



Made in Britain

POCKET-UFM Ultrasonic Flowmeter

Installation Manual

Version 5.0



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1.0 Introduction

Congratulations on choosing the Sonic Driver™ POCKET-UFM™ clamp-on ultrasonic flowmeter, figure (1).



Figure (1) The Sonic Driver POCKET-UFM.

The ultrasonic flowmeter (UFM) uses advanced Digital Signal Processing (DSP) and transit time measurement techniques (Sonic Driver™) 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 meters intuitive and easy to use menu driven User Interface (UI) the UFM can display;

- Flow velocity
- Volumetric flow rate
- Mass flow rate
- Heat quantity flow rate

With the addition of a wall thickness measuring probe the UFM can also function as a pipe wall thickness gauge (WTG).

1.1 Transit Time Measurement

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

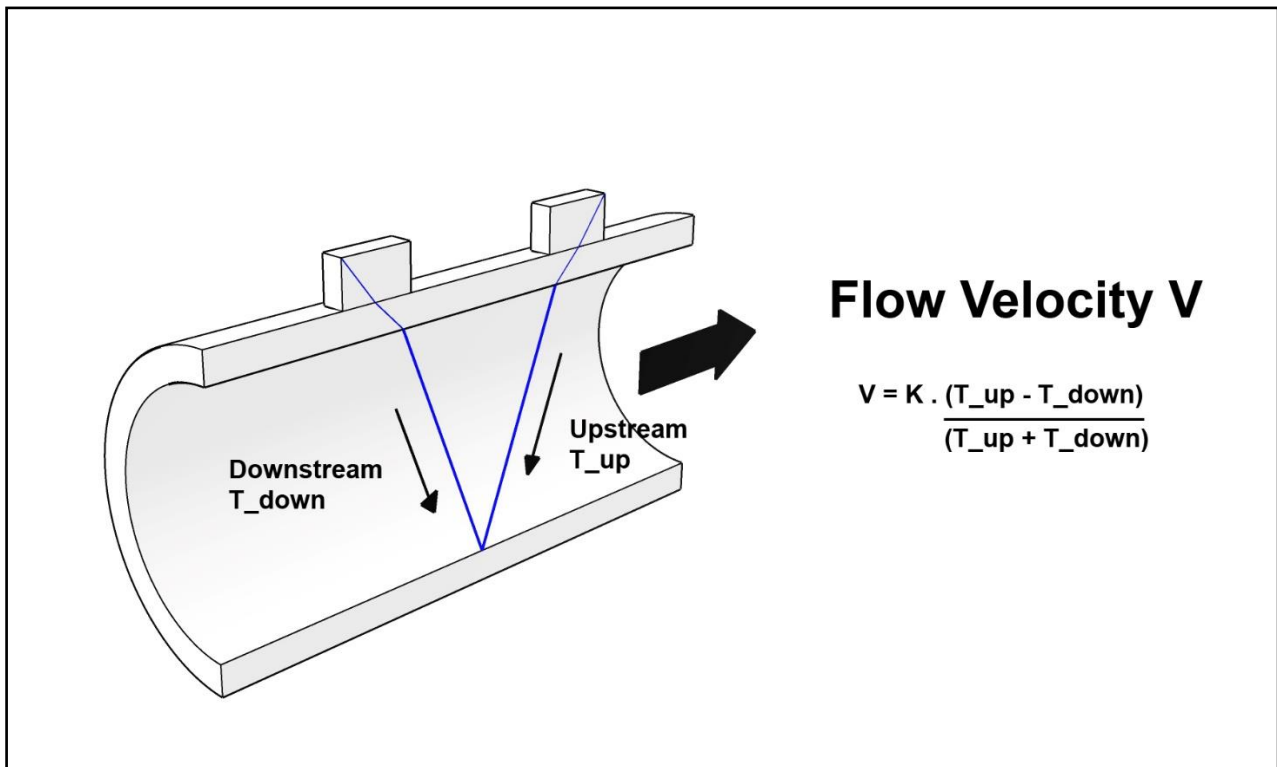


Figure (2) The principle of transit time flow measurement.

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 Specific Heat Capacity of the fluid allows the UFM to calculate heat flow rate.

All of these rates can be totalled and positive, negative and net values displayed.

1.2 Packing List



Figure (3) UFM Carry Case and Contents.

