User's Manual

REGAL Series

RH20 Handheld Ultrasonic Flowmeter

UMRH20-830-01C

Revised October 10, 2012

WARNING!

(1) The RH20 flowmeter is not certified for use in hazardous environments. The local site safety codes and regulations must be observed.

(2) The RH20 flowmeter contains three AAA Ni-HM rechargeable batteries. Please charge them fully before using the flowmeter. The batteries must be recycled or disposed of properly.

Contents

RH20 Quick Start Guide

This Quick Start is provided solely to help the operator to get the flowmeter up and running as quickly as possible. For complete information on the flowmeter and its operation procedures, please refer to the User's Manual. For frequently-asked questions and answers, please visit our technical support website at: http://www.spiremt.com/support.html

Step 1: Power On

Charge the battery fully before using the instrument.

Press the ON button. The meter will go through a self-checking process to make sure everything is alright. After a few seconds, the screen will display some flowmeter information. If it does not show up properly, please contact Spire Metering immediately.

Step 2: Configure the Flowmeter

2.1: Enter transducer info

Change the Scale Factor: Press keys M45 (e.g., press MENU, 4 and 5 keys orderly.) Then, press the ENT key. Key in the scale factor of the transducer pair you are planning to use, the ENT key again.

M45
Scale Factor
1
=>0.951_

2.2: Enter pipe info

Pipe OD: Press keys M11, and then ENT. The display should be similar to the figure on the right. Now enter the pipe outer diameter, and press the ENT key to confirm.

M11
Outer Diameter
2.375 in
=>_

Wall-thickness: Press the ▼/- key to scroll down to the next menu, M12. Press ENT and enter the pipe's wall-thickness value. Press ENT again to confirm.

Pipe ID: Press ▼/- to scroll down to M13. The correct ID value should be displayed on the screen. There is no need to change anything.

Pipe Material: Press ▼/- to scroll down to M14. Press ENT and then use ▼/- to select the right item. If pipe material is not shown on the list (non-standard material), select any one them. Press ENT to confirm.

M14
Pipe Material
=> 0. Carbon Steel
1. StainlessSteel

Sound Speed in Pipe Wall: Press ▼/- to scroll down to M15. If you find your pipe material on the list in the previous step, the flowmeter should already know the sound speed. You can just skip this step and go to the next.

Otherwise, press ENT and enter the sound speed of your pipe material. You can find this information in the User's Manual. When you are done, press ENT to confirm.

Pipe lining: If your pipe has lining inside, enter the lining information on menu windows M16-M18.

2.3: Enter fluid info

Fluid Type: Use the ▼/- key to scroll down to M20, or, simply press keys M20. Then, press ENT and select the item that matches your fluid type. If you do not find a match (non-standard fluid), just select any item on the list. Press the ENT key to confirm.

Sound Speed in Fluid: If you found your fluid type in the previous step, the flowmeter already has the sound speed info. Therefore, skip this step and go the next.
Otherwise, press ▼/- to scroll down to M21. Press ENT and key in the sound speed of your fluid. You can find this information in the User's Manual. When you are done, press ENT to confirm.

2.4: Enter transducer installation info

Transducer Type: Use the ▼/- key to scroll down to M23. Press ENT and select the proper transducer type from the list, then, press ENT to confirm.
Important note: If HS transducers are used for the measurement, select item *10. Standard HS;* if HM transducers are used, select item *11. Standard HM*; if M1 transducers are used, select *8. Standard M1;* if L1 transducers are used, select *14. Standard L1*.If S1HT or M1HT transducers are used, select *Standard S1* or *Standard M1* accordingly.

Mounting Method: Use the ▼/- key to scroll down to or, simply press keys M24. Then, press ENT and select the proper item and press ENT to confirm. For pipes smaller than 1", try the W-method. For pipes from 1" to 12", use V-method. For pipes larger than 12", use the Z-method.

```
M24
Transducer Mounting
=>0. V-Method
  1. Z-Method
```

Mounting Spacing: Use the ▼/- key to scroll down to M25. The displayed value is the suggested mounting spacing between the two transducers (see the figure on the right). Write down this number, as you will need it later when installing the transducers.

```
M25
Transducer Spacing
   0.731126 in
```

Step 3: Install Transducers

The following figures show three examples of the installation. *Please see the Appendix for installation details.*

Step 4: Fine Tuning

On the main unit, press M90 to enter into menu M90. There are three important numbers (so-called triplets) displayed on this window: Transit-time ratio R, signal strength S and signal quality Q. Their values should fall into the right ranges in order to justify the reading:

R: 97% ~ 103%
S: 600 ~ 999
Q: 60 ~ 99.

```
M90          101.53%
Strenth+Quality
S=635, 634    Q=86
   System Normal
```

If these values are not in the above ranges, you need to verify the parameters you have entered in Step 2. If you believe your entries are correct and the three numbers are still off their ranges, you may need to check your installation. Here are some tips:

- Make sure the transducer mounting area on the pipe is coating-free and smooth.
- Moving transducers closer to or away from each other will increase or decrease the transit-time ratio R.
- For small metal pipes (1" ~ 1.5"), wrap some acoustic damping materials around the pipe, but leave an open window for the transducers to make direct contact with the pipe surface. Examples of damping material are GraceIce, WaterShield material, silicone, epoxy, etc. *Warning!* Be aware of their temperature limitations and other safety instructions.
- For copper pipes of 1" or stainless steel pipes of 1"~1.5", we recommend using flow-cell transducers to achieve better results.

Please refer to section 2.9.4 of the User's Manual for more details.

The sound speed information in menu M92 might also be useful for debugging. The displayed value should be close to the one you have entered in step 2.2. If you have entered fluid type in step 2.2 instead, and you do not know the fluid's sound speed, you can find this information in the Appendix of the User's Manual.

```
M92
Fluid Sound Vel
       0.0000 m/s
```

If all three parameters are good, and the sound speed measurement in M92 looks reasonable, your installation is done. You are ready to look at your measurement results on menu window M00.

Note that the menu windows shown above are for illustration only. The values in those windows may not be meaningful.

1. Introduction

§1.1 Preface

A member of the Regal Series, the RH20 Handheld Ultrasonic Flowmeter is the first member of the 3rd generation ultrasonic flow meters from Spire Metering. It is carefully designed for portability and ease of use while still maintaining the capability of a full-size flowmeter.

The RH20 is based on clamp-on transit-time flow measurement principle. It measures the flow rate of liquid in a pipe from outside of the pipe by using a pair of ultrasonic transducers. In general, the liquid should be full in the pipe, and should contain very little particles or bubbles. Examples of applicable liquids are: water (hot water, chill water, city water, sea water, etc.); sewage; oil (crude oil, lubricating oil, diesel oil, fuel oil, etc.); chemicals (alcohol, acids, etc.); waste; beverage and liquid food; solvents and other liquids.

Due to the nature of the clamp-on technique, the transducer installation is simple and no special skills or tools are required. Besides, there is no pressure drop, no moving parts, no leaks and no contamination.

The RH20 utilizes our proprietary technologies such as advanced signal processing, low-voltage transmitting, small signal receiving with self-adaptation, etc. It also incorporates the latest surface-mounting semiconductors and mini PCB design techniques. The built-in rechargeable Ni-H battery can work continuously for more than 8 hours without recharge.

The RH20 also has a built-in data-logger, which allows storage of 2,000 lines of data. The stored information can be downloaded to a PC through its RS232 connection port with Spire Metering's StufManager™ PC software or Windows HyperTerminal software. The RH20 also provides digital output such as frequency output and pulsed totalizer output.

§1.2 Features

* ±0.5% of linearity
* Accuracy: ±1% of reading in velocity, plus ±0.03ft/s (10mm/s)
* Bi-directional measurement
* 4 flow totalizers
* Proprietary low-voltage transmission technology
* Wide pipe size range (1" ~ 120")
* Built-in data-logger
* Clamp-on transducer. Easy to install and to maintain
* Optional flow-cell transducer or insertion transducer available for excellent long-term stability and high accuracy demand
* Lightweight, portable (Main unit 1.2lbs)
* USB interface to computer for easy data download
* StufManager™ PC software

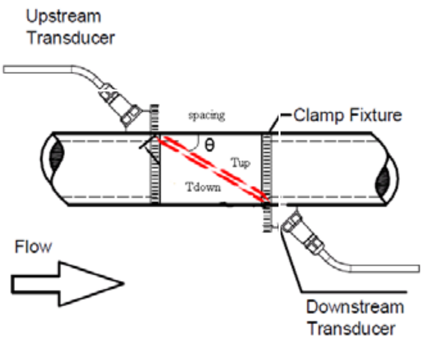
§1.3 Principle of Measurement

The RH20 ultrasonic flowmeter is designed to measure the velocity of liquid within a closed conduit. It uses the well-known transit-time technology. The transducers are a non-contacting, clamp-on type. They do not block the flow, thus there is no pressure drop. They are easy to install and remove.

The RH20 utilizes a pair of transducers that function as both ultrasonic transmitters and receivers. The transducers are clamped on the outside of a closed pipe at a specific distance from each other. The transducers can be mounted in the V-method where the sound transverses the pipe twice, or W-method where the sound transverses the pipe four times, or in the Z-method where the transducers are mounted on opposite sides of the pipe and the sound crosses the pipe once. The selection of the mounting methods depends on pipe and liquid characteristics.

The RH20 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.

$$V = \frac{MD}{\sin 2\theta} \times \frac{\Delta T}{T_{up} \bullet T_{down}}$$



Where

θ 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

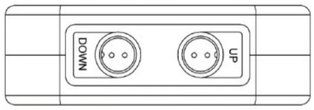
T_{up} is the time for the beam traveling from upstream the transducer to the downstream transducer

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

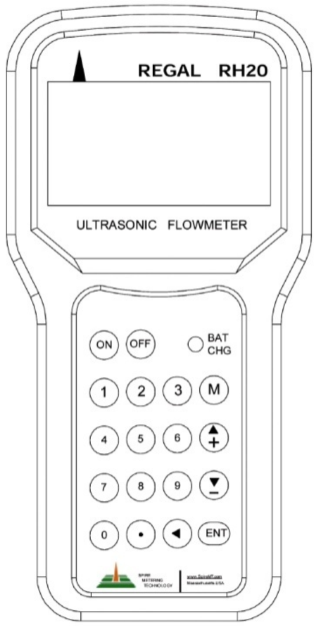
$\Delta T = T_{up} - T_{down}$

§1.4 Parts Identification

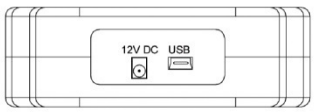
Top View



Front View

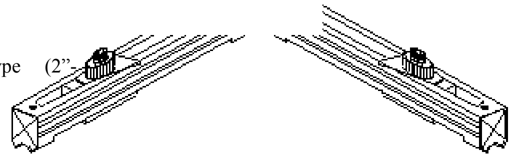


Bottom View

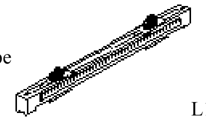


Transducers:

HM-type (2”-

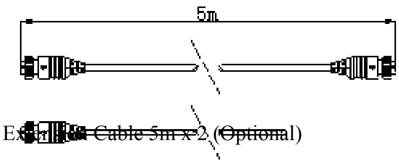


HS-type

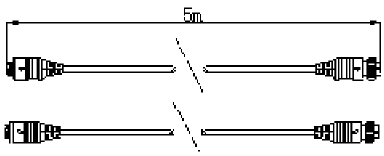


L1-type(Optional)

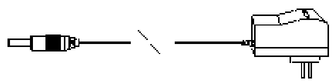
Transducer Cable 5m x 2



Extension Cable 5m x 2 (Optional)



AC/DC Power and Battery
Charger Adapter



RS232C Serial Cable

§1.5 Typical Applications

The RH20 flowmeter can be applied to a wide range of pipe flow measurements. The pipe size ranges from 1”-120” (20mm-3000mm). A variety of liquid applications can be accommodated: ultra-pure liquids, potable water, oil, chemicals, raw sewage, reclaimed water, cooling water, river water, sea water, plant effluent, etc. Because the transducers are non-contacting and have no moving parts, the flowmeter will not be affected by flow pressure or liquid properties. Standard transducers are rated to 80℃, and higher temperatures can be accommodated. For further information, please consult the manufacturer for assistance.

For small pipes, you may choose the flow-cell transducer, instead of the clamp-on transducer, in order to get better accuracy and better long-term stability.

§1.6 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 100 years, even when the power is lost or turned off. Password protection is provided to avoid inadvertent configuration changes or totalizer resets.

