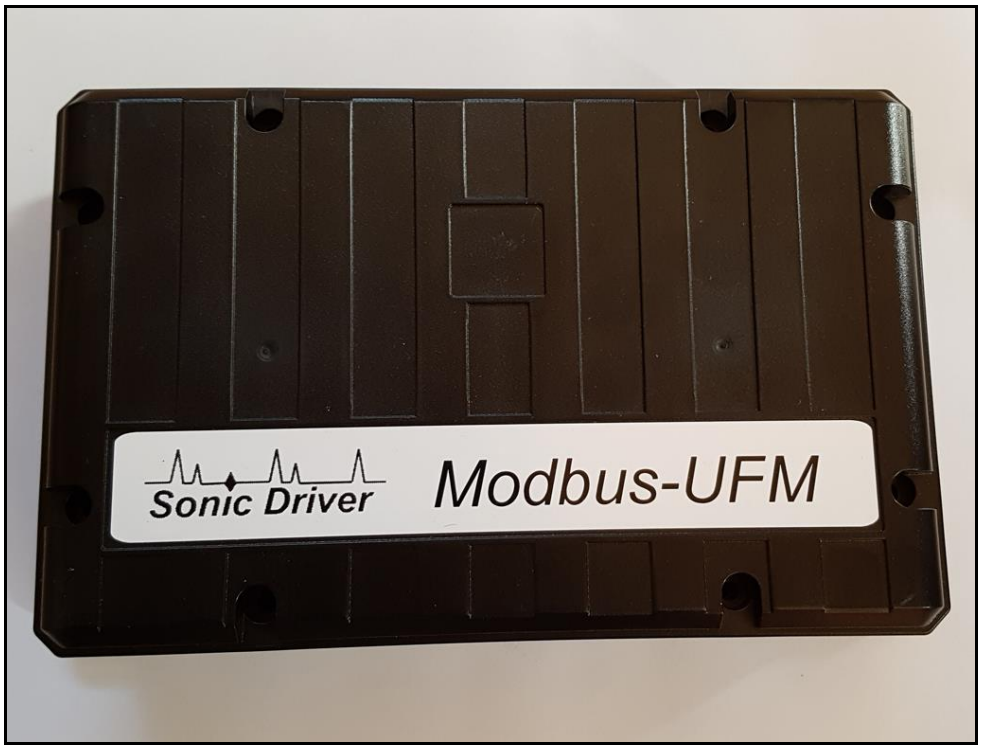
Made in Britain

MODBUS WALL-UFM Ultrasonic Flowmeter

Installation Manual

Version 4.0



1st July 2024

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1.0 Introduction

Congratulations on choosing the Sonic Driver ^{TM} MODBUS WALL-UFM wall or panel mounted clamp-on ultrasonic flowmeter, figure (1).

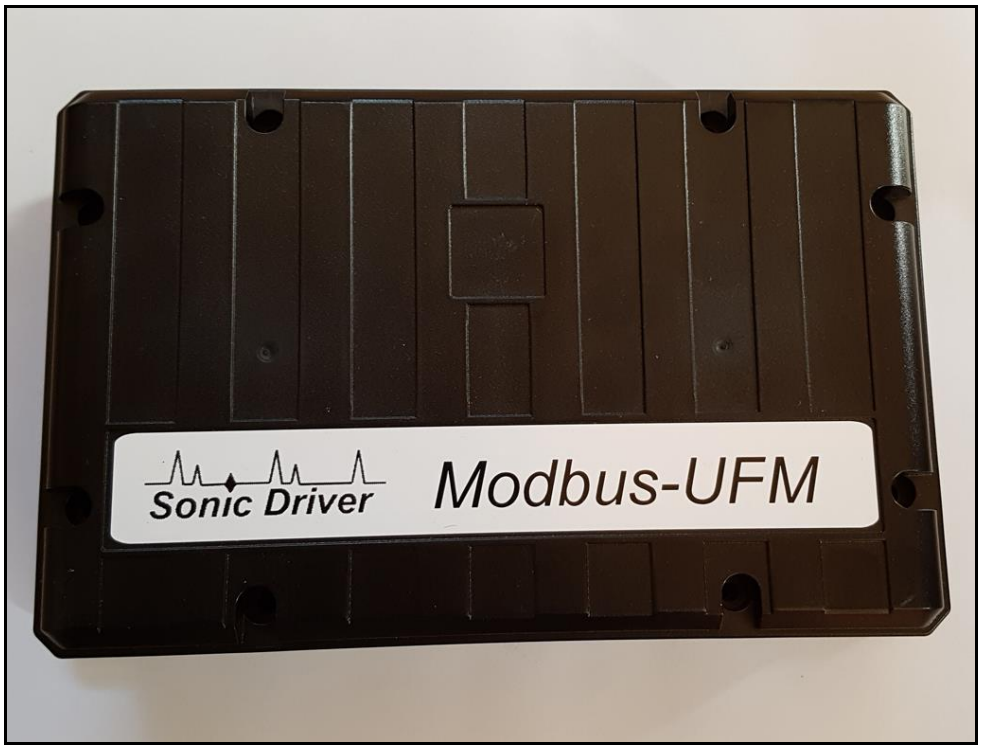

Figure (1) The Sonic Driver MODBUS WALL-UFM.

The ultrasonic flowmeter (UFM) uses advanced Digital Signal Processing (DSP) and transit time measurement techniques (Sonic Driver ^{TM}) to make accurate and reliable clamp-on ultrasonic flow velocity measurements on liquids flowing in closed pipes

Using information about the installation, entered by the user, using the meter's PC based configuration program (Windows) the UFM can calculate;

- Flow velocity (m/s)
- Volumetric flow rate (l/min)
- Mass flow rate (kg/min)
- Heat quantity flow rate (KJ/s)
- Inlet temperature (degC)
- Outlet temperature (degC)
- Flow positive total (l)
- Flow negative total (l)
- Flow net total (l)

When making heat measurements the UFM is designed to comply with EN1434-1 section 8 and its Appendix A.

In order to make heat measurements it is necessary to fit optional plug-in PT100 modules to measure inlet and outlet temperatures on heating or chilling systems.

All of the above flow measurements and a complete set of diagnostics are available over Modbus RTU RS485.

For installation a PC is connected to the UFM via a bidirectional USB/RS485 converter.

All installation parameters are available for editing over Modbus RTU.
The UFM comes in 3 different versions;

- Standard - outer pipe diameter ranged 10.0 to 115.0 mm
- Medium - outer pipe diameter ranged 115.0 to 225.0 mm
- Large - outer pipe diameter ranged 225.0 to 6500.0 mm

Once installed the PC and converter can be disconnected and the UFM connected to a Modbus RTU RS485 network and back to a control room or Cloud based monitoring applications where a Modbus Master polls the UFM Slave.

1.1 Transit Time Measurement

The principle of flow measurement using ultrasonic clamp-on transit time measurement is simple, see figure (2).

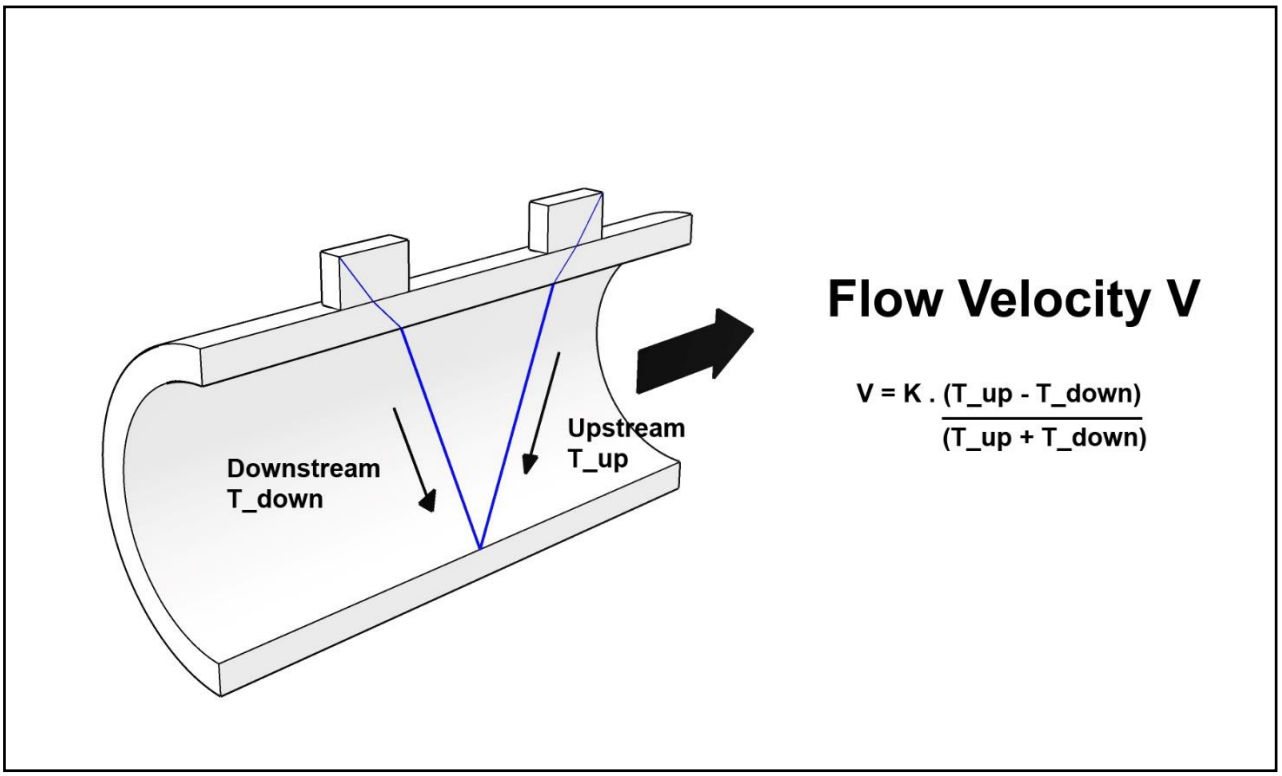

Figure (2) The principle of transit time flow measurement.