Within the UFM carry case, see figure (3) you should find;

Item	Quantity
POCKET-UFM	1
PEEK/Stainless Steel Flow Transducer	2
Wall Thickness (WTG) Probe	Optional
Ball Chain Mounting Clamp	2
Tape Measure	1
Coupling Gel	1
Battery	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 Ltd 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 instructions fully.
- 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.
- Avoid striking the clear display window and keypad with sharp objects.

1.4 Cleaning

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

1.5 Storage

When not in use the UFM and transducers should ideally be cleaned and stored in the carry case they were supplied in.

1.6 Fitting/Changing Internal Battery

The UFM is powered by a single 9 V internal battery. Sonic Driver recommend a high capacity primary battery of at least 1200 mAh be used.

To fit or change the battery slide the cover of the battery compartment in the rear of the UFM, see figure (4).

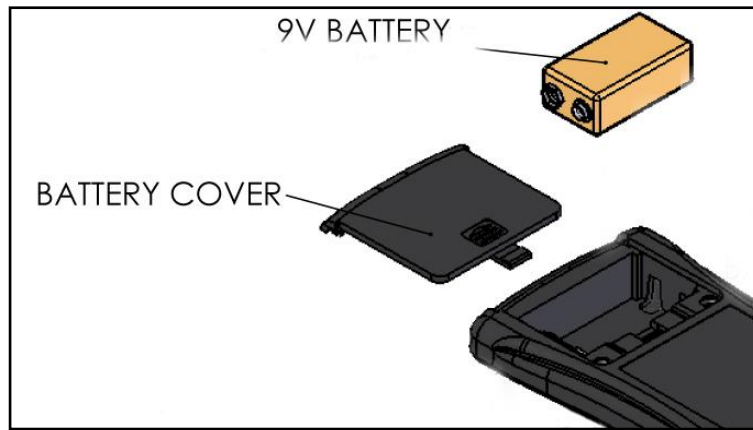


Figure (4) Battery compartment.

Lower capacity or use of rechargeable battery will decrease the run time of the UFM.

1.7 Connecting The Flow Transducers

Connect the flow transducers to the Lemo connectors at the top of the UFM, see figure (5).



Figure (5) Flow transducer connection.

Red flow transducer is mounted on the pipe downstream, black flow transducer is mounted upstream.

When using the WTG probe then connector orientation is not important.

1.8 Mounting The Flow Transducers

Mount the flow transducers on the pipe using the chain clamps supplied, see figure (6). 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.

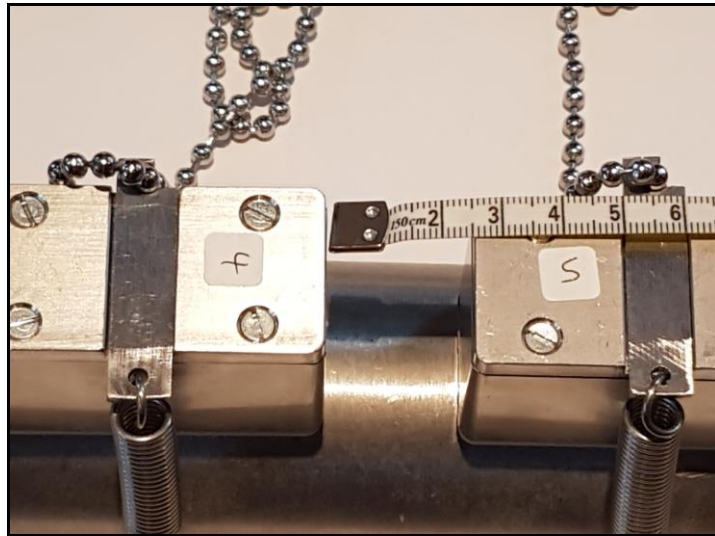


Figure (6) Flow transducer mounting, spacing is 25 mm between front faces.

In figure (7) and figure (8) the transducers are misaligned and twisted, as a result the UFM will make poor flow measurements.



Figure (7) Misaligned transducers.



Figure (8) Twisted transducers.

When using the WTG probe it is possible to simply hold the probe on the pipe by hand, making good contact using coupling gel.

1.9 Turning the UFM On

To power on a POCKET-UFM press and hold the On key.

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 message will be displayed prompting user action. If the error persists contact customer support, see appendix A.

