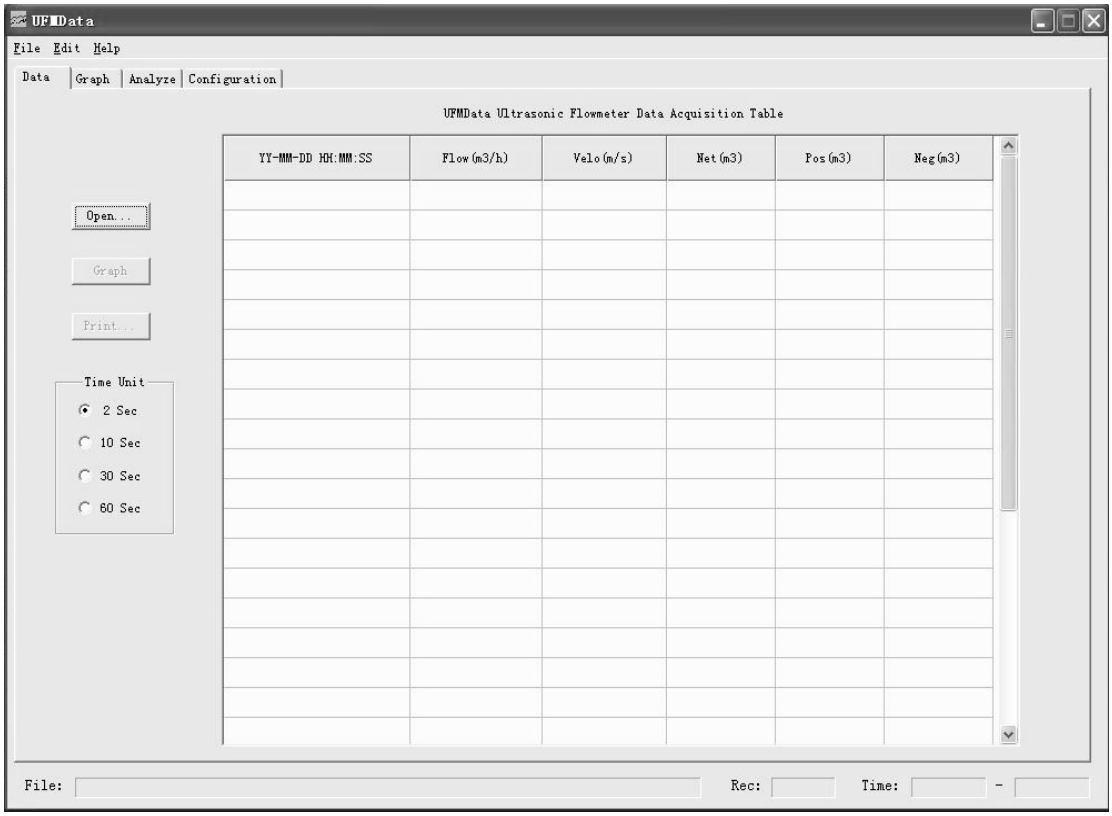


Figure 3-7 PC Data Table

"Open" button: Press this button to read in the flowmeter data files under "INNOVA SONIC PORTABLE" directory. Theses files are data collected by the PDA.

"Graph" button: Press this button to jump to the "Graph" page, where data are displayed in graphs.

"Print…" button: Press this button to print the table. Basic printing settings can be set in the Print dialog box.

"Time Unit" button: These buttons are used to adjust the display time. Available time units include 2 sec, 10 sec, 30 sec, and 60 sec. The default unit is 2 sec. When a time unit other than 2 sec is selected, the data in the table will be displayed and printed according to the selected time interval.

Below the data table, the "File" text box shows the File Path, "Rec" shows the number of the data and "Time" shows the time range for data acquisition.

The contents of the data table are: date & time, flow rate, flow velocity, net total flow, positive total flow and negative total flow.

5.2.2 Graph display and printing

Click "Graph" button in the data table to enter the Graph display page as shown in Figure 3-8. This page allows you to display and print loaded data by graphs intuitively. Users can adjust the color of the curve or change display unit as required.

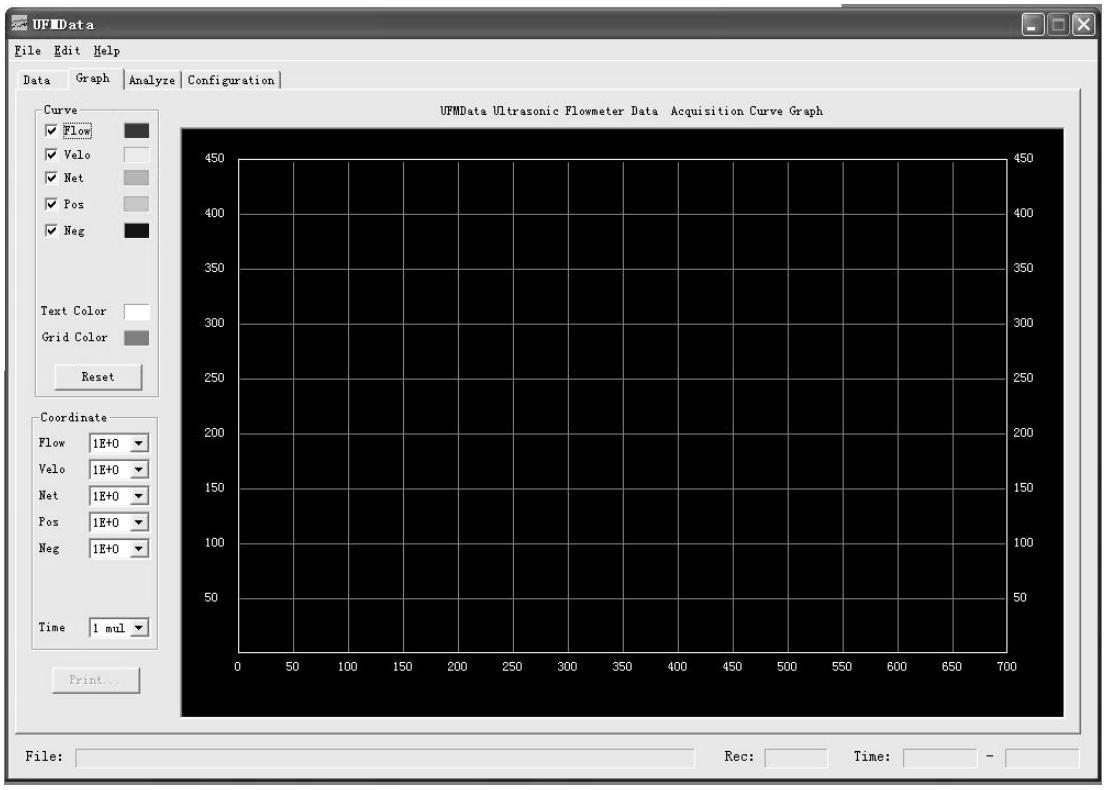


Figure3-8 Graph

This page is divided up into 2 parts: the graph display area with black background is the main page and the left is the graph display setup area.

“Curve” check box: Placing a check mark to the left of the graph name displays the corresponding graph in the graph area. Clicking the color box to the right of the graph name changes the color of the graph. You can change the text color of the coordinate by clicking the color box to the right of “Text Color”, or change the coordinate grid color by clicking “Grid Color” color box.

“Coordinate” check box: Select to display the graph at different magnifications. Magnification can be changed in the range of 10-4~108 (default is 100). Once it is changed, the curve displayed on the vertical ordinate will be changed accordingly. “Time”: Used to change range of the time scale. 1mul stands for 50 sec per scale, 2mul for 25 sec, 5mul for 10 sec and 10mul for 5sec. Once it is changed, the curve displayed on the horizontal ordinate will be changed accordingly.

“Reset” button: Press to restore the colors of the curves into defaults.

“Print” button: Press to print the graph.

At the bottom of the page, the “File” text box shows the File Path; “Rec” shows the number of the data and “Time” shows the time range for the data acquisition.

5.2.3 Data Analysis and Printing

As shown in Figure 3-9, the data analysis page is used to perform statistical analysis on collected flowmeter data. Its contents include:

Qmax: Maximum values of flow rate and flow velocity;

Qmin: Minimum values of flow rate and flow velocity;

Qavg: Average values of flow rate and flow velocity;

Dev: Deviation of flow rate and flow velocity;

UPmax: Maximum upwards variable rate of flow rate and flow velocity;

DPmax: Maximum downwards variable rate of flow rate and flow velocity;

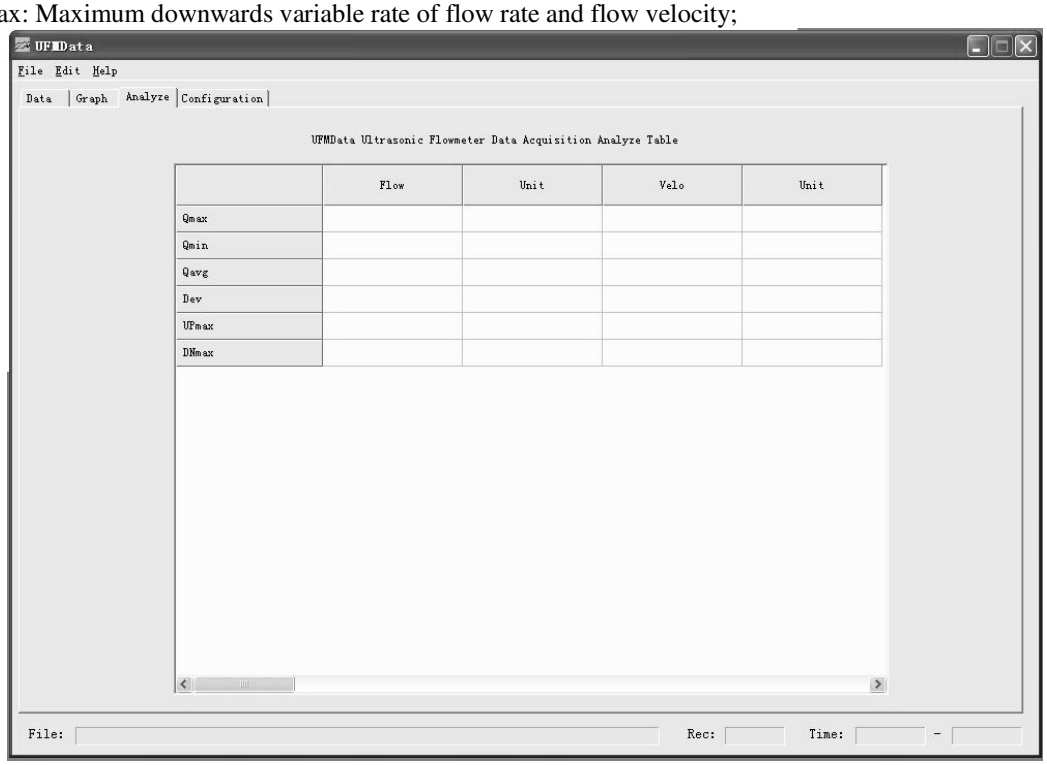


Figure 3-9 Data Statistical Analysis Page at PC Terminal

5.2.4 Configuration Information Display

As shown in Figure 3-10, this page displays the configuration information of the flowmeter. This page cannot be printed.

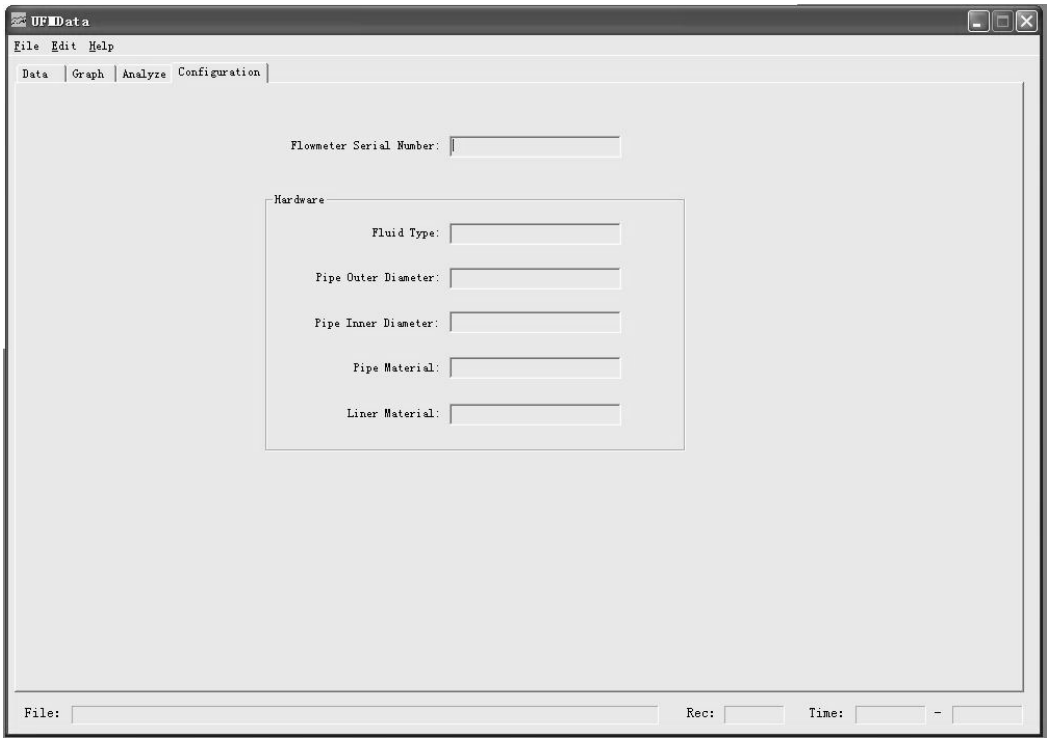


Figure 3-10 Configuration Information Display

Flowmeter Serial Number: Displays flowmeter serial number;

Fluid Type: Displays fluid type being measured;

Pipe Outer Diameter: Displays pipe outer diameter;

Pipe Inner Diameter: Displays pipe inner diameter;

Pipe Material: Displays pipe material;

Liner Material: Displays liner material.

5.2.5 Menu Functions

There are three menus in the Menu bar of the program: “File”, “Edit” and “Help”.

As shown in Figure 3-11, the File submenu has the following functions:

Figure 3-11 File Menu

“Open”: Opens the data files stored under the “INNOVA SONIC PORTABLE” directory;

“Save As”: Saves reports as text files (.txt) and Excel files (.xls);

“Print”: Prints data tables or graphs;

“Page Setup”: Sets the paper settings for printing, such as Paper Size, Paper Direction, etc.

“Print Preview”: Previews the printing contents.

As shown in Figure 3-12, the “Edit” submenu has the following functions:

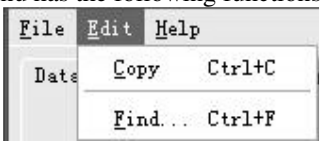


Figure 3-12 Edit Menu

“Copy”: Copies the selected region.

“Find”: Searches the data in the report.

As shown in Figure 3-13, the “Help” submenu has the following functions:

Figure 3-13 Help Menu

“Help”: Operating instructions for this software.

“About”: Software copyright, version information, and so on.

6 Windows Display Codes

6.1 List of Windows Display Codes

Flow/Totalizer Display	00	Flow Rate/Net Totalizer			49	Network Communication Tester
	01	Flow Rate/Velocity			50~54	For expansion
	02	Flow Rate/POS Totalizer		Input/Output	55	CL Mode Select
	03	Flow Rate/NEG Totalizer			56	CL 4mA or 0mA Output Value
	04	Date Time/Flow Rate			57	CL 20mA Output Value
	05~	* For expansion			58	* For expansion
	08	System Error Codes			59	CL Current Output
	09	Flow Today			60	Date and Time
Initial Parameter setup	10	Pipe Outer Perimeter			61	Software Vertion and ESN
	11	Pipe Outer Diameter			62	* For expansion
	12	Pipe Wall Thickness			63~71	* For expansion
	13	Pipe Inner Diameter			72	Working Timer
	14	Pipe Material			73~81	* For expansion
	15	Pipe Sound Velocity			82	Date Totalizer
	16	Liner Material			83	Automatioc Correction
	17	Liner Sound Velocity			84~89	* For expansion
	18	Liner Thickness		**Diagnosis**	90	Signal Strength and Quality
	20	Fluid Type			91	TOM/TOS*100
	21	Fluid Sound Velocity			92	Fluid Sound Velocity
	22	Fluid Viscosity			93	Total Time and Delta Time
	23	Transducer Type			94	Reynolds Number and Factor
	24	Transducer Mounting		Appendix	+0	Power ON/OFF time
	25	Transducer Spacing			+1	Total Working Hours
	26	Parameter Setups			+2	Last Power Off Time
	27	Cross-sectional Area			+3	Last Flow Rate
	28	Hold Previous Data			+4	ON/OFF Times
	29	Empty Pipe Setup			+5	Calculator
FlowUnit Options	30	Measurement Unit			+6	Medium Sound Velocity Variety Threshold
	31	Flow Rate Units			+7	Communication Protocol Sselect
	32	Totalizer Units			-0	* For expansion
	33	Totalizer Multiplier		Shortcut Keys	Flow	Flow Rate
	34	Net Totalizer			Velo	Flow Velocity
	35	Positive Totalizer			+Total	Positive Total
	36	Negative Totalizer			-Total	Negative Total
	37	Totalizer Reset			Sig	signal Strength and Quality
	38	Manual Totalizer			Aout	Analog Output
Setup Options	40	Damping			Error	Error Code
	41	Low Flow Cutoff Value			Comm	Communication Information Between PDA
	42	Set Zero				And Flowmeter
	43	Reset Zero				
	44	Manual Zero Point				
	45	Scale Factor				
	46	Network ID Address Code				
	47	System Lock				
	48	* For expansion				

6.2 MENU Display explanation

This section will cover individual menu displays indepth.

