Installation and Configuration Manual
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Micro Motion® 7829 Viscomaster® and Viscomaster Dynamic™ Viscosity Meters

Micro Motion®

EMERSON™
Process Management

Contents

Chapter 1
Introduction

1.1 Safety guidelines

Handle the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter with great care.

- Do not drop the meter.
- Do not use liquids incompatible with materials of construction.
- Do not operate the meter above its rated pressure or maximum temperature.
- Do not pressure test beyond the specified test pressure.
- Ensure all explosion-proof requirements have been applied.
- Ensure the meter and associated pipework are pressure tested to 1-1/2 times the maximum operating pressure after installation.
- Always store and transport the meter in its original packaging, including the transit cover secured by grub screws.
- To return a meter, refer to the Return Policy appendix for more information on the Micro Motion return policy.

Safety messages are provided throughout this manual to protect personnel and equipment. Read each safety message carefully before proceeding to the next step.

1.2 About the meter

1.2.1 What is it?

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is a digital viscosity meter, based on the proven tuning fork technology of Micro Motion. It is an all-welded sensor designed to be mounted directly into a pipeline or in a tank. Viscosity and density are determined from the resonance of the tuning fork immersed in the fluid, and a temperature sensor (RTD) is also fitted within the meter.

The meter is available in a 316 stainless steel, and the immersed tines can be laminated with PFA to inhibit the build up of residues such as asphaltenes.

The meter contains integral processing electronics to provide full configuration, enabling it to perform a variety of calculations.

Two forms of output are available:

- Two off 4-20 mA analog outputs, factory set but have individually configurable span, bias, limits, and filter options. The standard factory settings for these outputs are Line Kinematic Viscosity on Analog Output 1 and Line Temperature on Analog Output 2. Alternatively, the analog outputs may be controlled by one of the following:
    - Line dynamic viscosity
    - Line density
    - Base or referred kinematic viscosity
    - Base or referred density (API or Matrix referral)
    - Line temperature

Note: The Viscomaster Dynamic meter's analog output 2 is set to temperature and only the span, bias, and limits can be changed.

- An RS-485 (Modbus) interface, giving access to other measurement results, system information and configuration parameters.

No signal converter is required, which simplifies wiring and enables the meter to be connected directly to a plant monitoring and control systems and/or a local indicator.

The meter is factory set to perform API density referral. Re-configuration of the meter's default settings (see Appendix A) is achieved by linking a PC to the Modbus (RS-485) connection and running Micro Motion's ADView or ProLink II (v2.9 or later) software. Once configured, the PC can be removed.

1.2.2 7829 Viscomaster meter measurements

The 7829 Viscomaster meter directly measures the following fluid properties:

- Line dynamic viscosity – measured in centiPoise - cP.
- Line Density – measured in kg/m_3, g/cc, lb/gal, or lb/ft^3.
- Temperature – measured in °C or °F.

From these properties, the meter calculates:

- Line and base (referred) kinematic viscosity – measured in centiStokes - cSt.
- Line and base (referred) density – API or Matrix.
- Referral is made to 15°C, 1.013 bar; or at 60°F, 14.5 psi.

1.2.3 7829 Viscomaster Dynamic meter measurements

The 7829 Viscomaster Dynamic meter directly measures the following fluid properties:

- Line dynamic viscosity – measured in centiPoise - cP.
- Temperature – measured in °C or °F.

From these properties, the meter calculates:

- Line kinematic viscosity – measured in centiStokes - cSt.

Note: The line kinematic viscosity calculation requires the user input of a base (or reference) density value and a temperature (at which the base density value is valid).

1.2.4 What is it used for?

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is designed specifically to control the viscosity of Heavy Fuel Oil (HFO) used by power plants. This is typically achieved by adjusting the heating of incoming HFO to maintain the viscosity within the limits set by the engine manufacturer.

HFO is a low cost, high viscosity fuel derived from refinery wastes. The quality of the oil and its viscosity/temperature characteristics can vary due to:

- Stratification within storage tanks.
- Contamination in transit storage.
- Variations in the production process at the refinery or at the blending plant.

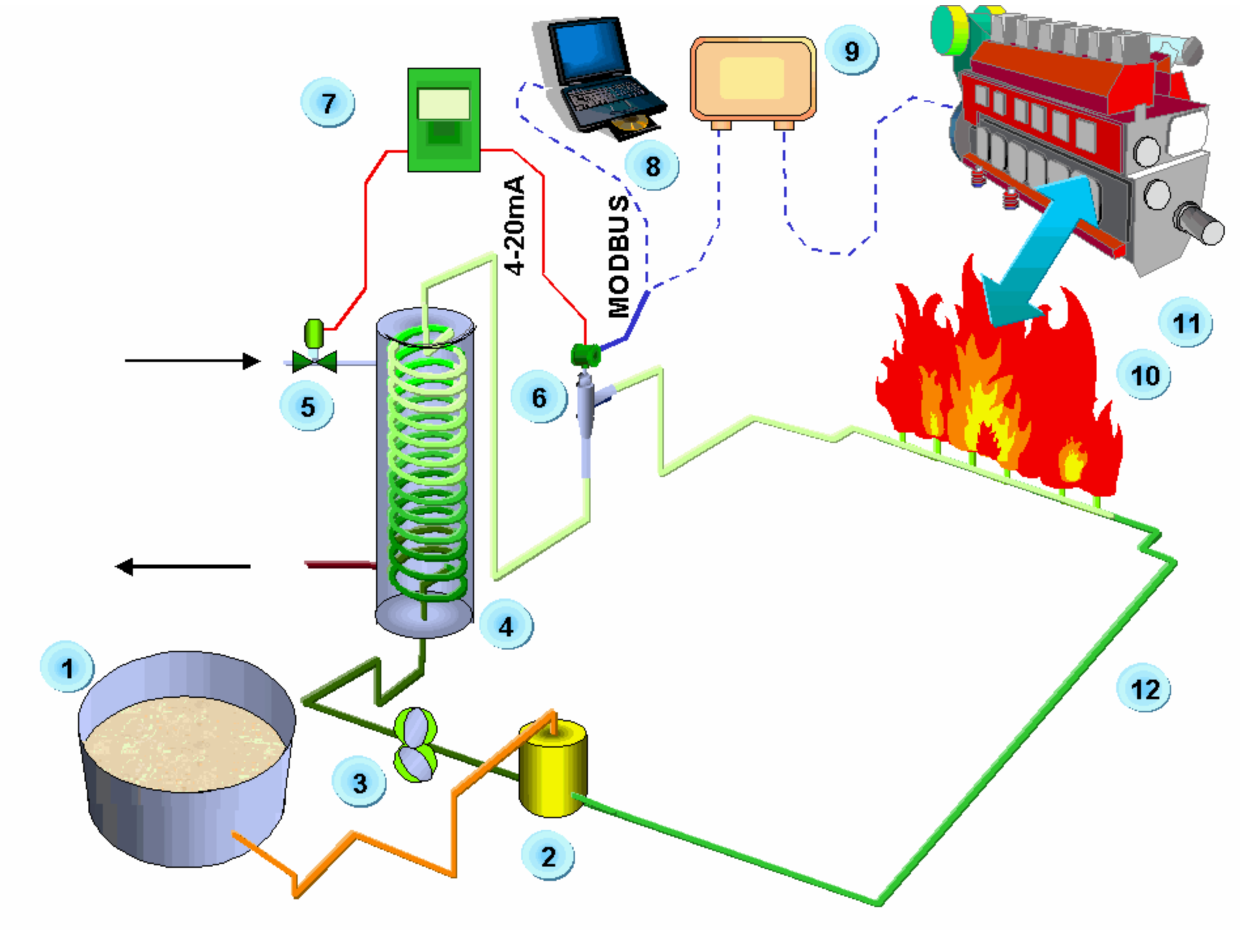
HFO heating is usually required to ensure that the viscosity of the oil at the injectors of a large diesel engine or burner nozzle is maintained at the optimum value (typically between 10 cSt and 20 cSt). Failure to observe the viscosity limits results in inefficient combustion, pollution problems and higher operating costs (either due to excessive fuel being burnt or premature wear to engine components).

Since simple temperature control has been shown to be ineffective due to the variability of oil quality in HFO, viscosity control is usually performed.

A typical HFO fuel circuit is shown in Figure 1-1.

Note: In some installations, equipment may be installed in between the viscosity transmitter and the burner / engine to remove contaminants from the fuel; the efficient operation of this equipment may also depend on the viscosity of the HFO.

Figure 1-1 **Typical HFO Fuel Circuit**



1	HFO fuel tank	**7**	Heater Controller
2	Mixer	**8**	Personal Computer (PC)
3	Re-circulation pump	**9**	Engine Management Computer
4	Fuel heater	**10**	Burner or
5	Control valve	**11**	Large Diesel Engine
6	Viscomaster	**12**	Unburned fuel return

Chapter 2
Installation

2.1 Introduction

All drawings and dimensions given in this manual are given here for planning purposes only. Before commencing fabrication, reference should always be made to the current issue of the appropriate drawings. Contact Micro Motion for details.

For further information on handling and using the meter, see **"Safety guidelines" on page 1**

There are a variety of external factors that affect the ability of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter to operate successfully. In order to ensure that your system works correctly, the effects of these factors must be taken into consideration when designing your installation.

There are two main aspects to consider:

- The accuracy and repeatability of the measurements
- The relevance of the measurements to the overall purpose of the system

Factors which may adversely affect accuracy and repeatability include:

- The presence of gas or bubbles within the fluid being measured
- Non-uniformity of the fluid
- The presence of solids as contaminants
- Fouling of the meter
- Temperature gradients
- Cavitations and swirls
- Operating at temperatures below the wax point of crude oils
- The correct pipe diameter that corresponds to the calibration of the meter.

In some applications, absolute accuracy is less important than repeatability. For example, in a system where the control parameters are initially adjusted for optimum performance, and thereafter only checked periodically.

The term achievable accuracy can be used to describe a measure of the product quality that can be realistically obtained from a process system. It is a function of measurement accuracy, stability and system response. High accuracy alone is no guarantee of good product quality if the response time of the system is measured in tens of minutes, or if the measurement bears little relevance to the operation of the system. Similarly, systems which require constant calibration and maintenance cannot achieve good achievable accuracy.

Factors which may adversely affect the relevance of the measurements could include:

- Measurement used for control purposes being made too far away from the point of control, so that the system cannot respond properly to changes.
- Measurements made on fluid which is unrepresentative of the main flow.

2.2 Installation effects

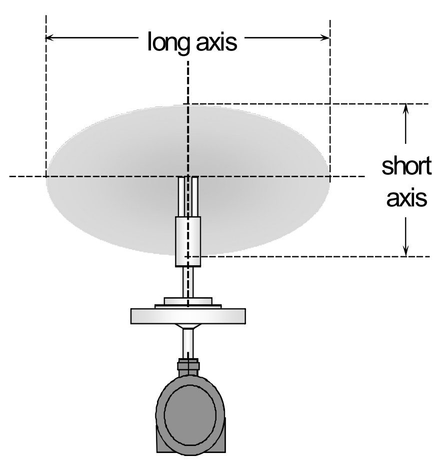
Unlike other Micro Motion meters, the vibrating tines of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter are not totally enclosed. The walls of the pipe or tank in which the meter is installed will introduce boundaries to the fluid flow, and this will have an effect on the calibration of the sensor.

To overcome this, Micro Motion calibrates the meter under a variety of pre-defined conditions corresponding to the installation and pipe schedule. This condition is selected when ordering the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter, so that by calibrating the meter under the same boundary conditions as the installation, the need for additional on-site calibration is eliminated.

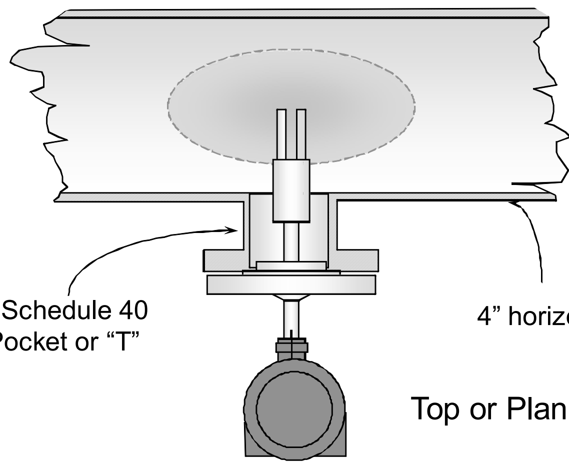
2.2.1 Boundary effects

Any insertion device or meter can only measure the properties of the fluid within the region of fluid to which it is sensitive.

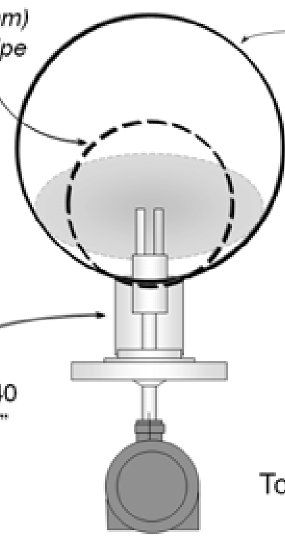
For practical reasons, it is helpful to consider the sensitive, or effective region, for the viscometer as an ovoid centered on the tips of the tines with its long axis aligned with the direction in which the tines vibrate, as shown below. The meter is insensitive to the properties of the fluid outside this region and progressively more sensitive to fluid properties the closer the fluid is to the tines. Density can be considered a "mass centered" effect and viscosity a "surface centered" effect in this visualization; i.e. the measurement of density is more uniformly sensitive to the density of fluid throughout the region while viscosity measurement is much more critically sensitive to fluid on the surface of the tines.



If part of this volume is taken up by the pipework or fittings there is said to be a boundary effect; i.e., the intrusion of the pipe walls will alter the calibration. The diagram below illustrates the meter installed in a pocket on the side of a 4" (100 mm) horizontal pipe line (viewed from above). The effective region is completely enclosed within the pipe line and thus is completely fluid.

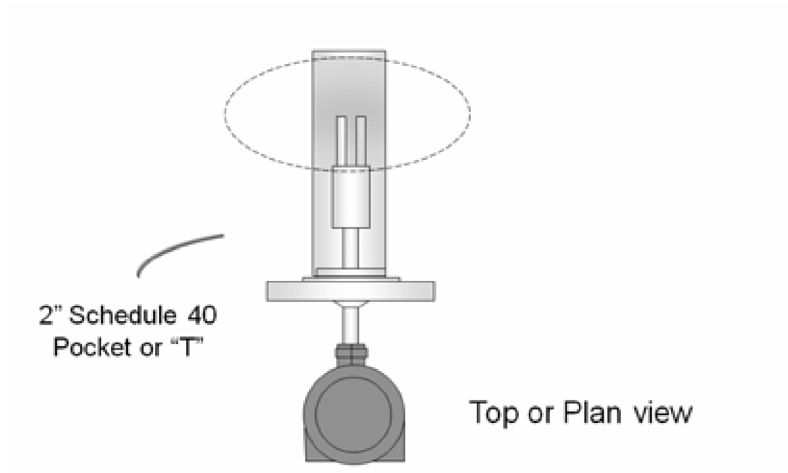


This next view shows other pipe outlines superimposed:



The smaller circle represents a 4" (100 mm) vertical pipe, which because the meter orientation is constant irrespective of pipe orientation intersects the effective region. The 6" (150 mm) pipe is the smallest pipe diameter to completely enclose the effective region when the pipe is vertical. Thus smaller pipe diameters can lead to a variety of different geometries which would each require a separate calibration.

An alternative condition is shown in the next diagram where the side pocket is extended until it passes completely through the effective region producing a "core":



From this, it would appear that almost every installation requires a separate in situ calibration – a very undesirable situation. The problem is resolved by providing standard calibration geometries which can be used in all pipe work configurations and thereby allow the factory calibration conditions to be reproduced in the process.

2.2.2 Fluid at the sensor

The fluid in the effective zone of the meter must be of uniform composition and at uniform temperature. It must be representative of the fluid flow as a whole.

This is achieved either by mixing of the fluid either using a static inline mixer or taking advantage of any natural pipe condition that tends to cause mixing, such as pump discharge, partially open valves. The viscometer should be installed downstream where the flow is just returning to laminar flow conditions.

2.2.3 Thermal effects

Avoid temperature gradients in the fluid and in the pipe work and fittings immediately upstream and downstream of the viscometer.

Always insulate the viscometer and surrounding pipework thoroughly. Insulation must be at least 1" (25 mm) of rockwool, preferably 2" (50 mm) (or equivalent insulating heat jacket) and enclosed in a sealed protective casing to prevent moisture ingress, air circulation, and crushing of the insulation. Special insulation jackets are available from Micro Motion for the flow-through chambers, which, because of the low volumetric flow rates and hence low heat flow, are more vulnerable to temperature effects.

Avoid direct heating or cooling of the viscometer and associated pipe work upstream and downstream that is likely to create temperature gradients. If it is necessary to provide protection against cooling due to loss of flow, electrical trace heating may be applied, provided it is thermostatically controlled and the thermostat is set to operate below the minimum operating temperature of the system.

2.2.4 Entrained gas

Gas pockets can disrupt the measurement. A brief disruption in the signal caused by transient gas pockets can be negated in the signal conditioning software, but more frequent disruptions or serious gas entrainment must be avoided. This can be achieved by observing the following conditions:

- Keep pipe lines fully flooded at all times
- Vent any gas prior to the viscometer
- Avoid sudden pressure drops or temperature changes which may cause dissolved gases to break out of the fluid
- Maintain a back pressure on the system sufficient to prevent gas break out (e.g. back pressure equivalent to twice the 'head loss' plus twice the vapour pressure)
- Maintain flow velocity at the sensor within the specified limits.

2.2.5 Solids contamination

- Avoid sudden changes of velocity that may cause sedimentation.
- Install the viscometer far enough downstream from any pipework configuration which may cause centrifuging of solids (e.g. bends).
- Maintain flow velocity at the sensor within the specified limits.
- Use filtration if necessary.

2.2.6 Vibration effects

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter has been extensively tested under severe vibration conditions, both in the test laboratory and Marine/Power Station/Burner applications. The meter is approved according to the Lloyds Register standard, levels ENV 1, 2 and 3 and operates correctly up to the classification level of ENV4 (vibration test 2). This vibration level, ENV 4 includes correct operation at vibration levels of 4 g rms between frequencies of 5–100 Hz, and is used to describe the requirements for engine mounted equipment.

If vibration levels exceed these limits, or the meters are not installed as recommended by Micro Motion, Micro Motion cannot take responsibility for the correct operation of these units.

2.3 General fitting notes

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter uses a 1.5" Swagelok style of fitting which requires no seals, minimizing maintenance and spares. These fittings are leak proof over a wide range of pressure and temperature conditions, and during rapid temperature cycling, which may occur during the transfer from HFO to distillate fuel.

The meter should normally be installed horizontally, with the slot between the tines vertical; this ensures that, for low flow rates, any solids or gas bubbles are not trapped. When installed in a flow-through chamber, however, provided that the flow rate is within the recommended range, the transmitter can be mounted horizontally or vertically.

Allow at least 7.8" (200 mm) clearance to enable the meter to be removed from the fitting.

2.4 Standard installations

2.4.1 Overview

To overcome the need for in situ calibration for every installation, three standard installations are proposed. If an installation conforms to one of these standards, the factory calibration of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is valid, and in-situ calibration unnecessary. The three installations are summarized in Table 2-1.