Error codes and their meanings can be found in the Main Menu under the Diagnostics Menu.

In order to turn the UFM off from the Main Menu press and hold the “</Off” key.

A progress bar decrements to turn the UFM off.

If the “</Off” key is released before the progress bar fully decrements the UFM returns to the Measurement screen.

The “</Off” key has no function when in Measurement Mode.

If there is no keypad activity in User Interface (UI) mode for 60 seconds then the UFM will automatically power off. Automatic power off does not apply in Measurement mode.

The LCD backlight will flash when the battery is low and needs to be changed.

2.0 Using the Quick Start Sequence

Once powered on the UFM will be in UI mode displaying the Main Menu.

The Main Menu allows the user to select a group of parameters to edit or a meter function;

- Quick Start
- Installation
- System Settings
- Diagnostics
- Load/Save Setups

The Quick Start function takes the user through the minimum sequence of parameters needed to get the UFM measuring reliably;

- Transducer Type
- Transducer Mounting
- Pipe Diameter
- Pipe Wall Thickness
- Pipe Material
- Liner Material
- Fluid
- Fluid Temperature

Each parameter is described below in the relevant section.

After selecting Transducer Type and Transducer Mounting it is also possible to jump to the end of the sequence by pressing the Run/Stop key.

2.1 Transducer Menu

This menu allows the user to change transducer settings.

2.1.1 Type

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

- DS05
- DS10
- DS20
- DS40
- DM10 (**Default**)
- DM20
- DN40
- Flow Other
- WTG

DM sensors are Sonic Driver standard PEEK/stainless steel design. DN sensors are Sonic Driver small pipe design. DS sensors are Sonic Driver large pipe design.

If Flow Other is selected then the user will be prompted to enter detailed transducer specific information.

The ability to select Flow Other is intended for use when using the UFM with special sensors supplied by Sonic Driver.

Wall Thickness Gauging (WTG) is for use with dual element 5 MHz wall thickness probes.

When operating as a wall thickness gauge the user can scroll between 3 display modes by repeatedly pressing the “Enter” key, the modes are;

- Full display of wall thickness measurement and all measurement diagnostics.
- A-Scan showing the raw received ultrasonic signal.
- Processed signal showing the measured signal corresponding to the wall thickness.

2.1.2 Mounting

The user is prompted to select the sound path in the pipe from a list;

- Auto
- Z
- V
- N
- W
- 5
- 6 (**Default**)
- 7
- 8

- 9
- 10
- 11
- 12

Selecting Auto means that the UFM determines for itself which sound path to use. Ideally choose a number of passes that results in a path length in the fluid of 100 mm or greater.

- Z or 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 (9).

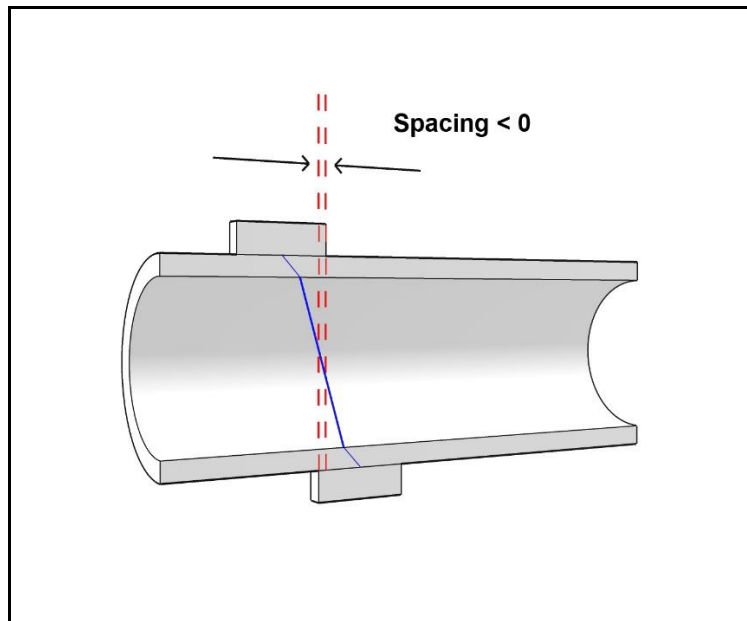


Figure (9) Z or 1 pass, demonstrating a negative transducer spacing.

- V or 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 (10).