Flow Rate/Net Totalizer

MENU 0 0

```
Flow 0.1154 m3/h  *R
NET          +97×1m3
```

Displays flow rate and net totalizer.

If the net totalizer has been turned off (refer to M34), the net totalizer value displayed is the total prior to its turn off.

Flow Rate/Velocity

MENU 0 1

```
Flow  0.1129 m3/h *R
Vel      1.0415  m/s
```

Displays flow rate and velocity.

Flow Rate/Positive Totalizer

MENU 0 2

```
Flow 0.1129  m3/h *R
POS            0X1m3
```

Displays flow rate and positive totalizer.

Select the positive totalizer units in Window M32.

If the positive totalizer has been turned off, the positive totalizer value displayed is the total prior to its turn off.

Flow Rate/Negative Totalizer

MENU 0 3

```
Flow 0.1120  m3/h *R
NEG            0X1m3
```

Displays flow rate and negative totalizer.

Select the negative totalizer units in Window M32.

If the negative totalizer has been turned off (refer to M36), the value displayed is the total prior to turn off.

Date & Time/Flow Rate

MENU 0 4

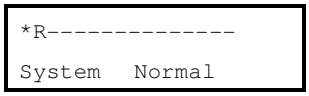
```
03-04-03 15:49:40 *R
Flow      0.1116m3/h
```

Displays the current date & time and flow rate.

The time setting method is found in Window M60.

System Error Codes

MENU 0 8

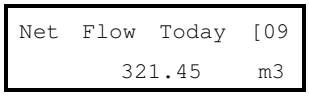


Displays the working condition and the system error codes. More than one error code can occur at the same time.

The explanations of error codes and detailed resolution methods can be found in "Troubleshooting" chapter.

Flow Today

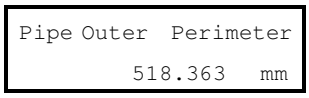
MENU 0 9



Displays net total flow today.

Pipe Outer Perimeter

MENU 1 0

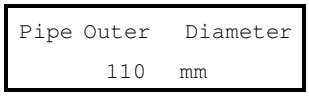


Input pipe outer perimeter in this window.

If the outer diameter is the known parameter, input pipe outer diameter in Window No.11. It is NOT necessary to enter both Outer PERIMETER & Outer DIAMETER, if you enter one of these values, the instrument will calculate the other.

Pipe Outer Diameter

MENU 1 1

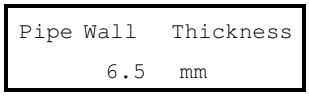


Input pipe outer diameter in this window, or enter pipe outer perimeter in Window M10. The pipe outer diameter must range from 1" to 200" (25mm to 6000mm).

Note: Input either pipe outer diameter or pipe outer perimeter.

Pipe Wall Thickness

MENU 1 2



Input pipe wall thickness in this window. If the pipe inner diameter is already known, skip this window and input it in Window M13.

Pipe Inner Diameter

MENU 1 3

```
Pipe Inner  Diameter
        97 mm
```

Input pipe inner diameter in this window. If the pipe outer diameter (or perimeter) and pipe wall thickness has been entered, press [▼] to skip this window.

Note: Input either pipe wall thickness or pipe inner diameter.

Pipe Material

MENU 1 4

```
Pipe  Material    [14
0. Carbon  Steel
```

Input pipe material in this window. The following options are available (by[▼]、[▲] buttons or numerical keys).

0. Carbon Steel
1. Stainless steel
2. Cast Iron
3. Ductile Iron
4. Copper
5. PVC
6. Aluminum
7. Asbestos
8. FiberGlass-Epoxy
9. Other

Refer to item 9 “Other”; it is possible to input other materials, which are not included in previous eight items. Once item 9 is selected, the relevant pipe sound velocity must be inputted in Window M15.

Pipe Sound Velocity

MENU 1 5

```
Pipe Sound Velocity
                  m/s
```

Input pipe sound velocity in this window. This function is only used when item 9 “Other” is selected in Window M14. At the same time, this window cannot be visited. System will calculate automatically according to the existing parameters.

Liner Material

MENU 1 6

```
Liner  Material   [16
0.  None, Liner
```

Select the liner materials in this window.

The following options are available:

0. None
1. Tar Epoxy

2. Rubber
3. Mortar
4. Polypropylene
5. Polystryol
6. Polystyrene
7. Polyester
8. Polyethylene
9. Ebonite
10. Teflon
11. Other

Item 11 “Other” is available to input other materials that are not included in the previous list. Once the “Other” is selected, the relevant liner sound velocity must be inputted in Window M17.

Liner Sound Velocity

MENU 1 7

```
Liner Sound Velocity
        0 m/s
```

Input liner sound velocity in this window. It can only be visited when item “Other” in Window M16 is selected.

Liner Thickness

MENU 1 8

```
Liner Thickness  [18
                0 mm
```

Input liner thickness in this window. It can only be visited when a definite liner is selected in Window M16.

Fluid Type

MENU 2 0

```
Fluid    Type    [20
0.  Water
```

Select fluid type in this window. The following options are available:

0. Water
1. Sea Water
2. Kerosene
3. Gasoline
4. Fuel Oil
5. Crude Oil
6. Propane
7. Butane
8. Other
9. Diesel Oil
10. Castor Oil
11. Peanut Oil
12. Gasoline #90
13. Gasoline #93
14. Alcohol
15. Water (125C)

"Other" refers to any fluid. The relevant sound velocity must be inputted in Window M21.

Fluid Sound Velocity

MENU 2 1

```
Fluid Sound Velocity
      1482.9m/s
```

Input fluid sound velocity in this window. It can only be used when item "Other" is selected in Window M20, i.e. it is unnecessary to input when it is one of the fluids listed in Window M20. The instrument uses default value.

Fluid Viscosity

MENU 2 2

```
Fluid  Sound     [22
      1.0038cST
```

Input fluid's kinematics viscosity in this window. It can only be used when item "Other" is selected in Window M20. To Calculate Centistokes, Divide Centipoises by the Specific Gravity of the fluid.

Transducer Type

MENU 2 3

```
Transducer Type  [23
0. Standard
```

For the Innova-Sonic, parameter 0 (standard) should be selected regardless what transducer type is used.

Transducer Mounting

MENU 2 4

```
Transducer  Mounting
0.       V
```

Four mounting methods are available:

0. V (V Method, sound waves bounce 2 times)
1. Z (Z Method, sound waves do not bounce, but transit the pipe)
2. N (N Method, sound waves bounce 3 times. Small Pipe)
3. W (W Method, sound waves bounce 4times. Very Small Pipe)

Transducer Spacing

MENU 2 5

```
Transducer   Spacing
     148.666  mm
```

The operator must mount the transducer according to the transducer spacing displayed (be sure that the transducer spacing is measured precisely during installation). The system will display the data automatically after the pipe parameters have been entered.

For different transducers, the meanings of the number displayed in M25 are different. See the table below:

Transducer selected in MENU23	The meaning of the number displayed in Window MENU23
0. Standard	The distance between the corresponding terminal faces of the 2 clamp-on transducers (See figure 4-1.)
1. Insertion Type S	The distance between the centers of the 2 plug-in transducers
2. Insertion Type H	The distance between the centers of the 2 plug-in transducers
3. Insertion Type E	The distance between the centers of the 2 plug-in transducers
4. User Type	The distance between the corresponding terminal faces of the 2 transducers. (See figure 4-1.)

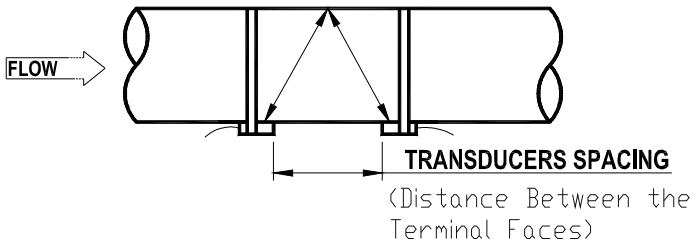


Figure 4-1 Clamp-on transducer Spacing (Distance Between the 2 Terminal Faces)

Note

The actual spacing must be identical to the value displayed in Window M25.

Initial Parameter Setups and Save

MENU 2 6

```
Parameter Setups [26
Entry to SAVE
```

Load and save parameters in this window. 18 groups are available to load and save by three methods:

0. Entry to Save
1. Entry to Load
2. To Browse

Select “Entry to Save”, press ENT. An ID code and the original parameters are displayed in the window. Press UP/DOWN ARROW to move the ID code, and then press the ENT key again to save the current parameter in the current ID..

When selecting “Entry to Load”, press ENT, and the system will read and calculate the parameters automatically and display the transducer mounting spacing in Window M25.

Cross-sectional Area

MENU 2 7

```
Cross-sectional Area
    31415.9     mm2
```

Displays the cross-sectional area inside the pipe.

Holding with Poor Signal

MENU 2 8

```
Hold with PoorSig [28
NO
```

Select "Yes" to hold last good flow signal displayed if the flowmeter experiences a poor signal condition. This function allows continued data calculation without interruption. This would be used in circumstances of continuous flow, but gaps in the fluid, (air bubbles or slugs of solids) which pass through the flow stream causing the signal quality to reduce. Once these disturbances have passed, the Signal Quality should return to a higher value, if holding with Poor Sig is set to YES, then the meter will keep the existing flow rate during these flow disturbances.

Empty Pipe Setup

MENU 2 9

```
Empty pipe setup [29
30
```

This parameter is used to overcome the possible problems that usually show up when the pipe being measured is empty. Since signals can be transmitted through the pipe wall, the flowmeter may still read a flow while measuring an empty pipe. To prevent this from happening, you can specify a value. When the signal quality falls below this value, the measurement stops automatically. If the flowmeter is already able to stop measuring when the pipe is empty, a value in the range of 30 to 40 should also be entered in this window to ensure no measurement when the pipe is empty. It should be understood that the instrument is NOT designed to function correctly on an empty pipe.

Measurement Units

MENU 3 0

```
Measurement Units In
0.  Metric
```

Select the measurement unit in this window as follows:

0. Metric
1. English

Factory default is metric.

Flow Rate Units

MENU 3 1

```
Flow Rate Units  [31
m3/h
```

Select flow rate units and time units.

0. Cubic Meters (m3)
1. Liters (l)
2. (American) Gallons (gal)
3. Imperial Gallons (ig)
4. Million Gallons (mg)
5. Cubic Feet (cf)
6. American Barrels (bal)

7. Imperial Barrels (ib)
8. Oil Barrels (ob)

The following time units are available:
/Day
/Hour
/Min
/Sec

Factory default is Cubic Meters/hour.

Totalizer Units

MENU 3 2

```
Totalizer  Units [32
  Cubic  Meters (m3)
```

Select totalizer units in this window. The available unit options are as same as those found in Window M31. Factory default is Cubic Meters.

Totalizer Multiplier

MENU 3 3

```
Totalizer Multiplier
  0.          X0.001
```

The totalizer multiplier acts as the function to increase the totalizer indicating range. The totalizer multiplier can be applied to the positive totalizer, negative totalizer and net totalizer at the same time. The following options are available:

0. x 0.001 (1E-3)
1. x 0.01
2. x 0.1
3. x 1
4. x 10
5. x 100
6. x 1000
7. x 10000(1E+4)

Factory default factor is x1

ON/OFF Net Totalizer

MENU 3 4

```
Net  Totalizer    [34
          ON
```

Turn On or Off the Net totalizer in this window. “ON” indicates the totalizer is turned on, while “OFF” indicates it is turned off. When it is turned off, the net totalizer displays in Window M00 will not change. Factory default is “ON”.

ON/OFF Positive Totalizer

MENU 3 5

```
POS   Totalizer   [35
          ON
```

Turn On or Off the positive totalizer in this window. “ON” indicates the flowmeter will totalize flow in the positive direction. When it is turned off, the positive totalizer display in Window M02 will not change. Factory default is “ON”.

ON/OFF Negative Totalizer

MENU 3 6

```
NEG   Totalizer  [36
        ON
```

Turn On/off negative totalizer in this window. “On” indicates the totalizer is turned on. When it is turned off, the negative totalizer displays in Window M03 will not change. Factory default is “ON”.

Totalizer Reset

MENU 3 7

```
Totalizer Reset? [37
     Selection
```

Reset totalizer and all parameters in this window. Press [ENT]; move UP or DOWN arrow to select “YES” or “NO”. After “YES” is selected, the following options are available:

None
All
NET
POS
NEG.

Using the UP or DOWN Arrows, select the desired totalizer you wish to reset, then press ENT.

Manual Totalizer

MENU 3 8

```
Manual Totalizer
Press ENT When Ready
```

The manual totalizer is a separate totalizer. Press ENT to start, and press ENT to stop it. It is used for flow measurement and calculation.

Damping

MENU 4 0

```
Damping          [40
       10  sec
```

The damping factor ranges from 0～999 seconds.

0 indicates no damping; 999 indicates the maximum damping.

The function of damping is to display the data smoothly. Its principle is the same as that in a single-section RC filter. The damping factor value corresponds to the circuit time constant. Usually a damping factor of 3 to 10 is recommended in applications.

Low Flow Cutoff Value

MENU 4 1

```
Low Flow Cutoff Val.
      0.01  m/s
```

Low Flow Cutoff is used to make the system display as "0" value at lower and smaller flows to avoid any invalid totalizing. For instance, if the cutoff value is set as 0.03, system will take all the measured flow values below ±0.03 as "0". Usually 0.03 is recommended in most applications.

Set Zero

MENU 4 2

```
Set Zero          [42
Press ENT to go
```

When fluid is in the static state, the displayed value is called the "Zero Point". When the "Zero Point' is not at zero in the flowmeter, the difference is going to be added into the actual flow values and measurement differences will occur in the flowmeter.

Set zero must be carried out after the transducers are installed and the flow inside the pipe is in the **absolute static state (no liquid movement in the pipe)**. *It is imperative that the user understands that simply closing a valve, or securing a pump will NOT guarantee the complete stoppage of fluid movement in the pipe. Sufficient time should be allowed for the hydraulic forces in the fluid to subside PRIOR to activating the Set Zero Command.*

Once you are positive of NO FLUID MOVEMENT in the pipe system you may select the Set Zero command with will adjust the instruments "Zero Point" resulting from different pipe mounting locations and parameters as compared to the flow calibration laboratory. The measuring accuracy at low flow is consequently enhanced.

Press [ENT], wait approximately 45 seconds.

Press MENU 00 to return to the main flow display and read zero flow.

Activating the "Set zero" while there is flow may cause the flow to be displayed as "0". If so, it can be recovered via Window M43.

Reset Zero

MENU 4 3

```
Reset Zero        [43
          No
```

Select "YES" in this window to reset "Zero Point" which was set by the user. Selecting this function will reverse the Set Zero command of Menu 42. The previous Zero Setting will be restored in the flow meter.

Manual Zero Point

MENU 4 4

```
Manual Zero Point [44
         0m3/h
```

This method is not commonly used. It is only suitable for experienced operators to set zero under conditions where it is not preferable to use other methods. Enter the value manually to add to the measured value to obtain the actual value. For instance:

Actual measured value = 250 m^3/H
Offset Value = 10 m^3/H
INNOVA SONIC PORTABLE Display = 240 m^3/H

Normally, set the value to "0".

Scale Factor

MENU 4 5

```
Scale Factor     [45
          1
```

Due to variations encountered in real field application installations as compared to perfect laboratory calibration systems, there may exist a circumstance in which the measured flow value disagrees with a customers know reference value. Causes for these variations can be pipe internal conditions, hydraulic flow profiles inside the piping systems, etc…Should the "measured" flow value differ from the "real" flow value, a scale factor can be applied to offset this. For example, should the instrument display 90 GPM, but the customer reference indicates the flow is actually 100 GPM, a value of 1.1 would be entered in Menu 45.

Ideally, the Scale Factor should remain at its default value of 1 for the highest performance.

System Lock

MENU 4 7

```
System Lock      [47
**** Unlock ****
```

"Lock" the instrument.

