

# RH40 Portable Flow Meter

The RH40 Handheld Ultrasonic Flow & BTU Meter is a revolutionary portable meter with multiple functions. **It is the most compact portable meter on the market.** It is designed to accommodate the challenge of onsite flow and energy measurements. The applications range from **field servicing, maintenance, or even temporary flow and energy surveys.**

The RH40 compact design offers a single-handed hold and extreme ease of use. Using the latest signal processing technology, which has demonstrated its robustness and data measurement repeatability, the portable meter offers highly accurate and reliable measurements. The meter is self-explanatory and simple to follow. The RH40 is also a handheld energy meter when it is equipped with a BTU measurement module.

The unique clamp-on fixture design, for both the flow transducers and temperature sensors, makes the installation hassle-free. No special skills or tools are required. The Li-Ion battery allows the user to measure flow and energy for an extended period of time- up to 8 hours. A built-in data logger memory of up to 2GB gives the user the flexibility of using the meter for data-logging and data-analysis.

The RH40 is the **best choice for flow survey, meter verification, pump checking, HVAC and energy balancing, facility management, and other demanding flow and energy monitoring applications.**

## Features

- Accurately measures energy and flow using non-intrusive technology
- Capability of measuring bi-directional flow/Energy
- Ease of use and fast installation
- Able to measure on a very wide pipe size range, from 0.5” up to 120”
- Ergonomic design, allowing the main unit to be held and operated with one hand
- Signal quality tracking and self-adaptation for robust performance
- Suitable for pure liquids and liquids with some particles. No dependency on conductivity
- Suitable for all commonly used pipes

- Rechargeable battery for 8 hours of operation
- Self-explanatory user interface. Step-by-step Quick Start guidance
- Optional built-in large data logger
- PC software for data download and real-time data acquisition
- Bluetooth and serial interfaces for PC link
- $\pm 0.5\%$  of linearity
- Accuracy:  $\pm 1\%$  of reading in velocity plus  $\pm 0.03\text{ft/s}$  ( $10\text{mm/s}$ )

## **Typical Applications**

The RH40 handheld flow and BTU meter is a perfect fit for the following applications:

- Energy consumption supervision and water conservation management
- Cooling system and air conditioning/glycol solutions
- Water, including hot water, chilled water, city water, sea water, and more
- Sewage and drainage water with small particle quantity
- Oil, including crude oil, lubricating oil, diesel oil, fuel oil, and more
- Various chemicals, including alcohol, acids, and more
- Solvents
- Beverage and food processors
- Water and waste treatment
- Power plants (nuclear, thermal & hydropower) heat energy boiler feed water
- Metallurgy and mining applications (e.g., acid recovery)
- Marine operation and maintenance
- Pulp and paper
- Pipeline leak detection, inspection, tracking, and collection
- Water distribution network monitoring

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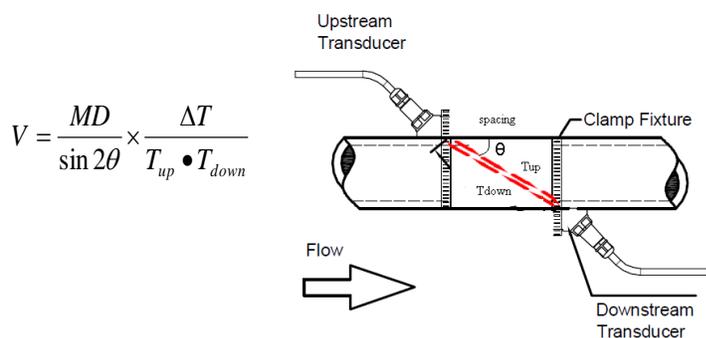
# 1.Introduction

## §1.1 Principle of Measurement

The Regal Series flow and energy meters are based on the transit-time measurement principle, where the system utilizes a pair of sensors which function as both ultrasonic transmitter and receiver. The sensors are installed on the pipe wall, either clamped on the outside of the pipe or inserted into the pipe at a specific distance from each other. The flow meter operates by alternately transmitting and receiving a coded burst of sound energy between the two sensors and measuring the transit time it takes for sound to travel between the two sensors. The difference in the transit time is directly related to the velocity of the liquid in the pipe. The flow rate is then calculated based on the transit-time difference, the geometry of the pipe and the fluid dynamics formula.

The sensors, or transducers, are commonly mounted with the Z-method or the V-method. There are several types of transducers you may choose for your application. HS and HM transducers have mounting rails. They are, therefore, easy to install. You may need a clamping strap to secure the mounting rail to the pipe if the magnet on the rail does not work with the pipe. See Appendix §9.2 for details on the different types of transducers. All the other types of transducers do not have a mounting rail. You can clamp them on to pipe using the supplied clamping strap. Installation using these clamping straps is an easy, straight-forward process. **The installation process is fully explained in Section §3.**

The RH40 operates by alternately transmitting and receiving a frequency-modulated burst of sound energy between the two transducers and measuring the transit time that it takes for sound to travel between the two transducers. The difference in the transit time measured is directly and exactly related to the velocity of the liquid in the pipe, as shown in the following equation and figure.



Where

$\theta$  is the angle between the sound path and the flow direction

M is the number of times the sound traverses the flow

D is the pipe diameter

$T_{up}$  is the time for the beam traveling from upstream the transducer to the downstream transducer

$T_{down}$  is the time for the beam traveling from the downstream transducer to the upstream transducer

$$\Delta T = T_{up} - T_{down}$$

Both flow and thermal measurements are necessary to calculate energy usage. There are two methods for thermal energy calculation:

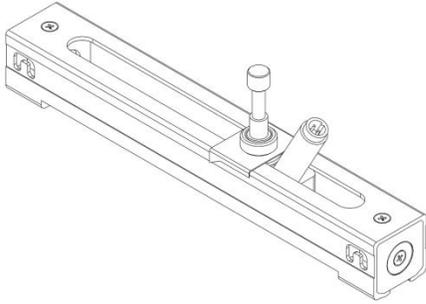
(1)  $Q_t = Q \times (T_2 - T_1) \times C_t$ ,

(2)  $Q_t = Q \times (TC_2 - TC_1)$

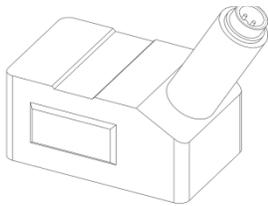
**The site of the transducer installation is very important.** Here are some recommendations for selecting the right site:

- In order to achieve high accuracy, we recommend using a pipe with at least a 15D straight-pipe run: upstream 10D and downstream 5D, where D is pipe diameter. A longer, upstream straight-pipe run is best.
- If there is a valve upstream and the valve is not fully open, it could generate flow disturbance.
- If there is a pump upstream, we recommend a pipe with at least a 30D straight pipe run.
- If the pipe is vertical, make sure the flow is going upward, not downward. Downward flow could produce air gaps, if the flow is free fall.
- If the pipe is horizontal, make sure the pipe is **FULL**. The transducer needs to be installed on the side of the pipe, not on the top or bottom of the pipe.

## §1.2 Parts Identification



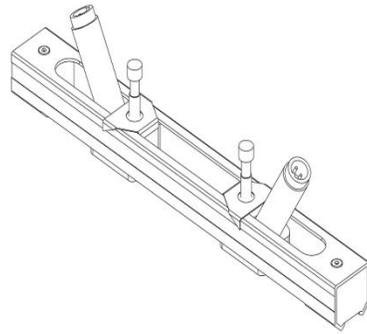
**RM Transducer**



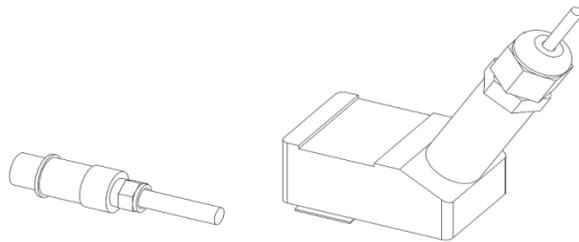
**LF Transducer (optional)**



**Charger with Adapter**



**RS2 Transducer**

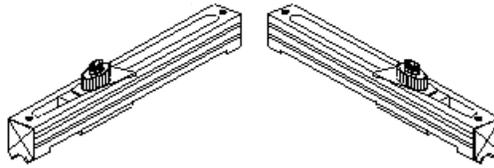


**Temperature Sensors**

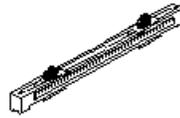


**Clamping Strap**

**HM-type (2"-28")**



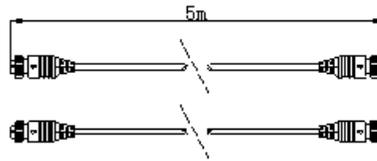
**HS-type**



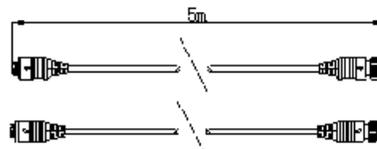
**L1-type  
(Optional)**



**Transducer Cable 5m x 2**



**Extension Cable 5m x 2**



**USB Cable**



**Complete RH40 Kit, including carrying case, measuring tape, nylon clamping straps, and software CD**

### §1.3 Product Identification

Each set of the RH40 series flow meter has a unique product identification number, or ESN. This number is written into the software and can only be modified by the manufacturer with a special tool. In the case of any hardware failure, please provide this number when contacting the manufacturer. It is displayed in Menu Window M55. The window can be accessed by pressing the following series of keys:

**M** → 5 (System) → 5 (Version/SN#)

See section §2.4 for more information on display windows.

### §1.4 Data Integrity and Built-in Time-Keeper

All user-entered configuration values are stored in the built-in, non-volatile flash memory that can retain the data for over one hundred years. The memory integrity is retained even when the power is disconnected or turned off. Password protection is provided to avoid inadvertent configuration changes or totalizer resets.

A time-keeper is integrated in the flow meter. It works as the time base for flow totalizing. The time-keeper remains operational as long as the battery's terminal voltage is over 1.5V. In the case of battery failure, the time keeper will not keep running, and the time data will be lost. The user **must** re-enter proper time values after the battery is restored. Improper time values will affect the totalizer as well as many other functions. Re-entering the time value is a crucial step after battery failure because the totalizer is a factor in accurate flow rate measurement.

### §1.5 Technical Specifications

<b>Design</b>	Portable 
<b>Flow Measurement</b>	Volumetric flow rate, total flow, velocity. Bi-directional.
<b>Energy Measurement</b>	Measure Energy rate and energy total. Dual RTD is required.

<b>Flow Velocity</b>	± 10 m/s (± 32 ft/s), bi-directional.	
<b>Flow Accuracy</b>	±1% of reading ±0.01m/s (±0.03ft/s) in velocity*	
<b>Temperature Accuracy</b>	Within 0.1°C	
<b>Repeatability</b>	0.5%	
<b>Response Time</b>	0.5s. Configurable between 0.5s and 99s.	
<b>Display/Keypad</b>	LCD with backlight. 4 x 16 letters. 5 x 4 tactile-feedback membrane keypad plus 4 utility keys.  Displays instantaneous Energy rate/total, flow rate/total (positive, negative and net), velocity.	
<b>Units</b>	English (U.S.) or metric.	
<b>Totalizers</b>	Positive totalizer, negative totalizer, net totalizer, manual totalizer.	
<b>Output</b>	4-20mA Optically isolated Open Collector Transistor output (OCT) for frequency and pulse	
<b>Recording</b>	Automatically records the daily total of the last 128 days, the monthly total of the last 64 months and the yearly total of the last 5 years.	
<b>Data Logger</b>	>150,000 measured values.	
<b>Communication Interface</b>	Bluetooth and RS232. Supports the MODBUS protocol.	
<b>Software</b>	PC software for data logger download and real-time data acquisition.  Available apps for Android.	
<b>Pipe Size Range</b>	0.5" - 120" (DN15mm - DN3,000mm), depending on transducer.	
<b>Pipe Material</b>	All metals, most plastics, some lined pipes**.	
<b>Liquid Type</b>	Virtually all liquids (full pipe).	
<b>Liquid Temperature</b>	32°F - 176°F (0°C - 80°C) or 32°F - 312°F (0°C - 155°C), depending on transducer type	
<b>Enclosure</b>	Handset:  Plastic with anti-shock protection 1.2 lbs (538g) with batteries	Carrying case:  Aluminum alloy protective case. Suitable for normal and harsh environment
<b>Environmental Protection</b>	IP54	IP54
<b>Handheld Dimensions</b>	Handset: 8"x4"x1.5" (205mmx103mmx37mm)	Carrying case: 20"x15"x6"

		(501mmx380mmx152mm)
<b>Weight</b>	Handset: 1.2 lbs (538g) with batteries	Carrying case: 15 lbs (7.5kg) approximate
<b>Power source</b>	3 AAA Ni-H built-in batteries. When fully recharged, it will last over 8 hours of operation. AC power supply to charge batteries.	

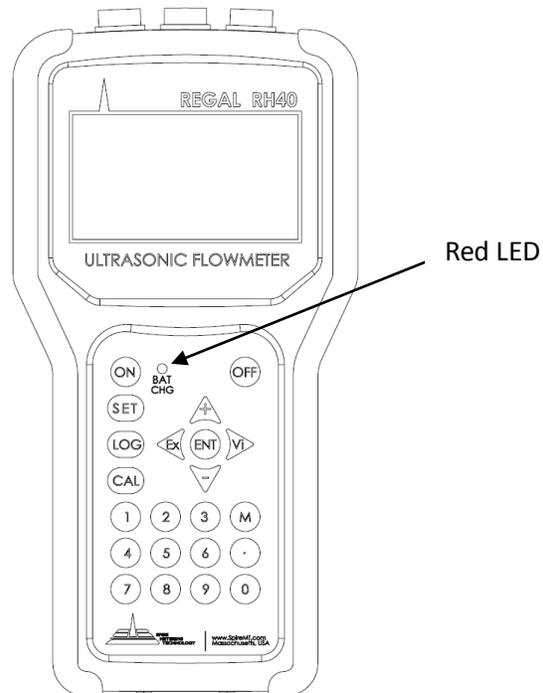
*\*Note: This accuracy rate is only applicable under the reference conditions and with a velocity above 0.5 ft/s. Flow rate is calculated by multiplying velocity with the inner cross-section area of the pipe.*

*\*\*Note: See section §3.1, #5 for more information on lined pipes.*

## 2.Flow Rate Measurement

### §2.1 Built-in Battery

The RH40 flow meter can operate either from the built-in Ni-H rechargeable battery or from an external AC power supply. The battery will last over 8 hours of continuous operation when fully charged. In addition, the AC power supply allows the device to run while charging. The red LED will be on when the battery is charging.



The battery-charging circuit employs both constant-current and constant-voltage charging methods. The battery charges quickly at the beginning, and the current tapers off as the battery approaches full power. In other words, the current becomes smaller and smaller throughout the charging process. As a result, there should be no problems with over-charging. This also means that the process of bringing the device to full power can take up a significant amount of time. **We recommend charging the device overnight to get close to 100% power.** The charger can be connected to the handset at all times when constant measurement is required. **If extended use of the handset is required, it is best to leave the device plugged in.**

When fully charged, the **terminal voltage peaks at around 4.25V**. The terminal voltage is displayed on window menu M56 (press buttons M, 5, and 6, in succession). When the battery is nearly consumed, the battery voltage drops to below 3V. The approximate remaining working time for the battery is indicated

in this window as well. The remaining working time is estimated based on the battery voltage at the time. **Some errors may occur, especially when the terminal voltage is in the range between 3.70 to -3.90 volts.**

For battery maintenance and replacement, please refer to Appendix §9.1.A

## §2.2 Power On

Press the **ON** key to turn on the power, and **OFF** to turn off the power. Once the flow meter is turned on, it will run a self-diagnostic program—checking the hardware first, and then, the software integrity. If there are any abnormalities, corresponding error messages will be displayed. (See Section §6 for more information on error messages.)

Under normal conditions, there should be no display of error messages, and the flow meter will proceed to the main window. This menu can also be accessed at any time by pressing the ◀ (“Ex”) key up to three times, depending on the menu window in use at the time. The main menu will display the signal strength, signal quality, and transit-time ratio. These readings are based on the most recent pipe parameters configured, or by the initial program.

The flow measurement will keep running in the background without change, regardless of any user window browsing or viewing activities. Only when the user enters new pipe parameters will the flow meter change measurement to reflect these alterations.

When new pipe parameters are entered or when the power is turned on, the flow meter will enter into a self-adjusting mode. The device will account for the increase in receiving circuits so that the signal strength will be within a proper range. Using this step, the flow meter finds the best receiving signals. See Section §2.6 for more information of configuring the pipe parameters.

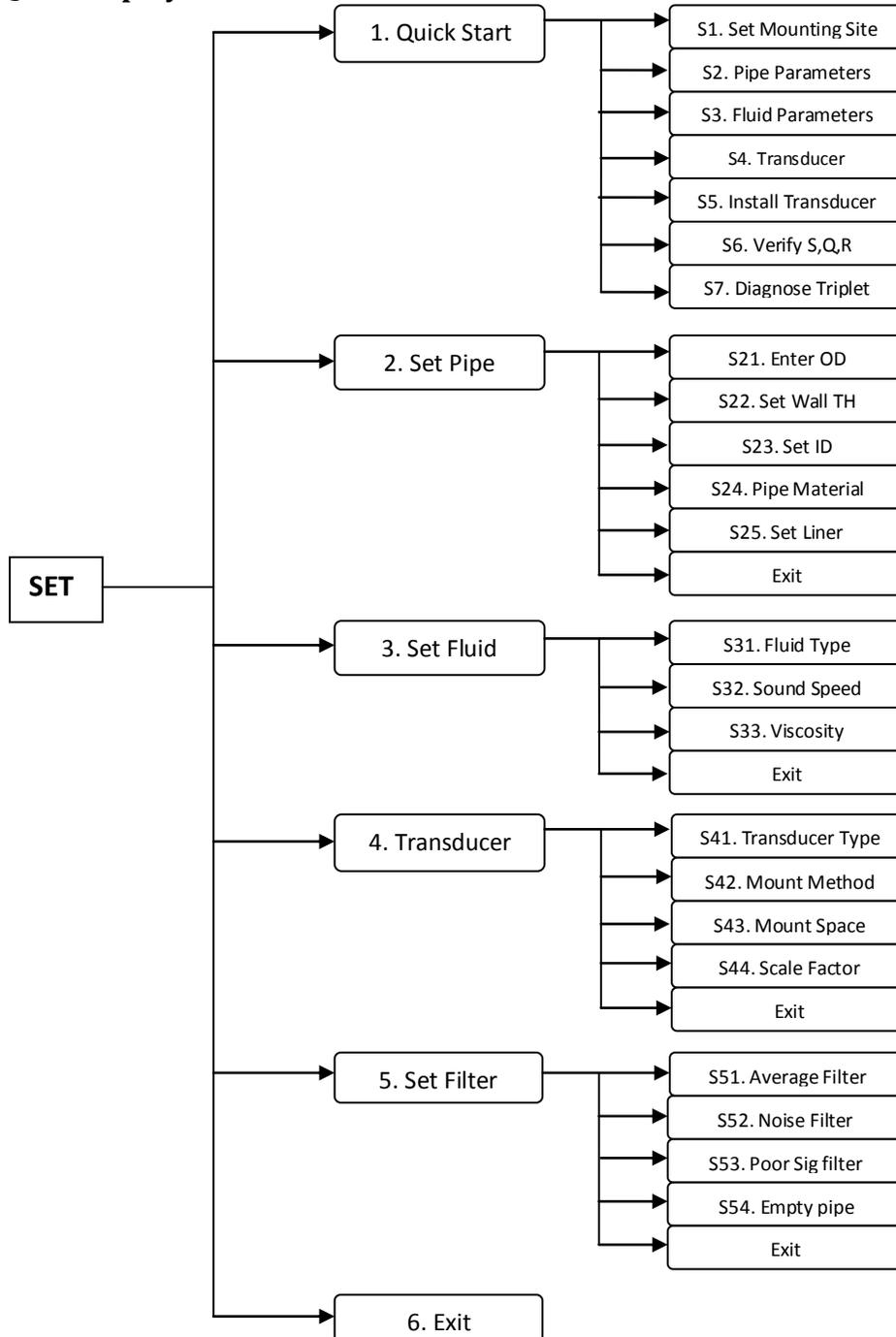
When the user adjusts the position of the installed transducers, the flow meter will re-adjust the signal gain automatically. Any user-entered configuration value will be stored in the NVRAM (non-volatile memory), until it is modified by the user.