A time-keeper is integrated in the flowmeter. It works as the time base for flow totalizing. The time-keeper remains operating as long as the battery’s terminal voltage is over 1.5V. In case of battery failure, the time-keeper will not keep running and the time data will lost. The user must re-enter proper time values after the battery failure is recovered. Improper time values will affect the totalizers as well as many other functions.

§1.7 Product Identification

Each set of the RH20 series flowmeter has a unique product identification number or ESN written into the software that can only be modified with a special tool by the manufacturer. In case of any hardware failure, please provide this number, which is located on menu window M61, when contacting the manufacturer.

§1.8 Specifications

Flow Velocity	± 10 m/s (± 32 ft/s), bi-directional.
Physical Quantity	Volumetric flow rate, total flow, velocity
Display/Keypad	LCD with backlight. 4x16 letters. 4x4 tactile-feedback membrane keypad. Displays instantaneous flow rate, flow total (positive, negative and net), velocity, and time.

Output	Optically isolated Open Collector Transistor output (OCT) for frequency and pulse.
Recording	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 5years.
Linearity	0.5%
Repeatability	0.5%
Accuracy*	±1% of reading ±0.01m/s (±0.03ft/s) in velocity*
Response Time	0.5s. Configurable between 0.5s and 99s.
Pipe Size Range	1" - 120" (DN25mm - DN3,000mm), depending on transducer.
Pipe Material	All metals, most plastics, some lined pipes.
Rate Units	Meter, Feet, Cubic Meter, Liter, Cubic Feet, USA Gallon, Imperial Gallon, Oil Barrel, USA Liquid Barrel, Imperial Liquid Barrel, Million USA Gallons. User configurable.
Totalizer	Positive totalizer, negative totalizer, net totalizer, and manual totalizer.
Liquid Types	Virtually all liquids (full pipe).
Liquid Temperature	32˚F - 176˚F (0˚C - 80˚C) or 32˚F - 312˚F (0˚C - 155˚C), depending on transducer type
Security	Setup lockout. Access code needed for unlocking
Communication Interface	RS232. Supports the MODBUS protocol.
Software	StufManager™ PC software for data logger download and real-time data acquisition.
Transducers	HS, HM, L1, S1HT, M1HT
Transducer Cable	Standard 2x15' (2x5m), optional 2x30' (2x10m)
Power Supply	3 AAA Ni-H built-in batteries. When fully charged it will last over 8 hours of operation. 100V-240VAC for the charger
Data Logger	Built-in data logger can store over 2,000 lines of data
Manual Totalizer	7-digit press-key-to-go totalizer for calibration
Protection (Handset)	IP54
Housing Material (Case)	ABS. Aluminum alloy protective case. Suitable for normal and harsh environments
Handset Size	8"x4"x1.5" (205mmx103mmx37mm)
Carrying Case Size	20"x18"x6" (508mmx457mmx152mm)
Handset Weight	1.2 lbs (514g) with batteries
Package Weight	16 lbs (8kg) for standard package

2. Measurement

§2.1 Built-in Battery

The instrument can operate either from the built-in Ni-H rechargeable battery, which will last over 8 hours of continuous operation when fully charged, or from an external AC/power supply from the battery charger. When the red LED is on, the battery is charging.

The battery-charging circuit employs both constant-current and constant-voltage charging methods. It has a characteristic of fast charging at the beginning and very slow charging when the battery approaches to full charge.

Since the charging current becomes tapered when the battery charging is nearly completed (i.e. the charging current becomes smaller and smaller), there should be no over-charging problem. This also means the charging progress can last very long. To get close to 100% power, charge the device overnight. The charger can be connected to the handset all the time when an around-the-clock measurement is required.

When fully charged, the terminal voltage reaches around 4.25V. The terminal voltage is displayed on window M07. When the battery is nearly consumed, the battery voltage drops to below 3V. The approximate remaining working time is indicated in this window as well. Notice that the battery remaining working time is estimated based on the current battery voltage. It may have some errors, especially when the terminal voltage is in the range from 3.70 to 3.90 volts.

For battery maintenance and replacement, please refer to Appendix §8.1.

§2.2 Power On

Press ON key to turn on the power and press OFF to turn off the power.

Once the flowmeter is turned on, it will run a self-diagnostic program, checking first the hardware and then the software integrity. If there is any abnormality, corresponding error messages will be displayed.

Generally, there should be no display of error messages, and the flowmeter will go to the most commonly used Menu Window #01 (M01) to display the Velocity, Flow Rate, Positive Totalizer, Signal Strength and Signal Quality, based on the pipe parameters configured last time by the user or by the initial program.

The flow measurement program always operates in the background of the user interface. This means that the flow measurement will keep running regardless of any user menu window browsing or viewing. Only when the user enters new pipe parameters will the flowmeter change measurement to reflect the new parameter changes.

When new pipe parameters are entered or when the power is turned on, the flowmeter will into a self-adjusting mode to adjust the gain of the receiving circuits so that the signal strength will be within a proper range. By this step, the flowmeter finds the best receiving signals. The user will see the progress by the number 1, 2, or 3, located on the lower right corner of the display.

When the user adjusts the position of the installed transducers, the flowmeter will re-adjust the signal gain automatically.

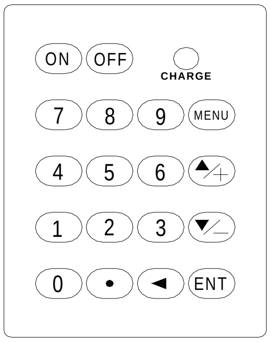
Any user-entered configuration value will be stored in the NVRAM (non-volatile memory), until it is modified by the user.

§2.3 Keypad

The keypad of the flowmeter has 16+2 keys.

Keys 0 ~ 9 and . are keys to enter numbers.

Key ▲/+ is the going UP key when the user wants to go to the upper menu window. It also works as '+' key when entering numbers.



Key ▼/- is the going DOWN key when the user wants to go to the lower menu window. It also works as the '–' key when entering numbers.

Key ◄ is the backspace key when the user wants go left or wants to delete the character that is located to the left of the cursor.

Key ENT is the ENTER key for any input or selections.

Key MENU is the key for the direct menu access. Whenever the user wants to proceed to a certain menu window, the user can press this key followed by a 2-digit number.

The MENU key is shortened as the 'M' key hereafter when referring to menu windows.

The ON key is for the power on.

The OFF key is for the power off.

§2.4 Menu Windows

The user interface of this flowmeter comprises about 100 different menu windows that are numbered by M00, M01, M02 … M99.

There are two methods to get into a certain menu window:

(1) Direct jump in. The user can press the MENU key followed by a 2-digit number. For example, the menu window M11 is for setting up pipe outer diameter. Pressing MENU 1 1 will display the M11 menu window immediately.

(2) Press ▲/+ or ▼/- key. Each ▲/+ key press will lead to the lower-numbered menu window. For example, if the current window is on M12, the display will go to window M11 after the ▲/+ key is pressed once.

There are three different types of menu windows:
(1) Menu windows for number entering, e.g., M11 for setting up the pipe outer diameter.
(2) Menu windows for option selection, e.g., M14 for the selection of pipe materials.
(3) Results display windows, e.g. window M00 for displaying Velocity, Flow Rate, etc.

For number entering windows, the user can directly press the digit keys if the user wants to modify the value. For example, if the current window is on M11, and the user wants to enter 219.2345 as the pipe outer diameter, then, the flowing keys should be pressed: 2 1 9 . 2 3 4 5 ENT.

For option selection windows, the user should first press the ENT key to get into option selection mode. Then, use ▲/+, ▼/-, or digit key to select the right option. Consequently, press the ENT to make the selection.
For example, assume your pipe material is stainless steel and you are currently on menu window M14 which is for the selection of pipe materials (if you are on a different window, you need press MENU 1 4 first in order to enter into the M14 window.) You need to press the ENT key to get into the option selection mode. Then, either press the ▲/+ or ▼/- keys to make the cursor on the line that displays "1. Stainless Steel", or press the 1 key directly. At the end, press ENT again to make the selection.

Generally, the ENT key must be pressed to get into the option selection mode for option modifications. If the "Locked M47 Open" message is indicated on the lowest line of the LCD display, it means that the modification operation is locked out. In such cases, the user should go to M47 to have the instrument unlocked before any further modification can be made.

§2.5 Menu Window List

M00~M09 windows for the display of the instantaneous flow rate, net totalizer value, positive totalizer value, negative totalizer value, instantaneous flow velocity, date time, battery voltage and estimated working hours for the battery.

M10~M29 windows for entering system parameters, such as pipe outer diameter, pipe wall thickness, liquid type, transducer type/model, transducer installation method, etc. Transducer installation spacing is also displayed on one of the windows. .

M30~M38 windows for flow rate unit selection and totalizer configuration. User can use these windows to select flow rate unit, such as cubic meter or liter, as well as to turn on/off each totalizer, or to zero the totalizers.

M40~M49 windows for setting response time, zeroing/calibrating the system and changing the password.

M50~M53 windows for setting up the built-in logger.

M60-M78 windows for setting up the time-keeper and displaying software version, system serial number ESN and alarms.

M82 window for viewing the data totalizer.

M90~M94 windows for displaying diagnostic data. These data are very useful when doing a more accurate measurement.

M97~M99 are not windows but commands for window copy output and pipe parameter output.

M+0~M+8 windows for some additional functions, including a scientific calculator, display of the total working time and display of the time and the flow rate when the device is turned on and turned off.

Other menu windows such as M88 have no functions, or functions that were cancelled because they were not applied to this version of the software.

The major reason why the menu windows are arranged in the above way is to make this version be compatible with previous versions. This will make life easier for users of the former version.

§2.6 Steps to Configure the Parameters

In order to make the RH20 work properly, the user must follow the following steps to configure the system parameters:

(1) Pipe size and pipe wall thickness
For standard pipes, please refer to Appendix §8.3 for outer diameter and wall thickness data. For non-standard pipes, the user has to measure these two parameters.

(2) Pipe materials
For non-standard pipe material, the sound speed of the material must be entered. Please refer to Appendix C for sound speed data.
For standard pipe materials and standard liquids, the sound speed values have already been programmed into the flowmeter, therefore there is no need to enter them again.

(3) Liner material, its sound speed and liner thickness, if there is any liner.

(4) Liquid type (for non-standard liquid, the sound speed of the liquid should be entered.)

(5) Transducer type.

(6) Transducer mounting methods (the V-method and Z-method are the common methods)

(7) Check the transducer distance displayed on window M25 and install the transducers accordingly.

Example: For standard (commonly used) pipe materials and standard (commonly measured) liquids, the parameter configuration steps are as following:

(1) Press keys MENU 1 1 to enter into M11 window. Input the pipe outer diameter through the keypad and press ENT key.

(2) Press key ▼/- to enter into M12 window. Input the pipe thickness through the keypad and press ENT key.

(3) Press key ▼/- to enter into M14 window. Press ENT key to get into the option selection mode. Use keys ▲/+ and ▼/- to scroll up and down to the proper pipe material, and then press ENT key.

(4) Press key ▼/- to enter into M16 window. Press ENT key to get into the option selection mode. Use keys ▲/+ and ▼/- to scroll up and down to the proper liner material, and then press ENT key. Select “No Liner”, if there is no liner.

(5) Press key ▼/- to enter into M20 window. Press ENT key to get into the option selection mode. Use keys ▲/+ and ▼/- to scroll up and down to the proper liquid, and then press ENT key.

(6) Press key ▼/- to enter into M23 window. Press ENT key to get into the option selection mode. Use keys ▲/+ and ▼/- to scroll up and down to the proper transducer type, and then press ENT key.

(7) Press key ▼/- to enter into M24 window. Press ENT key to get into the option selection mode. Use keys ▲/+ and ▼/- to scroll up and down to the proper transducer mounting method, and then press ENT key.

(8) Press key ▼/- to enter into M25 window. The transducer installation distance will be displayed on the window. Based on this distance, install the transducers on the pipe now. After installation is completed, press ENT key to go to M01 window to check if the measurement result is good.

The first-time users may need some time to get familiar with the operation. However, the user-friendly interface of the instrument makes the operation quite easy and simple. You will soon find that it is actually very quick to configure the instrument with very little key pressing, since the interface allows the user to go to the desired operation directly without any extra steps.

The following tips will facilitate the operation of this instrument.

(1) When the current window is one between M00 to M09, pressing a number key x will enter into the M0x window directly. For example, if the current window display is M01, pressing 7 leads to window M07.

(2) When the current window is one between M00 to M09, pressing ENT key will lead to window M90 for displaying diagnostic data. Press ENT key again to return to the previous window. Press the . key to go to window M11.

(3) When the current window is M25, pressing ENT key will lead to window M01.