Two ultrasonic transducers are coupled or clamped to the outside of the pipe at a predetermined distance apart.

Ultrasonic pulses travel between the transducers through the pipe wall and the fluid within the pipe.

If the fluid is flowing then it takes slightly longer for the ultrasound to travel against the flow (upstream time T_up) than with the flow (downstream time T_down), see figure(2).

In a typical installation the individual times measured upstream and downstream are just a few hundred microseconds, the difference between them is typically measured in tens of nanoseconds.

This very small time difference (T_up - T_down) is measured by the UFM and is directly proportional to the flow velocity (V) of the fluid.

Knowing the pipe internal cross-sectional area the UFM can calculate volumetric flow rate in many common engineering units. A further knowledge of the density of the fluid allows the UFM to calculate mass flow rate.

Finally, a knowledge of inlet and outlet fluid temperature and Enthalpy of the fluid allows the UFM to calculate heat flow rate.

1.2 Packing List

Within the UFM packaging you should find;

Item	Quantity
MODBUS WALL-UFM	1
PEEK/Stainless Steel Flow Transducer	2
Chain Mounting Clamp	2
Tape Measure	1
Coupling Gel	1

Table (1) Packing List.

If any item on the packing list is missing or has been damaged in transit contact Service, see Appendix A.

1.3 General Precautions

The content of this manual has been carefully checked and is believed to be accurate.

Sonic Driver Ltd assumes no responsibility for any inaccuracies that may be contained in this manual.

In no event will Sonic Driver be liable for direct, indirect, special, incidental or consequential damages resulting from any defect or omission in this manual, even if we are advised of the possibility of such damages.

Sonic Driver Ltd reserves the right to make improvements to its manuals, instructions and products at any time, without notice or obligation. The latest revisions may be found on the company web site, see appendix A.

The UFM is a precision measuring instrument and should be handled and operated with care;

- Before operating the UFM for the first time read the installation manual and operating instruction fully.
- Further detail on connecting and using the UFM on a Modus RTU network are available in Modbus WALL Ultrasonic Flowmeter Modbus RTU Slave Meter, Operating Instructions, including a full register map.
- Only use the UFM in the way and for the purpose that it is intended.
- Do not subject the UFM to bumps and shocks such as caused by dropping the UFM.
- Keep the UFM and its transducers and probes clean.
- Only use the UFM within its ambient temperature and stated level of Ingress Protection.
- Avoid excessive stress and bending of transducer cables and connectors.

1.4 Cleaning

Wipe the UFM and sensors with tissue or soft cloth after use, remove excess coupling gel.

1.5 Connecting the Flow Transducers

Connect the flow transducers to the screw terminal connectors in the screw terminal compartment of the UFM, see figure (3).

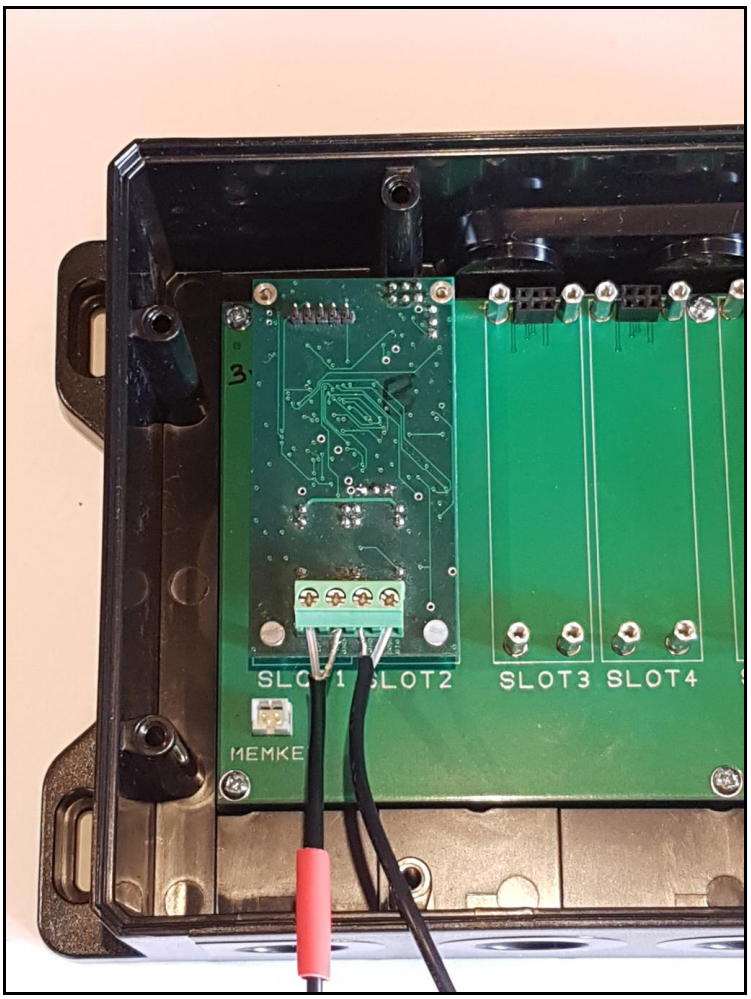

Figure (3) Flow transducer connection.

The left-hand screw terminals connect the flow transducer which is mounted on the pipe downstream, the right-hand screw terminals connect the flow transducer which is mounted upstream.

Note the orientation of each cable's core and braid in the screw terminals in figure (3).

1.6 Mounting the Flow Transducers

Mount the flow transducers on the pipe using the chain clamps supplied, see figure (4). Ensure that the arrow on the labels (arrowhead and flights) on the flow transducers is pointing in the direction of flow.

Use coupling gel between the transducers and the pipe to give good ultrasonic contact.

Measure the spacing of the transducers using the tape measure provided, note that spacing is measured between the front faces of the transducers. Ensure the transducers are facing each other and aligned axially along the pipe.

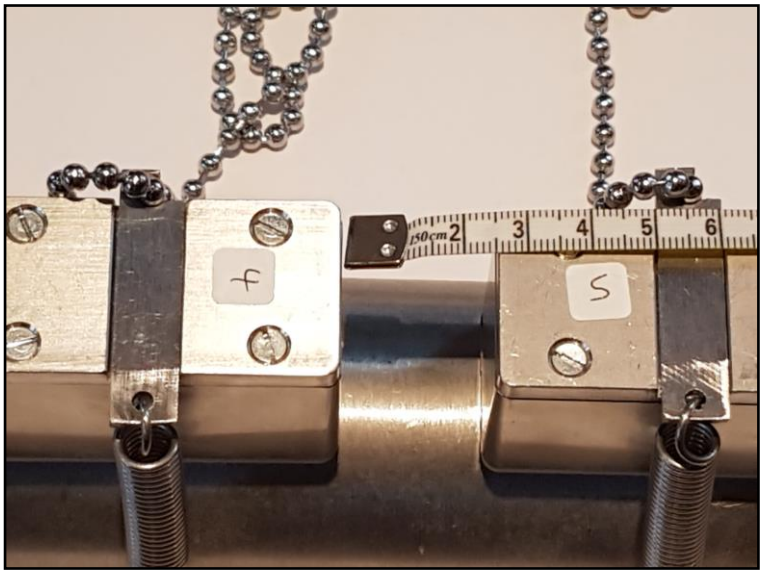

Figure (4) Flow transducer mounting, spacing is 25mm between front faces.

In figure (5) and figure (6) the transducers are misaligned and twisted, as a result the UFM will make poor flow measurements.

Figure (5) Misaligned transducers.

Figure (6) Twisted transducers.

