Installation and Maintenance Manual
MMI-20018377, Rev. AA
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Micro Motion® 7812 Gas Density Meter

Micro Motion

EMERSON
Process Management

IMPORTANT NOTICE

DO NOT	drop the meter. **HANDLE WITH CARE**
DO NOT	use liquids incompatible with **MATERIALS OF CONSTRUCTION**
DO NOT	operate the meter above its **RATED PRESSURE**
DO NOT	**PRESSURE TEST** above the specified **TEST PRESSURE**
DO NOT	expose the meter to excessive vibration **(>0.5g continuous)**
ENSURE	all **ELECTRICAL SAFETY** requirements are met
ENSURE	all **EXPLOSION PROOF** requirements are applied
ENSURE	meter and associated pipework are **PRESSURE TESTED** to 1½ times the maximum operating pressure after installation

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Chapter 1
Introduction

1.1 General

The 7812 Gas Density Meter was specifically designed for metering gas in pipelines. Measurements are made continuously with the accuracy equal to that normally associated with the best laboratory methods. The 7812 is a replacement for the 7810, 7811, and 3093 Series, and is fully interchangeable with them, incorporating the following design improvements:

- Single sensing element for all density ranges up to 400 kg/m^3.
- New design of vibrating cylinder sensing element, which offers less sensitivity to changes in gas composition and a lower Velocity of Sound Effect.
- Improved temperature equilibrium performance.
- Improved accuracy.
- Improved maintenance features, including new amplifier electronics and a more serviceable gas filter arrangement.
- A 4-wire PT100 temperature sensor has been incorporated for installation and check purposes.

This meter is suitable for most types of installation. Aspects such as performance, response characteristics, filtration and servicing vary from application to application and require careful consideration as described in this manual.

The vibrating cylinder sensing element is sensitive to changes in density and, since it is unstressed and is manufactured from Ni-span C steel, it has very stable characteristics. The influence of other variables such as temperature, line pressure, flow rate and gas composition are minimized and carefully defined so that, where necessary and for high precision measurements, suitable corrections can be applied.

Only one low voltage supply is required for the density measurement and the power consumption is low thus minimising self-heat generation. The output signal is a square wave, the frequency depending on the gas density. This type of signal can be transmitted over long distances and easily measured without any loss in accuracy. The PT100 temperature sensor may be used in the conventional manner.

1.2 Principle of operation

The density-sensing element consists of a thin metal cylinder, which is activated so that it vibrates in a hoop mode at its natural frequency. The gas is passed over the outer and inner surfaces of the cylinder and is thus in contact with the vibrating walls. The mass of gas, which vibrates with the cylinder, depends upon the gas density and, since increasing the vibrating mass decreases the natural frequency of vibration, the gas density is simply determined by measuring this frequency.

An amplifier, magnetically coupled to the sensing element, maintains the conditions of vibration and provides the output signal (see Figure 1-1 and Figure 1-2). The amplifier and signal output circuits are encapsulated in epoxy resin.

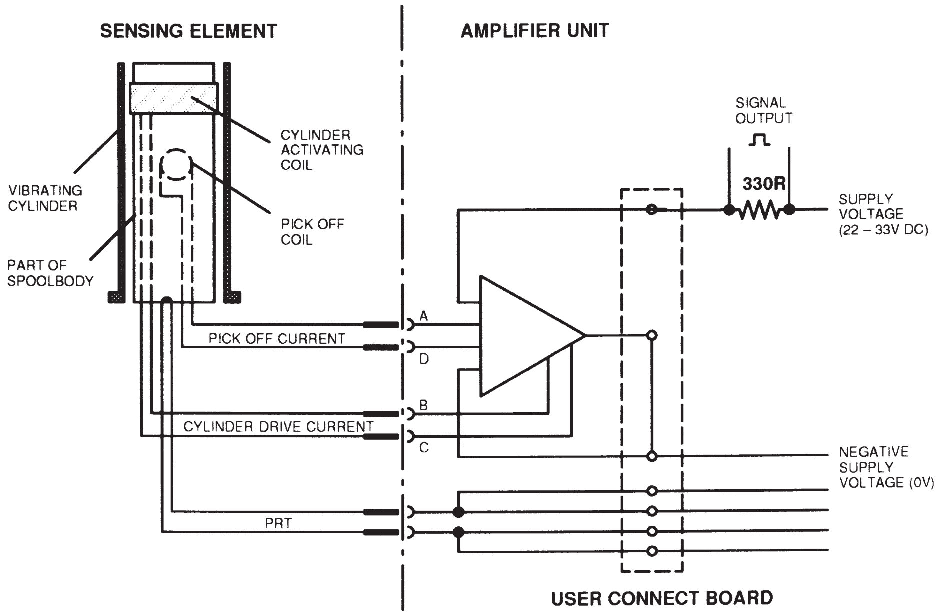


Figure 1-1: Schematic block diagram of meter circuit (2-wire system)

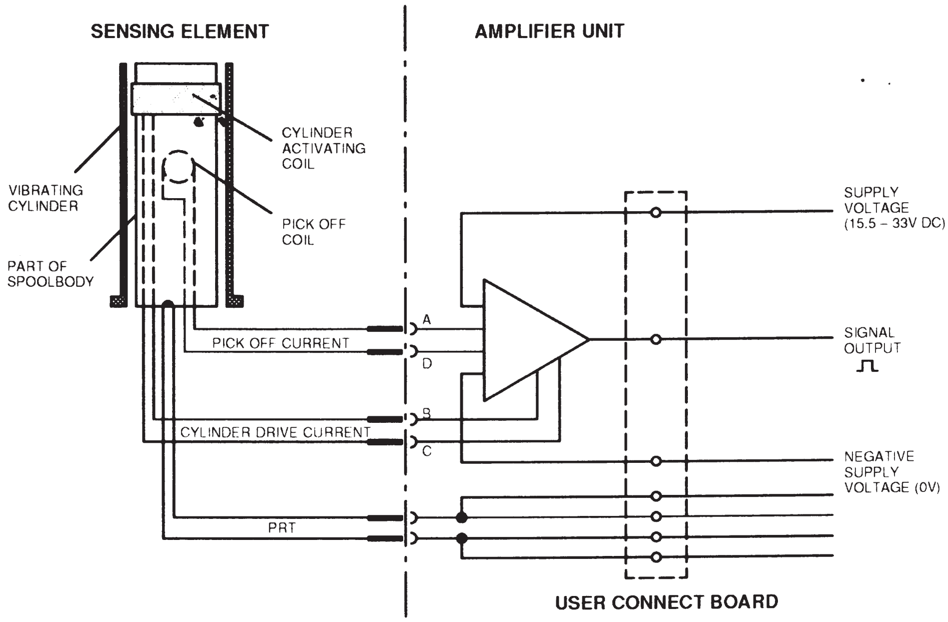


Figure 1-2: Schematic block diagram of meter circuit (3-wire system)

1.3 Design features

1.3.1 Accuracy

The instrument design achieves high accuracy by minimizing the effects of the variables such as pressure, temperature, sound velocity and viscosity, whilst providing insensitivity to plant vibration and variations in power supply. Since the power consumption is extremely small, the self-induced heat may also be neglected. The absolute accuracy is therefore mainly defined by the accuracy of calibration and correction applied.

1.3.2 Repeatability

The repeatability of measurement is within ±0.01% of full scale density.

1.3.3 Stability

The long-term stability of this density sensor is mainly governed by the stability of the vibrating cylinder sensing element. This cylinder is manufactured from one of the most stable metals and, being unstressed, will maintain its properties for many years. However, corrosion and deposition on the cylinder will degrade the long-term stability and care should be taken to ensure that the process gas is suitable for use with materials of construction. The possibility of deposition is reduced by the use of filters but, should deposition take place, the sensing element can be removed and cleaned.

1.4 The 7812 versions

The following meter types are available, covering the basic density ranges:

Type No.	Range (kg/m^3)[1]	Calibration Gas
78121x	1.5 - 10	Nitrogen
78122x	9 - 90	Nitrogen
78123x	25 - 250	Nitrogen
78124x	40 - 400 (pocket)	Argon
78125x	40 – 400 (cross pipe)	Argon
If **x = A**: Fluorocarbon (FPM/FKM) 0 rings are used for the gas path ways. if **x = B**: Ethylene Propylene 0 rings are used for the gas path ways.		

Nitrogen calibration should be used for low density and natural gas applications. Argon calibration should be used for high density and heavy hydrocarbon applications.

1.5 Frequency relationship

The relationship between gas density and the output frequency follows a well-defined law:

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

or

$$\tau = \frac{-K1 + \sqrt{K1^2 - 4K2(K0 - \rho)}}{2K2}$$

Where: ρ = Density (kg/m^3)

τ = Meter Time Period (μs)

K0, KI, K2 = Calibration coefficients

[1] An additional option for low density range measurement (0 to 3 kg/m^3), ± 0.5% of full scale, is available as a special purchase. Contact your local Micro Motion sales office for more information.

Range selection and linearization are normally introduced within the readout system. In addition, there is an influence on the measurement performance from changes in gas temperature and composition. These are as specified on the calibration certificate of an instrument and should form the basis of manual or automatic corrections if the full performance potential is to be achieved.

1.6 Safety

The 7812 meters have been subjected to the necessary safety regulations and have qualified for ATEX certification to Class EEx ia IIC T5.

For ATEX safety information, refer to the safety instructions booklet 78125010/SI.

For Pressure Equipment Directive (PED) safety information, refer to safety instructions booklet 78128012/SI.

For CSA safety information, refer to Appendix H.

Chapter 2
Applications

2.1 General

The 7812 Gas Density Meter provides a continuous and accurate measurement of gas density. This measurement can be made at the actual flowing conditions of temperature and pressure and, in consequence, is ideally suited for high-performance gas flow metering tasks.

2.2 Orifice plate metering

The orifice meter is probably the most widely used meter type for gas measurement. It has the advantage that it does not require flow calibration, as this is defined from dimensional measurements and application of International Standards (ISO 5167 and AGA3). For flow measurements in either mass units or volume units, it is necessary to determine the fluid density in addition to the differential pressure.

The 7812 gas density meter offers a direct measurement of density and is an alternative to density calculation using pressure, temperature and composition measurements. It offers low measurement uncertainty and is therefore of prime use in major gas metering stations where best accuracy is required. Orifice metering systems are discussed in more detail in Appendix C.

2.3 Volumetric flow meters

Positive displacement meters or turbine flow meters can be converted to mass flow meters using the 7812 gas density meter and a simple readout system. Please note that the 7950/51 Signal Converter cannot accept a flow meter input.

Since both flow meter and density sensor signals are in frequency form, the readout system need use only digital techniques (see Figure 2-1).

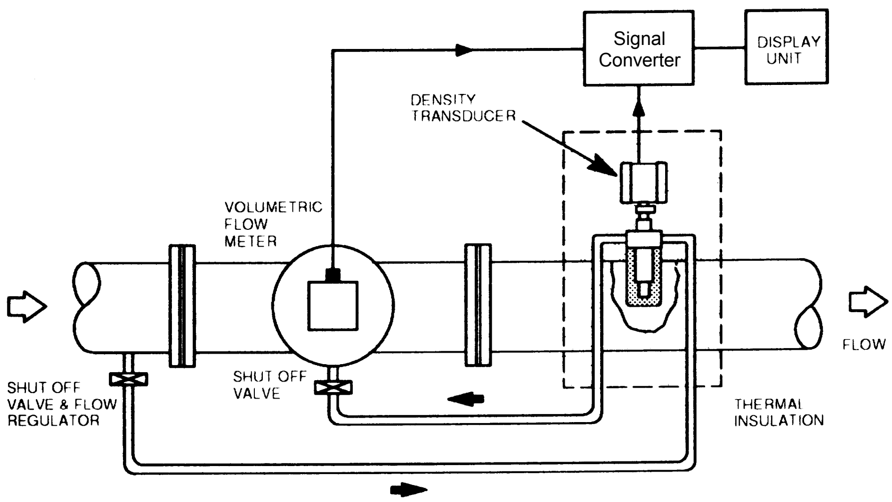


Figure 2-1: Typical volumetric flow metering system

The combined uncertainties of the density measurement and signal converter are considerably less than that of volumetric flow meters. Therefore, the overall accuracy of mass flow measurement will be almost entirely determined by the accuracy of the volumetric flow meter.

2.4 Other applications

Other applications include process monitoring and control in chemical and petrochemical plants where density or specific gravity of a gas is required as a control variable.

Chapter 3
General Installation

3.1 Delivery component list

Check that the following items have been included on delivery:

- 7812 Gas Density Meter.
- Nitrogen or Argon Gas Calibration Certificate.
- User Gas Calibration Certificate (if requested).
- Thermal conductor plus silicone fluid (except for 78125).
- Housing blanking plug.
- Cable gland adapter.

3.2 General installation considerations

The basic objective of an installation is to pass a representative sample of gas through the 7812 in a controlled manner such that the temperature and pressure are at known conditions. Typically, this means that they need to be the same as the line conditions.

It is worth remembering that the 7812 will always read the correct density for the gas that is inside it. Installation errors result from the sample gas in the 7812 not being what the installer believes it to be in terms of composition, temperature or pressure.

The following points should be considered when planning the installation of the 7812:

(a) All necessary mechanical and electrical safety standards **MUST** be applied.

(b) The effects of the following on the 7812:

- Density Equilibrium.
- Temperature Equilibrium.
- Pressure Equilibrium.
- Sample flow rate and response time.
- Deposition, Corrosion and Condensation.
- Vibration.
- Accuracy of calibration.
- Effects of velocity of sound.

(c) When installing the 7812 in a pipeline, we recommend you do not exceed a 10% reduction of the cross-sectional area at the point of insertion to ensure minimal effect on pressure.

(d) Adequacy of sample extraction, filtration and conditioning for preventing dirt or condensates from causing non-operation of the 7812.

(e) Interaction between the 7812 installation and the flow meter.

(f) Unregistered gas, which passes through the 7812 but not the flow meter.

(g) The proving system (e.g. vacuum systems, calibration gas, etc.)

(h) The use of duplicate 7812 meters for performance comparison and for provision of automatic alarm.

(i) Accessibility to the system components for proving and maintenance.

These points are considered in more detail in the paragraphs below and in subsequent chapters.

3.3 Density equilibrium

Three factors affect the equality of density of the sample gas and the pipeline gas:

(a) The gas in the density sensor should be representative of the main flow with regard to the proportions of different gas constituents. This is normally best achieved by ensuring that there is a small flow rate of sample gas.

(b) The pressure of the sample gas **MUST** be approximately equal to the pipeline pressure as density varies proportionately with absolute pressure for an ideal gas.

(c) The temperature of the sample gas **MUST** be approximately equal to the pipeline gas temperature as density varies inversely with absolute temperature.

3.4 Temperature equilibrium

The major installation consideration is that of temperature equilibrium. If the required density is that of the main pipeline at the pipeline temperature, it is important that the 7812 is at the same temperature.

A temperature difference of 1°C will cause an error of between 0.3% and 0.6% depending on the gas composition. Good temperature equilibrium between the 7812 and pipe is therefore essential and may be achieved by:

(a) Using thermal insulation over the 7812 and associated pipework.

(b) Using a short well-insulated inlet sample pipe.

(c) Using the silicone fluid and pocket cylinder in the recommended way. This will significantly increase the temperature equilibrium and decrease the response time of the 7812.

(d) Using the smallest acceptable sample flow rate.

(e) Using the 78125 variant mounted in a cross pipe installation; this gives direct contact with the in-line gas, thus minimizing temperature errors.

The temperature in the 7812 can be checked using the Class A PRT mounted in the spool body.

For an internal pocket installation, the recommendations in Chapter 4 of this manual should be followed. Using the silicone fluid and aluminium cylinder improves the thermal performance by more than 90% and in order for the silicone to remain in the base of the pocket, the installation should be vertical. If a non-vertical installation is preferred then the silicone fluid should be replaced with a heat sink compound.

For installations where an external pocket is used or the temperature cannot be maintained at that of the pipeline, the 7812 PRT can be used to correct the measured density to the conditions of the pipeline. To do this, some form of density referral method will need to be employed.

3.5 Pressure equilibrium

It is first necessary to define whether the gas in the 7812 should be at the same pressure as that at the gas take-off tapping point. It is then necessary to ensure that the pressure difference between the 7812 and the required tapping point is kept to a minimum by ensuring that there is low sample flow rate and that relevant filters are not causing excessive restriction. It is normally recommended that the gas flow is controlled by a needle valve which can be mounted before or after the 7812 depending on the chosen installation method. It is common to install a flow meter to monitor this flow, and is very useful for ensuring that filters are not blocking, which can cause errors in some installations.

The usual recommended density measurement is taken from the gas return point (or density point). This reduces the significance of the pressure build up across the fine gauge filters.

The state of the filters and any resultant excessive pressure drop can be determined by varying the sample flow rate and monitoring the magnitude of the resultant density changes. The 7812 filters can be easily exchanged without disconnecting the associated pipe work. For further details, see Chapter 8.

Note: The 78125 meter, the direct replacement of the 3093, is a filterless unit that is installed in a filtered cross-pipe installation and is thus held, by definition, at the line pressure.

3.6 Flow rate

The recommended flow rate is 5 ±1 Litres per hour, but anywhere in the region of 1 to 10 Litre(s) per hour is acceptable. (At flow rates above 10 Litre(s) per hour, the density reading will start to become slightly unstable and a small density error may be introduced.)

To maintain this flow rate, a pressure differential is required across the 7812. If the filters are clean, the flow rate will be approximately:

$$Q = 0.5\sqrt{\frac{\Delta P}{\rho}}$$

where

Q = sample gas flow rate in litres/minute

ΔP = differential pressure across the *7812*, in mbar

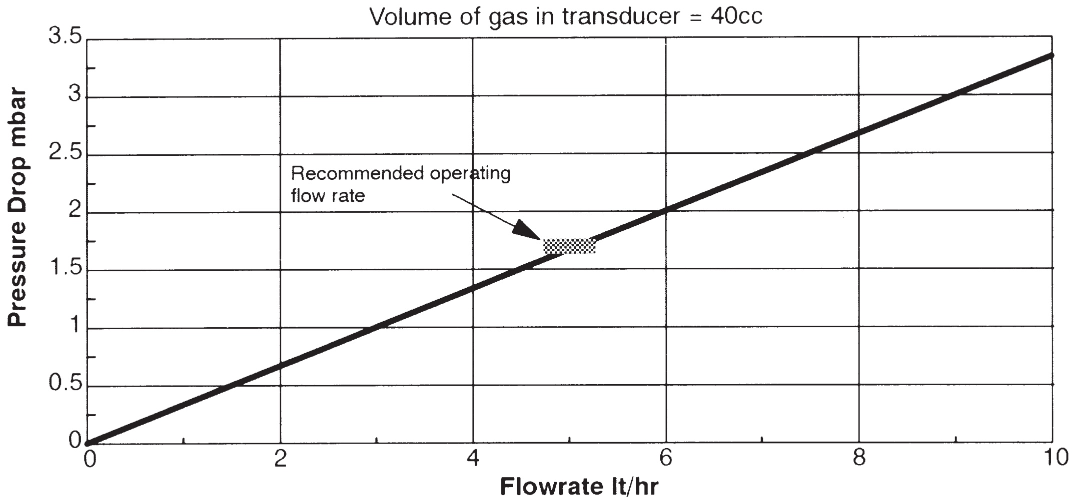
ρ = density of gas, in kg/m^3

(About 85% of this differential pressure is across the 2 micron filter, and the remainder is across the 90 micron filter.)