§2.7 Transducers Mounting Allocation

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

An optimal location would be defined as a long straight pipe line full of liquid that is to be measured. The piping can be in a vertical or horizontal position. The following table shows examples of optimal locations.

Principles to select an optimal location:

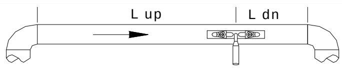
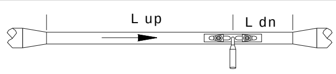
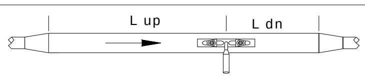
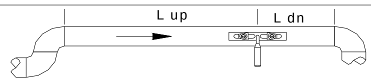
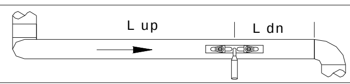
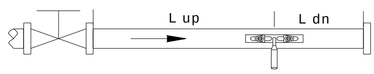
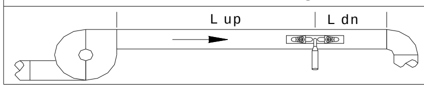
(1) The straight pipe should be long enough to eliminate irregular-flow-induced error. Typically, the length of the straight pipe should be 15 times of the pipe diameter (15D), the longer the better.
The transducers should be installed at a pipe section where the length of the straight pipe at the upstream side is at least 10D and at downstream side is at least 5D. Additionally, the transducer installation site should be at least 30D away from the pump. Here D stands for pipe outer diameter. Refer to the following table for more details.

(2) Make sure that the pipe is completely full of liquid.

(3) Make sure that the temperature of the mounting location does not exceed the range for the transducers.

(4) Select a relatively new straight pipe line if it is possible. Old pipe tends to have corrosions and depositions, which could affect the results. If you have to work on an old pipe, we recommend you to treat the corrosions and depositions as if they are part of the pipe wall or as part of the liner. For example, you can add an extra value to the pipe wall thickness parameter or the liner thickness parameter to take into account the deposition.

(5) Some pipes may have a kind of plastic liner which creates a certain amount of gaps between the liner and the inner pipe wall. These gaps could prevent ultrasonic waves directly traveling. Such conditions will make the measurement very difficult. Whenever possible, try to avoid this kind of pipes. If you have to work on this kind of pipe, try our plug-in transducers that are installed permanently on the pipe by drilling holes on the pipe while liquid is running inside.

Piping Configuration and Transducer Position	Upstream Dimension L_{up} x Diameters	Downstream Dimension L_{down} x Diameters
	10D	5D
	10D	5D
	10D	5D
	12D	5D
	20D	5D
	20D	5D
	30D	5D

§2.8 Transducers Installation

The transducers used by the RH20 series ultrasonic flowmeter are made of piezoelectric crystals both for transmitting and receiving ultrasonic signals through the wall of liquid piping system. The measurement is realized by measuring the traveling 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 the performance of the system. Meticulous care should be taken for the installation of the transducers.

Steps to the installation of the transducers:

(1) Locate an optimal position where the straight pipe length is sufficient (see the previous section), and where pipes are in a favorable condition, e.g., newer pipes with ease of operation and no rust.

(2) Clean any dust and rust on the spot where the transducers are to be installed. For a better result, polishing the pipe outer surface with a sander is strongly recommended.

(3) Apply adequate ultrasonic couplant (grease, gel or Vaseline)* on to the transducer transmitting surface as well as to the installation spot on the pipe surface. Make sure there is no gap between the transducer transmitting surface and the pipe surface.

Extra care should be taken to avoid any sand or dust particles left between the pipe surface and the transducer surface.

Horizontally lined pipes could have gas bubbles inside the upper part of the pipe. Therefore, it is recommended to install the transducers horizontally by the side of the pipe.
There are three ways to mount the transducers on to the pipe: by magnetic force, by clamp-on fixture and by hand. If the pipe material is metal, the magnetic force will hold the transducer on the pipe. Otherwise, you may simply hold the transducer rack and press it against the pipe if you just need a quick measurement, or, you may use a metal strip or the provided clamp fixture to install the transducers.

Please see Appendix §8.2 for more installation information.

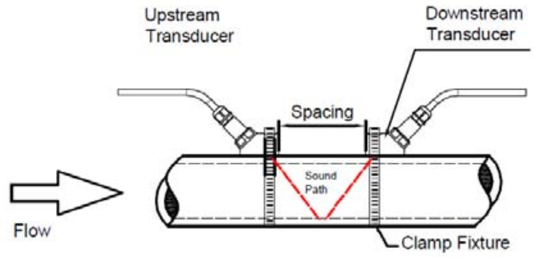
**Note: It is recommended to use the SOUNDSAFE product from Sonotech, Inc. as the ultrasonic couplant for safety considerations. Other couplants, such as grease, gel, and Vaseline, can be used as alternatives, but at your own risk.*

§2.8.1 Transducer Spacing

The spacing value shown on menu window M25 refers to the distance of inner spacing between the two transducers (see the following figures). The actual distance of the two transducers should be as close as possible to this spacing value.

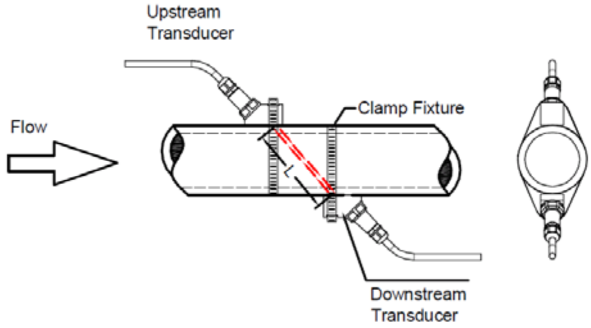
§2.8.2 V-method Installation

V-method installation is the most widely used method for daily measurement with pipe inner diameters ranging from 25mm (1") to 400mm (16"). It is also called the reflective method.



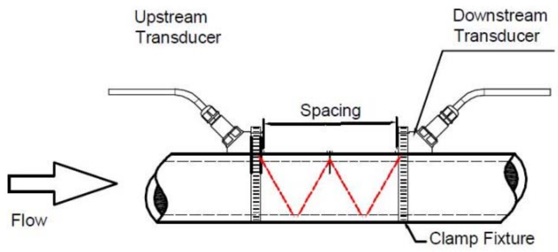
§2.8.3 Z-method Installation

Z-method is commonly used when the pipe diameter is between 200mm (8") and 3,000mm (120").



§2.8.4 W-method Installation

W-method is usually used on plastic pipes with a diameter from 20mm (3/4") to 50mm (2").



§2.8.5 N-method Installation

This method is rarely used.

§2.9 Installation Checkup

After 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, etc. As such, one can be sure that the flowmeter is working properly and the results are reliable and accurate.

§2.9.1 Signal Strength

Signal strength indicates the amplitude of receiving ultrasonic signals by a 3-digit number. [000] means there is no signal detected and [999] refers to the maximum signal strength that can be received.

Although the instrument works well when the signal strength ranges from 500 to 999, stronger signal strength should be pursued, because a stronger signal means a better result. The following methods are recommended to obtain strong signals:

(1) If the current location is not good enough for a stable and reliable flow reading, or if the signal strength is lower than 700, relocate to a more favorable location.

(2) Try to polish the outer surface of the pipe, and apply more couplant to increase the signal strength.

(3) Tenderly adjust the position of the two transducers, both vertically and horizontally, while checking the signal strength. Stop at the position where the signal strength reaches to maximum. Then, check the transducer spacing to make sure it is the same as or very close to what window M25 shows.

§2.9.2 Signal Quality

Signal quality is indicated as the Q value in the instrument. A higher Q value would mean a higher Signal to Noise Ratio (short for SNR), and accordingly a higher degree of accuracy able to be achieved. Under normal pipe condition, the Q value is in the range of 60-99, the higher the better.

Causes for a lower Q value could be:

(1) Interference from other instruments and devices nearby, such as a power frequency transverter which could cause strong interference. Try to relocate the flowmeter to a new place where the interference can be reduced.

(2) Bad sonic coupling between the transducers and the pipe. Try to polish the pipe surface again, clean the surface and apply more couplant, etc.

(3) The selected pipe section is difficult to conduct the measurement. Relocate to a more favorable pipe line.

§2.9.3 Total Transit Time and Delta Time

The total transit time (or traveling time) and the delta time are displayed on menu window M93. They are the primary data for the instrument to calculate the flow rate. Therefore, the measured flow rate will vary as the total transit time and delta time vary.

The total transit time should remain stable or vary in a very small range.

The delta time normally varies less than 20%. If the variation exceeds 20% in either positive or negative direction, there could be certain kinds of problems with the transducer installation. The user should check the installation for sure.

§2.9.4 Transit Time Ratio

This ratio is usually used to check whether the transducer installation is good and whether the entered pipe parameters are in consistency with 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 exceeded, the user should check:

(1) If the entered pipe parameters are correct?

(2) If the actual spacing of the transducers is the same as or close to what shown on window M25?

(3) If the transducer are installed properly in the right direction?

(4) If the mounting location is good, if the pipe has changed shape, or if the pipe is too old (i.e., too much corrosion or deposition inside the pipe)?

(5) If there is any interference source inside of the pipe?

(6) If there are other aspects which do not meet the measurement requirements as recommended before?

Please refer to Appendix §8.2 for more installation details.

3. How To

§3.1 How to check if the instrument works properly

Generally speaking, when 'R' is displayed in the lower right corner of the LCD display, the instrument is working properly.

If an 'H' flashes instead, the received signal could be poor. Please refer to Chapter 5fortroubleshooting.

If an 'I' is displayed, it means that there is no signal detected.

If a 'J' is displayed, it means that the hardware of this instrument could be out of order. Refer to Chapter 5 for details.

§3.2 How to check the liquid flowing direction

(1) Make sure that the instrument works properly

(2) Check the flow rate display. If the value is POSITIVE, the direction of the flow will be from the ORANGE transducer to the GREEN transducer; if the value is NEGATIVE, the direction will be from the GREEN transducer to the ORANGE transducer.

§3.3 How to change units systems

Use menu window M30 for the selection of units systems, either English or in Metric.

§3.4 How to select a flow rate unit

Use menu window M31 to select the flow rate unit as well as the corresponding time unit.

§3.5 How to use the totalizer multiplier

Use window M33 to select a proper multiplying factor for the totalizer multiplier. Make sure that the rate of the totalizer pulse is not too fast, nor too slow. A speed of several pulses per minute is preferable.

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 period 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.

§3.6 How to turn on and off the totalizers

Use M34, M35 and M36 to turn on or turn off the POS, NEG, or NET totalizer, respectively.

§3.7 How to reset the totalizers

Use M37 to reset the flow rate totalizers.

§3.8 How to restore the factory default setups

Go to window M37.Press . key followed by the backspace key ◄

This operation will erase all the parameters entered by the user and setup the instrument with factory default values.

§3.9 How to use the damper to stabilize the flow rate

The damper acts as a filter for a stable reading. If '0' is entered in window M40, that means there is no damping. A bigger number brings a more stable effect. But bigger damper numbers will prevent the instrument from acting quickly.

Numbers of 0 to 10 are commonly used for the damper value.

§3.10 How to use the zero-cutoff function

The number displayed in window M41 is called the zero-cutoff value. When the absolute value of the measured flow rate is less than the zero-cutoff value, the measured flow rate will be replaced with '0'. This is to avoid any invalid accumulation when the actual flow is below the zero-cutoff value.

The zero-cutoff operation does not affect the flow measurement when the actual flow is greater than the zero-cutoff value.

§3.11 How to setup a zero point

When the flow in a pipe is absolutely stopped, the flowmeter could still give a small non-zero flow rate reading. In order to make the measurement accurate, it is necessary to remove this "zero point" reading.
Window M42 allows us to take care of this issue. At first, the user should make sure that the liquid in the pipe is totally stopped (no velocity). Then, go to window M42 and press the ENT key to start the zero point setup function.

§3.12 How to change the flow rate scale factor

A scale factor (SF) is the ratio between the "actual flow rate" and the flow rate measured by the flowmeter. It can be determined by calibration with standard flow calibration equipment. To change the SF, press M45, then the ENT key, enter the new SF, and press ENT again.
Note: the default scale factor is labeled on the transducers.

§3.13 How to use the password locker

The password locker 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 on the windows.

The password locking / unlocking is done in window M47. The system can be locked without a password or with a password consisted of 1 to 4 digits.

For no-password locking / unlocking, just press ENT key in window M47.
If the password is forgotten, please contact the manufacturer.

§3.14 How to use the built-in data logger

The built-in data logger has a space of 24K bytes of memory, which will hold about 2000 lines of data.
Use M50 to turn on and turn off the logger as well as to select the items to be logged.
Use M51 to set up the starting time, time interval, and the logging duration.