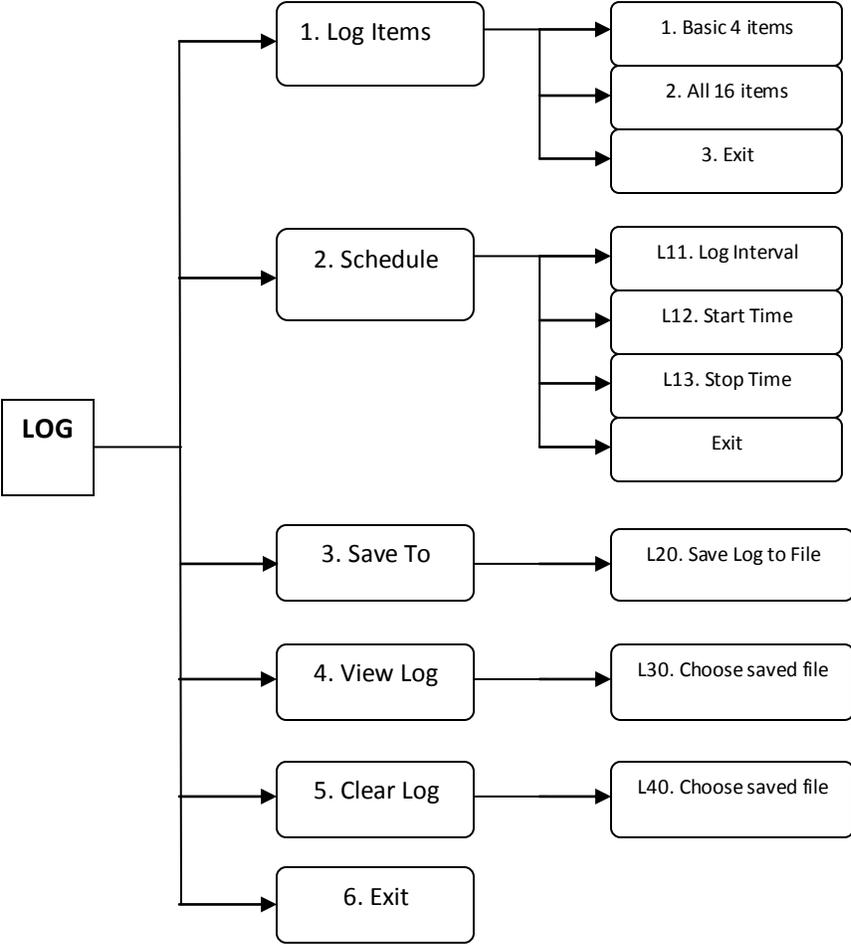
## §2.3 Keypad

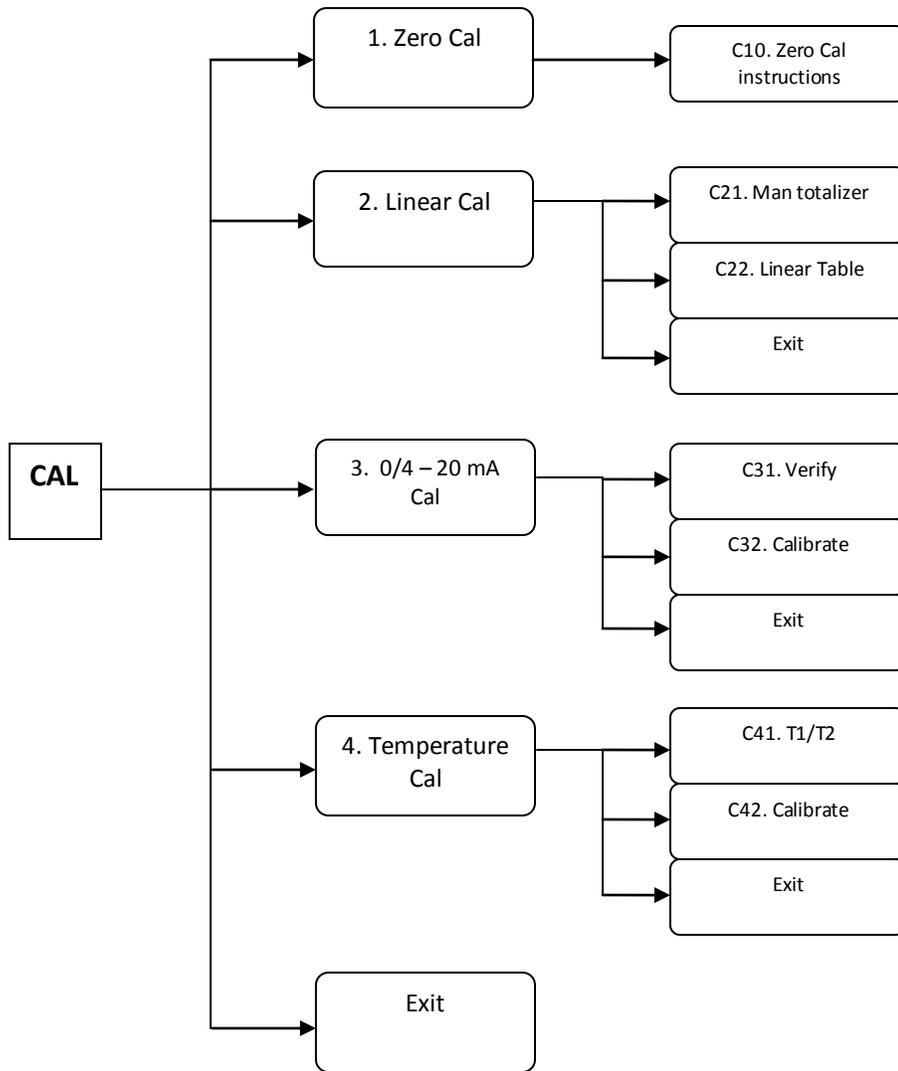
- The **SET** key is used to configure the pipe parameters.
- The **LOG** key is used to set up and view the built-in data-logger.

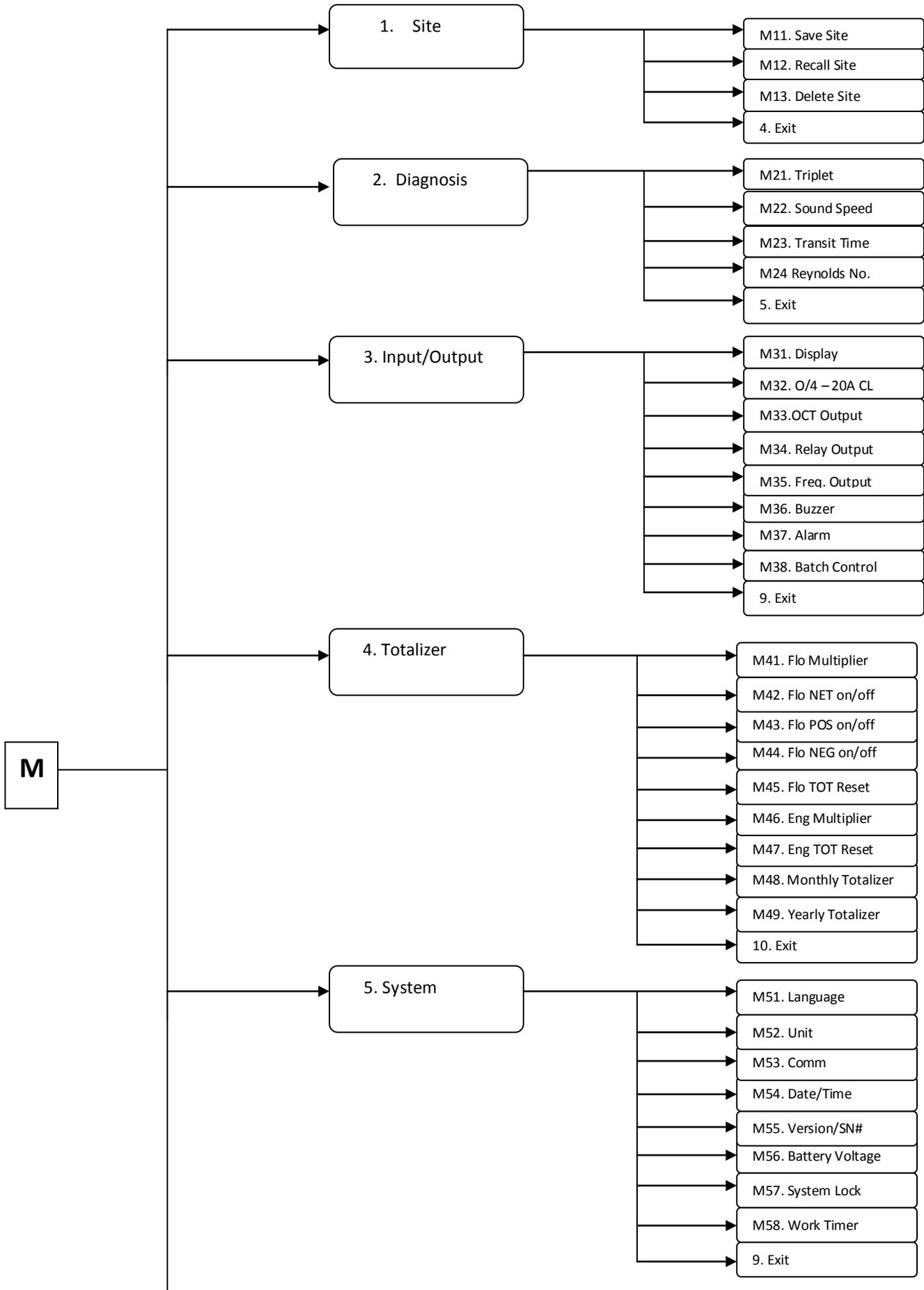
- The **CAL** key is used to set up calibrations.
- The **M** key is used to access all the other menu functions.
- The **ENT** key is the enter key to confirm or acknowledge any input or selections.
- The  (“Ex”) key is the exit or backspace key.
- The  key is used to view measurements.
- The  key is used to navigate up, or to add numbers together.
- The  key is used to navigate down, or to subtract numbers.
- The **0** through **9** and **.** keys are used to enter numbers and values.

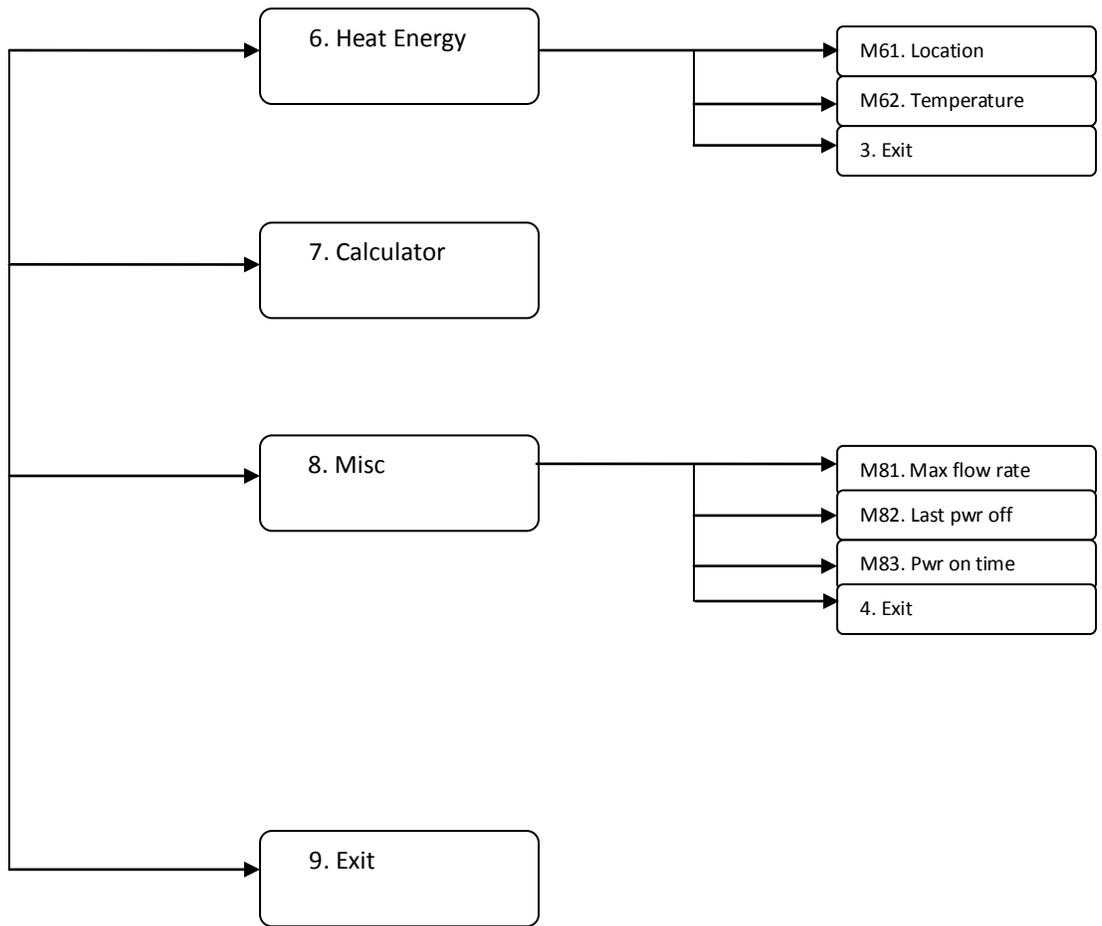
## §2.4 Display Windows











## §2.5 Display Window List

SET → Quick Start	Windows solely to help the user get the flow meter up and running as quickly as possible. They include instructions on preparing mounting site, setting pipe parameters, setting fluid parameters, and setting transducer parameters, followed by instructions on transducer installation, verification, and diagnosis.
SET → Set Pipe	Windows to set pipe parameters. This includes outer diameter, wall thickness, inner diameter, pipe material, and pipe liner.
SET → Set Fluid	Windows to set fluid parameters. This includes fluid type, sound speed, and viscosity.
SET → Set Transducer	Windows to set transducer parameters. This includes transducer type, mount method, mount space, and scale factor.
SET → Set Filter	Windows to set up filter parameters. This includes average filter, noise filter, poor signal filter, and empty pipe.
LOG → Log Items	Windows to set up data logging. This includes logging a basic set of 4 items, or logging all 16 items.
LOG → Schedule	Windows to set up schedule for data logging. This includes logging interval, start time, and stop time.
LOG → Save To	Window to save logged data to a customary file name.
LOG → View Log	Window to view any previously saved logged data.
LOG → Clear Log	Window to delete a previously saved logged data.
CAL → Zero	Window to set up zero calibration.
CAL → Linear	Window to set up linear calibration. This includes manual totalizer and a linear table.
CAL → 0/4 – 20mA	Window to verify that the output of the 0/4 – 20mA is accurate.
CAL → Temp	Window to set up temperature calibration
M11 – M13 → Site	Windows to store, recall, and delete site parameters, respectively.
M21 – M24 → Diagnosis	Windows to display triplet, sound speed, transit time, and Reynolds time, respectively.
M31 – M38 → Input/Output	Windows to change display settings, 0/4-20mA CL, OCT output, Relay output, Frequency output, buzzer, alarm, and batch control, respectively.

M41 – M49 → Totalizer	Windows to set up totalizer. Includes totalizer unit, multiplier, NET on/off, POS on/off, NEG on/off, totalizer reset, daily, monthly, and yearly totalizer, respectively.
M51 – M58 → System	Windows to change and/or view the system settings. Includes language, system units, COMM, date/time, ESN, battery life, set up system lock, and working timer, respectively.
M61 – M65 → Heat Energy	Windows to set up the heat energy. Includes location, energy unit, multiplier, total reset, and temperature, respectively.
M60 → Calculator	Window that features a scientific calculator.
M71 – M73 → Misc	Windows for additional functions such as maximum flow rate, last power off, and power on time.

## §2.6 Steps to Configure the Parameters

### Step 1: Enter transducer info

*Change the Scale Factor:* The scale factor can be found printed on the transducer pair. Press keys S44 (e.g., press **SET**, **4** and **4** keys, consecutively). Then, press the **ENT** key. Key in the new scale factor of the transducer pair you are planning to use. Press **ENT** to confirm.

S44
Scale Factor
>= 1.01

### Step 2: Enter pipe info

All pipe parameters can be entered by pressing keys S1 (e.g., press **SET**, **1** consecutively) and then, scroll down to Step 2 using the **▼/-** key. Finally, press **ENT**. To find your pipe's parameters, visit [http://www.engineeringtoolbox.com/pipes-tubes-dimensions-t\\_16.html](http://www.engineeringtoolbox.com/pipes-tubes-dimensions-t_16.html). Select the type of pipe you are using, and click the corresponding link. Once you have this information, proceed with the following steps.

*Pipe OD:* Enter the pipe outer diameter, and press the **ENT** key to confirm.

S2a:
Outer Diameter
2.375 in

*Wall-thickness:* Press the **▼/-** key to scroll down to the next parameter. Press **ENT** and enter the pipe wall-thickness value. Press **ENT** again to confirm. If pipe wall thickness is unknown, Spire can provide a device to measure this value.

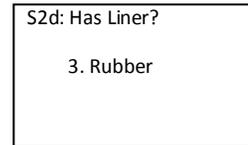
*Pipe Material:* Press **▼/-** to scroll down. Press **ENT** and then use **▼/-** to select the material of the pipe you are using. If your pipe material is not shown on the list (non-standard material), select Other. Press **ENT** to confirm.

S2c:
Select Pipe
1. Carbon Steel

*Sound Speed in Pipe Wall:* If your pipe material is on the list in the previous step, the flow meter will automatically skip this step and go to the next step. You do not have to enter in the Sound Speed unless you have selected Other as your pipe material.

If you selected Other as your pipe material, you will have to enter the sound speed manually. Press **ENT** which will prompt you to enter the correct sound speed for the pipe wall material you are using. You can find this data in the Appendix §9.3 of the User’s Manual. When you are done, press **ENT** to confirm.

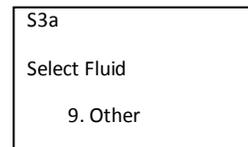
*Pipe lining:* Press **▼/–** to scroll down, and then, press **ENT**. If your pipe has lining inside, enter the lining information. Press **ENT** to confirm. Press **◀** (“Ex”) to go back to the Quick Start menu.



### Step 3: Enter fluid info

From the Quick Start menu, scroll down to Step 3.

*Fluid Type:* Press **ENT** and select the item that matches your fluid type. If you do not find a match (non-standard fluid), select item 9 (Other). Press the **ENT** key to confirm.



*Sound Speed in Fluid:* If you found your fluid type in the previous step, the flow meter already has the sound speed data. Therefore, skip this step and go on to the next.

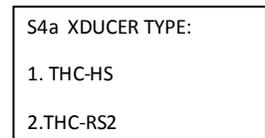
Otherwise, exit to the main screen and press keys S32. Press **ENT** and key in the sound speed of your fluid. You can find this information in Appendix §9.3 of the User’s Manual. When you are done, press **ENT** to confirm.

### Step 4: Enter transducer installation info

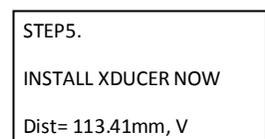
From the Quick Start menu, scroll down to Step 4.

*Transducer Type:* Press **ENT** to edit the type of transducer. Use the **▼/–** key to scroll down and press **ENT** and select the proper transducer type from the list. *Note: The type of transducer you are using will be printed on the side of the transducers.* Press **ENT** to confirm.

*Mounting Method:* Use the **▼/–** key to scroll down to the mounting method selection screen. Then, press **ENT** and select the proper method. Press **ENT** to confirm. For pipes smaller than 1”, try the W-method. For pipes from 1” to 12”, use the V-method. For pipes larger than 12”, use the Z-method. See Section §3.3 for more details on how to select the proper method.



*Mounting Spacing:* Use the **▼/–** key to scroll down to Step 5. The displayed value is the mounting spacing between the two transducers (see the image on the right). **Write down this number, as you will need it later when installing the transducers.**



## STOP!

It is extremely important to enter the parameters properly before installing the transducers. Incorrect parameters result in operation errors and inaccurate measurements. Common parameter errors are incorrect wall thickness, usually due to corrosion on the pipe. See Section §3.4 for more details on issues caused by wall thickness problems.