1.7 Mounting the UFM

When wall mounting the UFM refer to Figure (7),

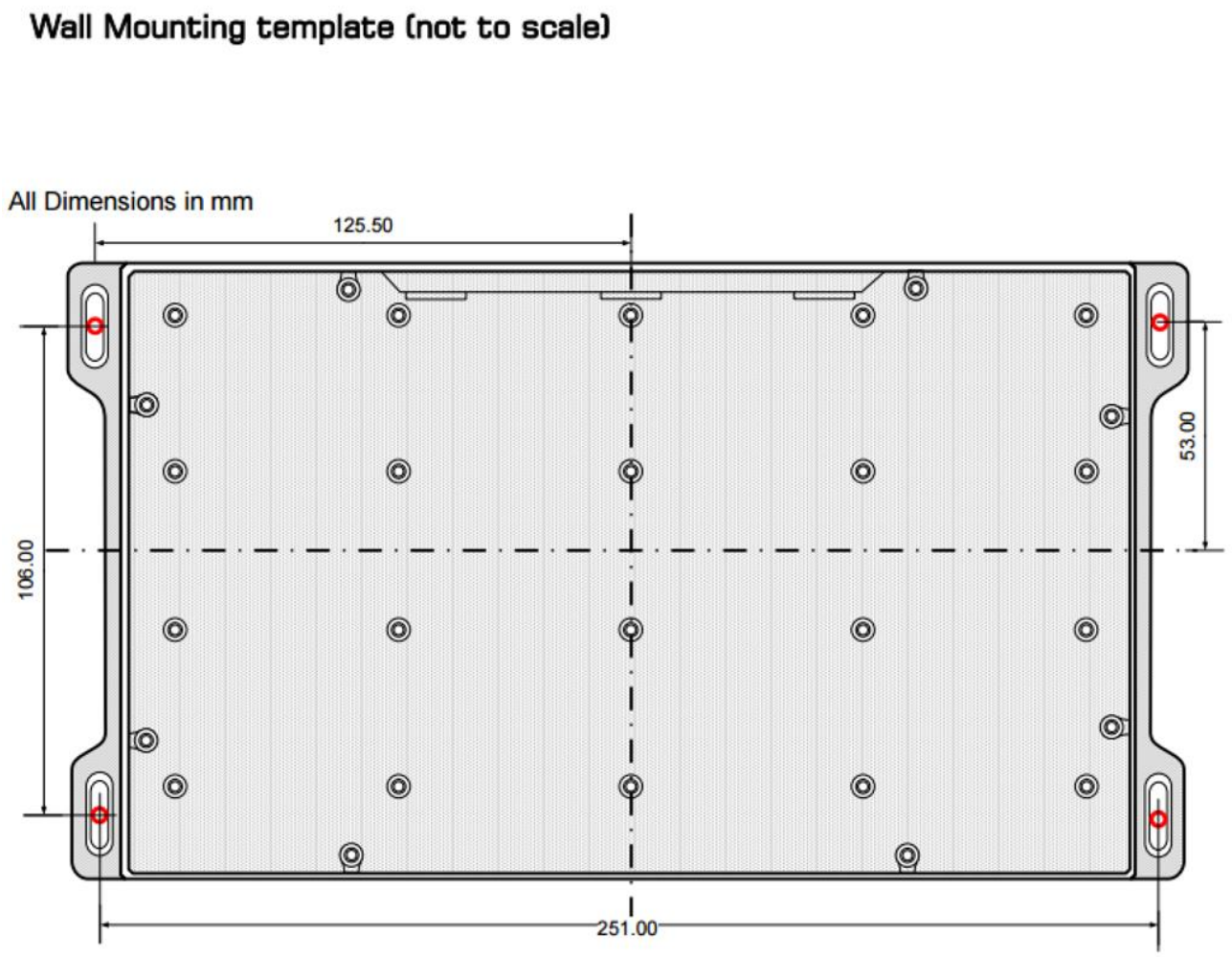

Figure (7) Wall mounting the UFM.

1.8 Wiring the UFM

To power on the UFM simply apply DC power.

Only qualified Electricians should install the UFM.

Always install a ground fault interrupt circuit (GFIC)/residual current circuit breaker (RCCB) with a maximum trigger current of 30 mA.

If installed outside, provide over voltage protection through an MCB rated not greater than 5 Amps.

With fixed wiring, a disconnecting device (local interruption) must be integrated into the power supply line. It must be installed near the device, be able to be reached easily by the operator and labelled as a disconnecting device.

Use cable glands to match the IP rating of the enclosure and its installation.

1.9 Turning the UFM On

To power on the UFM simply apply DC power.

As soon as the UFM is switched on a self-diagnostic program will start. If an error is detected an error will be available in the Modbus error code register. If the error persists, contact customer support.

Error codes and their meanings can be found at the end of this manual, appendix C.

1.10 Modbus RTU RS485 Connection

Flow measurements and a complete set of diagnostics from the UFM are available over Modbus RTU RS485.

Physical connection to the 2-wire bus is made via the screw terminals on the MODBUS WALL-UFM labelled ‘A’ and ‘B’, see Figure (8).

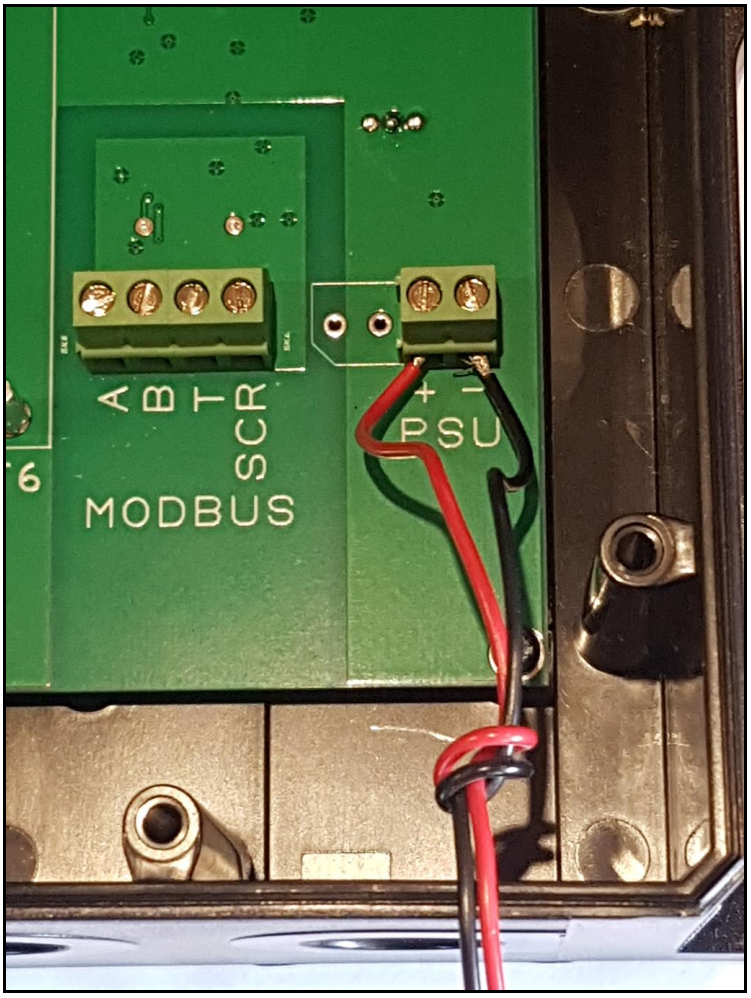

Figure (8) Physical Modbus RTU connections

Note that some equipment manufacturers label their terminals in other ways, e.g., ‘+’ and ‘-‘ so the exact order that the wires are connected may be reversed.

The terminal marked SCR is for connection of a cable screen. This may be connected at the Master or Slave UFM if necessary.

For installation and commissioning a PC is connected to the UFM via a bidirectional USB/RS485 converter.

All installation parameters are available for editing over Modbus RTU.

Once installed the PC and converter can be disconnected and the UFM connected to a Modbus RTU network or back to a control room where a Modbus Master polls the UFM Slave.

2.0 Installing and Using the Configuration Program

2.1 Installation

Create a folder on the PC drive, typically named C:\MODBUS WALL-UFM

Download or copy the installation program from the supplied media to the folder.

If supplied in zip format then unzip the file into the folder.

Locate and run the setup.exe program.

Follow the on-screen instructions.

2.2 Using the Configuration Program

When the Configuration program is run the following dashboard is displayed, Figure (9).