Use M52 to select the data storage direction. Data can be stored in a logger buffer (this means it is stored in the units memory, which is fairly small) or directed to the RS-232C interface without being stored into the logger buffer.

Use M53 to view the data in the logger buffer.

Use M52 to clear the logging data remaining in the RS-232C interface and in the logger buffer.
The data stored in the data logger can be downloaded to a PC with the Windows Hyper Terminal utility. Or, you may use Spire Metering's StufManager™ software to do the downloading. This software also helps you to set up the data logger. Please go to the following website for more details: http://www.spiremt.com/support/rh20.html

§3.15 How to use the Frequency Output

All of the RH20 series flowmeters have Frequency Output functionality. This frequency output signal, which represents the flow rate, is intended to connect with other instruments.

The Frequency Output is totally user-configurable. Usually, four parameters should be configured.

Enter the lower limit of flow rate in window M68 and the higher limit of flow rate in window M69.

Enter the frequency range in window M67.

For example, assume that the flow rate varies in a range from 0 m^3/h to 3000 m^3/h, and the required output signal frequency should be in a range from 200 Hz to 1000 Hz. The user should enter 0 in M68 and 3000 in M69, and enter 200 and 1000 in window M67.

Please note that the user needs to select the frequency output option (the 13th option, “FO output”) in window M78. The user must also make the OCT (Open Collector Output) hardware connection to the device which is supposed to use the frequency output signal.

§3.16 How to use the Totalizer Pulse Output

The flowmeter will produce a pulse output with every unit of liquid flow. This pulse could be used by an external pulse counter to accumulate the flow rate.

Refer to§3.4 and §3.5 for the setup of the totalizer units and multiplier.

The totalizer pulse output can only be connected to OCT or BUZZER hardware devices.

For 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 to achieve this, the following steps must be performed:

(1) Select the Cubic Meter (m^3) unit in window M32.
(2) Select the Multiplier factor as '2. X0.1'in window M33.
(3) Select the output option '9. POS INT Pulse' in window M77. (INT stands for totalized)

§3.17 How to produce an alarm signal

There are 2 types of hardware alarm signals that are available with this instrument. One is the Buzzer, and the other is the OCT output.

Possible triggering sources of the alarming events for both the Buzzer and the OCT output:

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

There are two alarms in this instrument, #1 alarm and #2 alarm. They can be configured in windows M73, M74, M75 and M76.

For example, assume we need the Buzzer to start beeping when the flow rate is less than 300 m^3/h and greater than 2000 m^3/h. The following setup steps would be recommended.

(1) Enter flow rate lower limit 300 in M73 for #1 alarm,
(2) Enter flow rate upper limit 2000 in M74 for #1 alarm,
(3) Select item '6. Alarm #1' in M77.

§3.18 How to use the built-in Buzzer

The built-in buzzer is user-configurable. It can be used as an alarm. Use M77 for setups.

§3.19 How to use the OCT output

The OCT output is on/off type. It is user-configurable. For example, you can set the OCT output to be a pulse signal for flow accumulation.
Use M77 for the setup.
Notice that the Frequency Output shares the same OCT hardware.
The OCT output is wired to pin 6 (for positive) and pin 5 (for ground) of the RS-232 connector. Refer to section §6.1 for more details.

§3.20 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. Modification will be needed only when the battery is totally exhausted, or when the replacement of the batteries takes a long time so that the original clock data get lost.

Press the ENT key in M61 for modification. Use the dot key to skip over the digits that need modification.

§3.21 How to adjust the LCD contrast

Use M70 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.

§3.22 How to use the RS232 serial interface

Use M62 for the setup of the RS-232C serial interface.

§3.23 How to view the Totalizers

Use M82 to view the daily totalizer, the monthly totalizer and the yearly totalizer.

§3.24 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 window M72, press ENT key and select YES to reset the working timer.

§3.25 How to use the manual totalizer

Use M38 for the manual totalizer setup. Press ENT key to start and stop the totalizer.

§3.26 How to check the ESN

Every set of the RH20 series flowmeters utilizes a unique ESN to identify the meter. The ESN is an 8-digit number that provides the information of version and manufacturing date.

The user can also employ the ESN for instrumentation management.

The ESN is displayed in window M61.

Use M+1 to view the total working time since the instrument was shipped out of the manufacturer.
Use M+4 to view the total number of times the instrument has been turned on and off since the instrument was shipped out of the manufacturer.

§3.27 How to check the battery life

Use M07 to check how long the battery will last. Also please refer to §2.1 for further details.

§3.28 How to charge the built-in battery

Refer to §2.1

§3.29 How to calibrate the flowmeter

Refer to website: http://www.spiremt.com/support/rh20.html, under section "Frequently Questions".

4. Menu Window Details

Menu window No.	Function
M00	Display POS (positive), NEG (negative) and NET (net) totalizer values. Display signal strength, signal quality and working status
M01	Display POS totalizer, instantaneous flow rate, velocity, signal strength, signal quality and working status
M02	Display NEG totalizer, instantaneous flow rate, velocity, signal strength, signal quality and working status
M03	Display NET totalizer, instantaneous flow rate, velocity, signal strength, signal quality and working status
M04	Display date and time, instantaneous flow rate, signal strength, signal quality and working status
M05	Display date and time, velocity, signal strength, signal quality and working status
M06	Display the wave shape of the receiving signal
M07	Display the battery terminal voltage and its estimated lasting time
M08	Display all of the detailed working status, signal strength, signal quality
M09	Display today's total NET flow, velocity, signal strength, signal quality and working status
M10	Window for entering the outer perimeter of the pipe
M11	Window for entering the outer diameter of the pipe Valid range: 0 to 6000mm.
M12	Window for entering pipe wall thickness
M13	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 there is no need to change anything in this window.
M14	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
M15	Window for entering the sound speed of non-standard pipe materials
M16	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) Polystryol (6)Polystyrene (7) Polyester (8) Polyethylene (9) Ebonite (10) Teflon
M17	Window for entering the sound speed of non-standard liner materials
M18	Window for entering the liner thickness, if there is a liner
M19	Window for entering the roughness coefficient of the pipe inner surface

M20	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 -45°C (7) Butane at 0°C (8)Other liquids (9) Diesel Oil (10)Caster Oil (11)Peanut Oil (12) #90 Gasoline (13) #93 Gasoline (14) Alcohol (15) Hot water at 125°C
M21	Window for entering the sound speed of non-standard liquids
M22	Window for entering the viscosity of non-standard liquids
M23	Window for selecting transducer type There are 14 different types of transducers for selection. If the π 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.
M24	Window for selecting the transducer mounting methods Four methods can be selected: (0) V-method (1) Z-method (2) N-method (3) W-method
M25	Display the transducer mounting spacing or distance
M26	Entry to store the pipe parameters into the internal NVRAM (non-volatile memory)
M27	Entry to read the previously saved pipe parameters
M28	Entry to determine whether or not to keep the last correct value when poor signal condition occurs. YES is the factory default
M29	Window to set the threshold below which the receiving signal is defined as poor. Valid number: from 000 to 999. 0 is the factory default
M30	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.
M31	Window for selecting flow rate unit system. Flow rate can be in 0. Cubic meter short for (m^3) 1. Liter (l) 2. USA gallon (gal) 3. Imperial Gallon (igl) 4. Million USA gallon (mgl) 5. Cubic feet (cf) 6. USA liquid barrel (bal) 7. Imperial liquid barrel (ib) 8. Oil barrel (ob) 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.
M32	Window for selecting the totalizer unit
M33	Window for setting the totalizer multiplying factor The multiplying factor ranges from 0.001 to 10000
M34	Turn on or turn off the NET totalizer
M35	Turn on or turn off the POS totalizer

M36	Turn on or turn off the NEG totalizer
M37	(1) Totalizer reset (2) 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.
M38	Manual totalizer used for calibration. Press any key to start and press the key again to stop the totalizer.
M39	Language selection: Chinese or English.
M40	Flow rate damper setup. The damping parameter ranges from 0 to 999 seconds. 0 means there is no damping. Factory default is 10 seconds.
M41	Zero flow rate (or low flow rate) cut-off to avoid invalid accumulation.
M42	Zero point setup. Make sure the liquid in the pipe is not running while doing this
M43	Clear the zero point value, and restore the factory default zero point.
M44	Set up a flow bias. Generally this value should be 0.
M45	Flow rate scale factor. The factory default is '1'. Keep this value as '1' when no calibration has been made. *Note: the default calibrated scale factor is labeled on the transducers.*
M46	Network address identification number (IDN). Any integer can be entered except 13(0DH, carriage return), 10 (0AH, line feeding), 42 (2AH), 38, 65535. Every set of the instrument in a network environment should have a unique IDN. Please refer to the chapter for communications.
M47	System locker to avoid modification of the system parameters
M48	Not used
M49	Window for network communication test
M50	Window to set up the schedule-based data saving. Select the items to be saved.
M51	Window to set up the schedule for the schedule-based data saving
M52	Data output direction control. (1) If 'To RS-232' is selected, all the data will be directed to the RS-232 interface (2) If 'To buffer ' is selected, the data will be stored into the built-in logger memory (3) Allow user to clear data buffer
M53	Logger buffer viewer. It functions as a file editor. Use Dot, backspace UP and DN keys to browse the buffer. If the logger is ON, the viewer will automatically refresh once new data are stored
M54	Not used
M55	Not used
M56	Not used
M57	Not used
M58	Not used
M59	Not used
M60	99 years calendar. Press ENT for modification. Use the dot key to skip the digits that need no modification.
M61	Display Version Information and Electronic Serial Number (ESN) that are unique for

	each RH20 series flowmeter. The user can use the ESN for instrumentation management
M62	RS-232 setup. Baud rate can be 75 to 115,200 bps
M63	Not used
M64	Not used
M65	Not used
M66	Not used
M67	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
M68	Window to set up the minimum flow rate which corresponds to the lower frequency limit of the frequency output
M69	Window to set up the maximum flow rate which corresponds to the upper frequency limit of the frequency output
M70	LCD display backlight control. The entered value indicates how many seconds the backlight will be on with every key pressing.
M71	LCD contrast control. The LCD will become darker when a small value is entered.
M72	Working timer. It can be reset by pressing ENT key, and then selecting YES.
M73	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 M78 or M77
M74	Alarm #1 upper threshold setup
M75	Alarm #2 lower threshold setup
M76	Alarm #2 upper threshold setup
M77	Buzzer setup. If a proper input source is selected, the buzzer will beep when the trigger event occurs
M78	OCT (Open Collector Output) setup By selecting a proper triggering source, the OCT circuit will close when the trigger event occurs
M79	Not used
M80	Window to set up a link to another RH20 flowmeter through RS-232. The keypad and display can be used for the other hand set
M81	Not used
M82	Setup for daily totalizer, monthly totalizer and yearly totalizer
M83	Not used
M84	Not used
M85	Not used
M86	Not used
M87	Not used
M88	Not used
M89	Not used
M90	Display signal strength, signal quality and transit time ratio (upper right corner).
M91	Display the transit time ratio. The ratio value should be in the range of 100±3% if the

	entered pipe parameters are correct and the transducers are properly installed. Otherwise, the pipe parameters and the transducer installation should be checked.
M92	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.
M93	Display the total transit time and delta time(transit time difference between upstream and downstream traveling)
M94	Display the Reynolds number and the pipe factor used by the flow rate measurement program. *Note:* the pipe factor is rarely used.
M95	Not used
M96	Not used
M97	Command to store the pipe parameters either in the built-in data logger or to the RS-232C serial interface
M98	Command to store the diagnostic information either in the built-in data logger or to the RS-232C serial interface
M99	Command to copy the current display either to the built-in data logger or to the RS-232C serial interface
M+0	View the last 64 records of power on and off events. The recorded information includes the date and time as well as the corresponding flow rate when the power on or off occurs
M+1	Display the total working time of the instrument
M+2	Display the last power-off date and time
M+3	Display the last power-off flow rate
M+4	Display the total number of times the flowmeter has been powered on and off
M+5	A scientific calculator for the convenience of field applications. All the values are in single accuracy. All the mathematic operators are selected from a list.
M+6	Not used
M+7	Not used
M+8	Not used
M+9	Not used
M-0	Entry to hardware adjusting windows. Valid for the manufacturer only.

5.Troubleshooting

§5.1 Power-on Errors

When powered on, the RH20 series ultrasonic flowmeter automatically starts the self-diagnosis process to find if there are any hardware and 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.