### Example:

For standard, or commonly-used, pipe materials and standard liquids, the parameter configuration steps are as following:

- a. Press the **SET** key. Make sure that the option “1. Quick Start” is highlighted. Press **ENT**.
- b. You should see a “Select Mounting Site” window for information on ideal mounting conditions. Press the down arrow ▼ to move on to the next step.
- c. You should see the “Set Pipe Parameters” window. Press the **ENT** key to program the pipe parameters. Press **ENT** to edit the outer diameter. Press **ENT** again to save. Press the down arrow. ▼
- d. You should see the “S2b: Enter Pipe Wall-Thickness” window. Press **ENT** to edit the wall-thickness. Press **ENT** again to save. Press the down arrow. ▼
- e. You should see the “S2c: Select Pipe” window. Press **ENT** to select the pipe material. Using the up and down arrows, select the appropriate pipe material. Press **ENT** to save. Press the down arrow. ▼
- f. You should see the “S2d: Has Liner?” window. Press **ENT** if the pipe has no liner. Press **ENT** again, use the up and down arrows to select the appropriate liner. Press **ENT** to save. Use the arrow to exit. ◀
- g. You should see a “Set Fluid” window. Press the down arrow to access this menu. Press the **ENT** key. Use the up and down arrows to select the appropriate fluid. Press **ENT** again to save information. Use the ◀ arrow to exit.
- h. You should see a “Set Transducer” window. Press the **ENT** key. You should now see the “S4a: Transducer Type” window. Press the **ENT** key once again and use the up and down arrows to select the appropriate transducer type. Press **ENT** to save.

- i. Press the down button to access the transducer mounting method. You should see the “S4b: Transducer Mount” window. Press **ENT** to edit the mount method. Use the up and down arrows to select your appropriate method. Press **ENT** again to save.
- j. Use the down arrow button to edit the scale factor. You should see the “S4c: Enter Transducer Scale Factor” window. Press the **ENT** key to edit. Enter in the scale factor of the transducer pair you are planning to use. Press **ENT** key again to save. Use **◀** the arrow to exit.
- k. Press the down arrow to access this menu. You should see an “Install Transducers Now” window. The number displayed on the screen represents the distance between the two transducers (transducer spacing). For more information on installation press the **ENT** key.

*Refer to Quick Start for more information and diagrams.*

## 3. Installation

### §3.1 Mounting Allocation for Transducers

The first step in the installation process is to select an optimal location for installing the transducers in order to make the measurements reliable and accurate. A basic knowledge about the piping and its plumbing system is advised.

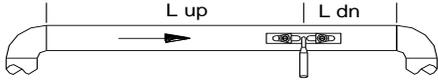
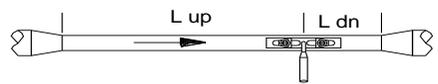
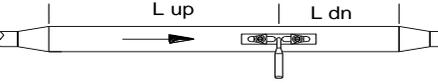
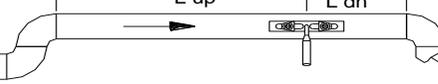
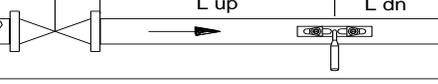
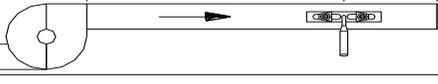
An optimal location is defined as a long, straight-pipe line filled with the liquid to be measured. This pipe can either be in a vertical or horizontal position. However, on a vertical pipe, an upwards flow direction is required. The following instructions will guide the user in finding an optimal location:

#### Principles to Select an Optimal Location:

- 1) The straight pipe should be long enough to eliminate any irregular-flow-induced errors. Typically, the length of the straight pipe should be at least 15 times the pipe outer diameter (represented as 15D). A run of over 15D, is more likely to yield a laminar, or undisturbed, flow. This is an ideal condition for accurate measurement. As a general rule, the longer the straight run, the higher the accuracy. The transducers should be installed at a pipe section where **the length of the straight pipe at the upstream side is at least 10D and the downstream is at least 5D. The transducer installation site should be at least 30D away from the pump.** Refer to Table A for more details.
- 2) **Make sure that the pipe is completely filled with liquid.** It is impossible to take an accurate measurement if there are any air bubbles. The equation used to calculate the flow rate assumes the pipe is filled completely with the liquid being measured. For the best results, make sure the pipe is under pressure. This way, it has to be full.
- 3) Make sure that the temperature on the mounting location does not exceed the range for the transducers. Refer to the transducer specification chart in Appendix 9.2.A.
- 4) If possible, select a relatively new straight-pipe line. Old pipes tend to have corrosions and depositions, which could affect the results. If an old pipe is used, **it is recommended that the corrosions and depositions are treated as if they were a part of the pipe wall or as part of the pipe liner (i.e. extra value is added to the pipe wall thickness or liner thickness parameters to take into account the deposition).**
- 5) Some pipes may have a type of **plastic liner**, which creates a certain amount of gaps between liner and inner pipe wall. These gaps could prevent the ultrasonic waves from direct travel. Such

conditions will make measurement very difficult. Whenever possible, try to avoid these kinds of pipes. **If lined pipes must be used, try our plug-in transducers that are installed permanently to the pipe by drilling holes on the pipe as liquid is flowing inside.**

**Table A**

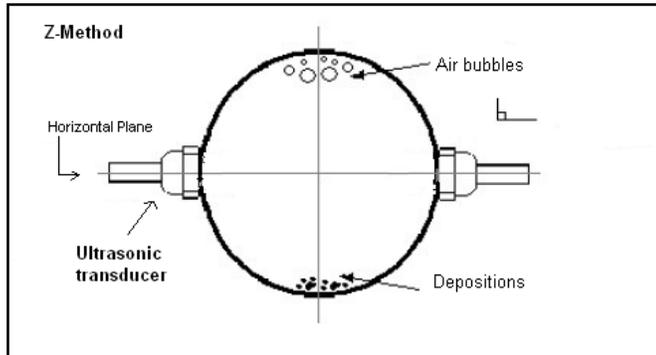
Piping Configuration and Transducer Position	Upstream Dimension	Downstream Dimension
	L up x Diameters	L dn x Diameters
	10D	5D
	10D	5D
	10D	5D
	12D	5D
	20D	5D
	20D	5D
	30D	5D

### §3.2 Transducer Installation

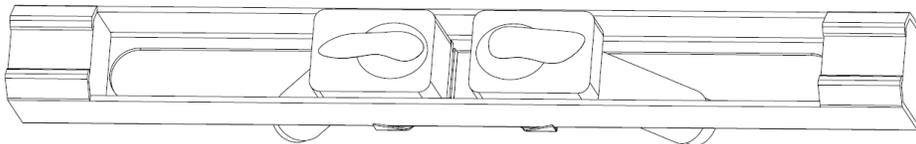
The transducers used by the RH40 Series Ultrasonic Flow Meter are made out of piezoelectric crystals for both transmitting and receiving ultrasonic signals through the wall of liquid-piping system. These excellent quality materials deliver high accuracy. The measurement is obtained by calculating the travel-time difference of the ultrasonic signals. Since the difference is very small, the spacing and the alignment of the transducers are critical factors to the accuracy of the measurement and to the performance of the system. **Meticulous care should be taken for the installation of the transducers.**

## Steps to Install the Transducers:

- 1) Determine an optimal location. The straight pipe at both sides of the transducers needs to be of **sufficient length** (See Section §3.1, #1). The pipes are required to be in **favorable condition** – newer pipes with no rust are recommended (See Section §3.1, #4). Horizontal pipes typically have gas bubbles inside, especially on the pipe ceiling. There also may be sediment on the pipe base. As a result, it is recommended that the transducers are installed on the side of, rather than the top or bottom of, a horizontal pipe. See Appendix §9.2 for more details.

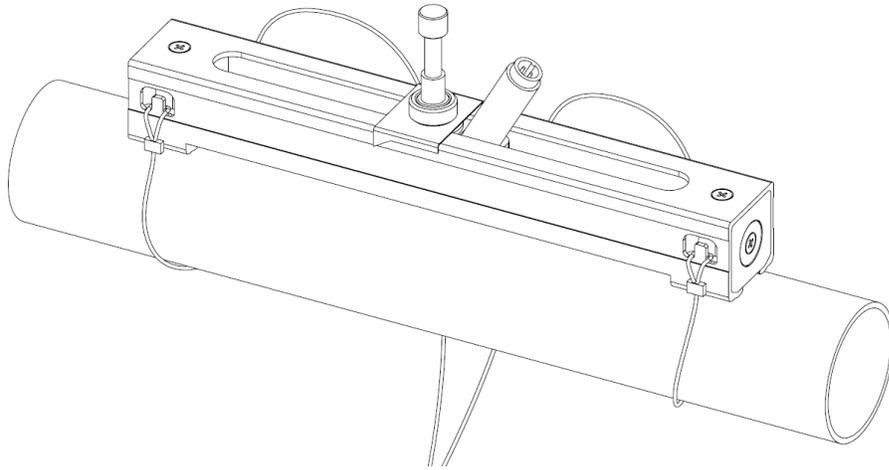


- 2) Make sure the chosen location is safe for and compatible with the operation of the flow meter.  
**The RH40 is not designed for contact with hazardous materials.**
- 3) Clean any dust and/or rust off the spot where the transducers are to be installed. For better results, **polishing the pipe's outer surface with a sander is strongly recommended.**
- 4) Extra care should be taken to avoid any sand or dust particles left between the pipe surface and the transducer surface. We recommend wiping the surface thoroughly with a damp towel or sponge. Once the surface is completely clean, dry it with a towel for best results.
- 5) Apply adequate ultrasonic couplant (grease, gel, or Vaseline®)\*. **Couplant should be spread over the entire transmitting surface on the transducer and the entire installation surface on the pipe.** Make sure there is no gap between the transducer transmitting surface and the pipe surface. However, be careful not to apply too much couplant, especially for small pipes. See figure below:



6) Consider the appropriate method for mounting the transducers on the pipe. There are **2 methods of mounting**:

- **Magnetic fixture:** If the pipe material is metal, the magnetic force will keep the transducers on the pipe.
- **Clamp-on fixture:** We provide **2 types of clamp-on fixtures**. The transducers may be pressed tightly against the pipe with the **nylon straps** provided. This is a quick and easy installation process. A **metal strip** is also provided as an alternative for a more permanent installation. Turn the screws on the metal strips clockwise to tighten, using a screwdriver or a wrench.



7) Install the transducers and space them carefully. See Appendix §9.2 for specifics on the HM and HS transducers. The spacing value shown on window S15 refers to the distance of inner spacing between the two transducers (See the figure in Section §2.3). The actual distance of the two transducers should be as close to this value as possible. **Read Section §3.3 for more details on transducer spacing.**

Please see Appendix §9.2 for more installation information.

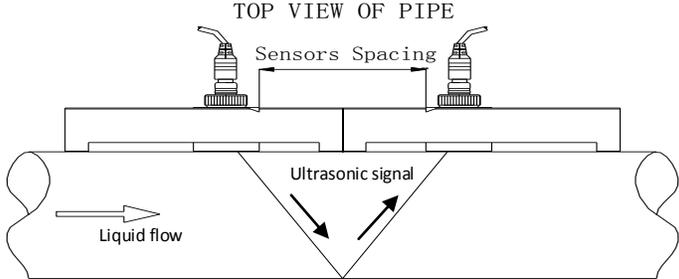
*\*NOTE: As a safety precaution, it is recommended that the Sonotech Inc. SOUNDSAFE product be used as the ultrasonic couplant. Other couplants such as grease, gel, or Vaseline® can be used as alternatives – but please use at your own risk!*

**STOP!**  
Before mounting, please read Section §3.3!  
Transducer spacing is critical to the accuracy of the meter readings.

**§3.3 Transducer Spacing**

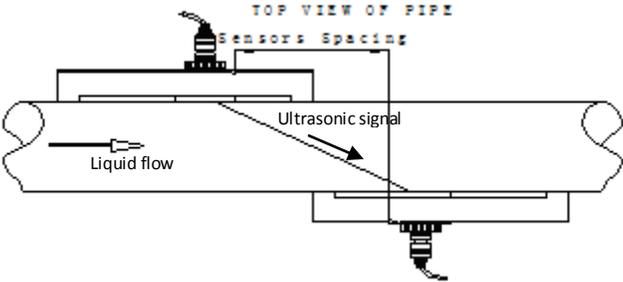
**V-Method Installation**

The V-method installation is the most widely used method for daily measurements. The inner diameter of the pipe ranges from **20mm to 300mm**. It is also known as the **reflective method**. The small sound path of pipes in this range can interfere with accuracy. This method doubles the sound path, thus, ensuring an accurate measurement.



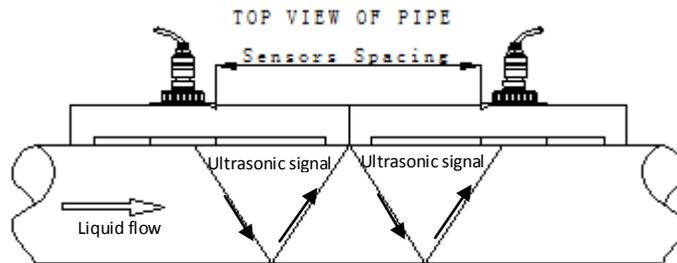
**Z-Method Installation**

The Z-method is commonly used for pipe diameters between **300mm and 5,000mm**. Signal strength is increased with this method.



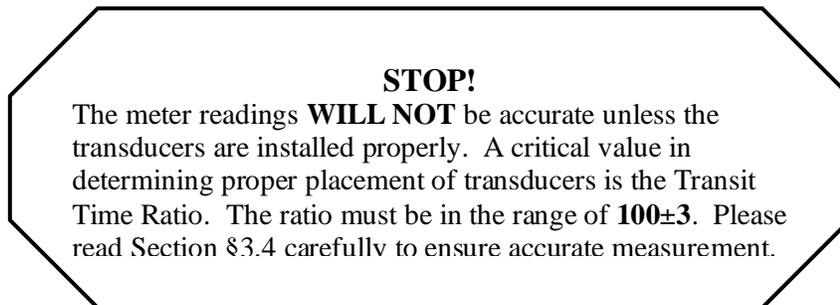
## W-Method Installation

The W-method is usually used on **plastic pipes** with **diameters between 10mm and 100mm**.



## N-Method Installation

The N-method is rarely used.



## §3.4 Installation Checkup

After the completion of the transducer installation, the user should check the following items:

- The receiving signal strength,
- The signal quality (Q value),
- The delta time (traveling time difference between the upstream and the downstream signals),
- The estimated liquid sound speed,
- The transit time ratio.

This process will ensure that the flow meter is working properly for the most reliable and accurate results.

### §3.4.A Signal Strength

Signal strength, represented as S, is a 3 digit number that represents the amplitude of the receiving ultrasonic signals. This value can be seen on the main menu. [000] means that there are no signals detected, and [999] is the maximum signal strength that can be received.

The flow meter will operate well when the **signal strength ranges from 500 to 999**. Regardless of the functioning range, **higher signal strength is always desirable**—the higher the number, the more reliable and accurate the results will be. The following methods are recommended to obtain strong signals:

- 1) Make sure the pipe is in excellent condition. Polish the outer surface of the pipe and apply more couplant between the pipe and transducers.
- 2) Carefully adjust the position of the two transducers, both vertically and horizontally. Check the signal strength after each movement. Stop at the position where the signal strength reaches a maximum. Be sure to check the transducer spacing to make sure it is still the same or very close to the figure displayed in S1, Step 5 (see Section §2.6).
- 3) If the current location of the transducers provides a signal strength that is lower than 700, try relocating into a location in more favorable condition.

### **§3.4.B Signal Quality**

Signal quality is indicated as the Q value for this instrument. This value can be seen on the main menu. A higher Q value means a higher Signal to Noise Ratio (SNR). Higher signal quality yields a higher degree of accuracy. Under normal pipe conditions, the Q value should be in the **range of 60 to 90**. A higher quality is always more desirable.

Causes for a low Q value may be:

- Interference from other instruments and devices nearby, such as a power frequency transverter, which could cause strong interference. If possible, relocate the flow meter to a location where interference is minimal.
- Bad sonic coupling between the transducers and the pipe. If the Q value is not in the desired range, we recommend polishing the pipe surface again. It is important to clean the surface after polishing. We also recommend adding more couplant. Finally, the pipe needs to be in the best condition possible.
- The selected pipe section is not conducive to accurate measurement. In some cases, the pipe material causes this problem with signal quality. For example, carbon steel pipes frequently feature corroded pipe sections, which would change pipe wall thickness values. In this case, we recommend using the Z-method for transducer installation. Increase or decrease the spacing between the transducers until the ratio is  $100 \pm 3$ . See section §3.4.D for more details. The user may also move the transducers to a pipe section that is in more favorable condition.

### §3.4.C Total Transit Time and Delta Time

The total transit time (or traveling time) and the delta time are both displayed on menu window M23.

This window can be accessed by pressing the following series of keys:

**M** → 2 (Diagnosis) → **M23** (Transit Time)

See section §3.4.D for more details. These values are the primary data used by the instrument to calculate the flow rate. They are the **most important values calculated by the flow meter**. The measured flow rate will vary as the total transit time and delta time vary. Therefore, the total transit time should remain stable or fluctuate only very slightly. **The device will adjust for any variance on its own until it is stable.**

The **delta time** normally varies less than 20%. **If the variation exceeds 20% in either positive or negative direction, there may have been errors in the installation of the transducers.** The user should examine the installation site for any apparent problems. The following list shows some common examples of installation errors that cause inaccuracies in measurement:

- There may be **insufficient couplant** between the transducers and the pipe surface.
- The transducers may not be spaced correctly or may have been placed in a non-favorable location. Either of these issues will cause **weak signal strength and quality**.
- The pipe may be only partially full or there may be air bubbles. If this is the case, the logarithm used to calculate the flow rate will not yield accurate readings. **Make sure that the pipe is completely full and that there are no air bubbles in the liner.**
- The **wall thickness values may be incorrect**. The error may have resulted from corrosion on the pipe. Use the Z-method of installation or move to a more favorable location.

### §3.4.D Transit Time Ratio

This ratio is used to check the quality of the transducer installation. It also verifies whether the entered pipe parameters are consistent to their actual values. If the pipe parameters are correct and the transducers are installed properly, the transit time ratio should be in the **range of 100±3**. If this range is not met, the user should verify the following:

- The entered pipe parameters are correct
- The actual spacing of the transducers is the same as or close to what is shown on window S1, Step 5 (see Section §2.6)

- The transducers are installed properly and are facing the right direction
- The mounting location is stable
- The pipe-run upstream and downstream of the transducers is straight
- The pipe is in adequate condition (the most common pipe quality issues are too much corrosion or too much deposition inside the pipe)
- There are no interference sources inside the pipe
- All aspects of the device meet the measurement requirements as listed above

Please refer to Appendix §9.2 for more installation details.

## 4. How To

### §4.1 How to check if the instrument is working properly

The lower right hand corner of the LCD display features the symbol corresponding to the device's current level of functionality. The following list explains the most commonly-seen symbols:

- 1) Generally speaking, when “R” is displayed, the device is working properly.
- 2) If an “H” flashes, then the received signal may be poor. See Section §6 for more on troubleshooting.
- 3) If an “I” is displayed, then no signal was detected.
- 4) If a “J” is displayed, then the hardware of this instrument may be out of order. See Section §6 for more details.

### §4.2 How to check the liquid flowing direction

- 1) Make sure that the instrument is working properly. There should be an “R” displayed in the lower right hand corner of the screen.
- 2) Check the flow rate display. If the value is **positive**, the direction of the flow will be **from the upstream transducer, which is connected to the upstream connector of the meter, to the downstream transducer**; if the value is **negative**, the direction will be **from the downstream transducer to the upstream transducer**.

### §4.3 How to change the unit's measurement system

The device can operate in either the English or the Metric system. This option can be accessed using the following series of keys:

M → System → Unit (M52) → Metric/English

#### §4.4 How to select a flow rate unit

Press keys M52, followed by the second sub-menu option “Flow Rate Unit” to select the flow rate unit as well as the corresponding time unit. This can be accessed as follows:

M → System → Unit (M52) → Flow Rate Unit

#### §4.5 How to use the totalizer multiplier

The user must enter the proper multiplying factor for the totalizer multiplier. In addition, the user should make sure that the rate of the totalizer pulse is not too fast or too slow. We recommend a speed of 2-3 pulses per minute. This setting can be accessed by pressing the following series of keys:

M → Totalizer → Multiplier (M42)

If the totalizer multiplying factor is too small, the output pulse will be very fast, and there could be a loss of pulses. The designed minimum pulse is 500 milliseconds.

If the totalizer multiplying factor is too large, the output pulse will be very slow, which might be a problem if the master device requires fast response.