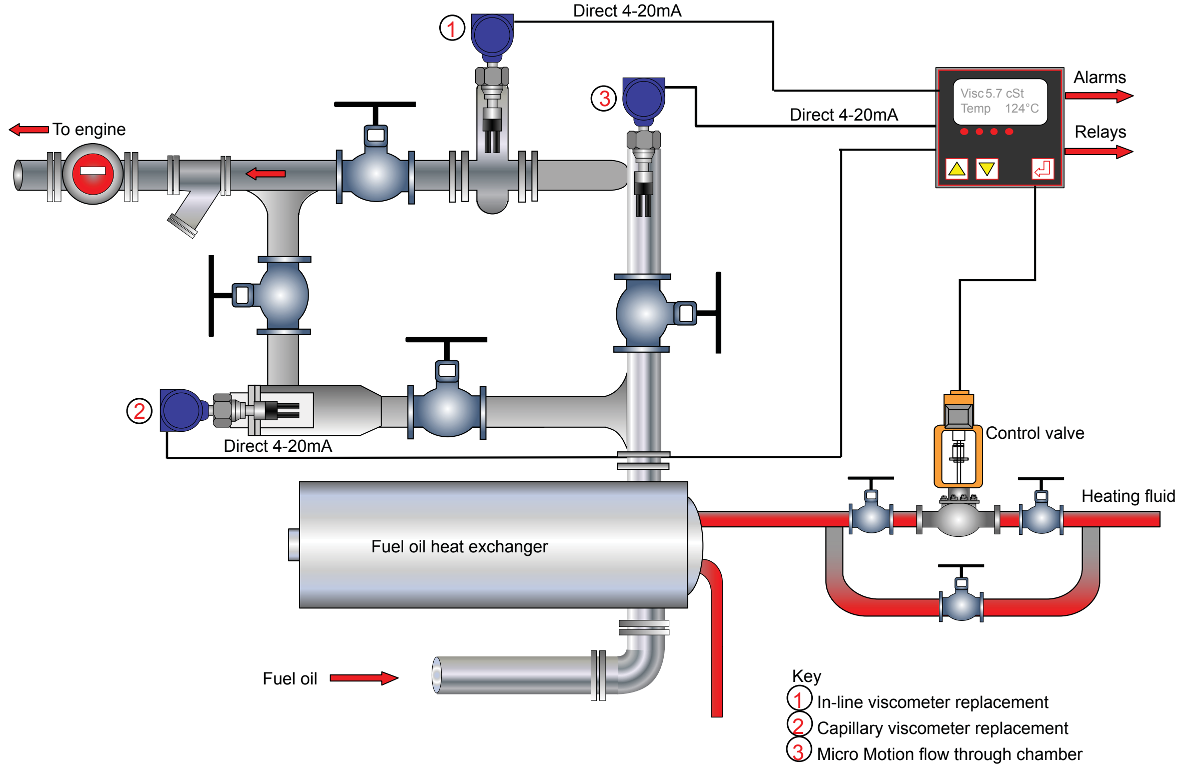
Note: Higher flow rate installations (up to 100 m³/hr) can be accommodated. Contact Micro Motion for details.

Table 2-1. Descriptions of standard installations

Standard installation	VAF VISCOTHERM / NAKAKITA Retrofit	VAF VISCOSENSE Retrofit	Flow-through chamber
Description	Viscomaster tines project into adapter kit with 2½“ Schedule 40 boundary.	Viscomaster tines are contained in a side pocket off the main flow, recessed by 25.4 mm (1 inch).	Viscomaster tines are contained in a flow-through chamber in which fluid is circulated from the main flow.
Flow rate (1)	10 to 330 l/min (0.6 to 20 m^3/hr) (2.6 to 87 US gal./min).	10 to 330 l/min (0.6 to 20 m^3/hr) (2.6 to 87 US gal./min).	10 to 330 l/min (0.6 to 20 m^3/hr) (2.6 to 87 US gal./min).
Viscosity limits	Up to 100 cSt.	Up to 100 cSt	Up to 100 cSt.
Temperature	-50 to 200°C (-58 to 392°F).	-50 to 200°C (-58 to 392°F).	-50 to 200°C (-58 to 392°F).
Main flow pipe size	As defined by capillary Viscomaster chamber.	50 mm (2").	50 mm (2").
Advantages	• Simple replacement of capillary viscometer. • Fast response. • Good flow and temperature conditioning.	• Simple replacement of torsional viscometer. • Fast response. • Good flow and temperature conditioning.	• Adaptable installation to any diameter main pipe and for tank applications. • Ideal for flow and temperature conditioning. • Fast response.

(1) Viscomaster tines project into adapter kit with 2-½“ Schedule 40 boundary and retracted by 1” (25 mm).

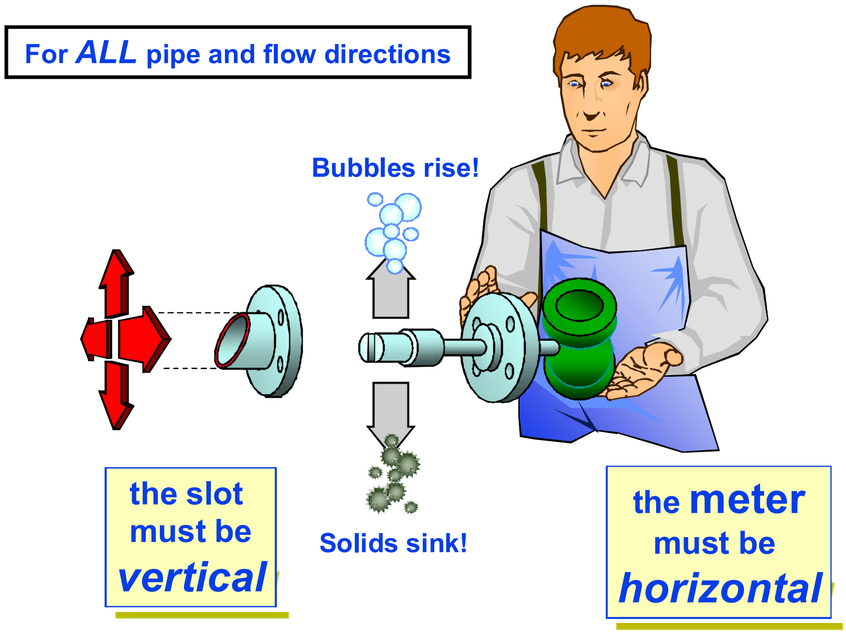
These three types of standard installation are graphically shown in the following schematic.



2.4.2 Meter orientation

The meter must always be installed horizontally, and orientated to allow flow in the gap between the tines. This is irrespective of the pipe line orientation, and helps to prevent the trapping of bubbles or solids on the meter.

Figure 2-1 **Meter orientation**



Note: All drawings and dimensions given in the following sections are derived from detailed dimensional drawings. They are given here for planning purposes only. Before commencing fabrication, reference should always be made to the current issue of the appropriate drawings - contact Micro Motion for details.

2.4.3 Flow-through chamber installation

Flow-through chambers are fabricated by Micro Motion, and are available with either weld prepared ends or with flange or compression fittings for connection into the process pipe lines. They are available with 2" NB inlet and outlet pipes.

Note: The length of the inlet and outlet pipes must not be altered, otherwise the temperature response and stability of the fitting may be adversely affected.

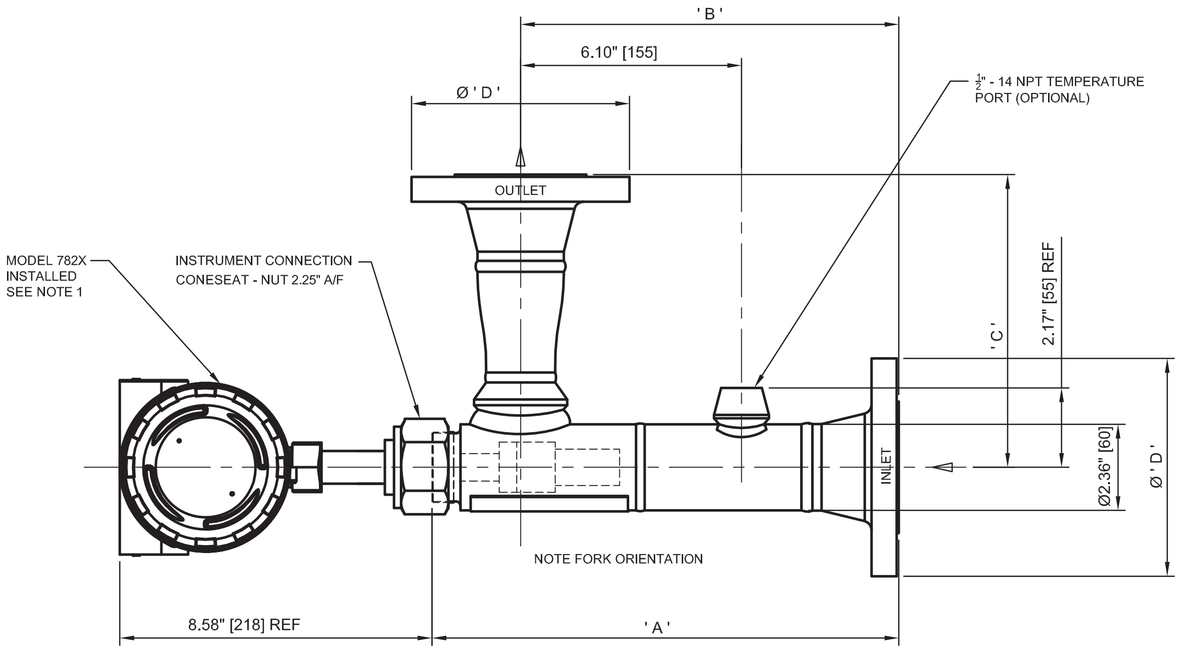
Conditions:

- Flow: constant, 5–300 l/min for 3" sch 80 calibration bore.
- Viscosity: 0.5 to 100 cP
- Temperature: -50 °C to 200 °C (–58 °F to 392 °F)
  [-40 °C to 200 °C (-40 °F to 392 °F) in hazardous areas]
- Pressure: 70 bar @ 204 °C, subject to process connections.

The PT100 is a direct insertion type, without a thermowell, and uses a ¾" Swagelok connection.

The diagram below shows an example of this type of standard installation.

Dimensions shown in inches (mm)



PROCESS CONNECTIONS	'A' DIM	'B' DIM	'C' DIM	'D' DIA
2" ANSI 150RF	12.60" [320]	10.20" [259]	7.80" [198]	5.98" [150]
2" ANSI 300RF	12.84" [326]	10.43" [265]	8.03" [204]	6.5" [165]
2" ANSI 600RF	13.23" [336]	10.83" [275]	8.43" [214]	6.5" [165]
(50mm) DIN 2527 DN50 PN40	11.97" [304]	9.57" [243]	7.17" [182]	6.5" [165]
(50mm) DIN 2527 DN50 PN100	12.76" [324]	10.35" [263]	7.95" [202]	7.68" [195]

The three compression fittings on the flow pockets (½" drain, ¾" temp probe, and 1-½" mounting nut for the meter) are rated to above the working pressure of the flow pocket. The fittings may be Swagelok or Parker; both are used in manufacture.

The fittings are certified to the following standards:

- Swagelok: SO9001 / 9002, ASME,TUV,CSA,DNV
- Parker: ISO 9001 / 9002, TUV, DNV, LLOYDS

2.4.4 VAF Viscosense retrofit

Conditions:

- Temperature: -50 to +200 °C (–58 °F to 392 °F)
- Flow: 40 to 330 l/min (2.5 to 20 m^3/hr) (11 to 87 US gal/min)
- Viscosity limit: Up to 100 cSt
- Pressure: As defined by process flanges
- Calibration boundary: 2-½” Schedule 40

This retro-fit kit has been specifically designed to provide a simple, direct replacement for existing vibration-type viscometers. Typically, the flange-to-flange distance is 5.9” (150 mm), although other larger versions can be accommodated (contact Micro Motion for details of the Universal retro-fit adapter). Usually, no pipework changes are necessary.

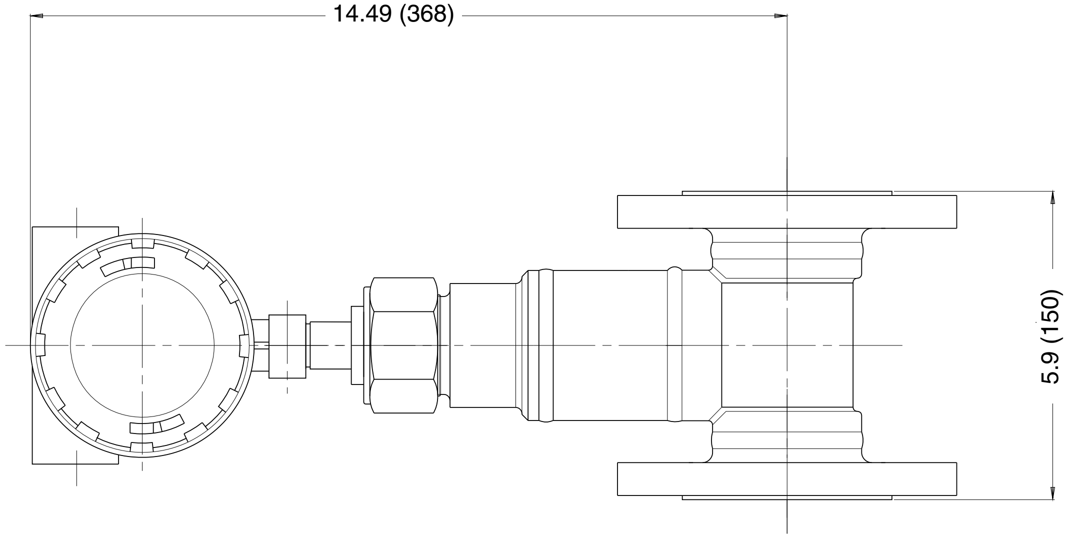
The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is mounted 0.98” (25 mm) away from the main flow line, allowing good product mixing, sensor protection and stable measurement conditions.

Typical dimensions are shown in Figure 2-2.

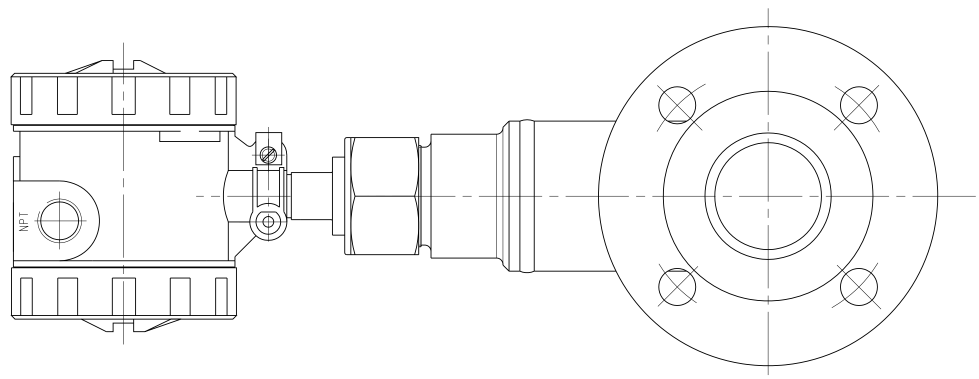
Note: The schematic shown may vary without notice, although overall dimensions will remain unchanged.

Figure 2-2 VAF Viscosense retrofit dimensions

Dimensions shown in inches (mm)



150 mm unit shown
DN50 PN16 flanges shown



2.4.5 VAF Viscotherm retrofit

Conditions:

- Temperature: -50 to +200°C (–58 °F to 392 °F)
- Flow: 40 to 330 l/min (2.5 to 20 m^3/hr) (11 to 87 US gal/min)
- Viscosity limit: Up to 100 cSt
- Pressure: As defined by process flanges
- Calibration boundary: 2–½” Schedule 40

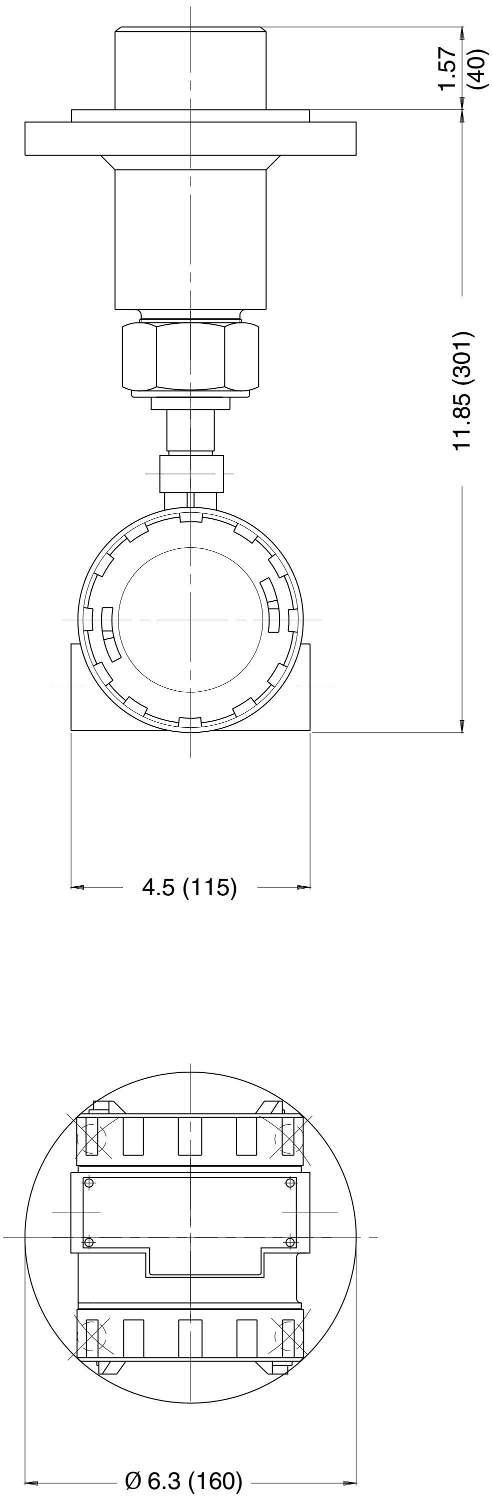
This retro-fit kit has been specifically designed to provide a simple, direct replacement for existing capillary viscometers. Typically, these viscometers are designed to operate with their own measurement chamber, to which this adapter will be attached. No pipework changes are necessary.

Typical dimensions are shown in Figure 2-3.

Note: The schematic shown may vary without notice, although overall dimensions will remain unchanged.

Figure 2-3 VAF Viscotherm retrofit dimensions

Dimensions shown in inches (mm)



2.5 Commissioning

1. Once the pipework installation has been prepared, and before installing the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter and thermal insulation, fit a blanking compression nut to the meter mounting, and pressurise and flush the system.
2. Isolate the system, depressurize and remove the blanking compression nut.
3. Install the meter, and tighten the fitting nut, but do not fit the thermal insulation.
4. Slowly pressurize the system and check for leaks, particularly if the normal operating temperature is high, or the meter has been fitted cold; tighten as necessary.
5. Now tighten the nut again, if necessary. Once you are satisfied with the integrity of the seal, the insulation can be fitted.
6. Once the system has stabilized and is leak free, fit the insulation material.

2.6 During normal running

Observe and record the normal operating temperatures and viscosity readings. You can monitor the system using ADView or ProLink II. (See the Using ADView and ProLink II chapter.)

When several systems are run in parallel and use the same fuel source, comparison of the readings between installations can be a useful indicator of possible system faults. Differences between readings or changes from the normally observed conditions should always be investigated to confirm that instrumentation is functioning correctly.

Particular attention should be paid to the conditions before and after engine shutdowns in order to detect any possibility of asphaltenes coating (precipitation of asphaltenes from the HFO caused by dilution with distillate fuel) which may cause the instrument to read high. If the re-circulation flow is high enough or the instruments have been supplied with PFA coating, asphaltenes or any other deposits should quickly be removed and the expected operating temperatures should be restored.

If the meter is still reading high and the oil quality is known not to have changed, then the instrument should be removed and cleaned with a rag. Removal should only be performed in accordance with the engine or burner manufacturers' recommendations or in accordance with safe site practice. This must include isolation and depressurization.

2.7 Removal and refitting procedure

All national and international safety regulations should be observed.

Observe safe working practice, wear protective clothing and safety glasses, and use suitable gloves to prevent burns or absorption of hot oil.