Error message	**Causes**	**Solutions**
ROM TestingError Data TestingError	Problem with the software	(1)Reboot the system (2)Contact the manufacturer.
Data StoringError	User-entered parameters get lost.	When this message is displayed, press ENT key to restore the default configuration.
System Clock Slow or Fast Error	Problem with the system clock or the crystal oscillator.	(1)Power on again (2)Contact the manufacturer
Date Time Error	Problem with the system calendar	Initialize the calendar in menu window M61
Reboot repetitively	Hardware problems	Contact the manufacturer

§5.2 Working Status Errors

The RH20 series ultrasonic flowmeter will show an Error Code (a single letter like I, R, etc.) in the lower right corner on menu windows M00, M01, M02, M03, M90 and M08. When any abnormal Error Code shows, counter-measures should be taken.

Error code	**Message displayed on window M08**	**Causes**	**Solutions**
R	System Normal	No error	
I	No Signal	(1)Unable to receive signals (2)Transducers installed improperly (3)Loosen contact or not enough couplant between transducer and pipe outer surface. (4)Pipe liners are too thick or the deposition inside of	(1 Adjust measuring location (2)Polish the pipe surface and clean the spot (3)Make sure the couplant is enough (4)Check the transducer cables

		the pipe is too thick. (5)Transducer cables are not properly connected	
J	Hardware Error	Hardware problem	Contact the manufacturer
H	PoorSig Detected	(1)Poor signal detected (2)Transducers installed improperly (3)Too much fouling (corrosion, deposition, etc.) (4)The pipe liner is too thick. (5)Problem with transducer cables	(1)Adjust measuring location (2)Polish the pipe surface and clean the spot (3)Make sure the couplant is enough (4)Check the transducer cables
Q	FrequOutputOver	The actual frequency for the Frequency Output is out of the range specified by the user	Check the values entered in window M66,M67,M68 and M69, and use a larger value in M69
F	System RAM Error Date Time Error CPU or IRQ Error ROM Parity Error	(1) Temporary problems with RAM, RTC (2) Permanent problems with hardware	(1) Turn on the power again (2) contact the manufacturer
1 **2** **3**	Adjusting Gain	Instrument is in the progress of adjusting the gain for the signal, and the number indicates the progressive steps	No need for action
K	Empty pipe	(1) No liquid inside the pipe (2) Incorrect setup in M29	(1) Relocate the meter to where the pipe is full of liquid (2) Enter 0 in M29

§5.3 Other Problems and Solutions

(1) Q: Why does the instrument display 0.0000 flow rate while the liquid in the pipe is actually flowing? The signal strength is checked to be good (the working status is "R") and the signal quality Q has a satisfactory value.
A: The problem is likely to be caused by the incorrect "Zero Point" setting. The user may have conducted the "Zero Point" setup while the flow was not standstill. To solve this problem, use the 'Reset Zero' function in menu window M43 to clear the zero point.

(2) Q: The displayed flow rate is much lower or much higher than the actual flow rate in the pipe under normal working conditions. Why?
A:
(a) The entered offset value might be wrong. Enter '0'offset in window M44.

(b) Incorrect transducer installation. Re-install the transducers carefully.

(c) The 'Zero Point' is wrong. Go to window M42 and redo the "Zero Point" setup. Make sure that the flow inside the pipe is standstill. No velocity is allowed during this setup process.

(3) Q: Why does the battery not work as long as the time indicated on M07?

A:

(a) The battery may have come to the end of its service life. Replace it with a new one.

(b) New battery is not compatible with the battery estimating software. The software needs to be upgraded. Please contact the manufacturer.

(c) The battery has not been fully charged.

(d) There is indeed a time difference between the actual working time and the estimated one, especially when the terminal voltage is in the range from 3.70 to 3.90 volts. Therefore, the estimated working time is for reference only.

For more information, please refer to website: http://www.spiremt.com/support/rh20.html

6. Serial Communication

§6.1 General

The RH20 series ultrasonic flowmeter integrates a USB communication interface and a complete set of serial communication protocol. By using this serial communication link, one can configure the flowmeter and acquire measurement results from a PC. The following steps must be completed:

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

§6.2 Connect the Flowmeter to a PC

A standard USB cable is provided with your RH20 unit. Just simply plug the cable to the flowmeter USB port on one end and to the computer on the other end. Then, turn on the flowmeter. 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.

§6.3 Check the Flowmeter COM Port Settings

Go to menu window M62 to check the COM port settings on your flowmeter. Write down the baud rate. You may need it later when you set up your computer's COM port.
If you want to change the baud rate, press ENT key and select the proper baud rate. Press ENT key again to confirm the change.

§6.4 Set up PC Software

You may use Windows HyperTerminal software to communicate to the flowmeter. You may also make your own PC software to communicate to the flowmeter by using the protocol described in the following section.
To facilitate the use of and to fully explore the potential of RH20 flowmeter, 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

§6.5Communication 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
DQD(CR)	Return flow rate per day	±d.ddddddE±dd
DQH(CR)	Return flow rate per hour	±d.ddddddE±dd (CR)（LF）
DQM(CR)	Return flow rate per minute	±d.ddddddE±dd (CR)（LF）
DQS(CR)	Return flow rate per second	±d.ddddddE±dd (CR)（LF）
DV(CR)	Return instantaneous flow velocity	±d.ddddddE±dd (CR)（LF）
DI+(CR)	Return POS totalizer	±dddddddE±d
DI-(CR)	Return NEG totalizer	±dddddddE±d (CR)（LF）
DIN(CR)	Return NET totalizer	±dddddddE±d (CR)（LF）
DID(CR)	Return Identification Number (IDN)	ddddd (CR)（LF）
DL(CR)	Return signal strength and signal quality	S=ddd,ddd Q=dd (CR)(LF)
DT(CR)	Return the current date and time	yy-mm-ddhh:mm:ss (CR)(LF)
M@(CR)***	Send a key value as if a key is pressed	
LCD(CR)	Return the current display contents	
FOdddd(CR)	Force the FO output to output a frequency of dddd Hz	
ESN(CR)	Return the ESN of the flowmeter	Ddddddd (CR)(LF)
RING(CR)	Handshaking Request from a MODEM	
OK(CR)	Acknowledgement from a MODEM	No action
GA	Command for GSM messaging	Please contact the manufacturer for detail
GB	Command for GSM messaging	
GC	Command for GSM messaging	
DUMP(CR)	Return the print buffer content	In ASCII string format
DUMP0(CR)	Clear the whole print buffer	In ASCII string format
DUMP1(CR)	Return the whole print buffer content	In ASCII string Format, 24KB in length
W	Prefix of an IDN-addressing-based networking command. The IDN address is a word, ranging 0-65534.	
N	Prefix of an IDN-addressing-based networking command. The IDN address here is a single byte value, ranging 00-255.	Not recommend for use.
P	Prefix of any command with checksum	

&	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’.

§6.6 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:
+1.234567E+12m3/d(CR)
+3.1235926E+00m/s(CR)
+1234567E+0m3(CR)

§6.7The M command and the ASCII Codes

The protocol provides the capability of virtual key-pressing. A remote RS-232C terminal can send an 'M' command along with a key code to simulate the scenario that the key is pressed through the keypad of the flowmeter. This functionality allows the user to operate the flowmeter in the office far away from the testing site.

For example, the command "M1" is sent to the flowmeter through the RS-232C link, the flowmeter will treat the command as if the user has pressed the 1 key through the keypad.

The ASCII codes and corresponding key values of the keypad keys are listed in the following table.

Key	Hexadecimal Key code	Decimal Key code	ASCII Code		Key	Hexadecimal Key code	Decimal Key code	ASCII Code
0	30H	48	0		8	38H	56	8
1	31H	49	1		9	39H	57	9
2	32H	50	2		.	3AH	58	:
3	33H	51	3		◄	3BH,0BH	59	;
4	34H	52	4		MENU	3CH,0CH	60	<
5	35H	53	5		ENT	3DH,0DH	61	=
6	36H	54	6		▲/+	3EH	62	>
7	37H	55	7		▼/-	3FH	63	?

7. Warranty and Service

§7.1 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 to the original purchaser. Spire Metering's obligation should be limited to restoring the meter to normal operation or replacing the meter, at Spire Metering's choice, and shall be conditioned upon receiving written notice of any alleged defect within 10 days after its discovery. Spire Metering will determine if the return of the meter is necessary. If it is, the user should be responsible for the one-way shipping fee from the customer to the manufacturer.

Spire Metering is not liable to any defects or damage attributable to misusage, improper installation, out-of-spec operating conditions, replacement of unauthorized parts and acts of nature. Additionally, fuses and batteries are not part of this warranty.

THE FOREGOING WARANTY 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.)

§7.2 Service

The manufacturer provides instrument installation for its customers, and the charge will depend on the complexity of the installation.

For operational problems, please contact the technical support department by telephone, fax, email or internet. In most cases, problems could be solved immediately.

For any hardware failure of the instrument, we recommend our customers to send back the instrument for service. Please contact the technical support department with the model number and serial number of the unit before sending the unit back to us. Both numbers can be found on the product label. For each service or calibration request, we will issue a Return Materials Authorization (RMA) number. Take notice that the cost for repairing can only be determined after receipt and inspection of the instrument. A quotation 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, or has been in contact with hazardous material which could pose any 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

as hazard-free device by a recognized organization, you are required to supply the certification for service.

3. If the return item does not have a RMA# associated, it will be sent back without any service conducted.

§7.3 Software Upgrade Service

We provide free-of-charge software upgrade services. Please contact the manufacturer for the software upgrade information. You may also go to our technical support website at http://www.spiremt.com/support/rh20.html for the latest downloads.

8. Appendix

§8.1 Battery Maintenance and Replacement

The battery is 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. Recharge the battery again to its full extent with the supplied AC adapter. To get close to 100% power, charge the device overnight

When the battery is unable to power the instrument for 2 to 3 hours after it is fully recharged, this usually indicates that the battery is near its product life and needs to be replaced. Please consult the manufacturer for replacing the battery pack.

§8.2 Transducer Installation Guide

§8.2.1 Find the mounting site

(A) Pipe must be full of liquids at the measurement site.
(B) No heavy corrosion of deposition inside of 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 (low to high):
Single Bend -> Pipe Reduction / Enlargement -> Outflow Tee -> Same Plane Multiple Bends -> Inflow Tee -> Out of Plane Multiple Bends -> Valve -> Pump

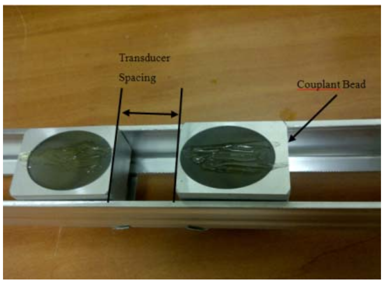
§8.2.2 Prepare the Pipe Surface

Clean the pipe surface where the transducers will be mounted. Remove rust and paint. Sand the surface if not smooth. Use 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.

§8.2.3Prepare the Transducer

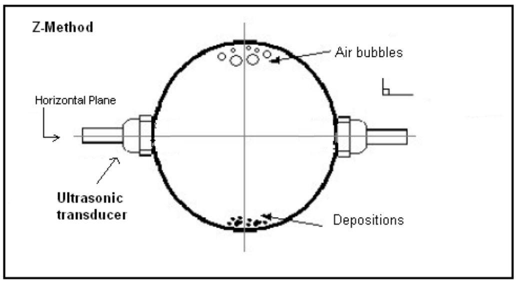
Clean the transducer surface. Keep the surface dry.

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



§8.2.4 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.

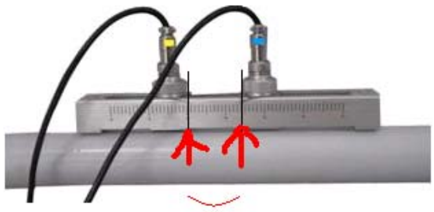
Move the transducer pair apart so that the mounting spacing between the two transducers is equal to the one shown in menu M25.

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 is a non-metal pipe, just push the transducer handle against the pipe and hold it during the measurement. You may also use clamps or metal strips to mount the rack.



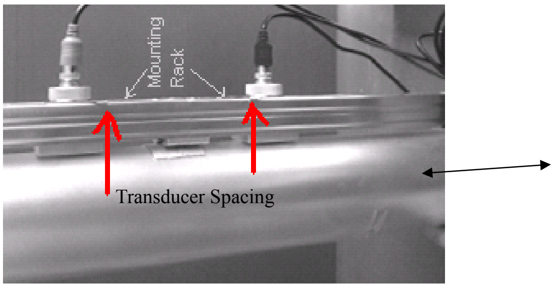
Transducer Spacing for HS Transducer

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

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

Damping material (GraceIce)

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 M25. Then follow the same steps as installing HS transducers, applying couplant as necessary.