Once the system is locked, any modification is prohibited in the system, but parameters are still readable. "Unlock" by the password only. The password is composed of 1 to 4 numbers.（Please contact us if the password is forgotten.）

CL Mode Select

MENU 5 5

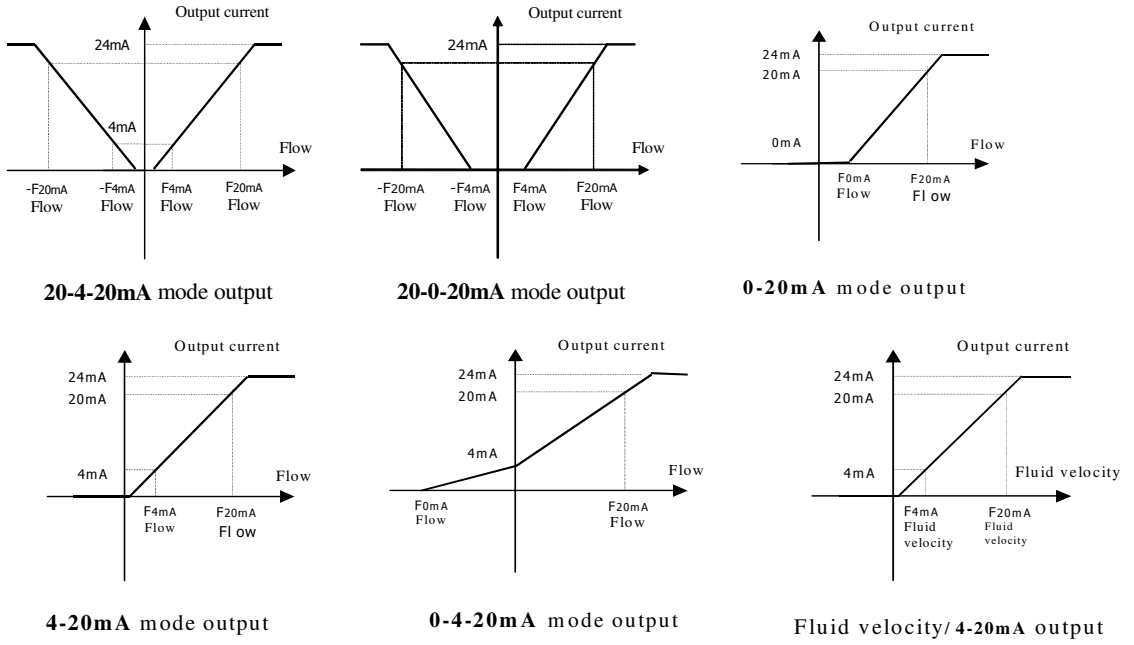
```
CL Mode Select  [55
0. 4 - 20mA
```

Select a CL Output Mode in this window. The following are available parameters:

0.	4-20mA Output Mode	set up the output range from 4-20mA
1.	0-20 mA	set up the output range from 0-20mA
2.	0-20mA via RS232	set up to control by Serial Port (205 Series Only)
3.	4-20mA vs Fluid	set up the output range 4-20mA in flow units (GPM)
4.	20-4-20mA Mode	set up the output range from 20-4-20mA

5. 0-4-20mA Mode set up the output range from 0-4-20mA
6. 20-0-20mA Mode set up the output range from 20-0-20mA
7. 4-20mA VS. Velocity set up the output range from 4-20mA in Velocity units (FPS)

Current output characteristics of each mode are shown below. Users can select one mode to meet their requirements



20-4-20mA mode output **20-0-20mA** mode output **0-20mA** mode output

4-20mA mode output **0-4-20mA** mode output Fluid velocity/**4-20mA** output

Figure4-2 4-20A Output Characteristics

In six graphs shown above, flow F_{0mA} or F_{4mA} indicates the value that the user entered in Window M57; and flow F_{20mA} indicates the value that users entered in Window M58. In the 4-20mA and 0-20mA modes, F_{0mA}（or F_{4mA}）and F_{20mA} can be selected as a positive or negative flow value as long as the two values are not the same. As for modes 20-4-20mA and 20-0-20mA, the INNOVA SONIC PORTABLE ignores the positive and negative value of the actual flow; therefore, both F_{0mA}（or F_{4mA}） and F_{20mA} must be selected as positive flow values.

In mode 0-4-20mA, F_{0mA} must be select as a negative value and F_{20mA} as a positive value. Furthermore, in mode 4-20mA, the output current is indicated as velocity.

With accuracy better than 0.1%, The CL output of INNOVA SONIC PORTABLE is fully programmable and can be set to various output modes such as 4~20mA or 0~20mA. Use Window M55 to select the output mode.

Input the flow value represented by 4mA in Window M56 and input the value represented by 20mA in Window M57. For example, if the flow range of a pipe is 0~1000m3/h, input 0 in window M56 and 1000 in M57. If the flow range is 1000~0~2000m^3/h, without reference of the flow direction, you can use 20~4~20mA mode (select in Window M55) by inputting 1000 in Window M56 and 2000 in M57. If the flow direction is considered, 0~4~20mA output mode can be selected. When the flow is in negative direction, the output current is in the range of 0~4mA. When the flow is in positive direction, the output current is in the range of 4~20mA. Output mode is selected in Window M58. Input “-1000” in Window M56 and “2000” in M57.

Use Window M58 to validate whether the current loop itself has been “calibrated” or not. To do so, follow the steps below:

Press MENU 5 8 ENT key. Move out “0mA”, “ 4mA”, “8mA” in turn using ▲/+ or ▼/– and at the same time measure the output of the current loop with a precise current meter. Calculate the errors between the two values and check weather the error is in the allowed error range. If not, calibrate the current loop according to the §3.36 section of this chapter.

Window M59 allows you to check the current CL output that is varied with the flow.

CL 4mA or 0mA Output Value

MENU 5 6

```
CL 4mA Output  Value
        0 m3/h
```

Set the CL output value according to the flow value at 4mA or 0mA.（4mA or 0mA are determined by the settings in Window M56）. The flow unit's options are as same as those in Window M31. Once "velocity 4-20mA"is selected in Window M56, the unit should be set as m/s.

CL 20mA Output Value

MENU 5 7

```
CL 20 mA Output Value
      14400 m3/h
```

Set the CL output value according to the flow value at 20mA. The flow unit is the same as that found in Window M31.

CL Checkup

MENU 5 8

```
CL  Checkup      [58
Press ENT When Ready
```

Check if the current loop has been calibrated before leaving the factory. Press ENT, move ▲/+or ▼/- separately to display 0mA, 4mA till 24mA, and at the same time, check with an ammeter to verify that CL output terminals No. 31 and 32 agree with the displayed values. It is necessary to re-calibrate the CL if over the permitted tolerance.

Analog Output Calibration

Note: Under general conditions, don't perform this operation unless the current value displayed on Window M58 is not identical to the actual output. Each flowmeter has been strictly calibrated by the manufacturer before leaving the factory.

Before calibrating the analog input, you must enter the hardware-debugging window using the following procedure:

Press MENU - 0 ENT, input the password "4213068" and press ENT key again to open the window. The unfolded window is available only in current power-on period. It is automatically closed once you turn off the power.

Press MENU - 1 ENT to enter the calibration mode for CL 4mA output. Measure the output of the current loop with a precise current meter and at the same time adjusts displayed data by using ▲/+ or ▼/– key. Stop adjusting when the current meter shows 4.00.

Then, press ENT key to enter the calibration mode of the CL 20mA output and calibrate it in the same way as in the 4mA.

Stored in the EEPROM, the results of calibration will not be lost even when the power is off.

CL Current Output

MENU 5 9

```
CL Current Output [59
     0.0000   mA
```

Displays CL current output. The display of 10.0000mA indicates that CL current output value is 10.0000mA。If the difference between displaying value and CL output value is too large, the current loop then needs to be re-calibrated accordingly.

Date and Time Settings

MENU 6 0

```
YY-MM-DD  HH:MM:SS
03-04-04  10:05:04
```

Date and time modifications are made in this window. The format for setting time setting is 24 hours. Press ENT, wait until “>” appears, the modification can be made.

Software Version and ESN

MENU 6 1

```
Ultrasonic Flowmeter
    S/N=04071188
```

Displays software version and electronic serial number (ESN) of the instrument. This ESN is uniquely assigned to each INNOVA SONIC PORTABLE flowmeter ready to leave the factory. The factory uses it for files setup and for management by the user.

Working Timer

MENU 7 2

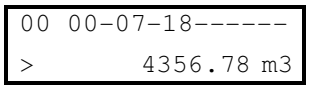
```
Working  Timer    [72
   00000011:16:38
```

Display the totalized working hours of the INNOVA SONIC PORTABLE since last reset. It is displayed by HH:MM:SS. If it is necessary to reset it, press ENT, and select “YES”.

Date Totalizer

MENU 8 2

```
Date  Totalizer   [82
```



This window makes it possible to review the historical flow data totalizer for any day for the last 64 days, any month for last 64 months and any year for last 5 years.

Press ENT, use the ▲/+ or ▼/- to review totalizer in day, month or year. Press “0” to review by day, “1” for month and “2” for year.

Use the ▲/+or ▼/- to review the flow total for a specific day, month or year.

For instance, to display the flow total for July 18, 2000, the display “----------” at the upper right corner of the screen indicates that it was working properly the whole day. On the contrary, if “G” is displayed, it indicates that the instrument gain was adjusted at least once. Probably it was offline once on that day. If “H” is displayed, it indicates that poor signal was detected at least once. Also, it indicates that the operation was interrupted or problems occurred in the installation.

For details, please refer to the “Troubleshooting” chapter.

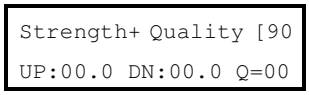
Automatic Correction

MENU 8 3

With the function of automatic flow correction, the flow lost in an offline session can be estimated and automatically amended. The estimation is based on the average value, which is obtained from flow rate before going offline and flow measured after going online the next time, multiplied times the time period that the meter was offline. Select “On” to enable this function or select “OFF” to disable it.

Signal Strength and Quality

MENU 9 0



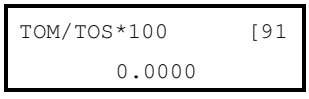
Displays the measured upstream and downstream signal strength and overall signal quality Q

Signal strength is indicated from 00.0～99.9. A reading of 00.0 indicates no signal detected, while 99.9 indicates maximum signal strength. Normally the signal strength should be ⩾60.0.

Signal quality Q is indicated by 00～99. Therefore, 00 indicates the poorest signal while 99 indicates the best signal. Normally, signal quality Q value should be better than 50.

TOM/TOS*100

MENU 9 1



Display the ratio between the actual measured transit time (Time of Flight Measured) and the calculated transmit time (Time of Flight Suspected) according to user's requirement. This is in essence an "Actual VS Theoretical" comparison. Normally the ratio should be 100±3%. If the difference is too large, the user should check if the parameters are entered correctly, especially the sound velocity of the fluid and the installation of the transducers.

Fluid Sound Velocity

MENU 9 2

```
Fluid Sound Velocity
      0.0000m/s
```

Displays the measured fluid sound velocity. Normally this value should be approximately equal to the entered value in Window M21. If the difference is too large, it probably results from an incorrect value entered in Window M21 or improper installation of the transducers.

Total Time and Delta Time

MENU 9 3

```
Total  Time,  Delta
Time
 8.9149uS, -171.09nS
```

Display the measured ultrasonic average time (unit: uS) and delta time of the upstream and downstream (unit: nS) time. The velocity calculation in INNOVA SONIC PORTABLE is based on the two readings; especially the delta time will best indicate if the instrument is running steadily. Normally the fluctuation in the ratio of the delta time should be lower than 20%; Otherwise, the system may not run steadily. It is, then, necessary to check if the transducers are installed properly or if the parameters have been entered correctly.

Reynolds Number and Factor

MENU 9 4

```
Reynolds Number  [94
 0.0000      1.0000
```

Display the Reynolds number that is calculated by INNOVA SONIC PORTABLE flowmeter and the factor that is set currently by the flowmeter. Normally this scaling factor is the average of line and surface velocity factor inside the pipe.

Power ON/OFF Time

MENU + 0

```
ON/OFF  Time    [+0
Press ENT When Ready
```

To view the power on/off time and flow rate for the last 64 update times to obtain the offline time period and the corresponding flow rate. Enter the window, press ENT to display the last update before the last 64 times of on/off time and flow rate values. “ON” on right hand indicates that time power is on; “00” on the upper left corner indicates “00-07-18 12:40:12” the date time; flow rate is displayed in the lower right corner.

Total Working Hours

MENU + 1

```
Total Work Hours  [+1
   00000113:02:08
```

This function makes it possible to view the total working hours since the INNOVA SONIC PORTABLE left the factory. The figure on the right indicates that the total working hours since the flowmeter left the factory is 113 hours 2 minutes 8 seconds.

Last Power Off Time

MENU + 2

```
Last Power Off  Time
 03-04-04  11:33:02
```

Displays the last power off time.

Last Flow Rate

MENU + 3

```
Last Flow Rate    [+3
     100.43m3/h
```

Displays the last flow rate.

Total ON/OFF Times

MENU + 4

```
ON/OFF   Times    [+4
          40
```

Display total on/off times since the INNOVA SONIC PORTABLE leaves the factory.

Calculator

MENU + 5

```
Calculator: Input X=
0
```

This window is a calculator capable of functional operation. How to use: Input the first parameter X, then

select an operator. If this operation has a second parameter, input the second parameter Y and put the result of the operation in X. For example:
To calculate 1+2, press MENU + 5 1 ENT, select operator "+" by using ▲/+, and press ENT 2 ENT.
This calculator also has a register function, which can be selected by operator selection.

Note: The calculator can also be used in a measuring process, and the measurement will not be affected.

Shortcut Key for Flow rate

Flow

```
Flowrate:
      +000000E+00m3/h
```

Displays flow rate, which equals to the contents of Flow when issuing command M00.

Shortcut Key for Flow Velocity

Velo

```
Flow  Velocity:
      +000000E+00m/s
```

Displays flow velocity, which equals to the contents of Vel after issuing command M01

Shortcut Key for POS Total Flow

+Total

```
POS Total Flow:
+0029383E−2m3
```

Displays positive total flow, which equals to the contents of POS after issuing command M02.

Shortcut Key for NEG Total Flow

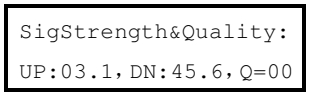
-Total

```
NEG Total Flow:
      +0029383E−2m3
```

Displays negative total flow, which equals to the contents of NEG after issuing command M03.

Shortcut Key for Signal Strength and Quality

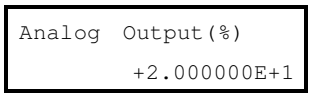
Sig



Displays signal strength and quality, which equals to the contents displayed in the window after issuing command M90.

Shortcut Key for Analog Output

Aout



Displays analog output（ 4~20mA）information.

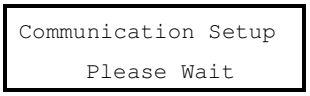
Shortcut key for error code

Error

Displays error codes during an operation. See chapter 5 for error code contents.

Shortcut Key for Communication Setup

Comm



Displays the communication condition between the PDA and the Flowmeter. This window Displays ”OK” if the connection has been made correctly. If not, it displays “Failure”, and you should check the Bluetooth Communications. Under normal conditions, you should not conduct detection repeatedly using this button, otherwise you may cause the PDA to shutdown.

6.3 Displaying Data in Full-Screen View

If you press the data display area with the stylus while measuring, display contents will be displayed in full screen and large font. Press any point in the full screen display area to return to normal display mode. This function makes it easier for operators to read data.

Only MENU 00~04 and the display contents of shortcut key Flow, Vel, +Total, -Total can be displayed in full screen view.

6.4 Defaults Restoration

Press MENU 3 7 key. After opening Window No.37, press . ◄ directly to reset the settings to defaults.

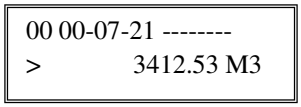
6.5Analog Voltage Output

Connect a 250Ω resistance to the current loop in parallel to transform 4~20mA into 1~5V voltage output.

6.6 Check Flow of Every Day/Month/Year

Window M82 allows you to read flow data history and the operating state of the instrument in the past 64 days.

Press MENU 8 2 key and select sub item No.0 “Day”. Then, the character is displayed as shown in right. The “00” – “63” in the upper left corner stands for serial number, the “00-07-21” in the middle for date and the “--------” in the upper right corner for operating state. Only “--------” being displayed on the status bar indicates the instrument was working properly at that working day. If there are other characters displayed, see the error code instruction for reference. The data 3412.53 in the bottom shows the net total flow of that working day.



To read the total flow of a month, press MENU 8 2 key and select sub item No.1 “Month”.

To read the total flow of a year, press MENU 8 2 key and select sub item No.2 “Year”.

6.7View Electronic Serial Number and Other Details

Every INNOVA SONIC PORTABLE ultrasonic flowmeter is distinguished by a unique electronic serial number (ESN) for ease of manufacturer and users’ management. (Note: Faked flowmeters don't have unique serial numbers or not at all). Use window M61 to view ESN and the type of the machine.

Window M+1 allows you to view the total working time since the flowmeter leaves the factory.

Window M+4 allows you to view total On/Off times since the flowmeter leaves the factory.

See “Troubleshooting” chapter for detailed information.

7 Troubleshooting

With a highly reliable design, the INNOVA SONIC PORTABLE has a very low failure rate. However, problems may occur due to unskilled operation, setting errors or measurements made in an extremely undesirable working condition. For this reason, the INNOVA SONIC PORTABLE has made improvements in its self-diagnostic function. Problems detected are displayed in time order in code form on the upper right corner of the LCD screen. Hardware malfunctions, though generally checked after power is on, can also be detected while the device is working normally. Information about other problems caused by wrong settings or undesirable working conditions can also be displayed. There are two kind of errors displayed in INNOVA SONIC PORTABLE:

(1) Error messages that are displayed during self-test after the power is switched on. After entering the measurement mode, if there is an error, " * F" will be displayed at the top left corner of the screen. Check displayed information and perform specific steps according to the following tables. If problems persist, please contact the manufacture.
(2) Errors concerning the specific signal received or wrong settings can be displayed in Window M08 in the form of an error code. Errors and solutions are listed in Table 6-1 and 6-2.