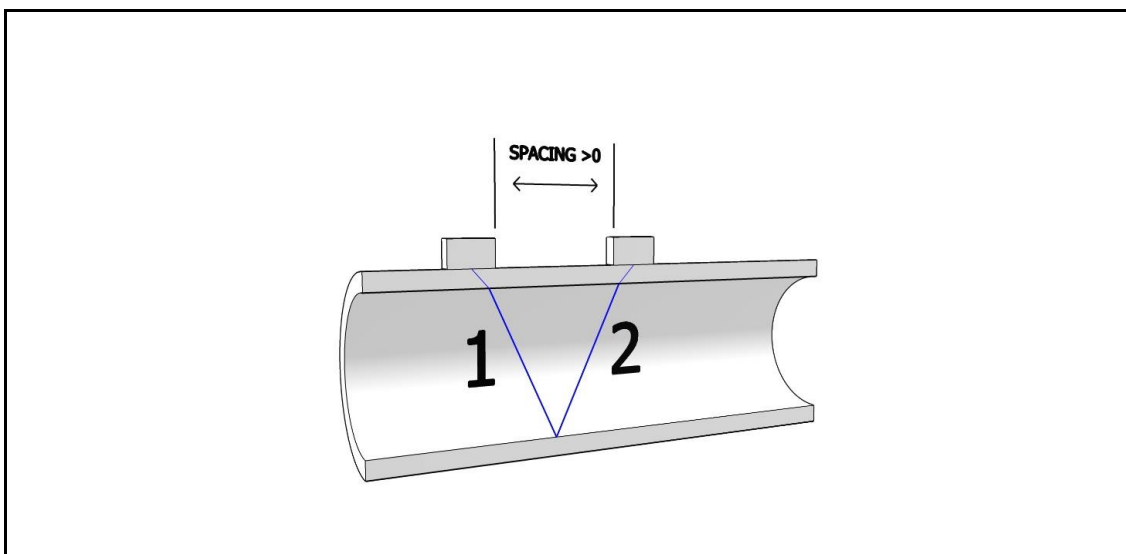


Figure (10) V or 2 passes.

- N or 3 passes, used on small diameter pipes.
- W or 4 passes, used on the smallest diameter pipes, see figure (11).

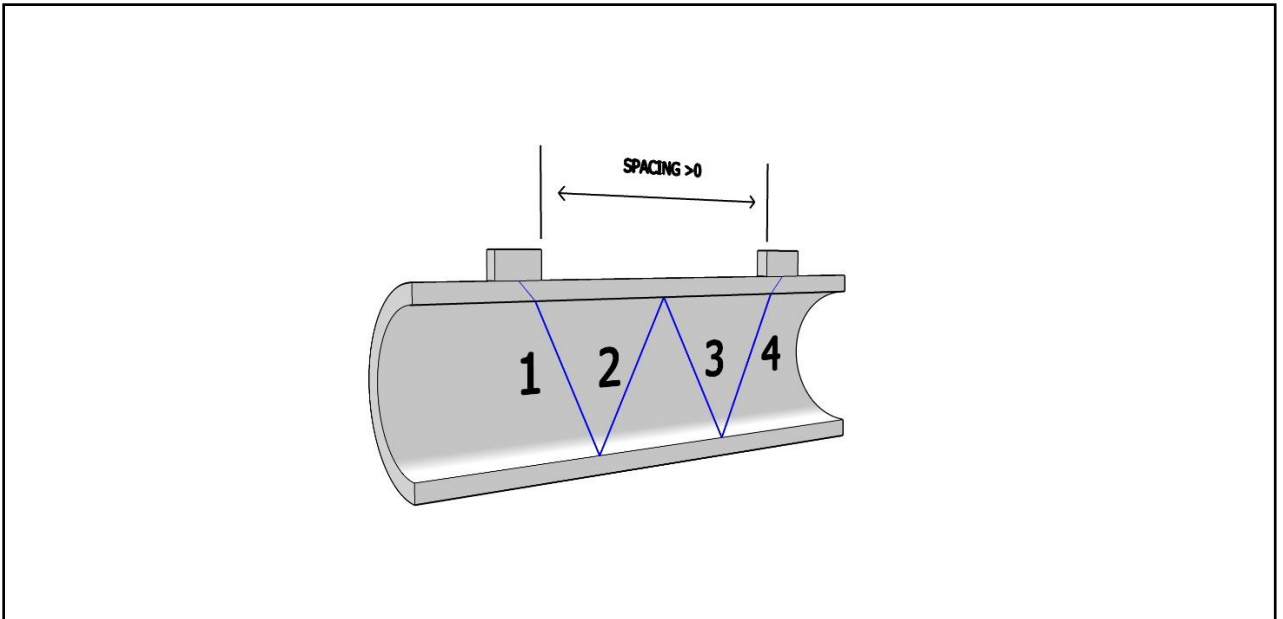


Figure (11) W or 4 passes.