This equation indicates that for natural gas with a typical application density of about 60 kg/m^3, a pressure differential of approximately 1.66 mbar is required to maintain a flow rate of 5 Litres per hour. Figure 3-1 shows the pressure drop across the 7812 for a typical natural gas application.

The flow rate is dependent on the gas density, which is affected by gas composition, temperature, and pressure. The first two parameters should not change suddenly, as this would leave the mixture in the pipe inhomogeneous and render measurements invalid for other reasons. Pressure may change rapidly but this change will be transmitted to the density meter very rapidly irrespective of the sample gas flow rate.

For most systems, the available differential pressure would create too high a flow for accurate density measurement and maximum 7812 reliability. A low flow rate helps to achieve pressure and temperature equilibrium, as well as extending the life of filters and minimising carry over of any condensate. It is therefore normal to include a flow control valve in the sample pipeline.



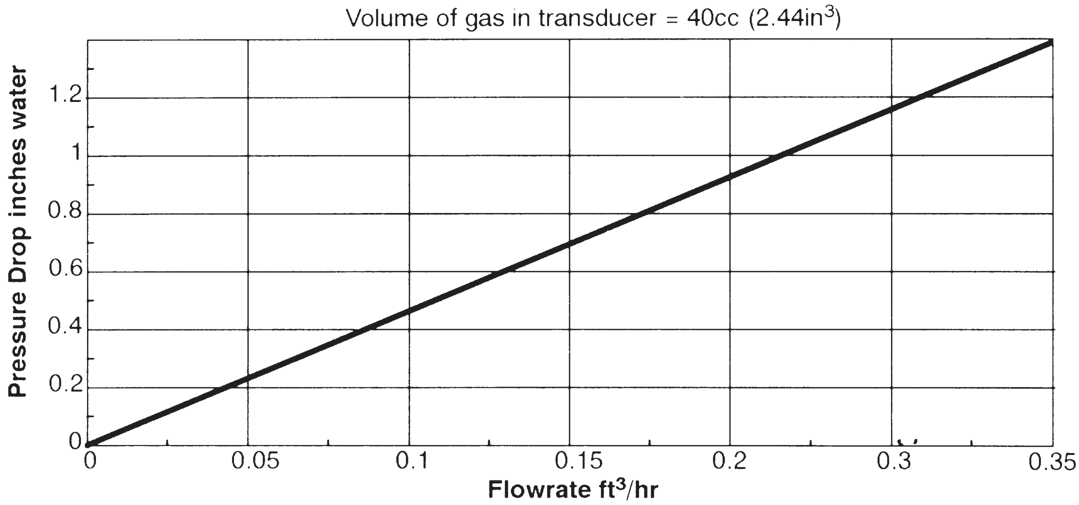


Figure 3-1: Pressure drop through 7812

3.7 Response time

Several different response times need to be considered:

(a) Response to pressure changes is instant.

(b) Response to temperature changes is the same response time as the pipework. For a faster response, it would be necessary to use the 7812 PRT.

(c) The response to composition changes: this depends on flow rate and dead volume.

For example:	7812 volume	40cc
	Filter volume	60cc
	Flowmeter volume (if upstream of 7812)	40cc
	Pipe volume	60cc

Response time at 4 l/hr = 3 minutes

In order to improve the response time, the inlet pipe should be short and of small diameter and any additional inlet filters should be of low volume.

3.8 Deposition, corrosion, condensation and vibration

The prevention of deposition, corrosion, and condensation on the vibrating cylinder sensing element is essential if drift in calibration and/or malfunction is to be avoided. It is also necessary to restrict the level of vibration experienced by the *7812*.

DEPOSITION

Deposition of solids on the cylinder will cause an increase in vibrating mass and thus a decrease in vibrating frequency. The *7812* density reading will be high with respect to the actual gas density. Massive deposition may cause oscillation to stop altogether by filling the gaps between the coils and cylinder walls.

A filter of the appropriate size is fitted on all *7812* units (except the 78125) in both the inlet and outlet gas paths to remove any solid particles that may be present in the sample gas. The outlet filter is incorporated for protection should a reverse flow occur. These filters can be exchanged in the field without the removal of any of the associated pipework.

If the gas is known to be excessively dirty, it is recommended that an external filter is installed in the inlet section of the sample line. This should be of sufficient area to cause only a negligible pressure drop at the maximum rate of flow, but of small volume to provide adequate response time to gas composition changes.

CORROSION

Corrosion of the cylinder element will reduce both its stiffness and its mass per unit length, but since its stiffness is of greater significance, the corrosion will cause a reduction in the resonant frequency. The *7812* density reading will therefore be high with respect to the actual gas density. Massive corrosion may cause oscillation to stop due to corroded particles blocking the gap as mentioned above.

In order to prevent corrosion of the sensing element and its maintaining system, the constituents of the process gas should be compatible with Ni-Span-C 902. Other materials that come into contact with the gas flow are stainless steel 316 S13, stainless steel AMS5643K, Emmerson & Cummins Type Stycast 2850FT, Catalyst 11, Permendur Iron, and AISI316 stainless steel filters.

It is preferable that any traces of corrosive elements present in the process gas that are likely to attack these materials should be removed by an appropriate absorbent trap, or other method, before the sample gas passes through the *7812*. In general, it is important that the gas is sufficiently dry so that water droplets cannot form as these, in the presence of certain gases, will cause corrosion.

As a general guide, the properties of Ni-Span-C 902, with regard to corrosion resistance, lie between those of stainless iron and stainless steel. If there is doubt about the corrosion properties of a gas, advice should be sought and, if necessary, tests conducted.

CONDENSATION

Condensation of water or other liquid vapours on the sensing element will cause effects similar to deposition of solids except that the effects will disappear if re-evaporation takes place.

If the gas flow is wet or near dew point, condensation within the *7812* may occur and any condensation on the sensing element will cause the effects described above. As the vibrating cylinder is very thin, its thermal capacity is very low in comparison to the heavy body of the unit. It is very likely that the sensing element will take up the gas flow temperature very quickly and condensation is more likely to occur on the outer casing and other component parts.

For certain applications, it may be necessary to use a sample tube at the gas take off point to prevent condensate carry over or to include a condensate trap in the sample line.

VIBRATION

The *7812* can tolerate vibration up to 0.5g, but levels in excess of this may affect the accuracy of the readings. In situations where this is likely to be encountered, anti-vibration gaskets (part number *7812*3723A) should be used, as detailed in section 4.5.1. This will reduce the effects of vibration by at least a factor of 3, at levels up to 10g and 2200Hz.

3.9 Recommended installations for 78121/2/3/4 pocket unit

3.9.1 Pressure recovery method

The pressure recovery method is the most common installation method for orifice metering and is recommended in the 'Institute of Petroleum measurement manual, Part XV, Metering Systems'.

Figure 3-2 is recommended as a convenient method for obtaining an optimum flow rate, as well as providing a means for checking the condition of the *7812*'s filters and the calibration of the sensor. Density is measured at the downstream tapping of the orifice plate for which the relevant 'expansion factor' must be used.

It is recommended that the sample input pipework and the heat conduction coil are made from 6mm instrument tubing, and the sample return pipework (from the *7812*), from 12mm tubing. The heat conduction coil should be firmly clamped to the external surface of the meter run to ensure that the temperature of the gas being measured is as close as possible to that of the main gas flow. The whole arrangement should be enveloped in thermal cladding at least 100mm thick.

The installation in Figure 3-2 has the following features:

- No bypass of the orifice plate.
- Flow is achieved because the pressure after the orifice is lower than that further downstream.
- Pressure drops through the valves and filters do not affect the reading as the pressure at the outlet, and hence inside the *7812*, is identical to the orifice downstream point. Hence if the filters are not maintained, the flow will decrease but the density reading will not be in error.
- The correct expansion factor for the downstream point must be used in the orifice flow calculations.
- The measured density at the Density point is used in the mass flow calculation as specified by ISO 5167 and AGA3.

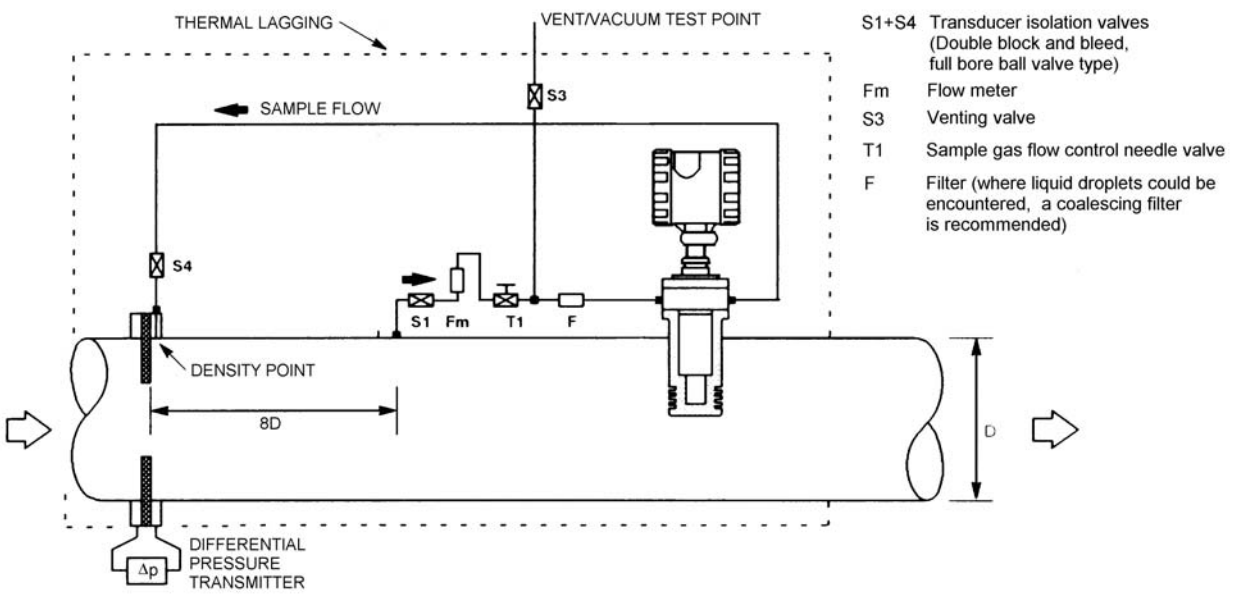


Figure 3-2: Pressure recovery method

3.9.2 Installation procedure

SETTING-UP

All the procedures described in this section should be carried out when the gas flow rate in the main pipeline is at the Nominal Design flow rate. If this condition cannot be conveniently obtained then the density percent offsets should be adjusted accordingly.

1. Close vent valve S3. Fully open flow control valve T1. Slowly and carefully, fully open valve S1 and then S4.

2. Allow at least 15 minutes for the purging and temperature stabilisation of the *7812*.

3. Close isolating valve S1. This will result in a change of indicated density. Immediately record the value of density thus obtained which should be the density at the 'density point'.

4. Re-open valve S1 and immediately adjust the flow control valve to give a density reading 0.02% above that observed in operation 3.

5. Close valve S1 again and check that the density decreases by 0.02%.

6. Return valve S1 to the fully open position.

Notes:

- The 0.02% value is considered the optimum value for most systems. However, if a quicker response is required, opening the flow control valve T1 would create a higher % value.
- Should the density increase by more than 0.02% with valve T1 at its minimum setting, then partially closing valve S1 should reduce the flow rate and the resultant density increase. However, this situation would suggest the flow control valve is too large for the application and ideally should be replaced by a more suitable type.
- All isolating valves should be of the FULL-BORE type to prevent unnecessary restriction.

FILTER CHECK

1. Record the present density reading without disturbing any valve setting.

2. Close isolating valve S1 and note the density reading.

(a) If the reading has decreased by more than 0.01% of that recorded in **1**, then it can be assumed that the *7812*'s filters are reasonably clean.

(b) If the reading has decreased by less than 0.01% of that recorded in operation 1, it is recommended that the *7812*'s filters are replaced or thoroughly cleaned and then the system optimised as detailed in Section 3.7.

3. After the filter check, return valve S1 to the fully open position.

RESPONSE TIME CHECK

1. Close valves S1 and S4 to isolate the *7812* and open valve S3 to vent it.

2. Pressurise the *7812* through valve S3 with a different gas to that within the pipeline and at a similar pressure to that of the pipeline. Close valve S3 and allow 15 minutes for temperature stabilisation.

3. Open valve S4 to expose the *7812* to pipeline pressure. Now open S1 to enable gas to flow through the *7812* at the set rate and measure the time taken for the *7812* to stabilise. This should be a good indication of the *7812*'s response to a change in gas composition.

GENERAL

An additional filter to the *7812* meter filter is normally fitted to ensure the gas is clean and dry. Typically a Balston 85 filter coalescer (accessory/spare part no. 450600770) or a Balston 95S-4 (accessory/spare part no. 450600810) is used, but any equivalent filter can be used.

Isolating valves should be included in the installation so that the *7812* meter can be isolated from the pipeline for filter replacement without the need to shut down the pipeline.

The gas inlet and outlet points should be designed so that they do not collect any liquid that might have condensed on the pipe wall.

3.9.3 Other methods

For most other methods, the density is required at the pressure conditions of the *7812* inlet. In these cases, any pressure drop through the filters and pipes will cause a small offset. These are minimised by putting the control valve downstream of the meter and controlling the flow to the recommended level.

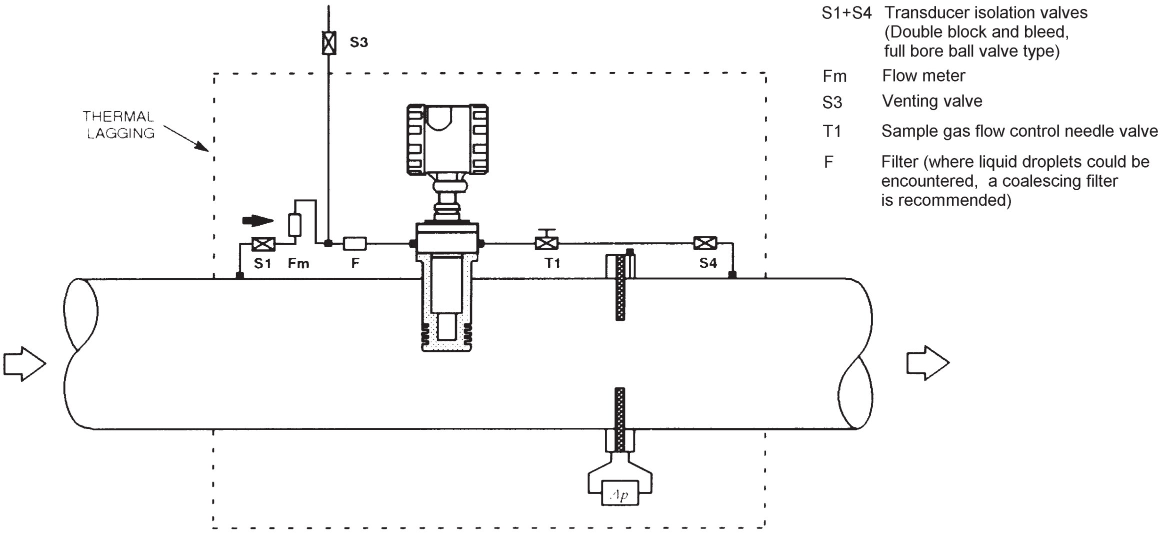


Figure 3-3: Differential Pressure Method

The installation shown in Figure 3-3 can be used with orifice metering or gas turbines. With gas turbines, it is common to have a tapping point on the turbine body in which case this would be used rather than the upstream tapping. The important features are:

- The sample flow bypasses the meter but should be low enough (5 l/hr) not to be of significance.
- The measured density is the upstream density that is the most commonly required point.
- Pressure drops through the filters will cause density errors if they become large.
- The control valve and the flow meter can be mounted on either side of the *7812* to suit the installation and dependent on where the density point is. For example if the upstream density point is required on an orifice application, the needle valve and flow meter would be downstream of the *7812* to reduce the pressure loss before the measurement.

If a convenient pressure drop is not available to generate the sample flow, the installation in Figure 3-4 can be used. The gas can be vented to flare or, in some cases to atmosphere. In this installation, the full pipe pressure is available as a pressure drop. Therefore, caution needs to be taken to ensure the flow is adequately controlled by the control valve. For high-pressure applications, a two-stage let down system may be required to prevent icing.

Other methods for generating the required DP (differential pressure) for the required flow can be used such as pitot tubes or natural bends or changes in section of the main pipework. For any of these other methods calculations need to be performed to check that the available DP will be sufficient to achieve an adequate sample flow rate.

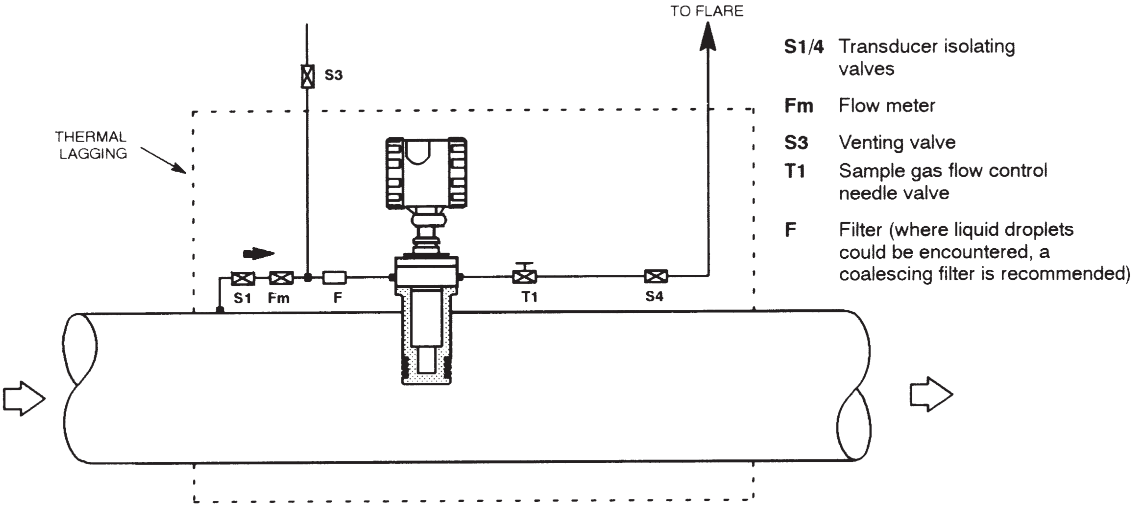


Figure 3-4: Vented gas method

3.10 RECOMMENDED INSTALLATION FOR 78125 CROSS PIPE UNITS

3.10.1 CROSS PIPE METHOD

Figure 3-5 below is recommended as a convenient way of measuring line density with minimal temperature and pressure effects. The sensing element is held in direct contact with pre-filtered on-line gas held in temperature equilibrium. Flow rates are governed by the flow path of the cross pipe and the filters held within it.