Table 6-1 Self Test Information, Cause and Solution

Error information	Cause	Solution
Rom Parity Error	* System ROM illegal or error	* Contact the manufacturer
Stored Data Error	* Stored Data Error	* Restart or contact the manufacturer
Hardware error	* Fatal error in sub CPU circuit	* Restart or contact the manufacturer
PF or Timer Slow Error PF or Timer Fast Error	* System clock error	* Contact the manufacturer
CPU or Interruption error, retry	*	* restart
Stored Data Error	* System RAM has problems	* Restart or contact the manufacturer
Time Or Batt Error	* System time chip error	* Restart or contact the manufacturer
When keys are pressed, no response from the screen No display or display disorderly.	*Disoperation，poor cable contact on the panel or insufficient power supply in the PDA	* soft reset； * Check whether the cables on the panel are contacted well or the PDA battery is fully charged.
No response when keys are pressed on the PDA. Press “comm”,display “OK”.	*The software is unauthorized, that is the “Serial Number” in the “About” window isn’t identical to the serial number on the transmitter.	*If you bought several flowmeters, please check whether the “Serial Number” is identical to that of the transmitter. Otherwise, contact the company.
No response when keys are pressed on the PDA. Press “comm”,display “Failure”	*The cable connected to the PDA is broken or not properly linked.	*Check the cable
When turning off the PDA, the response of the program is too slow or no response at all.	*The shutdown sequence in not correct. The transmitter is switched off first.	*On completing the measurement, the PDA program should be closed before switching off the transmitter.
The format of the data displayed in the Information Display area is not correct.	*False communication between PDA and Transmitter.	*Restart the program connection or press “Comm” to reconnect.

Table 6-2 Error Code, Cause and Solution

Code	Corresponding display on M08 menu	Cause	Solution
*R	System Normal	*System operates normally	
*J	SCPU Fatal Error	* Hardware failure	* contact the company
*I	Signal Not Detected	* No signal received * A poor contact between transducers and the pipe, or too little couplant supplied * the transducer has not been installed properly. *Too much scale formation in the inside wall * New liner	* Make sure the transducer is close to the pipe. Use sufficient couplant. * Make sure no rust stains, no oil, paint and no rust on the pipe surface. Use flat file to clean the pipe surface. * Check the original settings * You can only clean the couplant or change the pipe. But under normal conditions you can try to change a measuring point. * Wait until the liner saturated and solidified.
*H	Low Signal Strength	* Poor signal * Same cause of the above	* The same as above column
*H	Poor Signal Quality	* Poor signal quality * Include the above mentioned causes	* Same as above
*E	Current Loop over 20mA (Ignore it if the measuring process don't use current output)	* 4-20mA current loop overflow over 120%. * Wrong current loop output settings	* Recheck the settings (see M56 operation instruction) or make sure the actual flow is not too big.
*F	See Table 5.1	* Self-checking error * Perpetual hardware failure	* Restart the device and observe the information displayed on the screen. If the problem persists ,contact the company. * contact the company.
*G	Adjusting Gain=>S1 Adjusting Gain=>S2 Adjusting Gain=>S3 Adjusting Gain=>S4 （Displayed in M00，M01，M02，M03 windows）	* These 4 steps mean that the machine is going on the gain adjustment, preparing for the normal measurement. If the machine stops on S1 or S2, or shifts between S1 and S2, it denotes that the received signal is too low or the waveform is not good. The reasons may include all above-mentioned causes.	
*K	Empty pipe， M29 menu settings	No liquid in the pipe or wrong settings	If there is liquid in the pipe ,input ”0” in the M 29 menu.

8 Appendix

8.1 Install INNOVA SONIC PORTABLE Software on PDA

Note: Read this section before reinstalling the PDA program.

To install communication software (take Palm DeskTop V4.1 as an example) using the HotSync Manager of the PDA , follow the following steps:

1. Install Palm Desktop to your computer. For details, see the PDA user's manual.
2. Connect the PDA to your computer with USB cable (or serial port cable) according to the HotSync manager on the Windows system disk.

Figure 6-1 Choose Sync Connection Mode of the PDA and Desktop Computer

3. Run Palm Desktop, and select [View] -> [Quick Install] on the menu or click "Install" icon.

Figure 6-2 Run sync software

4. Select the corresponding user on the pop-up window and click [Add] button to install communication software application INNOVA SONIC PORTABLE.prc and serial number file Dslp.pdb. See Figure 6-3.

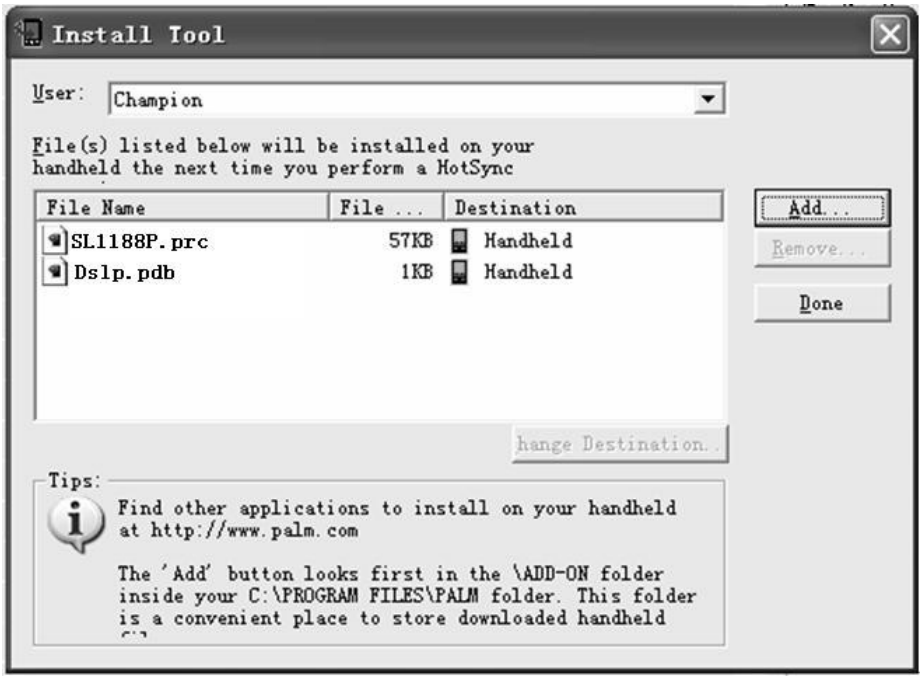


Figure 6-3. Select a User Name and Sync File INNOVA SONIC PORTABLE.prc and Dslp.pdb

5. Click the HotSync icon of the PDA or press the HotSync key on the sync jack and install the application according to the clue.

Figure 64 Press sync button to synchronize

6. For application icons displayed on the PDA after installation, see Figure 6-5.

Figure6-5 The Application Icons Displayed on the PDA After Installation

When not using the PDA for a extended period of time, or there is not enough battery charge, please recharge it in time.

8.2 UFMData Installation

8.2.1 Hardware requirements

CPU: PII266 or faster，Memory: 64M or more，Display resolution: 1024*768 or higher。

8.2.2 OS Requirements

Windows 98SE 4.10.2222A or later, IE4.01 or later.

8.2.3 Installing Method

Step 1: Open Setup file in the UFMData directory to enter installation page, as shown in Fig. 6-6. Click “Next” to proceed.

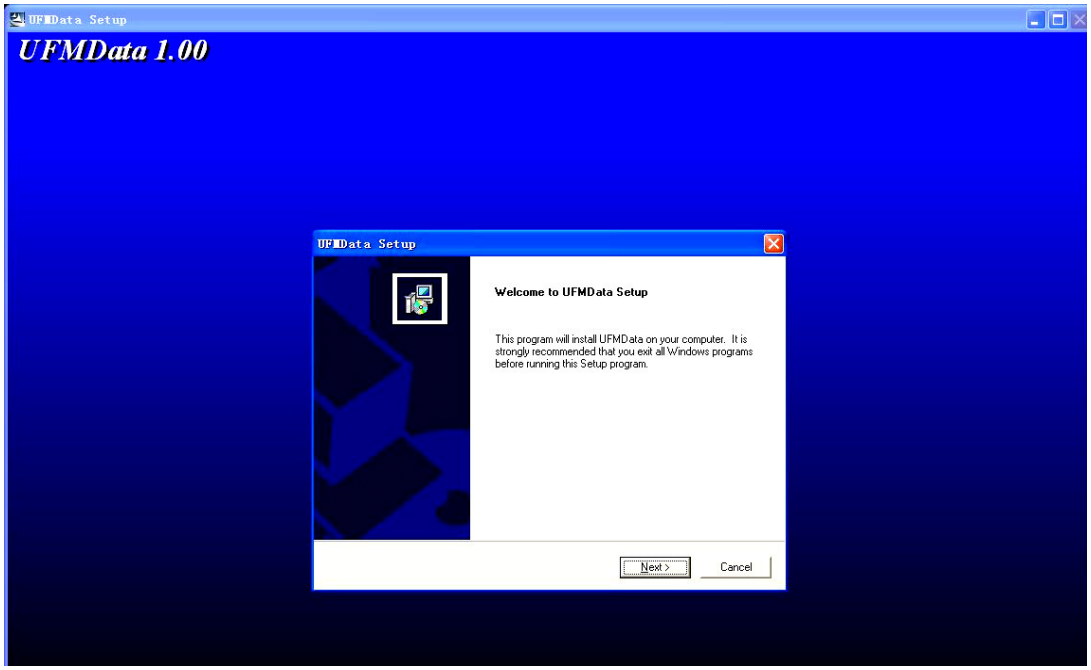


Figure 6-6 UFMData Setup Interface

Step 2: Select an installation directory. Click “Next” to accept the default directory. If you want to change the installation directory, click “Browse” to select a directly and click “next” to continue to the next step, as shown in Figure 6-7.

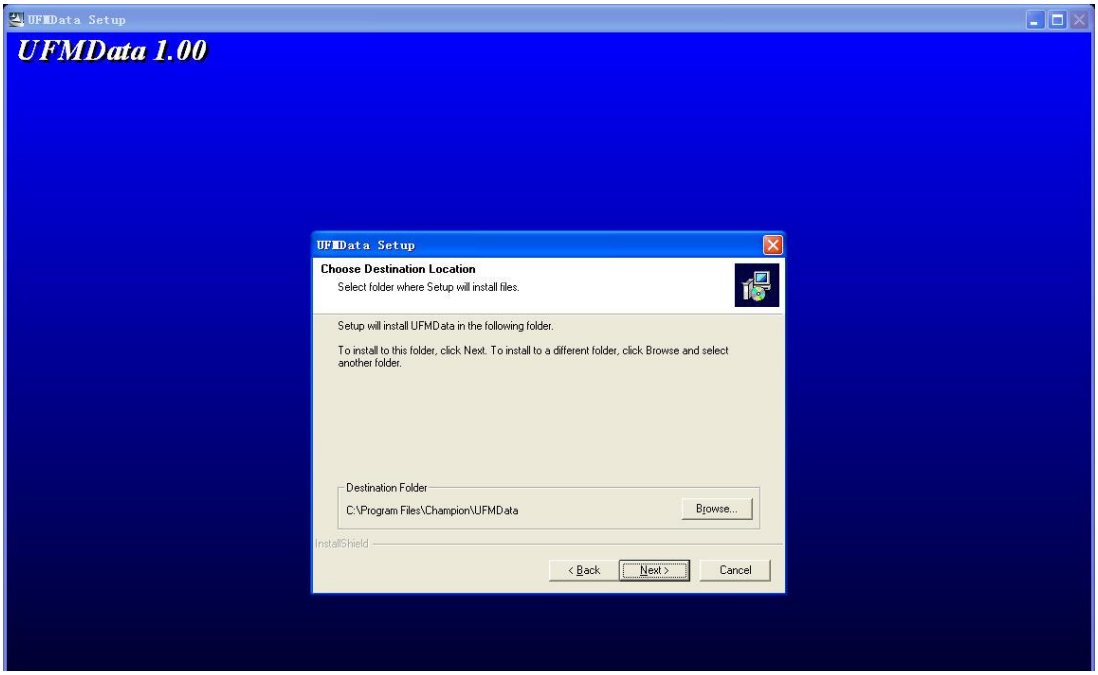


Figure 6-7 Select a UFMData Installation Directory

Step 3: Select a program folder, then click “Next” to enter next step, as shown in Figure 6-8.

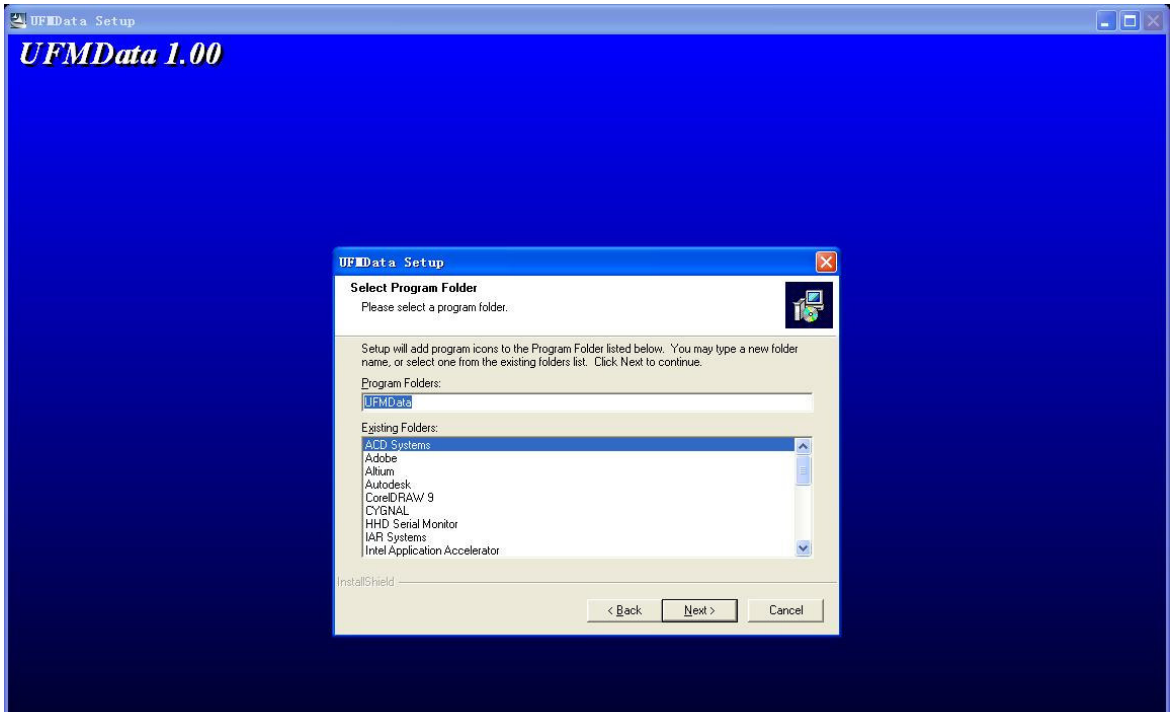


Figure 6-8 Select UFMDataProgram Folder

Step 4: Click “Finish” to finish installation, as shown in Figure 6-9.

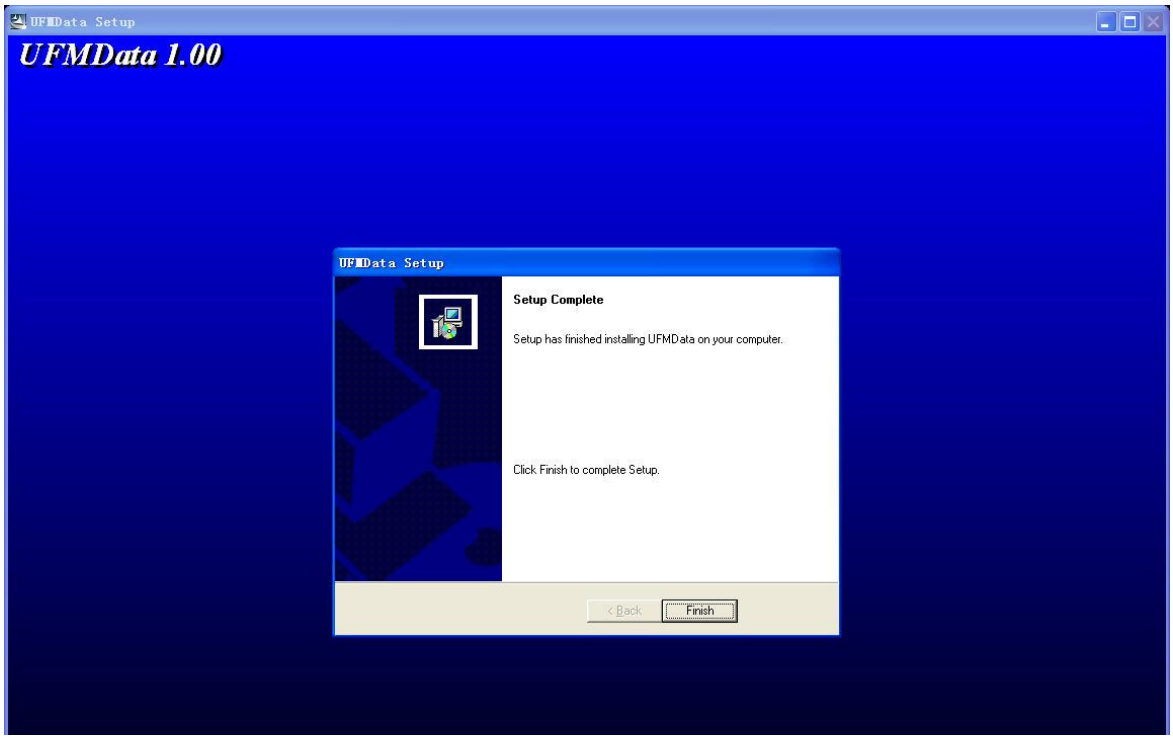


Figure 6-9 Finish UFMData Installation

8.3 Sound Velocity and Viscosity of Common Liquid

Liquid	Velocity of Sound (m/s)	Viscosity (mm^2/s)
Water 20℃	1482	1.0
Water 50℃	1543	0.55
Water 75℃	1554	0.39
Water 100℃	1543	0.29
Water 125℃	1511	0.25
Water 150℃	1466	0.21
Water 175℃	1401	0.18
Water 200℃	1333	0.15
Water 225℃	1249	0.14
Water 250℃	1156	0.12
Acetone	1190	
Carbonyl	1121	
Ethanol	1168	
Alcohol	1440	1.5
Ketone	1310	
Acetaldehyde	1180	
Glycol	1620	