- 5 to 11 and 12, etc.

It may be that on the smallest diameter pipes then the recommended transducer spacing at 12 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 9 or 11 passes.

Red flow transducer is mounted on the pipe downstream, black flow transducer is mounted upstream, see figure (5).

When using the WTG probe then connector orientation is not important.

2.2 Pipe Menu

The following parameters allow the user to specify the pipe.

2.2.1 Outer Diameter

The user is prompted to enter a value for the pipe outer diameter. Allowed values are ranged 10.0 to 6500.0 mm, default 56.0 mm.

2.2.2 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.

2.2.3 Material

The user can select the pipe material from a list;

- Carbon Steel
- Stainless 304
- Stainless 316
- Cast Iron
- Ductile Iron
- Copper
- PVC (**Default**)
- Lead
- Nylon
- PE
- Aluminium
- Asbestos
- Fibre Glass
- Other

If Other is selected then the user is prompted to enter the transverse (shear) speed of sound in the pipe material, see below. Otherwise the transverse speed of sound in the pipe material is read from a database held in the UFM.

2.2.4 Sound Velocity

Appearance of this parameter is context driven. If the user selected Other from the list of pipe materials then the user is prompted to enter the transverse speed of sound in the pipe material. Otherwise the speed of sound in the pipe material is read from a database held in the UFM.

Allowed values are ranged 500 to 7000 m/s, default 1060 m/s (PVC).

2.3 Liner Menu

This menu allows the user to change pipe lining settings.

2.3.1 Material

The user can select a pipe liner material from a list;

- None (Default)
- Cement
- Epoxy
- Glass
- PP
- Teflon
- Rubber
- Other

The list allows no liner (None) to be selected.

2.3.2 Sound Velocity

Appearance of this parameter is context driven. If the user selected Other from the list of liner materials then the user is prompted to enter the transverse speed of sound in the liner material. Otherwise the speed of sound in the liner material is read from a database held in the UFM.

Allowed values are ranged 500 to 7000 m/s, default 0 m/s (None).

2.3.3 Thickness

Appearance of this parameter is context driven. If the user selected a liner then the user is prompted for the thickness of the liner. Allowed values are ranged 0.5 to 100.0 mm, default 0.0 mm (None).

2.4 Fluid Menu

This menu allows the user to change fluid settings.

2.4.1 Type

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

- **Water (Default)**
- Sea Water
- Kerosene
- Petrol
- Fuel Oil
- Crude Oil
- Freon R134a
- Freon R22
- Diesel Oil
- Castor Oil
- F-76 Fuel Oil
- Novec 1230
- Glycol/Water
- Alcohol
- Other

If the user selected Other from the list of fluid types then the user is prompted to enter various other context driven parameters including; Fluid Sound Velocity, Fluid Kinematic Viscosity and Fluid Density.

2.4.2 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, Fluid Density and Fluid Specific Heat Capacity to be recalculated.

3.0 Sensor Positioning

After completing entry of all parameters in the Quick Start function sequence the user is prompted to confirm Transducer Type and is then taken to the Sensor Positioning screen.

Using the entered parameters the UFM calculates and gives the required transducer spacing on the pipe. The screen also displays the number of passes selected by the user or calculated by the UFM if in Auto Passes mode.

Clamp the transducers on the pipe using the supplied chain clamps and coupling gel, measure the spacing using the tape measure provided. The user is then presented with a sensor positioning screen showing,

- Graph of received ultrasonic signal
- Signal to Noise Ratio
- ATA/ETA

If the parameters entered are all correct then the graph should appear as in figure (12).