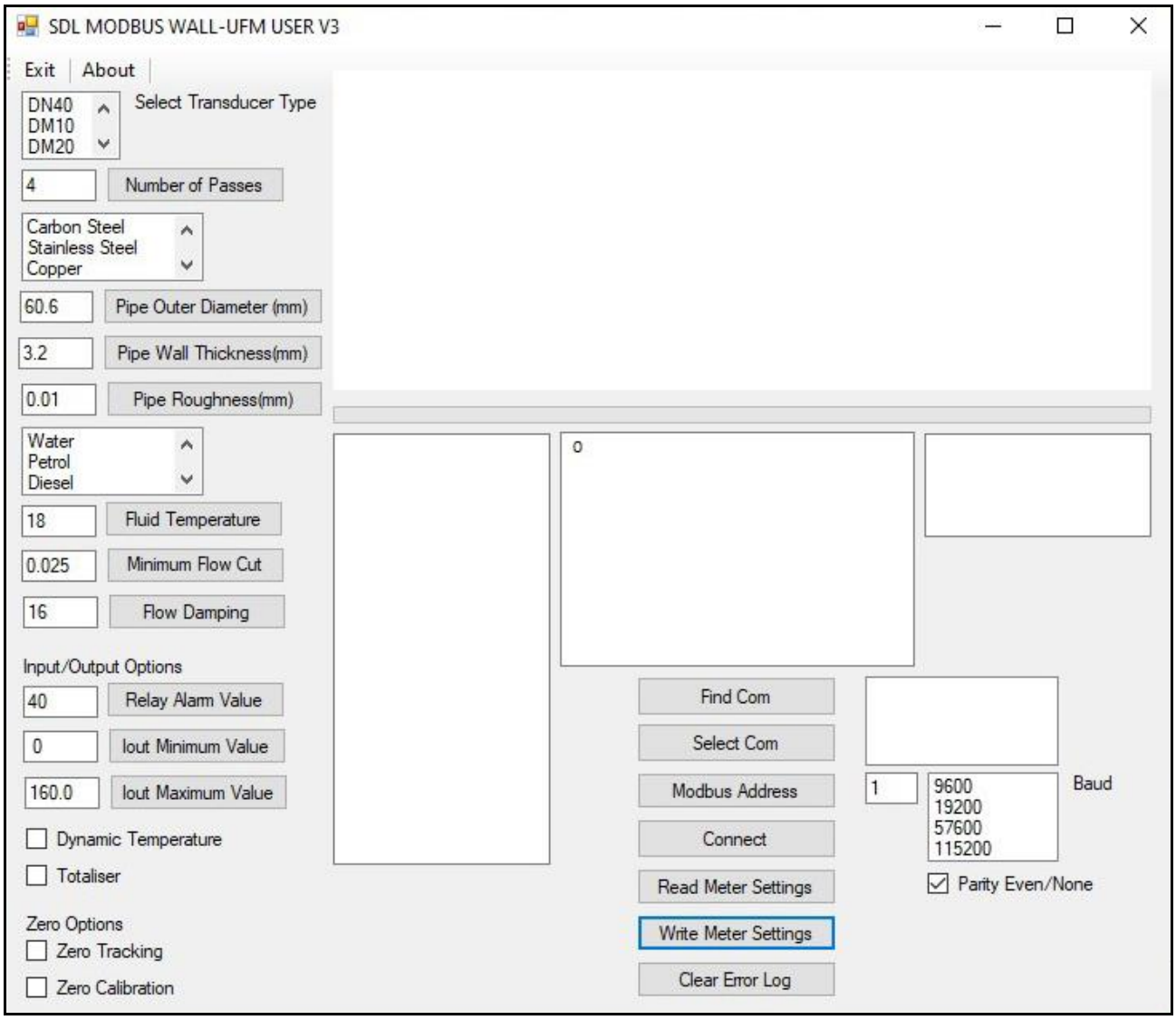

Figure (9) Configuration Program Dashboard

When run the dashboard is blank, as shown. It is necessary to connect to the UFM.

Click the Find Com button, see figure (10).

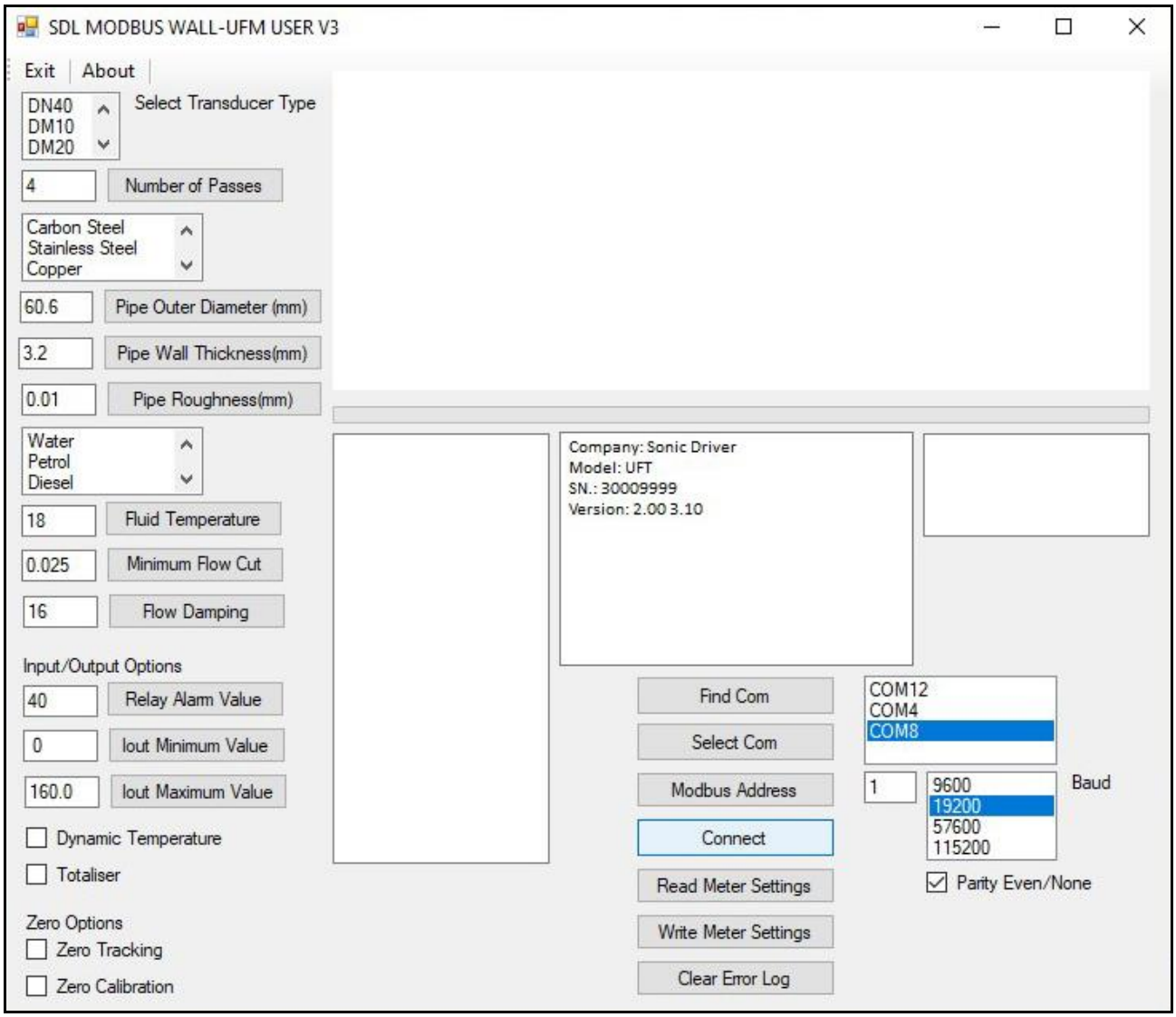

Figure (10) Connect to the UFM

A list of available comports will be shown. Highlight the comport associated with the USB/RS485 converter in use by clicking on the list, it will highlight in blue. The correct com port to use can be identified using Windows Device Manager.

The baud rate will automatically change to 115200. Change this option to 19200.

As shipped the Modbus address of the UFM is set to 1. At this time do not change this value.

Press the Select Com button to use the highlighted comport.

Now press the Connect button, the configuration program will connect to the UFM and show a set of default factory parameters, see figure (11).

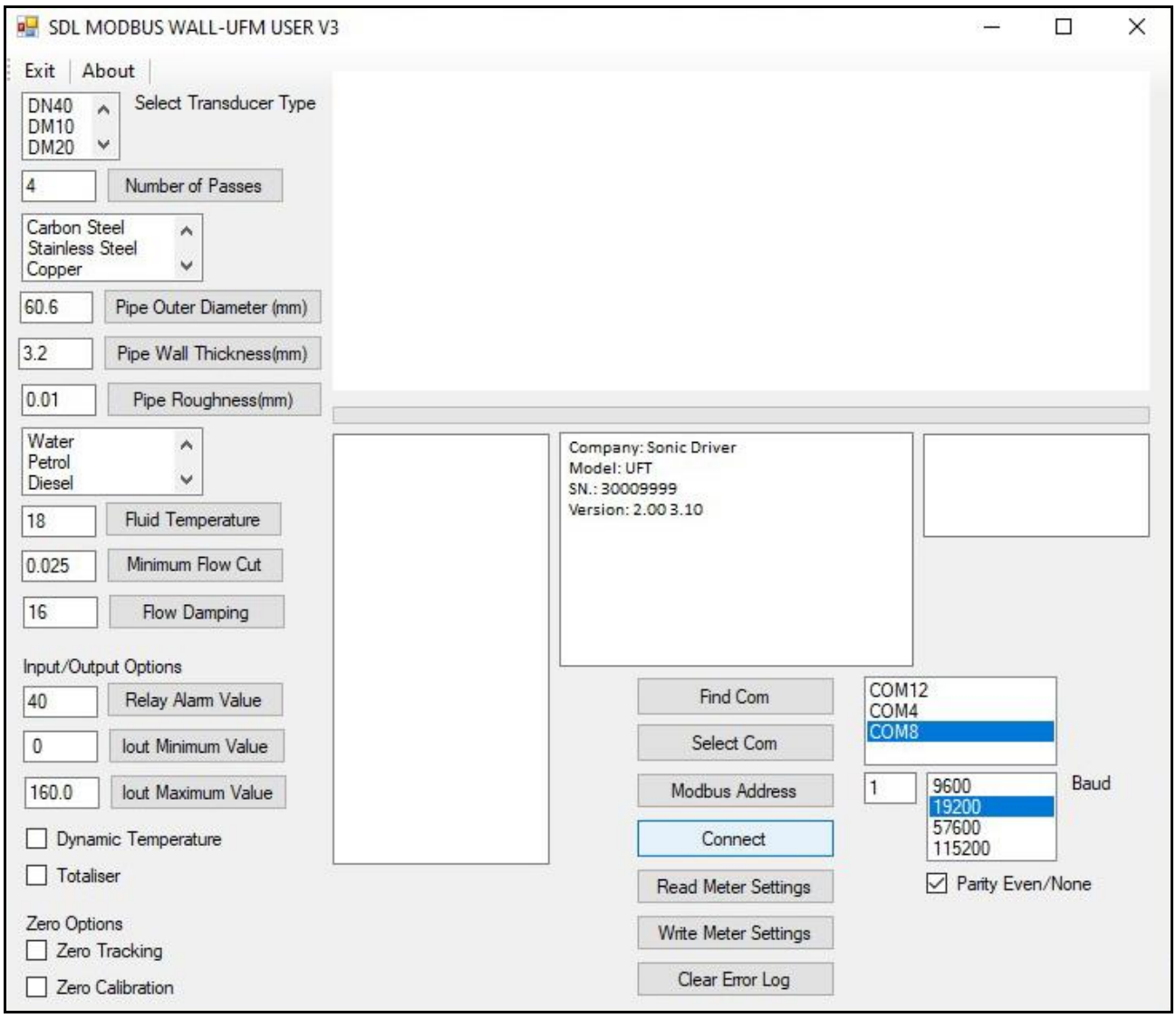

Figure (11) Default Parameter Values.