Liquid	Velocity of Sound (m/s)	Viscosity (mm^2/s)
Glycerin	1923	1180
Gas	1250	0.80
66#Gas	1171	
80#Gas	1139	
0#Gas	1385	
Benzene	1330	
Methylbenzene	1340	
Toluene	1170	0.69
Tetra chloromethane	938	
Kerosene	1420	2.3
Petroleum	1290	
Pine oil	1280	
Chloroethylene	1050	0.82
Dagang jet fuel	1298	
Daqing 0#jet fuel	1290	
Arachis oil	1472	
Castor oil	1502	

8.4 Sound Velocity of Common Materials

Pipe Material	Sound Velocity (m/s)
Steel	3206
ABS	2286
Aluminum	3048
Brass	2270
Cast iron	2460
Bronze	2270
Fiber glass-epoxy	3430
Glass	3276
Polyethylene	1950
PVC	2540

Liner Material	Sound Velocity (m/s)
PTFE	1225
Titanium	3150
Cement	4190
Bitumen	2540
Porcelain enamel	2540
Glass	5970
Plastic	2280
Polyethylene	1600
PTFE	1450
Rubber	1600

8.5 Sound Velocity in Water (1 atm) at Different Temperatures

Temperature		Sound Speed in Water	
°C	°F	m/s	ft/s
61	141.8	1,551	5,089
62	143.6	1,552	5,092
63	145.4	1,552	5,092
64	147.2	1,553	5,095
65	149.0	1,553	5,095
66	150.8	1,553	5,095
67	152.6	1,554	5,099
68	154.4	1,554	5,099
69	156.2	1,554	5,099
70	158.0	1,554	5,099
71	159.8	1,554	5,099
72	161.6	1,555	5,102
73	163.4	1,555	5,102
74	165.2	1,555	5,102
75	167.0	1,555	5,102
76	168.8	1,555	5,102
77	170.6	1,554	5,099
78	172.4	1,554	5,099
79	174.2	1,554	5,099
80	176.0	1,554	5,099
81	177.8	1,554	5,099
82	179.6	1,553	5,095
83	181.4	1,553	5,095
84	183.2	1,553	5,095
85	185.0	1,552	5,092
86	186.8	1,552	5,092
87	188.6	1,552	5,092
88	190.4	1,551	5,089
89	192.2	1,551	5,089
90	194.0	1,550	5,086
91	195.8	1,549	5,082
92	197.6	1,549	5,082
93	199.4	1,548	5,079
94	201.2	1,547	5,076
95	203.0	1,547	5,076

Temperature		Sound Speed in Water	
°C	°F	m/s	ft/s
96	204.8	1,546	5,072
97	206.6	1,545	5,069
98	208.4	1,544	5,066
99	210.2	1,543	5,063
100	212.0	1,543	5,063
104	220.0	1,538	5,046
110	230.0	1,532	5,026
116	240.0	1,524	5,000
121	250.0	1,526	5,007
127	260.0	1,507	4,944
132	270.0	1,497	4,912
138	280.0	1,487	4,879
143	290.0	1,476	4,843
149	300.0	1,465	4,807
154	310.0	1,453	4,767
160	320.0	1,440	4,725
166	330.0	1,426	4,679
171	340.0	1,412	4,633
177	350.0	1,398	4,587
182	360.0	1,383	4,538
188	370.0	1,368	4,488
193	380.0	1,353	4,439
199	390.0	1,337	4,387
204	400.0	1,320	4,331
210	410.0	1,302	4,272
216	420.0	1,283	4,210
221	430.0	1,264	4,147
227	440.0	1,244	4,082
232	450.0	1,220	4,003
238	460.0	1,200	3,937
243	470.0	1,180	3,872
249	480.0	1,160	3,806
254	490.0	1,140	3,740
260	500.0	1,110	3,642

8.6 Common Pipe Dimensions (English)

OD	INCH		SCHEDULE		WALL	ID
1/8"	0.405"	10		10S	0.049"	0.307"
1/8"	0.405"	STD	40	40S	0.068"	0.269"
1/8"	0.405"	XS	80	80S	0.095"	0.215"
1/4"	0.540"	10		10S	0.065"	0.410"
1/4"	0.540"	STD	40	40S	0.088"	0.364"
1/4"	0.540"	XS	80	80S	0.119"	0.302"
3/8"	0.675"	10		10S	0.065"	0.545"
3/8"	0.675"	STD	40	40S	0.091"	0.493"
3/8"	0.675"	XS	80	80S	0.126"	0.423"
1/2"	0.840"	5		5S	0.065"	0.710"
1/2"	0.840"	10		10S	0.083"	0.674"
1/2"	0.840"	STD	40	40S	0.109"	0.622"
1/2"	0.840"	XS	80	80S	0.147"	0.546"
1/2"	0.840"	160			0.188"	0.464"
1/2"	0.840"	XX			0.294"	0.252"
3/4"	1.050"	5		5S	0.065"	0.920"
3/4"	1.050"	10		10S	0.083"	0.884"
3/4"	1.050"	STD	40	40S	0.113"	0.824"
3/4"	1.050"	XS	80	80S	0.154"	0.742"
3/4"	1.050"	160			0.219"	0.612"
3/4"	1.050"	XX			0.308"	0.434"
1"	1.315"	5		5S	0.065"	1.185"
1"	1.315"	10		10S	0.109"	1.097"
1"	1.315"	STD	40	40S	0.133"	1.049"
1"	1.315"	XS	80	80S	0.179"	0.957"
1"	1.315"	160			0.250"	0.815"
1"	1.315"	XX			0.358"	0.599"
11/4"	1.660"	5		5S	0.065"	1.530"
11/4"	1.660"	10		10S	0.109"	1.442"
11/4"	1.660"	STD	40	40S	0.140"	1.380"
11/4"	1.660"	XS	80	80S	0.191"	1.278"
11/4"	1.660"	160			0.250"	1.160"
11/4"	1.660"	XX			0.382"	0.896"
11/2"	1.900"	5		5S	0.065"	1.770"
11/2"	1.900"	10		10S	0.109"	1.682"
11/2"	1.900"	STD	40	40S	0.145"	1.610"
11/2"	1.900"	XS	80	80S	0.200"	1.500"
11/2"	1.900"	160			0.281"	1.388"
11/2"	1.900"	XX			0.400"	1.100"
2"	2.375"	5		5S	0.065"	2.245"
2"	2.375"	10		10S	0.109"	2.157"
2"	2.375"	STD	40	40S	0.154"	2.067"
2"	2.375"	XS	80	80S	0.218"	1.939"

OD	INCH		SCHEDULE		WALL	ID
2"	2.375"	160			0.344"	1.687"
2"	2.375"	XX			0.436"	1.503"
21/2"	2.875"	5		5S	0.083"	2.709"
21/2"	2.875"	10		10S	0.120"	2.635"
21/2"	2.875"	STD	40	40S	0.203"	2.469"
21/2"	2.875"	XS	80	80S	0.276"	2.323"
21/2"	2.875"	160			0.375"	2.125"
21/2"	2.875"	XX			0.552"	1.771"
3"	3.500"	5		5S	0.083"	3.334"
3"	3.500"	10		10S	0.120"	3.260"
3"	3.500"	STD	40	40S	0.216"	3.068"
3"	3.500"	XS	80	80S	0.300"	2.900"
3"	3.500"	160			0.438"	2.624"
3"	3.500"	XX			0.600"	2.300"
31/2"	4.000"	5		5S	0.083"	3.834"
31/2"	4.000"	10		10S	0.120"	3.760"
31/2"	4.000"	STD	40	40S	0.226"	3.548"
31/2"	4.000"	XS	80	80S	0.318"	3.364"
31/2"	4.000"	XX			0.636"	2.728"
4"	4.500"	5		5S	0.083"	4.334"
4"	4.500"	10		10S	0.120"	4.260"
4"	4.500"				0.156"	4.188"
4"	4.500"				0.188"	4.124"
4"	4.500"	STD	40	40S	0.237"	4.026"
4"	4.500"	XS	80	80S	0.337"	3.826"
4"	4.500"	120			0.438"	3.624"
4"	4.500"	160			0.531"	3.438"
4"	4.500"	XX			0.674"	3.152"
41/2"	5.000"	STD	40	40S	0.247"	4.506"
41/2"	5.000"	XS	80	80S	0.355"	4.290"
41/2"	5.000"	XX			0.710"	3.580"
5"	5.563"	5		5S	0.109"	5.345"
5"	5.563"	10		10S	0.134"	5.295"
5"	5.563"	STD	40	40S	0.258"	5.047"
5"	5.563"	XS	80	80S	0.375"	4.813"
5"	5.563"	120			0.500"	4.563"
5"	5.563"	160			0.625"	4.313"
5"	5.563"	XX			0.750"	4.063"
6"	6.625"	5		5S	0.109"	6.407"
6"	6.625"	10		10S	0.134"	6.357"
6"	6.625"				0.188"	6.249"
6"	6.625"	STD	40	40S	0.280"	6.065"
6"	6.625"	XS	80	80S	0.432"	5.761"
6"	6.625"	120			0.562"	5.501"
6"	6.625"	160			0.719"	5.187"
6"	6.625"	XX			0.864"	4.897"

OD	INCH		SCHEDULE		WALL	ID
7"	7.625"	STD	40	40S	0.301"	7.023"
7"	7.625"	XS	80	80S	0.500"	6.625"
7"	7.625"	XX			0.875"	5.875"
8"	8.625"			5S	0.109"	8.407"
8"	8.625"	10		10S	0.148"	8.329"
8"	8.625"	20			0.250"	8.125"
8"	8.625"	30			0.277"	8.071"
8"	8.625"	STD	40	40S	0.322"	7.981"
8"	8.625"	60			0.406"	7.813"
8"	8.625"	XS	80	80S	0.500"	7.625"
8"	8.625"	100			0.594"	7.437"
8"	8.625"	120			0.719"	7.187"
8"	8.625"	140			0.812"	7.001"
8"	8.625"	XX			0.875"	6.875"
8"	8.625"	160			0.906"	6.813"
9"	9.625"	STD	40	40S	0.342"	8.941"
9"	9.625"	XS	80	80S	0.500"	8.625"
9"	9.625"	XX			0.875"	7.875"
10"	10.750"			5S	0.134"	10.482"
10"	10.750"			10S	0.165"	10.420"
10"	10.750"				0.188"	10.374"
10"	10.750"	20			0.250"	10.250"
10"	10.750"	30			0.307"	10.136"
10"	10.750"	STD	40	40S	0.365"	10.020"
10"	10.750"	XS	60	80S	0.500"	9.750"
10"	10.750"	80			0.594"	9.562"
10"	10.750"	100			0.719"	9.312"
10"	10.750"	120			0.844"	9.062"
10"	10.750"	140			1.000"	8.750"
10"	10.750"	160			1.125"	8.500"
11"	11.750"	STD	40	40S	0.375"	11.000"
11"	11.750"	XS	80	80S	0.500"	10.750"
11"	11.750"	XX			0.875"	10.000"
12"	12.750"			5S	0.156"	12.438"
12"	12.750"			10S	0.180"	12.390"
12"	12.750"	20			0.250"	12.250"
12"	12.750"	30			0.330"	12.090"
12"	12.750"	STD		40S	0.375"	12.000"
12"	12.750"	40			0.406"	11.938"
12"	12.750"	XS		80S	0.500"	11.750"
12"	12.750"	60			0.562"	11.626"
12"	12.750"	80			0.688"	11.374"
12"	12.750"	100			0.844"	11.062"
12"	12.750"	120			1.000"	10.750"
12"	12.750"	140			1.125"	10.500"
12"	12.750"	160			1.312"	10.126"

OD	INCH		SCHEDULE		WALL	ID
14"	14.000"			10S	0.188"	13.624"
14"	14.000"	10			0.250"	13.500"
14"	14.000"	20			0.312"	13.376"
14"	14.000"	STD	30	40S	0.375"	13.250"
14"	14.000"	40			0.438"	13.124"
14"	14.000"	XS		80S	0.500"	13.000"
14"	14.000"	60			0.594"	12.812"
14"	14.000"	80			0.750"	12.500"
14"	14.000"	100			0.938"	12.124"
14"	14.000"	120			1.094"	11.812"
14"	14.000"	140			1.250"	11.500"
14"	14.000"	160			1.406"	11.188"
16"	16.000"			10S	0.188"	15.624"
16"	16.000"	10			0.250"	15.500"
16"	16.000"	20			0.312"	15.376"
16"	16.000"	STD	30	40S	0.375"	15.250"
16"	16.000"	XS	40	80S	0.500"	15.000"
16"	16.000"	60			0.656"	14.688"
16"	16.000"	80			0.844"	14.312"
16"	16.000"	100			1.031"	13.938"
16"	16.000"	120			1.219"	13.562"
16"	16.000"	140			1.438"	13.124"
16"	16.000"	160			1.594"	12.812"
18"	18.000"			10S	0.188"	17.624"
18"	18.000"	10			0.250"	17.500"
18"	18.000"	20			0.312"	17.376"
18"	18.000"	STD		40S	0.375"	17.250"
18"	18.000"	30			0.438"	17.124"
18"	18.000"	XS		80S	0.500"	17.000"
18"	18.000"	40			0.562"	16.876"
18"	18.000"	60			0.750"	16.500"
18"	18.000"	80			0.938"	16.124"
18"	18.000"	100			1.156"	15.688"
18"	18.000"	120			1.375"	15.250"
18"	18.000"	140			1.562"	14.876"
18"	18.000"	160			1.781"	14.438"
20"	20.000"			10S	0.218"	19.564"
20"	20.000"	10			0.250"	19.500"
20"	20.000"	STD	20	40S	0.375"	19.250"
20"	20.000"	XS	30	80S	0.500"	19.000"
20"	20.000"	40			0.594"	18.812"
20"	20.000"	60			0.812"	18.376"
20"	20.000"	80			1.031"	17.938"
20"	20.000"	100			1.281"	17.438"
20"	20.000"	120			1.500"	17.000"
20"	20.000"	140			1.750"	16.500"
20"	20.000"	160			1.969"	16.062"

OD	INCH		SCHEDULE		WALL	ID
22"	22.000"		10	10S	0.250"	21.500"
22"	22.000"	STD	20	40S	0.375"	21.250"
22"	22.000"	XS	30	80S	0.500"	21.000"
22"	22.000"	60			0.875"	20.250"
22"	22.000"	80			1.125"	19.750"
22"	22.000"	100			1.375"	19.250"
22"	22.000"	120			1.625"	18.750"
22"	22.000"	140			1.875"	18.250"
22"	22.000"	160			2.125"	17.750"
24"	24.000"		10	10S	0.250"	23.500"
24"	24.000"	STD	20	40S	0.375"	23.250"
24"	24.000"	XS		80S	0.500"	23.000"
24"	24.000"	30			0.562"	22.876"
24"	24.000"	40			0.688"	22.624"
24"	24.000"	60			0.969"	22.062"
24"	24.000"	80			1.219"	21.562"
24"	24.000"	100			1.531"	20.938"
24"	24.000"	120			1.812"	20.376"
24"	24.000"	140			2.062"	19.876"
24"	24.000"	160			2.344"	19.312"
26"	26.000"		10		0.312"	25.376"
26"	26.000"	STD		40S	0.375"	25.250"
26"	26.000"	XS		80S	0.500"	25.000"
28"	28.000"		10		0.312"	27.376"
28"	28.000"	STD		40S	0.375"	27.250"
28"	28.000"		20	80S	0.500"	27.000"
28"	28.000"		30		0.625"	26.750"
30"	30.000"		10		0.312"	29.376"
30"	30.000"	STD		40S	0.375"	29.250"
30"	30.000"	XS	20	80S	0.500"	29.000"
30"	30.000"		30		0.625"	28.750"
32"	32.000"		10		0.312"	31.376"
32"	32.000"	STD			0.375"	31.250"
32"	32.000"		20		0.500"	31.000"
32"	32.000"		30		0.625"	30.750"
32"	32.000"		40		0.688"	30.264"
34"	34.000"		10		0.312"	33.376"
34"	34.000"	STD			0.375"	33.250"
34"	34.000"		20		0.500"	33.000"
34"	34.000"		30		0.625"	32.750"
34"	34.000"		40		0.688"	32.624"
36"	36.000"		10		0.312"	35.376"
36"	36.000"	STD		40S	0.375"	35.250"
36"	36.000"	XS		80S	0.500"	35.000"
42"	42.000"	STD		40S	0.375"	41.250"
42"	42.000"	XS		80S	0.500"	41.000"

42"	42.000"		40		0.750"	40.500"
48"	48.000"	STD		40S	0.375"	47.250"
48"	48.000"	XS		80S	0.500"	47.000"