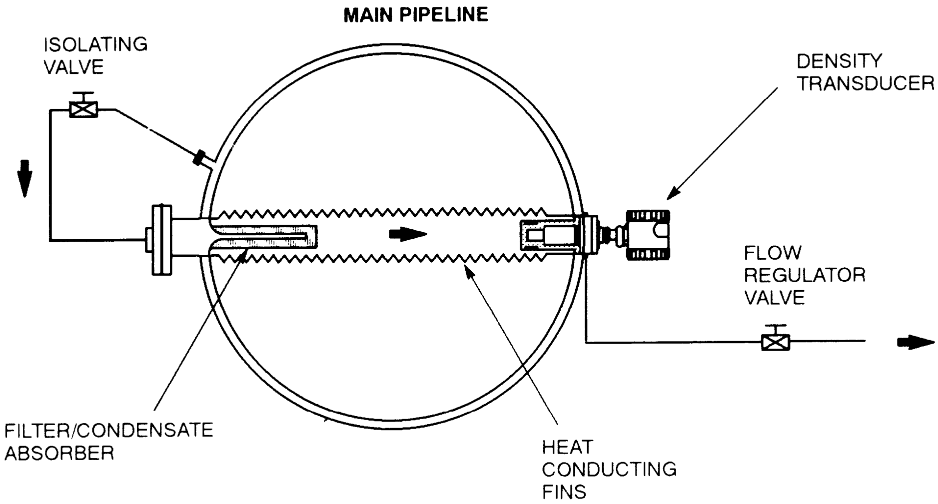


Figure Chapter 3-5: Cross pipe installation

3.10.2 INSTALLATION PROCEDURE

A small diameter pipe configuration is fitted across the interior of the main pipeline. It should be isolated from the main gas flow and be capable of accepting the threaded mounting base of the 78125 transducer. The pipe configuration should incorporate an isolating valve and a filtration system as shown in Figure 3-5. Minimal thermal lagging is required, mainly involving the sample gas pipeline, since the temperature of the gas surrounding the sensing element is being kept at main line gas temperature.

Chapter 4
Mechanical Installation

4.1 General

The 7812 is a sample by-pass meter which can be inserted into the main gas stream. This ensures good thermal equalisation yet allows the gas to be adequately filtered for reliable measurement. Gas density meters are normally used as part of a mass metering exercise and in consequence the location of the density meter, with regards to the flow measuring element, is most important.

4.2 Physical dimensions

The physical dimensions of the 78121/2/3/4 meter variants are shown in Figure 4-1. This unit has been designed to be a direct replacement for the 7810 and 7811 gas density meters. The 78125* meter is a direct replacement for the 3093 gas density meter and its physical dimensions are shown in Figure 4-2.

Note: For additional information regarding the physical dimensions of the meter, contact Micro Motion.

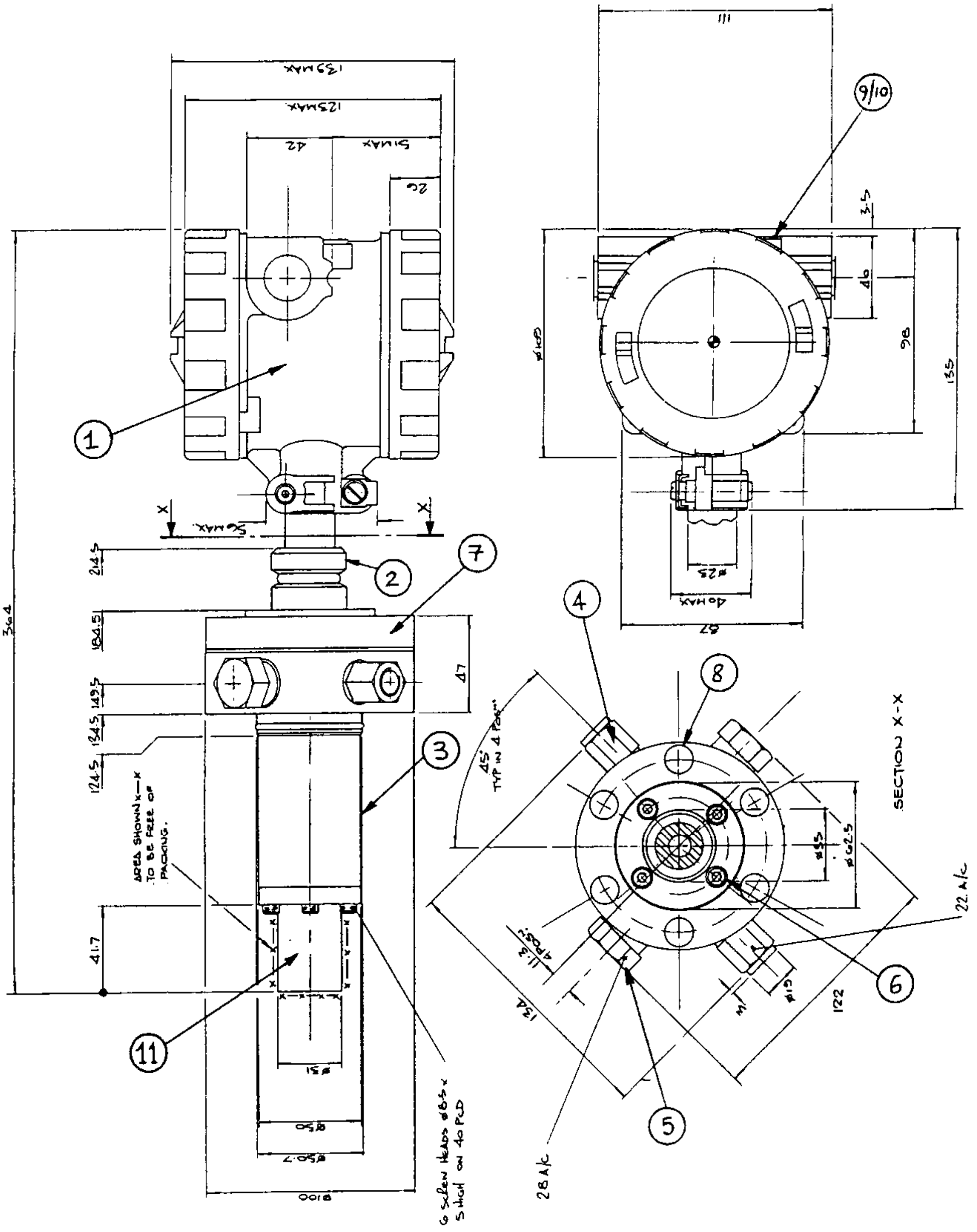


Figure 4-1: Physical dimensions of *7812*1/2/3/4 meters

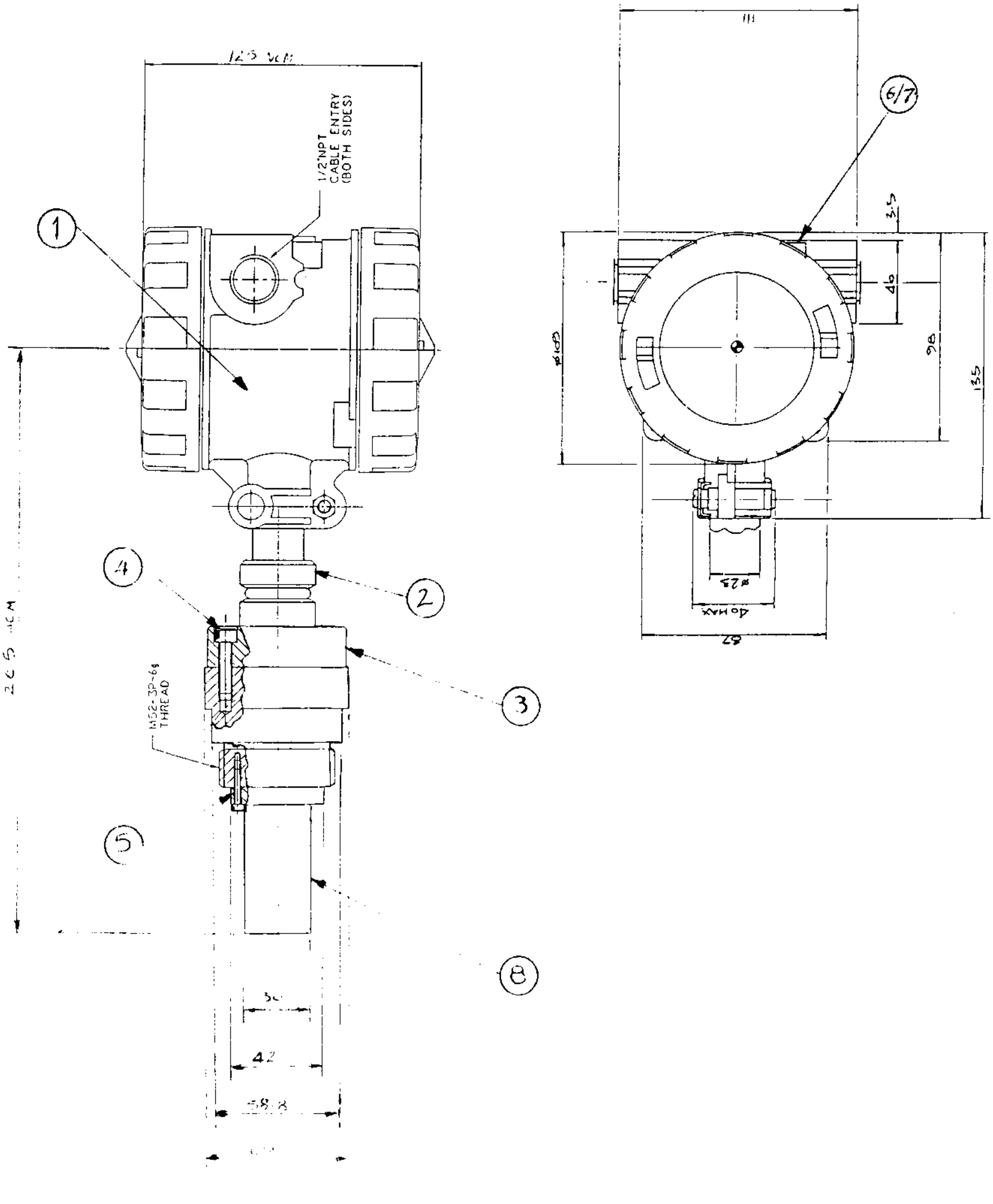


Figure 4-2: 78125 transducer - physical dimensions

4.3 Liners

The liners incorporate a replacement inconel spring which takes up tolerances of the specific cylinder assembly fitted. This enhances the long-term stability of the sensing element.

Note: The instrument is unaffected by the normal strip down and re-assembly operation. However, should a spool body or cylinder require replacing, then a new liner spring is recommended and a **recalibration** is imperative.

4.4 Filtration

For *7812*1/2/3/4 meters, two identical filter housings are provided adjacent to their respective gas connection ports. The ports are identified by a label and should always be correctly connected. The in-line filters used are a 2 micron (inlet) and 90 micron (outlet), the outlet filter affording some protection should a reverse gas flow occur.

This filter arrangement is optimised for best protection of the sensing element and is best suited for density measurement at the sample gas return point.

4.5 Pocket installation

An aperture is required in the pipeline to receive the pocket, which is inserted to the correct depth and welded into position without distortion. Ideally, the pocket should be installed on a vertical diameter at the top of the pipeline. Figure 4-3 shows the pocket installation drawing; a detailed drawing of the pocket dimensions is shown in Figure 4-4.

If high levels of vibration are likely encountered, fit two *7812*3723A anti-vibration gaskets as detailed in Section 4.5.1.

To enhance the temperature equalisation:

(a) Pour the supplied silicone fluid (20cc) into the pocket.

(b) Slip the aluminium cylinder over the lower end of the *7812*'s main housing.

The **main housing** can now be installed:

1. Fit one gasket to the pocket and insert the main housing complete with its 2" OID 'O' ring into the pocket.
2. Clamp the main housing securely in position by the clamp ring and its securing screws.
3. Connect the sample lines to their respective gas inlet and outlet ports, ensuring a relaxed pipeline run with the correct *7812* orientation.
4. Complete the electrical connections as detailed in Chapter 5.

A typical type of installation is shown in Figure 4-4. The advantages of this type of installation are as follows:

- Good temperature equalisation.
- Suitable for high pressure installations.
- Best anti-vibration arrangement.
- *7812* can be changed without pipeline closure.

The sophistication of the system employed rests with the customer but should include isolating valves in the sample by-pass line and preferably a flow control valve and a means of checking the sensor calibration in situ.

4.5.1 Anti-vibration installation

In cases where vibration levels are above the recommended maximum of 0.5g, two optional anti-vibration gaskets (accessory/spare part no. *7812*3723A) can be fitted to improve the vibration performance of the *7812*. These anti-vibration gaskets are manufactured from 0.2” (5mm) thick Neoprene and are fitted to either side of the main body of the *7812* to isolate it from any pipeline vibration. This installation has been evaluated at levels up to 10g maximum and 2200 Hz and shown to reduce the effects of vibration by at least a factor of 3 over the standard installation.

It should be noted that fitting these gaskets will raise the *7812* main body by approximately 0.4” (9mm) which will need to be taken into account when re-fitting the gas pipe connections.

The gaskets are fitted as follows (see Figure 4-2 for details):

1. Pour the supplied silicone fluid (20cc) into the pocket. Slip the aluminium cylinder over the lower end of the *7812*’s main housing.

2. Place one 5mm gasket between the pocket and the main body of the *7812*, and insert the main housing complete with its 2” *o/d* ‘O’ ring into the pocket, checking that the gasket is centrally positioned over the bolt holes.

3. Position the second gasket between the *7812* body and the clamping ring, again placing it centrally, such that the clamping ring does not touch the spigot and the bolts are located centrally in the *7812* main body holes.

4. Screw in six M8 x 65mm bolts (accessory/spare part no. 409601420) ensuring that the assembly stays concentric, that the bolts are clear from the main body and that the clamping ring is not touching the central spigot. It is important that there is no metal to metal contact between the *7812* and the clamping ring and bolts that hold it in position. This is how vibration isolation is achieved.

   (In most cases the bolts should be lightly greased to ensure they can be removed in the future, although if there is concern about the bolts coming loose and creating any sort of hazard, then Loctite Screw Lock should be used. An alternative to this is placing grease on the threads and a sealant around the bolt heads to prevent any risk of vibration loosing.)

5. Tighten the M8 bolts to a torque of 15 ± 5 lb/in (1.7 ± 0.6 Nm). This is equivalent to lightly finger tight with a 3” (80mm) long Allen key.