#### §4.6 How to turn on and off totalizers

Use menu window M43, M44, and M45 to turn on or turn off the NET, POS, and NEG totalizers, respectively. These menus can be accessed as follows:

M → Totalizer → NET on/off (M42), POS on/off (M43), or NEG on/off (M44)

#### §4.7 How to reset the totalizer

Use menu window M46 to reset the flow rate totalizers. This can be accessed as follows: M →

4.Totalizer → 6.TOT Reset (M46)

#### §4.8 How to use the damping filter to stabilize the reading

The damper acts as a filter for a stable reading. This setting can be adjusted in the “Avg Filter” menu,

which can be accessed through the following series of keys:

**SET** → **Set Filter** → **ENT**.

If a “0” is entered, there is no damping. A bigger number generally brings a more stable effect. However, a balance is required; bigger damping numbers will slow down the instrument’s response time.

#### **§4.9 How to use the zero-cutoff function (Noise Filter)**

This function can be accessed by pressing the following series of keys:

**SET** → **5** → **2**

#### **§4.10 How to set up the zero calibration**

Without a zero calibration, the flow meter may give a small non-zero flow rate reading even when the flow in the pipe is not running. In order to make an accurate measurement, it is necessary to set the correct zero calibration. While setting this data, the liquid flow should be completely turned off. If there is any value besides zero at the time zero velocity is set, all future results will be skewed. This window can be accessed by pressing the following series of keys:

**CAL** → **Zero Cal**. Press the **ENT** key to start the zero calibration.

#### **§4.11 How to change the flow rate scale factor**

The scale factor (SF) is the ratio between the “actual flow rate” and the flow rate measured by the flow meter. It can be determined with standard flow calibration equipment. This value can be adjusted by pressing the following series of keys:

**SET** → **Quick Start** → **Set Transducer Parameters** → **Scale Factor**. Press the **ENT** key to edit the scale factor.

#### **§4.12 How to use the password lock**

The password lock provides a means of preventing inadvertent configuration changes or totalizer resets. When the system is locked, the user can still browse menu windows, but cannot make any modifications to the windows.

The password locking/unlocking can be done in menu window M57, which can be accessed with the following series of keys:

**M** → **System** → **M57**.

The system can be locked with or without a password. A password-free lock can be enabled by pressing the **ENT** key while in menu window M57. A personalized password can also be set up. It must consist of 1 to 4 digits.

#### **§4.13 How to use the built-in data logger**

- 1) The built-in logger has a space of 24 KB of memory, which will hold about 2,000 lines of data.
- 2) Use window L10 to start logging; this can be accessed using the following series of keys: **LOG** → **Log Items**. This will turn on or off the logger as well as select the items to be logged.
- 3) Use windows L11, L12, L13 to set up the starting time, time interval, and logging duration, respectively. All of these windows can be accessed using the following series of keys: **LOG** → **Schedule**.
- 4) Use window L20 to save the logged data. The data can be stored in a logger buffer. Alternatively, the data can be directed to the RS-232C interface without being stored in the logger buffer. This window can be accessed using the following series of keys: **LOG** → **Save To**.
- 5) Use window L30 to view saved data in the logger buffer. This window can be accessed using the following series of keys: **LOG** → **View Log**.
- 6) Use window L40 to clear any unwanted logging data remaining in the RS-232C interface and in the logger buffer. This window can be accessed using the following series of keys: **LOG** → **Clear Log**.
- 7) The data stored in the data logger can be downloaded to any PC with the Windows Hyper Terminal program. Another option is Spire Metering's StufManager™ software. StufManager™ will also help the user set up the data logger. Please visit the following website for more details:  
<http://www.spiremt.com/support/rh20.html>.

#### **§4.14 How to use the Frequency Output**

All RH40 Series Flow Meters have a Frequency Output functionality. The signal for each device represents its flow rate for the purpose of communicating with other devices. The emitted frequency output signal is designed to connect with other instruments.

The Frequency Output is completely user-configurable. Usually, three parameters are configured:

- 1) Enter the frequency range in the "Freq Range" window as follows:  
**M** → **Input/Output** → **Frequency Output** → **Freq Range**
- 2) Enter the lower limit of flow rate in the "Freq Min" window as follows:  
**M** → **Input/Output** → **Frequency Output** → **Freq Min**

3) Enter the higher limit of flow rate in the “Freq Max” window as follows:

**M** → **Input/Output** → **Frequency Output** → **Freq Max**

Example: Assume that the flow rate varies in a range from 0m<sup>3</sup>/h to 3000m<sup>3</sup>/h and the required output signal frequency should be in the range 200Hz to 1000Hz. The user should enter 0 for the “Freq Min” window, 3000 for the “Freq Max” window, and 200 followed by 1000 for the “Freq Range” windows.

*\*\*\*Please note that the user needs to select the frequency output option \*\*\**

#### **§4.15 How to use the Totalizer Pulse Output**

The flow meter will produce a pulse output with every unit of liquid flow. This pulse could be used by an external pulse counter to measure the accumulation of the flow rate. Refer to §4.4 and §4.5 for the set up totalizer units and multiplier. **The totalizer pulse output can only be connected to OCT devices or BUZZER hardware devices.**

Example: Assume that the POS totalizer pulse output is needed and every pulse represents 0.1 cubic meter of liquid flow. Assume also that the pulse output is connected to an internal buzzer. With every 0.1 cubic meter of flow, we need the BUZZER to beep for a while. In order to achieve this, the following steps must be performed.

1) Select the Cubic Meter (m<sup>3</sup>) unit in window M52 → Flow Rate unit. This can be accessed as follows:

**M** → **System** → **Unit** (M 52) → **Flow Rate Unit** → **Change Volume**

2) Select the Multiplier factor as ‘2. X 0.1’ in menu window M41.

#### **§4.16 How to set up the alarm signal**

There are two types of hardware alarm signals that are available with this instrument. One is the buzzer, and the other is the OCT output.

The triggering sources of the alarming events for both the Buzzer and the OCT output could be:

- 1) There is no receiving signal
- 2) The signal received is too weak
- 3) The flow meter is not in normal measurement mode
- 4) The flow direction is changed
- 5) Overflow occurs at the Frequency Output
- 6) The flow is out of the specified range

#### **§4.17 How to use the built-in Buzzer**

The built-in buzzer is user-configurable. It can be used as an alarm. Use menu window M36, which may be accessed as follows: **M** → **Input/Output** → **Buzzer** (M36)

#### **§4.18 How to use the OCT output**

The OCT output is on/off type. It is user-configurable. The user can access this menu by pressing M33.

#### **§4.19 How to modify the built-in calendar**

No modification on the built-in calendar will be needed in most cases. The calendar consumes an insignificant amount of power. Modifications will only be needed when the battery has been totally exhausted or when the replacement battery takes so long that the original time data is lost. Use window menu M54 to change the time and date. This menu can be accessed as follows: **M** → **System** → **Date/Time** (M54)

#### **§4.20 How to adjust the LCD contrast**

Use M312 to adjust the LCD contrast. The adjusted results will be stored in the EEPROM so that the MASTER ERASE (factory default restoration) will make no effect on the contrast. M312 may be accessed as follows: **M** → **Input/Output** → **M31: Display** → **M312: LCD Bklt**

#### **§4.21 How to use the RS232 serial interface**

This menu can be accessed by pressing buttons M, 5, and 3, in succession (M53).

#### **§4.22 How to view the Totalizers**

Use menu windows M47, M48, and M49 to view the daily, monthly, and yearly totalizer, respectively.

These menu windows may be accessed as follows: **M** → **Totalizer** → **M47: Daily TOT** (or **M48: Monthly TOT** or **M49: Yearly TOT**).

#### **§4.23 How to use the Working Timer**

Use the working timer to check the time that has passed with a certain kind of operation. For example, use it as a timer to show how long a fully-charged battery will last. In menu window M58 press **ENT** key and select **YES** to reset the working time. M58 may be accessed as follows: **M** → **System** → **M58: Work Timer**.

#### **§4.24 How to use the manual totalizer**

Use menu window C21, which can be accessed as follows: **CAL** → **Linear Cal** → **C21: Man Totalizer**.

Press any key to start and press the key again to stop the totalizer.

#### **§4.25 How to check the ESN**

Every set of the RH40 Series Flow Meters utilizes a unique ESN to identify the meter—the ESN in an eight-digit number that provides the product version and manufacturing date.

The user can also employ the ESN for instrumentation management.

The ESN is displayed in menu window M55, which can be accessed as follows: **M** → **System** → **Version/SN#** (M55).

#### **§4.26 How to check the battery life**

The battery life is displayed on window M56, which can be accessed by pressing buttons M, 5, and 6, consecutively.

#### **§4.27 How to calibrate the flow meter**

There are 4 calibration functions for the RH40: Zero Calibration, Linear Calibration, 0/4-20 mA loop calibration, and temperature calibration. These can be found by pressing the CAL key on the device.

- 1) For Zero Calibration, refer to Section 4.11.
- 2) Linear and 0/4-20 mA loop calibration are unavailable at this time. For updates, please contact Spire Metering at support@spiremt.com.
- 3) For Temperature Calibration, normally, there is no need for such calibration, as the device is calibrated in the factory. In case you need to re-calibrate the sensors, contact Spire Metering at support@spiremt.com.

## 5.Menu Window Details

Key	Sub-Key	Window Number	Function	
SET	Quick Start	Step 1: Mounting Site	S1 Window which provides instructions on selecting a mounting site: - Pipe is full - Straight pipe: 10D upstream, 5D downstream - Vertical pipe: flow must go up. - Horizontal pipe: transducer must be on the side of pipe.	
		Step 2: Set Pipe Parameters	S2a	Window for entering the outer diameter of the pipe Valid range: 0 to 6000mm.
			S2b	Window for entering pipe wall thickness
			S2c	Window for selecting pipe material Standard pipe materials (no need to enter the material sound speed) include: (1) carbon steel (2) stainless steel (3) cast iron (4) ductile iron (5) copper (6) PVC (7) aluminum (8) asbestos (9) fiberglass
			S2d	Window for selecting the liner material. Select none(1) for pipes without any liner. Standard liner materials (no need to enter liner sound speed) include: (2) Tar Epoxy (3) Rubber (4) Mortar (5) Polypropylene (6) Polystyrol (7)Polystyrene (8) Polyester (9) Polyethylene (10) Ebonite (11) Teflon
		S3: Set Fluid Parameters	S3a	Window for selecting fluid type For standard liquids (no need to enter liquid sound speed) include: (1) Water (2) Sea Water (3) Kerosene (4) Gasoline (5) Fuel oil (6) Crude Oil (7) Propane at -45C (8) Butane at 0C (9)Other liquids (10) Diesel Oil (11)Caster Oil (12)Peanut Oil (13) #90 Gasoline (14) #93 Gasoline (15) Alcohol (16) Hot water at 125C
		S4: Set Transducer Parameters	S4a	Window for selecting transducer type There are 30 different types of transducers for selection. The user needs to configure the 3 transducer parameters.
			S4b	Window for selecting the transducer mounting methods Four methods can be selected: (0) V-method (1) Z-method (2) N-method (3) W-method
			S4c	Window to set the flow rate scale factor. The factory default is '1'. Keep this value as '1' when no calibration has been made.
		S5: Install Transducer Now	S5a	Window for transducer mount distance and installation: a) Mark 2 spots of the same side on pipe surface, with the distance equal to the number shown. b) Sand & clean the spots, make surface smooth. c) put compound on transducer surface. d) Clamp transducer onto pipe. Cable towards outside. e) Finish wiring then power up.
	S6: Verify		Window to verify the signal strength, signal quality and transit time ratio shown	
	S7: Diagnose		Window to Diagnose Triplet	
	Set Pipe	S21: Set OD		Window for entering the outer diameter of the pipe. Valid range: 0 to 6000mm.
		S22: Set Wall TH		Window for entering the pipe wall thickness.
		S23: Set ID		Window for entering the inner diameter of the pipe. If pipe outer diameter and wall thickness are entered correctly, the inner diameter will be calculated automatically, thus no need to change anything in this window.
		S24: Pipe Material		Window for selecting pipe material Standard pipe materials (no need to enter the material sound speed) include:

			(0) carbon steel (1) stainless steel (2) cast iron (3) ductile iron (4) copper (5) PVC (6) aluminum (7) asbestos (8) fiberglass
	S25: Set Liner		Window for selecting the liner material. Select none for pipes without any liner. Standard liner materials (no need to enter liner sound speed) include: (1) Tar Epoxy (2) Rubber (3) Mortar (4) Polypropylene (5) Polystyrene (6) Polystyrene (7) Polyester (8) Polyethylene (9) Ebonite (10) Teflon
	Set Fluid	S31: Fluid Type	Window for selecting fluid type For standard liquids (no need to enter liquid sound speed) include: (0) Water (1) Sea Water (2) Kerosene (3) Gasoline (4) Fuel oil (5) Crude Oil (6) Propane at -45C (7) Butane at 0C (8) Other liquids (9) Diesel Oil (10) Caster Oil (11) Peanut Oil (12) #90 Gasoline (13) #93 Gasoline (14) Alcohol (15) Hot water at 125C
S32: Sound Speed		Window for entering the sound speed of non-standard liner materials	
S33: Viscosity		Window for entering the viscosity of non-standard liquids	
	Set Xducer	S41: Transducer Type	Window for selecting transducer type There are 14 different types of transducers for selection. If the $\pi$ type spool-piece transducers are used, the user needs to configure the 3 transducer parameters. Otherwise, the user needs to configure the 4 transducer parameters.
S42: Mount Method		Window for selecting the transducer mounting methods Four methods can be selected: (0) V-method (1) Z-method (2) N-method (3) W-method	
S43: Mount Space		Window to display the transducer mounting space or distance.	
S44: Scale Factor		Window to set the flow rate scale factor. The factory default is '1'. Keep this value as '1' when no calibration has been made.	
	Set Filter	S51: Damping Filter	Window to set the damping constant.
S52: Noise Filter		Window to set the velocity cutoff for noise flow.	
S53: PoorSig Filter		Window to set the poor signal filter. If last reading was acceptable, select (1) Yes. If last reading was not acceptable, select (2) No.	
S54: Empty Pipe		Window to establish setting for an empty pipe. During normal operation, pipe should be full.	
LOG	Log Items	L10: Basic 4 Items	Window to instruct device to log only basic information.
		L10: All 16 Items	Window to instruct device to log all 16 items available on RH30.
	Schedule	L11: Log interval	Window for entering the interval at which the flowmeter will log data.
		L12: Start Time	Window for entering the start time of the logger. (Year-Month-Day and Hour-Minute-Second)
		L13: Stop Time	Window for entering the end time of the logger. (Year-Month-Day and Hour-Minute-Second)
	Save To	L20	Window to save recorded log to a customizable file name.
	View Log	L30	Window to view a previously recorded log.
	Clear Log	L40	Window to clear a previously recorded log.
CAL	Zero Cal	C10	Window to set up the Zero point. Make sure the liquid in the pipe is not running during setup.
	Linear Cal	C21: Man	Window for manual totalizer used for calibration. Press any key to start and press the

		Totalizer	key again to stop the totalizer.		
		C22: Linear Table	Window to view linear table. (1) Add data point. (2) View table.		
	0/4 – 20 mA Cal	C31: Verify	Verify 0/4-20 mA loop.		
		C32: Calibrate	Currently unavailable for the RH40		
	Temp cal	C41: T1/T2	Window to display temperature for supply line and return line.		
		C42: Calibrate	Window to calibrate temperature sensors. User must enter password. Use resistors to recalibrate sensors.		
M	Site	M11: Save Site	Window to store the pipe parameters into the internal NVRAM (non-volatile memory).		
		M12: Recall Site	Window to recall the previously saved pipe parameters		
		M13: Delete Site	Window to delete previously saved pipe parameters		
	Diagnosis	M21: Triplet	Window to display the signal strength, signal quality and transit time ratio.		
		M22: Sound Speed	Window to display the estimated sound speed of the fluid in the pipe. If this value has an obvious difference with the actual fluid sound speed, the user is recommended to check if the pipe parameters are correct and if the transducer installation is good.		
		M23: Transit-time	Window to display the total transit time and delta time (transit time difference between upstream and downstream traveling).		
		M24: Reynolds	Window to display the Reynolds number and the pipe factor used by the flow rate measurement program. Note, the pipe factor is rarely used.		
	Input/Output	M31: Display	M311: Main window	Window to control main window display. Choose between flow rate, velocity, TOT-POS, and ENERGY-RATE.	
			M312: LCD Bklt	Window to control the LCD display backlight. The entered value indicates how many seconds the backlight will be on with every key pressing.	
			M313: Buzzer	Window to turn buzzer on or off.	
		M32: 0/4-20 mA CL	CL Mode	Select the current loop (CL) mode.	
			Output Param	Enter flow rate.	
			Param Min	Enter minimum for 0/4 mA signal.	
			Param Max	Enter maximum for 20 mA signal.	
			CL Reading	Display present output of the current loop circuit.	
		M33: OCT output	Pulse Width	OCT (Open Collector Output) setup. By selecting a proper triggering source, the OCT circuit will close when the trigger event occurs	
			Trigger Source	Select the pulse type for the trigger source.	
		M34: Relay Output	Window to select event for relay trigger source.		
M35: Freq Output		Freq Range	Window to set up the frequency range (lower limit and upper limit) for the frequency output. Valid values: 0Hz-9999Hz. Factory default is 1-1001 Hz		
		Freq Min	Window to set up the minimum flow rate which corresponds to the lower frequency limit of the frequency output.		
		Freq Max	Window to set up the maximum flow rate which corresponds to the upper frequency limit of the frequency output.		
M36: Buzzer		Window to set up the buzzer. If a proper input source is selected, the buzzer will beep when the trigger event occurs			

	M37: Alarm	#1 Low Limit	Alarm #1 lower threshold setup. Below this threshold the #1 Alarm will be triggered. There are two alarming methods. User must select the alarming output items from window M33 or M36		
		#1 High Limit	Alarm #1 upper threshold setup.		
		#2 High Limit	Alarm #2 upper threshold setup.		
		#2 Low Limit	Alarm #2 lower threshold setup.		
	M38: Batch Control	Window to access the built-in batch controller.			
	Totalizer	M4(1): Flo Multiplier	Window to set the totalizer multiplying factor for the flow rate. The multiplying factor ranges from 0.001 to 10000.		
		M4(2): Flo NET ON/OFF	Window for turning on or off the NET totalizer		
		M4(3): Flo POS ON/OFF	Window for turning on or off the POS totalizer.		
		M4(4): Flo NEG ON/OFF	Window for turning on or off the NEG totalizer.		
		M4(5): Flo TOT Reset	Window for: (2) Totalizer reset (3) Restore the factory default settings. Press the dot key followed by the backspace key. Attention, it is recommended to make notes on the parameters before doing the restoration.		
		M4(6): Eng Multiplier	Window to set the multiplying factor for the Eng totalizer.		
		M4(7): Eng TOT Reset	Window to reset the Eng totalizer.		
		M4(8): Daily TOT	Window to set up for daily totalizer.		
		M4(9): Monthly TOT	Window to set up for monthly totalizer.		
M4(10): Yearly TOT		Window to set up for yearly totalizer.			
System	M51: Language	Window to set up the language Selection – English or Chinese.			
	M52: Unit	Metric/English	Window for selecting unit system. 'Metric' is the factory default. The conversion from English to Metric or vice versa will not affect the unit for totalizers.		
		Flow rate unit	Change Volume	Window for selecting flow rate unit system. Flow rate can be in: 1. Cubic meter short for (m <sup>3</sup> ) 2. Liter (l) 3. USA gallon (gal) 4. Imperial Gallon (igl) 5. Million USA gallon (mgI) 6. Cubic feet (cf) 7. USA oil barrel (bal) 8. Imperial oil barrel (ib)	
			Change Time	The flow unit in terms of time can be per day, per hour, per minute or per second. So there are 36 different flow rate units in total for selection.	
Flow rate TOT Unit	Window for selecting flow rate totalizer unit system. This can be in: 1. Cubic meter short for (m <sup>3</sup> )				

			<ul style="list-style-type: none"> <li>2. Liter (l)</li> <li>3. USA gallon (gal)</li> <li>4. Imperial Gallon (igl)</li> <li>5. Million USA gallon (mgl)</li> <li>6. Cubic feet (cf)</li> <li>7. USA oil barrel (bal)</li> <li>8. Imperial oil barrel (ib)</li> </ul>
	M53: COMM	Port Config	Window for RS-232 serial communication setup.
		Protocol	Window for communication protocol selection.
		Monitor	Window to verify the data being logged.
	M54: Date/Time	M54	Window for setting the date and time.
	M55: Version/ SN#	Window to display version information and Electronic Serial Number (ESN) that are unique for each RH40 series flowmeter. The user can use the ESN for instrumentation management.	
	M56: Battery	Window that displays the current battery voltage.	
	M57: System Lock	Window to set up systems lock to avoid modification of the system parameters.	
	M58: Work Timer	Working timer. It can be reset by pressing ENT key, and then select YES.	
Heat Energy	M61: Location	Window to configure the location of the transducers. They can be placed on the supply or the return line.	
	M62: Temp	Window to view the temperature of both transducers.	
Calculator		Window which includes scientific calculator for the convenience of field applications. All the mathematic operators are selected from a list.	
Misc.	M81: Max Flowrate	Window to view maximum flow rate for the day and for the month.	
	M82: Last pwr off	Window to display the last recorded time the device was powered off.	
	M83: Pwr On Time	Window to display the last recorded time the device was powered on.	