8.7 Common Pipe Dimensions (DIN)

PIPE SIZES & SCHEDULES

N.B. inches	N.B. mm	O.D. mm	WALL mm	Identification STD XS,XXS	Identification Schedule Number
1	25	33.4	3.4	STD	40
1	25	33.4	4.5	XS	80
1	25	33.4	6.4		160
1	25	33.4	9.1	XXS	
1 ¼	32	42.2	3.6	STD	40
1 ¼	32	42.2	4.9	XS	80
1 ¼	32	42.2	6.4		160
1 ¼	32	42.2	9.7	XXS	
1 ½	40	48.3	3.7	STD	40
1 ½	40	48.3	5.1	XS	80
1 ½	40	48.3	7.1		160
1 ½	40	48.3	10.2	XXS	
2	50	60.3	3.9	STD	40
2	50	60.3	5.5	XS	80
2	50	60.3	8.7		160
2	50	60.3	11.1	XXS	
2 ½	65	73.0	5.2	STD	40
2 ½	65	73.0	7.0	XS	80
2 ½	65	73.0	9.5		160
2 ½	65	73.0	14.0	XXS	
3	80	88.9	5.5	STD	40
3	80	88.9	7.6	XS	80
3	80	88.9	11.1		160
3	80	88.9	15.2	XXS	
3 ½	90	101.6	5.7	STD	40
3 ½	90	101.6	8.1	XS	80
4	100	114.3	6.0	STD	40
4	100	114.3	8.6	XS	80
4	100	114.3	11.1		120
4	100	114.3	13.5		160
4	100	114.3	17.1	XXS	
5	125	141.3	6.6	STD	40
5	125	141.3	9.5	XS	80
5	125	141.3	12.7		120
5	125	141.3	15.9		160
5	125	141.3	19.0	XXS	

6	150	168.3	7.1	STD	40
6	150	168.3	11.0	XS	80
6	150	168.3	14.3		120
6	150	168.3	18.3		160
6	150	168.3	21.9	XXS	
8	200	219.1	6.4		20
8	200	219.1	7.0		30
8	200	219.1	8.2	STD	40
8	200	219.1	10.3		60
8	200	219.1	12.7	XS	80
8	200	219.1	15.1		100
8	200	219.1	18.3		120
8	200	219.1	20.6		140
8	200	219.1	22.2	XXS	
8	200	219.1	2300		160
10	250	273.0	6.4		20
10	250	273.0	7.8		30
10	250	273.0	9.3	STD	40
10	250	273.0	12.7	XS	60
10	250	273.0	15.1		80
10	250	273.0	18.3		100
10	250	273.0	21.4		120
10	250	273.0	25.4	XXS	140
10	250	273.0	28.6		160
12	300	323.9	6.4		20
12	300	323.9	8.4		30
12	300	323.9	9.5	STD	
12	300	323.9	10.3	XS	40
12	300	323.9	12.7		
12	300	323.9	14.3		60
12	300	323.9	17.5		80
12	300	323.9	21.4		100
12	300	323.9	25.4	XXS	120
12	300	323.9	28.6		140
12	300	323.9	33.3		160
14	350	355.6	6.4		10
14	350	355.6	7.9		20
14	350	355.6	9.5	STD	30
14	350	355.6	11.1		40
14	350	355.6	12.7	XS	
14	350	355.6	15.1		60
14	350	355.6	19.0		80
14	350	355.6	23.8		100
14	350	355.6	27.8		120
14	350	355.6	31.8		140
14	350	355.6	35.7		160

		PIPE SIZES & SCHEDULES			
N.B.	**N.B.**	**O.D.**	**WALL**	**Identification**	
inches	mm	mm	mm	STD XS,XXS	Schedule number
16	400	406.4	6.4		10
16	400	406.4	7.9		20
16	400	406.4	9.5	STD	30
16	400	406.4	12.7	XS	40
16	400	406.4	16.7		60
16	400	406.4	21.4		80
16	400	406.4	26.2		100
16	400	406.4	31.0		120
16	400	406.4	36.5		140
16	400	406.4	40.5		160
18	450	457.0	6.4		10
18	450	457.0	7.9		20
18	450	457.0	9.5	STD	
18	450	457.0	11.1		30
18	450	457.0	12.7	XS	
18	450	457.0	14.3		40
18	450	457.0	19.0		60
18	450	457.0	23.8		80
18	450	457.0	29.4		100
18	450	457.0	34.9		120
18	450	457.0	39.7		140
18	450	457.0	45.2		160
20	500	508.0	6.4		10
20	500	508.0	9.5	STD	20
20	500	508.0	12.7	XS	30
20	500	508.0	15.1		40
20	500	508.0	20.6		60
20	500	508.0	26.2		80
20	500	508.0	32.5		100
20	500	508.0	38.1		120
20	500	508.0	44.4		140
20	500	508.0	50.0		160
22	550	559.0	6.4		10
22	550	559.0	9.5	STD	20
22	550	559.0	12.7	XS	30
22	550	559.0	22.2		60
22	550	559.0	28.6		80
22	550	559.0	34.9		100
22	550	559.0	41.3		120
22	550	559.0	47.6		140
22	550	559.0	54.0		160
24	600	610.0	6.4		10
24	600	610.0	9.5	STD	20
24	600	610.0	12.7	XS	
24	600	610.0	14.3		30
24	600	610.0	17.5		40
24	600	610.0	24.6		60
24	600	610.0	31.0		80

24	600	610.0	38.9		100
24	600	610.0	46.0		120
24	600	610.0	52.4		140
24	600	610.0	59.5		160
26	650	660.0	7.9		10
26	650	660.0	9.5	STD	
26	650	660.0	12.7	XS	20
28	700	711.0	7.9		10
28	700	711.0	9.5	STD	
28	700	711.0	12.7	XS	20
28	700	711.0	15.9		30
30	750	762.0	7.9		10
30	750	762.0	9.5	STD	
30	750	762.0	12.7	XS	20
30	750	762.0	15.9		30
32	800	813.0	7.9		10
32	800	813.0	9.5	STD	
32	800	813.0	12.7	XS	20
32	800	813.0	15.9		30
32	800	813.0	17.5		40
34	850	864.0	7.9		10
34	850	864.0	9.5	STD	20
34	850	864.0	12.7	XS	30
34	850	864.0	15.9		40
34	850	864.0	17.5		
36	900	914.0	7.9		10
36	900	914.0	9.5	STD	
36	900	914.0	12.7	XS	20
36	900	914.0	15.9		30
36	900	914.0	19.0		40

8.8 Cement Lined Pipes liner thicknesses

Size in.	Nominal Pipe Length ft.	Standard Thickness			Double Thickness		
		Minimum Thickness in.	Weight Per Foot lb	Weight Per Length lb	Minimum Thickness in.	Weight Per Foot lb	Weight Per Length lb
4	20	1/16	0.87	17	1/8	1.71	34
6	20	1/16	1.3	26	1/8	2.57	51
8	20	1/16	1.74	35	1/8	3.45	69
10	20	1/16	2.15	43	1/8	4.28	86
12	20	1/16	2.57	51	1/8	5.12	102
14	20	3/32	4.49	90	3/16	8.93	179
16	20	3/32	5.13	103	3/16	10.19	204
18	20	3/32	5.76	115	3/16	11.47	229
20	20	3/32	6.4	128	3/16	12.73	255
24	20	3/32	7.68	154	3/16	15.31	306
30	20	1/8	12.76	255	1/4	25.42	508
36	20	1/8	15.31	306	1/4	30.51	610
42	20	1/8	17.82	356	1/4	35.53	711
48	20	1/8	20.35	407	1/4	40.6	812
54	20	1/8	22.89	458	1/4	45.68	914
60	20	1/8	24.71	494	1/4	49.32	986
64	20	1/8	26.35	527	1/4	52.61	1052

8.9 Cast Iron Pipe Data

Nominal Pipe Size (in.)	Class A		Class B		Class C		Class D	
	Outside Diameter (in.)	Wall Thickness (in.)	Outside Diameter (in.)	Wall Thickness (in.)	Outside Diameter (in.)	Wall Thickness (in.)	Outside Diameter (in.)	Wall Thickness (in.)
3	3.80	0.39	3.96	0.42	3.96	0.45	3.96	0.48
4	4.80	0.42	5.00	0.45	5.00	0.40	5.00	0.52
6	6.90	0.44	7.10	0.48	7.10	0.51	7.10	0.55
8	9.05	0.46	9.05	0.51	9.30	0.56	9.30	0.60
10	11.10	0.50	11.10	0.57	11.40	0.62	11.40	0.68
12	13.20	0.54	13.20	0.62	13.50	0.68	13.50	0.75
14	15.30	0.57	15.30	0.66	15.65	0.74	15.65	0.82
16	7.40	0.60	17.40	0.70	17.80	0.80	17.80	0.89
18	19.50	0.64	19.50	0.75	19.92	0.87	19.92	0.96
20	21.60	0.67	21.60	0.80	22.06	0.92	22.06	1.03
24	25.80	0.76	25.80	0.89	26.32	1.05	26.32	1.16
30	31.74	0.88	32.00	1.03	32.40	1.20	32.74	1.37
32	37.96	0.99	38.30	1.15	38.70	1.36	39.16	1.58
42	44.20	1.10	44.50	1.28	45.10	1.54	45.58	1.78
48	50.50	1.26	50.80	1.42	51.40	1.71	51.98	1.99
54	56.66	1.35	57.10	1.55	57.80	1.90	58.40	2.23
60	62.80	1.39	63.40	1.67	64.20	2.00	64.82	2.38
72	75.34	1.62	76.00	1.95	76.88	2.39		
84	87.54	1.72	88.54	2.22				

Nominal Pipe Size (in.)	Class E		Class F		Class G		Class H	
	Outside Diameter (in.)	Wall Thickness (in.)	Outside Diameter (in.)	Wall Thickness (in.)	Outside Diameter (in.)	Wall Thickness (in.)	Outside Diameter (in.)	Wall Thickness (in.)
3								
4								
6	7.22	0.58	7.22	0.61	7.38	0.65	7.38	0.69
8	9.42	0.66	9.42	0.66	9.60	0.75	9.60	0.80
10	11.60	0.74	11.60	0.80	11.84	0.86	11.84	0.92
12	13.78	0.82	13.78	0.89	14.08	0.97	14.08	1.04
14	15.98	0.90	15.98	0.99	16.32	1.07	16.32	1.16
16	18.16	0.90	18.16	1.08	18.54	1.18	18.54	1.27
18	20.34	1.07	20.34	1.17	20.78	1.28	20.78	1.39
20	22.54	1.15	22.54	1.27	23.02	1.39	23.02	1.51
24	26.90	1.31	26.90	1.45	27.76	1.75	27.76	1.88
30	33.10	1.55	33.46	1.73				
32	39.60	1.80	40.04	2.02				
42								
48								
54								
60								
72								
84								

8.10 Ductile Iron Pipe Data

Nominal Pipe Size (in.)	Outside Diameter (in.)	Pipe Wall Thickness (in.)						
		Class 50	Class 51	Class 52	Class 53	Class 54	Class 55	Class 56
3	3.96		0.25	0.28	0.31	0.43	0.37	0.40
4	4.80		0.26	0.29	0.32	0.35	0.38	0.41
6	6.90	0.25	0.28	0.31	0.34	0.37	0.40	0.43
8	9.05	0.27	0.30	0.33	0.36	0.39	0.42	0.45
10	11.10	0.29	0.32	0.35	0.38	0.44	0.47	
12	13.20	0.31	0.34	0.37	0.40	0.43	0.46	0.49
14	15.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51
16	17.40	0.34	0.37	0.40	0.43	0.46	0.49	0.52
18	19.50	0.35	0.38	0.41	0.44	0.47	0.50	0.53
20	21.60	0.36	0.39	0.42	0.45	0.48	0.51	0.54
24	25.80	0.38	0.41	0.44	0.47	0.50	0.53	0.56
30	32.00				0.51	0.55	0.59	0.63
36	38.30				0.58	0.63	0.68	0.73
42	44.50				0.65	0.71	0.77	0.83
48	50.80				0.72	0.79	0.86	0.93
54	57.10				0.81	0.89	0.97	1.05

8.11 Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Acetic anhydride (22)	$(CH_3CO)_2O$	1.082 (20°C)	1,180	3,871.4	2.5	0.769	8.274
Acetic acid, anhydride (22)	$(CH_3CO)_2O$	1.082 (20°C)	1,180	3,871.4	2.5	0.769	8.274
Acetic acid, nitrile	C_2H_3N	0.783	1,290	4,232.3	4.1	0.441	4.745
Acetic acid, ethyl ester (33)	$C_4H_8O_2$	0.901	1,085	3,559.7	4.4	0.467	5.025
Acetic acid, methyl ester	$C_3H_6O_2$	0.934	1,211	3,973.1		0.407	4.379
Acetone	C_3H_6O	0.791	1,174	3,851.7	4.5	0.399	4.293
Acetonitrile	C_2H_3N	0.783	1,290	4,232.3	4.1	0.441	4.745
Acetonylacetone	$C_6H_{10}O_2$	0.729	1,399	4,589.9	3.6		
Acetylen dichloride	$C_2H_2Cl_2$	1.26	1,015	3,330.1	3.8	0.400	4.304
Acetylene tetrabromide (47)	$C_2H_2Br_4$	2.966	1,027	3,369.4			
Acetylene tetrachloride (47)	$C_2H_2Cl_4$	1.595	1,147	3,763.1		1.156 (15°C)	12.438 (59°F)
Alcohol	C_2H_6O	0.789	1,207	3,960	4.0	1.396	15.02
Alkazene-13	$C_{15}H_{24}$	0.86	1,317	4,320.9	3.9		
Alkazene-25	$C_{10}H_{12}Cl_2$	1.20	1,307	4,288.1	3.4		
2-Amino-ethanol	C_2H_7NO	1.018	1,724	5,656.2	3.4		
2-Aminotolidine (46)	C_7H_9N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
4-Aminotolidine (46)	C_7H_9N	0.966 (45°C)	1,480	4,855.6		1.863 (50°C)	20.045 (122°F)
Ammonia (35)	NH_3	0.771	1,729 (-33°C)	5,672.6 (-27°F)	6.68	0.292 (-33°C)	3.141 (-27°F)
Amorphous Polyolefin		0.98	962.6 (190°C)	3158.2 (374°F)		26,600	286,000
t-Amyl alcohol	$C_5H_{12}O$	0.81	1,204	3,950.1		4.374	47.064
Aminobenzene (41)	$C_6H_5NO_2$	1.022	1,639	5,377.3	4.0	3.63	39.058
Aniline (41)	$C_6H_5NO_2$	1.022	1,639	5,377.3	4.0	3.63	39.058
Argon (45)	Ar	1.400 (-188°C)	853 (-188°C)	2798.6 (-306°F)			

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Azine	C_6H_5N	0.982	1,415	4,642.4	4.1	0.992 (20°C)	10.673 (68°F)
Benzene (29, 40, 41)	C_6H_6	0.879	1,306	4,284.8	4.65	0.711	7.65
Benzol (29, 40, 41)	C_6H_6	0.879	1,306	4,284.8	4.65	0.711	7.65
Bromine (21)	Br_2	2.928	889	2,916.7	3.0	0.323	3.475
Bromo-benzene (46)	C_6H_5Br	1.522	1,170 (20°C)	3,838.6 (68°F)		0.693	7.456
1-Bromo-butane (46)	C_4H_9Br	1.276 (20°C)	1,019 (20°C)	3,343.2 (68°F)		0.49 (15°C)	5.272 (59°F)
Bromo-ethane (46)	C_2H_5Br	1.460 (20°C)	900 (20°C)	2,952.8 (68°F)		0.275	2.959
Bromoform (46, 47)	$CHBr_3$	2.89 (20°C)	918	3,011.8	3.1	0.654	7.037
n-Butane (2)	C_4H_{10}	0.601 (0°C)	1,085 (-5°C)	3,559.7 (23°F)	5.8		
2-Butanol	$C_4H_{10}O$	0.81	1,240	4,068.2	3.3	3.239	34.851
sec-Butylalcohol	$C_4H_{10}O$	0.81	1,240	4,068.2	3.3	3.239	34.851
n-Butyl bromide (46)	C_4H_9Br	1.276 (20°C)	1,019 (20°C)	3,343.2 (68°F)		0.49 (15°C)	5.272 (59°F)
n-Butyl chloride (22, 46)	C_4H_9Cl	0.887	1,140	3,740.2	4.57	0.529 (15°C)	5.692 (59°F)
tert Butyl chloride	C_4H_9Cl	0.84	984	3,228.3	4.2	0.646	6.95
Butyl oleate	$C_{22}H_{42}O_2$		1,404	4,606.3	3.0		
2, 3 Butylene glycol	$C_4H_{10}O_2$	1.019	1,484	4,868.8	1.51		
Cadmium (7)	Cd		2,237.7 (400°C)	7,341.5 (752°F)		1.355cp (440°C)	14.579 (824°F)
Carbinol (40, 41)	CH_4O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.478
Carbitol	$C_6H_{14}O_3$	0.988	1,458	4,783.5			
Carbon dioxide (26)	CO_2	1.101 (-37°C)	839 (-37°C)	2,752.6 (-35°F)	7.71	0.137 (-37°C)	1.474 (-35°F)
Carbon disulphide	CS_2	1.261 (22°C)	1,149	3,769.7		0.278	2.991