Check that the isolation valves have been fully closed, remove insulation and allow to cool to a safe level (cooling will tend to reduce any retained pressure) and de-pressurize the system if a drain valve or pressure relieving valve is fitted.

When the above conditions are satisfied, slacken the lock nut by 1-½ to 2 turns, sufficient for the sensor to be rocked. (If necessary, jolt the meter loose with a blow of the hand to the amplifier housing.) This will allow the seal between the sensor and the chamber retro-fit kit to be broken. Do not slacken the lock nut further unless the seal is broken and the sensor is definitely loose in the fitting.

Note: If the system is still pressurized, the meter may lift and be held against the retaining nut. Rocking and alternately pushing the sensor in and out of the pocket within the limits allowed by the slackened nut will break any seal and allow oil under pressure to seep past the lock nut. If this leakage is excessive, re-tighten the lock nut and take further action to de-pressurize the system.

When the meter can be rocked in the flow chamber and there is no serious or continuous escape of oil, it is safe to remove the lock nut.

Always keep all parts of your body away from the axis of the sensor (i.e., the direction in which the sensor will be withdrawn). If the system is under pressure or suddenly comes under pressure (e.g., due to valve failure or pump start), and the lock nut is not in place, the instrument may be forcibly ejected from the flow chamber and cause serious injury.

Clean and maintain the meter as directed and then refit it, as described in Section 2.5.

Chapter 3
Electrical Connections

For installations in hazardous areas:

- **For ATEX installations, the electrical installation must strictly adhere to the safety information given in the ATEX safety instructions booklet shipped with this manual. See Section 1.1 for important information.**
- **For installations in USA and Canada, the electrical installation must strictly adhere to the Electrical Codes and a conduit seal is required within 2" (50 mm) of the enclosure.**

3.1 Introduction

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter has two types of output:

- Two 4-20mA analog outputs

  The *Viscomaster Dynamic* has a *single* fully configurable output proportional to a user-specified parameter. The *Viscomaster* has *two* fully configurable outputs.

  The parameters that can be output on each analog output are as follows:

Note: In all cases, the limit values of each analog output are configurable.

Viscomaster Dynamic		Viscomaster	
Analog Output 1	**Analog Output 2**	**Analog Output 1**	**Analog Output 2**
Dynamic viscosity (cP)	Temperature (1)	Dynamic viscosity (cP)	Dynamic viscosity (cP)
Kinematic viscosity (cSt) (1)		Kinematic viscosity (cSt) (1)	Kinematic viscosity (cSt)
Line density		Temperature	Temperature (1)
Temperature		Line density	Line density
		Referred density	Referred density
		Referred viscosity	Referred viscosity
		CII	CII
		CCAI	CCAI

(1) Factory default selection.

- A Modbus (RS-485) interface, giving access to other measurement results, system information and configuration parameters. The Modbus interface is also used to configure the meter, using a PC running the Micro Motion ADView or ProLink II software (see Using ADView and ProLink II chapter).

It is recommended that both outputs are installed, requiring a minimum of eight wires (two for each output, and two for power). Although you may not immediately require the Modbus connection, it may be required for in-situ calibration adjustment and future system enhancements, and the cost of the additional wires is trivial compared to the expense of installing them retrospectively.

A number of factors must be taken into account when planning the electrical installation. These include:

- Power supply
- EMC
- Ground connections
- Cables
- Surge protection
- Installation in explosive area
- Modbus connections
- Analog connections.

3.2 Installation considerations

3.2.1 Power supply

The power supply to the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter must have the following requirements:

- Voltage: Nominally 24 VDC, but in the range 20 to 28 VDC.
- Current: for transmitter – 50 mA; for mA outputs – 22 mA per output.

If several meters are to be used within a local area, one power supply can be used to power them all; where the meters are distributed over a wide area and cabling costs are high, it may be more cost effective to use several smaller, local power supplies.

Upon leaving the factory, the two 4-20 mA analog outputs are non-isolated as they are powered through internal links to the power supply input. However, if split-pads “LNK A” (Analog Output 1) and “LNK B” (Analog Output 2) by the terminal block are ‘broken’, they become isolated and require a separate 20-28 VDC power supply (see the 4–20 mA outputs section for details).

If an RS-232 to RS-485 converter is used (for example to connect to a serial port on a PC), this may also require a power supply (see the Further information on RS-485 section for details).

Care should be taken where there is the possibility of significant common-mode voltages between different parts of the system. For example, if the meter is locally powered from a power supply which is at a different potential to the RS-485 ground connection (if used).

3.2.2 EMC

To meet the EC Directive for EMC (Electromagnetic Compatibility), it is recommended that the meter be connected using a suitable instrumentation cable containing an overall screen. This should be earthed at both ends of the cable. At the meter, the screen can be earthed to the meter body (and therefore to the pipework), using a conductive cable gland.

3.2.3 Ground connections

It is not necessary to earth the meter through a separate connection; this is usually achieved directly through the metalwork of the installation.

The electronics and communications connections (RS-485/Modbus and 4-20 mA analog output) of the meter are not connected to the body of the meter. This means that the negative terminal of the power supply can be at a different potential to the earthed bodywork.

In the majority of applications, it is not necessary to connect the RS-485 ground connection. In areas where there is a significant amount of electrical noise, higher communications integrity may be obtained by connecting the negative power terminal (pin 2) of the meter to the communications ground. If this is done, it is important to ensure that the possibility of ground loops (caused by differences in earth potential) is eliminated.

3.2.4 Cabling requirements

Although it is possible to connect separate cables to the meter for power, RS-485 and the 4-20 mA analog output, it is recommended that all connections are made through one instrumentation-grade cable.

Connections for the Analog and Modbus signals should be individually screened twisted-pairs with an overall screen, foil or braid for the cable. Where permissible, the screen should be connected to earth at both ends. (At the meter, this is best done using a conductive cable gland.)

Cables should conform to BS2538. In the USA, use Belden 9402 (two-pair) or Beldon 85220 (single-pair). Other cables that are suitable are those that meet BS5308 Multi-pair Instrumentation Types 1 and 2, Belden Types 9500, 9873, 9874, 9773, 9774 etc.

The typical maximum recommended cable length for the above cable types is 1000 m (3200 ft), but care must be taken to ensure that the power supply at the meter is at least 20 V. Thus, for 24 V power supply, the overall resistance for the power supply connections (both wires in series) must be less than 100 ohms.

In order to complete the wiring, you will need the following parts:

- ½” NPT to M20 gland adapter
- ½” NPT blanking plug
- M20 x 1 cable gland (not supplied).

The gland adapter and blanking plug are supplied with the meter – these two parts are Exd rated. However, you will need to get a suitably rated cable gland:

- For non-hazardous area installations, use an IP68 or higher rated cable gland.
- For hazardous area installations use an Exd-rated cable gland.

In hazardous areas, all parts must be explosion-proof. Alternative parts may be required in order to meet local electrical installation regulations.

3.2.5 Surge protection

Careful consideration should be given to the likelihood of power supply surges or lightning strikes. The power supply connections of the meter have a surge arrestor fitted that gives protection against power supply transients.

If there is a possibility of lightning strikes, external surge protection devices - one for each pair of signals and the power supply - should be installed as close to the meter as possible.

Another method of surge protection is to connect an MOV (Metal Oxide Varistor) (breakdown voltage >30 V) with an NE-2 neon bulb in parallel across each wire and ground. These can be mounted in a junction box close to the meter.

If the RS-485/Modbus output is permanently connected to a PC, an independently powered, fully isolated RS-485 to RS-232 converter should be used. (See the Further information on RS-485 section for details).

3.2.6 Installation in explosive areas

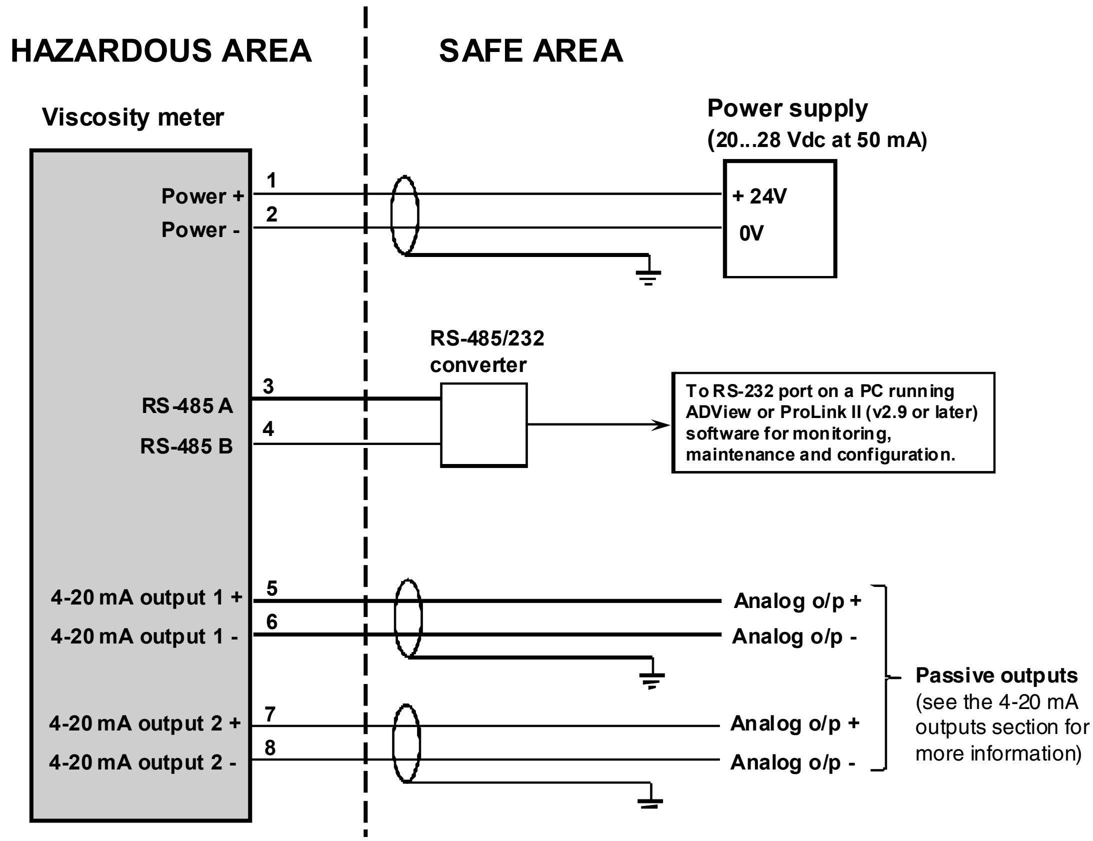
For installations in hazardous areas:

- **For ATEX installations, the electrical installation must strictly adhere to the safety information given in the ATEX safety instructions booklet shipped with this manual. See Section 1.1 for important information.**
- **For installations in USA and Canada, the electrical installation must strictly adhere to the Electrical Codes and a conduit seal is required within 2” (50 mm) of the enclosure.**

The meter is an explosion-proof and flameproof device. However, it is essential to observe the rules of compliance with current standards concerning flameproof equipment:

- Electronics housing caps should be tightened securely and locked in position by their locking screws.
- The electrical cable or conduit should have an appropriate explosion-proof cable gland fitted.
- If any electrical conduit entry port is not used, it should be blanked off using the appropriate explosion-proof blanking plug, with the plug entered to a depth of at least five threads.
- The spigot must be locked in place.

Figure 3-1 **Wiring diagram**



Notes

1. The main 24 VDC power supply must supply the following: 20 to 28 VDC at 50 mA for transmitter; and, 22 mA per analog output used.
2. The RS-485/232 converter and PC are not normally installed permanently. However it is strongly recommended that the wiring to the meter is made at installation.
3. Upon leaving factory, the two analog outputs are non-isolated as they are powered through internal links to Power Supply Input.
4. If split-pads “LNK A” (Analog Output 1) and “LNK B” (Analog Output 2) by the terminal block are broken, the two 4-20 mA analog outputs become isolated; direct connections to an external power supply is then required. A second or third external 20 to 28 VDC power supply can be used. (See 4-20 mA outputs section for more details).
5. Typically, four pairs of shielded 19/0.30 mm^2 (#16 AWG) to 19/0.15 mm^2 (#22 AWG) wires are used for wiring.
6. The naming conventions for RS-485 signals differ between manufacturers. If RS-485 communications do not function correctly, try swapping the ‘A’ and ‘B’ signals over at one end of the link.

3.3 Wiring the meter

Figure 3-2 shows the terminal board of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter. To reveal the terminal board, it is necessary to unscrew the housing cap; the procedure is described in the Wiring Procedure section.

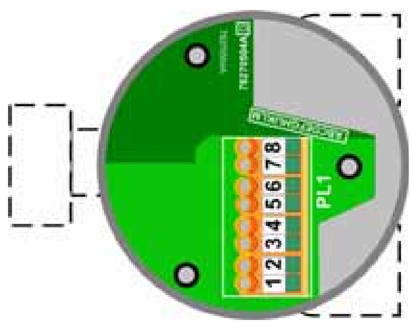
Note: If the meter is to be used in hazardous areas, the electrical installation must strictly adhere to the safety information given in the ATEX safety instructions booklet that shipped with this manual. See also Section 1.1 for more safety information.

The connections to the meter are:

- Power
- Modbus (RS-485) communications
- Analog outputs (4-20 mA).

It is recommended that you install all connections (eight cores) at installation, to avoid the possibility of expensive alterations to the cabling at a later date. Typically, four pairs of shielded 19/0.30 mm^2 (#16 AWG) to 19/0.15 mm^2 (#22 AWG) wires are used.

Figure 3-2 View of the terminal board

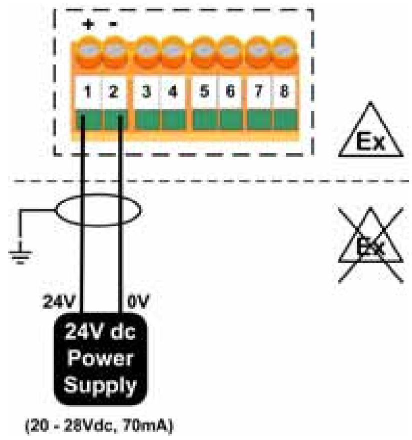


3.4 Power supply input

Terminals **1** and **2** are for connecting an external 24 VDC power supply, as guided in Figure 3-3.

Ensure that the loop resistance of the cable(s) is such that the voltage at the meter terminals is greater than 20 volts. (The maximum voltage at the meter terminals is 28 VDC.)

Figure 3-3 Power supply connections



3.5 Modbus (RS-485)

Terminals **3** and **4** are for RS-485/Modbus connections to a PC, as shown in Figure 3-4. For cable distances above 100 m, see the Further information on RS-485 section.

Note: The PC and converter are always located in a non-hazardous (safe) area.

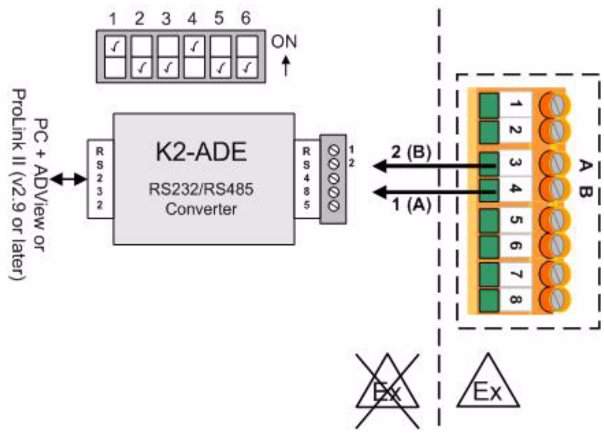
The RS-485/232 converter and PC are not normally installed permanently. However it is strongly recommended that the wiring to the meter is made at the time of installation.

For detailed information on RS-485, see the Further information on RS-485 section.

Note: If you encounter communication difficulties with RS-485, swap over the 'A' and 'B' signal connections at one end of the network.

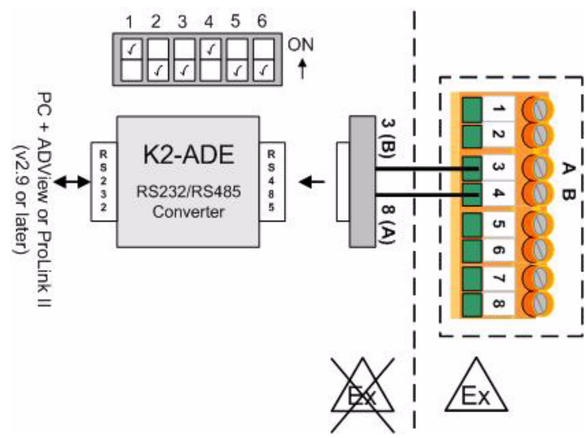
Figure 3-4 **Modbus connections < 100 m**

Terminal block version



OR

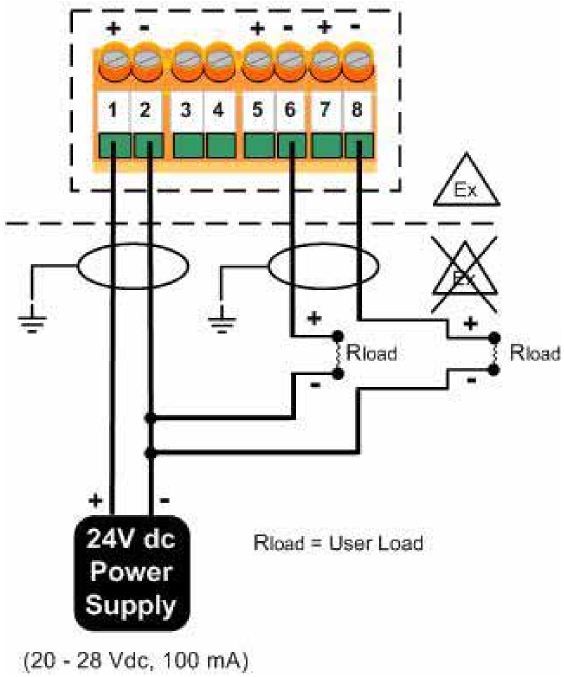
9-pin DIN connector
version



3.6 4-20 mA outputs

Terminals **5**, **6**, **7** and **8** are for connecting the two 4-20 mA analog outputs to external devices, such as a signal converter. Upon leaving the factory, the two 4-20 mA analog outputs are non-isolated as they are powered through internal links to the Power Supply Input.

Figure 3-5 4–20 mA output using the main power supply



However, if split-pads "LNK A" (Analog Output 1) and "LNK B" (Analog Output 2) by the terminal block are 'broken', they become isolated and require direct connections to another external 20–28 VDC power supply. A second or third external 20–28 VDC supply can be used.

To isolate the analog outputs from internal power, use a sharp knife to cut the fine metal strip (or trace) for the appropriate split-pad (see Figure 3-6).