Most importantly the Company, Model, serial number and hardware and software version of the UFM will be read and displayed.

Now press the Read Meter Setup button, the configuration program will read the actual setup of the UFM, which will be different to the factory defaults if the UFM has previously been programmed with different values, see figure (12)

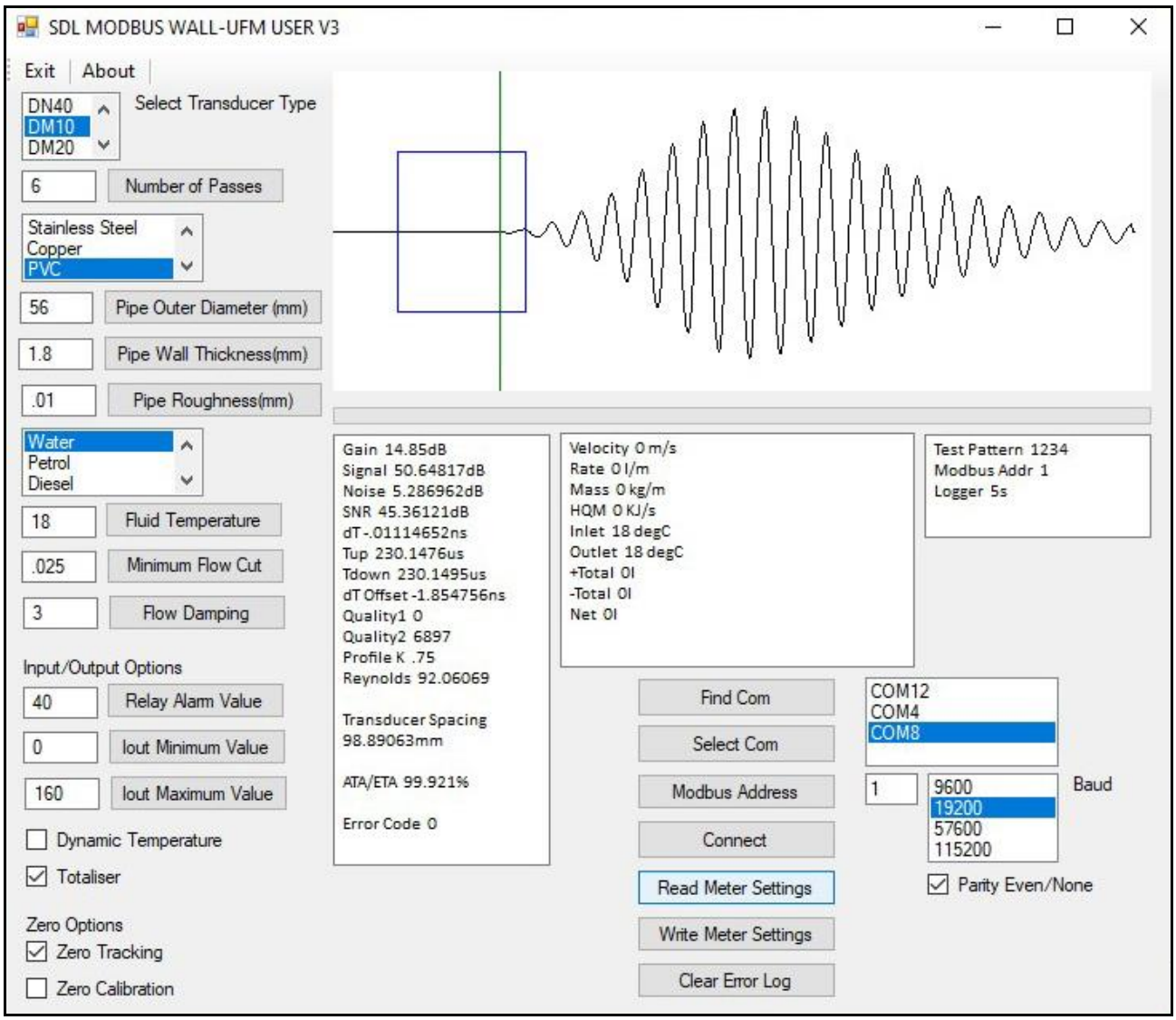

Figure (12) Read Meter Setup.

The configuration program reads and displays the ultrasonic signal being measured. The first arrival of the signal should appear in the blue square, the green line indicates where the UFM has determined the first arrival to be. If the UFM is not confident then this line will be red.

Flow measurement and diagnostics are shown in the relevant text boxes on the dashboard.

Given the parameter values entered the UFM displays the required spacing for the transducers clamped on the pipe in the diagnostics listing.

The progress bar under the scope display updates as data and parameters are downloaded.

2.3 Configuring the UFM

The UFM requires correct entry of the Quick Start parameters shown on the left-hand side of the dashboard, see figure (13).

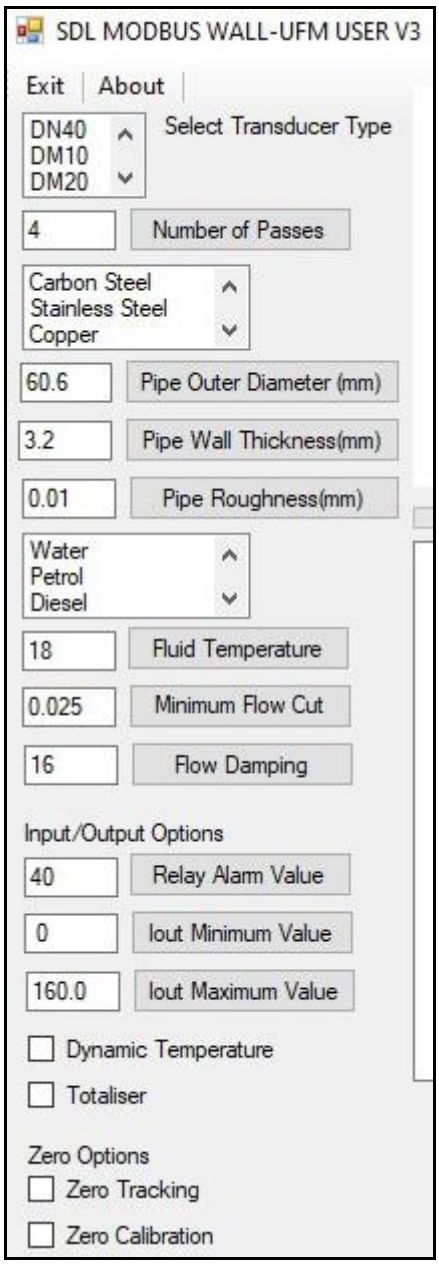

Figure (13) Quick Start Parameters.

Parameters and settings in the UFM can be edited by;

- Selecting an item using a scrolling list
- Ticking a Tick Box
- Direct numerical entry

It is important to note that after direct numerical entry of a parameter value it is important to press the named button next to the entry for it to be checked against limits, entered and saved.

If the value entered it not within limits, then the entry is rejected

Once the installation configuration has been set press the Write Meter Settings button see figure (14), which sends the configuration to the UFM.

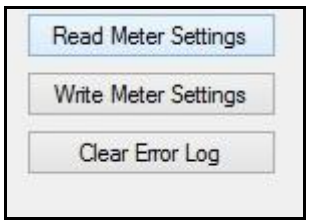

Figure (14) Write and Read UFM Settings.

To read a previously configured UFM configuration press the Read Meter Settings button.

To make flow measurements continue to press the Read Meter Settings button.

For more details on using the dashboard read the Operating Instructions manual that accompanies this Installation Manual.

2.4 Other Communication Software

For experienced users of Modbus RTU there are several communications programs available for download online.

The UFM has been tested using Modbus Poll (for Windows platform) and Modbus Monitor (for Android and Windows platforms).

3.0 Quick Start Sequence

Once powered on the UFM will be in Modbus Idle State awaiting communication.

From the Configuration program the user can use the Quick Start sequence down the left-hand side of the window which takes them through the minimum sequence of parameters needed to get the UFM measuring reliably and accurately, see figure (13);

- Transducer Type
- Transducer Number of Passes
- Pipe Material
- Pipe Outer Diameter
- Pipe Wall Thickness
- Pipe Wall Roughness
- Pipe Material
- Fluid Type
- Fluid Temperature

Each parameter is described below in the relevant section.

Parameters relating to current output, relay alarm and PT100 inputs are only effective if the relevant optional plug-in modules are fitted, see the Operating Instructions which accompany this Installation Manual for more details.

3.1 Transducer Menu

This menu allows the user to change transducer settings.