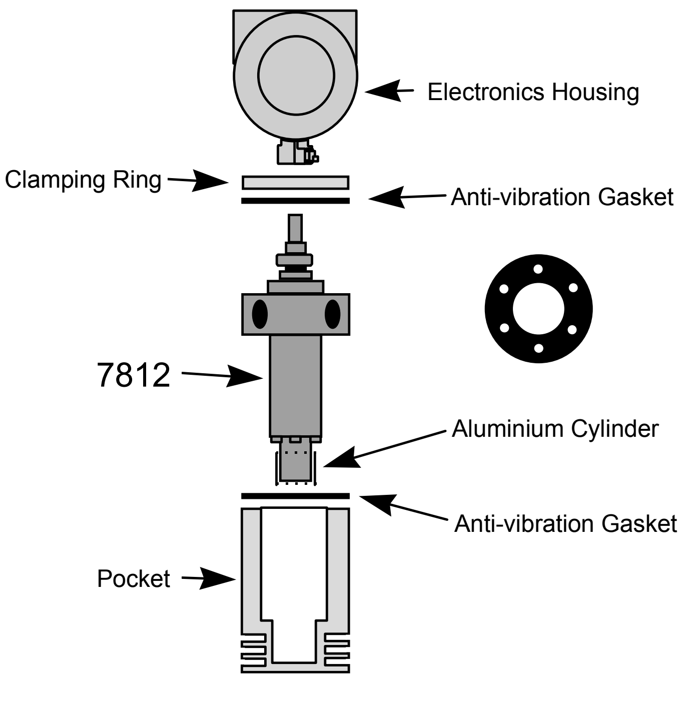


Figure 4-3: Exploded view of *7812* anti vibration installation

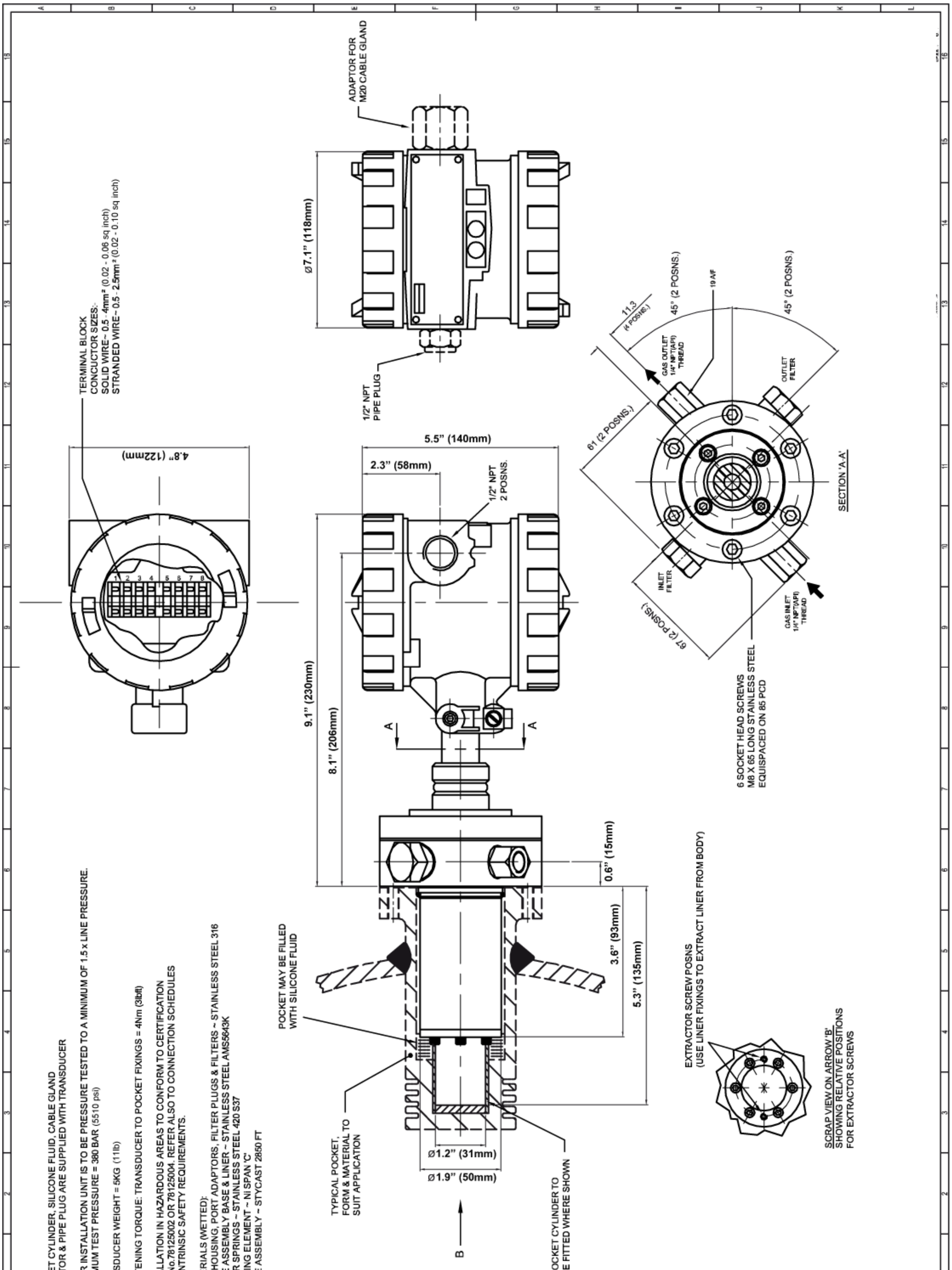


Figure 4-4: *7812* pocket installation drawing

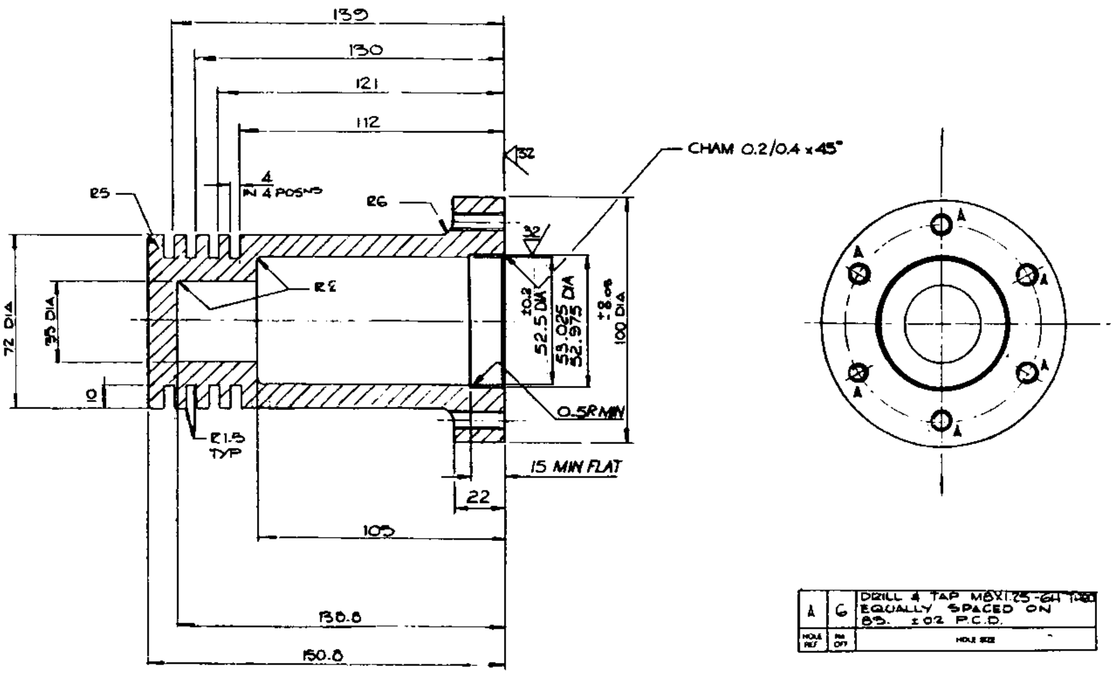


Figure 4-5: Pocket drawing

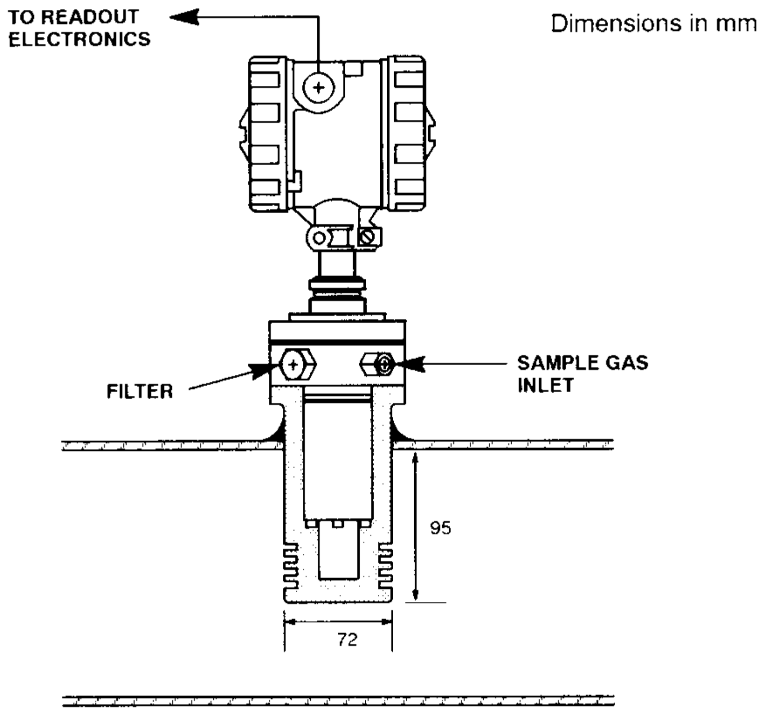


Figure 4-6: Typical pocket installation

4.6 External pocket installation

In this arrangement, the sensing element of the *7812* is enclosed in a robust housing. The housing can be either bonded directly on to the pipeline, using Thermon Heat Transfer Cement or equivalent. Figure 4-6 depicts this arrangement.

It is essential that temperature equalisation is maintained between the pipeline gas and the sample gas at the *7812*. In order to achieve this, the sample gas pipework must be kept to a minimum and, in conjunction with the *7812* and the external pocket housing, must be adequately lagged for thermal insulation.

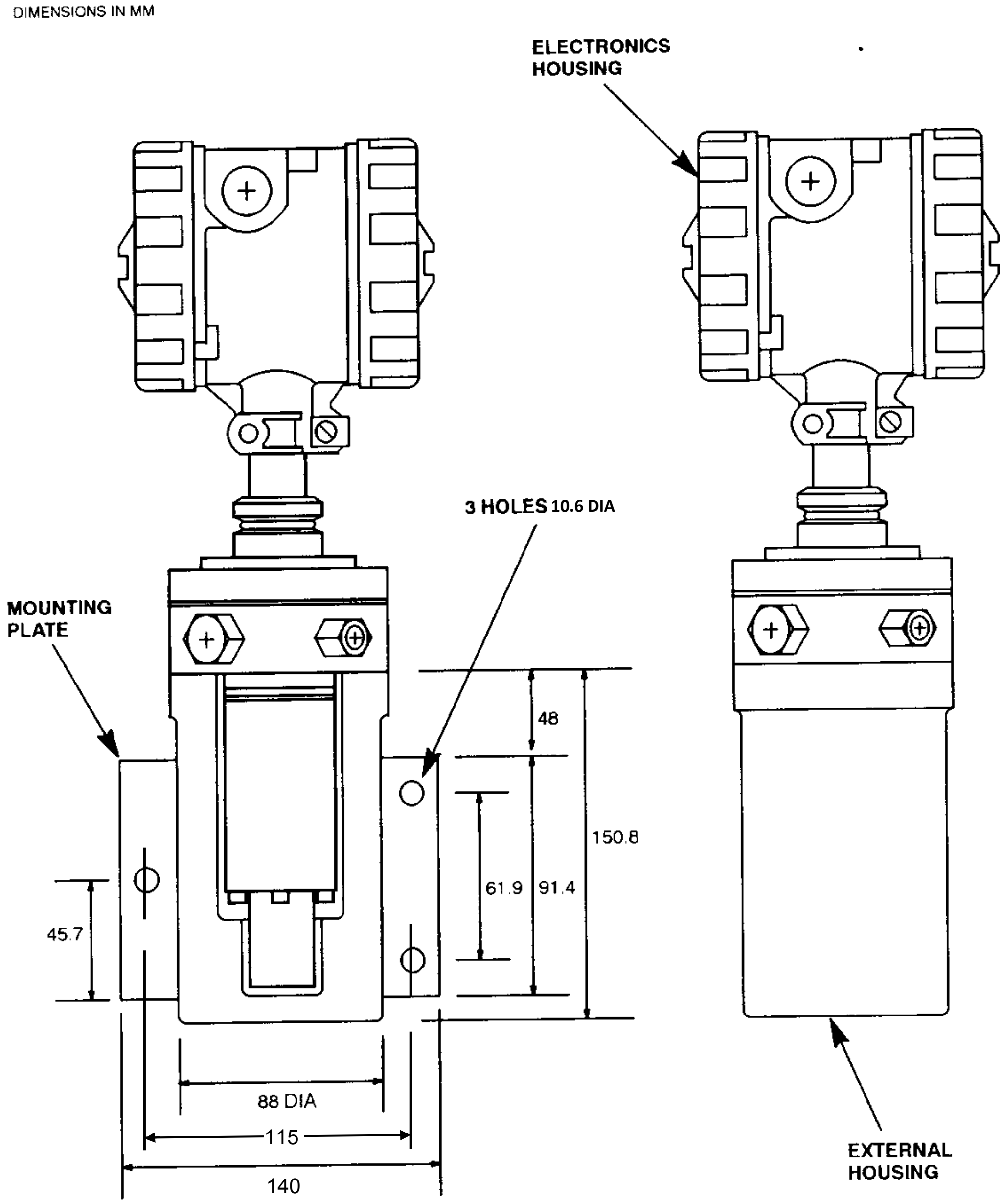
For installation of the *7812*, it has been assumed that the housing has been assembled to its pipeline and that the sample pipelines are ready for connection.

See Section 4.5 for installation instructions.

4.7 Post-installation mechanical checks

After installation, the *7812* should be pressure tested, with **gas only,** to 1½ times the maximum working pressure of the system.

CAUTION: The 7812 pressure test figure should NOT be exceeded to avoid possible changes to the calibration characteristics. Check around all joints for signs of leakage of gas.



Note: If required, a suitable spacer may be fitted in order to prevent the electronics housing from fouling during wall mounting.

Figure 4-7: External pocket installation

Chapter 5
Electrical Installation

5.1 General

The electrical connections to the *7812* gas density meter are governed by the environment within which the *7812* is mounted. When installed in hazardous areas, connections between the *7812* and the power supply/readout equipment must be completed through ZENER SAFETY BARRIERS or GALVANIC ISOLATORS.

The electrical cable enters the amplifier housing through a cable gland assembly. The terminal layout of the *7812* is shown in Figure 5-1.

The amplifier housing has two chambers; the one which is nearest to the cable gland axis contains the terminals for connecting the *7812* to signal processing instrument. The other chamber contains the amplifier unit, its PCB encapsulated in a circular plastic container. The complete module is secured in place by one keyway and one centrally positioned clamping screw. Behind the maintaining amplifier there is an interconnect terminal board which links the sensor to the maintaining amplifier, the maintaining amplifier to the user connect board and the RTD to the user-connect board.

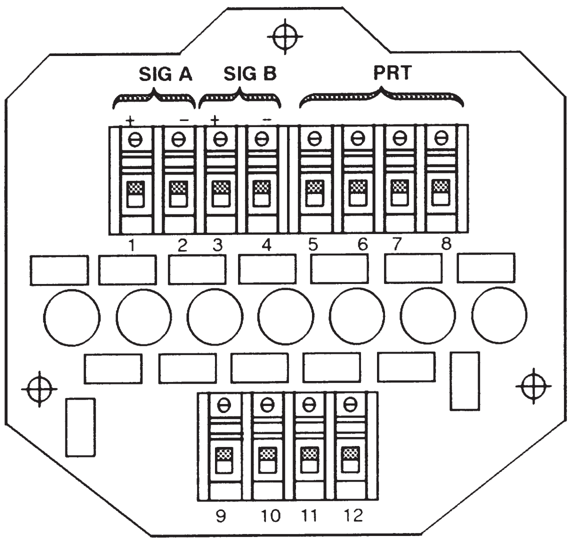


Figure 5-1: 7812 main terminal board connections

5.2 EMC cabling and earthing

To meet the EC Directive for EMC (Electromagnetic Compatibility), it is recommended that the meter be connected using a suitable instrumentation cable and earthed through the meter body and pipework.

The instrumentation cable should have individual screen(s), foil or braid over each twisted pair and an overall screen to cover all cores. Where permissible, the overall screen should be connected to earth at *both ends* (360° bonded at both ends). The inner individual screen(s) should be connected at *only one end*, the controller (e.g. Signal Converter) end.

Note that for intrinsic safety, termination of the inner individual screen(s) to earth in the hazardous area is NOT generally permitted.

Use suitable cables that meet BS5308 multi-pair Instrumentation Types 1 or 2.

5.3 Use with Signal Converters and Flow Computers

The *7812* can be operated in two general environments, either in SAFE AREAS or in HAZARDOUS AREAS. **When used in hazardous areas, safety barriers or galvanic isolators MUST be interposed between the *7812* and signal processing equipment**.

5.4 System connections (7950/7951)

The following pages contain wiring diagrams for connecting the *7812* to the 795x Series of Signal Converters.

For each of the following products, diagrams are given for 2-wire and 3-wire connections for both safe and hazardous areas:

- 7950 Signal Converter.
- 7951 Signal Converter.

When the *7812* is installed in a hazardous area, refer to the safety instruction booklet shipped with the unit for ATEX installations and general safety matters. For CSA-approval installation drawings, refer to the system drawings in Appendix H.

Section 5.5 contains a similar set of diagrams for wiring to other manufacturer equipment.

5.4.1 Connections to 7950 Signal Converter

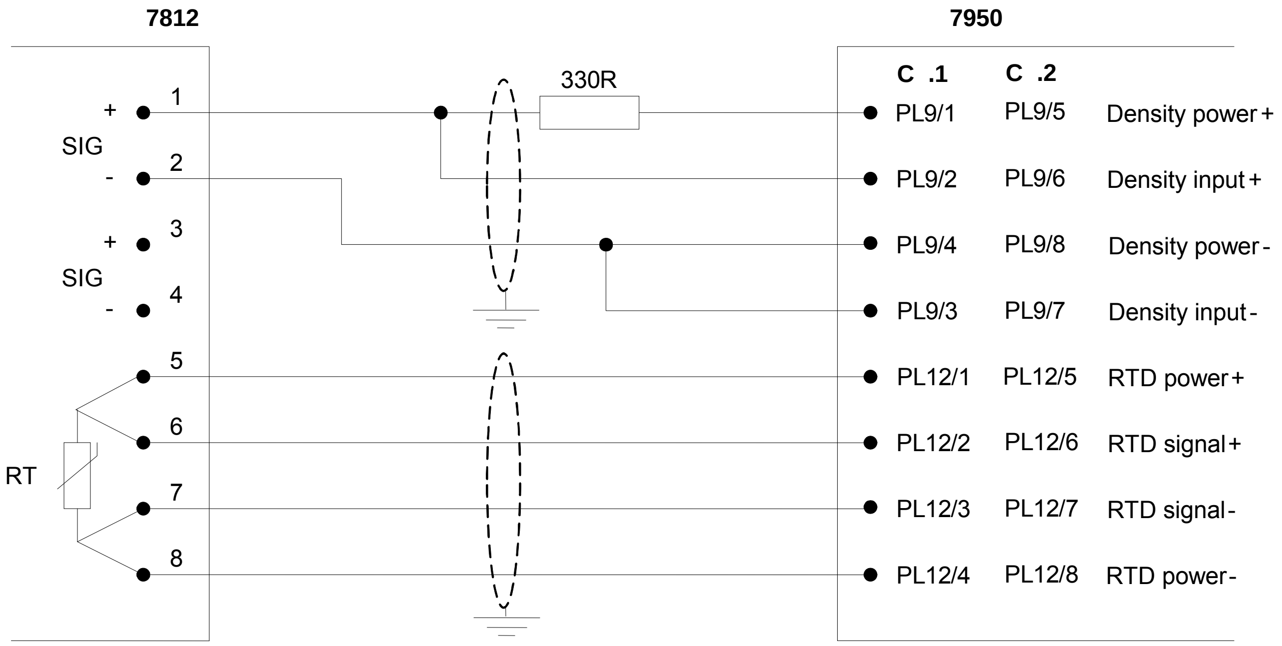
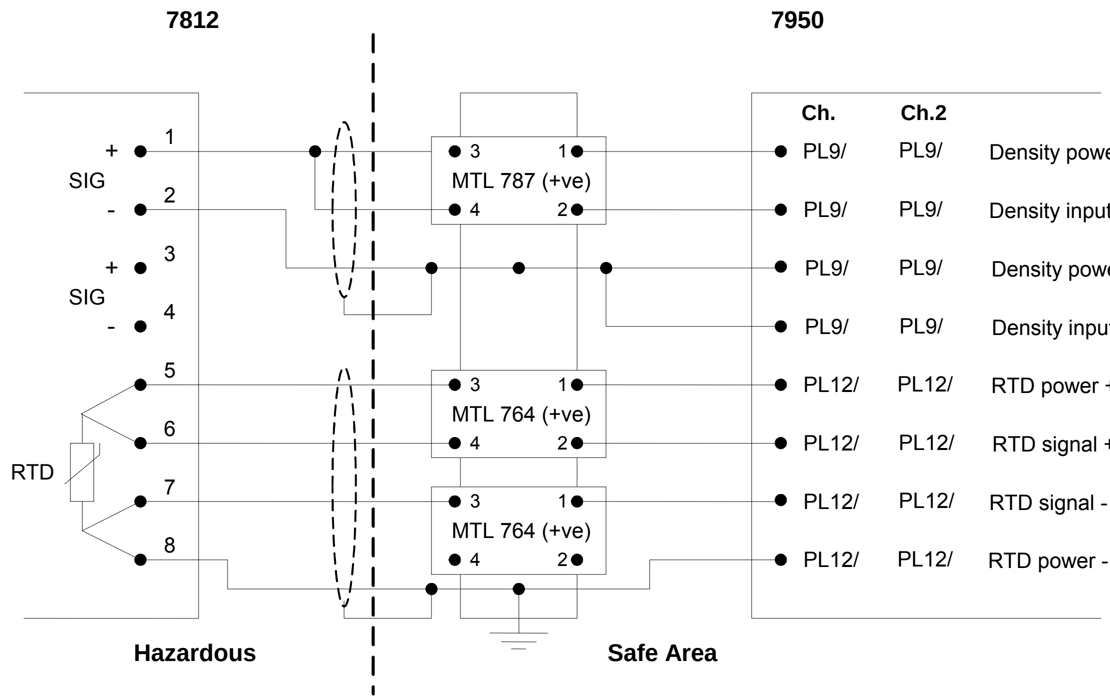
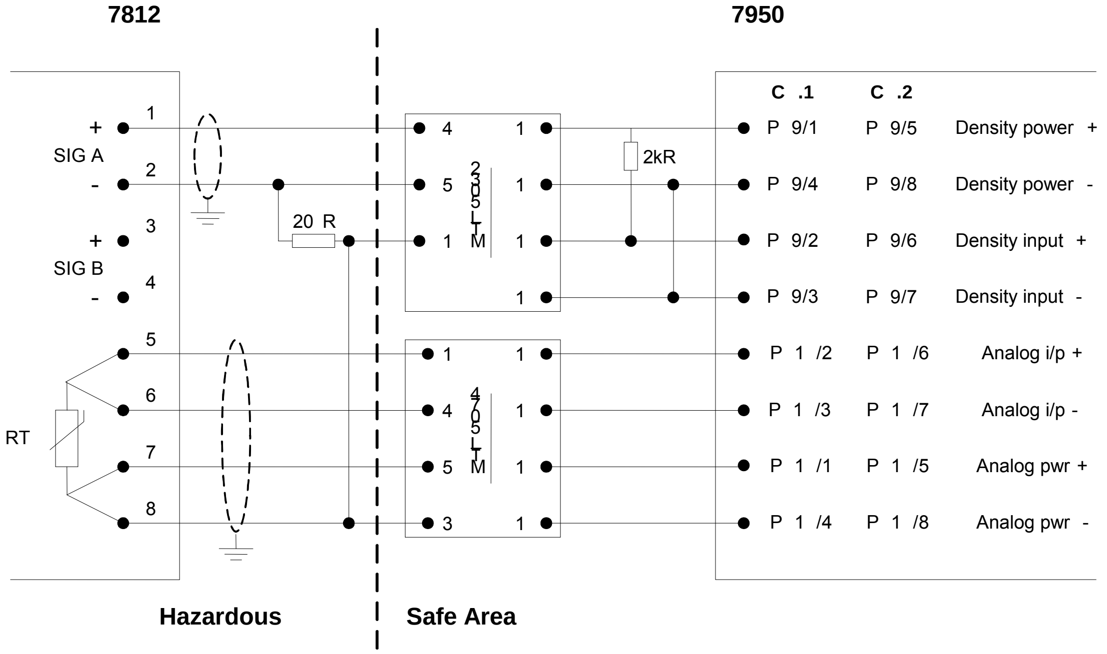