Figure 3-6 Isolating an analog output from internal power (for external power connection)

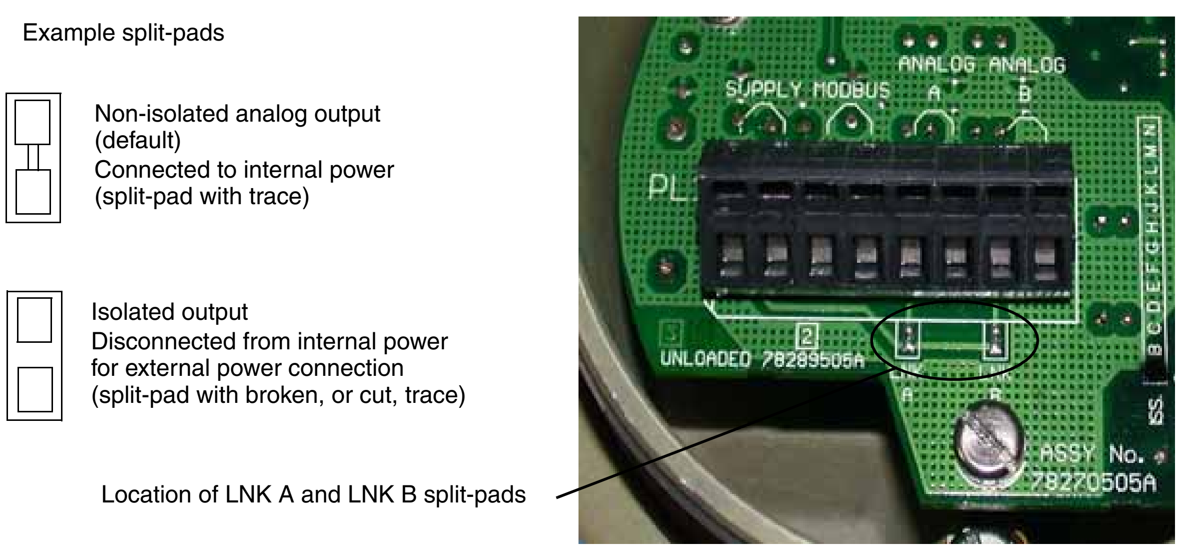
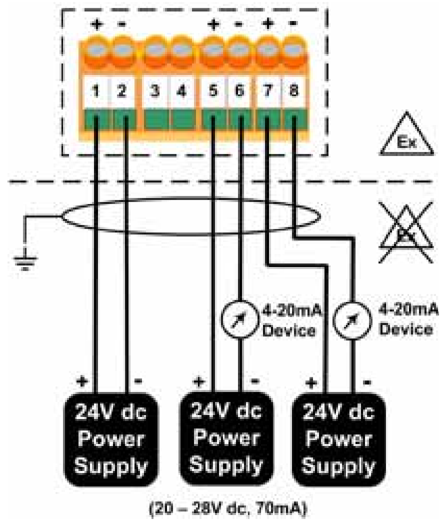


Figure 3-7 **4–20 mA output using a third power supply**

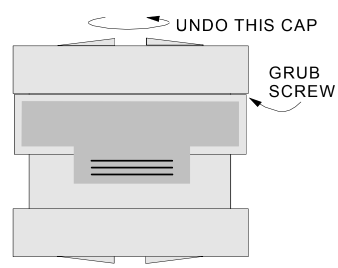


Note: The external device must be located in a non-hazardous (safe) area unless it is explosion proof and suitably certified.

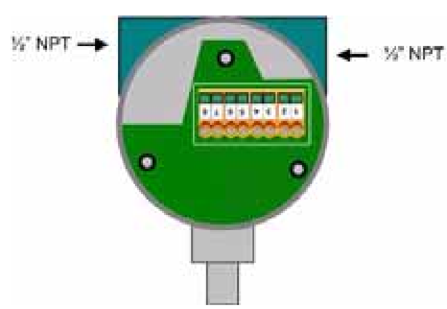
Fault conditions within the meter are indicated by a 2 mA output. If this is detected, the Modbus link can be used to interrogate the meter to establish the likely cause of the problem.

3.7 Wiring procedure

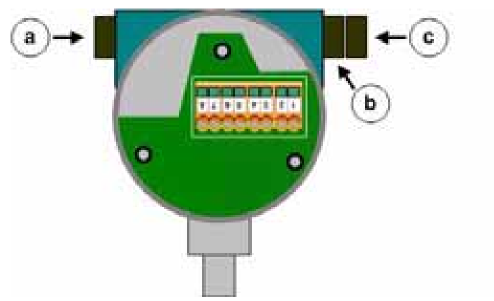
1. Open the Terminal Board side of the meter's electronics housing by undoing the 2.5 mm AF grub screw and unscrewing the lid anticlockwise.



2. Fit the M20 gland adaptor into the most convenient ½" NPT hole.

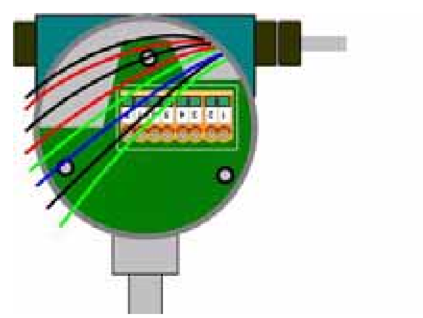


3. Fit the M20 x 1 cable gland to the adapter. Fit a ½” NPT blanking plug to the unused hole.

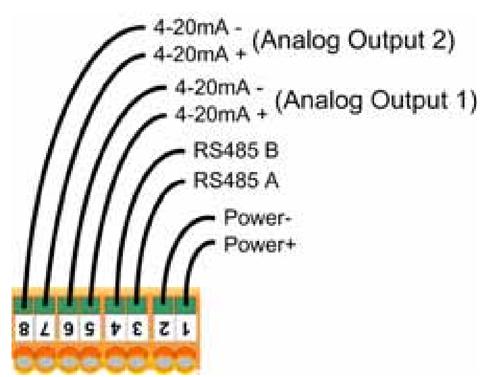


a: ¾” NPT Blanking Plug.
b: ¾” NPT to M20 adaptor.
c: M20 cable gland.

4. Insert the cable through the cable gland and adaptor so that the multi-core cable is gripped leaving 200 mm of free, unscreened wire to connect to the terminal blocks.

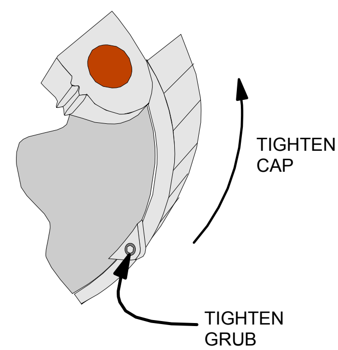


5. Wire up the cable cores as shown



6. When you have screwed the wires into the correct terminals, carefully tuck the wires around the electronics, and tighten the cable gland.

VIEW FROM UNDERNEATH THE ELECTRONICS:



7. Screw the housing cap on fully and tighten the locking grub screw using the 2.5 mm AF hex drive.

3.8 Further information on RS-485

3.8.1 RS-485

The meter's Modbus communications uses the RS-485 electrical standard. This uses the difference between the two signal cores to transmit and detect logic levels, and is therefore able to tolerate significantly higher levels of common mode noise than RS-232, which uses the voltage between the signal core and a common earth. A brief summary of some typical characteristics of the two standards is given below.

	RS-485	RS-232
Signal detection	Differential	Single-ended
Receiver threshold	200 mV	+1.5 V
Meter output swing	0 to +5 V (no load) +2 to +3 V (120 ohm load)	± 8 V

A converter is required for communication between the two standards. Further details are given in Section 3.8.2.

Only two signal connections are required for RS-485, usually called A and B, sometimes '+' and '–'.

Note: Unfortunately, different manufacturers have interpreted the standard in different ways. Some have a 'logic 1' represented by signal A being more positive than signal B, others have made the opposite interpretation. If you encounter communication difficulties with RS-485, the first remedy is to swap over the 'A' and 'B' signal connections at one end of the network.

For areas which may experience high common mode signals, a third conductor can be used as a ground reference for the communications signals. If used, this should be connected to Terminal 2 (Power supply negative) on the meter.

3.8.2 RS-485 to RS-232

Converters are available from a number of sources, and can range from simple in-line devices that simply plug into a PC's RS-232 port, to programmable devices with full isolation between the two networks.

Note: The meter uses a half-duplex implementation of RS-485, such that the A and B signals are used for data transmission in both directions. This requires that the RTS line is toggled to indicate the transmission direction. This can be done by the host computer, or automatically by an RS-485/232 converter which has the facility to do so. If you are using Windows NT, 2000 or XP on your PC, you should use a converter which automatically changes RTS (as detailed below) otherwise the link may not work correctly.

For simple installations**,** where the following conditions are valid, a simple in-line converter will be satisfactory:

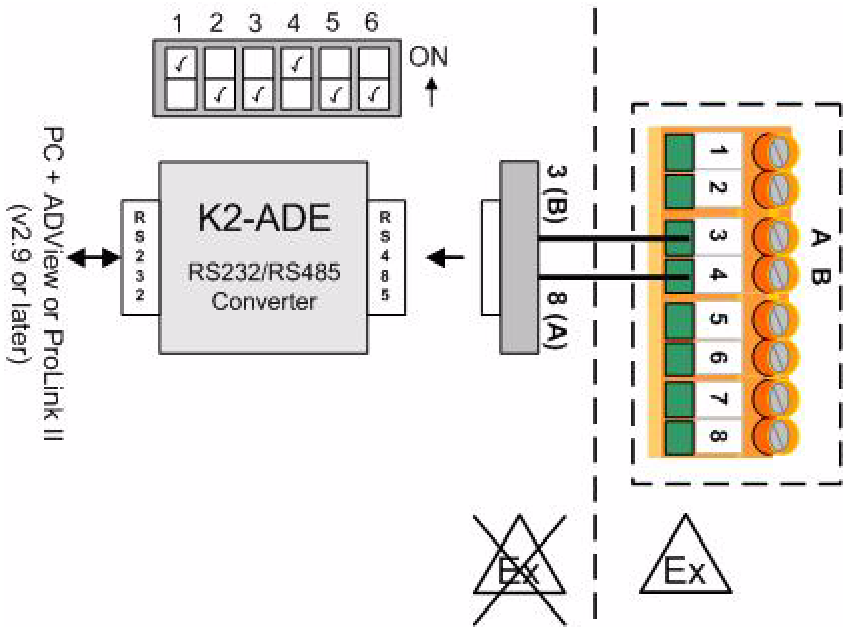
- The Modbus network is less than about 150 ft (50 m).
- The number of devices on the bus is low.
- No common mode problems.

Micro Motion recommends the K2–ADE (Terminal Block type or DIN connector type) converter, manufactured by KK Systems Ltd that will work with Windows 98, NT, 2000 and XP. This converter is available through Micro Motion when you purchase the ADView software. The ADView software package includes the latest Windows version of the software, plus a K2-ADE RS-485/RS-232 converter (Terminal Block version).

The K2-ADE converter derives its power from the PC's RS-232 port RTS or DTR line, which must be held permanently in the high state. This is normally adequate for short distances where there are only a few devices on the network. However, the ability of the port to supply sufficient power is not guaranteed, especially for laptop PCs, and it may be necessary to connect an external power supply. This may also be necessary if using Windows NT, 2000 or XP.

To check the voltage levels, measure the voltages on the RTS input (pin 7) and the DTR input (pin 4) while the converter is connected to the PC (or other RS-232 device). This procedure needs a break-out box (not supplied). Whichever input is powering the converter must have at least +6 V during communications. Where the power is found to be insufficient, a 9 VDC supply can be connected between Pin 9 (+) and Pin 5 (GND) of the RS-232 connector. Connections are shown in Figure 3-8**.** See also the manufacturer's technical information for details.

Figure 3-8 Powering the converter with an external 9 VDC supply



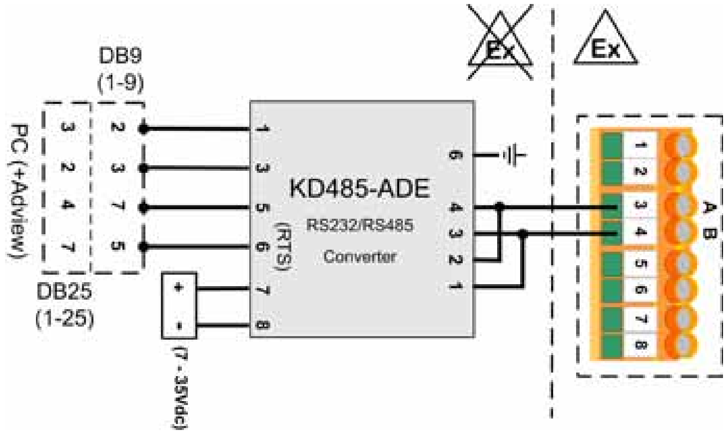
For permanent installations and cables distances greater than 100 m

For permanent installations, and where the network length is more than 100 m or so, Micro Motion can supply the following DIN-rail mounted device from KK Systems Ltd.

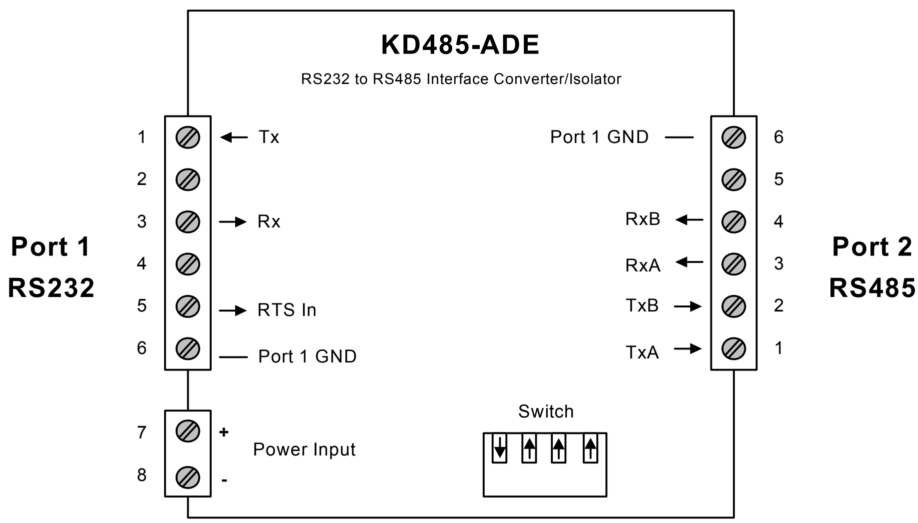
- KD485–ADE

The KD485–ADE is three-way isolated, providing isolation between the two ports and the power supply. It requires a +7 to +35 V power supply and typically takes 1 to 2 W; (power consumption is largely independent of supply voltage). It is capable of working with Windows 98, NT, 2000 and XP. For a PC running Windows NT/2000/XP, the RTS connection can be omitted.

Figure 3-9 Modbus connections > 100 m



The default configuration of the KD485-ADE has Port 2 configured for 9600 baud. This is the correct baud rate for the meter. (See Section 3.8.4 for details).



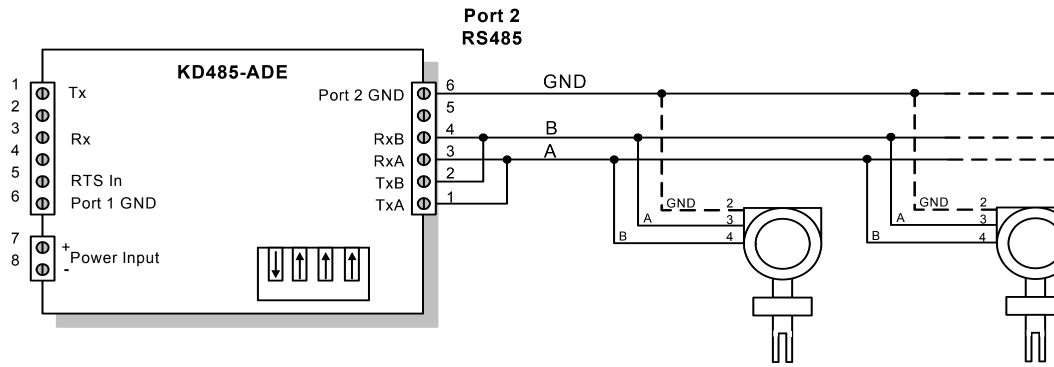
The switch on the KD485-ADE should be set with SW1 On (to enable half-duplex operation on Port 2), with the other three switches (SW2, SW3, SW4) set to Off.

Note: In most systems, the ground (GND) connection on pin 6 of port 2 will be unnecessary.

When two or more devices are connected on the same RS-485 network, this is known as a multi-drop configuration (see Section 3.8.3). Each device must be configured with its unique slave address before being installed on the network.

3.8.3 RS-485 multi-drop

When several devices are connected in parallel on an RS-485 network, this is known as a multi-drop network. Although it is theoretically possible to have up to 256 devices, in practice this is limited to around 32 or less, depending largely on the driving power of the Master. Each device has a unique slave address. For the meter, this address must be individually programmed using the ADView or ProLink II (v2.9 or later) software, before being connected to the multi-drop network (see section 4.4.3 for details).



Wiring is quite straightforward: simply connect ‘B’ terminal to ‘A’ terminal, A to B. On some devices, the RS-485 signals may be marked + and –. The + signal generally corresponds to the A signal, and the – signal to B. If you encounter communication difficulties with RS-485, the first remedy is to swap over the ‘A’ and ‘B’ connections at one end of the network.

3.8.4 Transmission mode

The meter’s RS-485 interface uses the following parameter settings, which are not selectable:

- Baud rate: 9600
- Bits: 8
- Parity: None
- Stop bits: 2

Chapter 4
Using ADView and ProLink II

4.1 Using ADView software

4.1.1 What is ADView?

ADView is a software package provided by Micro Motion to enable you to:

- Configure our density and viscosity meters.
- View and save data from them.
- Check that they are functioning correctly.

ADView is installed on a PC and interacts with the density/viscosity meter through one of the PC's standard serial (RS-232) ports.

ADView requires Microsoft's Windows operating system: Windows 3.1, 95, 98, NT, 2000 or XP.

Note: To connect to an RS-485/Modbus device, such as the meter, you will need an adapter between the PC and the meter (see Electrical Connections chapter).

ADView provides many useful facilities, such as:

- Setting up serial link to communicate with the meter
- Configuring the meter
- Displaying data in real time, or as a graph
- Logging data to a file
- Verifying correct operation of the system, and diagnosing faults
- Loading or storing Modbus register values
- Read/write to individual Modbus registers.

4.1.2 Installing ADView

ADView software is available for the PC on a variety of media (for example, CD-ROM) and is freely available to download from the Micro Motion web site (at www.micromotion.com).

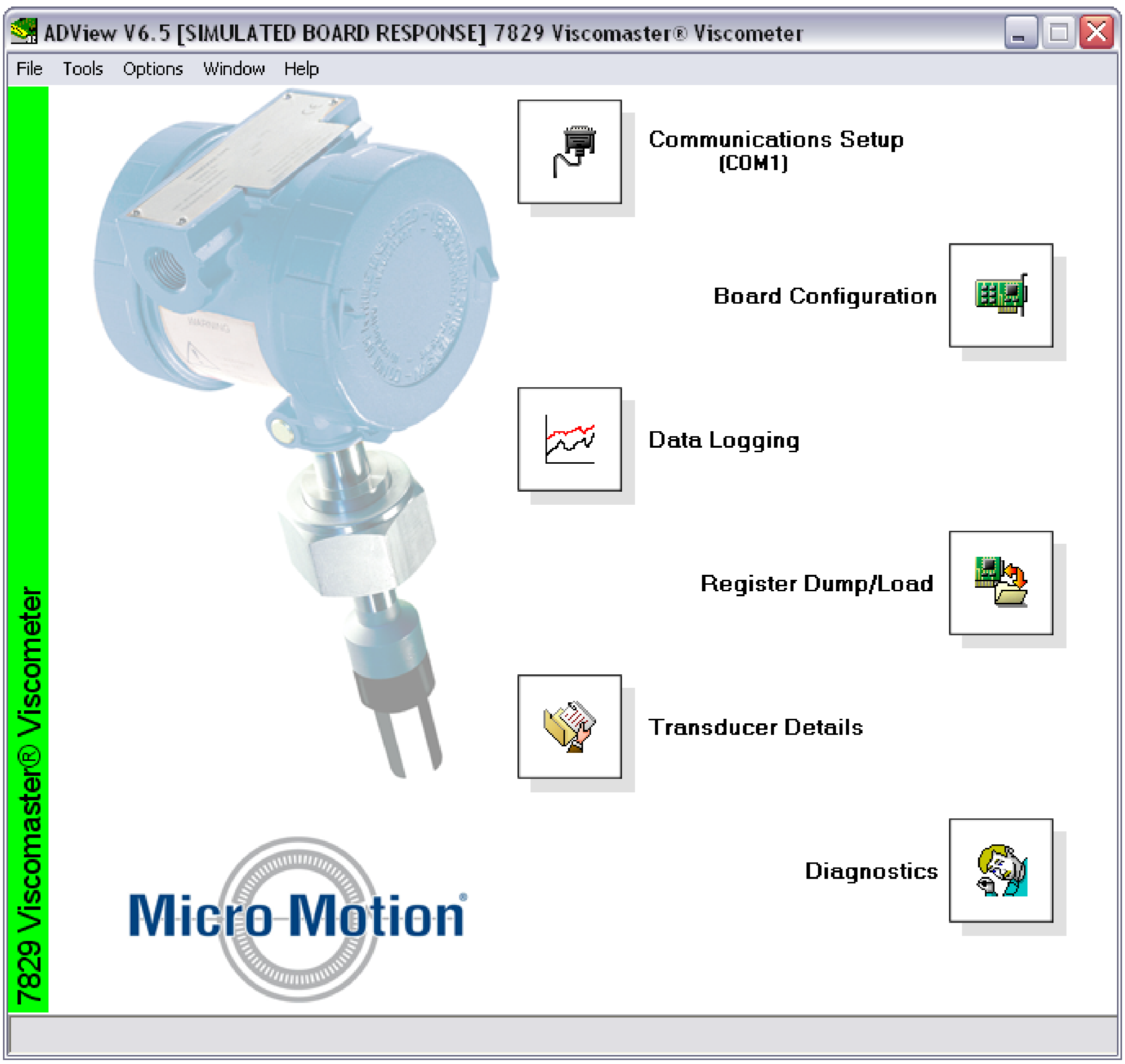
1. Identify the media containing the installation files for ADView.
2. Insert the media into an appropriate drive on your PC.
3. If the installation program does not begin automatically, run the set-up '.exe' file that is on the media. This does vary between different PC operating systems. In general, open the File Manager or Windows Explorer, browse the drive containing the media and double-click on the set-up '.exe'.)