3.1.1 Type

The user is prompted to select the type of sensors mounted on the pipe from a list;

- DN40
- DM10 **(Default)**
- DM20
- DS10

DM sensors are Sonic Driver standard PEEK/stainless steel design. DN sensors are Sonic Driver small pipe design. DS sensors are for larger diameter pipes.

3.1.2 Number of Passes

The user is prompted to enter the number of times the sound path crosses the pipe. Allowed values are 1 to 16.

Ideally choose a number of passes that results in a path length in the fluid of 100 mm or greater.

- 1 pass, most common on large diameter pipes, typically 100 mm or more in diameter. If the UFM suggests a negative spacing, then this is measured as in figure (14).

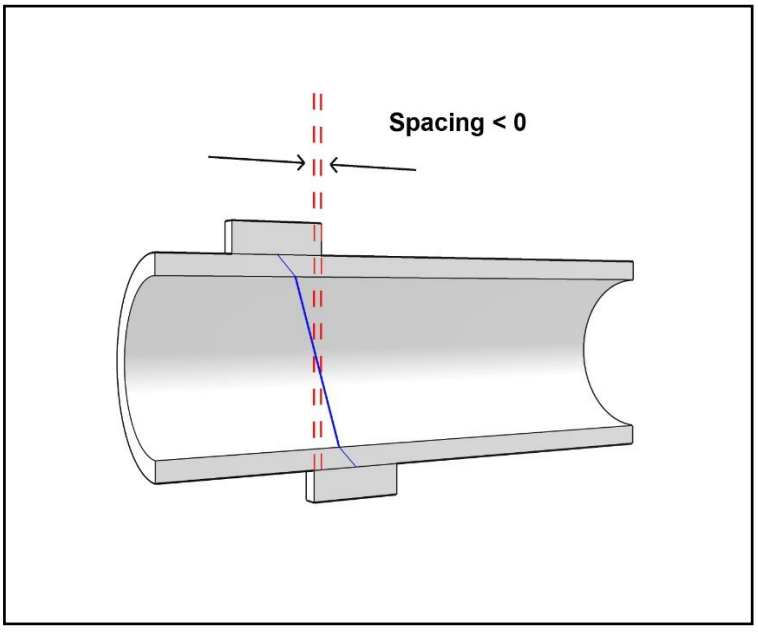

Figure (14) 1 pass, demonstrating a negative transducer spacing.

- 2 passes, the most commonly used method, this is the simplest to install as both sensors are on the same side of the pipe, see figure (15).

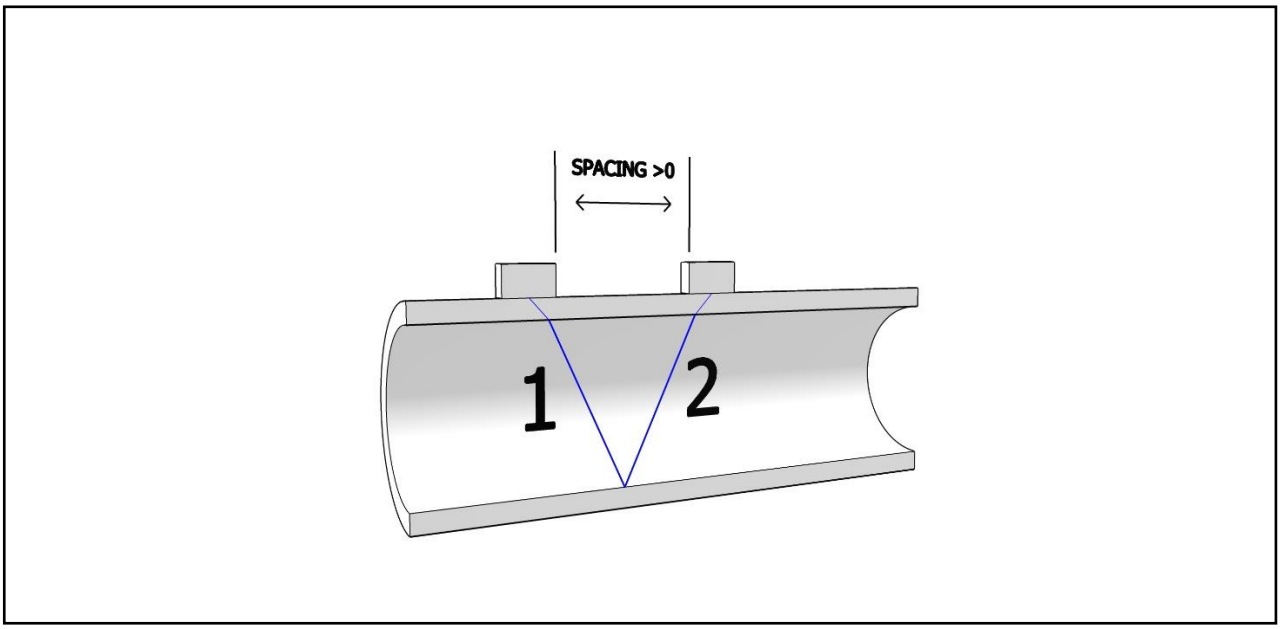

Figure (15) 2 passes.

- 3 passes, used on small diameter pipes.
- 4 passes, used on the smallest diameter pipes, see figure (16).

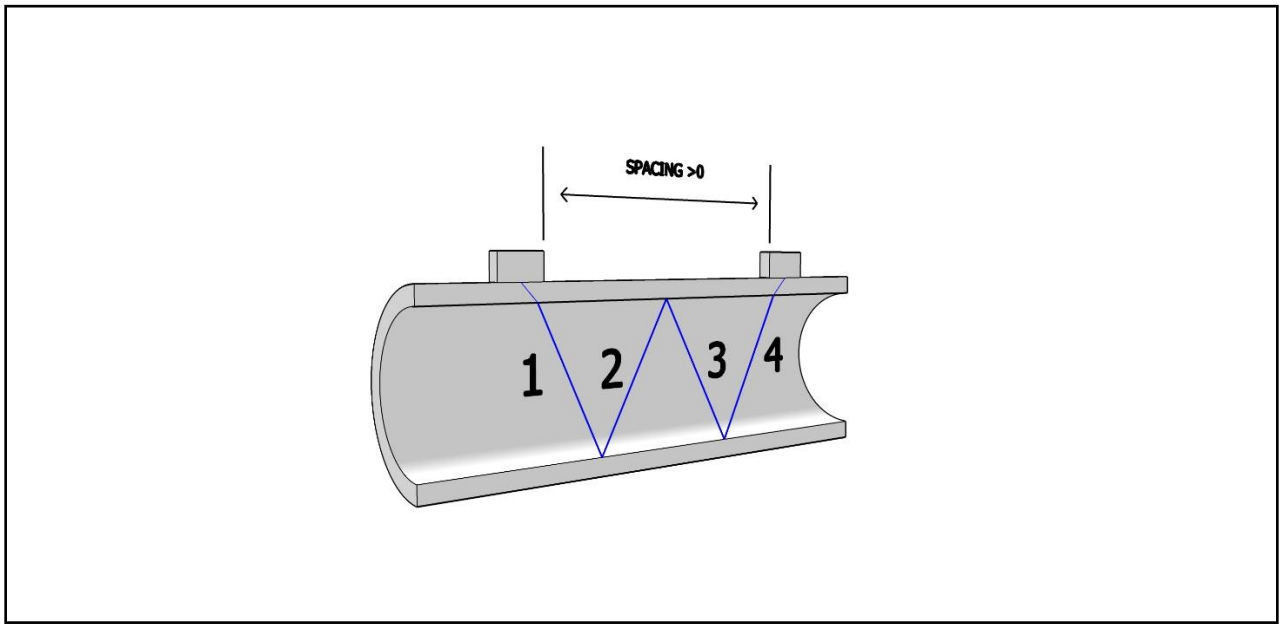

Figure (16) 4 passes.

- 5 to 15 and 16, etc.

It may be that on the smallest diameter pipes then the recommended transducer spacing at 16 passes is not sufficient to allow the transducers to be coupled on the same side of the pipe, using an even number of passes as they still touch. In this case it is unavoidable to couple the transducers on opposite sides of the pipe using an odd number of passes, for example 13 or 15 passes.

3.2 Pipe Menu

The following parameters allow the user to specify the pipe.

3.2.1 Material

The user can select the pipe material from a list;

- Carbon Steel
- Stainless Steel
- Copper
- PVC **(Default)**
- Cast Iron
- Ductile Iron
- HDPE

3.2.2 Outer Diameter

The user is prompted to enter a value for the pipe outer diameter. The UFM comes in 3 different versions;

- Standard - outer pipe diameter ranged 10.0 to 115.0 mm
- Medium - outer pipe diameter ranged 115.0 to 225.0 mm
- Large - outer pipe diameter ranged 225.0 to 6500.0 mm

The default is 56.0 mm for all versions.

3.2.3 Wall Thickness

The user is prompted to enter a value for the pipe wall thickness. Allowed values are ranged 0.5 to 100.0 mm, default 1.8 mm.

3.2.4 Pipe Wall Roughness

The user is prompted to enter a value for the peak/trough height of the roughness on the inside surface of the pipe. Allowed values are ranged 0.001 to 10.000 mm, default 0.010 mm.

This value is used in flow profile correction calculations. See Appendix B for a list of typical values.