Sound Speeds of Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Carbon tetrachloride (33, 35, 47)	CCl_4	1.595 (20°C)	926	3038.1	2.48	0.607	6.531
Carbon tetrafluoride (14) (Freon 14)	CF_4	1.75 (-150°C)	875.2 (-150°C)	2,871.5 (-238°F)	6.61		
Cetane (23)	$C_{16}H_{34}$	0.773 (20°C)	1,338	4,389.8	3.71	4.32	46.483
Chloro-benezene	C_6H_5Cl	1.106	1,273	4,176.5	3.6	0.722	7.768
1-Chloro-butane (22, 46)	C_4H_9Cl	0.887	1,140	3,740.2	4.57	0.529 (15°C)	5.692 (59°F)
Chloro-diFluoromethane (3) (Freon 22)	$CHClF_2$	1.491 (-69°C)	893.9 (-50°C)	2,932.7 (-58°F)	4.79		
Chloroform (47)	$CHCl_3$	1.489	979	3,211.9	3.4	0.55	5.918
1-Chloro-propane (47)	C_3H_7Cl	0.892	1,058	3,471.1		0.378	4.067
Chlorotrifluoromethane (5)	$CClF_3$		724 (-82°C)	2,375.3 (-116°F)	5.26		
Cinnamaldehyde	C_9H_8O	1.112	1,554	5,098.4	3.2		
Cinnamic aldehyde	C_9H_8O	1.112	1,554	5,098.4	3.2		
Colamine	C_2H_7NO	1.018	1,724	5,656.2	3.4		
o-Cresol (46)	C_7H_8O	1.047 (20°C)	1,541 (20°C)	5,055.8 (68°F)		4.29 (40°C)	46.16 (104°F)
m-Cresol (46)	C_7H_8O	1.034 (20°C)	1,500 (20°C)	4,921.3 (68°F)		5.979 (40°C)	64.334 (104°F)
Cyanomethane	C_2H_3N	0.783	1,290	4,232.3	4.1	0.441	4.745
Cyclohexane (15)	C_6H_{12}	0.779 (20°C)	1,248	4,094.5	5.41	1.31 (17°C)	14.095 (63°F)
Cyclohexanol	$C_6H_{12}O$	0.962	1,454	4,770.3	3.6	0.071 (17°C)	0.764 (63°F)
Cyclohexanone	$C_6H_{10}O$	0.948	1,423	4,668.6	4.0		
Decane (46)	$C_{10}H_{22}$	0.730	1,252	4,107.6		1.26 (20°C)	13.55 (68°F)
1-Decene (27)	$C_{10}H_{20}$	0.746	1,235	4,051.8	4.0		
n-Decylene (27)	$C_{10}H_{20}$	0.746	1,235	4,051.8	4.0		
Diacetyl	$C_4H_6O_2$	0.99	1,236	4,055.1	4.6		

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Diamylamine	$C_{10}H_{23}N$		1,256	4,120.7	3.9		
1,2 Dibromo-ethane (47)	$C_2H_4Br_2$	2.18	995	3,264.4		0.79 (20°C)	8.5 (68°F)
trans-1,2-Dibromoethene (47)	$C_2H_2Br_2$	2.231	935	3,067.6			
Dibutyl phthalate	$C_8H_{22}O_4$		1,408	4,619.4			
Dichloro-t-butyl alcohol	$C_4H_8Cl_2O$		1,304	4,278.2	3.8		
2,3 Dichlorodioxane	$C_2H_6Cl_2O_2$		1,391	4,563.6	3.7		
Dichlorodifluoromethane (3) (Freon 12)	CCl_2F_2	1.516 (40°C)	774.1	2,539.7	4.24		
1,2 Dichloro ethane (47)	$C_2H_4Cl_2$	1.253	1,193	3,914		0.61	6.563
cis1,2-Dichloro-ethene (3, 47)	$C_2H_2Cl_2$	1.284	1,061	3,481			
trans1,2-Dichloro-ethene (3, 47)	$C_2H_2Cl_2$	1.257	1,010	3,313.6			
Dichloro-fluoromethane (3) (Freon 21)	$CHCl_2F$	1.426 (0°C)	891 (0°C)	2,923.2 (32°F)	3.97		
1-2-Dichlorohexafluoro-cyclobutane (47)	$C_4Cl_2F_6$	1.654	669	2,194.9			
1-3-Dichloro-isobutane	$C_4H_8Cl_2$	1.14	1,220	4,002.6	3.4		
Dichloro methane (3)	CH_2Cl_2	1.327	1,070	3,510.5	3.94	0.31	3.335
1,1-Dichloro-1,2,2,2 tetra fluoroethane	$CClF_2$-$CClF_2$	1.455	665.3 (-10°C)	2,182.7 (14°F)	3.73		
Diethyl ether	$C_4H_{10}O$	0.713	985	3,231.6	4.87	0.311	3.346
Diethylene glycol	$C_4H_{10}O_3$	1.116	1,586	5,203.4	2.4		
Diethylene glycol, monoethyl ether	$C_6H_{14}O_3$	0.988	1,458	4,783.5			
Diethylenimide oxide	C_4H_9NO	1.00	1,442	4,731	3.8		
1,2-bis(DiFluoramino) butane (43)	$C_4H_8(NF_2)_2$	1.216	1,000	3,280.8			
1,2-bis(DiFluoramino)-2-methylpropane (43)	$C_4H_9(NF_2)_2$	1.213	900	2,952.8			
1,2-bis(DiFluoramino) propane (43)	$C_3H_6(NF_2)_2$	1.265	960	3,149.6			

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
2,2-bis(DiFluoramino propane (43)	$C_3H_6(NF_2)_2$	1.254	890	2920			
2,2-Dihydroxydiethyl ether	$C_4H_{10}O_3$	1.116	1,586	5,203.4	2.4		
Dihydroxyethane	$C_2H_6O_2$	1.113	1,658	5,439.6	2.1		
1,3-Dimethyl-benzene (46)	C_8H_{10}	0.868 (15°C)	1,343 (20°C)	4,406.2 (68°F)		0.749 (15°C)	8.059 (59°F)
1,2-Dimethyl-benzene (29, 46)	C_8H_{10}	0.897 (20°C)	1,331.5	4,368.4	4.1	0.903 (20°C)	9.716 (68°F)
1,4-Dimethyl-benzene (46)	C_8H_{10}		1,334 (20°C)	4,376.6 (68°F)		0.662	7.123
2,2-Dimethyl-butane (29, 33)	C_6H_{14}	0.649 (20°C)	1,079	3,540			
Dimethyl ketone	C_3H_6O	0.791	1,174	3,851.7	4.5	0.399	4.293
Dimethyl pentane (47)	C_7H_{16}	0.674	1,063	3,487.5			
Dimethyl phthalate	$C_8H_{10}O_4$	1.2	1,463	4,799.9			
Diiodo-methane	CH_2I_2	3.235	980	3,215.2			
Dioxane	$C_4H_8O_2$	1.033	1,376	4,514.4			
Dodecane (23)	$C_{12}H_{26}$	0.749	1,279	4,196.2	3.85	1.80	19.368
1,2-Ethanediol	$C_2H_6O_2$	1.113	1,658	5,439.6	2.1		
Ethanenitrile	C_2H_3N	0.783	1,290	4,232.3		0.441	4.745
Ethanoic anhydride (22)	$(CH_3CO)_2O$	1.082	1,180	3,871.4		0.769	8.274
Ethanol	C_2H_6O	0.789	1,207	3,960	4.0	1.39	14.956
Ethanol amide	C_2H_7NO	1.018	1,724	5,656.2	3.4		
Ethoxyethane	$C_4H_{10}O$	0.713	985	3,231.6	4.87	0.311	3.346
Ethyl acetate (33)	$C_4H_8O_2$	0.901	1,085	3,559.7	4.4	0.489	5.263
Ethyl alcohol	C_2H_6O	0.789	1,207	3,960	4.0	1.396	15.020
Ethyl benzene (46)	C_8H_{10}	0.867 (20°C)	1,338 (20°C)	4,389.8 (68°F)		0.797 (17°C)	8.575 (63°F)
Ethyl Bromide (46)	C_2H_5Br	1.461 (20°C)	900 (20°C)	2,952.8 (68°F)		0.275 (20°C)	2.959 (68°F)
Ethyliodide (46)	C_2H_5I	1.950 (20°C)	876 (20°C)	2874 (68°F)		0.29	3.12

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Ether	$C_4H_{10}O$	0.713	985	3231.6	4.87	0.311	3.346
Ethyl ether	$C_4H_{10}O$	0.713	985	3231.6	4.87	0.311	3.346
Ethylene bromide (47)	$C_2H_4Br_2$	2.18	995	3264.4		0.79	8.5
Ethylene chloride (47)	$C_2H_4Cl_2$	1.253	1,193	3914		0.61	6.563
Ethylene glycol	$C_2H_6O_2$	1.113	1,658	5439.6	2.1	17.208 (20°C)	185.158 (68°F)
d-Fenochone	$C_{10}H_{16}O$	0.947	1,320	4330.7		0.22	2.367
d-2-Fenechanone	$C_{10}H_{16}O$	0.947	1,320	4330.7		0.22	2.367
Fluorine	F	0.545 (-143°C)	403 (-143°C)	1322.2 (-225°F)	11.31		
Fluoro-benzene (46)	C_6H_5F	1.024 (20°C)	1,189	3900.9		0.584 (20°C)	6.283 (68°F)
Formaldehyde, methyl ester	$C_2H_4O_2$	0.974	1,127	3697.5	4.02		
Formamide	CH_3NO	1.134 (20°C)	1,622	5321.5	2.2	2.91	31.311
Formic acid, amide	CH_3NO	1.134 (20°C)	1,622	5321.5		2.91	31.311
Freon R12			774.2	2540			
Furfural	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
Furfuryl alcohol	$C_5H_6O_2$	1.135	1,450	4757.2	3.4		
Fural	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
2-Furaldehyde	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
2-Furancarboxaldehyde	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
2-Furyl-Methanol	$C_5H_6O_2$	1.135	1,450	4757.2	3.4		
Gallium	Ga	6.095	2,870 (30°C)	9416 (86°F)			
Glycerin	$C_3H_8O_3$	1.26	1,904	6246.7	2.2	757.1	8,081.836
Glycerol	$C_3H_8O_3$	1.26	1,904	6246.7	2.2	757.1	8,081.836
Glycol	$C_2H_6O_2$	1.113	1658	5439.6	2.1		
50% Glycol / 50% H_2O			1,578	5,177			

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Helium (45)	He_4	0.125 (-269°C)	183 (-269°C)	600.4 (-452°F)		0.025	.269
Heptane (22, 23)	C_7H_{16}	0.684 (20°C)	1,131	3,710.6	4.25	0.598 (20°C)	6.434 (68°F)
n-Heptane (29, 33)	C_7H_{16}	0.684 (20°C)	1,180	3,871.3	4.0		
Hexachloro-Cyclopentadiene (47)	C_5Cl_6	1.7180	1,150	3,773			
Hexadecane (23)	$C_{16}H_{34}$	0.773 (20°C)	1,338	4,389.8	3.71	4.32 (20°C)	46.483 (68°F)
Hexalin	$C_6H_{12}O$	0.962	1,454	4,770.3	3.6	70.69 (17°C)	760.882 (63°F)
Hexane (16, 22, 23)	C_6H_{14}	0.659	1,112	3,648.3	2.71	0.446	4.798
n-Hexane (29, 33)	C_6H_{14}	0.649 (20°C)	1,079	3,540	4.53		
2,5-Hexanedione	$C_6H_{10}O_2$	0.729	1,399	4,589.9	3.6		
n-Hexanol	$C_6H_{14}O$	0.819	1,300	4,265.1	3.8		
Hexahydrobenzene (15)	C_6H_{12}	0.779	1,248	4,094.5	5.41	1.31 (17°C)	14.095 (63°F)
Hexahydrophenol	$C_6H_{12}O$	0.962	1,454	4,770.3	3.6		
Hexamethylene (15)	C_6H_{12}	0.779	1,248	4,094.5	5.41	1.31 (17°C)	14.095 (63°F)
Hydrogen (45)	H_2	0.071 (-256°C)	1,187 (-256°C)	3,894.4 (-429°F)		0.003 (-256°C)	0.032 (-429°F)
2-Hydroxy-toluene (46)	C_7H_8O	1.047 (20°C)	1,541 (20°C)	5,055.8 (68°F)		4.29 (40°C)	46.16 (104°F)
3-Hydroxy-toluene (46)	C_7H_8O	1.034 (20°C)	1,500 (20°C)	4,921.3 (68°F)		5.979 (40°C)	64.334 (104°F)
Iodo-benzene (46)	C_6H_5I	1.823	1,114 (20°C)	3,654.9 (68°F)		0.954	
Iodo-ethane (46)	C_2H_5I	1.950 (20°C)	876 (20°C)	2,874 (68°F)		0.29	3.12
Iodo-methane	CH_3I	2.28 (20°C)	978	3,208.7		0.211	2.27
Isobutyl acetate (22)	$C_6H_{12}O$		1,180 (27°C)	3,871.4 (81°F)	4.85		

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Isobutanol	$C_4H_{10}O$	0.81 (20°C)	1,212	3,976.4			
Iso-Butane			1,219.8	4002			
Isopentane (36)	C_5H_{12}	0.62 (20°C)	980	3,215.2	4.8	0.34	3.658
Isopropanol (46)	C_3H_8O	0.785 (20°C)	1,170 (20°C)	3,838.6 (68°F)		2.718	29.245
Isopropyl alcohol (46)	C_3H_8O	0.785 (20°C)	1,170 (20°C)	3,838.6 (68°F)		2.718	29.245
Kerosene		0.81	1,324	4,343.8	3.6		
Ketohexamethylene	$C_6H_{10}O$	0.948	1,423	4,668.6	4.0		
Lithium fluoride (42)	LiF		2,485 (900°C)	8,152.9 (1652°F)	1.29		
Mercury (45)	Hg	13.594	1,449 (24°C)	4,753.9 (75°F)		0.114	1.226
Mesityloxide	$C_6H_{16}O$	0.85	1,310	4,297.9			
Methane (25, 28, 38, 39)	CH_4	0.162 (-89°C)	405 (-89°C)	1,328.7 (-128°F)	17.5		
Methanol (40, 41)	CH_4O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.478
Methyl acetate	$C_3H_6O_2$	0.934	1,211	3,973.1		0.407	4.379
o-Methylaniline (46)	C_7H_9N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
4-Methylaniline (46)	C_7H_9N	0.966 (45°C)	1,480	4,855.6		1.863 (50°C)	20.095 (122°F)
Methyl alcohol (40, 44)	CH_4O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.478
Methyl benzene (16, 52)	C_7H_8	0.867	1,328 (20°C)	4,357 (68°F)	4.27	0.644	7.144
2-Methyl-butane (36)	C_5H_{12}	0.62 (20°C)	980	3,215.2		0.34	3.658
Methyl carbinol	C_2H_6O	0.789	1,207	3,960	4.0	1.396	
Methyl-chloroform (47)	$C_2H_3Cl_3$	1.33	985	3,231.6		0.902 (20°C)	9.705 (68°F)
Methyl-cyanide	C_2H_3N	0.783	1,290	4,232.3		0.441	4.745
3-Methyl cyclohexanol	$C_7H_{14}O$	0.92	1,400	4,593.2			

Sound Speed in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Methylene chloride (3)	CH_2Cl_2	1.327	1,070	3,510.5	3.94	0.31	3.335
Methylene iodide	CH_2I_2	3.235	980	3,215.2			
Methyl formate (22)	$C_2H_4O_2$	0.974 (20°C)	1,127	3,697.5	4.02		
Methyl iodide	CH_3I	2.28 (20°C)	978	3,208.7		0.211	2.27
a-Methyl naphthalene	$C_{11}H_{10}$	1.090	1,510	4,954.1	3.7		
2-Methylphenol (46)	C_7H_8O	1.047 (20°C)	1,541 (20°C)	5,055.8 (68°F)		4.29 (40°C)	46.16 (104°F)
3-Methylphenol (46)	C_7H_8O	1.034 (20°C)	1,500 (20°C)	4,921.3 (68°F)		5.979 (40°C)	64.334 (104°F)
Milk, homogenized			1,548	5,080			
Morpholine	C_4H_9NO	1.00	1,442	4,731	3.8		
Naphtha		0.76	1,225	4,019			
Natural Gas (37)		0.316 (-103°C)	753 (-103°C)	2,470.5 (-153°F)			
Neon (45)	Ne	1.207 (-246°C)	595 (-246°C)	1,952.1 (-411°F)			
Nitrobenzene (46)	$C_6H_5NO_2$	1.204 (20°C)	1,415 (20°C)	4,642.4 (68°F)		1.514	16.29
Nitrogen (45)	N_2	0.808 (-199°C)	962 (-199°C)	3,156.2 (-326°F)		0.217 (-199°C)	2.334 (-326°F)
Nitromethane (43)	CH_3NO_2	1.135	1,300	4,265.1	4.0	0.549	5.907
Nonane (23)	C_9H_2O	0.718 (20°C)	1,207	3,960	4.04	0.99 (20°C)	10.652 (68°F)
1-Nonene (27)	C_9H_{18}	0.736 (20°C)	1,207	3,960	4.0		
Octane (23)	C_8H_{18}	0.703	1,172	3,845.1	4.14	0.73	7.857
n-Octane (29)	C_8H_{18}	0.704 (20°C)	1,212.5	3,978	3.50	0.737	.930)
1-Octene (27)	C_8H_{16}	0.723 (20°C)	1,175.5	3,856.6	4.10		
Oil of Camphor Sassafrassy			1,390	4,560.4	3.8		
Oil, Car (SAE 20a.30)		1.74	870	2,854.3		190	2,045.093
Oil, Castor	$C_{11}H_{10}O_{10}$	0.969	1,477	4,845.8	3.6	0.670	7.209