4. When the installation program starts, you will be asked to supply your name and company name for registration purposes, and supply a directory path into which ADView's files can be loaded (a default directory path will be suggested).
5. Follow the installation instructions until installation is complete. It will normally only take a few minutes. You can abandon the installation if you need to do so.

4.1.3 Starting ADView

Start the ADView software by navigating through the Start Menu to the program entry of ADView 6. Left-click on it once and the window shown below will then appear.

Note: Developments in ADView may mean that the screen shots differ slightly from the ones you will see on your PC screen.



Each of the six icons gives you access to the various facilities of ADView. You can choose to connect a Modbus device to one of the PC's serial ports, or you can use ADView's built-in simulation of the meter.

To run the simulation, choose **Options > Simulate board response** from the menu bar and choose the appropriate densitometer option. Then, click on the **OK** buttons, as necessary, to return to the main ADView screen. When simulation is chosen, ADView ignores the serial port and supplies simulated data. However, you do still need to click on the **Communications Setup** button followed by the **Connect** button. Then, click on the **OK** buttons, as necessary, to return to the main ADView screen.

Setting up serial communications

To operate with a real Modbus device, you will need to connect it to a suitable power supply (see the technical manual for the device) and need a connection to a serial port on the PC. Full details for connecting to the Modbus (RS-485) link on the meter are in Chapter 4.

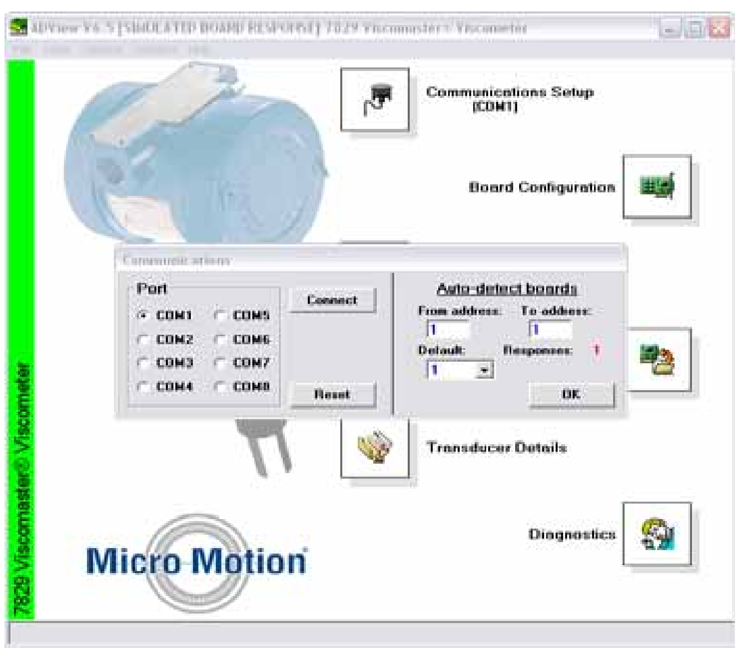
ADView automatically configures the selected port with the correct settings for the device. For the meter, this is 9600 baud rate, 8 data bits, no parity, 1 stop bit, and Xon/Xoff (software) flow control.

Note for Windows NT users

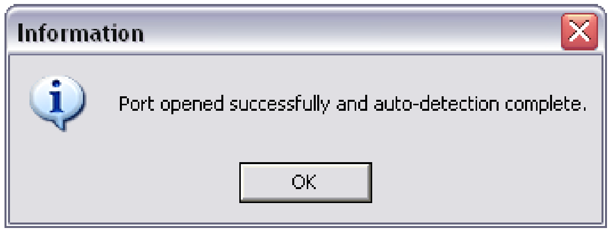
An interesting feature of Windows NT is that it does not allow the RTS line to be toggled directly; any attempt to do so will result in a crash or other problem. Unfortunately, some RS-485/232 converters require RTS to be toggled. To overcome this difficulty, ADView reads the OS environment variable to determine whether the operating system is Windows NT. If it is, ADView does not toggle RTS, and you will need to use an RS-232/485 adapter which automatically switches the data direction without using RTS.

To set the OS variable, click on the **Start** button, then choose **Settings > Control Panel**. Click on the System icon, and select the Environment tab. A list of environment variables and their values is shown. If OS does not appear in the list, type ‘OS’ (no speech marks) in the **Variable** text box, and ‘Windows_NT’ (no speech marks or spaces) in the Value box.

To check whether the link is working, you can use the auto-detect facility in ADView. Select the correct PC port, and then click on the **Connect** button in the Communications dialog box. ADView will set the port communications parameters, and then attempt to establish contact with any Modbus devices connected to the serial link, within the address limits set in the dialog box.



When it finds a device, the message box below appears:



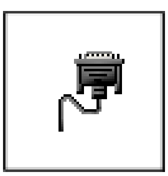
If no active device is found, a warning message is given:

In this case, check that the device is powered up correctly, that the cables and adapter are pushed fully home, and that the communications settings on the device and selected serial port are the same.

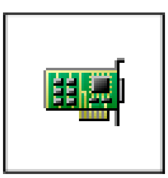
4.1.4 Understanding ADView features

ADView facilities

The main ADView window gives access to the various facilities available. A brief description of each is listed below. Using the facilities is largely intuitive so that you can quickly learn the system.

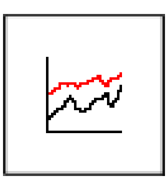


Communications Setup
Sets up and checks RS-232/RS-485 communications.



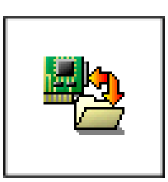
Board Configuration

- Enables you to select the measured parameter and range for the analog output, and to configure density referral by entering matrix values or K factors, as well as special calculations, line pressure and averaging time.
- Displays instantaneous values of a selectable output parameter and the analog output.

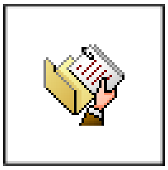


Data logging

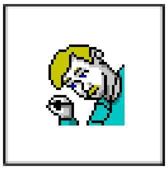
- Provides tabular data from meters of line and base density, temperature and special function. One parameter can be displayed as a graph.
- Data can also be logged to a file in either Excel (tab delimited) or Notepad (space delimited) formats.
- The frequency at which results are logged can be set, and logging can be started and stopped.



Register dump/load
With this facility you can dump the contents of all (or selected) Modbus registers from the device, or alternatively transmit values to them. File format is selectable (Excel/tab delimited, or Notepad/Space delimited).



Meter details
Shows a list of meter details such as type, serial number, calibration dates, software version, etc.



Diagnostics
Enables you to view:
- live sensor readings
- the status of the meter
- values of working coefficients

You can also verify calculations.

Menu bar

File	Exit	Exit ADView program.
Tools	Health Check	Determines whether the system is functioning correctly.
	Register Read/Write	A facility for reading or writing to any of the Modbus registers (see Section)
	Direct Comms.	Enables you to specify exactly what will be transmitted on the Serial link (see Appendix D).
	Engineer Status	Only used by Micro Motion service engineers.
Options	Simulate board response/ Actual Board	Allows you to select between these two options
	Enable / disable screensaver	Allows you to select between these two options. When enabled, the screensaver operates as configured by the Windows system settings.
Window		Provides a means of opening or selecting ADView's facilities.
Help	About ADView	Displays software version number.

Configuring a slave address

The factory configuration sets the slave address to 1. However, in many applications it will be necessary to allocate another address. In a multi-drop application, where several Modbus devices are connected on the same network, it is essential to configure unique slave addresses for each device.

To do this, you will need to run ADView and use the Register Read/Write facility, detailed in "Register Read / Write" on page 44. Check the value in Register 30 (Modbus Slave Address). If it is not the required value, enter the desired value and click on the write button. The meter will now be configured with the new slave address.

Board configuration

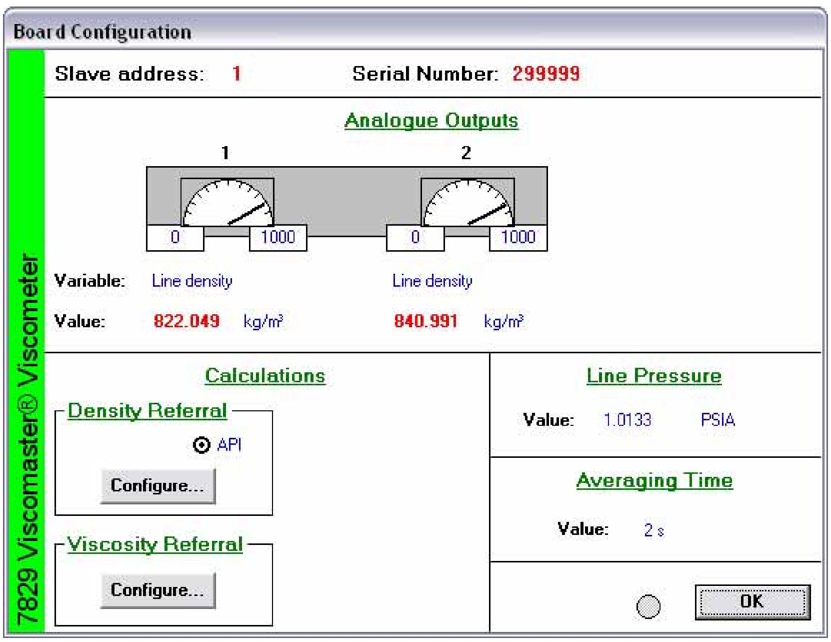
The board configuration controls the way in which the meter will process and present data, user settings, calibration constants and other factors. This data is stored in non-volatile memory known as registers; a full list of the registers used in the meter is given in Appendix D.

To configure the meter, it is necessary to write data into the configuration registers using the RS485/Modbus link. ADView provides a convenient and graphical way of doing this without you needing to know about register addresses and data formats.

Certain parameters are not available for configuration by ADView, including the Density Offset value which may be required to fine tune the calibration of the meter. However, ADView does have tools for reading and writing to individual Modbus registers (using the **Tools > Register Read/Write** facility), and for direct communication on the Modbus (using **Tools > Direct Comms**). More details and examples are given in Appendix D, but for the significant majority of applications these tools will not be required.

There is no facility within ADView or the meter to ‘reset’ to a default configuration. Therefore, before attempting any alterations to the configuration, you are strongly advised to use the Register Dump/Load facility in ADView to store the existing configuration (see “Register Dump / Load” on page 43). Then, if any mishap occurs, you will be able to restore the configuration from the saved file.

ADView’s Board Configuration window is shown below:



To exit from any of the configuration windows without making any changes, press the **Esc** key on your computer keyboard.

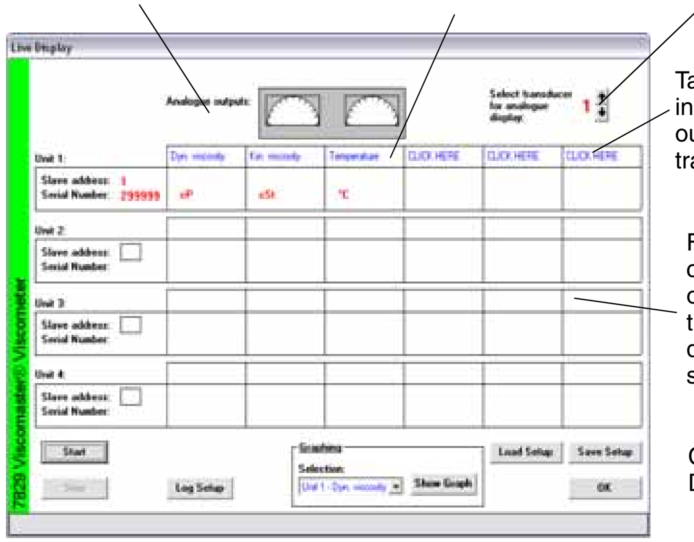
Density referral (Configure... button)

To configure the density referral calculation, you will need to enter the relevant information.

- For *matrix referral*, this is a set of four values of density for each of up to five different temperatures; Appendix B gives more details on this.
- For *API referral*, you can select the product type, which automatically adjusts the coefficients of the General Density Equation (see Section 6.1.5), or enter your own values.

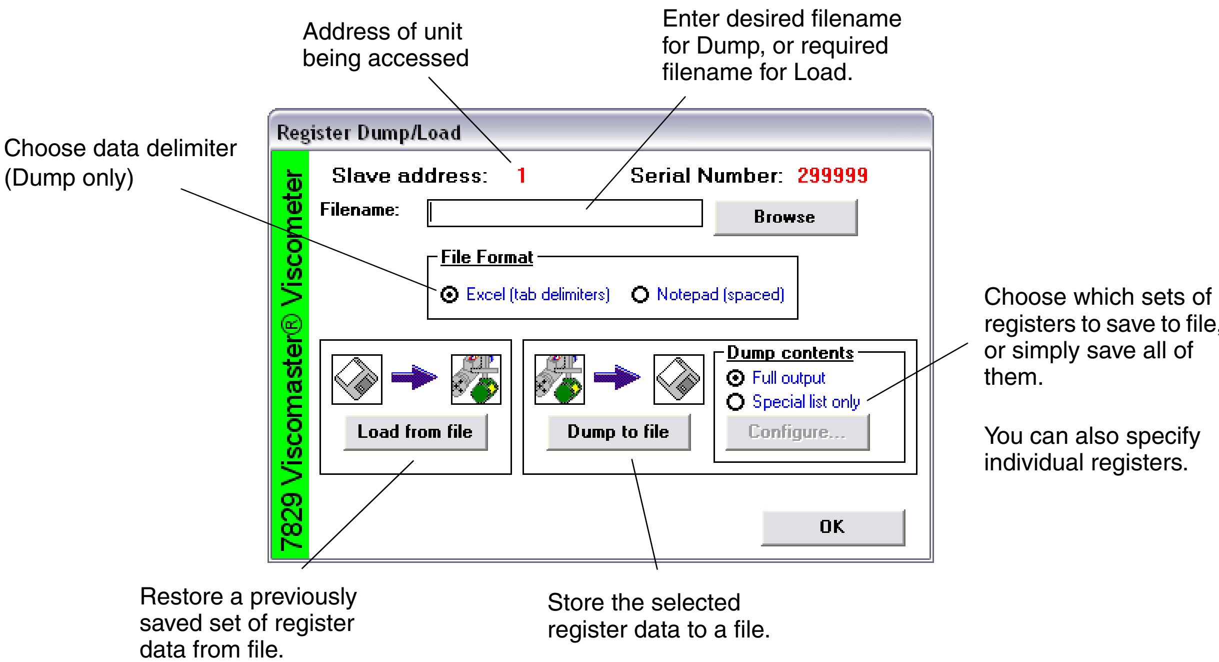
Data logging

ADView’s Data Logging function is a useful tool for checking setups and performing experimental data capture. The diagram below explains some of the features.



Register Dump / Load

This facility is essential for saving the configuration of your meter. You should use it to save the current configuration before you start to alter it, in order to restore it if things go wrong for any reason. Also, if you send the meter away for servicing or re-calibration, you should save the current configuration. Details are given below.



Register Read / Write

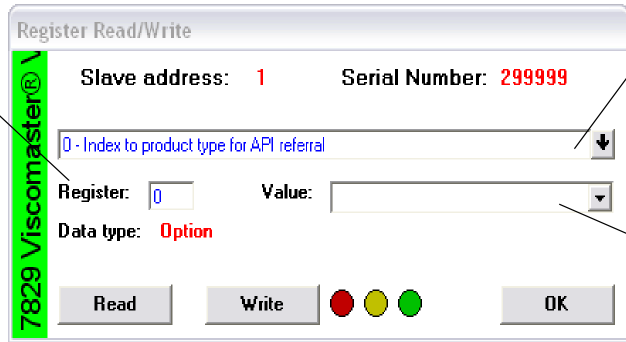
In a few cases, it may be useful to write directly to a single Modbus register. Two likely occasions for using this feature are to set the Slave Address of the unit and to configure a density offset. Appendix B has a complete list of the registers.

Before making any changes to individual registers, you should save the current configuration to a file to safeguard your configuration if anything goes wrong. See “Data Logging” for more information.

From ADView’s menu bar, select **Tools > Register Read/Write**.

The current register number appears here.

The **Read** button causes the current value of the chosen register to be displayed.



To see a complete list of Modbus register numbers and descriptors, click here.

Choose the one you want to access.

For non-numerical values, click here to see complete list of possible entries and select one to write into the register.

Enter numerical values directly.

The **Write** button causes the current value to be written to the selected register.

You can read and write to any number of registers. When you have done all you want to, click **OK**.

4.2 Using ProLink II software

4.2.1 Overview

ProLink II is a Windows-based configuration and management tool for Micro Motion meters. It provides complete access to meter functions and data.

This chapter provides basic information for connecting ProLink II to your meter. The following topics and procedures are discussed:

- Requirements (see Section 4.2.2)
- Configuration upload/download (see Section 4.2.4)

The instructions in this manual assume that users are already familiar with ProLink II software. For more information on using ProLink II, see the ProLink II manual.

4.2.2 Requirements

To use ProLink II with a 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter, the following are required:

- ProLink II v2.9 or later
- Signal converter(s), to convert the PC port's signal to the signal used by the meter
  - For RS-485 connections, an RS-485 to RS-232 signal converter.
  - 25-pin to 9-pin adapter (if required by your PC)

4.2.3 Connecting from a PC to a meter

Table 1-1 describes the options for connecting ProLink II to your meter.

Connection	Physical layer	Protocol
RS-485 terminals or RS-485 network	RS-485	Modbus

4.2.4 ProLink II configuration upload/download

ProLink II provides a configuration upload/download function which allows you to save configuration sets to your PC. This allows:

- Easy backup and restore of meter configuration
- Easy replication of configuration sets

Micro Motion recommends that all meter configurations be downloaded to a PC as soon as the configuration is complete.

To access the configuration upload/download function:

1. Connect ProLink II to your meter.
2. In the ProLink II software application, open the **File** menu.
   - To save a configuration file to a PC, use the **Load from Xmtr to File** option.
   - To restore or load a configuration file to a meter, use the **Send to Xmtr from File** option.