§8.3 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
Type K						
3/4	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 1/4	1 3/8	1.375	0.004	0.0015	0.065	0.006
1 1/2	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 1/2	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 1/2	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

Type L						
3/4	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 1/4	1 3/8	1.375	0.004	0.0015	0.055	0.006
1 1/2	1 5/8	1.625	0.0045	0.002	0.060	0.006
2	2 1/8	2.125	0.005	0.002	0.070	0.007
2 1/2	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 1/2	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

Type M						
3/4	7/8	0.875	0.003	0.001	0.032	0.003
1	1 1/8	1.125	0.0035	0.0015	0.035	0.004
1 1/4	1 3/8	1.375	0.004	0.0015	0.042	0.004
1 1/2	1 5/8	1.625	0.0045	0.002	0.049	0.005
2	2 1/8	2.125	0.005	0.002	0.058	0.006
2 1/2	2 5/8	2.625	0.005	0.002	0.065	0.006
3	3 1/8	3.125	0.005	0.002	0.072	0.007
3 1/2	3 5/8	3.625	0.005	0.002	0.083	0.008
4	4 1/8	4.125	0.005	0.002	0.095	0.010

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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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	-	-
11/4	1.660	0.065	-	-	5S
		0.109	-	-	10S
		0.140	STD	40	40S
		0.191	XS	80	80S
		0.250	-	160	-
		0.382	XXS	-	-
11/2	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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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	-	-	5S
		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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 Carbon Steel Wall Thickness	ANSI B 36.10 Carbon Steel Schedule Number	ANSI B 36.19 Stainless Steel 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 ºC)		Sound Speed Long. Wave（25ºC)	
	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 (25ºC)		Sound Speed* Long.Wave (25ºC)	
	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
Tintanium	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,Iight 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 (ºC) 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	*All data given at 25°C (77 F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
Acetic anhydride(22)	$(CH_3CO)_2O$	1.082 (20°C)	1,180	3,871.4	2.5	0.769	8.274
Acetic acid,anhydride(22)	$(CH_3CO)_2O$	1.082 (20°C)	1,180	3,871.4	2.5	0.769	8.274
Acetic acid,nitrile	C_2H_3 N	0.783	1,290	4,232.3	4.1	0.441	4.745
Acetic acid,ethyl ester(33)	C_4H_8 O_2	0.901	1,085	3,559.7	4.4	0.467	5.025
Acetic acid,methyl ester	$C_3H_6O_2$	0.934	1,211	3,973.1		0.407	4.379
Acetone	C_3H_6O	0.791	1,174	3,851.7	4.5	0.399	4.293
Acetonitrile	C_2H_3N	0.783	1,290	4,232.3	4.1	0.441	4.745
Acetonylacetone	$C_6H_{10}O_2$	0.729	1,399	4,589.9	3.6		
Acetylen dichloride	$C_2H_2CL_2$	1.26	1,015	3,330.1	3.8	0.400	4.304
Acetylentetrabromide(47)	$C_2H_2Br_4$	2.966	1,027	3,369.4			
Acetylen tetrachloride(47)	$C_2H_2CL_4$	1.595	1,147	3,763.1		1.156 (15°C)	12.438 (59°F)
Alcohol	C_2H_6O	0.789	1,207	3,960	4.0	1.396	15.02
Alkazene-13	$C_{15}H_{24}$	0.86	1,317	4,320.9	3.9		
Alkazene-25	$C_{10}H_{12}CL_2$	1.20	1,307	4.288.1	3.4		
2-Amino-ethanol	C_2H_7NO	1.018	1,724	5,656.2	3.4		
2-Aminotolidine(46)	C_7H_9N	0.999 (20°C)	1,618	5,308.4		4.394 (20°C)	47.279 (68°F)
4-Aminotolidine(46)	C_7H_9N	0.999 (45°C)	1,480	4,855.6		1.863 (50°C)	20.045 (122°F)
Ammonia(35)	NH_3	0.771	1,729 (-33°C)	5,672.6 (-27°F)	6.68	0.292 (-33°C)	3.141 (-27°F)
Amorphous Polyolefin		0.98	962.6 (190°C)	3158.2 (374°F)		26,600	286.000
t-Amyl alcohol	$C_5H_{12}O$	0.81	1,204	3,950.1		4.374	47.064
Aminobenzene(41)	$C_6H_5NO_2$	1.022	1,639	5,377.3	4.0	3.63	39.058
Aniline(41)	$C_6H_5NO_2$	1.022	1,639	5,377.3	4.0	3.63	39.058
Argon(45)	Ar	1.400 (-188°C)	853 (-188°C)	2798.6(-306°F)			

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.* Specific Gravity	Sound Speed m/s	Sound Speed ft/s	Δv/ºC m/s/ºC	Kinematic Viscosity×10^{-6} m^2/s	Kinematic Viscosity×10^{-6} ft^2/s
Azine	C_6H_5N	0.982	1,415	4,642.4	4.1	0.992 (20ºC)	10.673 (68ºF)
Benzene(29,40,41)	C_6H_6	0.879	1,306	4,284.8	4.65	0.711	7.65
Benzol(29,40,41)	C_6H_6	0.879	1,306	4,284.8	4.65	0.711	7.65
Bromine(21)	Br_2	2.928	889	2,916.7	3.0	0.323	3.475
Bromo-benzene(46)	C_6H_5Br	1.522	1,170 (20ºC)	3,838.6 (68ºF)		0.693	7.456
1-Bromo-butane(46)	C_4H_9Br	1.276 (20ºC)	1,019 (20ºC)	3,343.2 (68ºF)		0.49 (15ºC)	5.272 (59ºF)
Bromo-ethane(46)	C_2H_5Br	1.460 (20ºC)	900 (20ºC)	2,952.8 (68ºF)		0.275	2.959
Bromoform(46,47)	$CHBr_3$	2.89 (20ºC)	918	3,011.8	3.1	0.654	7.037
n-Butane(2)	C_4H_{10}	0.601 (0ºC)	1,085 (-5ºC)	3,559.7 (23ºF)	5.8		
2-Butanol	$C_4H_{10}O$	0.81	1,240	4,068.2	3.3	3.239	34.851
Sec-Butylalcohol	$C_4H_{10}O$	0.81	1,240	4,068.2	3.3	3.239	34.851
n-Butyl bromide(46)	C_4H_9Br	1.276 (20ºC)	1,019 (20ºC)	3,343.2 (68ºF)		0.49 (15ºC)	5.272 (59ºF)
n-Butyl chloride(22,46)	C_4H_9CL	0.887	1,140	3,740.2	4.57	0.529 (15ºC)	5.692 (59ºF)
Tert Butyl chloride	C_4H_9CL	0.84	984	3,228.3	4.2	0.646	6.95
Butyl oleate	$C_{22}H_{42}O_2$		1,404	4,606.3	3.0		
2,3 Butylene glycol	$C_4H_{10}O_2$	1.019	1,484	4,808.8	1.51		
Cadmium(7)	CD		2,237.7 (400ºC)	7,341.5 (752ºF)		1.355cp (440ºC)	14.579 (824ºF)
Carbinol(40,41)	CH_4O	0.791 (20ºC)	1,076	3,530.2	2.92	0.695	7.478
Carbitol	$C_6H_{14}O_3$	0.988	1,458	4,783.5			
Carbon dioxide(26)	CO_2	1.101 (-37ºC)	839 (-37ºC)	2,752.6 (-35ºF)	7.71	0.137 (-37ºC)	1.474 (-35ºF)
Carbon disulphide	CS_2	1.261 (22ºC)	1,149	3,769.7		0.278	2.991

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
Carbon tetrachloride (33,35,47)	CCL_4	1.595 (20ºC)	929	3038.1	2.48	0.607	6.531
Carbon tetrafluoride(14) (Freon 14)	CF_4	1.75 (-150ºC)	875.2 (-150ºC)	2,871.5 (-238ºF)	6.61		
Cetane(23)	$C_{16}H_{34}$	0.773 (20ºC)	1,338	4,389.8	3.71	4.32	46.483
Chloro-benezene	C_6H_5CL	1.106	1,273	4,176.5	3.6	0.722	7.768
1-Chloro-butane(22,46)	C_4H_9CL	0.887	1,140	3,740.2	4.57	0.529 (15ºC)	5.692 (59ºF)
Chloro-diFluoromethane (3)(Freon 22)	$CHCLF_2$	1.491 (-69ºC)	893.9 (-50ºC)	2,932.7 (-58ºF)	4.79		
Chloroform(47)	$CHCL_3$	1.489	979	3,211.9	3.4	0.55	5.918
1-Chloro-propane(47)	C_3H_7CL	0.892	1,058	3,471.1		0.378	4.067
Chlorotrifluoromethane (5)	$CCLF_3$		724 (-82ºC)	2,375.3 (-116ºF)	5.26		
Cinnamaldehyde	C_9H_8O	1.112	1,554	5,098.4	3.2		
Cinnamic aldehyde	C_9H_8O	1.112	1,554	5,098.4	3.2		
Colamine	C_2H_7NO	1.018	1,724	5,656.2	3.4		
o-Cresol(46)	C_7H_8O	1.047 (20ºC)	1,541 (20ºC)	5,055.8 (68ºF)		4.29 (40ºC)	46.16 (104ºF)
m-Cresol(46)	C_7H_8O	1.034 (20ºC)	1,500 (20ºC)	4,923.1 (68ºF)		5.979 (40ºC)	64.334 (104ºF)
Cyanomethane	C_2H_3N	0.783	1,290	4,232.3	4.1	0.441	4.745
Cyclohexane(15)	C_6H_{12}	0.779 (20ºC)	1,248	4,094.5	5.41	1.31 (17ºC)	14.095 (63ºF)
Cyclohexanol	$C_6H_{12}O$	0.962	1,454	4,770.3	3.6	0.071 (17ºC)	0.764 (63ºF)
Cyclohexanone	$C_6H_{10}O$	0.948	1,423	4,668.6	4.0		
Decane(46)	$C_{10}H_{20}$	0.730	1,252	4,107.6		1.26 (20ºC)	13.55 (68ºF)
1-Decene(27)	$C_{10}H_{20}$	0.746	1,235	4,051.8	4.0		
n-Decene(27)	$C_{10}H_{20}$	0.746	1,235	4,051.8	4.0		
Diacetyl	C_4H_6O	0.99	1,236	4,055.1	4.6		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.* Specific Gravity	Sound Speed m/s	Sound Speed ft/s	Δv/ºC m/s/ºC	Kinematic Viscosity×10^{-6} m^2/s	Kinematic Viscosity×10^{-6} ft^2/s
Diamylamine	$C_{10}H_{23}N$		1.256	4,120.7	3.9		8.5 (68°F)
1,2Dibromo-ethane(47)	$C_2H_4Br_2$	2.18	995	3,264.4		0.79 (20ºC)	
trans-1,2-Dibromoethene (47)	$C_2H_2Br_2$	2.231	935	3,067.6			
Diburtylphthalate	$C_8H_{22}O_4$		1,408	4,619.4			
Dichloro-t-butylalcohol	$C_4H_8Cl_2O$		1,304	4,278.2	3.8		
2,3Dichlorodioxane	$C_2H_6Cl_2O_2$		1,391	4,563.6	3.7		
Dichloeodifluoromethane (3)(Freon12)	CCl_2F_2	1.516 (40ºC)	774.1	2,539.7	4.24		
1,2Dichloro ethane(47)	$C_2H_2Cl_2$	1.253	1,193	3,914		0.61	6.563
cis1,2-Dichloro-ethene (3,47)	$CHCl_2F$	1.284	1,061	3,481			
trans1,2-Dichloro-ethene (3,47)	$C_4Cl_2F_6$	1.257	1,010	3,313.6			
Dichloro-fluoromethane (3)(Freon21)	$C_4H_8Cl_2$	1.426 (0ºC)	891 (0ºC)	2,923.2 (32°F)	3.97		
1-2-Dichlorohexafluoro-cyclobutane(47)	$CClF_2$-$CClF_2$	1.654	669	2,914.9			
1-3-Dichloro-isobutane	$C_4H_{10}O$	1.14	1,220	4,002.6	3.4		
Dichloro methane(3)	$C_4H_{10}O_3$	1.327	1,070	3,510.5	3.94	0.31	3.335
1,1-Dichloro-1,2,2,2 tetra fluoromethane	$C_6H_{14}O_3$	1.455	665.3 (-10ºC)	2,182.7 (14°F)	3.73		
Diethyl ether	C_4H_9NO	0.713	985	3,231.6	4.87	0.311	3.346
Diethylene glycol	$C_4H_8(NF2)_2$	1.116	1,586	5,203.4	2.4		
Diethylene glycol Monoethyl ether	$C_4H_9(NF_2)_2$	0.988	1,458	4,783.5			
Diethylenmide oxide	$C_3H_6(NF_2)_2$	1.00	1,442	4,731	3.8		
1,2-bis(DiFluoramino) butane(43)	$C_{10}H_{23}N$	1.216	1,000	3,280.8			
1,2-bis(DiFluoramino)-2-methylpropane(43)	$C_2H_4Br_2$	1.213	900	2,952.8			
1,2-bis(DiFluoramino) propane(43)	$C_2H_2Br_2$	1.265	960	3,149.6			