# 6. Troubleshooting

## §6.1 Power-on Errors

When powered on, the RH40 series ultrasonic flow meter will automatically start the self-diagnostic process to determine if there are any hardware and/or software problems. If a problem is identified, an error message will be displayed. The following table shows the possible error messages, the corresponding causes, and their solutions.

<b>Error Message</b>	<b>Causes</b>	<b>Solutions</b>
ROM Parity Error	ROM operation illegal/error	1. Reboot the system 2. Contact the manufacturer
Stored Data Error	User entered parameters were lost	Press ENT key to restore the default configuration
SCPU Fatal Error	SCPU hardware fatal error	1. Reboot the system 2. Contact the manufacturer
System Clock Slow or Fast Error	Problem with the system clock or the crystal oscillator	
CPU or IRQ Error	Problem with RAM chip	
System RAM error	Problem with RAM chip	
Time Date Error	Problem with date/time chip	1. Initialize the calendar in menu window M54 2. Contact the manufacturer
No Display, Erratic or Abnormal Operation	Problem with wiring	Double-check wiring connections
No response to key pressing	Keypad is locked; bad plug connection	Press keys M, 5, and 7, consecutively (M57). From there, unlock the keypad.
Reboot Repetitively	Hardware problems	Contact the manufacturer

## §6.2 Working Status Errors

The RH40 series ultrasonic flow meter will show an Error Code (i.e. a single letter, e.g. I, R, etc.) in the lower right corner of the main menu window. When any abnormal error code shows, counter-measures should be taken.

Error Code	Message Displayed on main menu window	Causes	Solutions
R	System Normal	No Error	
I	No Signal	<ul style="list-style-type: none"> <li>• Unable to receive signal</li> <li>• Transducers installed improperly</li> <li>• Loose contact, or not enough couplant between transducer and pipe surface</li> <li>• Pipe liners are too thick, or the deposition inside the pipe is too thick.</li> <li>• 5. Transducer cables are not properly connected.</li> </ul>	<ol style="list-style-type: none"> <li>1. Polish the pipe surface and clean the spot. Remove paint.</li> <li>2. Make sure there is adequate couplant.</li> <li>3. Make sure the transducer is in tight contact with pipe surface</li> <li>4. Check transducer cables</li> <li>5. Check installation parameter settings</li> <li>6. Find a better measurement site (newer pipe, no corrosion, no deposition)</li> </ol>
J	Hardware Error	Hardware problem	Contact the manufacturer
H	Poor Sig. Detected	Poor signal detected. Similar to error code I.	Refer to error code I.
E	Current Loop Over 20mA	4-20mA loop output over 120%. Improper settings for current loop output	<ol style="list-style-type: none"> <li>1. Ignore it if current loop output is not used</li> <li>2. Check current loop settings in menu window M32</li> <li>3. Confirm if the actual flow rate is too high</li> </ol>
Q	Frequency Output Over	<ul style="list-style-type: none"> <li>• The frequency output is 120% over</li> <li>• 2. Improper settings for frequency output.</li> <li>3. The actual flow rate is too high.</li> </ul>	<ol style="list-style-type: none"> <li>1. Ignore if frequency output is not used</li> <li>2. Check the values entered in menu window M35</li> <li>3. Use a larger value in M35 if needed</li> <li>4. Confirm if the actual flow rate is too high</li> </ol>
F	System RAM Error Date Time Error CPU or IRQ Error ROM Parity Error	<ul style="list-style-type: none"> <li>• Temporary problems with RAM, RTC</li> <li>• 2. Permanent problems with hardware</li> </ul>	<ol style="list-style-type: none"> <li>1. Reboot the system</li> <li>2. Refer to Table 6.1, and contact the manufacturer</li> </ol>
G	Adjusting Gain > s1 Adjusting Gain > s2 Adjusting Gain > s3 Adjusting Gain > s4 (Shown in M311) <b>**VERIFY**</b>	Instrument is in progress of adjusting the gain for the signal, and the number indicates the progressive steps.	No need for action
K	Empty Pipe	<ul style="list-style-type: none"> <li>• No liquid inside the pipe</li> </ul>	<ol style="list-style-type: none"> <li>1. If the pipe is not full, relocate the flow meter to where the pipe is full of liquid.</li> </ol>

			2. If the pipe is full, enter 0 in M** <b>FIND THIS</b> **
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### §6.3 Other Problems and Solutions

**Q:** Why does the instrument display 0.0000 flow rate while the liquid in the pipe is actually flowing? The signal strength, R, is in good range and the signal quality, Q, is a satisfactory value.

**A:** The problem is likely to be caused by an incorrect zero calibration. The user may have conducted the zero point set up while the flow was not at a complete standstill. To solve this problem, press keys C1 and follow the directions given.

**Q:** Why is the displayed flow rate much lower or much higher than the actual flow rate in the pipe despite being under normal working conditions?

**A:** There are three possible explanations for this error:

- 1) The entered offset value may be incorrect. Enter “0” offset in window S44. Please see Section §4.11 for more information on changing the scale factor.
- 2) Incorrect transducer installation. Re-install the transducers carefully.
- 3) The zero calibration was set wrong. Press keys C1 and redo the zero calibration setup. The flow inside the pipe needs to be at a standstill. This menu can be accessed as follows: **CAL** → **Zero**  
**Cal**

**Q:** Why is there no signal even when the installation requirements are met, pipe is new, and pipe material is in good quality?

**A:** Check the following:

- Is the installation method suitable for the pipe size?
- Are the entered installation parameters correct?
- Are the wirings correct?
- Is there adequate couplant? Are the transducers in good contact with pipe?
- Is the pipe full?
- Is the distance between the transducers true to the value shown in window S43? Accessed as follows: **SET** → **Set Transducer** → **Mount Space** (S43). This should be the same figure from the set-up process, which was accessed on Step 5 under the Quick Start menu window (S1, Step 5).
- Are the transducers facing the right direction?

**Q:** If the pipe in use features a heavily scaled inside, and/or poor or no signal detected, is it possible to conduct a measurement? Are there options for conducting a measurement on an old pipe?

**A:** Follow the instructions below:

- Check if the pipe is filled with liquid.
- Try the Z method. If the pipe is close to a wall, and it is hard to do the Z-method installation, the user may use an inclined pipe or even vertical pipe with an upward flow direction.
- Carefully select a good pipe section and fully polish/clean the installation area of the pipe surface. Apply a wide band of couplant on each transducer face. Install the transducers properly. See Section §3 for more details on proper transducer installation.
- Slowly and carefully move each transducer with respect to each other around the installation point until the maximum signal is found. Be sure that the new installation location is free of scales inside the pipe and that the pipe is properly rounded (not distorted). This way, the sound waves will not bounce outside of the intended area.
- For pipe with a thick scale inside or outside, try to clean the scale off – if accessible from the inside. *\*\*Note: This method is not always successful. Therefore, in that case, adequate sound wave transmission is not possible due to the layer of scale between the transducers and inside pipe wall.\*\**

**Q:** Can the flow meter work normally for a few years without stop under harsh environment where power supply voltage varies widely?

**A:** Yes, the RH40 flow meter employs intelligent signal processing algorithms to handle strong interference coming from either power lines or radiation. It also automatically adjusts itself to the optimal operation status when sound wave strength varies due to changing environment.

For more tips, please visit <http://www.spiremt.com/support.html>.

# 7. Communication

## §7.1 General

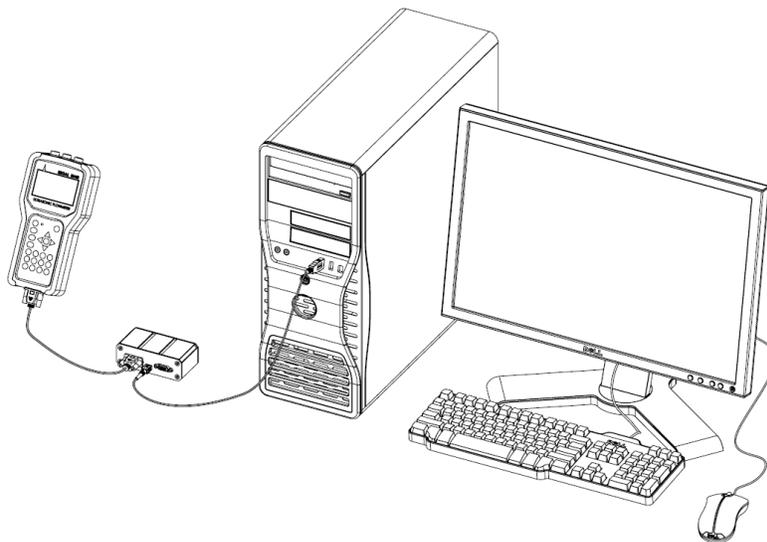
The RH40 series ultrasonic flow meter uses a simple USB communication interface for access to a variety of communication devices. The RH40 includes an extension with a DB-9 connector. This meter uses ModBus for communication. The user can configure the flow meter to acquire measurements from a PC by completing the following steps:

- Install the USB driver on the PC. This will generate a virtual COM port for the flow meter.
- Connect the flow meter to the PC through the USB cable provided with the flow meter unit
- Check the flow meter COM port settings (Baud rate, parity, etc.)
- Set up PC software, either Hyper Terminal or StufManager™ software

## §7.2 Connect the Flowmeter to a PC

A standard USB cable and serial cable are provided with your RH40 unit. Plug the serial cable into the port at the bottom of the meter. Plug the other end of the serial cable into the terminal box. Plug one end of the USB cable into the computer and the other end into the port on the terminal box. Then, turn on the flow meter. Your computer should automatically detect the USB connection and sign a virtual COM port (VCOM).

*Note:* you need to install the USB driver before connecting the USB cable.



## §7.3 Check the Flowmeter COM Port Settings

Go to menu window M53 to check the COM port settings on your flow meter. baud rate is displayed under 1. Port Config. Write down the baud rate. It is needed later in order to set up the computer's COM port. If you want to change

### M53: COMM

1. Port Config
2. Protocol
3. Monitor

the baud rate, press ENT key while in the Port Config window and select the proper baud rate. Press ENT key again to confirm the change.

### §7.4 Set up PC Software

Windows HyperTerminal software can be used to communicate with the flow meter. You may also make your own PC software to communicate to the flow meter by using the protocol described in the following section. Any PC software can be used to communicate with the flow meter if the user follows the subsequent protocol.

To facilitate the use of and to fully explore the potential of the RH40 flow meter, Spire Metering has developed proprietary PC software, StufManager™ software. This software is particularly useful for those who are not familiar with computer communication technology.

Please visit the following technical support website for more information on PC software:  
<http://www.spiremt.com/support/rh20.html>.

### §7.5 Communication Protocol

The protocol is comprised of a set of basic commands that are strings in ASCII format, ending with a carriage (CR) and line feed (LF). Commonly used commands are listed in the following table.

Command	Function	Data Format
<b>DQD(CR)</b>	Return flow rate per day	±d.dddddE±dd (CR) (LF) *
<b>DQH(CR)</b>	Return flow rate per hour	±d.dddddE±dd (CR) (LF)
<b>DQM(CR)</b>	Return flow rate per minute	±d.dddddE±dd (CR) (LF)
<b>DQS(CR)</b>	Return flow rate per second	±d.dddddE±dd (CR) (LF)
<b>DV(CR)</b>	Return instantaneous flow velocity	±d.dddddE±dd (CR) (LF)
<b>DI+(CR)</b>	Return POS totalizer	±ddddddE±d (CR) (LF) **
<b>DI-(CR)</b>	Return NEG totalizer	±ddddddE±d (CR) (LF)
<b>DIN(CR)</b>	Return NET totalizer	±ddddddE±d (CR) (LF)
<b>DID(CR)</b>	Return Identification Number (IDN)	dddd (CR) (LF)
<b>DL(CR)</b>	Return signal strength and signal quality	S=ddd,ddd Q=dd (CR)(LF)
<b>DT(CR)</b>	Return the current date and time	yy-mm-ddhh:mm:ss (CR)(LF)

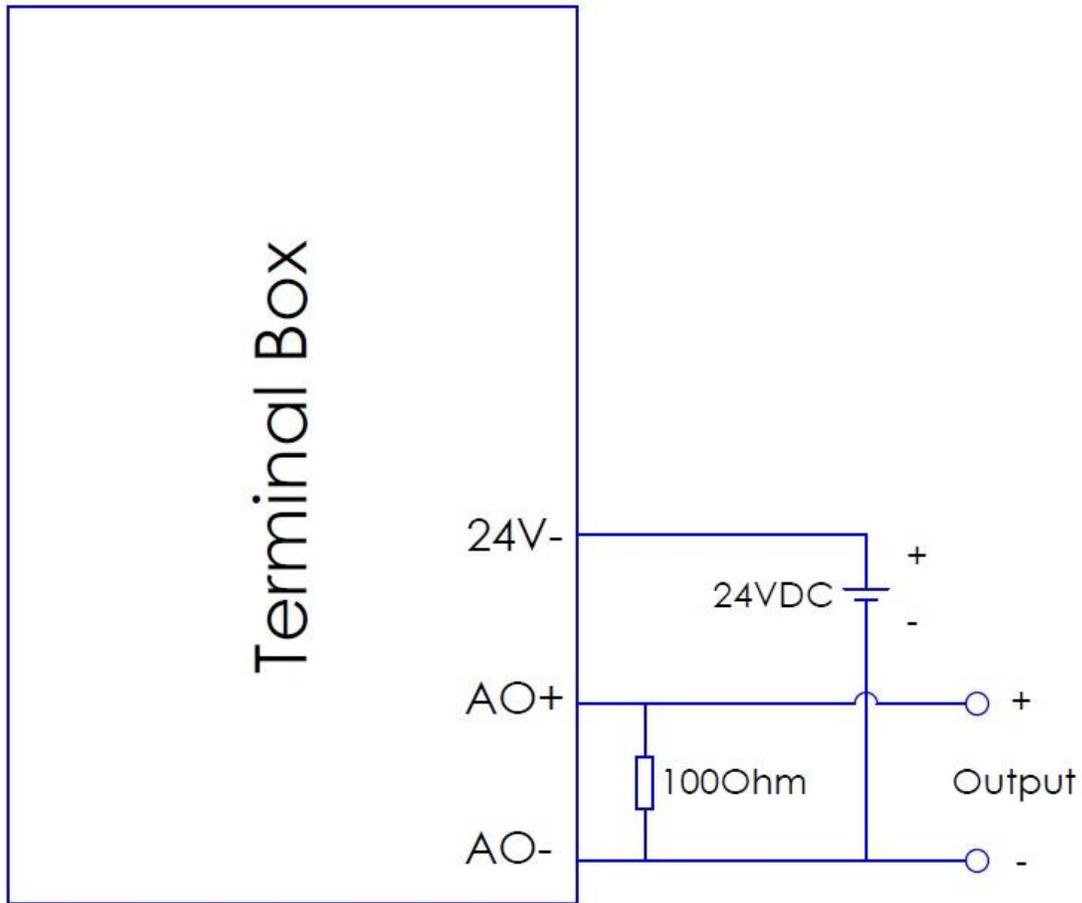
<b>M@(CR)***</b>	Send a key value as if a key is pressed	
<b>LCD(CR)</b>	Return the current display contents	
<b>FOddd(CR)</b>	Force the FO output to output a frequency of dddd Hz	
<b>ESN(CR)</b>	Return the ESN of the flowmeter	Dddddddd (CR)(LF)
<b>RING(CR)</b>	Handshaking Request from a MODEM	
<b>OK(CR)</b>	Acknowledgement from a MODEM	No action
<b>GA</b>	Command for GSM messaging	Please contact the manufacturer for detail
<b>GB</b>	Command for GSM messaging	
<b>GC</b>	Command for GSM messaging	
<b>DUMP(CR)</b>	Return the print buffer content	In ASCII string format
<b>DUMP0(CR)</b>	Clear the whole print buffer	In ASCII string format
<b>DUMP1(CR)</b>	Return the whole print buffer content	In ASCII string Format, 24KB in length
<b>W</b>	Prefix of an IDN-addressing-based networking command. The IDN address is a word, ranging 0-65534.	
<b>N</b>	Prefix of an IDN-addressing-based networking command. The IDN address here is a single byte value, ranging 00-255.	Not recommend for use.
<b>P</b>	Prefix of any command with checksum	
<b>&amp;</b>	Command binder to make a longer command by combining up to 6 commands	

Notes \* CR stands for Carriage Return and LF for Line Feed.

\*\* "d" stands for a digit number of 0~9.

\*\*\* @ stands for the key value, e.g., 30H for the value of ASCII key "0".

The following is a wiring diagram for the 4-20mA output. The password for 4-20mA configuration is 4213068.



## §7.6 Protocol Prefix Usage

### 1) Prefix P

The prefix P can be added before any command in the above table to have the returning data followed with two bytes of CRC check sum, which is the adding sum of the original character string.

Take the Return POS Totalizer Value command, DI+(CR), as an example. Assume that DI+(CR) would return +1234567E+0m3(CR)(LF) (the string in hexadecimal is 2BH, 31H, 32H, 33H, 34H, 35H, 36H, 37H, 45H, 2BH, 30H, 6DH, 33H, 20H, 0DH, 0AH), then PDI(CR) would return +1234567E+0m3!F7(CR)(LF). The '!' acts as the starter of the check sum (F7) which is obtained by adding up the string 2BH, 31H, 32H, 33H, 34H, 35H, 36H, 37H, 45H, 2BH, 30H, 6DH, 33H, 20H.

Please note that it is allowed to not have data entry or to have SPACES (20H) character before the '!' character.

### 2) Prefix W

The prefix W is used for networking commands. The format of a networking command is:

W + IDN address string + basic command.

The IDN address should have a value between 0 and 65534, except 13(0DH), 10 (0AH), 42(2AH,\*), 38(26H, &).

For example, if we want to visit the instantaneous flow velocity of device IDN=12345, the following command should be sent to this device: W12345DV(CR). The corresponding binary code is 57H, 31H, 32H, 33H, 34H, 35H, 44H, 56H, 0DH.

### 3) Prefix N

The prefix N is a single byte IDN network address, not recommended in a new design.

### 4) Command binder &

The & command binder or connector can connect up to 6 basic commands to form a longer command so that it will make the programming much easier.

For example, assume we want device IDN=4321 to return the flow rate, velocity and POS totalizer value simultaneously. The combined command would be W4321DQD&DV&DI+(CR), and the result would be:

+1234567E+0m3(CR)

# 8. Warranty and Service

## **§8.1 Warranty**

The products manufactured by Spire Metering are warranted to be free from defects in materials and workmanship for a period of one year from the date of shipment while under use of the original purchaser. Spire Metering's obligation shall be limited to restoring the meter to normal operation or replacing the meter—at the company's choice—and shall be conditioned upon receiving written notice of any alleged defect within 10 days after its discovery. Spire Metering will make the determination if the return of the meter is necessary. In the case that a full return is deemed required, the user will be responsible for the one-way shipping fee from the customer to the manufacturer.

Spire Metering is not liable for any defects or damage attributable to misuse, improper installation, operation outside of the recommended conditions, replacement of unauthorized parts, and acts of nature.

Fuses and batteries are not included under warranty.

THIS WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER EXPRESS OR IMPLIED WARRANTIES (INCLUDING BUT NOT LIMITED TO WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND WARRANTIES ARISING FROM DEALING, TRADE OR USAGE.)

## **§8.2 Service**

The manufacturer provides unit installation for its customers. The charge will depend on the complexity of the installation.

The most important criteria that effects accurate measurement and proper functionality of the device is the installation of the transducers. Section §3 and Appendix §9.2 provide in-depth information on transducer installation. A checklist to ensure proper installation is located in Section §3.4. Additionally, information on troubleshooting any issues that occur in powering on or operating the device can be found in Section §6.

For operational problems, please contact the technical support department by telephone, fax, or email. The user may contact Spire at support@spiremt.com or 978-263-7100, extension 612. In most cases, problems can be resolved immediately.

For any hardware failures with the device, we recommend that our customers send the unit back to Spire for servicing. Please contact the technical support department with the model number and the serial number before returning the unit. Both numbers can be found on the product label.