4.2.5 ProLink II language

ProLink II can be configured for the following languages:

- English
- French
- German

To configure the ProLink II language, choose **Tools > Options**.

In this manual, English is used as the ProLink II language.

Chapter 5
Calibration Check

5.1 Calibration

5.1.1 Factory calibration

Prior to leaving the factory, the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is calibrated within a standard physical boundary (typically 52.5 mm diameter) against Transfer Standard instruments traceable to National Standards.

Three fluids ranging in density from 1 to 1000 kg/m^3 are used to establish the general density equation constants K0, K 1, and K2 (see Section 5.1.5). The temperature coefficients (K18 and K19) are derived from the air-point and material properties.

The calibration procedure relies on units being immersed in fluids whose density is defined by Transfer Standards. Great attention is paid to producing temperature equilibrium between the fluid, the unit under test and the Transfer Standard (see Section 5.1.2). In this way, accurate calibration coefficients covering the required density range can be produced.

Viscosity calibration is achieved using three fluids (or four for the 0 – 10 cP range) with different calibrated viscosity values to derive the three general viscosity equation coefficients V0, V1, and V2 (see Section 5.1.4.)

All instruments are over-checked on water to verify the density calibration, and with two different fluids to check the viscosity calibration. This check is monitored by the Micro Motion Quality Assurance Department.

5.1.2 Calibration of Transfer Standards

The Transfer Standards for viscosity calibration are fluids which have been accurately measured within the Micro Motion Standards Laboratory. For density calibration, Transfer Standard instruments used in the calibration are selected instruments which are calibrated by the British Calibration Service Calibration Laboratory and are certified.

Transfer Standard calibration uses a number of density-certified liquids, one of which is water. The densities of these reference liquids are obtained using the Primary Measurement System whereby glass sinkers of defined volume are weighed in samples of the liquids.

Calibration of the Transfer Standard instruments is performed under closely controlled laboratory conditions and a calibration certificate is issued. Calibrations are repeated, typically every six months, producing a well-documented density standard.

5.1.3 Instrument calibration

Each meter is issued with its own calibration which is programmed into the instrument electronics before it leaves the factory. Under normal circumstances it should not be necessary to re-calibrate the meter provided it is used in the environment for which it was calibrated originally.

The calibration data is shown on a calibration certificate supplied with the instrument. The calibration contains the following:

- The instrument serial number
- Four typical points in the output signal Quality Factor / Viscosity relationship, across the meter's operating range. This relationship is using the general viscosity equation coefficients, which are also listed.
- Several sample points from the output signal/density relationship. These have been calculated using the general density equation with the calibrated coefficients listed.
- Temperature coefficient data, K18 and K19; this defines the correction which should be applied to achieve the best density accuracy if the instrument is operating at product temperatures other than 20 °C.
- One instrument air (density) data point for check calibration purposes.

The values for all the V and K coefficients shown on the calibration certificate are programmed into the meter's registers, and should not be altered.

Note: If the meter is used in an application dissimilar to the one for which it was originally calibrated, it may be necessary to re-calculate the V and K coefficients. Contact Micro Motion for further details.

5.1.4 General viscosity equation

The General Viscosity Equation, used to calibrate the meter and shown in the Calibration certificate is:

$$\eta = V0 + V1 / Q^2 + V2 / Q^4$$

where η is the calculated viscosity, Q is the quality factor of the tuning fork, and V0, V1 and V2 are viscosity coefficients, derived from the factory calibration data and selected to optimise the accuracy of the viscosity measurement across the calibrated viscosity range for the known physical conditions.

5.1.5 General density equation

The General Density Equation, used to calibrate the meter and shown in the Calibration certificate is:

$$\rho = K0 + K1\tau + K2\tau^2$$

where ρ is the calculated density, τ is the time period (in µs) of the tuning fork, and K0, K1 and K2 are density coefficients, derived from the factory calibration data and selected to optimise the accuracy of the density measurement across the calibrated density range.

Temperature effects are also compensated for using a second equation:

$$\rho' = \rho(1 + K18(t - 20)) + K19(t - 20)$$

where ρ' is the new (temperature compensated) density value, t is the measurement temperature, and K18 and K19 are temperature correction coefficients.

5.2 Calibration certificate examples

5.2.1 Viscomaster sample calibration certificate

Note: Figure 5-1 is an example only. It is NOT the calibration certificate for your Viscomaster.

Figure 5-1 Example Calibration Certificate for Viscomaster (Metric Units)

CALIBRATION CERTIFICATE

```
7829FEANAJBBBA VISCOMETER                          SERIAL NO     : XXXXXX
                                                   CAL DATE      : 15DEC04
                                                   PRESSURE TEST : 160 Bar

VISCOSITY CALIBRATION AT 20°C (2” Schedule 40)

       VISCOSITY  QUALITY          VISCOSITY = V0 + V1.1/Q**2 + V2.1/Q**4
          (cP)    FACTOR
                                   INSTRUMENT CHECK DATA
          0.59    920.79
         10.67    268.64           AIR POINT (20°C) QUALITY FACTOR = 5208
         53.36    123.35
        108.16     84.25
```



```
              ULTRA-LOW RANGE      LOW RANGE
              (0.59 - 10.67)       (10.67 - 108.16)

       V0 =   -4.90450E-01          -1.40975E+00
       V1 =    8.49042E+05           8.81886E+05
       V2 =   -3.13525E+09          -7.39203E+08

DENSITY CALIBRATION AT 20°C (2” Schedule 40)

       DENSITY  TIME PERIOD B        DENSITY =  K0 + K1.TB + K2.TB**2
       (kg/M3)      (usec)
                                                K0  =  -2.55203E+03
          0    526.090                          K1  =   1.33903E-02
        (Air   525.982)                         K2  =   9.19530E-03
        300    556.194
        500    575.391
        800    603.042                 Dt = D ( 1 + K18(t-20) ) + K19(t-20)
        1000   620.793
        1600   671.239                          K18 =  -4.614E-04
                                                K19 =  -1.101E+00
```



```
                                                           --------------
Where  D  = Density (uncorrected)                         | FINAL TEST & |
       Dt = Density (temperature corrected)               |  INSPECTION  |
       Dv = Density (temp and viscosity corrected)        |              |
       TB = Time Period B(uS)                             |              |
        Q = Quality factor                                |              |
        t = temperature (°C)                              |              |
                                                           --------------
 Ref No:- XXXXXX/Vx.x                                      DATE : 16DEC04
```

5.2.2 Viscomaster Dynamic sample calibration certificate

Note: Figure 5-2 is an example only. It is NOT the calibration certificate for your Viscomaster.

Figure 5-2 Example Calibration Certificate for Viscomaster Dynamic (Metric Units)

CALIBRATION CERTIFICATE

```
7829FEANAJRBBA VISCOMETER                                 SERIAL NO     : XXXXXX
                                                          CAL DATE      : 03FEB05
                                                          PRESSURE TEST : 160 Bar

VISCOSITY CALIBRATION AT 20°C (2" Schedule 40)

       VISCOSITY  QUALITY            VISCOSITY = V0 + V1.1/Q**2 + V2.1/Q**4
          (cP)    FACTOR
                                     INSTRUMENT CHECK DATA
          0.77     84.85
         10.78    265.92             AIR POINT (20°C) QUALITY FACTOR = 5094
         53.30    123.35
        107.75     85.60

                  example

              ULTRA-LOW RANGE       LOW RANGE
              (0.77 - 10.78)        (10.78 - 107.75)

       V0 =   -1.18001E+00          -1.29351E+00
       V1 =    9.43728E+05           8.59976E+05
       V2 =   -6.69315E+09          -4.46850E+08

                  example

                                                           --------------
Where  TB = Time Period B(uS)                             | FINAL TEST & |
       Q = Quality factor                                 |  INSPECTION  |
       t = temperature (°C)                               |              |
                                                          |              |
                                                          |              |
                                                          |              |
                                                           --------------
 Ref No:- XXXXXX/Vx.x                                      DATE : 03FEB05
```

5.3 User calibration checks

5.3.1 Ambient air calibration check

An air check is a simple and convenient method to see if any long term drift or corrosion and deposition on the tines has occurred.

Ambient air check procedure:

1. Isolate and, if necessary, disconnect the meter from the pipeline.
2. Clean and dry the wetted parts of the meter and leave them open to the ambient air.
3. Apply power to the instrument and check that the time period of the instrument agrees with the figure shown on the calibration certificate to within ±100 ns. If the meter is not at 20°C, compensate for this by adding an offset of +110 ns for every °C above 20°C, or by subtracting an offset of +110 ns/°C below 20°C.
4. Re-fit the meter to the pipeline if serviceable or remove for further servicing.

5.3.2 On-line calibration adjustment

An on-line calibration adjustment may be required if:

- The physical boundary surrounding the tines is different from the physical boundary used for the factory calibration.
- The unit has suffered long term drift or corrosion of the tines.

The meter is a very accurate and stable instrument, and will normally provide good measurements. If it is suspected of giving incorrect results, you should confirm this by carefully checking the integrity of the fluid temperature measurement, and compare this with the temperature measurement given by meter. You should also verify the integrity of the density check measurement. It is only after you have eliminated all other possible causes of error that you should attempt to make adjustments to the calibration of meter.

Normally the density calibration adjustment is made by configuring a simple density offset into the instrument. If a more detailed calibration adjustment is required, such as a two- or three-fluid calibration adjustment for offset and scale, then refer to Micro Motion.

Calibration adjustment - stable liquids (*not for* Viscomaster Dynamic):

1. Using ADView (see Using ADView and ProLink II chapter), reset the line density offset (register 173) to 0, and the line density scaling factor (register 174) to 1.
2. Ensure that the system has reached its stable operating temperature.
3. With the meter operating at typical process conditions, draw off a sample of the liquid into a suitable container, and note the meter density reading and the operating temperature.
4. Measure the density of the sample under defined laboratory conditions using a hydrometer or other suitable equipment. Refer this to the operating conditions at the meter.
5. Calculate the density offset required to make the meter measurement the same as the measured density of the sample.
6. Using ADView's Register Read/Write tool, configure the meter with the calculated line density offset (Register 173).

For further details on these procedures, reference should be made to:

Energy Institute:	HM7. Density, sediment and water. Section 1: General guidance on test methods (formerly PMM Part VII, S1) 1st ed 1996 ISBN 978-0-85293-154-7
Energy Institute:	HM8. Density, sediment and water. Section 2: Continuous density measurement (formerly PMM Part VII, S2) 2nd ed Sept 1997 ISBN 978-0-85293-175-2
American Petroleum Institute:	Manual of Petroleum Measurement Standards Chapter 14 - Natural Gas Fluids - Section 6: Installing and proving density meters used to measure hydrocarbon liquid with densities between 0.3 and 0.7 gm/cc at 15.56°C (60°F) and saturation vapour pressure, April 1991.

Chapter 6
General Maintenance

6.1 Overview

Care is essential in handling of the meter during its removal from and fitment to the pipeline/tank and during transportation. Wherever possible, retain and use the original packaging.

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is rugged and robust, and has no moving parts. When correctly installed and operated, servicing is not normally required, even with poor quality fluid, and no periodic maintenance procedure is specified. It is recommended that a visual inspection is carried out at intervals to check for leaks and physical damage, and corrective maintenance carried out when required.

ADView's Data Logging facility can be used whenever necessary to verify that the meter is functioning correctly.

Check calibrations should be carried out at specified intervals in order to identify a malfunction or deterioration in meter performance. If a fault or a drop in performance is detected, further tests are required to identify the cause of the fault. Remedial action is limited to cleaning the meter tines, making good any poor connections, and replacing the internal electronics. In the extreme cases the complete meter may need to be replaced.

Note: The electronics within the meter contain calibration information relevant to that particular meter only. The circuit boards operate as a pair, and therefore both boards must be changed together. Contact Micro Motion for more details if you need to change the boards.

6.2 General maintenance

No periodic maintenance procedure is specified, but the following procedure is recommended for periodic inspection. It can also be used when fault finding.

6.2.1 Physical checks

1. Examine the meter, its electronics housing and cables for any signs of damage and corrosion.
2. Make sure that the spigot connection is tight.
3. Check the meter for sign of leakage.
4. Check that there is no ingress of water/fluid into the electronics housing.
5. Ensure that the threads on the covers are well greased (graphite grease) and that the 'O' rings are in good condition.

Note: The covers MUST be completely screwed down and, in the case of an explosion-proof enclosure application, DO NOT FAIL to tighten the locking screws.

6.2.2 Electrical check

1. Check the power supply and current consumption at the meter terminals, pins 1 and 2, having disconnected all analog outputs. These should give 35 mA to 42 mA at 22.8 V to 25.2 V.

   If the current consumption is outside this range, contact Micro Motion.

6.2.3 Performance check

When several systems are run in parallel and use the same fluid source, comparison of the line viscosity, base density and temperature readings between installations can be a useful indicator of possible system faults. Differences between readings, or changes from the normally observed conditions should always be investigated to confirm that instrumentation is functioning correctly.

6.2.4 Calibration check

1. Carry out a check calibration as detailed in the Calibration Check chapter.
2. Compare the results obtained with the previous calibration figures to identify any substantial deterioration in meter performance or any malfunction.

Note: A drop in meter performance is likely due to a build up of deposition on the tines which can be removed by the application of a suitable solvent. See Mechanical Servicing below.

Note: Malfunctions generally could be the result of electrical/electronic faults in either the meter or the readout equipment. Always check the readout equipment first before attention is directed to the meter.

6.3 Fault analysis and remedial action

A fault may be categorized as either an erratic reading or a reading which is outside limits.

Electrical faults can also cause symptoms which appear to affect the readings and it is recommended that the electrical system is checked first, before removing the meter for servicing.

6.3.1 Troubleshooting faults

Table 6-1 **Faults and possible causes**

Fault	Possible causes	Remedy
Readings fluctuate slightly, i.e., are noisy	Analog output averaging time not long enough	Increase the averaging time using ADView's Board Configuration facility (see the Using ADView and ProLink II chapter).
Erratic readings	One or more of: Gas bubbles around tines; cavitations; severe vibration or electrical interference; large amount of contaminants	Remove primary cause; e.g.: -install air release units to release gas; -apply back pressure to discourage formation of bubbles; -remove cause of vibration Alternatively, it may be necessary to adjust the Time Period Trap.
Readings outside limits	Deposition and/or corrosion on the tines.	Clean tines.

Table 6-1 Faults and possible causes *continued*

Fault	Possible causes	Remedy
Analog output = 0 mA	No power to analog output	If voltage across pins 5 and 6 is not 15 to 28 V, replace power supply.
	Analog output circuit failure	Use ADView's facility to set the analog output to 4, 12 or 20 mA (in Board Configuration) to check whether the output is functioning. If not, replace circuit boards.
Analog output is 2 mA	Alarm condition caused by lack of power to meter	If voltage across pins 1 and 2 is not 20 to 28 V, check and replace main power supply.
	Alarm condition caused by other internal failure	Use ADView Diagnostics to check that phase locked loop is in lock.
Temperature readings incorrect	If analog output and Modbus appear to be functioning correctly, the temperature sensor has probably failed.	Return the meter to Micro Motion for servicing.
Viscosity reads high during normal running	Flow rate too low	Increase flow or change to smaller flow-through chamber
	Insulation defective	Repair or replace insulation
	PFA laminate damaged, leading to coating of fork tines	Remove meter for visual check; return to Micro Motion for servicing.
	Calibration data is corrupted	Compare calibration data to certificate or stored configuration. Reprogram as necessary.
Viscosity reads high after engine shutdown or restart	Pump coated with aspaltenes.	Check pump delivery; service pump.
	Bypass not fully closed.	Close bypass.
	PFA laminate damaged, leading to coating of fork tines	Remove meter for visual check; return to Micro Motion for servicing.
	Calibration data is corrupted	Compare calibration data to certificate or stored configuration. Reprogram as necessary; return to Micro Motion for servicing.
meter does not communicate with ADView	Power failure to meter	Check power supply to meter and converter; replace if necessary
	Power supply to RS-485/232 converter failed.	Check wiring
	A and B Modbus connections reversed	Check wiring
	RS-485/232 converter failed, wired incorrectly, or connected the wrong way round	Try another converter
	ADView incorrectly installed on PC	Re-install ADView
	Incorrect Slave address chosen for meter	Check slave address
	RS-232 port on PC failed.	Connect to another free RS-232 port on the PC, if available. Alternatively connect a known working RS-232 device to the PC to check that the port is working.

6.3.2 Mechanical servicing

This mainly comprises the cleaning of any deposition or corrosion from the tines. Deposition is removed by the use of a suitable solvent. For corrosion, solvent and the careful use of a fine abrasive will usually be sufficient. Take care not to damage the PFA lamination if installed. However where extensive corrosion has been treated, it is highly recommended that a full calibration is carried out to check the meter characteristics.

Care is essential in handling the meter during transit, installation, and removal from the pipeline/tank.

6.3.3 Time period trap

Disturbances in the fluid caused by bubbles, cavitations or contaminants can cause sudden changes in the measured output, which may, under some circumstances, give rise to instability (i.e. hunting) in a control system relying on the measurement. The meter can maintain the analog output during such perturbations by ignoring the aberrant measurement, and maintaining the output at the last good measured value. This facility is known as the Time Period Trap (TPT).

Under all normal circumstances, the factory settings for the TPT should be used. However, in extreme cases it may be necessary to alter the settings to meet the demands of a particular system. This should only be done after monitoring the behavior of the system for some time, to establish the normal running conditions.

Great care must be taken not to reduce the sensitivity of the meter so that normal response to fluctuations in the fluid is impaired.

The time period trap facility works as follows:

> After each measurement of the time period (of the meter's vibrating tines) the new value is compared with the previous value. If the difference between them is smaller than the allowable tolerance, the output is updated to correspond to the new measured value, and the TPT remains inoperative; i.e., operation is normal. If the difference exceeds the allowable tolerance, the output remains at the its previous level, and does not follow the apparent sudden change in value.

This process is repeated until either of the following:

- The latest measured value falls back to the level of the original value, indicating that the transient has passed; or
- The TPT count is reached. At this point it is assumed that the change in value is not due to a random disturbance, and the output adopts the value of the latest reading.

Two Modbus Registers control the operation of the Time Period Trap facility. These can be changed, if necessary, using ADView's Register Read/Write facility.

- **Modbus Register 138:** contains the maximum allowable change in the time period between readings, specified in µs. The preset value is 10.

- **Modbus Register 137:** contains the Time period count, which is the maximum number of measurements to be rejected before resuming normal operation; the preset value is 2. If the value is set to 0, TPT is disabled, and the output will always follow the time period measurement. If you want to program another value, it should be determined experimentally, and be equal to the length of the longest undesirable transients which are likely to arise. If the value is set too high, the meter will be slow to respond to genuine changes in the fluid properties.

Appendix A
Factory Default Settings

A.1 Default configuration for analog outputs

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is supplied in a standard configuration. Analog Output 1 is set to provide line kinematic viscosity, in cSt. Analog Output 2 is set to provide line temperature, in °C. (Other units are kg/m^3 for density; API base density derivation is also configured for the Viscomaster meter.)

The complete set of default values are shown below.