Figure 5-2: 7950 2-wire connection to 7812 (non-hazardous areas)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-3: 7950 2-wire connection to 7812 using Shunt-Diode Safety Barriers (Hazardous areas)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-4: 7950 2-wire connection to 7812 using Galvanic Isolators (Hazardous areas)

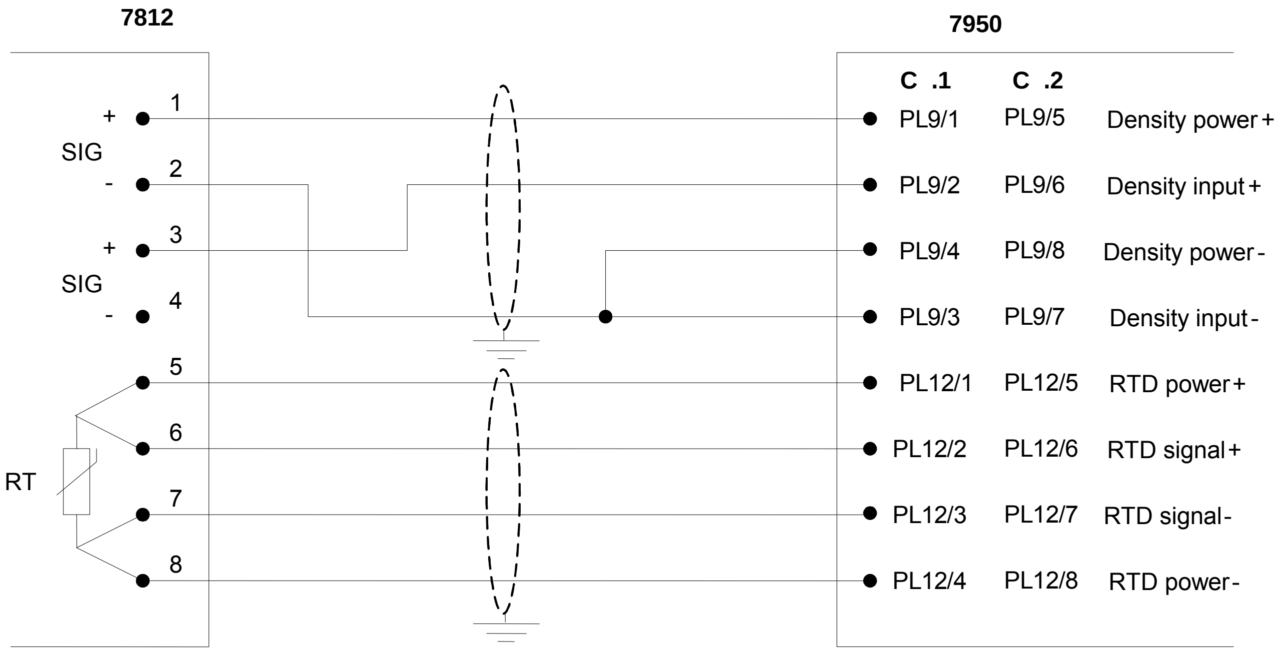
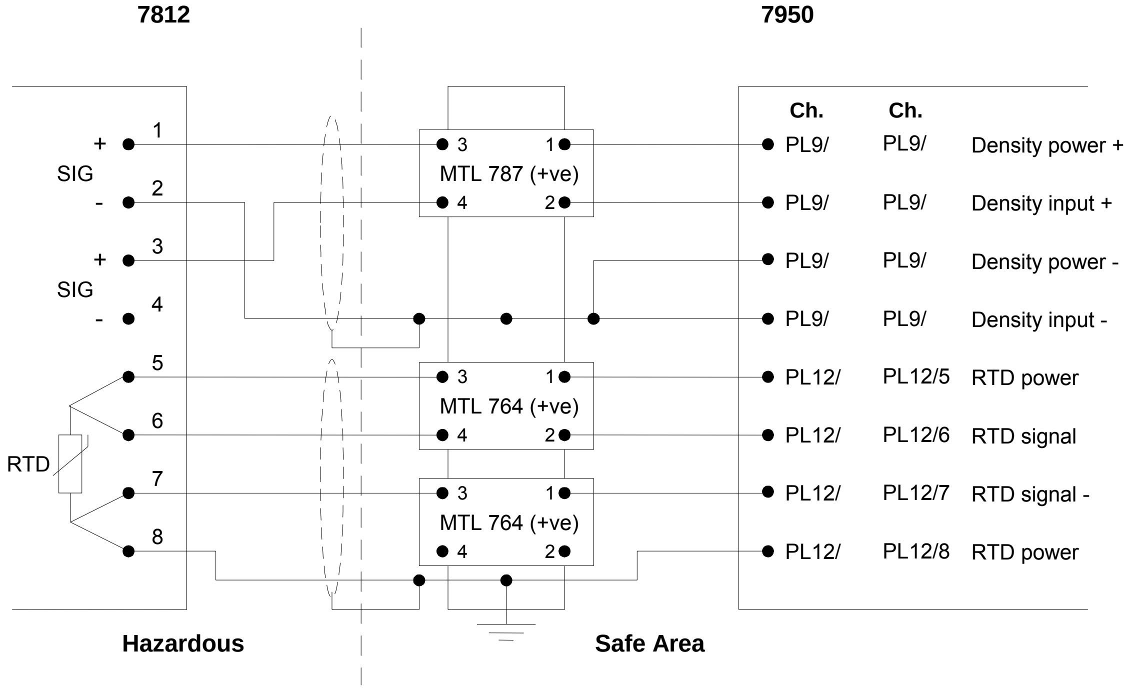
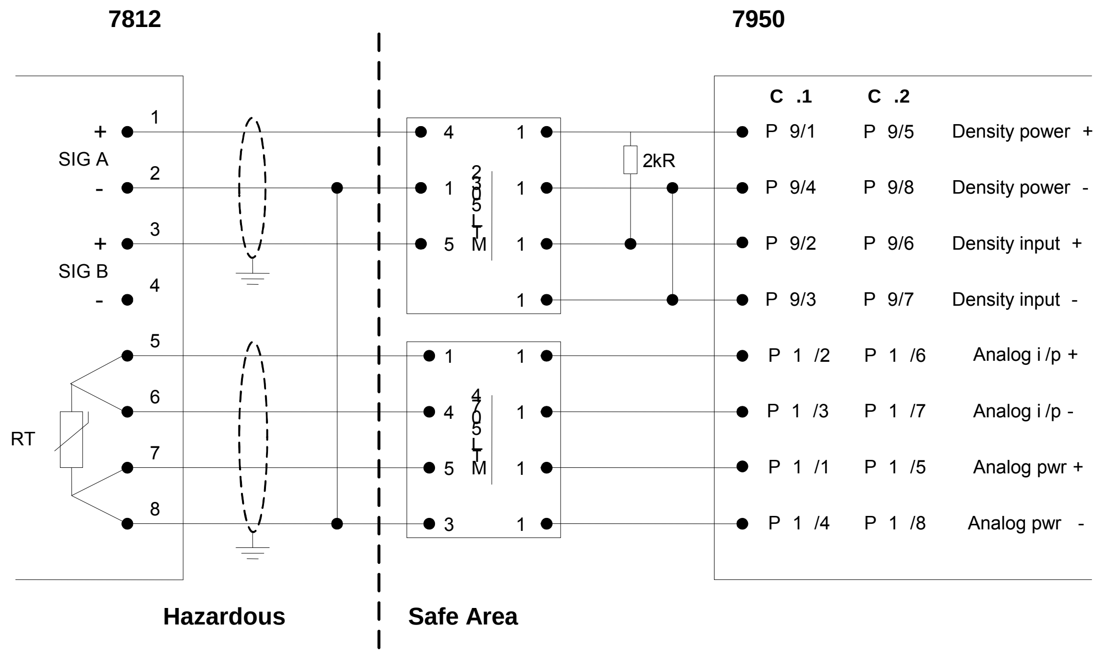


Figure 5-5: 7950 3-wire connection to 7812 (Safe areas)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-6: 7950 3-wire connection to 7812 using Shunt-Diode Safety Barriers (Hazardous areas)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-7: 7950 3-wire connection to 7812 using Galvanic Isolators (Hazardous areas)

5.4.2 Connections to 7951 Signal Converter/Flow computer

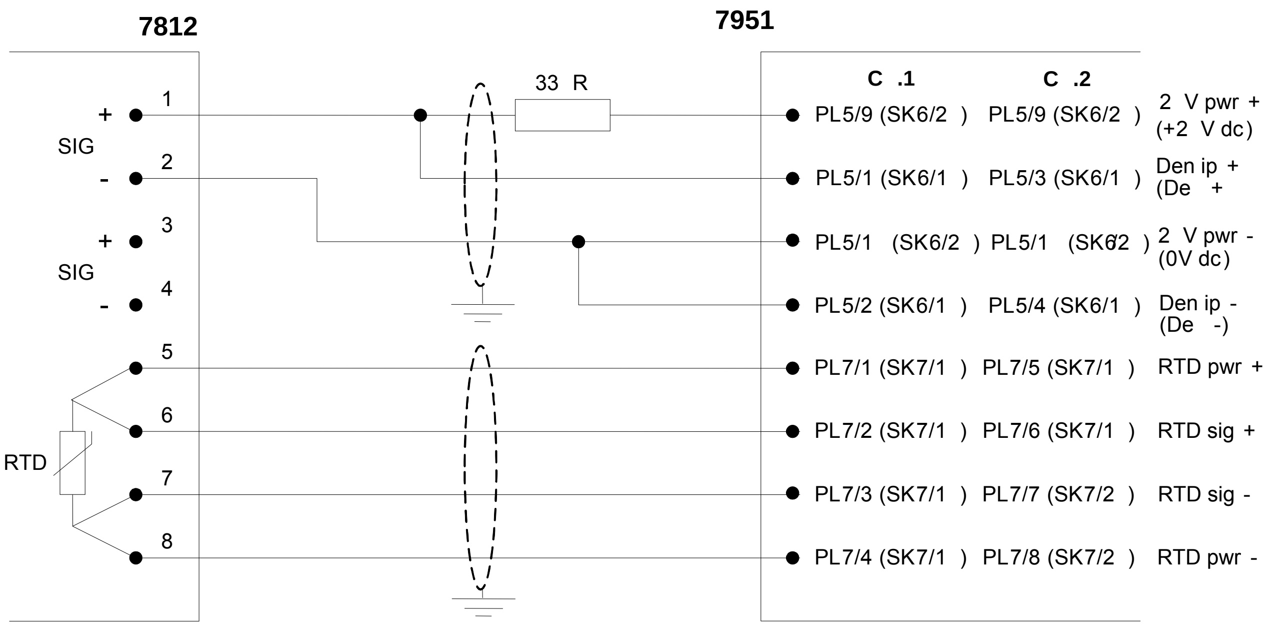
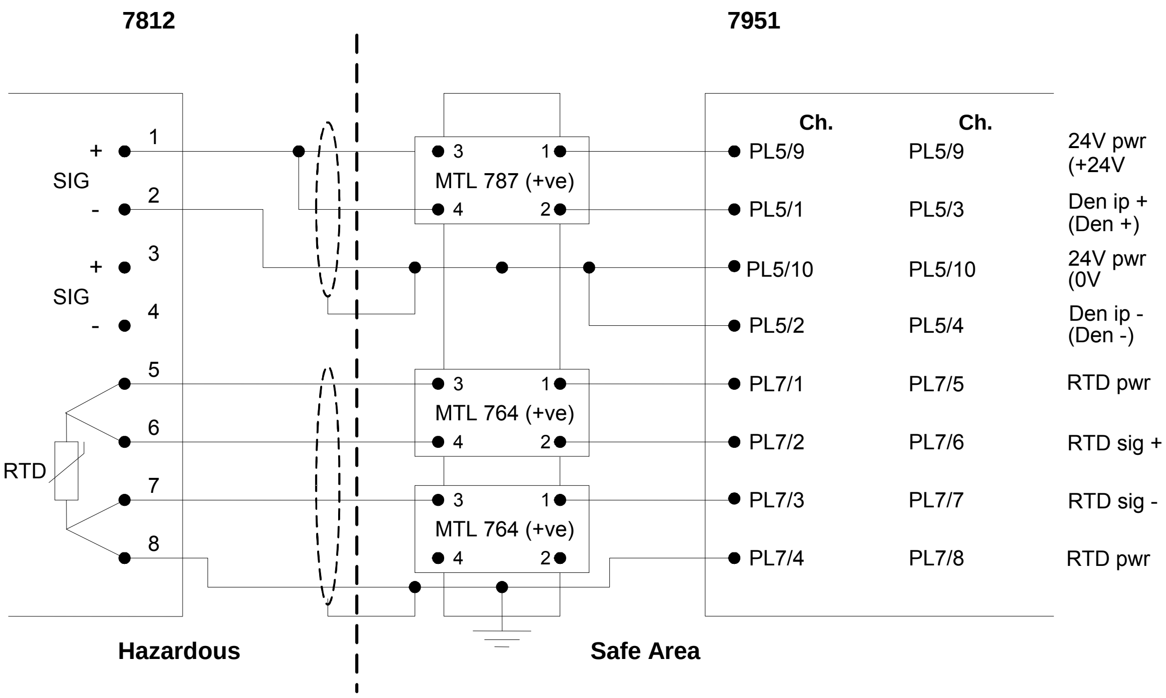


Figure 5-8: 7951 2-wire connection to 7812 (Safe areas)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-9: 7951 2-wire connection to 7812 (Hazardous areas)

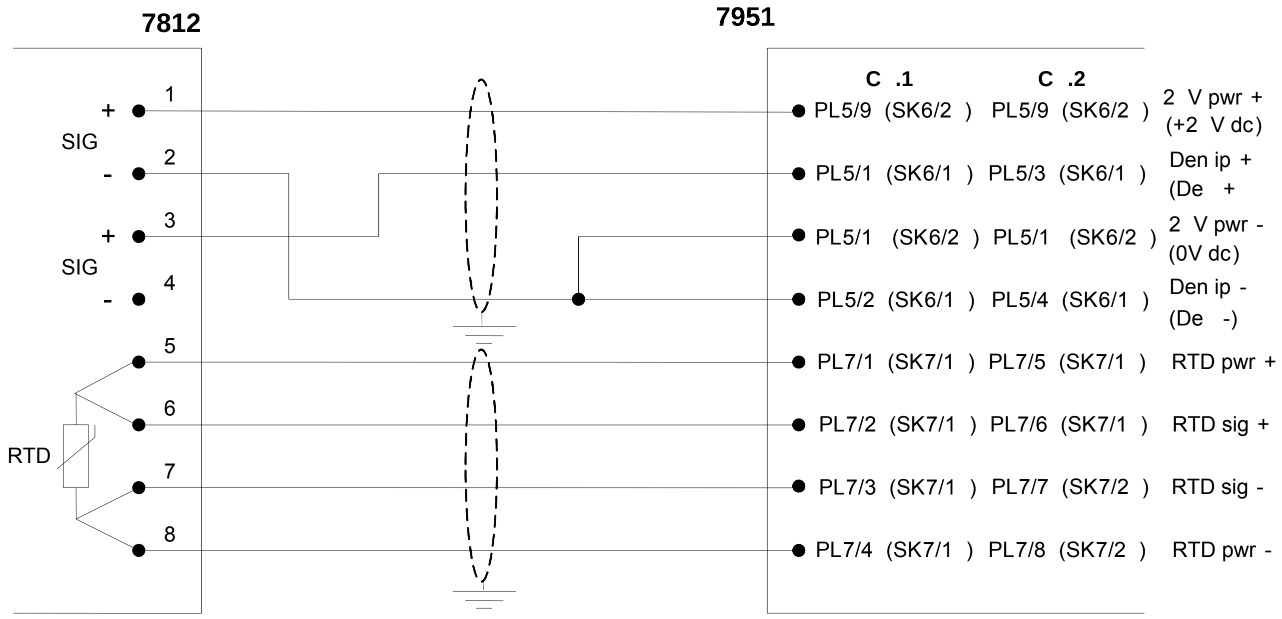
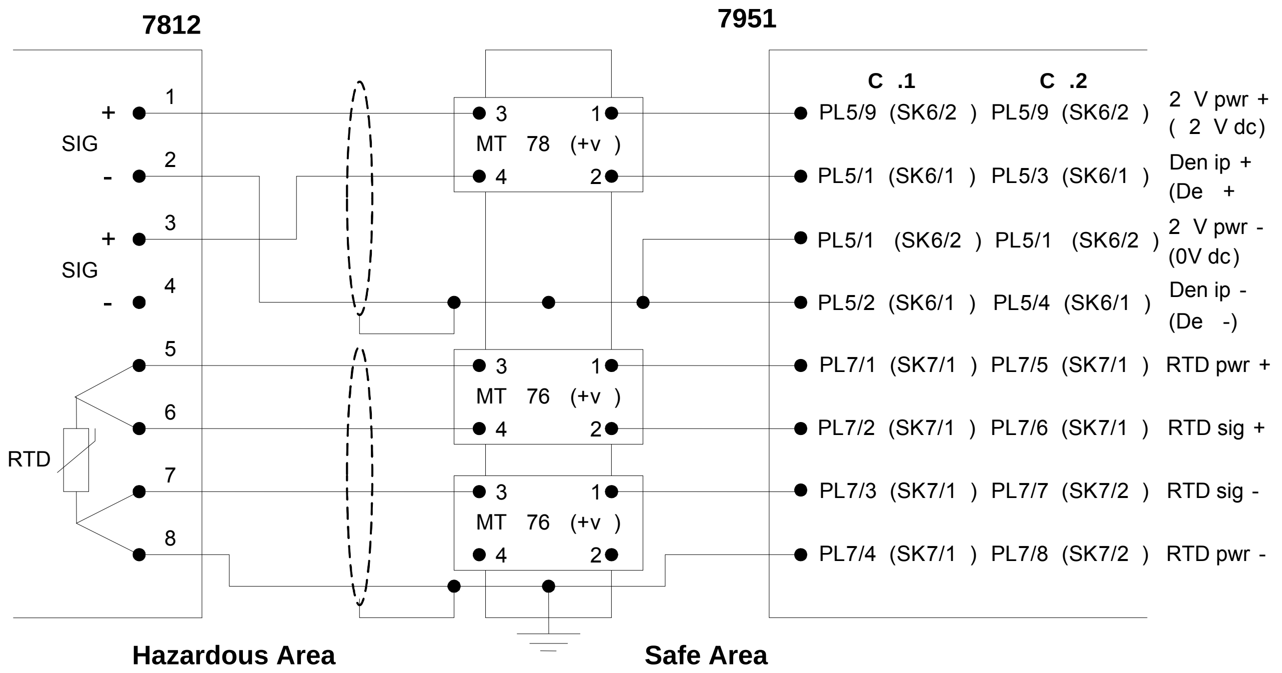


Figure 5-10: 7951 3-wire connection to 7812 (Safe areas)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-11: 7951 3-wire connection to 7812 (Hazardous areas)

5.5 System connections (CUSTOMER'S OWN EQUIPMENT)

5.5.1 Non-hazardous areas

Power supply to Density Meter: 15.5V to 33V dc, 25mA min.
Power supply to RTD: 5mA max.