For any service or calibration request, we will issue a Return Materials Authorization (RMA). Spire can only determine the details of the repair (complexity of repair, timetable, cost) after receipt and inspection of the instrument. A quote will be sent to the customer before proceeding with the service.

### **Important Notice for Product Return**

Before returning the instrument for warranty repair or service, please read the following carefully:

- 1) If the return item has been exposed to nuclear or other radioactive environment and/or has been in contact with hazardous materials, which could pose any sort of danger to our personnel, the unit cannot be serviced.
- 2) If the return item has been exposed to or in contact with dangerous materials, but has been recognized as a hazard-free device by a reputable organization, you are required to include the certificate for service.
- 3) If the return item does not include the RMA number provided, it will be sent back without any service conducted.

For more information, please see Spire's RMA Policy and Procedure.

### **§8.3 Software Upgrade Service**

Spire provides free software upgrade services. Please contact the manufacturer for software upgrade information. You may also visit our technical support website at <http://www.spiremt.com/support/rh20.html> for the latest downloads.

# 9. Appendix

## §9.1 RH40 Meter and Battery Maintenance

### §9.1.A Battery Maintenance and Replacement

The RH40 features a Ni-H rechargeable battery. Therefore, it is recommended to discharge the battery by leaving the instrument **on** (it will automatically turn **off** after a few minutes) every 3 months.

In between these times, the battery can be fully charged with the supplied AC adapter. To get close to 100% battery power, charge the device overnight.

When not connected to the AC adapter, the battery should last **2 to 3 hours after being fully charged**.

When the device's battery is no longer sustaining that life, this normally indicates that the battery has exceeded its product life. The typical product life of a battery is 2-3 years. Please consult the manufacturer, at [sales@spiremt.com](mailto:sales@spiremt.com), for replacing the battery pack.

### §9.1.B Meter Calibration

Although it is not required for operation, Spire recommends meter calibration approximately once every 2 years for maximum efficiency. Please contact [support@spiremt.com](mailto:support@spiremt.com) for more information. See Section §8.2 for instructions on sending in meters for service.

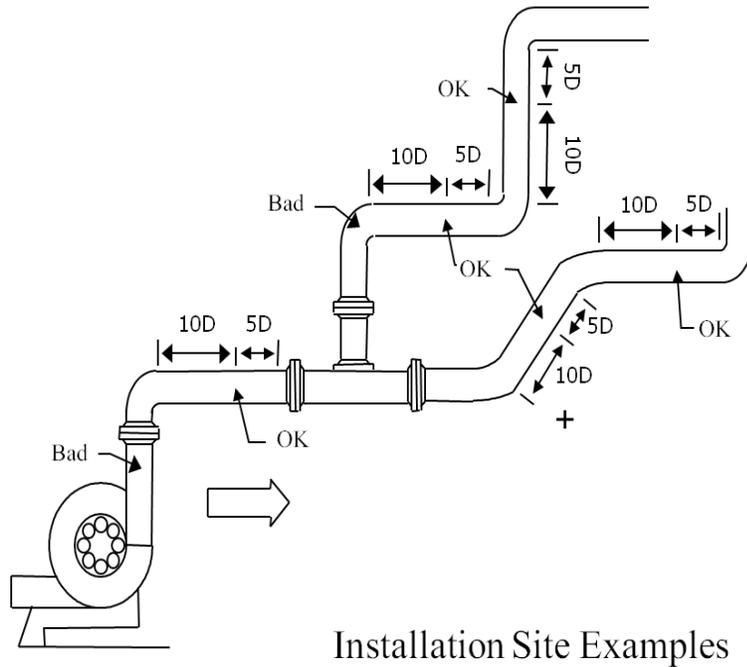
## §9.2 Transducer Installation Guide

### §9.2.A Find the mounting site

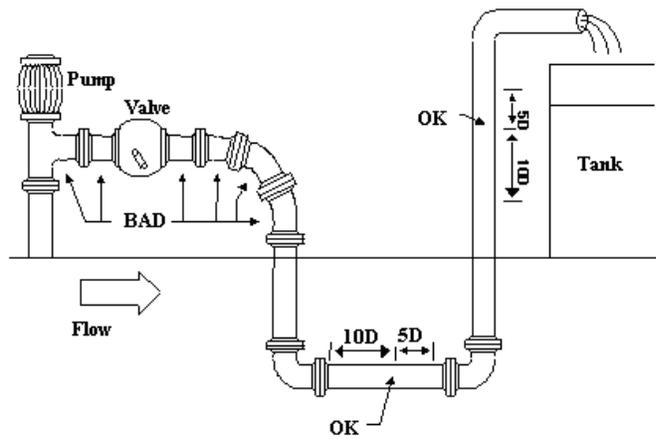
- A) Pipe must be full of liquid at the measurement site.
- B) No heavy corrosion or deposition inside the pipe.
- C) Must be a safe location.
- D) The straight run of the pipe must not be shorter than 15D as a general guideline, where D is the pipe diameter. Insufficient straight pipe length will degrade the accuracy of the results.
- E) The transducer mounting site should be 10D straight run upstream and 5D straight run downstream.
- F) If there are flow disturbing parts such as pumps, valves, etc. on the upstream, the straight pipe length should be increased. The disturbance strength of those flow conducting parts will be (from low to high):

*Single Bend → Pipe Reduction / Enlargement → Outflow Tee → Same Plane Multiple Bends*

→ Inflow Tee → Out of Plane Multiple Bends → Valve → Pump



Installation Site Examples

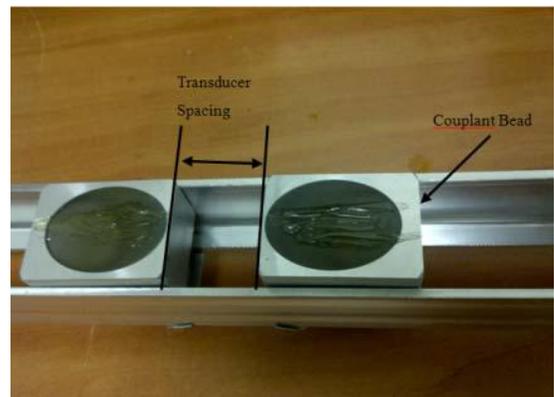


### §9.2.B Prepare the Pipe Surface

Clean the pipe surface where the transducers will be mounted. Remove rust and paint. Sand the surface if not smooth. Use a wet cloth to wipe off the powder after sanding. Dry up the surface. A dry, clean surface will ensure a good acoustic bond between the transducer and the pipe.

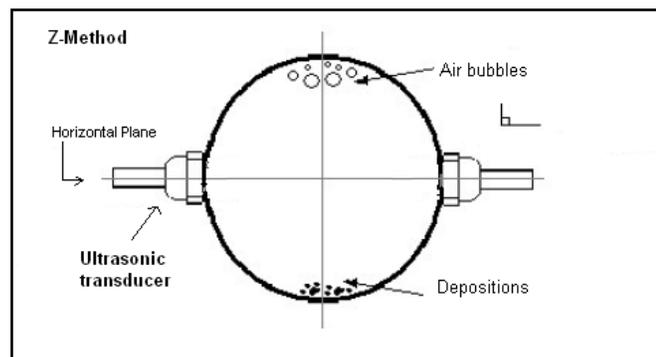
### §9.2.C Prepare the Transducer

Clean the transducer surface. Keep the surface dry. Put couplant on transducer surface as shown in the figure on the right. Do not put more couplant than needed, especially for small pipes.



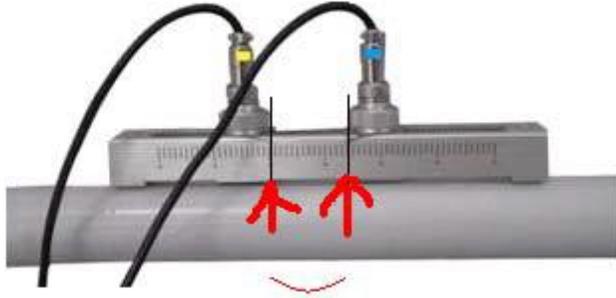
### §9.2.D Install the Transducers

For horizontal pipe lines, it is recommended to install the transducers on the side instead of on the top or bottom of the pipe. This is to avoid air bubbles on the top and sediments on the bottom of the pipe.



#### *HS-type transducer:*

- Connect the transducer cables to the main unit.
- Move the transducer pair apart so that the mounting spacing between the two transducers is equal to the one shown in window S43
- Apply a small amount of couplant in the prepared area of the pipe where transducers will be in contact.
- Align the transducer mounting rack with the pipe axis.
- Release the transducer rack if magnetic force takes effect.
- If the pipe material is non-metal, push the transducer handle against the pipe and hold it during the measurement. Clamps or metal strips may be used to mount the rack.

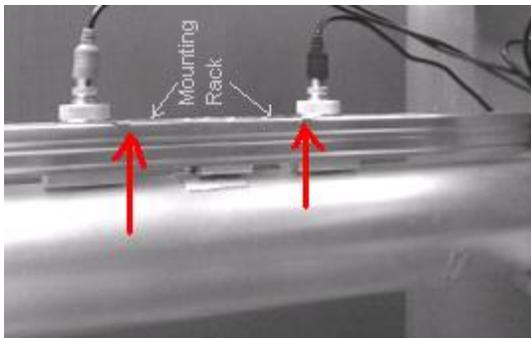


For pipe size 1”~1.5” metal pipe, we recommend a damping material to be used around the pipe surface, such as GraceIce.

If wrapping acoustic damping material is not an option, try to put some acoustic couplant around the pipe to absorb the acoustic noise.

***HM-type transducer:***

Connect the transducer cables to the main unit. Move the transducer pair apart so that the mounting spacing between the two transducers is equal to the one shown in menu window S43. Then, follow the same steps as installing HS transducers, applying couplant as necessary.



**§9.3 Pipe Size Tables**

Table A1: Standard copper tubes according ASTM B88.

Nominal Size (Inches)	Actual Outside Diameter (Inches)		Tolerance on Outside Diameter (Inches)		Wall Thickness (Inches)	
			Annealed	Drawn	Nominal	Tolerance
<b>Type K</b>						
¾	7/8	0.875	0.003	0.001	0.065	0.006
1	1 1/8	1.125	0.0035	0.0015	0.065	0.006
1 ¼	1 3/8	1.375	0.004	0.0015	0.065	0.006
1 ½	1 5/8	1.625	0.0045	0.002	0.072	0.007
2	2 1/8	2.125	0.005	0.002	0.083	0.008
2 ½	2 5/8	2.625	0.005	0.002	0.095	0.010
3	3 1/8	3.125	0.005	0.002	0.109	0.011
3 ½	3 5/8	3.625	0.005	0.002	0.120	0.012
4	4 1/8	4.125	0.005	0.002	0.134	0.013

<b>Type L</b>						
¾	7/8	0.875	0.003	0.001	0.045	0.004
1	1 1/8	1.125	0.0035	0.0015	0.050	0.005
1 ¼	1 3/8	1.375	0.004	0.0015	0.055	0.006
1 ½	1 5/8	1.625	0.0045	0.002	0.060	0.006
2	2 1/8	2.215	0.005	0.002	0.070	0.007
2 ½	2 5/8	2.625	0.005	0.002	0.080	0.008
3	3 1/8	3.125	0.005	0.002	0.090	0.009
3 ½	3 5/8	3.625	0.005	0.002	0.100	0.010
4	4 1/8	4.125	0.005	0.002	0.114	0.011

Table A2: Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
1/8	0.405	0.049	-	-	10S
		0.068	STD	40	40S
		0.095	XS	80	80S
1/4	0.540	0.065	-	-	10S
		0.088	STD	40	40S
		0.119	XS	80	80S
3/8	0.675	0.065	-	-	10S
		0.091	STD	40	40S
		0.126	XS	80	80S
1/2	0.840	0.065	-	-	5S
		0.083	-	-	10S
		0.109	STD	40	40S
		0.147	XS	80	80S
		0.187	-	160	-
		0.294	XXS	-	-

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
3/4	1.050	0.065	-	-	5S
		0.083	-	-	10S
		0.113	STD	40	40S
		0.154	XS	80	80S
		0.218	-	160	-
		0.308	XXS	-	-
1	1.315	0.065	-	-	5S
		0.109	-	-	10S
		0.133	STD	40	40S
		0.179	XS	80	80S
		0.250	-	160	-
		0.358	XXS	-	-
1 1/4	1.660	0.065	-	-	5S
		0.109	-	-	10S
		0.140	STD	40	40S
		0.191	XS	80	80S
		0.250	-	160	-
		0.382	XXS	-	-
1 1/2	1.900	0.065	-	-	5S
		0.109	-	-	10S
		0.145	STD	40	40S
		0.200	XS	80	80S
		0.281	-	160	-
		0.400	XXS	-	-
2	2.375	0.065	-	-	5S
		0.109	-	-	10S
		0.154	STD	40	40S
		0.218	XS	80	80S
		0.344	-	160	-
		0.436	XXS	-	-

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
2 1 / 2	2.875	0.083	—	—	5S
		0.120	—	—	10S
		0.203	STD	40	40S
		0.276	XS	80	80S
		0.375	—	160	—
		0.552	XXS	—	—
3	3.500	0.083	—	—	5S
		0.120	—	—	10S
		0.216	STD	40	40S
		0.300	XS	80	80S
		0.438	—	160	—
		0.600	XXS	—	—
3 1 / 2	4.000	0.083	-	—	5S
		0.120	-	—	10S
		0.226	STD	40	40S
		0.318	XS	80	80S
		0.636	XXS	—	—
4	4.500	0.083	-	—	5S
		0.120	-	—	10S
		0.237	STD	40	40S
		0.337	XS	80	80S
		0.438	-	120	—
		0.531	-	160	—
		0.674	XXS	—	—
5	5.536	0.109	-	—	5S
		0.134	-	—	10S
		0.258	STD	40	40S
		0.375	XS	80	80S
		0.500	-	120	—
		0.625	-	160	—
		0.750	XXS	—	—

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
6	6.625	0.109	-	-	5S
		0.134	-	-	10S
		0.280	STD	40	40S
		0.432	XS	80	80S
		0.562	-	120	-
		0.719	-	160	-
		0.864	XXS	-	-
8	8.625	0.109	-	-	5S
		0.148	-	-	10S
		0.250	-	20	-
		0.277	-	30	-
		0.322	STD	40	40S
		0.406	-	60	-
		0.500	XS	80	80S
		0.594	-	100	-
		0.719	-	120	-
		0.812	-	140	-
		0.875	XXS	-	-
0.906	-	160	-		
10	10.750	0.134	-	-	5S
		0.165	-	-	10S
		0.250	-	20	-
		0.307	-	30	-
		0.365	STD	40	40S
		0.500	XS	60	80S
		0.594	-	80	-
		0.719	-	100	-
		0.844	-	120	-
		1.000	XXS	140	-

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
12	12.750	0.156	-	-	5S
		0.180	-	-	10S
		0.250	-	20	-
		0.330	-	30	-
		0.375	STD	-	40S
		0.406	-	40	-
		0.500	XS	-	80S
		0.562	-	60	-
		0.688	-	80	-
		0.844	-	100	-
		1.000	XXS	120	-
		1.125	-	140	-
		1.312	-	160	-
14	14.000	0.156	-	-	5S
		0.188	-	-	10S
		0.250	-	10	-
		0.312	-	20	-
		0.375	STD	30	-
		0.438	-	40	-
		0.500	XS	-	-
		0.594	-	60	-
		0.625	XXS	-	-
		0.750	-	80	-
		0.938	-	100	-
		1.094	-	120	-
		1.250	-	140	-
1.406	-	160	-		

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
16	16.000	0.165	-	-	5S
		0.188	-	-	10S
		0.250	-	10	-
		0.312	-	20	-
		0.375	STD	30	-
		0.500	XS	40	-
		0.656	-	60	-
		0.844	-	80	-
		1.031	-	100	-
		1.219	-	120	-
		1.439	-	140	-
		1.549-	-	160	-
		18	18.000	0.165	-
0.188	-			-	10S
0.250	-			10	-
0.312	-			20	-
0.375	STD			-	-
0.438	-			30	-
0.500	XS			-	-
0.562	-			40	-
0.750	-			60	-
0.938	-			80	-
1.156	-			100	-
1.375	-			120	-
1.562	-			140	-
1.781	-	160	-		

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
20	20.000	0.188	-	-	5S
		0.218	-	-	10S
		0.250	-	10	-
		0.375	STD	20	-
		0.500	XS	30	-
		0.594	-	40	-
		0.812	-	60	-
		1.031	-	80	-
		1.281	-	100	-
		1.500	-	120	-
		1.750	-	140	-
		1.969	-	160	-
22	22.000	0.188	-	-	5S
		0.218	-	-	10S
		0.250	-	10	-
		0.375	STD	20	-
		0.500	-	40	-
		0.875	-	60	-
		1.125	-	80	-
		1.375	-	100	-
		1.625	-	120	-
		1.875	-	140	-
		2.215	-	160	-

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
24	24.000	0.218	-	-	5S
		0.250	-	-	10S
		0.375	-	10	-
		0.500	STD	20	-
		0.562	XS	-	-
		0.688	-	30	-
		0.969	-	60	-
		1.219	-	80	-
		1.531	-	100	-
		1.812	-	120	-
		2.062	-	140	-
		2.344	-	160	-
26	26.000	0.312	-	10	
		0.375	STD	-	
		0.500	XS	20	
28	28.000	0.312	-	10	
		0.375	STD	-	
		0.500	XS	20	
		0.625	-	30	
30	30.000	0.250	-	-	5S
		0.312	-	10	10S
		0.375	STD	-	-
		0.500	XS	20	-
		0.625	-	30	-
		0.750	-	40	-

Table A2 (continued): Standard ANSI Pipe Size Data for Carbon Steel and Stainless Steel Pipe

Nominal Pipe Size (in)	Outer Diameter (in)	Wall Thickness (in)	ANSI B 36.10	ANSI B 36.10	ANSI B 36.19
			Carbon Steel	Carbon Steel	Stainless Steel
			Wall Thickness	Schedule Number	Schedule Number
32	32.000	0.312	-	10	-
		0.375	STD	-	-
		0.500	XS	20	-
		0.625	-	30	-
		0.688	-	40	-
34	34.000	0.344	-	10	10S
		0.375	STD	-	-
		0.500	XS	20	-
		0.625	-	30	-
		0.688	-	40	-
36	36.000	0.312	-	10	10S
		0.375	STD	-	-
		0.500	XS	20	-
		0.625	-	30	-
		0.750	-	40	-
42	42.000	0.375	STD	-	-
		0.500	XS	20	-
		0.625	-	30	-
		0.750	-	40	-
48	48.000	0.375	STD	-	-
		0.500	XS	-	-

Table A3: Standard Classes of Cast Iron Pipe

Nominal Pipe Size (in.)	Class A		Class B		Class C		Class D	
	Outer Diameter (in.)	Wall Thickness (in.)	Outer Diameter (in.)	Wall Thickness (in.)	Outer Diameter (in.)	Wall Thickness (in.)	Outer 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	0.48	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				

Table A3 (continued): Standard Classes of Cast Iron Pipe

Nominal Pipe Size (in.)	Class E		Class F		Class G		Class H	
	Outer Diameter (in.)	Wall Thickness (in.)	Outer Diameter (in.)	Wall Thickness (in.)	Outer Diameter (in.)	Wall Thickness (in.)	Outer 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								

Table A4: Standard Classes of Ductile Iron Pipe

Nominal Pipe Size (in)	Outer 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
32	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

## §8.4 Sound Speed Tables

Table A5: Sound Speed Data of Solids

Material	Sound Speed Shear Wave ( 25 °C)		Sound Speed Long. Wave ( 25°C)	
	m/s	ft/s	mm/us	in/us
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 )	2,235	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

Table A5 (continued): Sound Speeds in Solids

Material	Sound Speed* Shear Wave ( 25°C )		Sound Speed* Long Wave ( 25°C )	
	m/s	ft/s	mm/us	in/us
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 ( LD )			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	0.00748