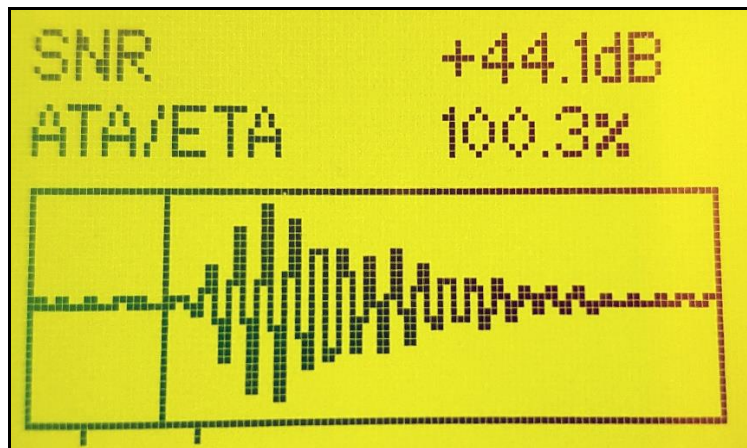


Figure (12) Ideal Sensor Positioning.

However, if the user has an incomplete knowledge of the pipe then the screen may look like figure (13) or figure (14).



Figure (13) Non-ideal Sensor Positioning, transducers too far apart.

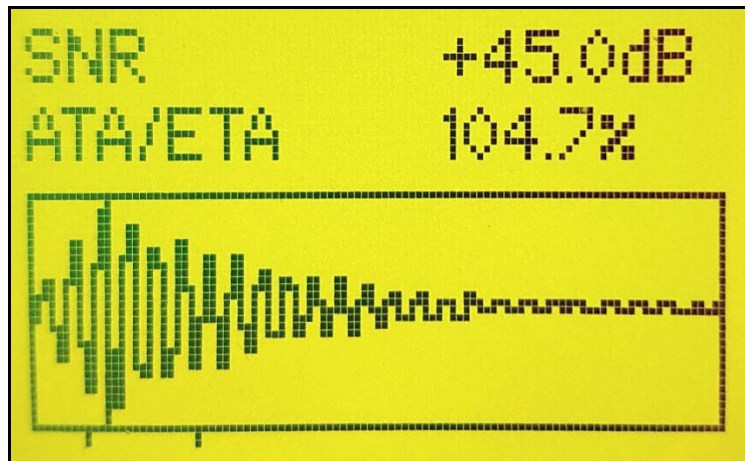


Figure (14) Non-ideal Sensor Positioning, transducers too close together.

In figure (13) the received signal is too far to the right, the user should slide the transducers closer together.

In figure (14) 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 line acting as arrival marker is between the 2 guide marks, 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.

SNR should peak and be above 24 dB.

3.1 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 where practical the advised upstream and downstream straight sections, see below, figure (15).
- 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.
- Pipe linings that are not bonded properly or are not conductive of ultrasound (rubber) will cause measurement problems.
- 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.

3.2 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 (15).