3.4 Fluid Menu

This menu allows the user to change fluid settings.

3.4.1 Type

The user can select the fluid in the pipe from a list;

- Water **(Default)**
- Petrol
- Diesel
- Glycol/Water

Sound Velocity, Kinematic Viscosity and Density for the selected fluid are stored in an internal database withing the UFM. These values are automatically temperature compensated.

3.4.2 Temperature

The user is prompted to enter the temperature of the fluid in the pipe. Allowed values are ranged -20 to +150 degC, default 18 degC.

Changing Fluid Temperature causes Fluid Sound Velocity, Fluid Kinematic Viscosity and Fluid Density to be recalculated.

4.0 Sensor Positioning

Using the entered parameters, the UFM calculates and gives the required transducer spacing on the pipe under diagnostics.

The user is then presented with a sensor positioning screen and diagnostics showing,

- Graph of received ultrasonic signal
- Calculated sensor spacing
- Number of sound passes in the pipe
- Signal to Noise Ratio
- ATA/ETA

If the parameters entered are all correct, then the graph should appear as in figure (17).

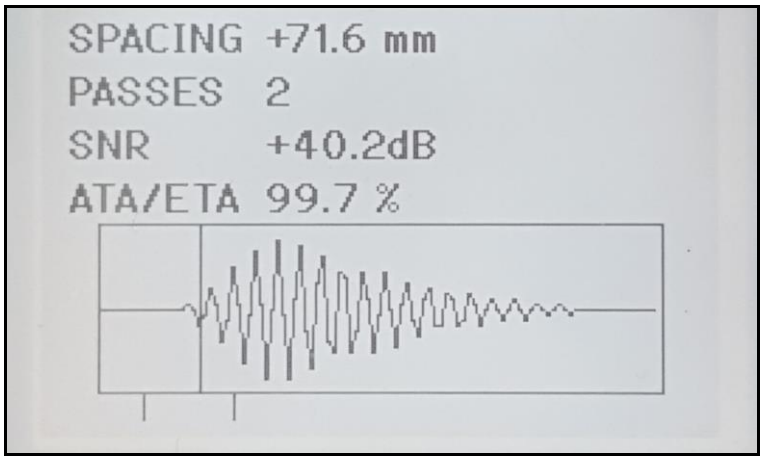

Figure (17) Ideal Sensor Positioning.

However, if the user has an incomplete knowledge of the pipe, then the screen may look like figure (18) or figure (19).

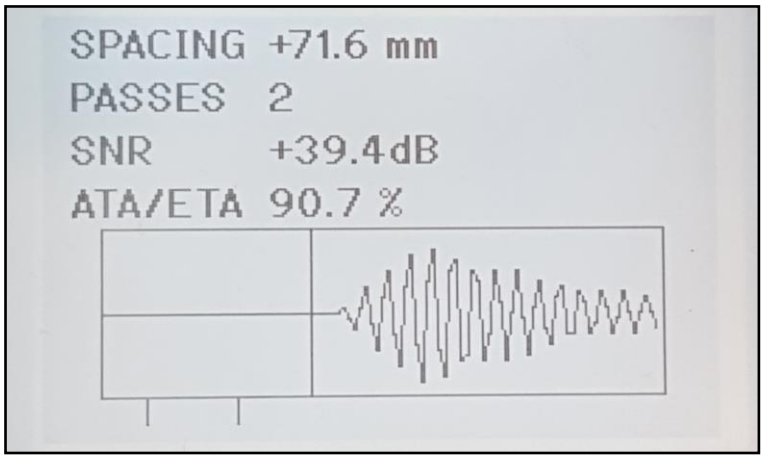

Figure (18) Non-ideal Sensor Positioning, transducers too far apart.

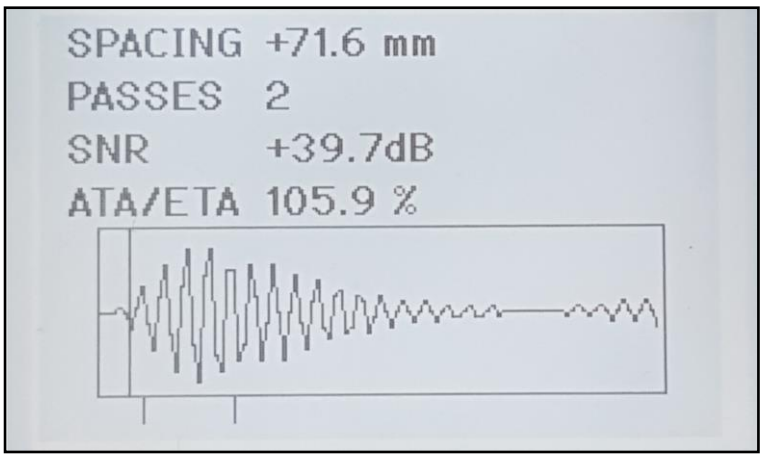

Figure (19) Non-ideal Sensor Positioning, transducers too close together.

In figure (18) the received signal is too far to the right, the user should slide the transducers closer together.

In figure (19) the received signal is too far to the left, the user should slide the transducers further apart.

The most common cause of an incomplete or incorrect spacing is a lack of knowledge about the pipe wall thickness.

As long as the vertical green line acting as arrival marker is within the blue square, resulting in an ATE/ETA value between 97 and 103 % then the UFM will measure accurately. It is acceptable to reposition the transducers to adjust their spacing by +/- 5 mm to optimise the positioning screen, the arrival marker will move on the screen accordingly.

If the UFM is not confident then the vertical line will turn red.

SNR should peak and be above 24 dB.

4.1 Optimising Transducer Mounting Location

For the best results ensure that,

- Ideally the transducers are mounted on bare pipe material, for metal pipes this should be metal free from dust, rust and paint.
- Consider a location away from internal corrosion, sediment and streams of entrained air, do not mount the transducers top to bottom on the pipe, mount at 2 or 10 o'clock.
- Avoid mounting the transducers either on or opposite axial welds along the pipe.
- Ensure the transducers are aligned axially along the pipe.
- Mount the transducers away from bends, valves and other inserted instrumentation.
- Observe were practical the advised upstream and downstream straight sections, see below, figure (20).
- Ensure the pipe will always be full at the point of installation, ideally mount the transducers at a low point in the system.
- If mounting the transducers on a vertical pipe section ensure the flow direction is upwards in the section.
- Composite pipes can have de-laminations in their wall thickness, this type of pipe is

notoriously bad when installing a UFM.

- Ensure the temperature at the transducer location is within the transducers rated range.
- Ideally the fluid should be free of particulates and bubbles, in the limit then an alternative method such as Doppler flow measurement may be required.
- Porous pipes, such as concrete can cause measurement problems.
- Using information from Standard Pipe Tables can be inaccurate, it is always best to measure the pipe outer diameter and wall thickness.
- No matter how accurate the meter is at making a velocity measurement, an inaccurate knowledge of the internal cross-sectional area of the pipe will lead to inaccuracy in the conversion to volumetric flow rate.

4.2 Upstream and Downstream Pipe Runs

Ideally the UFM transducers should be installed on as long a section of straight pipe as is possible, see figure (20).

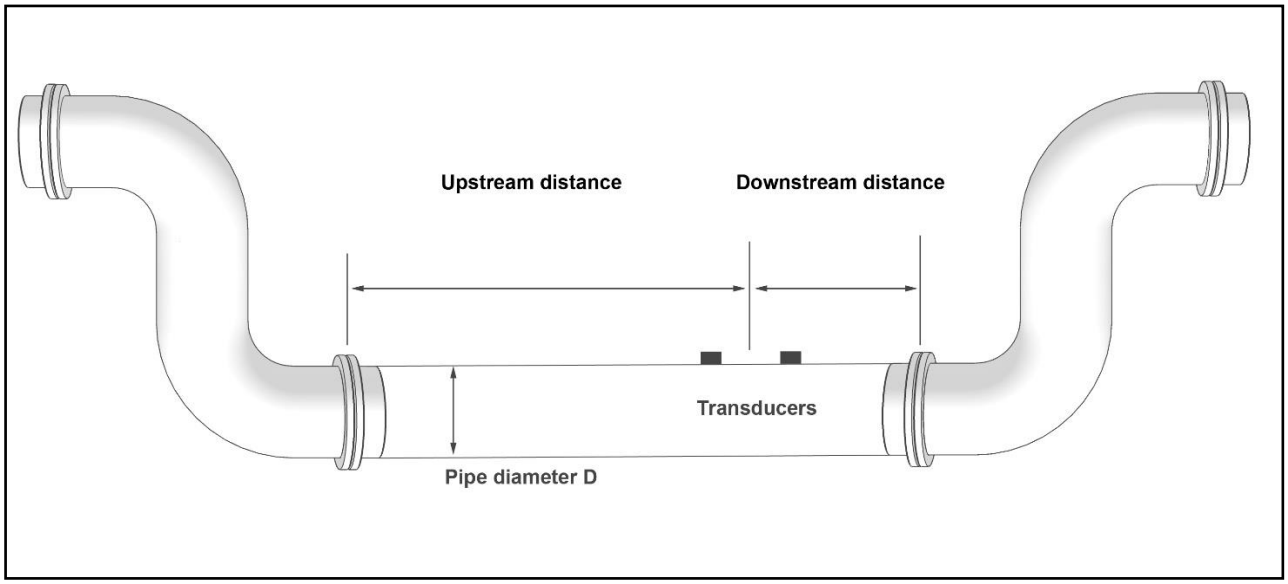

Figure (20) Upstream and downstream pipe lengths.