Table A6: Sound Speed in Water at atmosphere pressure. Unit: t (°C) v (m/s)

t	v	t	v	t	v	t	v
0	1402.3	25	1496.6	50	1542.5	75	1555.1
1	1407.3	26	1499.2	51	1543.5	76	1555.0
2	1412.2	27	1501.8	52	1544.6	77	1554.9
3	1416.9	28	1504.3	53	1545.5	78	1554.8
4	1421.6	29	1506.7	54	1546.4	79	1554.6
5	1426.1	30	1509.0	55	1547.3	80	1554.4
6	1430.5	31	1511.3	56	1548.1	81	1554.2
7	1434.8	32	1513.5	57	1548.9	82	1553.9
8	1439.1	33	1515.7	58	1549.6	83	1553.6
9	1443.2	34	1517.7	59	1550.3	84	1553.2
10	1447.2	35	1519.7	60	1550.9	85	1552.8
11	1451.1	36	1521.7	61	1551.5	86	1552.4
12	1454.9	37	1523.5	62	1552.0	87	1552.0
13	1458.7	38	1525.3	63	1552.5	88	1551.5
14	1462.3	39	1527.1	64	1553.0	89	1551.0
15	1465.8	40	1528.8	65	1553.4	90	1550.4
16	1469.3	41	1530.4	66	1553.7	91	1549.8
17	1472.7	42	1532.0	67	1554.0	92	1549.2
18	1476.0	43	1533.5	68	1554.3	93	1548.5
19	1479.1	44	1534.9	69	1554.5	94	1547.5
20	1482.3	45	1536.3	70	1554.7	95	1547.1
21	1485.3	46	1537.7	71	1554.9	96	1546.3
22	1488.2	47	1538.9	72	1555.0	97	1545.6
23	1491.1	48	1540.2	73	1555.0	98	1544.7
24	1493.9	49	1541.3	74	1555.1	99	1543.9

Table A7: Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C (77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s	m/s/ $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
Acetic anhydride(22)	(CH <sub>3</sub> CO) <sub>2</sub> O	1.082 (20°C)	1,180	3,871.4	2.5	0.769	8.274
Acetic acid,anhydride(22)	(CH <sub>3</sub> CO) <sub>2</sub> O	1.082 (20°C)	1,180	3,871.4	2.5	0.769	8.274
Acetic acid,nitrile	C <sub>2</sub> H <sub>3</sub> N	0.783	1,290	4,232.3	4.1	0.441	4.745
Acetic acid,ethyl ester(33)	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	0.901	1,085	3,559.7	4.4	0.467	5.025
Acetic acid,methyl ester	C <sub>3</sub> H <sub>6</sub> O <sub>2</sub>	0.934	1,211	3,973.1		0.407	4.379
Acetone	C <sub>3</sub> H <sub>6</sub> O	0.791	1,174	3,851.7	4.5	0.399	4.293
Acetonitrile	C <sub>2</sub> H <sub>3</sub> N	0.783	1,290	4,232.3	4.1	0.441	4.745
Acetylacetone	C <sub>6</sub> H <sub>10</sub> O <sub>2</sub>	0.729	1,399	4,589.9	3.6		
Acetylen dichloride	C <sub>2</sub> H <sub>2</sub> CL <sub>2</sub>	1.26	1,015	3,330.1	3.8	0.400	4.304
Acetylenetetrabromide(47)	C <sub>2</sub> H <sub>2</sub> Br <sub>4</sub>	2.966	1,027	3,369.4			
Acetylen tetrachloride(47)	C <sub>2</sub> H <sub>2</sub> CL <sub>4</sub>	1.595	1,147	3,763.1		1.156 (15°C)	12.438 (59°F)
Alcohol	C <sub>2</sub> H <sub>6</sub> O	0.789	1,207	3,960	4.0	1.396	15.02
Alkazene-13	C <sub>15</sub> H <sub>24</sub>	0.86	1,317	4,320.9	3.9		
Alkazene-25	C <sub>10</sub> H <sub>12</sub> CL <sub>2</sub>	1.20	1,307	4,288.1	3.4		
2-Amino-ethanol	C <sub>2</sub> H <sub>7</sub> NO	1.018	1,724	5,656.2	3.4		
2-Aminotolidine(46)	C <sub>7</sub> H <sub>9</sub> N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
4-Aminotolidine(46)	C <sub>7</sub> H <sub>9</sub> N	0.999 (45°C)	1,480	4,855.6		1.863 (50°C)	20.045 (122°F)
Ammonia(35)	NH <sub>3</sub>	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 <sub>5</sub> H <sub>12</sub> O	0.81	1,204	3,950.1		4.374	47.064
Aminobenzene(41)	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	1.022	1,639	5,377.3	4.0	3.63	39.058
Aniline(41)	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	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)			

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$ m/s/°C	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s		m <sup>2</sup> /s	ft <sup>2</sup> /s
Azine	C <sub>6</sub> H <sub>5</sub> N	0.982	1,415	4,642.4	4.1	0.992 (20°C)	10.673 (68°F)
Benzene(29,40,41)	C <sub>6</sub> H <sub>6</sub>	0.879	1,306	4,284.8	4.65	0.711	7.65
Benzol(29,40,41)	C <sub>6</sub> H <sub>6</sub>	0.879	1,306	4,284.8	4.65	0.711	7.65
Bromine(21)	Br <sub>2</sub>	2.928	889	2,916.7	3.0	0.323	3.475
Bromo-benzene(46)	C <sub>6</sub> H <sub>5</sub> Br	1.522	1,170 (20°C)	3,838.6 (68°F)		0.693	7.456
1-Bromo-butane(46)	C <sub>4</sub> H <sub>9</sub> Br	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 <sub>2</sub> H <sub>5</sub> Br	1.460 (20°C)	900 (20°C)	2,952.8 (68°F)		0.275	2.959
Bromoform(46,47)	CHBr <sub>3</sub>	2.89 (20°C)	918	3,011.8	3.1	0.654	7.037
n-Butane(2)	C <sub>4</sub> H <sub>10</sub>	0.601 (0°C)	1,085 (-5°C)	3,559.7 (23°F)	5.8		
2-Butanol	C <sub>4</sub> H <sub>10</sub> O	0.81	1,240	4,068.2	3.3	3.239	34.851
Sec-Butylalcohol	C <sub>4</sub> H <sub>10</sub> O	0.81	1,240	4,068.2	3.3	3.239	34.851
n-Butyl bromide(46)	C <sub>4</sub> H <sub>9</sub> Br	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 <sub>4</sub> H <sub>9</sub> CL	0.887	1,140	3,740.2	4.57	0.529 (15°C)	5.692 (59°F)
Tert Butyl chloride	C <sub>4</sub> H <sub>9</sub> CL	0.84	984	3,228.3	4.2	0.646	6.95
Butyl oleate	C <sub>22</sub> H <sub>42</sub> O <sub>2</sub>		1,404	4,606.3	3.0		
2,3 Butylene glycol	C <sub>4</sub> H <sub>10</sub> O <sub>2</sub>	1.019	1,484	4,808.8	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 <sub>4</sub> O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.478
Carbitol	C <sub>6</sub> H <sub>14</sub> O <sub>3</sub>	0.988	1,458	4,783.5			
Carbon dioxide(26)	CO <sub>2</sub>	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 <sub>2</sub>	1.261 (22°C)	1,149	3,769.7		0.278	2.991

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$ m/s/°C	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s		m <sup>2</sup> /s	ft <sup>2</sup> /s
Carbon tetrachloride (33,35,47)	CCL <sub>4</sub>	1.595 (20°C)	929	3038.1	2.48	0.607	6.531
Carbon tetrafluoride(14) (Freon 14)	CF <sub>4</sub>	1.75 (-150°C)	875.2 (-150°C)	2,871.5 (-238°F)	6.61		
Cetane(23)	C <sub>16</sub> H <sub>34</sub>	0.773 (20°C)	1,338	4,389.8	3.71	4.32	46.483
Chloro-benzene	C <sub>6</sub> H <sub>5</sub> CL	1.106	1,273	4,176.5	3.6	0.722	7.768
1-Chloro-butane(22,46)	C <sub>4</sub> H <sub>9</sub> CL	0.887	1,140	3,740.2	4.57	0.529 (15°C)	5.692 (59°F)
Chloro-diFluoromethane (3)(Freon 22)	CHCLF <sub>2</sub>	1.491 (-69°C)	893.9 (-50°C)	2,932.7 (-58°F)	4.79		
Chloroform(47)	CHCL <sub>3</sub>	1.489	979	3,211.9	3.4	0.55	5.918
1-Chloro-propane(47)	C <sub>3</sub> H <sub>7</sub> CL	0.892	1,058	3,471.1		0.378	4.067
Chlorotrifluoromethane (5)	CCLF <sub>3</sub>		724 (-82°C)	2,375.3 (-116°F)	5.26		
Cinnamaldehyde	C <sub>9</sub> H <sub>8</sub> O	1.112	1,554	5,098.4	3.2		
Cinnamic aldehyde	C <sub>9</sub> H <sub>8</sub> O	1.112	1,554	5,098.4	3.2		
Colamine	C <sub>2</sub> H <sub>7</sub> NO	1.018	1,724	5,656.2	3.4		
o-Cresol(46)	C <sub>7</sub> H <sub>8</sub> O	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 <sub>7</sub> H <sub>8</sub> O	1.034 (20°C)	1,500 (20°C)	4,923.1 (68°F)		5.979 (40°C)	64.334 (104°F)
Cyanomethane	C <sub>2</sub> H <sub>3</sub> N	0.783	1,290	4,232.3	4.1	0.441	4.745
Cyclohexane(15)	C <sub>6</sub> H <sub>12</sub>	0.779 (20°C)	1,248	4,094.5	5.41	1.31 (17°C)	14.095 (63°F)
Cyclohexanol	C <sub>6</sub> H <sub>12</sub> O	0.962	1,454	4,770.3	3.6	0.071 (17°C)	0.764 (63°F)
Cyclohexanone	C <sub>6</sub> H <sub>10</sub> O	0.948	1,423	4,668.6	4.0		
Decane(46)	C <sub>10</sub> H <sub>20</sub>	0.730	1,252	4,107.6		1.26 (20°C)	13.55 (68°F)
1-Decene(27)	C <sub>10</sub> H <sub>20</sub>	0.746	1,235	4,051.8	4.0		
n-Decene(27)	C <sub>10</sub> H <sub>20</sub>	0.746	1,235	4,051.8	4.0		
Diacetyl	C <sub>4</sub> H <sub>6</sub> O	0.99	1,236	4,055.1	4.6		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s		m <sup>2</sup> /s	ft <sup>2</sup> /s
Diamylamine	C <sub>10</sub> H <sub>23</sub> N		1,256	4,120.7	3.9		8.5 (68°F)
1,2Dibromo-ethane(47)	C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	2.18	995	3,264.4		0.79 (20°C)	
trans-1,2-Dibromoethene (47)	C <sub>2</sub> H <sub>2</sub> Br <sub>2</sub>	2.231	935	3,067.6			
Diburylphthalate	C <sub>8</sub> H <sub>22</sub> O <sub>4</sub>		1,408	4,619.4			
Dichloro-t-butylalcohol	C <sub>4</sub> H <sub>8</sub> Cl <sub>2</sub> O		1,304	4,278.2	3.8		
2,3Dichlorodioxane	C <sub>2</sub> H <sub>6</sub> Cl <sub>2</sub> O <sub>2</sub>		1,391	4,563.6	3.7		
Dichlorodifluoromethane (3)(Freon12)	CCl <sub>2</sub> F <sub>2</sub>	1.516 (40°C)	774.1	2,539.7	4.24		
1,2Dichloro ethane(47)	C <sub>2</sub> H <sub>2</sub> Cl <sub>2</sub>	1.253	1,193	3,914		0.61	6.563
cis1,2-Dichloro-ethene (3,47)	CHCl <sub>2</sub> F	1.284	1,061	3,481			
trans1,2-Dichloro-ethene (3,47)	C <sub>4</sub> Cl <sub>2</sub> F <sub>6</sub>	1.257	1,010	3,313.6			
Dichloro-fluoromethane (3)(Freon21)	C <sub>4</sub> H <sub>8</sub> Cl <sub>2</sub>	1.426 (0°C)	891 (0°C)	2,923.2 (32°F)	3.97		
1-2-Dichlorohexafluoro- cyclobutane(47)	CClF <sub>2</sub> -CClF <sub>2</sub>	1.654	669	2,914.9			
1-3-Dichloro-isobutane	C <sub>4</sub> H <sub>10</sub> O	1.14	1,220	4,002.6	3.4		
Dichloro methane(3)	C <sub>4</sub> H <sub>10</sub> O <sub>3</sub>	1.327	1,070	3,510.5	3.94	0.31	3.335
1,1-Dichloro-1,2,2,2 tetra fluoromethane	C <sub>6</sub> H <sub>14</sub> O <sub>3</sub>	1.455	665.3 (-10°C)	2,182.7 (14°F)	3.73		
Diethyl ether	C <sub>4</sub> H <sub>9</sub> NO	0.713	985	3,231.6	4.87	0.311	3.346
Diethylene glycol	C <sub>4</sub> H <sub>8</sub> (NF <sub>2</sub> ) <sub>2</sub>	1.116	1,586	5,203.4	2.4		
Diethylene glycol Monoethyl ether	C <sub>4</sub> H <sub>9</sub> (NF <sub>2</sub> ) <sub>2</sub>	0.988	1,458	4,783.5			
Diethylenmide oxide	C <sub>3</sub> H <sub>6</sub> (NF <sub>2</sub> ) <sub>2</sub>	1.00	1,442	4,731	3.8		
1,2-bis(DiFluoramino) butane(43)	C <sub>10</sub> H <sub>23</sub> N	1.216	1,000	3,280.8			
1,2-bis(DiFluoramino)- 2-methylpropane(43)	C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	1.213	900	2,952.8			
1,2-bis(DiFluoramino) propane(43)	C <sub>2</sub> H <sub>2</sub> Br <sub>2</sub>	1.265	960	3,149.6			

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$ m/s/°C	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s		m <sup>2</sup> /s	ft <sup>2</sup> /s
2,2-bis(Difluoromino propane)(43)	C <sub>3</sub> H <sub>6</sub> (NF <sub>2</sub> ) <sub>2</sub>	1.254	890	2920			
2,2-Dihydroxydiethyl ether	C <sub>4</sub> H <sub>10</sub> O <sub>3</sub>	1.116	1,586	5,2034	2.4		
Dihydroxyethane	C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	1.113	1,658	5,439.6	2.1		
1,3-Dimethyl-benzene(46)	C <sub>8</sub> H <sub>10</sub>	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 <sub>8</sub> H <sub>10</sub>	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 <sub>8</sub> H <sub>10</sub>		1,334 (20°C)	4,376.6 (68°F)		0.662	7.123
2,2Dimethyl-butane (29,33)	C <sub>6</sub> H <sub>14</sub>	0.649 (20°C)	1,079	3,540			
Dimethyl ketone	C <sub>3</sub> H <sub>6</sub> O	0.791	1,174	3,851.7	4.5	0.399	4.293
Dimethylpentane(47)	C <sub>7</sub> H <sub>16</sub>	0.674	1,063	3,487.5			
Dimethylphthalate	C <sub>8</sub> H <sub>10</sub> O <sub>4</sub>	1.2	1,463	4,799.9			
Diiodo-methane	CH <sub>2</sub> I <sub>2</sub>	3.235	980	3,215.2			
Dioxane	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	1.033	1,376	4,514.4			
Dodecane(23)	C <sub>12</sub> H <sub>26</sub>	0.749	1,279	4,196.2	3.85	1.80	19.368
1,2Ethanediol	C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	1.113	1,658	5,439.6	2.1		
Ethanenitrile	C <sub>2</sub> H <sub>3</sub> N	0.783	1,290	4,232.3		0.441	4.745
Ethanoic anhydride(22)	(CH <sub>3</sub> CO) <sub>2</sub> O	1.082	1,180	3,871.4		0.769	8.274
Ethanol	C <sub>2</sub> H <sub>6</sub> O	0.789	1,207	3,690	4.0	1.39	14.956
Ethanol amide	C <sub>2</sub> HNO	1.018	1,338 (20°C)	5,656.2	3.4		
Ethoxyethane	C <sub>4</sub> H <sub>10</sub> O	0.713	900 (20°C)	3,231.6	4.87	0.311	3.346
Ethyl acetate(33)	C <sub>4</sub> H <sub>8</sub> O <sub>2</sub>	0.901	876 (20°C)	3,559.7	4.4	0.489	5.263
Ethyl alcohol	C <sub>2</sub> H <sub>6</sub> O	0.789	890	3,960	4.0	1.396	15.020
Ethyl benzene(46)	C <sub>8</sub> H <sub>10</sub>	0.867 (20°C)	1,586	4,389.8 (68°F)		0.797 (17°C)	8.575 (63°F)
Ethyl Bromide(46)	C <sub>2</sub> H <sub>5</sub> Br	1.456 (20°C)	1,658	2,952.8 (68°F)		0.275 (20°C)	2.959 (68°F)
Ethyl iodide(46)	C <sub>2</sub> H <sub>5</sub> I	1.950 (20°C)	1,343 (20°C)	2874 (68°F)		0.29	3.12

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$ m/s/°C	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s		m <sup>2</sup> /s	ft <sup>2</sup> /s
Ether	C <sub>4</sub> H <sub>10</sub> O	0.713	985	3231.6	4.87	0.311	3.346
Ethyl ether	C <sub>4</sub> H <sub>10</sub> O	0.713	985	3231.6	4.87	0.311	3.346
Ethylene bromide(47)	C <sub>2</sub> H <sub>4</sub> Br <sub>2</sub>	2.18	995	3264.4		0.79	8.5
Ethylene chloride(47)	C <sub>2</sub> H <sub>4</sub> Cl <sub>2</sub>	1.253	1,193	3914		0.61	6.563
Ethylene glycol	C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	1.113	1,658	5439.6	2.1	17.208 (20°C)	185.158 (68°F)
d-Fenochone	C <sub>10</sub> H <sub>16</sub> O	0.974	1,320	4330.7		0.22	2.367
d-2-Fenecanone	C <sub>10</sub> H <sub>16</sub> O	0.974	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 <sub>6</sub> H <sub>5</sub> F	1.024 (20°C)	1,189	3900.9		0.584 (20°C)	6.283 (68°F)
Formaldehyde,methylester	C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	0.974	1,127	3697.5	4.02		
Formamide	CH <sub>3</sub> NO	1.134 (20°C)	1,622	5321.5	2.2	2.91	31.311
Formic acid,amide	CH <sub>3</sub> NO	1.134 (20°C)	1,622	5321.5		2.91	31.311
Freon R12			774.2	2540			
Furfural	C <sub>5</sub> H <sub>4</sub> O <sub>2</sub>	1.157	1,444	4737.5	3.7		
Furfuryl alcohol	C <sub>5</sub> H <sub>6</sub> O <sub>2</sub>	1.135	1,450	4757.5	3.4		
Fural	C <sub>5</sub> H <sub>4</sub> O <sub>2</sub>	1.157	1,444	4737.5	3.7		
2-Furaldehyde	C <sub>5</sub> H <sub>4</sub> O <sub>2</sub>	1.157	1,444	4737.5	3.7		
2-Furancarboxaldehyde	C <sub>5</sub> H <sub>4</sub> O <sub>2</sub>	1.157	1,444	4737.5	3.7		
2-Furyl-Methanol	C <sub>5</sub> H <sub>6</sub> O <sub>2</sub>	1.135	1,450	4757.2	3.4		
GAllium	Ga	6.095	2,870 (30°C)	9416 (86°F)			
Glycerin	C <sub>3</sub> H <sub>8</sub> O <sub>3</sub>	1.26	1,904	6246.7	2.2	757.1	
Glycerol	C <sub>3</sub> H <sub>8</sub> O <sub>3</sub>	1.26	1,904	6246.7	2.2	757.1	
Glycol	C <sub>2</sub> H <sub>6</sub> O <sub>2</sub>	1.113	1658	5439.6	2.1		8,081.8 36
50%Glycol/50%h2O			1,578	5,177			8,081.836