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^-6	
			m/s	ft/s	m/s/ºC	m²/s	ft²/s
2,2-bis(Difluoromino propane(43)	$C_3H_6(NF_2)_2$	1.254	890	2920			
2,2-Dihydroxydiethyl ether	$C_4H_{10}O_3$	1.116	1,586	5,2034	2.4		
Dihydroxyethane	$C_2H_6O_2$	1.113	1,658	5,439.6	2.1		
1,3-Dimethyl-benzene(46)	C_8H_{10}	0.868 (15ºC)	1,343 (20ºC)	4,406.2 (68°F)		0.749 (15ºC)	8.059 (59°F)
1,2-Dimethyl-benzene (29,46)	C_8H_{10}	0.897 (20ºC)	1,331.5	4,368.4	4.1	0.903 (20ºC)	9.716 (68°F)
1,4-Dimethyl-benzene(46)	C_8H_{10}		1,334 (20ºC)	4,376.6 (68°F)		0.662	7.123
2,2Dimethyl-butane (29,33)	C_6H_{14}	0.649 (20ºC)	1,079	3,540			
Dimethyl ketone	C_3H_6O	0.791	1,174	3,851.7	4.5	0.399	4.293
Dimethylpentane(47)	C_7H_{16}	0.674	1,063	3,487.5			
Dimethylphthalate	$C_8H_{10}O_4$	1.2	1,463	4,799.9			
Diiodo-methane	CH_2l_2	3.235	980	3,215.2			
Dioxane	$C_4H_8O_2$	1.033	1,376	4,514.4			
Dodecane(23)	$C_{12}H_{26}$	0.749	1,279	4,196.2	3.85	1.80	19.368
1,2Ethanediol	$C_2H_6O_2$	1.113	1,658	5,439.6	2.1		
Ethanenitrile	C_2H_3N	0.783	1,290	4,232.3		0.441	4.745
Ethanoic anhydride(22)	$(CH_3CO)_2O$	1.082	1,180	3,871.4		0.769	8.274
Ethanol	C_2H_6O	0.789	1,207	3,690	4.0	1.39	14.956
Ethanol amide	C_2HNO	1.018	1,338 (20ºC)	5,656.2	3.4		
Ethoxyethane	$C_4H_{10}0$	0.713	900 (20ºC)	3,231.6	4.87	0.311	3.346
Ethyl acetate(33)	$C_4H_8O_2$	0.901	876 (20ºC)	3,559.7	4.4	0.489	5.263
Ethyl alcohol	C_2H_6O	0.789	890	3,960	4.0	1.396	15.020
Ethyl benzene(46)	C_8H_{10}	0.867 (20ºC)	1,586	4,389.8 (68°F)		0.797 (17ºC)	8.575 (63°F)
Ethyl Bromide(46)	C_2H_5Br	1.456 (20ºC)	1,658	2,952.8 (68°F)		0.275 (20ºC)	2.959 (68°F)
Ethyliodide(46)	C_2H_5l	1.950 (20ºC)	1,343 (20ºC)	2874 (68°F)		0.29	3.12

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
Ether	$C_4H_{10}O$	0.713	985	3231.6	4.87	0.311	3.346
Ethyl ether	$C_4H_{10}O$	0.713	985	3231.6	4.87	0.311	3.346
Ethylene bromide(47)	$C_2H_4Br_2$	2.18	995	3264.4		0.79	8.5
Ethylene chloride(47)	$C_2H_4Cl_2$	1.253	1,193	3914		0.61	6.563
Ethylene glycol	$C_2H_6O_2$	1.113	1,658	5439.6	2.1	17.208 (20ºC)	185.158 (68°F)
d-Fenochone	$C_{10}H_{16}O$	0.974	1,320	4330.7		0.22	2.367
d-2-Fenechanone	$C_{10}H_{16}O$	0.974	1,320	4330.7		0.22	2.367
Fluorine	F	0.545 (-143ºC)	403 (-143ºC)	1322.2 (-225°F)	11.31		
Fluoro-benzene(46)	C_6H_5F	1.024 (20ºC)	1,189	3900.9		0.584 (20ºC)	6.283 (68°F)
Formaldehyde,methylester	$C_2H_4O_2$	0.974	1,127	3697.5	4.02		
Formamide	CH_3NO	1.134 (20ºC)	1,622	5321.5	2.2	2.91	31.311
Formic acid,amide	CH_3NO	1.134 (20ºC)	1,622	5321.5		2.91	31.311
Freon R12			774.2	2540			
Furfural	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
Furfuryl alcohol	$C_5H_6O_2$	1.135	1,450	4757.5	3.4		
Fural	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
2-Furaldehyde	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
2-Furancarboxaldehyde	$C_5H_4O_2$	1.157	1,444	4737.5	3.7		
2-Furyl-Methanol	$C_5H_6O_2$	1.135	1,450	4757.2	3.4		
GAllium	Ga	6.095	2,870 (30ºC)	9416 (86°F)			
Glycerin	$C_3H_8O_3$	1.26	1,904	6246.7	2.2	757.1	
Glycerol	$C_3H_8O_3$	1.26	1,904	6246.7	2.2	757.1	
Glycol	$C_2H_6O_2$	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	*All data given at 25ºC(77° F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
Helium(45)	He_4	0.125 (-269ºC)	183 (-269ºC)	600.4 (-452°F)		0.025	269
Heptane(22,23)	C_7H_{16}	0.684 (20ºC)	1,131	3,710.6	4.25	0.598 (20ºC)	6.434 (68°F)
n-Heptane(29,33)	C_7H_{16}	0.684 (20ºC)	1,180	3,871.3	4.0		
Hexachloro-Cyclopentadiene(47)	C_5Cl_6	1.7180	1,150	3,773			
Hexadecane(23)	$C_{16}H_{34}$	0.773 (20ºC)	1,338	4,389.8	3.71	4.32 (20ºC)	46.483 (68°F)
Hexalin	$C_6H_{12}O$	0.962	1,454	4,770.3	3.6	70.69 (17ºC)	760.882 (63°F)
Hexane(16,22,23)	C_6H_{14}	0.659	1,112	3,648.3	2.71	0.446	4.798
n-Hexane(29,33)	C_6H_{14}	0.649 (20ºC)	1,079	3,540	4.53		
2,5Hexanedione	$C_6H_{10}O_2$	0.729	1,399	4,589.9	3.6		
n-Hexanol	$C_6H_{14}O$	0.819	1,300	4,265.1	3.8		
Hexahydrobenzene(15)	C_6H_{12}	0.779	1,248	4,094.5	5.41	1.31 (17ºC)	14.095 (63°F)
Hexahydrophenol	$C_6H_{12}O$	0.962	1,454	4,770.3			
Hexamethylene(15)	C_6H_{12}	0.779	1,248	4,094.5		1.31 (17ºC)	14.095 (63°F)
Hydrogen(45)	H_2	0.071 (-256ºC)	1,187 (-256ºC)	3,894.4 (-429°F)		0.003 (-256ºC)	0.032 (-429°F)
2-Hydroxy-toluene(46)	C_7H_8O	1.047 (20ºC)	1.541 (20ºC)	5,055.8 (68°F)		4.29 (40ºC)	46.16 (104°F)
3-Hydroxy-toluene(46)	C_6H_5l	1.034 (20ºC)	1,500 (20ºC)	4,921.3 (68°F)		5.979 (40ºC)	64.334 (104°F)
lodo-benzene(46)	C_2H_5l	1.823	1,114 (20ºC)	3,654.9 (68°F)		0.954	
lodo-ethane(46)	CH_3l	1.950 (20ºC)	876 (20ºC)	2,874 (68°F)		0.29	3.12
lodo-methane	$C_6H_{12}O$	2.28 (20ºC)	978	3,208.7		0.211	2.27
isobutylacetate(22)	He_4		1,180 (27ºC)	3,871.4 (81°F)	4.85		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77°F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
lsobutanol	$C_4H_{10}O$	0.81 (20ºC)	1,212	3,976.4			
lso-Butane			1,219.8	4002			
lsopentane(36)	C_5H_{12}	0.62 (20ºC)	980	3,215.2	4.8	0.34	3.658
lsopropano(46)	C_3H_8O	0.758 (20ºC)	1,170 (20ºC)	3,838.6 (68°F)		2.718	29.245
Lsopropyl alcohol(46)	C_3H_8O	0.758 (20ºC)	1,170 (20ºC)	3,838.6 (68°F)		2.718	29.245
Kerosene		0.81	1,324	4,343.8	3.6		
Ketohexamethylene	$C_6H_{10}O$	0.948	1,423	4,668.6	4.0		
Lithium fluoride(42)	LiF		2,485 (900ºC)	8,152.9 (1652°F)	1.29		
Mercury(45)	Hg	13.594	1,449 (24ºC)	4,753.9 (75°F)		0.114	1.226
Mesityloxide	$C_6H_{16}O$	0.85	1,310	4,297.9			
Methane(25,28,38,39)	CH_4	0.162 (-89ºC)	405 (-89ºC)	1,328.7 (-128°F)	17.5		
Methano(40,41)	CH_4O	0.791 (20ºC)	1,076	3,530.2	2.92	0.695	7.748
Methyl acetate	$C_3H_6O_2$	0.934	1,211	3,973.1		0.407	4.379
o-Methyaniline(46)	C_7H_9N	0.999 (20ºC)	1,618	5,308.4		4.394 (20ºC)	47.279 (68°F)
4-Methyaniline(46)	C_7H_9N	0.966 (45ºC)	1,480	4,855.6		1.863 (50ºC)	20.095 (122°F)
Methyl alcohol(40,44)	CH_4O	0.791 (20ºC)	1,076	3,530.2	2.92	0.695	7.478
Methyl benzene(16,52)	C_7H_8	0.867	1,328 (20ºC)	4,357 (68°F)	4.27	0.644	7.144
2-Methyl-butane(36)	C_5H_{12}	0.62 (20ºC)	980	3,215.2		0.34	3.658
Methycarbinol	C_2H_6O	0.789	1,207	3,960	4.0	1.396	
Methy-chloroform(47)	$C_2H_3Cl_3$	1.33	985	3,231.6		0.902 (20ºC)	9.705 (68°F)
Methyl-cyanide	C_2H_3N	0.783	1,290	4,232.3		0.441	4.745
3-Methyl cyclohexanol	$C_7H_{14}O$	0.92	1,400	4,593.2			

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77° F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
Methylene chloride(3)	CH_2Cl_2	1.327	1,070	3,510	3.94	0.31	3.335
Methylene iodide	CH_2I_2	3.235	980	3,215.2			
Methyl formate(22)	$C_2H_4O_2$	0.974 (20ºC)	1,127	3,697.5	4.02		
Methyl iodide	CH_3I	2.28 (20ºC)	978	3,208.7		0.211	2.27
a-Methyl naphthalene	$C_{11}H_{10}$	1.090	1,510	4,954.1	3.7		
2-Methylpheno(46)	C_7H_8O	1.047 (20ºC)	1,541 (20ºC)	5,055.8 (68°F)		4.29 (40ºC)	46.16 (104°F)
3- Methylpheno(46)	C_7H_8O	1.034 (20ºC)	1,500 (20ºC)	4,921.3 (68°F)		5.979 (40ºC)	64.334 (104°F)
Milk,homogenized			1,548	5,080			
Morpholine	C_4H_9NO		1,442	4,731	3.8		
Naphtha		1.00	1,225	4,091			
Natural Gas(37)		0.76	753 (-103ºC)	2,470.5 (-153°F)			
Neon(45)	Ne	0.316 (-103℃)	595 (-246ºC)	1,952.1 (-411°F)			
Nitrobenzene(46)	$C_6H_5NO_2$	1.207 (-246℃)	1,415 (20ºC)	4,642.4 (68°F)		1.514	16.29
Nitrogen(45)	N_2	1.204 (20ºC)	962 (-199ºC)	3,156.2 (-326°F)		0.217 (-199ºC)	2.334 (-326°F)
Nitromethane(43)	CH_3NO_2	0.808 (-199℃)	1,300	4,265.1	4.0	0.549	5.90
Nonane(23)	C_9H_2O	1.135	1,207	3,960	4.04	0.99 (20ºC)	10.652 (68°F)
1-Nonene(27)	C_9H_{18}	0.718 (20ºC)	1,207	3,960	4.0		
Octane(23)	C_8H_{18}	0.736 (20ºC)	1,172	3,845.1	4.14	0.73	7.857
n-OCtane(29)	C_8H_{18}	0.723 (20ºC)	1,212.5	3,978	3.50	0.737	0.930
1-OCtane(27)	C_8H_{16}		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	$C_{11}H_{10}O_{10}$		1,477	4,854.8	3.6	0.670	7.209