	Parameter	Viscomaster Dynamic Factory default value	Viscomaster Factory default value
Analog output 1:	Variable	Line kinematic viscosity	Line kinematic viscosity
	Units	cSt	cSt
	4 mA setting	0	0
	20 mA setting	As ordered	As ordered
Analog output 2:	Variable	Temperature	Temperature
	Units	°C	°C
	4 mA setting	0	0
	20 mA setting	150°C	150°C
Alarms:	Coverage	General system Analog output User range	General system Analog output User range
	Hysteresis	2%	2%
Alarm user range:	Variable	Line kinematic viscosity	Line kinematic viscosity
	Units	cSt	cSt
	Low setting	0	0
	High setting	100	100
Viscosity referral:	Base or referral temperature	50 °C	50°C
	ASTM D341 temperatures T1 and T2	0 °C	0 °C
	ASTM D341 viscosities V1 and V2	0 cSt	0 cSt
Density calculations:	Temperature units	°C	°C
	Temperature offset	0	0
	Pressure units	bar	bar
	Pressure set value	1.013	1.013
	Line density units	kg/m^3	kg/m^3

	Parameter	Viscomaster Dynamic Factory default value	Viscomaster Factory default value
	Line density scale factor	(Not Applicable)	1
	Line density offset	(Not Applicable)	0
API referral:	Product type	(Not Applicable)	General refined
	User K0	(Not Applicable)	+0000E+00
	User K1	(Not Applicable)	+0000E+00
	Base temperature	(Not Applicable)	15
	Base pressure	(Not Applicable)	1.013
Output averaging time:		5 s	5 s
Modbus:	Slave address	1	1
	Byte order	Big Endian	Big Endian
	Register size	32 bit	32 bit
Hardware type:		Advanced fork	Advanced fork

Appendix B
Calculated Parameters

B.1 Overview

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is capable of calculating a number of parameters based on the measured line dynamic viscosity, density and temperature. From these results, line kinematic viscosity can be calculated. The Viscomaster (not Viscomaster Dynamic) can also calculate parameters such as base (referred) kinematic viscosity, CII and CCAI.

B.2 Base density referral

Base density is the density of the fluid at a specified base (or referral) temperature which is different to the line (i.e., the actual) temperature of the fluid. Base density can be calculated by the API Referral method.

B.2.1 API density referral

This calculation uses an iterative process to determine the density at the base temperature by applying temperature and pressure corrections using the API-ASTM-IP petroleum measurement tables.

The information required for the API density is:

- Reference pressure and reference temperature.
- Line pressure: This is not measured by meter, and must be entered as part of the configuration.
- Product type: Refined product, crude product, or user defined.

Density / temperature relationship

Correction factors in the revised API-ASTM-IP petroleum measurement tables are based on the following correlation equations:

$$\rho t / \rho_{15} = \exp [-\alpha_{15} \Delta t (1 + 0.8 \alpha_{15} \Delta t)]$$

where:

- ρt = Density at line temperature t °C
- ρ_{15} = Density at base temperature 15 °C.
- $\Delta t = (t - 15)$ °C
- α_{15} = Tangent thermal expansion coefficient per °C at base temperature of 15 °C.

The tangent coefficient differs for each of the major groups of hydrocarbons. It is obtained from the following relationship:

$$\alpha_{15} = \frac{K_0 + K_1\rho_{15}}{\rho_{15}^2}$$

where K_0 and K_1 are known as the API factors.

Hydrocarbon group selection

The hydrocarbon group can be selected as:

- General refined products
- General crude products
- User defined

K_0 and K_1 are programmed into the meter for the first two groups. For refined products the values of K_0 and K_1 are automatically selected according to the corrected density:

Hydrocarbon Group	Density Range (kg/m^3)	K_0	K_1
Gasolines	654 to 779	346.42278	0.43884
Jet Fuels	779 to 839	594.54180	0.0000
Fuel Oils	839 to 1075	186.9696	0.48618

For Crude Oil the API factors are:

Product	K_0	K_1
Crude oil	613.972226	0.0000

User defined factors can be entered as any sensible value.

Density / pressure relationship

Isothermal secant compressibility can be defined by the simplified equation:

$$\beta = \frac{1}{V_0}\left[\frac{\delta V_1}{P_1}\right]_t$$

- where liquid volume changes from V_0 to V_1 as the gauge pressure changes from zero (atmospheric) to P_1
- where

  β = Isothermal secant compressibility at temperature t

  δV_1 = Change of volume from V_0 to V_1

  P_1 = Gauge pressure reading (P - 1.013) bars
- hence

$$\frac{\rho_0}{\rho_1} = 1 - \beta P_1$$

- where

  ρ_0 = Corrected density at zero (atmospheric) gauge.

  ρ_1 = Uncorrected density (Kg/m^3)

  P_1 = (P - 1.013) where P is pressure in bars (P - base)

A correlation equation has been established for from the available compressibility data; such as,

$\log_e C = -1.62080 + 0.00021592t + 0.87096 \times 10^6(\rho_{15})^{-2} + 4.2092t \times 10^3(\rho_{15})^{-2}$ per bar

where

- $\beta = C \times 10^4$ Bar
- t = Temperature in deg C
- $\rho = \rho_{15} / 1000$ = oil density at 15 °C (kg/litre)

B.3 Kinematic viscosity

Kinematic viscosity is defined as:

$$\nu = \frac{\eta}{\rho}$$

where

- ν = kinematic viscosity (cSt)
- η = dynamic viscosity (cP)
- ρ = density (Kg/m^3)

B.4 Base kinematic viscosity referral using ASTM D341

Base kinematic viscosity is the viscosity of the fluid at a specified base (or referral) temperature which is different to the line (i.e., the actual) temperature of the fluid. Base viscosity can be calculated using the kinematic–viscosity–temperature charts covered by the ASTM D341 standard.

The base kinematic viscosity of a petroleum oil or liquid hydrocarbon can be determined at any temperature within a limited range, if the kinematic viscosities at two temperatures are known.

The ASTM D341 standard charts use the following equation:

$$\log\log(\nu + 0.7) = A - B\log T$$

where

- ν = kinematic viscosity (cSt)
- T = temperature (deg K)
- A and B are constants for the liquid (defined by the ASTM tables)

The meter can be programmed with up to four ASTM curves that allow viscosity referral over a wide operating range. A ratio technique is employed when operating between the ASTM curves.

B.5 Ignition quality

The ignition index (CII) is defined as:

$$CII = 270.795 + 0.1038 * t - 0.254565 * \rho_{15} + 23.708 * LOG(LOG(v + 0.7))$$

Where:

- t = Temperature in deg C
- ν = Kinematic viscosity (cSt)
- ρ_{15} = Density at base temperature 15°C.

The carbon aromaticity index (CCAI) is defined as:

$$CCAI = \rho_{15} - 81 - 141 * LOG(LOG(\nu + 0.85)) - 435 * LOG\left(\frac{(t + 273)}{323}\right)$$

Where:

- t = Temperature in deg C
- ν = Kinematic viscosity (cSt)
- ρ_{15} = Density at base temperature 15°C.

Appendix C
Safety Certification

C.1 Safety certification

Please contact Micro Motion if you need to have copies of the latest safety certification for the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter.

Appendix D
Modbus Communications

D.1 Overview

The Modbus/RS-485 communications facility on the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter can be useful in a number of ways. It is the only means of configuring the meter, and also gives access to diagnostic information not available on the analog output. Digital representations of the measured and calculated parameters are also available which lead to higher accuracy, and greater integration in digital networks and systems.

The RS-485 serial interface of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter communicates using the RTU Modbus protocol, which is a well established system used in many industrial applications. The protocol defines the way in which messages will be transmitted between Modbus devices, and details how the data will be formatted and ordered.

It is beyond the scope of this manual to give a full description of the protocol, but a useful reference on Modbus is the *Modbus Protocol Reference Guide* (PI-MBUS-200 Rev. D) (1992) published by Modicon Industrial Automation Systems Inc.

A Modbus network can have only one Master at any one time, with up to 32 Slaves. The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter acts as a slave device, and only communicates on the network when it receives a request for information from a Master device such as a computer or a PLC.

The implementation used on the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter is fully compliant with the Modicon Specification. All information is stored in memory locations in the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter referred to as Modbus Registers**.** These store all the data required to control the operation, calculations and data output of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter. Modbus communication with the meter consists of reading or writing to these registers.

The 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter implements only two Modbus commands:-

- Command 3: Read Modbus Register
- Command 16 (10_{16}): Write Modbus Register

Any number of registers can be read with Command 3, but only one register can be written to for each Command 16. This restriction does not limit the performance of the system, since all functions are mapped into the register structure in one way or another.

In most cases, it is unnecessary to understand the detail of the protocol, as this is taken care of by the application program. For example, the Micro Motion ADView or ProLink II software program enables you to configure the meter, and even read or write to individual Modbus registers, without you needing to know about Modbus.

However, if you are using a proprietary software package, or developing your own application software, the information given in this section will be invaluable.

D.2 Accessing Modbus registers

Any device which can drive the RS-485 interface on the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter can, in theory, access the Modbus registers. In practice, some sort of user interface is required to simplify the process.

ADView offers several ways of accessing the registers.

Board Configuration:	A graphical interface for viewing and setting the main configuration parameters of the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter. Direct access to registers is not offered.
Register Read/Write	This tool provides a simple window from which to read and write to named and numbered registers. When you write to a register, you are presented with a set of allowable values from which to choose. Thus the tool is only useful for communicating with Micro Motion meters. This is the simplest and most foolproof way of directly accessing the registers. Section 4 gives full details.
Direct Communications	This is another tool which allows you to compose a sequence of data to be transmitted to/from the Modbus. This can be used to communicate with any Modbus device, providing that you know the register addresses, data format, indices, etc. The composition of the data is entirely up to the user, although the tool does compute and insert a checksum. Only those well versed in the use of Modbus protocol should attempt to use this facility. It is mainly designed for testing Modbus transmissions which are subsequently to be used in an application specific environment. A worked example of using this tool is given in section D.7.

D.2.1 Establishing Modbus communications

If the meter Slave address or the values of Registers 47 and 48 are not known, Modbus communications cannot be carried out successfully, and it will be necessary to establish the current values in these items. If you are using ADView, you can search for the addresses of all connected slaves, and then interrogate the appropriate registers for each one.

If you are not using ADView, Section D.6 gives a procedure which will enable you to get this information.

D.3 Modbus implementation

D.3.1 Register size and content

All registers are 32 bits (whether they are integer or floating point types), although the Modbus specification states that registers are 16 bits and addresses and ‘number of register’ fields assume all registers are 16 bits long. All floating point values are in IEEE single precision format.

Registers are contiguous in the Modbus register ‘address space’. There is a one-to-one mapping of 32-bit meter register numbers to 16-bit Modbus register numbers. Therefore, only the full 32 bits of any register can be accessed. The upper and lower 16-bit segments have the same Modbus register number and consequently cannot be individually read.

Registers 47 and 48 within the meter allow the Modbus ‘dialect’ to be changed to suit the communicating device if it cannot easily be re-programmed. This is most easily done using ADView’s Register Read/Write tool (see the Using ADView and ProLink II chapter).

Their usage is as follows:

Modbus byte ordering

Register 47 contents	Modbus byte ordering
00000000_{16}	Big Endian (i.e. MSB first)
$FFFFFFFF_{16}$	Little Endian (i.e. LSB first)

Modbus register size

Register 48 contents	Modbus register size
00000000_{16}	16 bits
$FFFFFFFF_{16}$	32 bits

16-Bit register size (Register 48 = 00000000_{16})

In order to read 32-bit registers when Modbus registers are dealt with in units of 16 bits, you must specify **twice** the number of 32-bit register you want to read in the ‘number of registers’ field. For example, to read one 32-bit register, use '2'. If an attempt is made to read an odd number of registers, the command will fail.

32-Bit register size (Register 48 = $FFFFFFFF_{16}$)

In order to read 32-bit registers when Modbus registers are dealt with in units of 32 bits, you specify the actual number of registers you want in the ‘number of registers’ field. (for example, to read two 32-bit register in this mode, use '2'.

D.4 Modbus register assignments

Each register is identified by a unique number, and the list is organized by this number. For each register, the contents are described, along with the data type of the contents.

The data type is always 32 bits unless stated otherwise. Variable names are given for reference purposes only. They have no other use.

Note: All units locations (registers 3, 4, 5 and 26) must be set before entering other values.

In some cases the data in a register is used to represent a non-numerical quantity, known as an index. For example, the units of density can be kg/m^3, gm/cc, lb/gal or lb/ft^3 and these are represented by the numbers 91 to 94. Thus if Register 3 (line density) contains the value (index) 91, this means that the units of line density are kg/m^3. Index values may, of course, be used for more than one register.

Tables of these indices are given in Section D.5

Table D-1 Modbus register assignments

Register	Function	Data Type	Index Table (where applicable)
0	API product type	Long integer	D.5.1
1	API referral reference temperature	4-byte float	
2	API referral reference pressure	4-byte float	
3	Line density units	Long integer	D.5.2

Table D-1 **Modbus register assignments** *continued*

Register	Function	Data Type	Index Table (where applicable)
4	Base density units	Long integer	D.5.2
5	Temperature units	Long integer	D.5.2
9	Output averaging time	Long integer	D.5.3
10	Analog Output 1 selected variable	Long integer	D.5.4
11	Analog Output 2 selected variable	Long integer	D.5.4
14	PWM factor for 4mA on Analog Output 1	Long integer	
15	PWM factor for 20mA on Analog Output 1	Long integer	
16	PWM factor for 4mA on Analog Output 2	Long integer	
17	PWM factor for 20mA on Analog Output 2	Long integer	
20	RTD calibration factor	4-byte float	
21	Crystal oscillator calibration factor	4-byte float	
22	Diagnostics flags	Long integer	
23	Line density value when fixed by diagnostics	4-byte float	
24	Base density value when fixed by diagnostics	4-byte float	
25	Temperature value when fixed by diagnostics	4-byte float	
26	Pressure Units		D.5.2
27	Referral temperature for matrix referral	Long integer	D.5.5
30	Modbus Slave address	Long integer	
47	Modbus byte order		D.3.1
48	Modbus register size		D.3.1
49	Software type	Long integer	D.5.6
53	2^{nd} referral temperature for referred density	4-byte float	
57	Full unit part number	String	
61	Hardware type	Long integer	D.5.7
64	Write-protected copy of RTD factor	4-byte float	
65	Write-protected copy of crystal factor	4-byte float	
66	Write-protected copy of Analog O/P 1 ‘4mA PWM factor’	Long integer	
67	Write-protected copy of Analog O/P 1 ‘20mA PWM factor’	Long integer	
68	Write-protected copy of Analog O/P 2 ‘4mA PWM factor’	Long integer	
69	Write-protected copy of Analog O/P 2 ‘20mA PWM factor’	Long integer	
72	Write-protected copy of Time Period Low Limit	4-byte float	
73	Write-protected copy of Time Period High Limit	4-byte float	
74	Write-protected copy of Q Factor Low Limit	4-byte float	
75	Write-protected copy of Q Factor High Limit	4-byte float	
127	Stored checksum for the FRAM	Long integer	
128	K0	4-byte float	
129	K1	4-byte float	
130	K2	4-byte float	
131	K18	4-byte float	

Table D-1 Modbus register assignments *continued*

Register	Function	Data Type	Index Table (where applicable)
132	K19	4-byte float	
137	Meter time period trap count	Long integer	
138	Meter time period trap (difference in μs)	4-byte float	
139	Time period value when fixed by diagnostics	4-byte float	
140	Value represented by 4mA on analog output	4-byte float	
141	Value represented by 20mA on analog output	4-byte float	
146	Line pressure	4-byte float	
147 – 151	Temperatures for matrix referral	4-byte float	
152 – 171	Densities for matrix referral	4-byte float	
172	Atmospheric pressure	4-byte float	
173	Line density offset	4-byte float	
174	Line density scaling factor	4-byte float	
175	Special function calculation parameter A	4-byte float	
176	Special function calculation parameter B	4-byte float	
177	Special function calculation parameter C	4-byte float	
178	Special function parameter d / density of water	4-byte float	
179	Density of product A for special function calc.	4-byte float	
180	Density of product B for special function calc.	4-byte float	
181	Temperature offset	4-byte float	
182	User K0 value for API referral	4-byte float	
183	User K1 value for API referral	4-byte float	
185	User range (alarm) high value	4-byte float	
186	User range (alarm) low value	4-byte float	
192	Write-protected copy of K0	4-byte float	
193	Write-protected copy of K1	4-byte float	
194	Write-protected copy of K2	4-byte float	
195	Write-protected copy of K18	4-byte float	
196	Write-protected copy of K19	4-byte float	
201	Unit's original calibration date	Long integer	
202	Unit's most recent calibration date	Long integer	
203	Unit's serial number	Long integer	
204	Unit type	Long integer	D.5.8
256	Status Register	Long integer	D.5.9
257	Corrected line density (1)	4-byte float	
258	Corrected base density (1)	4-byte float	
259	Line temperature (1)	4-byte float	
260	Special function calculation result (1)	4-byte float	
261	Meter time period (in μs) (1)	4-byte float	
262	FRAM calculated checksums	Long integer	

Table D-1 **Modbus register assignments** *continued*

Register	Function	Data Type	Index Table (where applicable)
263	RTD resistance (in ohms) (1)	4-byte float	
264	Meter coil pickup level (in volts) (1)	4-byte float	
265	Meter resonance Q value (2)	4-byte float	
266	Electronics board temperature (in °C)		
267/8	Software version string (1)	String	
286	Time period A (1)	4-byte float	
287	Time period B (1)	4-byte float	
288	Referred density at 2nd referral temperature (1)	4-byte float	
289	Line dynamic viscosity (1)	4-byte float	
290	Line kinematic viscosity (1)	4-byte float	
294	Referred density API base density (15°C) (1)	4-byte float	
320	Calculation selection (write-protected)	Long integer	
321	Phase angle fixing (write-protected)	Long integer	
322	Write-protected copy of V0	4-byte float	
323	Write-protected copy of V1	4-byte float	
324	Write-protected copy of V2	4-byte float	
326	Write-protected copy of V3	4-byte float	
327	Write-protected copy of V4	4-byte float	
384	Value for Q when fixed	4-byte float	
385	Value for time period B when fixed	4-byte float	
386	Value for raw line density when fixed	4-byte float	
387	Value for line dynamic viscosity when fixed	4-byte float	
388	Value for line kinematic viscosity when fixed	4-byte float	
400	Line dynamic viscosity scale factor	4-byte float	
401	Line dynamic viscosity offset	4-byte float	
402	Line kinematic viscosity scale factor	4-byte float	
421	Line dynamic viscosity units	Long integer	D.5.10
422	V0	4-byte float	
423	V1	4-byte float	
424	V2	4-byte float	
426	V3	4-byte float	
427	V4	4-byte float	

(1) This is a live value. Although it can be written to, it would be pointless.
(2) This value is only valid when bit 3 (hex 08) is set in the diagnostics flag register (22), after a one-second pause.

D.5 Index codes

This section provides an interpretation of the numerical indices used to represent non-numerical values.

D.5.1 API product type

Used in Register 0. (The user values for K0 and K1 are stored in Registers 182 and 183.)

Index	Product Type
0	Crude (general crude)
1	Refined (general product)
2	User K0 and K1

D.5.2 Pressure, Temperature, Density and other Units

Used in Registers 3, 4, 5 and 26.

Index	Units
6	psi A
7	bar A
10	kg / cm^2
11	Pa
12	kPa
32	°C
33	°F
57	%
90	SGU
91	g / cm^3
92	kg / m^3
93	lb / gal
94	lb / ft^3
101	° Brix
102	° Baume heavy
104	° API

D.5.3 Output averaging time

Used in Register 9.

Index	Averaging Time
0	none
1	1 s
2	2 s
3	5 s
4	10 s
5	20 s
6	50 s
7	100 s

D.5.4 Analog output selection

Used in Register 10.

Index	Output
0	Density
1	Referred Density
2	Temperature
3	Special Function
4	4 mA
5	12 mA
6	20 mA
7	
8	Raw density
9	Line dynamic viscosity
10	Line kinematic viscosity
11	Referred kinematic viscosity

D.5.5 Referral temperature

Used in Register 27

Index	Referral Temperature
0	Lowest temperature value in matrix
1	↓
2	
3	
4	Highest temperature value in matrix

D.5.6 Software version

Used in Register 49.

Index	Density Referral
0	Matrix
1	API

D.5.7 Hardware type

Used in Registers 61.

Index	Meter Type
1	Advanced Fork

D.5.8 Unit type

Used on Register 204.

Index	Meter type
5	Advanced fork

D.5.9 Status register flags

Used in Register 256.