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77 °F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s	m/s/°C	m <sup>2</sup> /s	ft <sup>2</sup> /s
Helium(45)	He <sub>4</sub>	0.125 (-269°C)	183 (-269°C)	600.4 (-452°F)		0.025	269
Heptane(22,23)	C <sub>7</sub> H <sub>16</sub>	0.684 (20°C)	1,131	3,710.6	4.25	0.598 (20°C)	6.434 (68°F)
n-Heptane(29,33)	C <sub>7</sub> H <sub>16</sub>	0.684 (20°C)	1,180	3,871.3	4.0		
Hexachloro- Cyclopentadiene(47)	C <sub>5</sub> Cl <sub>6</sub>	1.7180	1,150	3,773			
Hexadecane(23)	C <sub>16</sub> H <sub>34</sub>	0.773 (20°C)	1,338	4,389.8	3.71	4.32 (20°C)	46.483 (68°F)
Hexalin	C <sub>6</sub> H <sub>12</sub> O	0.962	1,454	4,770.3	3.6	70.69 (17°C)	760.882 (63°F)
Hexane(16,22,23)	C <sub>6</sub> H <sub>14</sub>	0.659	1,112	3,648.3	2.71	0.446	4.798
n-Hexane(29,33)	C <sub>6</sub> H <sub>14</sub>	0.649 (20°C)	1,079	3,540	4.53		
2,5Hexanedione	C <sub>6</sub> H <sub>10</sub> O <sub>2</sub>	0.729	1,399	4,589.9	3.6		
n-Hexanol	C <sub>6</sub> H <sub>14</sub> O	0.819	1,300	4,265.1	3.8		
Hexahydrobenzene(15)	C <sub>6</sub> H <sub>12</sub>	0.779	1,248	4,094.5	5.41	1.31 (17°C)	14.095 (63°F)
Hexahydrophenol	C <sub>6</sub> H <sub>12</sub> O	0.962	1,454	4,770.3			
Hexamethylene(15)	C <sub>6</sub> H <sub>12</sub>	0.779	1,248	4,094.5		1.31 (17°C)	14.095 (63°F)
Hydrogen(45)	H <sub>2</sub>	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 <sub>7</sub> H <sub>8</sub> O	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 <sub>6</sub> H <sub>5</sub> l	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 <sub>2</sub> H <sub>5</sub> l	1.823	1,114 (20°C)	3,654.9 (68°F)		0.954	
Iodo-ethane(46)	CH <sub>3</sub> l	1.950 (20°C)	876 (20°C)	2,874 (68°F)		0.29	3.12
Iodo-methane	C <sub>6</sub> H <sub>12</sub> O	2.28 (20°C)	978	3,208.7		0.211	2.27
isobutylacetate(22)	He <sub>4</sub>		1,180 (27°C)	3,871.4 (81°F)	4.85		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$ m/s/°C	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s		m <sup>2</sup> /s	ft <sup>2</sup> /s
Isobutanol	C <sub>4</sub> H <sub>10</sub> O	0.81 (20°C)	1,212	3,976.4			
Iso-Butane			1,219.8	4002			
Isopentane(36)	C <sub>5</sub> H <sub>12</sub>	0.62 (20°C)	980	3,215.2	4.8	0.34	3.658
Isopropano(46)	C <sub>3</sub> H <sub>8</sub> O	0.758 (20°C)	1,170 (20°C)	3,838.6 (68°F)		2.718	29.245
Isopropyl alcohol(46)	C <sub>3</sub> H <sub>8</sub> O	0.758 (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 <sub>6</sub> H <sub>10</sub> 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 <sub>6</sub> H <sub>16</sub> O	0.85	1,310	4,297.9			
Methane(25,28,38,39)	CH <sub>4</sub>	0.162 (-89°C)	405 (-89°C)	1,328.7 (-128°F)	17.5		
Methano(40,41)	CH <sub>4</sub> O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.748
Methyl acetate	C <sub>3</sub> H <sub>6</sub> O <sub>2</sub>	0.934	1,211	3,973.1		0.407	4.379
o-Methylaniline(46)	C <sub>7</sub> H <sub>9</sub> N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
4-Methylaniline(46)	C <sub>7</sub> H <sub>9</sub> N	0.966 (45°C)	1,480	4,855.6		1.863 (50°C)	20.095 (122°F)
Methyl alcohol(40,44)	CH <sub>4</sub> O	0.791 (20°C)	1,076	3,530.2	2.92	0.695	7.478
Methyl benzene(16,52)	C <sub>7</sub> H <sub>8</sub>	0.867	1,328 (20°C)	4,357 (68°F)	4.27	0.644	7.144
2-Methyl-butane(36)	C <sub>5</sub> H <sub>12</sub>	0.62 (20°C)	980	3,215.2		0.34	3.658
Methylcarbinol	C <sub>2</sub> H <sub>6</sub> O	0.789	1,207	3,960	4.0	1.396	
Methyl-chloroform(47)	C <sub>2</sub> H <sub>3</sub> Cl <sub>3</sub>	1.33	985	3,231.6		0.902 (20°C)	9.705 (68°F)
Methyl-cyanide	C <sub>2</sub> H <sub>3</sub> N	0.783	1,290	4,232.3		0.441	4.745
β-Methyl cyclohexanol	C <sub>7</sub> H <sub>14</sub> O	0.92	1,400	4,593.2			

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s	m/s/ $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
Methylene chloride(3)	CH <sub>2</sub> Cl <sub>2</sub>	1.327	1,070	3,510	3.94	0.31	3.335
Methylene iodide	CH <sub>2</sub> I <sub>2</sub>	3.235	980	3,215.2			
Methyl formate(22)	C <sub>2</sub> H <sub>4</sub> O <sub>2</sub>	0.974 (20°C)	1,127	3,697.5	4.02		
Methyl iodide	CH <sub>3</sub> I	2.28 (20°C)	978	3,208.7		0.211	2.27
$\alpha$ -Methyl naphthalene	C <sub>11</sub> H <sub>10</sub>	1.090	1,510	4,954.1	3.7		
2-Methylpheno(46)	C <sub>7</sub> H <sub>8</sub> O	1.047 (20°C)	1,541 (20°C)	5,055.8 (68°F)		4.29 (40°C)	46.16 (104°F)
3- Methylpheno(46)	C <sub>7</sub> H <sub>8</sub> O	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 <sub>4</sub> H <sub>9</sub> NO		1,442	4,731	3.8		
Naphtha		1.00	1,225	4,091			
Natural Gas(37)		0.76	753 (-103°C)	2,470.5 (-153°F)			
Neon(45)	Ne	0.316 (-103°C)	595 (-246°C)	1,952.1 (-411°F)			
Nitrobenzene(46)	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	1.207 (-246°C)	1,415 (20°C)	4,642.4 (68°F)		1.514	16.29
Nitrogen(45)	N <sub>2</sub>	1.204 (20°C)	962 (-199°C)	3,156.2 (-326°F)		0.217 (-199°C)	2.334 (-326°F)
Nitromethane(43)	CH <sub>3</sub> NO <sub>2</sub>	0.808 (-199°C)	1,300	4,265.1	4.0	0.549	5.90
Nonane(23)	C <sub>9</sub> H <sub>2</sub> O	1.135	1,207	3,960	4.04	0.99 (20°C)	10.652 (68°F)
1-Nonene(27)	C <sub>9</sub> H <sub>18</sub>	0.718 (20°C)	1,207	3,960	4.0		
Octane(23)	C <sub>8</sub> H <sub>18</sub>	0.736 (20°C)	1,172	3,845.1	4.14	0.73	7.857
n-Octane(29)	C <sub>8</sub> H <sub>18</sub>	0.723 (20°C)	1,212.5	3,978	3.50	0.737	0.930
1-Octane(27)	C <sub>8</sub> H <sub>16</sub>		1,175.5	3,856.6	4.1		
Oil of Camphor Sassafrassy		1.74	1,390	4,560.4	3.8		
Oil, Car(SAE20a.30)		0.969	870	2,854.3		190	2,405.93
Oil, Castor	C <sub>11</sub> H <sub>10</sub> O <sub>10</sub>		1,477	4,854.8	3.6	0.670	7.209

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^6$	
			m/s	ft/s	m/s $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
Oil,Diesel		0.80	1,250	4,101			
Oil,FueiAA gravity		0.99	1,485	4,872	3.7		
Oil(Lubricating x200)			1,530	5,019.9			
Oil(Oive)		0.912	1,431	4,694.9	2.75	100	1,076.3 65
Oil(peanut)		0.936	1,458	4,783.5			
Oil(Sperm)		0.88	1,440	4,724.2			
Oil,6			1,509 (22°C)	4,951 (72°F)			
2,2-Oxydiethanol	CH <sub>10</sub> O <sub>3</sub>	1.116	1,586	5,203.4	2.4		
Oxygen(45)	O <sub>2</sub>	1.155 (-186°C)	952 (-186°C)	3,123.4 (-303°F)		0.173	1.861
Pentachloro-ethane(47)	C <sub>2</sub> HCl <sub>5</sub>	1.687	1,082	3,549.4			
pentalin(47)	C <sub>2</sub> HCl <sub>5</sub>	1.687	1,082	3,549.4			
Pentane(36)	C <sub>5</sub> H <sub>12</sub>	0.626 (20°C)	1,020	3,346.5		0.363	3.905
n-pentane(47)	C <sub>5</sub> H <sub>12</sub>	0.557	1,006	3,300.5		0.41	4.413
Perchlorocyclopentadiene(47)	C <sub>5</sub> Cl <sub>6</sub>	1.718	1,150	3,773			
Perchloro-ethylene(47)	C <sub>2</sub> Cl <sub>4</sub>	1.632	1,036	3,399			
Perfluoro-1-Hepten(47)	C <sub>7</sub> F <sub>14</sub>	1.67	583	1,912.7			
Perfluoro-n-Hexane(47)	C <sub>6</sub> H <sub>14</sub>	1.672	508	1,666.7			
Phene(29,40,41)	C <sub>6</sub> H <sub>6</sub>	0.879	1,306	4,284.8	4.65	0.711	7.65
b-Phenyl acrolein	C <sub>9</sub> H <sub>8</sub> O	1.112	1,554	5,098.4	3.2		
Phenylamine(41)	C <sub>6</sub> H <sub>5</sub> NO <sub>2</sub>	1.022	1,639	5,377.3	4.0	3.63	39.058
Phenyl bromide(46)	C <sub>6</sub> H <sub>5</sub> Br	1.522	1,170 (20°C)	3,838.6 (68°F)		0.693	7.465
Phenyl chloride	C <sub>6</sub> H <sub>5</sub> Cl	1.106	1,273	4,176.5	3.6	0.722	7.768
Phenyl iodide(46)	C <sub>6</sub> H <sub>5</sub> I	1.823	1,114 (20°C)	3,654.9 (68°F)		0.954 (15°C)	10.265 (59°F)
Phenyl methane(16,52)	C <sub>7</sub> H <sub>8</sub>	0.867 (20°C)	1,328 (20°C)	4,357 (68°F)	4.27	0.644	6.929
3-Phenylpropenal	C <sub>9</sub> H <sub>8</sub> O	1.112	1,554	5,098.4	3.2		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s	m/s $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
Phthalardione	C <sub>8</sub> H <sub>4</sub> O <sub>3</sub>		1,125 (152°C)	3,691 (306°F)			
Phthalicacid,anhydride	C <sub>8</sub> H <sub>4</sub> O <sub>3</sub>		1,125 (152°C)	3,691 (306°F)			
Phthalicanhydride	C <sub>8</sub> H <sub>4</sub> O <sub>3</sub>		1,125 (152°C)	3,691 (306°F)			
Pimelicketone	C <sub>6</sub> H <sub>10</sub> O	0.948	1,423	4,668.6	4.0		
Plexiglas,Lucite,Acrylic			2,651	8,698			
PolyterpeneResin		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		958 (900°C)	3,231.6 (1652°F)	0.64		
Potassium nitrate(48)	KNO <sub>3</sub>	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 <sub>3</sub> H <sub>8</sub>	0.585 (-45°C)	1,003 (-45°C)	3,290.6 (-46°F)	5.7		
1,2,3-Propanetriol	C <sub>3</sub> H <sub>8</sub> O <sub>3</sub>	1.26	1,904	6,246.7	2.2	000757	
1-Propanol(46)	C <sub>3</sub> H <sub>8</sub> O	0.78 (20°C)	1,222 (20°C)	4,009.2 (68°F)			
2-Propanol(46)	C <sub>3</sub> H <sub>8</sub> O	0.785 (20°C)	1,170 (20°C)	3,838.6 (68°F)		2.718	29.245
2-Propanone	C <sub>3</sub> H <sub>6</sub> O	0.791	1,174	3,851.7	4.5	0.399	4.293
Propene(17,18,35)	C <sub>3</sub> H <sub>6</sub>	0.563 (-13°C)	963 (-13°C)	3,159.4 (9°F)	6.32		
N-propyl-acetate(22)	C <sub>5</sub> H <sub>10</sub> O <sub>2</sub>		1,280 (2°C)	4,199 (36°F)	4.63		
n-propyl-alcohol	C <sub>3</sub> H <sub>8</sub> O	0.78 (20°C)	1,222 (20°C)	4,009.2 (68°F)		2.549	27.427
propylchloride(47)	C <sub>3</sub> H <sub>7</sub> Cl	0.892	1,058	3,471.1		0.378	4.067
propylene(17,18,35)	C <sub>3</sub> H <sub>6</sub>	0.536 (-13°C)	963 (-13°C)	3,159.4 (9°F)	6.32		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s	m/s $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
Pyridne	C <sub>6</sub> H <sub>5</sub> N	0.982	1,415	4,642.4	4.1	0.992 (20°C)	10.673 (68°F)
Refrigerant11(3,4)	CCl <sub>3</sub> F	1.49	828.3 (0°C)	2,717.5 (32°F)	3.56		
Refrigerant12(3)	CCl <sub>2</sub> F <sub>2</sub>	1.516 (-40°C)	774.1 (-40°C)	2,539.7 (-40°F)	4.24		
Refrigerant14(14)	CF <sub>4</sub>	1.75 (-150°C)	875.24 (-150°C)	2,871.5 (-238°F)	6.61		
Refrigerant21(3)	CHCl <sub>2</sub> F	1.426 (0°C)	891 (0°C)	2,923.2 (32°F)	3.97		
Refrigerant22(3)	CHClF <sub>2</sub>	1.491 (-69°C)	893.9 (50°C)	2,932.7 (122°F)	4.79		
Refrigerant113(3)	CCl <sub>3</sub> F-CClF <sub>2</sub>	1.563	783.7 (0°C)	2,571.2 (32°F)	3.44		
Refrigerant114(3)	CClF <sub>2</sub> -CClF <sub>2</sub>	1.455	665.3 (-10°C)	2,182.7 (14°F)	3.73		
Refrigerant115(3)	C <sub>2</sub> ClF <sub>5</sub>		656.4 (-50°C)	2,153.5 (-58°F)	4.42		
RefrigerantC318(3)	C <sub>4</sub> F <sub>8</sub>	1.62 (-20°C)	574 (-10°C)	1,883.2 (41°F)	3.88		
Selenium(8)	Se		1,072 (250°C)	3,517.1 (482°F)	0.68		
Silicone(30cp)		0.993	990	3,248		30	322.8
Sodiumfluoride(42)	NaF	0.877	2,082 (1000°C)	6,830.7 (1832°F)	1.32		
Sodiumfluoride(48)	NaNO <sub>3</sub>	1.884 (336°C)	1,763.3 (336°C)	5,785.1 (637°F)	0.74	1.37 (336°C)	14.74 (637°C)
Sodiumfluoride(48)	NaNO <sub>2</sub>	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		
Spiritofwine	C <sub>2</sub> H <sub>6</sub> O	0.789	1,207	3,960	4.0	1.397	15.02
Sulfur(7,8,10)	S		1,177 (250°C)	3,861.5 (482°F)	-1.13		
SulfueicAcid(1)	H <sub>2</sub> SO <sub>4</sub>	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		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^{-6}$	
			m/s	ft/s	m/s $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
1,1,2,2-Tetrabromoethane(47)	C <sub>2</sub> H <sub>2</sub> Br <sub>4</sub>	2.966	1,027	3,369.4			
1,1,2,2-Tetrachloroethane(67)	C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub>	1.595	1,147	3,763.4		1.156 (15°C)	12.438 (59°F)
Tetrachloroethane(46)	C <sub>2</sub> H <sub>2</sub> Cl <sub>4</sub>	1.553 (20°C)	1,170 (20°C)	3,838.6 (68°F)		1.19	12.804
Tetrachloro-ethene(47)	C <sub>2</sub> Cl <sub>4</sub>	1.632	1,036	3,399			
Tetrachlor-Methane (33,47)	CCl <sub>4</sub>	1.595 (20°C)	926	3,038.1		0.607	6.531
Tetradecane(46)	C <sub>14</sub> H <sub>30</sub>	0.763 (20°C)	1,331 (20°C)	4,366.8 (68°F)		2.86 (20°C)	30.773 (68°F)
Tetraethylene glycol	C <sub>8</sub> H <sub>18</sub> O <sub>5</sub>	1.123	1,568	5,203.4	3.0		
Tetrafluoro-methane(14) (Freon14)	CF <sub>4</sub>	1.75 (-150°C)	875.24 (-150°C)	2,871.5 (-238°F)	6.61		
Tetrahydro-1,4-isoxazine	C <sub>4</sub> H <sub>9</sub> NO	1.000	1,442	4,731	3.8		
Toluene(16,52)	C <sub>7</sub> H <sub>8</sub>	0.867 (20°C)	1,328 (20°C)	4,357 (68°F)	4.27	0.644	6.929
o-Toluidine(46)	C <sub>7</sub> H <sub>9</sub> N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
p-Toluidine(46)	C <sub>7</sub> H <sub>9</sub> N	0.966 (45°C)	1,480	4,855.6		1.863 (50°C)	20.053 (122°F)
Toluol	C <sub>7</sub> H <sub>8</sub>	0.866	1,308	4,291.3	4.2	0.58	6.24
Tribromo-methane(46,47)	CHBr <sub>3</sub>	2.89 (20°C)	918	3,011.8		0.645	7.037
1,1,1-Trichloroethane(47)	C <sub>2</sub> H <sub>3</sub> Cl <sub>3</sub>	1.33	985	3,231.6		0.902 (20°C)	9.705 (68°F)
Trichloro-ethene(47)	C <sub>2</sub> HCl <sub>3</sub>	1.464	1,028	3,372.7			
Trichloro-fluoromethaen (3)(Freon11)	CCl <sub>3</sub> F	1.49	828.3 (0°C)	2,171.5 (32°F)	3.56		
Trichloro-methane(47)	CHCl <sub>3</sub>	1.489	979	3,211.9	3.4	0.55	5.918
1,1,2-Trichloro-1,2,2,2-Trifluoro-Etham	CCl <sub>2</sub> F- CClF <sub>2</sub>	1.563	783.7 (0°C)	2,571.2 (32°F)			
Triethyl-amine(33)	C <sub>6</sub> H <sub>15</sub> N	0.726	1,123	3,684.4	4.47		
Triethyleneglycol	C <sub>6</sub> H <sub>14</sub> O <sub>4</sub>	1.123	1,608	5,275.6	3.8		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	<i>All data given at 25°C(77°F) unless otherwise noted.</i>					
		Specific Gravity	Sound Speed		$\Delta v/^\circ\text{C}$	Kinematic Viscosity $\times 10^6$	
			m/s	ft/s	m/s $^\circ\text{C}$	m <sup>2</sup> /s	ft <sup>2</sup> /s
1,1,1-Trifluoro-2-Chloro-2-Bromo-Ethane	C <sub>2</sub> HClBrF <sub>3</sub>	1.869	693	2,273.6			
1,2,2-Trifluorotrchloro-ethane(Freon113)	CCl <sub>2</sub> -CClF <sub>2</sub>	1.563	783.7 (0°C)	2,571.2 (32°F)	3.44		
d-1,3,3-Trimethylnorcamphor	C <sub>10</sub> H <sub>16</sub> O	0.947	1,320	4,330.7		0.22	2.367
Trinitrotoluene(43)	C <sub>7</sub> H <sub>5</sub> (NO <sub>2</sub> ) <sub>3</sub>	1.64	1,610 (81°C)	5,282.2 (178°F)			
Turpentine		0.88	1,255	4,117.5		1.4	15.064
Unisis800		0.87	1,346	4,416		1.00	
Water,distilled(49,50) Water,sea	H <sub>2</sub> O	0.996	1,498	4,914.7	-2.4	0.695	10.76
WoodAlcihol(40,41)	D <sub>2</sub> O		1,400	4,593	-2.4		
Xenon(45)		1.025	1,531	5,023	2.92	1.00	10.76
m-Xylene(46)	CH <sub>4</sub> O	0.791 (20°C)	1,076	3,530.2		0.695	7.478
o-Xylene(29,46)	Xe		630 (-109°C)	2,067 (-164°F)			
P-xylene(46)	C <sub>8</sub> H <sub>10</sub>	0.868 (15°C)	1,343 (20°C)	4,406.2 (68°F)		0.749 (15°C)	8.059 (59°F)
Xylenehexafluoride	C <sub>8</sub> H <sub>10</sub>	0.897 (20°C)	1,331.5	4,368.4	4.1	0.903 (20°C)	9.716 (68°F)
Zinc(7)	C <sub>8</sub> H <sub>10</sub>		1,334 (20°C)	4,376.6 (68°F)		0.662	7.123
1,1,1-Trifluoro-2-Chloro-2-Bromo-Ethane	C <sub>8</sub> H <sub>4</sub> F <sub>6</sub>	1.37	879	2,883.9		0.613	6.595
1,2,2-Trifluorotrchloro-ethane(Freon113)	Zn		3,298 (450°C)	10,820.2 (842°F)			