Sound Speed in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Oil, Diesel		0.80	1,250	4,101			
Oil, Fuel AA gravity		0.99	1,485	4,872	3.7		
Oil (Lubricating X200)			1,530	5,019.9			
Oil (Olive)		0.912	1,431	4,694.9	2.75	100	1,076.365
Oil (Peanut)		0.936	1,458	4,783.5			
Oil (Sperm)		0.88	1,440	4,724.4			
Oil, 6			1,509 (22°C)	4,951 (72°F)			
2,2-Oxydiethanol	$C_4H_{10}O_3$	1.116	1,586	5,203.4	2.4		
Oxygen (45)	O_2	1.155 (-186°C)	952 (-186°C)	3,123.4 (-303°F)		0.173	1.861
Pentachloro-ethane (47)	C_2HCl_5	1.687	1,082	3,549.9			
Pentalin (47)	C_2HCl_5	1.687	1,082	3,549.9			
Pentane (36)	C_5H_{12}	0.626 (20°C)	1,020	3,346.5		0.363	3.905
n-Pentane (47)	C_5H_{12}	0.557	1,006	3,300.5		0.41	4.413
Perchlorocyclopentadiene (47)	C_5Cl_6	1.718	1,150	3,773			
Perchloro-ethylene (47)	C_2Cl_4	1.632	1,036	3,399			
Perfluoro-1-Hepten (47)	C_7F_{14}	1.67	583	1,912.7			
Perfluoro-n-Hexane (47)	C_6F_{14}	1.672	508	1,666.7			
Phene (29, 40, 41)	C_6H_6	0.879	1,306	4,284.8	4.65	0.711	7.65
b-Phenyl acrolein	C_9H_8O	1.112	1,554	5,098.4	3.2		
Phenylamine (41)	$C_6H_5NO_2$	1.022	1,639	5,377.3	4.0	3.63	39.058
Phenyl bromide (46)	C_6H_5Br	1.522	1,170 (20°C)	3,838.6 (68°F)		0.693	7.456
Phenyl chloride	C_6H_5Cl	1.106	1,273	4,176.5	3.6	0.722	7.768
Phenyl iodide (46)	C_6H_5I	1.823	1,114 (20°C)	3,654.9 (68°F)		0.954 (15°C)	10.265 (59°F)
Phenyl methane (16, 52)	C_7H_8	0.867 (20°C)	1,328 (20°C)	4,357 (68°F)	4.27	0.644	6.929
3-Phenyl propenal	C_9H_8O	1.112	1,554	5,098.4	3.2		

Sound Speed in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Phthalardione	$C_8H_4O_3$		1,125 (152°C)	3,691 (306°F)			
Phthalic acid, anhydride	$C_8H_4O_3$		1,125 (152°C)	3,691 (306°F)			
Pthalic anhydride	$C_8H_4O_3$		1,125 (152°C)	3,691 (306°F)			
Pimelic ketone	$C_6H_{10}O$	0.948	1,423	4,668.6	4.0		
Plexiglas, Lucite, Acrylic			2,651	8,698			
Polyterpene Resin		0.77	1,099.8 (190°C)	3,608.4 (374°F)		39,000	419,500
Potassium bromide (42)	KBr		1,169 (900°C)	3,835.3 (1652°F)	0.71	.715cp (900°C)	7.693 (1652°F)
Potassium fluoride (42)	KF		1,792 (900°C)	5,879.3 (1652°F)	1.03		
Potassium iodide (42)	KI		985 (900°C)	3,231.6 (1652°F)	0.64		
Potassium nitrate (48)	KNO_3	1.859 (352°C)	1,740.1 (352°C)	5,709 (666°F)	1.1	1.19 (327°C)	12.804 (621°F)
Propane (2, 13) (-45° to -130°C)	C_3H_8	0.585 (-45°C)	1,003 (-45°C)	3,290.6 (-49°F)	5.7		
1,2,3-Propanetriol	$C_3H_8O_3$	1.26	1,904	6,246.7	2.2	.000757	
1-Propanol (46)	C_3H_8O	0.78 (20°C)	1,222 (20°C)	4,009.2 (68°F)			
2-Propanol (46)	C_3H_8O	0.785 (20°C)	1,170 (20°C)	3,838.6 (68°F)		2.718	29.245
2-Propanone	C_3H_6O	0.791	1,174	3,851.7	4.5	0.399	4.293
Propene (17, 18, 35)	C_3H_6	0.563 (-13°C)	963 (-13°C)	3,159.4 (9°F)	6.32		
n-Propyl acetate (22)	$C_5H_{10}O_2$		1,280 (2°C)	4,199 (36°F)	4.63		
n-Propyl-alcohol	C_3H_8O	0.78 (20°C)	1,222 (20°C)	4,009.2 (68°F)		2.549	27.427
Propylchloride (47)	C_3H_7Cl	0.892	1,058	3,471.1		0.378	4.067
Propylene (17, 18, 35)	C_3H_6	0.563 (-13°C)	963 (-13°C)	(3159.4) (9°F)	6.32		

Sound Speed in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Pyridine	C_6H_5N	0.982	1,415	4,642.4	4.1	0.992 (20°C)	10.673 (68°F)
Refrigerant 11 (3, 4)	CCl_3F	1.49	828.3 (0°C)	2,717.5 (32°F)	3.56		
Refrigerant 12 (3)	CCl_2F_2	1.516 (-40°C)	774.1 (-40°C)	2,539.7 (-40°F)	4.24		
Refrigerant 14 (14)	CF_4	1.75 (-150°C)	875.24 (-150°C)	2,871.5 (-238°F)	6.61		
Refrigerant 21 (3)	$CHCl_2F$	1.426 (0°C)	891 (0°C)	2,923.2 (32°F)	3.97		
Refrigerant 22 (3)	$CHClF_2$	1.491 (-69°C)	893.9 (50°C)	2,932.7 (122°F)	4.79		
Refrigerant 113 (3)	CCl_2F-$CClF_2$	1.563	783.7 (0°C)	2,571.2 (32°F)	3.44		
Refrigerant 114 (3)	$CClF_2$-$CClF_2$	1.455	665.3 (-10°C)	2,182.7 (14°F)	3.73		
Refrigerant 115 (3)	C_2ClF_5		656.4 (-50°C)	2,153.5 (-58°F)	4.42		
Refrigerant C318 (3)	C_4F_8	1.62 (-20°C)	574 (-10°C)	1,883.2 (14°F)	3.88		
Selenium (8)	Se		1,072 (250°C)	3,517.1 (482°F)	0.68		
Silicone (30 cp)		0.993	990	3,248		30	322.8
Sodium fluoride (42)	NaF	0.877	2,082 (1000°C)	6,830.7 (1832°F)	1.32		
Sodium nitrate (48)	$NaNO_3$	1.884 (336°C)	1,763.3 (336°C)	5,785.1 (637°F)	0.74	1.37 (336°C)	14.74 (637°F)
Sodium nitrite (48)	$NaNO_2$	1.805 (292°C)	1,876.8 (292°C)	6,157.5 (558°F)			
Solvesso #3		0.877	1,370	4,494.8	3.7		
Spirit of wine	C_2H_6O	0.789	1,207	3,960	4.0	1.396	15.02
Sulfur (7, 8, 10)	S		1,177 (250°C)	3,861.5 (482°F)	-1.13		
Sulfuric Acid (1)	H_2SO_4	1.841	1,257.6	4,126	1.43	11.16	120.081
Tellurium (7)	Te		991 (450°C)	3,251.3 (842°F)	0.73		

Sound Speeds in Various Fluids

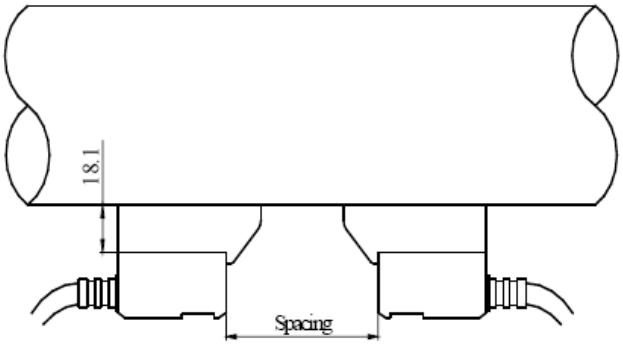
Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
1,1,2,2-Tetrabromo-ethane (47)	$C_2H_2Br_4$	2.966	1,027	3,369.4			
1,1,2,2-Tetrachloro-ethane (67)	$C_2H_2Cl_4$	1.595	1,147	3,763.1		1.156 (15°C)	12.438 (59°F)
Tetrachloroethane (46)	$C_2H_2Cl_4$	1.553 (20°C)	1,170 (20°C)	3,838.6 (68°F)		1.19	12.804
Tetrachloro-ethene (47)	C_2Cl_4	1.632	1,036	3,399			
Tetrachloro-Methane (33, 47)	CCl_4	1.595 (20°C)	926	3,038.1		0.607	6.531
Tetradecane (46)	$C_{14}H_3O$	0.763 (20°C)	1,331 (20°C)	4,366.8 (68°F)		2.86 (20°C)	30.773 (68°F)
Tetraethylene glycol	$C_8H_{18}O_5$	1.123	1,586	5,203.4	3.0		
Tetrafluoro-methane (14) (Freon 14)	CF_4	1.75 (-150°C)	875.24 (-150°C)	2,871.5 (-238°F)	6.61		
Tetrahydro-1,4-isoxazine	C_4H_9NO	1.000	1,442	4,731	3.8		
Toluene (16, 52)	C_7H_8	0.867 (20°C)	1,328 (20°C)	4,357 (68°F)	4.27	0.644	6.929
o-Toluidine (46)	C_7H_9N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
p-Toluidine (46)	C_7H_9N	0.966 (45°C)	1,480	4,855.6		1.863 (50°C)	20.053 (122°F)
Toluol	C_7H_8	0.866	1,308	4,291.3	4.2	0.58	6.24
Tribromo-methane (46, 47)	$CHBr_3$	2.89 (20°C)	918	3,011.8		0.654	7.037
1,1,1-Trichloro-ethane (47)	$C_2H_3Cl_3$	1.33	985	3,231.6		0.902 (20°C)	9.705 (68°F)
Trichloro-ethene (47)	C_2HCl_3	1.464	1,028	3,372.7			
Trichloro-fluoromethane (3) (Freon 11)	CCl_3F	1.49	828.3 (0°C)	2,717.5 (32°F)	3.56		
Trichloro-methane (47)	$CHCl_3$	1.489	979	3,211.9	3.4	0.55	5.918
1,1,2-Trichloro-1,2,2-Trifluoro-Etham	$CCl_2F\text{-}CClF_2$	1.563	783.7 (0°C)	2,571.2 (32°F)			
Triethyl-amine (33)	$C_6H_{15}N$	0.726	1,123	3,684.4	4.47		
Triethylene glycol	$C_6H_{14}O_4$	1.123	1,608	5,275.6	3.8		

Sound Speeds in Various Fluids

Substance	Chemical Formula	*All data given at 25°C (77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity x10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
1,1,1-Trifluoro-2-Chloro-2-Bromo-Ethane	$C_2HClBrF_3$	1.869	693	2,273.6			
1,2,2-Trifluorotrichloro-ethane (Freon 113)	$CCl_2F\text{-}CClF_2$	1.563	783.7 (0°C)	2,571.2 (32°F)	3.44		
d-1,3,3-Trimethylnorcamphor	$C_{10}H_{16}O$	0.947	1,320	4,330.7		0.22	2.367
Trinitrotoluene (43)	$C_7H_5(NO_2)_3$	1.64	1,610 (81°C)	5,282.2 (178°F)			
Turpentine		0.88	1,255	4,117.5		1.4	15.064
Unisis 800		0.87	1,346	4,416			
Water, distilled (49, 50)	H_2O	0.996	1,498	4,914.7	-2.4	1.00	10.76
Water, heavy	D^2O		1,400	4,593			
Water, sea		1.025	1,531	5,023	-2.4	1.00	10.76
Wood Alcohol (40, 41)	CH_4O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.478
Xenon (45)	Xe		630 (-109°C)	2,067 (-164°F)			
m-Xylene (46)	C_8H_{10}	0.868 (15°C)	1,343 (20°C)	4,406.2 (68°F)		0.749 (15°C)	8.059 (59°F)
o-Xylene (29, 46)	C_8H_{10}	0.897 (20°C)	1,331.5	4,368.4	4.1	0.903 (20°C)	9.716 (68°F)
p-Xylene (46)	C_8H_{10}		1,334 (20°C)	4,376.6 (68°F)		0.662	7.123
Xylene hexafluoride	$C_8H_4F_6$	1.37	879	2,883.9		0.613	6.595
Zinc (7)	Zn		3,298 (450°C)	10,820.2 (842°F)			

8.12 Addendum for High Temperature transducer Installation

Mounting Instruction of High Temperature Clamp-on Transducers



Using straps to install the High Temperature Clamp-on transducers, we must program the instrument to take into account the additional space dimensions of the HT blocks attached to the transducers. This additional dimension is actually 18.1 mm per transducer. So what we will do is tell the 205 that the pipe OD is actually larger by 18.1mm (x2), then we will tell the 205 that the pipe materials are actually the materials of the HT blocks, PEI, and the REAL pipe material will become a Liner. The liner thickness will be the ACTUAL pipe wall thickness.

Here's an example:

Pipe: 150 MM, Carbon Steel
OD: 168 MM
Wall: 6 MM
ID: 156 MM
Fluid: Water
Transducer Mount will be a V mount

Programming steps as follows:

MENU 11 (Pipe OD): 168 + 18.1 + 18.1=204.2 mm
MENU 12 (Pipe Water Thickness): 18.1 mm
MENU 13 (Pipe ID): 168 mm
MENU 14 (Pipe Material): OTHER (PEI)
MENU 15 (Pipe Sound Velocity): 2424.4 m/s
MENU 16 (Liner Material): OTHER (CARBON STEEL)
MENU 17 (Liner Sound Velocity): 3230 m/s
MENU 18 (Liner Thickness): 6 mm
MENU 20 (Fluid Type): WATER
MENU 23 (Transducer Type): STANDARD
MENU 24 (Transducer Mounting): V

This will provide a Transducer Spacing of:
MENU 25 (Transducer Spacing): 164.249 mm

The Pipe Materials here are PEI, and the Sound Velocity is 2424.4 meters per second or 7954.068 Feet per second. The Actual Pipe Material and wall thickness becomes the liner.

See Section 8.13 for Sound Speeds in Various Pipe Materials

8.13 Sound Speed in Various Pipe Materials

Material	Sound Speed* Shear Wave (25°C)		Sound Speed* Long. Wave (25°C)	
	m/s	ft/s	mm/µs	in./µs
Steel, 1% Carbon, hardened	3,150	10,335	5.88	0.2315
Carbon Steel	3,230	10,598	5.89	0.2319
Mild Steel	3,235	10,614	5.89	0.2319
Steel, 1% Carbon	3,220	10,565		
302 Stainless Steel	3,120	10,236	5.690	0.224
303 Stainless Steel	3,120	10,236	5.640	0.222
304 Stainless Steel	3,141	10,306	5.920	0.233
304L Stainless Steel	3,070	10,073	5.790	0.228
316 Stainless Steel	3,272	10,735	5.720	0.225
347 Stainless Steel	3,095	10,512	5.720	0.225
Aluminum	3,100	10,171	6.32	0.2488
Aluminum (rolled)	3,040	9,974		
Copper	2,260	7,415	4.66	0.1835
Copper (annealed)	2,325	7,628		
Copper (rolled)	2,270	7,448		
CuNi (70%Cu 30%Ni)	2,540	8,334	5.03	0.1980
CuNi (90%Cu 10%Ni)	2,060	6,759	4.01	0.1579
Brass (Naval)	2,120	6,923	4.43	0.1744
Gold (hard-drawn)	1,200	3,937	3.24	0.1276
Inconel	3,020	9,909	5.82	0.2291
Iron (electrolytic)	3,240	10,630	5.90	0.2323

Sound Speeds in Various Pipe Materials

Material	Sound Speed* Shear Wave (25°C)		Sound Speed* Long. Wave (25°C)	
	m/s	ft/s	mm/µs	in./µs
Iron (Armco)	3,240	10,630	5.90	0.2323
Ductile Iron	3,000	9,843		
Cast Iron	2,500	8,203	4.55	0.1791
Monel	2,720	8,924	5.35	0.2106
Nickel	2,960	9,712	5.63	0.2217
Tin, rolled	1,670	5,479	3.32	0.1307
Titanium	3,125	10,253	6.10	0.2402
Tungsten, annealed	2,890	9,482	5.18	0.2039
Tungsten, drawn	2,640	8,661		
Tungsten, carbide	3,980	13,058		
Zinc, rolled	2,440	8,005	4.17	0.1642
Glass, Pyrex	3,280	10,761	5.61	0.2209
Glass, heavy silicate flint	2,380	7,808		
Glass, light borate crown	2,840	9,318	5.26	0.2071
Nylon	1,150	3,772	2.40	0.0945
Nylon, 6-6	1,070	3,510		
Polyethylene (HD)			2.31	0.0909
Polyethylene (LD)	540	1,772	1.94	0.0764
PVC, CPVC	1,060	3,477	2.40	0.0945
Acrylic	1,430	4,690	2.73	0.1075
Asbestos Cement			2.20	0.0866
Tar Epoxy			2.00	0.0787
Mortar			2.50	0.0984
Rubber			1.90	0.0748