Bit	Hex Value	Flag Name	Definition
0	00000001	ST_IN_LOCK	P.L.L. is IN LOCK
1	00000002	ST_DIAG_ON	DIAGnostics ON
2	00000004	ST_FT1_ALM	4 to 20 mA output 1 in ALarM
3	00000008	ST_FT2_ALM (1)	4 to 20 mA output 2 in ALarM
4	00000010	ST_FT3_ALM (1)	4 to 20 mA output 3 in ALarM
5	00000020	ST_HART_BOARD (1)	whether HART BOARD is fitted
6	00000040	ST_RS232_BOARD (1)	whether RS232 BOARD is fitted
7	00000080	ST_SWITCH_BOARD (1)	whether SWITCH BOARD is fitted
8	00000100	ST_EXP0_BOARD	(reserved for future expansion)
9	00000200	ST_EXP1_BOARD	(reserved for future expansion)
10	00000400	ST_EXP2_BOARD	(reserved for future expansion)
11	00000800	ST_EXP3_BOARD	(reserved for future expansion)
12	00001000	ST_FT3_HART (1)	HART is in control of its 4 to 20 mA output
13	00002000	ST_BAD_STATUS	STATUS register corruption
14	00004000	ST_STAT_CORR	one or more STATus registers have been CORRected
15	00008000	ST_TOTAL_DEATH	status registers not updating - assume the worst
16	00010000	ST_USER_ALM	User defined variable in alarm
17	00020000		
18	00040000		
19	00080000		
20	00100000		
21	00200000	ST_TEMP_HI	TEMPerature reading too HIgh
22	00400000	ST_TEMP_LOW	TEMPerature reading too LOW
23	00800000	ST_ROM_CSF	ROM CheckSum Fail flag
24	01000000	ST_FRAM0_WPF	FRAM0 Write Protect Fail
25	02000000	ST_FRAM1_WPF (1)	FRAM1 Write Protect Fail
26	04000000	ST_FRAM0_RWE	FRAM0 Read/Write Error
27	08000000	ST_FRAM1_RWE (1)	FRAM1 Read/Write Error
28	10000000	ST_FRAM0_CSF	FRAM0 CheckSum Fail flag

29	20000000	ST_FRAM1_CSF (1)	FRAM1 CheckSum Fail flag
30	40000000	ST_FRAM0_ACK	FRAM0 ACK/data error
31	80000000	ST_FRAM1_ACK (1)	FRAM1 ACK/data error

(1) The status flags marked thus refer to hardware features not present in the meter. They can safely be ignored.

D.5.10 Line dynamic viscosity units

Used in Register 421.

Index	Variable
0	cP
1	P
2	Pas
3	mPas

D.6 Establishing Modbus communications

Using ADView, it is possible to establish which devices are available on the network, and their slave addresses. However, if you are not using ADView, the following procedure can be adopted.

If the meter Slave address or the values of Registers 47 and 48 are not known, Modbus communications cannot be carried out successfully, and it will be necessary to establish the current values in these items. The following procedure will do this.

The process is:

1. Find the slave address by trying all possible values until a response is received.
2. Establish whether the register size is 16 or 32 bits by reading register 48.
3. Find the byte order by reading register 47.

Step 1 Find the slave address

Make sure only the meter is connected to the Modbus Master, then send the following message (Read Register 47):

Slave Address	Command		Register Address			Checksum
00	03	00	47_{10}	00	02	checksum

Wait for a response. If there is none, repeat the same message, with the Slave address changed to 1, and await a response. Repeat the process until a response is obtained. This will show the slave address of the meter.

Step 2 Establish register size as 16-Bit versus 32-Bit

Send the following message (Read Register 48), where nn is the meter slave address:

Slave Address	Command		Register Address			Checksum
nn	03	00	48_{10}	00	02	checksum

The meter will respond with the following to show that the meter is set to 16-bits register size:

Slave Address	Command		Data Bytes	Checksum
nn	03	04	4 data bytes	checksum

Or, the meter will respond with the following to show that the meter is set to 32-bits register size.

Slave Address	Command		Data Bytes	Checksum
nn	03	08	8 data bytes	checksum

Thus, by reading the third byte of the response, you can deduce the value of Register 48.

Step 3 Find the byte order

Send the following message (Read Register 47), where nn is the meter's slave address:

Slave Address	Command		Register Address			Checksum
nn	03	00	47_{10}	00	02	checksum

The meter will respond with one of the following:

Slave Address	Command		Data Bytes	Checksum
nn	03	04	4 data bytes	checksum

Slave Address	Command		Data Bytes	Checksum
nn	03	08	8 data bytes	checksum

Examine the first four bytes of the data. If they are all 00, then the meter is in Big Endian mode; if they are all FF, then the mode is Little Endian.

D.7 Example of direct Modbus access

In many applications, direct access to Modbus will be unnecessary. ADView provides a way of configuring the 7829 Viscomaster® / Viscomaster Dynamic™ viscosity meter, and for accessing individual registers. This example describes how to access the meter directly, without the help of ADView.

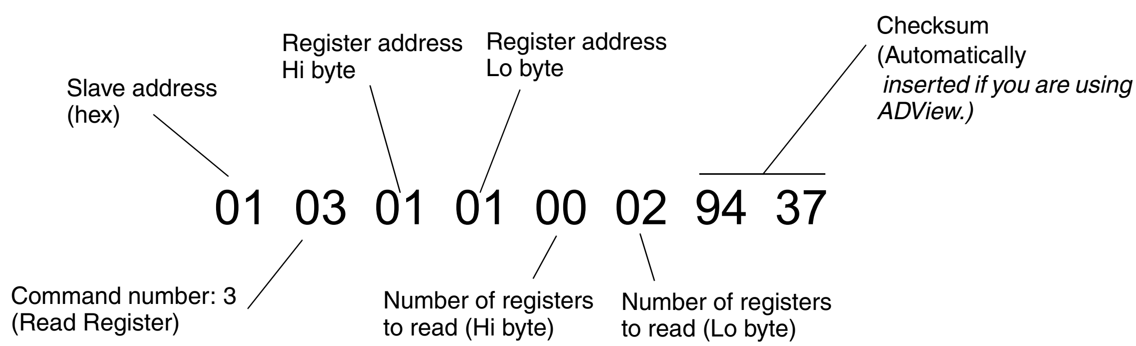
However, before you start, you should configure the meter using ADView (described in the Using ADView and ProLink II chapter), and also set the Modbus Byte Order and Register Size (see Modbus Communications appendix).

Note: You can use ADView's Direct Communications tool to test out the following sequences, or any others you want to try. This has the added advantage that ADView calculates and inserts the checksum value for you.

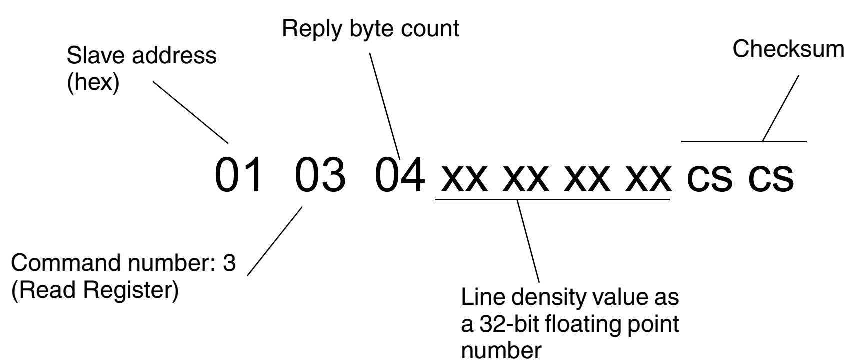
D.7.1 Example 1: Reading line density (16-bit register size)

The meter is assumed to have been configured with Register Size = 16-bit (Register 48 = 0), and has slave address = 1.

The following string will read the line density, which is held in Register 257 (0101_{16}).



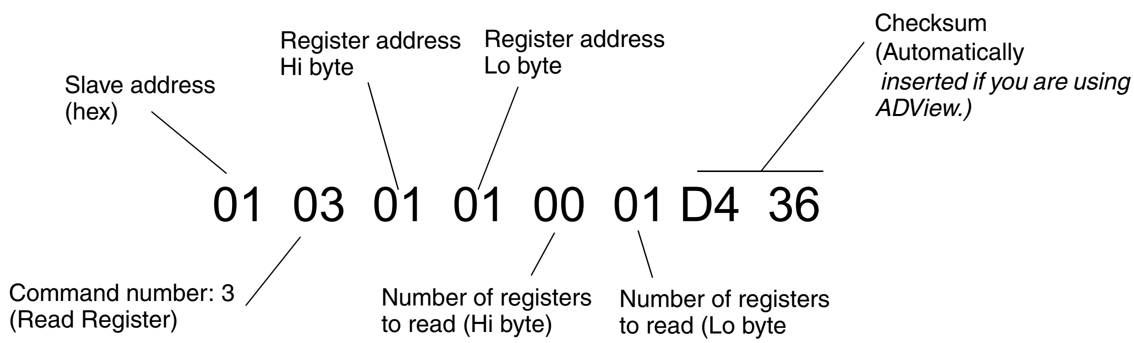
The reply from the meter will be:



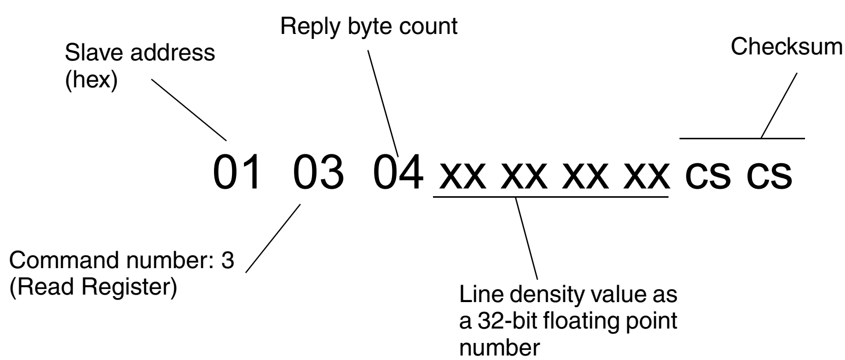
D.7.2 Example 2: Reading line density (32-bit register size)

The meter is assumed to have been configured with Register Size = 32-bit (Register 48 = $FFFF_{16}$), and has slave address = 1.

The following string will read the line density, which is held in Register 257 (0101_{16}).



The reply from the meter will be the same as for Example 1.



Appendix E
Product Data

E.1 Density / temperature relationship of hydrocarbon products

E.1.1 Crude oil

Table E-1 **Crude oil**

Temp. (°C)	Density (kg/m³)								
60	738.91	765.06	791.94	817.15	843.11	869.01	894.86	920.87	946.46
55	742.96	768.98	794.93	820.83	846.68	872.48	898.24	923.95	949.63
50	747.00	772.89	798.72	824.51	850.25	875.94	901.80	927.23	952.82
45	751.03	776.79	802.50	828.17	853.81	879.40	904.96	930.50	956.00
40	755.05	780.68	806.27	831.83	857.36	882.85	908.32	933.76	959.18
35	759.06	784.57	810.04	835.48	860.90	886.30	911.67	937.02	962.36
30	763.06	788.44	813.79	839.12	864.44	889.73	915.01	940.28	965.53
25	767.05	792.30	817.54	842.76	867.97	893.16	918.35	943.52	968.89
20	771.03	796.18	821.27	846.38	871.49	896.59	921.68	946.77	971.85
15.556	774.56	799.57	824.59	849.60	874.61	899.62	924.63	949.64	974.65
15	775.00	800.00	825.00	850.00	875.00	900.00	925.00	950.00	975.00
10	778.95	803.83	828.72	853.61	878.50	903.41	928.32	953.23	978.15
5	782.90	807.65	832.42	857.20	882.00	906.81	931.62	958.45	981.29
0	786.83	811.46	836.12	860.79	885.49	910.21	934.92	959.66	984.42

E.1.2 Refined products

Table E-2 **Refined products**

Temp. (°C)	Density (kg/m³)								
60	605.51	657.32	708.88	766.17	817.90	868.47	918.99	969.45	1019.87
55	610.59	662.12	713.50	769.97	821.49	872.00	922.46	972.87	1023.24
50	615.51	666.91	718.11	773.75	825.08	875.53	925.92	976.28	1026.60
45	620.49	671.68	722.71	777.53	828.67	879.04	929.38	979.69	1029.96
40	625.45	676.44	727.29	781.30	832.24	882.56	932.84	983.09	1033.32
35	630.40	681.18	731.86	785.86	835.81	886.06	938.28	986.48	1038.67
30	635.33	685.92	736.42	788.81	839.37	889.56	939.72	989.87	1040.01
25	640.24	690.63	740.96	792.55	842.92	893.04	943.16	993.26	1043.35
20	645.13	695.32	745.49	796.28	846.46	896.53	846.58	996.63	1046.68
15.556	649.46	699.48	749.50	799.59	849.61	899.61	949.62	999.63	1049.63

Table E-2 **Refined products** *continued*

Temp. (°C)	Density (kg/m^3)								
15	650.00	700.00	750.00	800.00	850.00	900.00	950.00	1000.00	1050.00
10	654.85	704.66	754.50	803.71	853.53	903.47	953.41	1003.36	1053.32
5	659.67	709.30	758.97	807.41	857.04	906.92	956.81	1006.72	1056.63
0	664.47	713.92	763.44	811.10	860.55	910.37	960.20	1010.07	1059.93

The above tables are derived from equations, which form the basis of the data in the *Revised Petroleum Measurement Tables* (IP 200, ASTM D1250, API 2540 and ISO R91 Addendum 1).

The density temperature relationship used is:

$$\frac{\rho_t}{\rho_{15}} = \exp[-\alpha_{15}\Delta_t(1+0.8\alpha_{15}\Delta_t)]$$

Where: ρ_t = Density at line temperature t°C (kg/m^3)

ρ_{15} = Density at base temperature 15°C (kg/m^3)

Δ_t = t°C –15°C (such as t – base temperature)

α_{15} = Tangent thermal expansion coefficient per °C at base temperature 15°C

The tangent thermal expansion coefficient differs for each of the major groups of hydrocarbons. It is obtained using the following relationship:

$$\alpha_{15} = \frac{K_0 + K_1\rho_{15}}{\rho_{15}^2}$$

Where: K_0 and K_1 = API factors and are defined as follows:

Product	Density Range (kg/m^3)	K_0	K_1
Crude Oil	771 – 981	613.97226	0.00000
Gasolines	654 – 779	346.42278	0.43884
Kerosines	779 – 839	594.54180	0.00000
Fuel Oils	839 – 1075	186.96960	0.48618

E.1.3 Platinum resistance law

Table E-3 **Platimum resistance law (To DIN 43 760)**

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°F	Ohms	°F	Ohms
–50	80.31	5	101.91	60	123.24	115	144.17	0	93.03	100	114.68
–45	82.29	10	103.90	65	125.16	120	146.06	10	95.21	110	116.83
–40	84.27	15	105.85	70	127.07	125	147.94	20	97.39	120	118.97
–35	86.25	20	107.79	75	128.98	130	149.82	30	99.57	130	121.11
–30	88.22	25	109.73	80	130.89	135	151.70	32	100.00	140	123.24
–25	90.19	30	111.67	85	132.80	140	153.58	40	101.74	150	125.37
–20	92.16	35	113.61	90	134.70	145	155.45	50	103.90	160	127.50
–15	94.12	40	115.54	95	136.60	150	157.31	60	106.07	170	129.62
–10	96.09	45	117.47	100	138.50	155	159.18	70	108.23	180	131.74
–5	98.04	50	119.40	105	140.39	160	161.04	80	110.38	190	133.86
0	100.00	55	121.32	110	142.29	165	162.90	90	112.53	200	135.97

E.1.4 Density of ambient air

Taken at a relative humidity of 50%.

Table E-4 Density of ambient air (in kg/m^3)

Air Pressure (mb)	Air Temperature (°C)						
	6	10	14	18	22	26	30
900	1.122	1.105	1.089	1.073	1.057	1.041	1.025
930	1.159	1.142	1.125	1.109	1.092	1.076	1.060
960	1.197	1.179	1.162	1.145	1.128	1.111	1.094
990	1.234	1.216	1.198	1.180	1.163	1.146	1.129
1020	1.271	1.253	1.234	1.216	1.199	1.181	1.163

E.1.5 Density of water

Use pure, bubble-free water.

Table E-5 Density of water (in kg/m^3 to ITS – 90 temperature scale)

Temp °C	0	2	4	6	8	10	12	14	16	18
0	999.840	999.940	999.972	999.940	999.848	999.699	999.497	999.244	998.943	998.595
20	998.203	997.769	997.295	996.782	996.231	995.645	995.024	994.369	993.681	992.962
40	992.212	991.432	990.623	989.786	988.922	988.030	987.113	986.169	985.201	984.208
60	983.191	982.150	981.086	980.000	978.890	977.759	976.607	975.432	974.237	973.021
80	971.785	970.528	969.252	967.955	966.640	965.305	963.950	962.577	961.185	959.774
100	958.345									

E.1.6 Velocity of sound in liquids

Table E-6 Velocity of sound in liquids

Liquid	Temp. (t °C)	Velocity of Sound (c ms^{-1})	Rate of Change ($\delta c / \delta t$ $ms^{-1}K^{-1}$)
Acetic acid	20	1173	----
Acetone	20	1190	–4.5
Amyl acetate	29	1173	----
Aniline	20	1656	–4.0
Benzene	20	1320	–5.0
Blood (horse)	37	1571	----
Butyl acetate	30	1172	–3.2
Carbon disulphide	25	1142	----
Carbon tetrachloride	20	940	–3.0
Chlorine	20	850	–3.8
Chlorobenzene	20	1290	–4.3
Chloroform	20	990	–3.3
Ethanol amide	25	1724	–3.4
Ethyl acetate	30	1133	–3.9
Ethyl alcohol	20	1162	–3.6
Formic acid	20	1360	–3.5
Heptane	20	1160	–4.5
n-Hexane	30	1060	----
Kerosene	25	1315	–3.6
Menthol	50	1271	----
Methyl acetate	30	1131	–3.7
Methyl alcohol	20	1121	–3.5
Methylene Chloride	25	1070	----
Nitrogen	–189	745	–10.6
Nonane	20	1248	----
Oil (castor)	19	1500	–4.1
Oil (olive)	22	1440	–2.8
Octane	20	1197	----
Oxygen	–186	950	–6.9

Table E-6 **Velocity of sound in liquids** *continued*

Liquid	Temp. (t °C)	Velocity of Sound (c ms^{-1})	Rate of Change (δc / δt ms^{-1}K^{-1})
n-Pentane	20	1044	–4.2
n-Propyl acetate	26	1182	----
Toluene	20	1320	–4.3
Turpentine	25	1225	----
Water (distilled)	10	1447.2	----
	20	1482.3	----
	30	1509.1	----
	50	1542.5	----
	70	1554.8	----
Water (sea)	–4	1430.2	----
	00	1449.5	----
	05	1471.1	----
	15	1507.1	----
	25	1534.7	----
o-Xylene	22	1352	----

Appendix F
Return Policy

F.1 General guidelines

Micro Motion procedures must be followed when returning equipment. These procedures ensure legal compliance with government transportation agencies and help provide a safe working environment for Micro Motion employees. Failure to follow Micro Motion procedures will result in your equipment being refused delivery.

Information on return procedures and forms is available on our web support system at **www.micromotion.com**, or by phoning the Micro Motion Customer Service department.

F.2 New and unused equipment

Only equipment that has not been removed from the original shipping package will be considered new and unused. New and unused equipment requires a completed Return Materials Authorization form.

F.3 Used equipment

All equipment that is not classified as new and unused is considered used. This equipment must be completely decontaminated and cleaned before being returned.

Used equipment must be accompanied by a completed Return Materials Authorization form and a Decontamination Statement for all process fluids that have been in contact with the equipment. If a Decontamination Statement cannot be completed (for example, for food-grade process fluids), you must include a statement certifying decontamination and documenting all foreign substances that have come in contact with the equipment.

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