Considering a pipe with an outer diameter of D then if possible, ensure at least 10D upstream distance between the transducers and a bend in the pipework.

In the case of an upstream Valve then if possible, ensure at least 20D upstream.

In the case of an upstream Pump then if possible ensure at least 30D upstream.

In all cases ideally ensure 5D downstream exists before a bend or obstruction in the pipework.

4.3 Transducer Mounting

Locate an optimum position on the pipe following the advice above.

Use Coupling gel. Apply adequate couplant and ensure no gap exists between the transducer and the pipe surfaces.

Banding or clamping is required to keep the transducers in place. It is recommended to use chain

clamps or 10 mm wide jubilee clips.

4.4 Transducer Spacing

Given that all information regarding the installation has been entered accurately and the advice above has been followed then the UFM will measure reliably and accurately.

This is confirmed by,

- A strong received signal strength
- A high SNR value
- Value of ATA/ETA close to 100%

If is acceptable to make small adjustments to the transducer spacing to optimise the received signal strength and ATA//ETA.

However, if large adjustments are necessary then the importance of wall thickness should be considered. Wall thickness is typically the parameter about which the user has the least knowledge.

If all other avenues have been explored, including recoupling the transducers at several different locations on the pipework then adjusting the wall thickness parameter may help.

5.0 Heat Metering

Heat meters measure the energy necessary to provide hot water or cooling to a location such as a building or room.

The meter measures the energy on the supply or return side of a heating (boiler) or cooling (chiller) device by measuring the flow rate of heat or cooling fluid and the temperature difference between the supply and return legs of the system.

The pipe from the source of heat or cooling entering a location is known as the Flow or inlet pipe.

The pipe from the location returning to the source is known as the Return or outlet pipe.

The meter is programmed to be installed on the return pipe. This is the colder pipe for heating systems and the warmer pipe for cooling systems.

With the addition of PT100 plug-in modules for real-time measurement of inlet and outlet temperature the UFM can function as a heat meter.

For a boiler heating installation the flow measurement needs to be made on the cold side of the system.

For a chiller cooling installation the flow measurement needs to be made on the warm side of the system.

If the correct meter installation position is not used and/or the temperature sensing elements are not placed on the correct flow/return legs then a meter may be up to 10 % inaccurate.

5.1 Calculation Method

Heat measurement is designed to comply with EN1434-1 Section 8 and its Appendix A.

6.0 Error Codes

As soon as the UFM is switched on a self-diagnostic program will start. This program fully tests both the UFM hardware and software.

If an error is detected an error code is generated prompting user action. If the error persists contact customer support, see appendix A.

Error codes and their meanings can be found in Appendix C.

7.0 Specification

The UFM specification, features and performance are listed below;

- Pipe outer diameters ranging from 10 to 6500 mm. The UFM comes in 3 different versions;
    - Standard - outer pipe diameter ranged 10.0 to 115.0 mm
    - Medium - outer pipe diameter ranged 115.0 to 225.0 mm
    - Large - outer pipe diameter ranged 225.0 to 6500.0 mm
- Temperature range for control unit -10 to +65 degC.
- Weight 700 g.
- Dimensions 270 x 150 x 80 mm.
- IP68 enclosure. Use cable glands to match the IP rating of the enclosure and its installation.
- 12 to 24 Vdc PSU at 10 W.

Features

- Intuitive installation and commissioning using configuration program running on a PC.
- Full set of measured values and instrument and measurement diagnostics available over Modbus RTU RS485.
- Signal oscilloscope for sensor positioning and diagnostics.
- Internal database of pipe and fluid materials.
- Fluid database of sound speed, density and viscosity compensated for fluid temperature (if temperature is known from optional PT100 input)
- Heat quantity measurement (if inlet and outlet temperatures are known from optional PT100 inputs).
- Heat measurement designed to comply with EN1434-1 Section 8 and Appendix A.
- Flow positive, negative and net totalisers.

Performance

- Measurement principle ultrasonic transit time difference.
- Flow velocity range 0.01 to 25 m/s.
- Resolution 0.25 mm/s.
- Repeatability 0.15 % of measured value.
- Accuracy +/- 0.5 to +/- 3.0 % of measured value for velocity greater than 0.2 m/s, depending on application.
- Turn down ratio 1/100.
- Measurement rate 1 Hz as standard.
- Gas/solids < 10 % of volume.

Quantity and units of measurement

- Flow velocity (m/s)
- Volumetric flow rate (l/min)
- Mass flow rate (kg/min)
- Energy flow rate (KJ/s)
- Inlet temperature (degC)
- Outlet temperature (degC)
- Flow positive total (l)
- Flow negative total (l)
- Flow net total (l)

Optional plug in IO modules

- Galvanic and optical isolation.
- Namur levels for signalling.
- 16 bit resolution.
- Active 4 to 20 mA current output.
- Passive 4 to 20 mA current output.
- Alarm Relay (NO and NC) output.
- PT100 input (4 wire).

Transducers

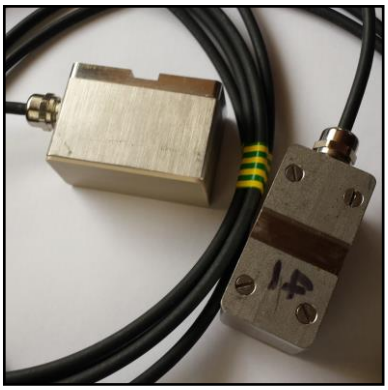

Figure (21) PEEK/stainless steel transducers.

- A range of sensor sizes to cover the range of pipe outer diameter 10 to 6500 mm.
- Material stainless steel and PEEK.
- Temperature range, -10 to +80 degC standard.
- Ingress Protection rated IP54, with IP68 option.
- Cable length 3 m as standard.
- Matched pairs for accurate zero flow measurement.

8.0 Product Identification

Each UFM and pair of flow transducers come with a unique Identification code. This is printed in the lid to the screw terminal area.

In the case of the UFM this is also written into the software and can be read using the Configuration program.

In the event of a need to contact Sonic Driver please have these codes available to quote.

9.0 Service

The UFM is a sophisticated measuring instrument and contains no user serviceable parts.

For all operational problems please contact our service department by telephone or email, see Appendix A.

Sonic Driver do offer a software upgrade service. Please contact the factory for information about the latest software.

10.0 Limited Warranty and Disclaimer

Sonic Driver Ltd warrants to the end purchaser, for a period of one year from the date of shipment from our factory, that all new products manufactured by it are free from defects in materials and workmanship.

This warranty does not cover products that have been damaged due to normal use, misapplication, abuse, lack of maintenance, or improper installation.

Sonic Driver obligation under this warranty is limited to the repair or replacement of a defective product, if the product is inspected by Sonic Driver Ltd and found to be defective. Repair or replacement is at the discretion of Sonic Driver Ltd.

If the product is outside of the warranty period a purchase order must be received from the end purchaser before repair work will start.

The product must be thoroughly cleaned and any contamination removed before it will be accepted for return.

The purchaser must determine the applicability of the product for its desired use and assumes all risks in connection therewith. Sonic Driver Ltd assumes no responsibility or liability for any omissions or errors in connection with the use of its products.

Sonic Driver Ltd will under no circumstances be liable for any incidental, consequential, contingent or special damages or loss to any person or property arising out of the failure of any product, component or accessory.

All expressed or implied warranties, including the implied warranty of merchantability and the implied warranty of fitness for a particular purpose or application are expressly disclaimed and shall not apply to any products sold or services rendered by Sonic Driver Ltd.

The above warranty supersedes and is in lieu of all other warranties, either expressed or implied and

all other obligations or liabilities.

No agent or representative of Sonic Driver Ltd has any authority to alter the terms of this warranty in any way.

Appendix A Contact Details

Telephone: +44(0)7971 273000

Postal Address: Sonic Driver Ltd, Lochiel, Llaneilian Road, Amlwch, Gwynedd, LL68 9HU, UK.

Email: service@sonic-driver.com

Website: www.sonic-driver.com

Appendix B Table of typical pipe roughness values

When a fluid flows through a pipe then the pipes own internal roughness is important when considering friction losses.

Pipe manufacturers often quote a pipe roughness value for their products.

Some typical figures are given below.

Pipe Material	**Peak to Trough Roughness (mm)**
Concrete	0.3 to 3.0
Cast Iron	0.26
Galvanized Iron	0.15
Asphalted Cast Iron	0.12
Commercial or Welded Steel	0.045
PVC, Glass and other drawn tubing	0.0015

By default the Sonic Driver flowmeter uses a figure of 0.01 mm as a good compromise for most common pipes.

Appendix C Error codes

Error codes are a 16 bit value, where each bit represents an error flag with value 0 when there is no error and 1 when an error condition is present;

- 0 Processor internal address error
- 1 Processor internal math error
- 2 Processor internal oscillator error
- 3 Processor internal stack error
- 4 External FRAM memory error
- 5 SPI1 bus error
- 6 SPI2 bus error
- 7 TOFM communications error
- 8 UART error
- 9 Spare
- 10 Spare

- 11 Spare
- 12 Spare
- 13 Spare
- 14 Spare
- 15 Spare

Spare bits are always 0.

Sonic Driver