The frequency at which the *7812* is operating can be detected in one of two ways:

(a) For the 2-wire option, a 330Ω series resistor should be used in the +ve power line. The electrical connections to be made are shown in Figure 5-12. The signal across the 330Ω resistor is greater than 2V peak to peak. The minimum impedance of the signal measuring equipment should be 500kΩ. Where necessary, the 1nF capacitors will block the power supply dc voltage to the measuring equipment.

(b) For the 3-wire option, the frequency can be measured directly. The electrical connections to be made are shown in Figure 5-14.

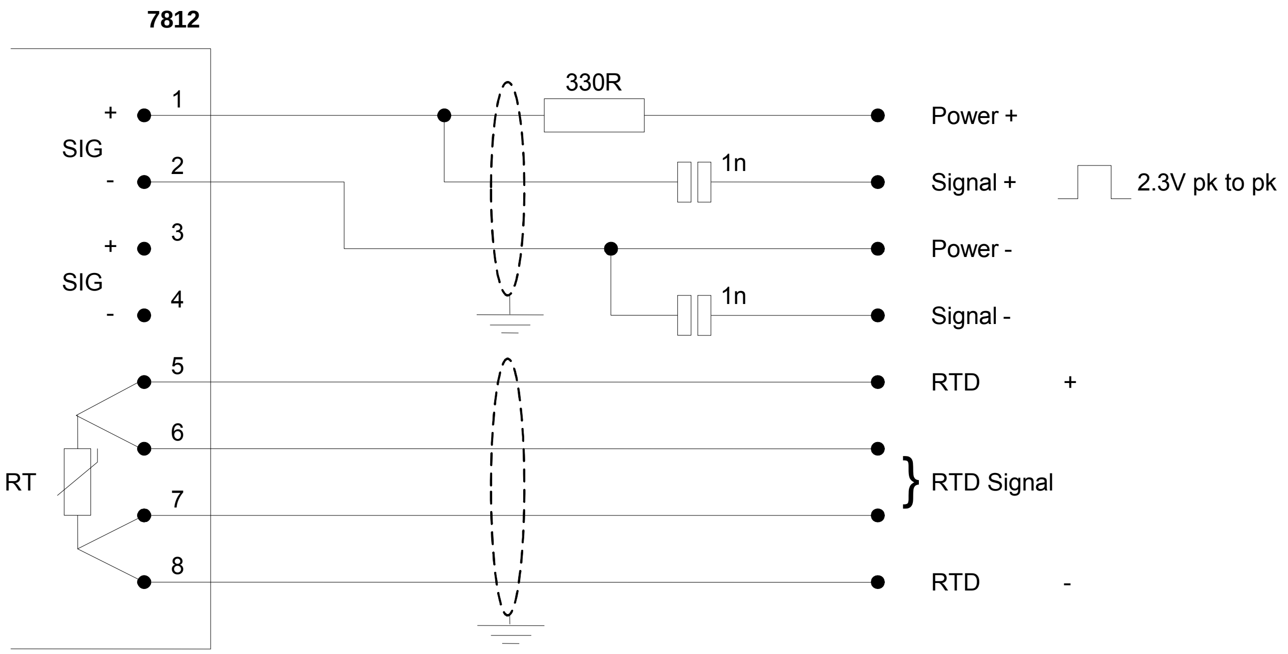
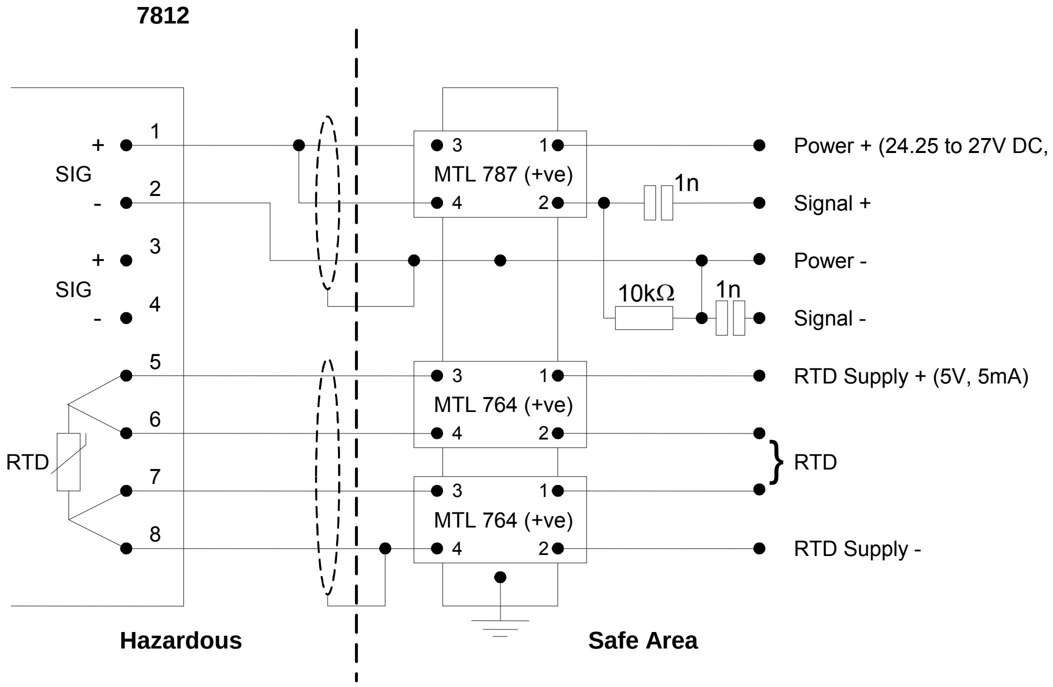


Figure 5-12: 2-wire connections for 7812 (Safe area)

5.5.2 Hazardous areas

The following wiring diagrams are provided to assist with using the *7812* in safe areas and hazardous areas. **When the 7812 is installed in a hazardous area, refer to the safety instruction booklet shipped with the unit for ATEX installations and general safety matters. For CSA installation drawings, refer to the system drawings in Appendix H.**



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-13: 2-wire connections for 7812 (Hazardous area)

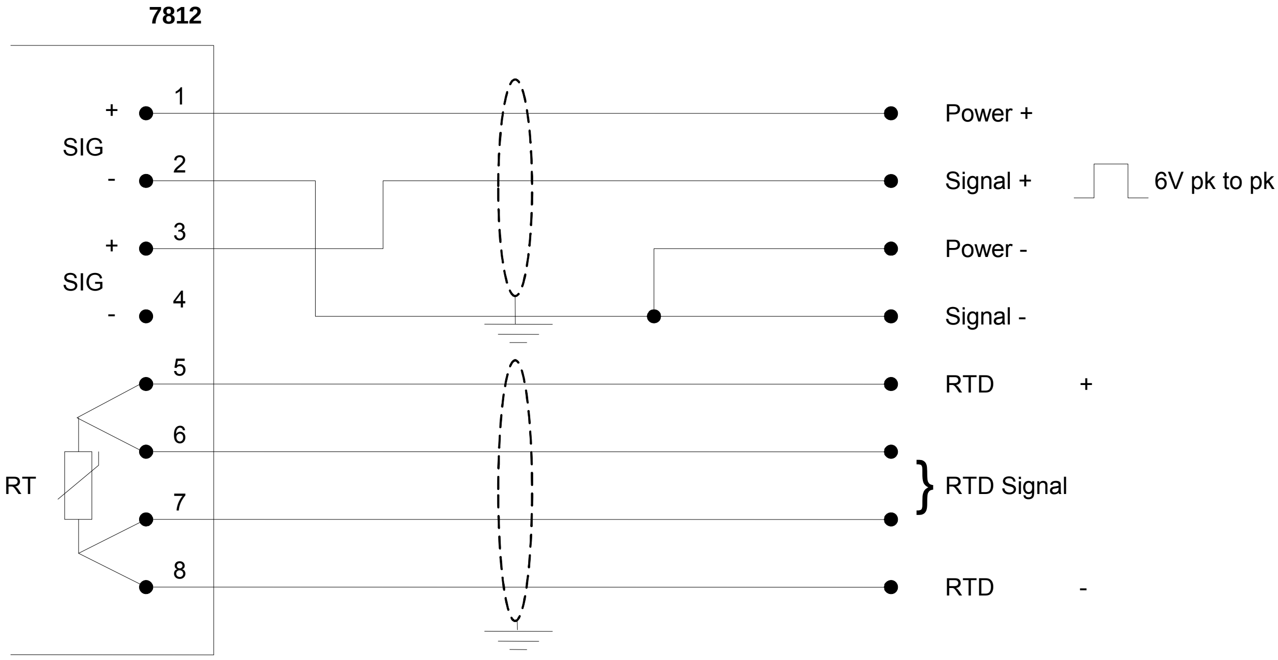
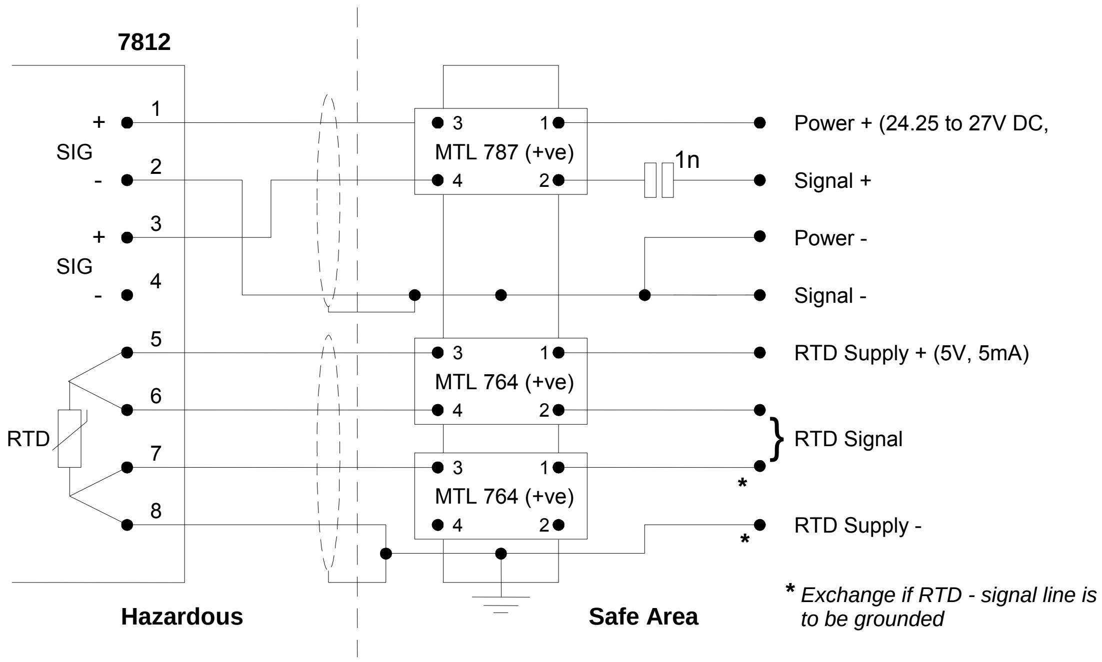


Figure 5-14: 3-wire connections for 7812 (Safe area)



Note: When the ATEX-approved *7812* is installed in a hazardous area, the safety instruction booklet shipped with the unit is the authoritative document.

Figure 5-15: 3-wire connections for 7812 (Hazardous area)

5.6 Post-installation checks

After installation, the following procedure will indicate to a high degree of confidence that the *7812* is operating correctly.

(a) Electrical Check

Measure the current consumption and the supply voltage at the 7812 amplifier. This should be within the following limits:

15.5V to 33V dc	(Safe Areas)
15.5V to 21.5V dc	(Hazardous Areas)
17mA ±1 mA	(Safe and Hazardous Areas).

(b) Stability Check

Check the stability of the frequency output signal using a period meter on a 1000 cycle count. The measurement scatter should be within 2ns. If this value is exceeded, it is likely that dirt is present on the sensing element. This test may be performed at any gas density, provided that it is stable and unchanging.

It should be noted that it is not practical to attempt this test in high vibration or noisy environments.

(c) Discontinuity Check

If the output signal is being fed through a signal converter to a chart recorder, it is normally good practice to slowly increase the gas pressure in the *7812* to its maximum value and then slowly vent it to atmospheric conditions. This test ensures that any discontinuities of performance throughout the whole range will be identified as a step or spike on the otherwise smooth plot at a specific density value on both the increasing and decreasing gas pressure. Any such discontinuity can be further investigated to resolve whether the *7812* or recorder is at fault.

Chapter 6
Interpretation of Calibration Certificate

6.1 Calibration certificate

The 7812 Gas Density Meters are calibrated at the factory and are supplied with their own test and calibration certificates (see Appendix B). This certificate specifies the various calibration constants, which allow the user to convert the output periodic time signal from the *7812* into a density value.

6.2 Instrument serial numbers

Two serial numbers are listed on each calibration certificate; the sensor number and vibrating cylinder number. If the cylinder is replaced a new certificate must be issued since the calibration data is unique to each cylinder. If the cylinder is simply removed for cleaning and then replaced, the calibration should remain unchanged, but after re-assembly a calibration check should be made to ensure that the assembly is correct and that there has been no damage.

6.3 Pressure test

The pressure to which the *7812* has been tested is specified on each certificate.

6.4 General density equation

The basic meter constants, KO, K1 and K2, are computed from the factory calibration by recording the periodic time of the output signal at specified density values. Using these constants and the general density equation, the density of the gas within the meter can be calculated.

Density $D = K0 + K1\tau + K2\tau^2$ ……………………………(1)

Where: D = Uncorrected density (kg/m^3)

τ = Periodic time (μs)

K0, K1, K2 = Constants from Calibration Certificate

It is stated on the calibration certificate that the basic constants are determined from a calibration at a temperature of 20°C and on a known gas (Argon or Nitrogen). If the operating conditions of the *7812* differ from that of the calibration conditions, a correction to the density calculated using the general equation is required.

> **NOTE:** For optimum density measurements, signal converters/ flow computers must resolve the time period signal to within ±1ns. To achieve this with the 7950/7951/7955, configure the Target Cycle Time on them to be 10 seconds.

6.5 Temperature corrections

If the *7812* operates at temperatures other than 20°C, a correction to the density calculated using equation (1) should be made for best accuracy. The equation for temperature correction uses coefficient data given on the calibration certificate and is as follows:

$Dt = D[1 + K18(t - 20)] + K19(t - 20)$ ……………(2)

Where: Dt = Temperature corrected density (kg/m^3)

D = Calculated density using Equation (1)

t = Temperature (°C)

K18, K19 are constants from Calibration Certificate.

6.6 User gas offset data

The *7812* is normally calibrated on nitrogen or argon. If the *7812* meters are used on gases other than their calibration gas it may be desirable to introduce a calibration offset. This calibration offset is due to changes in the velocity of sound of the gas and is further described in Appendix D.

The **User Gas Equation** is an approximate description of the necessary corrections for a typical mixture of the calibration gas and methane and is of greatest value in determining the magnitude of any calibration offset.

$$\text{Corrected Density} = \rho\left[1+\frac{K3\left(\frac{C_c}{T_c+273}-\frac{C_g}{T_g+273}\right)}{(\rho+K4)}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Where: C_g = Specific Gravity/Ratio of specific heats of measured gas.

C_c = Specific Gravity/Ratio of specific heats of calibration gas.

ρ = Indicated density or temperature corrected density.

K3 = Meter Constant.

K4 = Meter Constant.

T_c = Calibration Coefficients.

T_g = Temperature of gas being measured.

Constants K3 and K4 for the *7812* will be quoted on the calibration certificate along with equation (3), characterised for that calibration.

If a **User Gas Calibration Certificate** is required, contact the factory using the details on the back page. This is a unique computer-corrected calibration certificate for which the user should supply the following data:

(a) The type and percentage content (in mass or volume units) of constituent gases in the mixture.

(b) The required calibration density range in kg/m^3. This density range must be within the density range of the nitrogen or argon calibration range.

(c) The mean operating temperature in °C.

This data, along with the primary calibration data of the instrument, is then used to calculate new calibration factors of K0, K1, K2, K18 and K19.

It should be noted that the temperature correction coefficients of K18 and K19 now include the effect of changes in velocity of sound with temperature and operate from a DATUM temperature which is now the specified **mean operating temperature** and not 20°C as is the normal practice.

Chapter 7

Calibration and Performance

7.1 Factory calibration

The *7812* Gas Density Meters are calibrated prior to leaving the factory against Transfer Standard Instruments traceable to National Standards. The Transfer Standard meters are calibrated using the PTZ calculation of density using Wagner and Span gas density equations.

7.2 Calibration of transfer standards

The calibration is carried out in accordance with the conditions listed below.

7.2.1 Calibration gas

Calibration gases used are high purity oxygen-free nitrogen and high purity argon, both with stated impurities giving an error in density from pure gas of less than 20 parts per million.

7.2.2 Calibration temperature

Controlled 20°C in a stabilised draught-free chamber measured by a UKAS-certified 100-Ω PRT, uncertainty less than ±0.05°C. This is equivalent to ±0.02% at density reading at the control.

7.2.3 Pressure measurement

Eleven points spaced roughly equidistant throughout the range of the *7812*, including a vacuum reading for field calibration checks. Measurement is made using a UKAS-certified Pressurements pressure balance (deadweight tester) with an uncertainty of less than ±0.01% of reading.

7.2.4 Evaluation of density

The calculation of density is made from the measurement of pressure and temperature using the Wagner and Span Equations of State for Nitrogen and Argon.

7.2.5 Derivation of constants

A best fit of these experimental points to the following curve is determined:

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

The values K0, K1 and K2 are derived for the required density range and these are then used to produce a calibration table of density against periodic time/frequency over a large number of points in the working range.

7.2.6 Computed data

Computation of stages 7.2.5 and 7.2.6 above is achieved by a computer program specially developed for this purpose. The input to the computer is the program and the experimental pressure/temperature data from 7.2.3 and 7.2.4 above. The computer output is included directly in the calibration data supplied with the *7812* without further transcription to avoid errors.

7.3 Calibration using transfer standards

Two **transfer standard** instruments are employed for cross comparison purposes and use ‘white spot’ nitrogen or high pure argon gas as follows.

7.3.1 Preparation

7812 meters to be calibrated, and the two certified transfer standard *7812* meters are connected into a pressurising/vacuum system and immersed in a water bath at 20°C.

7.3.2 Calibration

After temperature equalisation, the *7812* meters are pressurised to density values as indicated by the Transfer Standard Instruments and the periodic times are noted.

7.3.3 Computation

From the data collected a best-fit equation is applied in order to establish the *7812* constants.

7.4 Temperature coefficient evaluation

The temperature coefficient is determined at the zero density conditions from measurements at 20°C and typically 70°C. From these measurements the temperature correction factors K18 and K19 are determined and then specified on the calibration certificate.