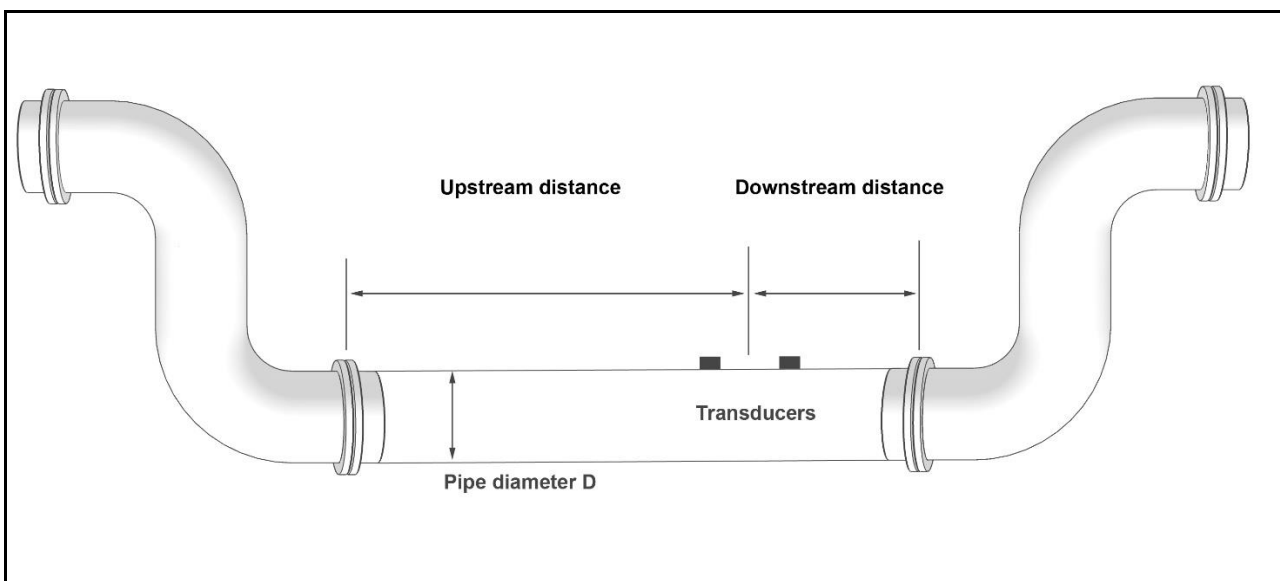


Figure (15) Upstream and downstream pipe lengths.

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.

3.3 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 surface.

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

chain clamp supplied or 10 mm wide jubilee clips.

3.4 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 it 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.

4.0 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 message will be displayed prompting user action. If the error persists contact customer support, see appendix A.

Error codes and their meanings can be found in the Main Menu under the Diagnostics Menu.

- MATH, there is a problem with the UFM central maths processor.
- STACK, there is a stack overflow problem.
- ADDR, there is a memory addressing problem.
- OSC, the UFM core oscillator is suffering a problem.
- SYSTEM, a general system wide fault has occurred.
- SPI2, there is a problem with the internal SPI data bus.
- I2C1, there is a problem with the internal I2C data bus.
- FRAM, there is a problem with the UFM external FRAM memory.

5.0 Icons

The UFM has a series of icons along the top of the LCD.

The meanings of these icons are from left to right as they appear;

- Maple leaf, unreliable measurement, check installation.
- Display, LCD backlight on/off.
- Loudspeaker, Audio buzzer on/off.
- Bell, I2C1 error.

- Clock, SYSTEM or timing error.
- Warning Triangle, MATH, STACK, ADDR or OSC error.
- Spinner, SPI2 or FRAM error.

In addition to showing icons, depending on the flow regime, see figure (16) the UFM displays;

- Zero, no flow
- L, laminar
- Tr, transition
- T, turbulent

in the top-left when in measurement mode.

Laminar flow is generally regarded to exist for Reynolds Number less than 2300, transition is in the range 2300 to 4000 and turbulent flow typically has a Reynolds Number greater than 4000.

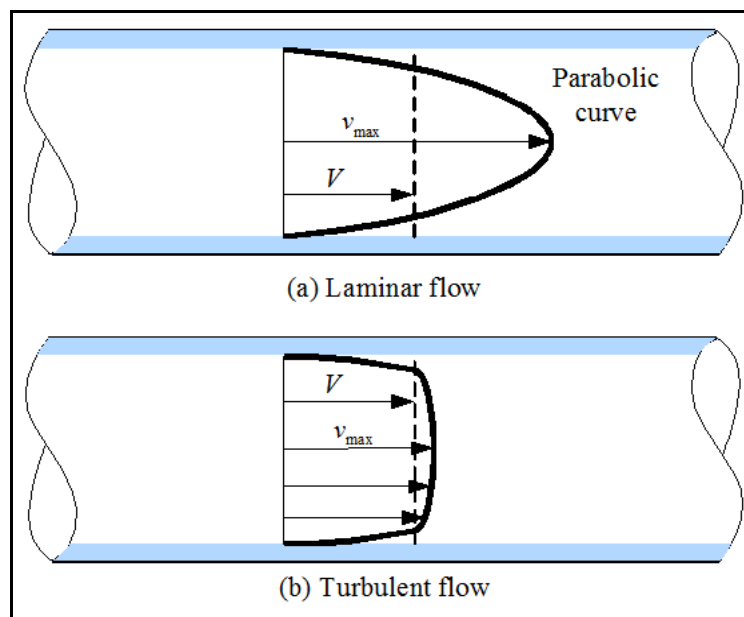


Figure (16) Laminar (a) and turbulent (b) flow.

6.0 Battery Life

The POCKET-UFM is powered by a single high capacity 9 Vdc PP3 primary cell 1200 mAh.