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/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 (22ºC)	4,951 (72°F)			
2,2-Oxydiethanol	$CH_{10}O_3$	1.116	1,586	5,203.4	2.4		
Oxygen(45)	O_2	1.155 (-186ºC)	952 (-186ºC)	3,123.4 (-303°F)		0.173	1.861
Pentachloro-ethane(47)	C_2HCl_5	1.687	1,082	3,549.4			
pentalin(47)	C_2HCl_5	1.687	1,082	3,549.4			
Pentane(36)	C_5H_{12}	0.626 (20ºC)	1,020	3,346.5		0.363	3.905
n-pentane(47)	C_5H_{12}	0.557	1,006	3,300.5		0.41	4.413
Perchlorocyclopentadiene(47)	C_5Cl_6	1.718	1,150	3,773			
Perchloro-ethylene(47)	C_2Cl_4	1.632	1,036	3,399			
Perfluoro-1-Hepten(47)	C_7F_{14}	1.67	583	1,912.7			
Perfluoro-n-Hexane(47)	C_6H_{14}	1.672	508	1,666.7			
Phene(29,40,41)	C_6H_6	0.879	1,306	4,284.8	4.65	0.711	7.65
b-Phenyl acrolein	C_9H_8O	1.112	1,554	5,098.4	3.2		
Phenylamine(41)	$C_6H_5NO_2$	1.022	1,639	5,377.3	4.0	3.63	39.058
Phenyl bromide(46)	C_6H_5Br	1.522	1,170 (20ºC)	3,838.6 (68°F)		0.693	7.465
Phenyl chloride	C_6H_5Cl	1.106	1,273	4,176.5	3.6	0.722	7.768
Phenyl iodide(46)	C_6H_5l	1.823	1,114 (20ºC)	3,654.9 (68°F)		0.954 (15ºC)	10.265 (59°F)
Phenyl methane(16,52)	C_7H_8	0.867 (20ºC)	1,328 (20ºC)	4,357 (68°F)	4.27	0.644	6.929
3-Phenylpropenal	C_9H_8O	1.112	1,554	5,098.4	3.2		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
Phthalardione	$C_8H_4O_3$		1,125 (152ºC)	3,691 (306°F)			
Phthalicacid,anhydride	$C_8H_4O_3$		1,125 (152ºC)	3,691 (306°F)			
Phthalicanhydride	$C_8H_4O_3$		1,125 (152ºC)	3,691 (306°F)			
Pimelicketone	$C_6H_{10}O$	0.948	1,423	4,668.6	4.0		
Plexiglas,Lucite,Acrylic			2,651	8,698			
PolyterpeneResin		0.77	1,099.8 (190ºC)	3,608.4 (374°F)		39,000	419,500
Potassium bromide(42)	KBr		1,169 (900ºC)	3,835.3 (1652°F)	0.71	715CP (900ºC)	7.693 (1652°F)
Potassium fluoride(42)	KF		1,792 (900ºC)	5,879.3 (1652°F)	1.03		
Potassium iodide(42)	Kl		958 (900ºC)	3,231.6 (1652°F)	0.64		
Potassium nitrate(48)	KNO_3	1.859 (352ºC)	1,740.1 (352ºC)	5,709 (666°F)	1.1	1.19 (327ºC)	12.804 (621°F)
Propane(2,13) (-45°to-130ºC)	C_3H_8	0.585 (-45ºC)	1,003 (-45ºC)	3,290.6 (-46°F)	5.7		
1,2,3-Propanetriol	$C_3H_8O_3$	1.26	1,904	6,246.7	2.2	000757	
1-Propanol(46)	C_3H_8O	0.78 (20ºC)	1,222 (20ºC)	4,009.2 (68°F)			
2-Propanol(46)	C_3H_8O	0.785 (20ºC)	1,170 (20ºC)	3,838.6 (68°F)		2.718	29.245
2-Propanone	C_3H_6O	0.791	1,174	3,851.7	4.5	0.399	4.293
Propene(17,18,35)	C_3H_6	0.563 (-13ºC)	963 (-13ºC)	3,159.4 (9°F)	6.32		
N-propyl-acetate(22)	$C_5H_{10}O_2$		1,280 (2ºC)	4,199 (36°F)	4.63		
n-propyl-alcohol	C_3H_8O	0.78 (20ºC)	1,222 (20ºC)	4,009.2 (68°F)		2.549	27.427
propylchloride(47)	C_3H_7Cl	0.892	1,058	3,471.1		0.378	4.067
propylene(17,18,35)	C_3H_6	0.536 (-13ºC)	963 (-13ºC)	3,159.4 (9°F)	6.32		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77º F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
Pyridne	C_6H_5N	0.982	1,415	4,642.4	4.1	0.992 (20ºC)	10.673 (68°F)
Refrigerant11(3,4)	CCl_3F	1.49	828.3 (0ºC)	2,717.5 (32°F)	3.56		
Refrigerant12(3)	CCl_2F_2	1.516 (-40ºC)	774.1 (-40ºC)	2,539.7 (-40°F)	4.24		
Refrigerant14(14)	CF_4	1.75 (-150ºC)	875.24 (-150ºC)	2,871.5 (-238°F)	6.61		
Refrigerant21(3)	$CHCl_2F$	1.426 (0ºC)	891 (0ºC)	2,923.2 (32°F)	3.97		
Refrigerant22(3)	$CHClF_2$	1.491 (-69ºC)	893.9 (50ºC)	2,932.7 (122°F)	4.79		
Refrigerant113(3)	CCl_2F-$CClF_2$	1.563	783.7 (0ºC)	2,571.2 (32°F)	3.44		
Refrigerant114(3)	$CClF_2$-$CClF_2$	1.455	665.3 (-10ºC)	2,182.7 (14°F)	3.73		
Refrigerant115(3)	C_2ClF_5		656.4 (-50ºC)	2,153.5 (-58°F)	4.42		
RefrigerantC318(3)	C_4F_8	1.62 (-20ºC)	574 (-10ºC)	1,883.2 (41°F)	3.88		
Selenium(8)	Se		1,072 (250ºC)	3,517.1 (482°F)	0.68		
Silicone(30cp)		0.993	990	3,248		30	322.8
Sodiumfluoride(42)	NaF	0.877	2,082 (1000ºC)	6,830.7 (1832°F)	1.32		
Sodiumfluoride(48)	$NaNO_3$	1.884 (336ºC)	1,763.3 (336ºC)	5,785.1 (637°F)	0.74	1.37 (336ºC)	14.74 (637ºC)
Sodiumfluoride(48)	$NaNO_2$	1.805 (292ºC)	1,876.8 (292ºC)	6,157.5 (558°F)			
Solvesso#3		0.877	1,370	4,494.8	3.7		
Spiritofwine	C_2H_6O	0.789	1,207	3,960	4.0	1.397	15.02
Sulfur(7,8,10)	S		1,177 (250ºC)	3,861.5 (482°F)	-1.13		
SulfueicAcid(1)	H_2SO_4	1.841	1,257.6	4,126	1.43	11.16	120.081
Tellurium(7)	Te		991 (450ºC)	3,251.3 (842°F)	0.73		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25ºC(77° F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/ºC	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/ºC	m^2/s	ft^2/s
1,1,2,2-Tetrabromo-ethane(47)	$C_2H_2Br_4$	2.966	1,027	3,369.4			
1,1,2,2-Tetrachloro-ethane(67)	$C_2H_2Cl_4$	1.595	1,147	3,763.4		1.156 (15ºC)	12.438 (59°F)
Tetrachloroethane(46)	$C_2H_2Cl_4$	1.553 (20ºC)	1,170 (20ºC)	3,838.6 (68°F)		1.19	12.804
Tetrachloro-ethene(47)	C_2Cl_4	1.632	1,036	3,399			
Tetrachlor-Methane (33,47)	CCl_4	1.595 (20ºC)	926	3,038.1		0.607	6.531
Tetradecane(46)	$C1_4H_3O$	0.763 (20ºC)	1,331 (20ºC)	4,366.8 (68°F)		2.86 (20ºC)	30.773 (68°F)
Tetraethylene glycol	$C_8H_{18}O_5$	1.123	1,568	5,203.4	3.0		
Tetrafluoro-methane(14) (Freon14)	CF_4	1.75 (-150ºC)	875.24 (-150ºC)	2,871.5 (-238°F)	6.61		
Tetrahydro-1,4-isoxazine	C_4H_9NO	1.000	1,442	4,731	3.8		
Toluene(16,52)	C_7H_8	0.867 (20ºC)	1,328 (20ºC)	4,357 (68ºF)	4.27	0.644	6.929
o-Toluidine(46)	C_7H_9N	0.999 (20ºC)	1,618	5,308.4		4.394 (20ºC)	47.279 (68°F)
p-Toluidine(46)	C_7H_9N	0.966 (45ºC)	1,480	4,855.6		1.863 (50ºC)	20.053 (122°F)
Toluol	C_7H_8	0.866	1,308	4,291.3	4.2	0.58	6.24
Tribromo-methane(46,47)	$CHBr_3$	2.89 (20ºC)	918	3,011.8		0.645	7.037
1,1,1-Trichloro-ethane(47)	$C_2H_3Cl_3$	1.33	985	3,231.6		0.902 (20ºC)	9.705 (68°F)
Trichloro-ethene(47)	C_2HCl_3	1.464	1,028	3,372.7			
Trichloro-fluoromethaen (3)(Freon11)	CCl_3F	1.49	828.3 (0ºC)	2,171.5 (32°F)	3.56		
Trichloro-methane(47)	$CHCl_3$	1.489	979	3,211.9	3.4	0.55	5.918
1,1,2-Trichloro-1,2,22-Trifluoro-Etham	CCl_2F-$CClF_2$	1.563	783.7 (0ºC)	2,571.2 (32°F)			
Triethyl-amine(33)	$C_6H_{15}N$	0.726	1,123	3,684.4	4.47		
Triethyleneglycol	$C_6H_{14}O_4$	1.123	1,608	5,275.6	3.8		

Table A7 (continued): Sound Speed of Liquids

Substance	Chemical Formula	*All data given at 25°C(77° F) unless otherwise noted.*					
		Specific Gravity	Sound Speed		Δv/°C	Kinematic Viscosity×10^{-6}	
			m/s	ft/s	m/s/°C	m^2/s	ft^2/s
1,1,1-Trifluoro-2-Chloro-2-Bromo-Ethane	$C_2HClBrF_3$	1.869	693	2,273.6			
1,2,2-Trifluorotrichloro-ethane(Freon113)	CCl_2-$CClF_2$	1.563	783.7 (0°C)	2,571.2 (32°F)	3.44		
d-1,3,3-Trimethylnorcamphor	$C_{10}H_{16}O$	0.947	1,320	4,330.7		0.22	2.367
Trinitrotoluene(43)	$C_7H_5(NO_2)_3$	1.64	1,610 (81°C)	5,282.2 (178°F)			
Turpentine		0.88	1,255	4,117.5		1.4	15.064
Unisis800		0.87	1,346	4,416		1.00	
Water,distilled(49,50) Water,sea	H_2O	0.996	1,498	4,914.7	-2.4	0.695	10.76
WoodAlcihol(40,41)	D_2O		1,400	4,593	-2.4		
Xenon(45)		1.025	1,531	5,023	2.92	1.00	10.76
m-Xylene(46)	CH_4O	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_8H_{10}	0.868 (15°C)	1,343 (20°C)	4,406.2 (68°F)		0.749 (15°C)	8.059 (59°F)
Xylenehexafluoride	C_8H_{10}	0.897 (20°C)	1,331.5	4,368.4	4.1	0.903 (20°C)	9.716 (68°F)
Zinc(7)	C_8H_{10}		1,334 (20°C)	4,376.6 (68°F)		0.662	7.123
1,1,1-Trifluoro-2-Chloro-2-Bromo-Ethane	$C_8H_4F_6$	1.37	879	2,883.9		0.613	6.595
1,2,2-Trifluorotrichloro-ethane(Freon113)	Zn		3,298 (450°C)	10,820.2 (842°F)			