7.5 Calibration check methods

The check methods outlined here are ideal for sample by-pass systems but can be applied to all *7812* meters. Whilst not confirming the point by point accuracy of a full calibration, satisfactory results obtained from these checks, coupled with the long term stability of the *7812* meters, assure maintained accuracy and correct operation of the instrument.

7.5.1 Ambient air test

With ambient air in the *7812*, check from the calibration certificate that the frequency of the output signal corresponds to the density of the ambient air.

The accuracy to which this measurement should be made depends on the density span and accuracy required from the instrument. The following figures may be of assistance for this test since they show the change in air density with ambient conditions.

Air Pressure (mm Hg)	Density at 10°C (kg/m^3)	Density at 20°C (kg/m^3)
790	1.294	1.247
760	1.224	1.199
730	1.195	1.152

7.5.2 Atmospheric pressure test

This is probably the most convenient test to perform. The *7812* should be isolated from the gas pipeline by closing shut off valves. The gas in the *7812* is then slowly vented to atmosphere. This will give a density measurement equivalent to the gas at atmospheric conditions. Care should be taken, especially if the initial gas pressure is high, to vent very slowly in order to prevent cooling due to gas expansion.

7.5.3 Vacuum test point

This is the most accurately obtainable test point and is achieved by isolating the *7812* from the gas pipeline and then evacuating the sensing chamber using a conventional vacuum pump (less than 1 mmHg). The main advantages of using this test point are that the *7812* temperature and the gas composition are of little significance.

Note: This zero density condition will **NOT** give a zero indication when using the calibration factors of K0, K1 and K2 and the check must be with respect to the zero density time period as listed on the calibration certificate.

One limitation of the vacuum test method is that whilst it accurately checks the zero point, it does not check the instrument sensitivity. In theory, and it has been proved by practice, it is not possible to change the instrument sensitivity without also changing its zero point unless the spoolbody has aged badly or been replaced.

A 0.01µs offset is equivalent to 0.004kg/m^3 and, typically, an agreement of ±0.015µs should be achieved (see Section 8.3).

The velocity of sound of the gas will also change the instrument sensitivity, but this is allowed for when generating an instrument calibration certificate and will only become apparent, to a limited degree, when changing from one gas type to another.

7.5.4 Pressure/temperature of known gas test

Calibration checks can be made using the pressure/temperature/density relationship of a known gas but in such circumstances the measurement should be made with care and sufficient time should be allowed for stabilisation. The measurement accuracy will typically be about 0.5% of reading.

Chapter 8
Maintenance

8.1 General

The 7812 Gas Density Meters have no moving parts, thereby reducing the maintenance requirements.

Check calibrations should be carried out at specified intervals in order to highlight a malfunction or deterioration in *7812* performance. If a fault or a drop in *7812* performance is discovered, further tests are required to identify the cause of the fault. The remedial action is limited to checking for deposition, corrosion and condensation on the sensing element, the state of the inline filters and some electrical checks on the amplifier/spoolbody circuits. The *7812* may require cleaning and, in extreme cases, the *7812* may need to be replaced.

CAUTION: Extreme care is required in the handling of the 7812 during transit and its installation or removal from the pipeline.

8.2 Calibration check methods

The check methods described in Chapter 7 when carried out on the 7812 will qualify the instrument's serviceability.

8.3 Mechanical maintenance

(a) Filter Check

WARNING: It is important that care be taken to prevent the ingress of dirt or particles into the unit during filter servicing, as failure to do so will severely affect the performance of the unit.

The two in-line filters are easily accessible for servicing and may be checked with the *7812* in-line in one of two ways: either visually by removing them from the *7812* following the procedure in Section 8.5, or leaving the *7812* in-situ, isolating it from the main line and pressure then carefully removing the two filter ports. Care must be taken to ensure that no dirt or particles exist on the filters or enter the unit during the check.

The filter may also be checked experimentally by following the procedure in Section 3.9.3.

(b) Deposition, Corrosion & Condensation Check

1. Close the inlet and outlet valves to isolate the *7812* and bleed to atmosphere.
2. Connect a simple vacuum pump, capable of reducing the pressure to lower than 1mm Hg, to the pressure monitor port, or other suitable connection to the isolated system.
3. With the meter operating under these vacuum conditions, connect a frequency/timer counter, with a stability/accuracy of better than one part in 100,000 (or a Flow/Process Computer) to the signal output and negative supply lines.
4. Check the zero density time period/frequency reading with that given on the Calibration Certificate.
5. If the reading differs significantly from the calibrated figure (making allowance for the maximum specified temperature coefficient of 0.002kg/m^3 per °C and the fact that a 0.004kg/m^3 change in density corresponds to a 0.01µs change in frequency/time period), the cause will probably be deposition, corrosion or condensation.

If this effect occurs to an extent which is unacceptable, the *7812* should be stripped down so that the sensing element may be cleaned or replaced.

8.4 Electrical maintenance

The 7812 amplifier housing showing the terminal board and amplifier/interconnect board is illustrated in Figure 8-1. The interconnection diagram is included for reference in Figure 8-2.

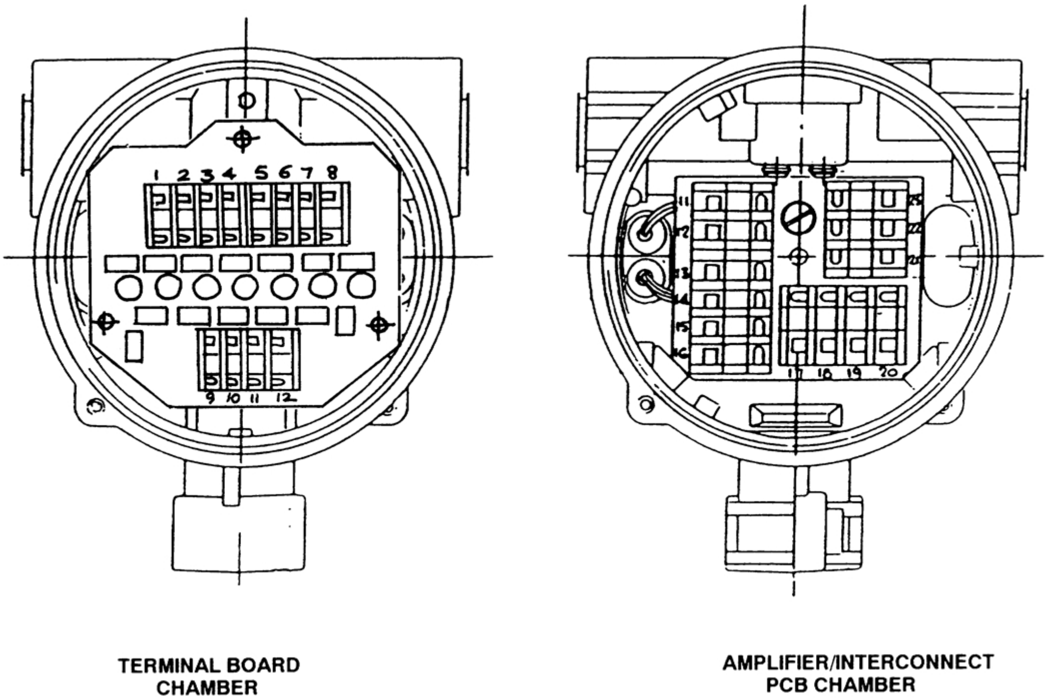


Figure 8-1: Amplifier housing

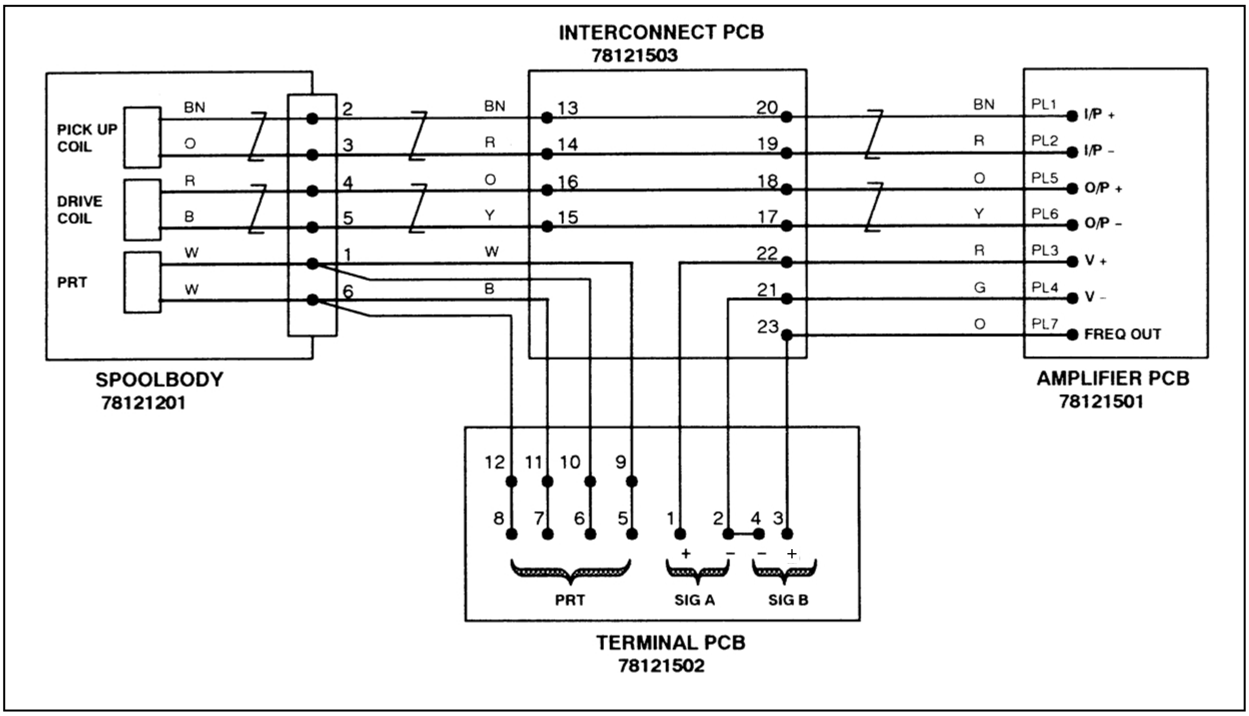


Figure 8-2: 7812 Interconnection diagram

(a) Carry out power supply and current consumption tests at the *7812* terminals. These should give:

17mA ±1mA at l5.5V to 33V

Remove the power supply to the *7812*. If the current consumption is suspect, replace the *7812* amplifier.

(b) Identify the drive coils (terminals 15 and 16) and disconnect the drive coil wires from the amplifier. Measure the resistance of the drive coils. This should be:

70Ω ±10 Ω at 20°C.

Reconnect the drive coil wires to the amplifier.

(c) Identify the pick up coils (terminals 13 and 14) and disconnect the pick-up wires from the amplifier. Measure the resistance of the pick-up coils. This should be:

70Ω ±10 Ω at 20°C.

Reconnect the pick-up coil wires to the amplifier.

(d) Check the 100 Ω Platinum Resistance Thermometer element across terminals 9, 10, 11 and 12. The value of the element resistance is temperature dependent as shown in Appendix E.

8.5 De-mounting the 7812

Note: All screws must be locked using Loctite Screw Lock and may need Loctite Solvent applied before removal.

8.5.1 Removing the *7812* from the pipeline

Pocket Installation Versions (78121/2/3/4)

(a) Isolate the *7812* from the main pipeline.

(b) Switch off electrical excitation.

(c) Vent the sample by-pass pipeline to atmosphere and disconnect from the *7812*. Cover open ends of by-pass pipeline.

(d) Remove the amplifier housing cover to the chamber which contains the user connect board. This is the chamber nearest to the cable gland axis. Release the cable connections to the terminal block, slacken off the gland nut and allow the cable to be withdrawn. Isolate the free ends.

(e) Remove the six screws holding the instrument in the pocket.

(f) Transfer the instrument to a clean environment for further stripping.

Cross Pipe Installation Versions (78125)

a) Isolate the transducer using the inlet and outlet shut off valves.

b) Switch off electrical excitation.

c) Bleed any residual compressed gas to atmosphere via a convenient bleed valve.

d) Remove the amplifier housing cover to the chamber which contains the user connect board. This is the chamber nearest to the cable gland axis. Release the cable connections to the terminal block, slacken off the gland nut and allow the cable to be withdrawn. Isolate the free ends.

e) Unscrew the unit from the cross pipe.

f) Transfer the instrument to a clean environment for further stripping.

8.5.2 Removing the electronic housing

(a) Remove the screw cover furthest away from the cable gland axis. This allows access to the chamber that contains the maintaining amplifier,

(b) Remove the centrally positioned clamping screw, ease out and disconnect the encapsulated PCB from the interconnect board, terminals 17 to 23.

(c) Disconnect the spoolbody electrical connections, terminals 11 to 16.

(d) Remove the clamping pin that locks the housing in place on to the spigot and ease off the housing taking care not to damage any of the connection wires.

M14 Bonded Seal:
470112790 (E.P.)
470112800 (FPM/FKM)

M17 Bonded Seal:
470112810 (E.P.)
470112820 (FPM/FKM)

Note: For further part numbers, see the list in Section 8.8.

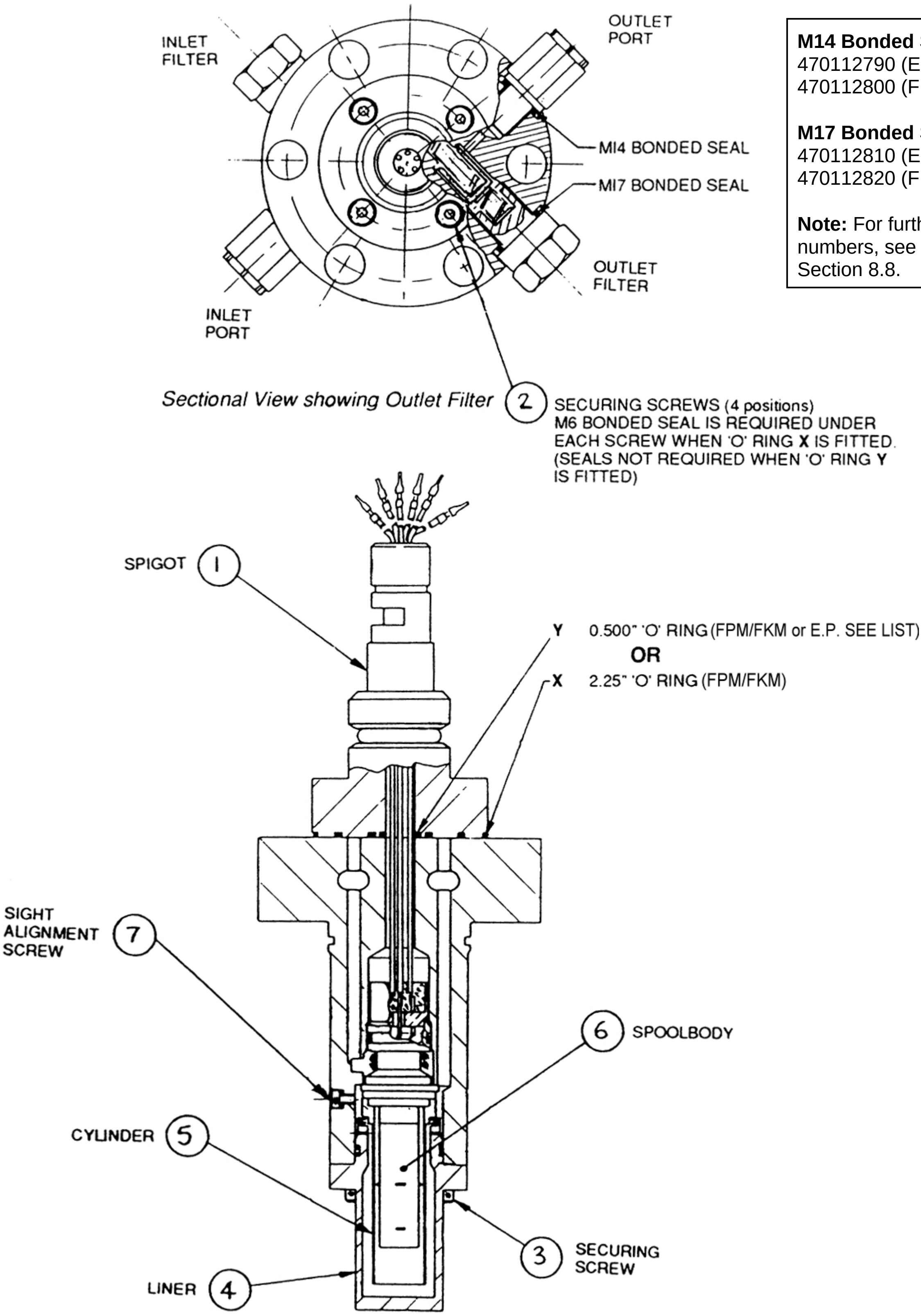


Figure 8-3: Sectional views of 78121/2/3/4 meters:

8.5.3 Removing the spigot

(a) The spigot (Figure 8-3, item 1) may be removed by the removal of the four screws (item 2) which secures it to the main housing. Pass the connection wires through the spigot taking care not to damage them.

(b) Examine the ‘O’ rings and, if necessary, renew them.

8.5.4 Removing the cylinder, spoolbody and filters

CAUTION: The cylinder wall is fragile. Great care is required during any stripping or re-assembly of the sensing element.

Pocket Installation Versions 78121/2/3/4 (See Figure 8-3)

(a) Remove the six screws (item 3) which secures the liner (item 4) to the main housing.

(b) Exercising great care, ease off the liner in an axial direction, allowing access to the cylinder/ spoolbody assembly. Two ‘jacking’ holes are provided to accomplish the removal using two of the securing screws (item 3).

(c) Carefully lift off the cylinder (item 5) and clean by lightly wiping with a lint-free tissue soaked in the appropriate solvent.

(d) Again, exercising great care, ease out the spoolbody (item 6). Clean the spoolbody and examine for corrosion.

(e) Undo the two filter housings and remove the filters together with the springs. The filters may now be cleaned in acetone.

If no corrosion or other damage is apparent on any of the piece parts, the instrument may be reassembled in reverse order. During re-assembly of the sensing element, special attention is required to correctly orientate the cylinder/spoolbody combination. For this purpose, item 7 (sight alignment screw) is removed allowing the scribe marks on the cylinder and spoolbody to be checked for alignment during the clamping action of the liner (see Figure 8-). Refit item 7 complete with new bonded seal.

Refit *7812* to the installation using operations in reverse order.

Notes:

1. It is recommended that ‘0’ rings be renewed during re-assembly and lightly coated with silicone grease.

2. Smear the threads of the filter housing, gas inlet and outlet ports thinly with anti-seize compound before re-assembly.