Under normal operating conditions the battery life of the UFM is in excess of 12 hours continuous measurement.

If using a rechargeable cell or primary cell with lower capacity then the run time of the UFM will be reduced.

If using a rechargeable cell then use the external charger recommended by that cell's manufacturer.

The UFM has an auto off feature to preserve battery life, if no keypad entry is made for 60 seconds when operating in the UI mode then the meter will auto power off. This feature is not available when in measurement mode

The LCD backlight will flash when the battery is low and needs to be changed.

7.0 Specification

The UFM has the following specification, features and performance;

- Pipe outer diameters ranging from 10 to 6500 mm.
- Temperature range for pocket meter -10 to +65 degC.
- Weight 230 g (including internal PP3 battery).
- Dimensions 185 x 85 x 25 mm.
- IP54 enclosure.
- Full 128 x 68 pixel graphics display with backlight.
- Full 17 key tactile keypad with audio feedback.
- Integral wall thickness gauging, 2 to 24 mm.
- Battery life up to 12 hours continuous use on a standard 9 V PP3 battery for easy replacement.

Features

- Light weight and small for easy, one handed operation.
- Intuitive installation using menu driven UI.
- Full set of instrument and measurement diagnostics.
- Signal oscilloscope for sensor positioning and diagnostics.
- Internal database of pipe, fluid and lining materials.
- Wall thickness gauging as standard using wall thickness probe.
- Heat quantity measurement (if inlet and outlet temperatures are known).
- All measured values can be totalled.
- Ability to save up to 10 configurations for different measurement points.

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
- Volumetric flow rate
- Mass flow rate
- Energy flow rate
- Volume
- Mass
- Energy

Transducers

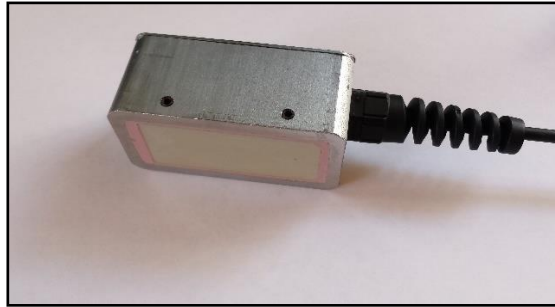


Figure (17) PEEK/stainless steel transducers.

- 3 operating frequencies to cover the range of pipe outer diameter 10 to 6500 mm.
- DM10, 1 MHz for pipes of 25 to 750 mm.
- DS10, 1 MHz for pipes of 50 mm and over.
- DM20, 2 MHz for pipes less than 25 mm.
- DN40, 4 MHz for pipes less than 15 mm.
- Dimensions 60 x 30 x 35 mm and 40 x 20 x 25 mm for locations with limited access.
- Material stainless steel and PEEK.
- Temperature range -10 to +80 degC.
- Ingress Protection rated IP54, with IP68 option.
- Cable length 1.5 m as standard.
- Matched pairs for accurate zero flow measurement.

8.0 Product Identification

Each UFM, pair of flow transducers and wall thickness probe come with a unique Identification code.

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

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 fluid properties

Fluid	Longitudinal Speed of Sound (m/s)
Water 20 (degC)	1482
Acetone	1190
Methanol	1121
Ethanol	1166
Alcohol	1440
Glycerine	1923
Petrol	1250
Diesel	1385
Toluene	1170
Coal Oil	1420
Petroleum	1290
Pine Oil	1280
Castor Oil	1502
Glycol	1620
Peanut Oil	1472

Appendix C Table of pipe and lining material properties

Material	Shear Speed of Sound (m/s)
Steel	3206
ABS	2286
Aluminium	3046
Copper	2270
Cast Iron	2460
GRP	3430
Glass	3276
PVC	1060
Cement	4190
Teflon	1450
Rubber	1600

Appendix D Table of speed of sound in water

Temperature (degC)	Speed of Sound (m/s)
0	1402.3
5	1426.1
10	1447.2
15	1465.8
20	1482.3
25	1496.6
30	1509.0
35	1519.7
40	1528.8
45	1536.3
50	1542.5
55	1547.3
60	1550.9
65	1553.4
70	1554.7
75	1555.1
80	1554.4
85	1552.8
90	1550.4
95	1547.1
99	1543.9

Appendix E 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 - 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.