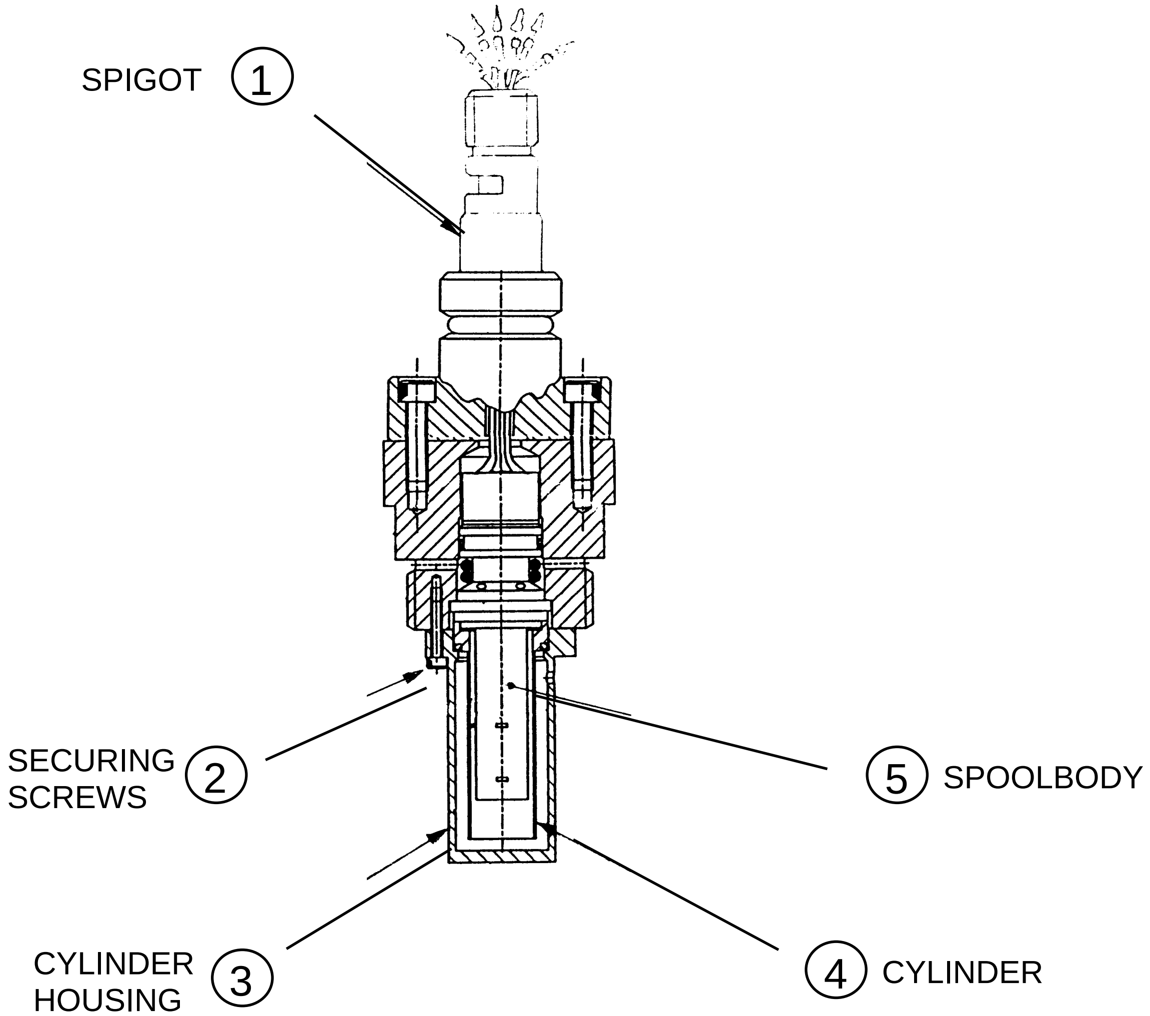


Figure Chapter 8-4: 78125 Transducer sectional view

Cross Pipe Installation Versions 78125 (See figure 8-4)

a) Remove the three screws (item 2) which secure the cylinder housing (item 3) to the mounting base.

b) Exercising great care, ease off the cylinder housing in an axial direction, allowing access to the cylinder/spoolbody assembly.

c) Carefully lift off the cylinder (item 4) and clean by lightly wiping with a lint-free tissue soaked in the appropriate solvent.

d) Again, exercising great care, ease out the spoolbody (item 5). Clean the spoolbody and examine for corrosion.

If no corrosion or other damage is apparent on any of the piece parts, the instrument may be reassembled in reverse order. During re-assembly of the sensing element, special attention is required to correctly orientate the cylinder/spoolbody combination (see figure 8-5).

Refit transducer to the installation using operations in reverse order.

Note: It is recommended that '0' rings be renewed during re-assembly and lightly coated with silicone grease.

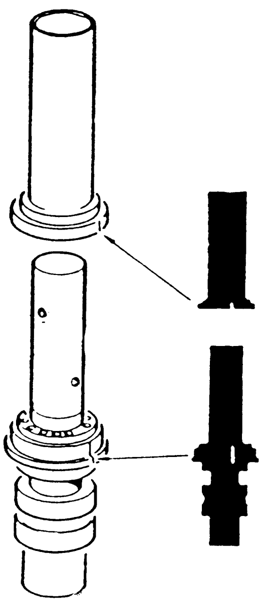


Figure Chapter 8-5: Spoolbody/Cylinder assembly showing scribe lines

8.6 Post maintenance tests

It is not necessary to carry out a full calibration on a *7812* that has undergone a full servicing. However, it is recommended that a check calibration, as described in Chapter 7, be carried out to ensure correct performance. Should such a check uncover a significant calibration offset, it is recommended that a full calibration is carried out or the *7812* is returned to the factory for further defect analysis.

If during servicing a cylinder has been changed, it is essential that a check calibration be carried out both at zero density and up range using the certificate figures for the new cylinder. However, it is normally recommended that a full calibration be carried out since the spoolbody may affect the calibration of the new cylinder.

8.7 Fault finding

The most likely cause of malfunction is the presence of dirt or condensate on the sensing element. A visual check on the condition of both cylinder and spoolbody will eradicate this source.

Disorientation of the spoolbody/cylinder and the fitting of the wrong cylinder, especially after a servicing, must not be ruled out. Great care is essential in this direction.

Lastly, amplifier malfunction is a possible cause. This can be proved by fitting a known serviceable amplifier to the *7812* or checking the suspect amplifier in a known serviceable *7812* system.

8.8 Spare parts list

The following table lists all spare parts available for the 7812 Gas Density Meter.
These are identified in Figure 8-6 for 78121/2/3/4 meters and Figure 8-7 for 78125 meters.

Part Number		Description	Material
423010350		Spring 0.437” O/D x 0.5’ long	
423010760		Compression Spring 0.312” O/D x 2.5” long	
450600260		Inlet Filter 2micron	
450600270		Outlet Filter 90micron	
450600720		Adapter Female to Male 1/4” NPT	ST/ST 316
470111450	*A	‘0’ Ring 1.125” I/D	FPM/FKM
470111340	*A	‘0’ Ring 0.500” I/D	FPM/FKM
470111470		‘0’ Ring 1.812” I/D	FPM/FKM
470111590	*A	‘0’ Ring 0.437” I/D	FPM/FKM
470112040		‘0’ Ring 0.437”I/D	E.P.
470112050	*B	‘0’ Ring 1.125” I/D	E.P.
470112540	*B	‘0’ Ring 18.1mm I/D, 21 .3mm O/D	SILICON
470112550		‘C’ Ring 26.97mm O/D	INCONEL X-750
470112560		Anti-Extrusion Ring 0.801” I/D	
470112570		Anti-Extrusion Ring 1.1” I/D	
470112610		Bonded Seal M4	E.P.
470112620	*B	Bonded Seal M4	FPM/FKM
470112680	*A	‘0’ Ring 97mm I/D, 102mm O/D	NITRILE
470112720		‘0’ Ring 20.5mm 30mmO/D	FPM/FKM
470112790		Bonded Seal M14	E.P.
470112800	*B	Bonded Seal M14	FPM/FKM
470112810	*A	Bonded Seal M17	E.P.
470112820	*B	Bonded Seal M17	FPM/FKM
470112830	*A	‘0’ Ring 0.500” I/D	E.P.
470112880	*B	‘0’ Ring 0.812” I/D, 0.937” O/D	E.P.
470112890	*B	‘0’ Ring 0.812” I/D, 0.937” O/D	FPM/FKM
470112930	*A	‘0’ Ring 2.25”I/D, 2.50”/D	FPM/FKM
78102000X		Gasket	NEOPRENE
78120202EVV		Amplifier Assembly (CENELEC)	
78120202FVV		Amplifier Assembly (ATEX, CSA)	
78120204A		Spoolbody Fabrication	
78122025A		Screws, plated, M5 x 20	
78122026A		Screws, plated, M6 x 25	NEOPRENE
78123723A		Gasket, anti-vibration	

Note: Spares listed are common to both 7812*A and 7812*B, except where indicated in column 2 by ***A** (7812*A only) or ***B** (7812*B only).

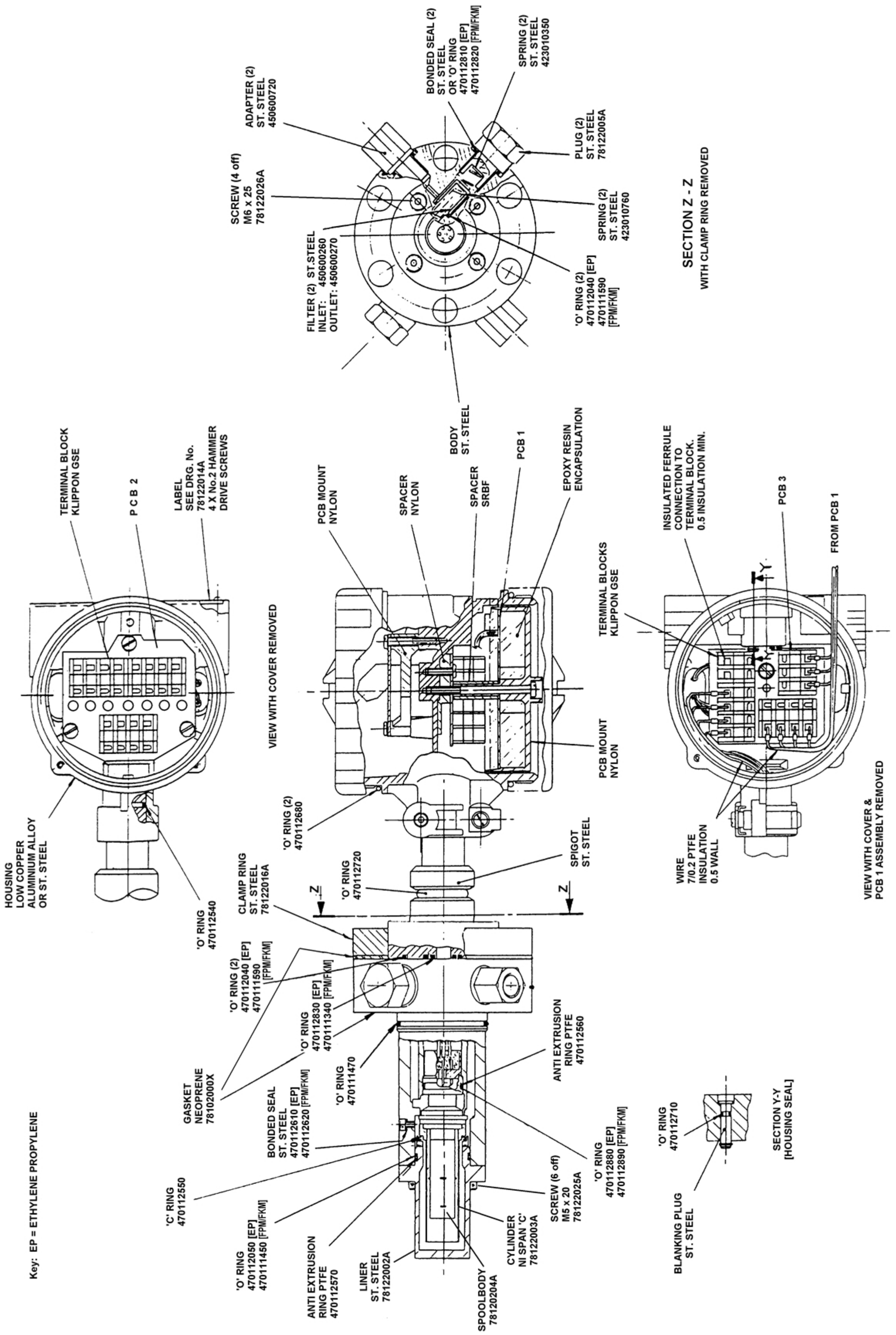


Figure 8-6: Cross-sectional view of 78121/2/3/4 Meter showing part numbers for spares

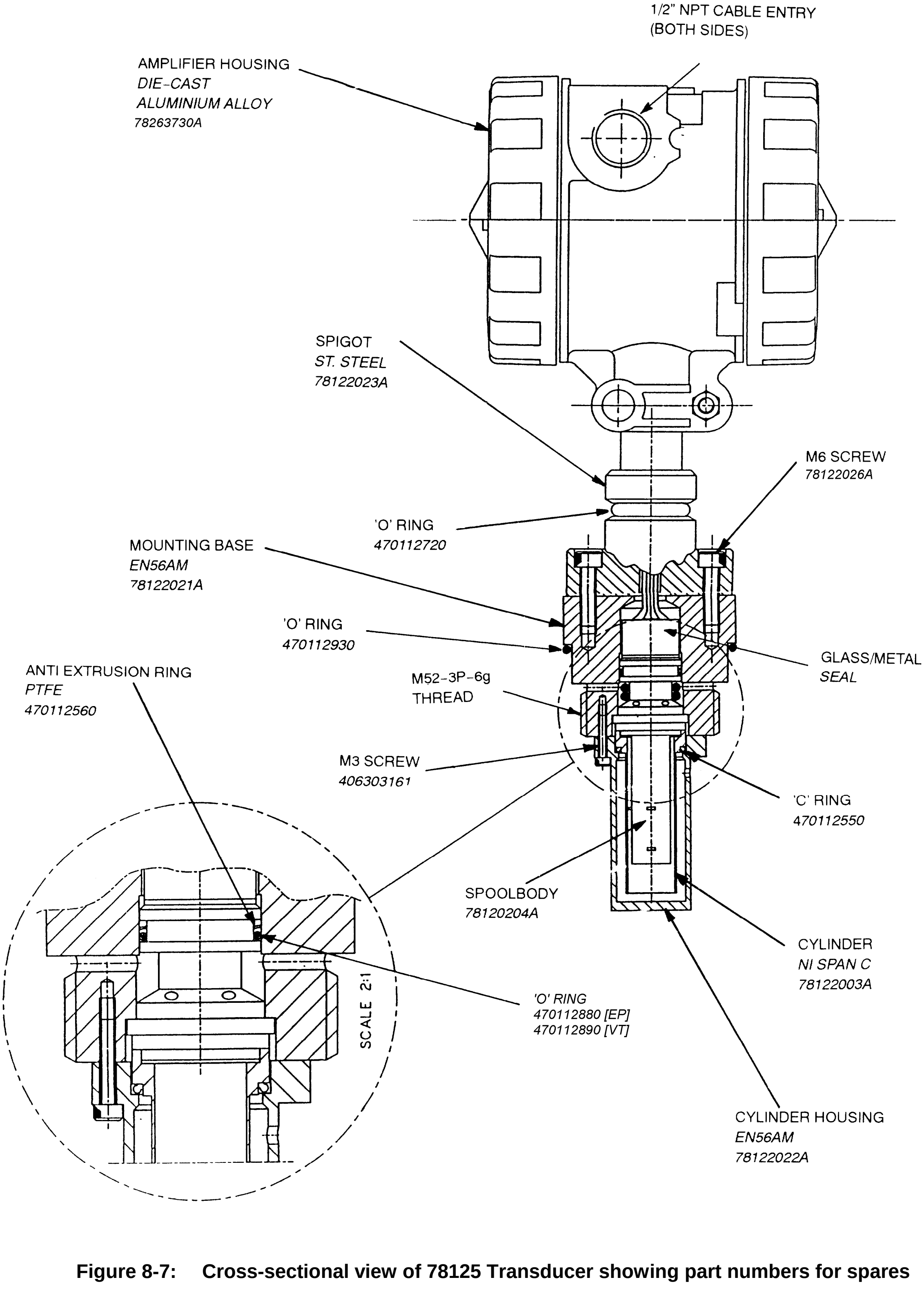


Figure 8-7: Cross-sectional view of 78125 Transducer showing part numbers for spares

Appendix A
7812 Specification

A.1 Performance

Density Range	1 to 400 kg/m^3 (0.06-25lb/ft^3)
Accuracy:	< ±0.1% of reading (Nitrogen) < ±0.15% of reading (Natural Gas and Ethylene outside its critical region)
Maximum Pressure:	Operating: 3625psi (250 bar) with pocket mounting kit Test: 5437psi (375 bar)
Pressure coefficient:	Negligible
Temperature range:	-4°F to 185°F (-20°C to +85°C)
Temperature coefficient:	<0.001 kg/m^3/°C (0.00003lb/ft3/ºF)

A.2 Electrical

Power supply:	+15.5 to 33Vdc, 25mA (Safe Areas)
Output Signal:	1960Hz ±10% at 0 kg/m^3 (0lb/ft^3) 1580Hz ±10% at 60 kg/m^3 (3.8lb/ft^3) Nominal 6V peak to peak for 3-wire system Nominal 2-3V peak to peak across 330Ω for 2-wire system

A.3 Mechanical

Gas connections:	¼" NPT (API) female
Integral filters: *(except 78125)*	Inlet: 2.0 micron Outlet: 90.0 micron
Max. dimensions:	14.5" x 5.5" (364 x 139mm)
Approx. weight:	1/2/3/4: 11lb (5kg) 78125: 7.7lb (3.5kg)
Materials:	Process gas must be compatible with Ni-Span-C902, Stainless Steel AISI316 Stycast Catalyst 11 and Permendur Iron

A.4 Safety approval

Status:	ATEX (See safety instruction booklet 78125010/SI.) Pressure Equipment Directive (See safety instruction booklet 78128012/SI.) CSA (See Appendix H)

A.5 Electromagnetic compatibility (EMC)

Status:	Approved to EN 61326:1997+A1+A2+A3

A.6 Environment

Environmental rating:	IP66 *(for the 78125, this applies once the unit is installed)*

Appendix B
Calibration Certificate

CALIBRATION CERTIFICATE

```
7812 GAS DENSITY METER                              Serial No: 123395
    78122AAGJACCA                                 Cylinder No: 5427
                                                 Amplifier No: 1837
PRESSURE TESTED TO  375 BAR                  Calibration Date: 19NOV10

DENSITY CALIBRATION FOR NITROGEN AT  20.2 DEG C

      Based on Pressure-Temperature-Density Data in IUPAC Tables

      DENSITY    PERIODIC TIME
      [KG/M3]        [uS]

         0         504.729
      [Air         507.401 indication only]
      8            522.368
      15           537.252         DENSITY = K0 + K1.T + K2.T**2
      20           547.630
      30           567.804         K0 =   -1.102146E+02
      40           587.272         K1 =   -1.095094E-02
      50           606.102         K2 =    4.541929E-04
      60           624.353
      70           642.075
      80           659.313
      90           676.103

TEMPERATURE COEFFICIENT DATA

      Dt = DI(1 + K18(t - 20 )) + K19(t - 20 )    K18 = -2.24E-05
                                                  K19 = -1.60E-04


USER GAS OFFSET DATA

      Nitrogen/Methane Gas Mixture Over Density Range  1 to  10 KG/M3

              (       K3     (            G  ))          K3 =  346
      DA = Dt (1 +  ------- (.00236 - ----))             K4 = 56.6
              (     (Dt+K4)  (          t+273))

      where
       T = Periodic Time (uS)
      DA = Actual Density (KG/M3)           Gas Specific Gravity
       t = Temperature (DEG.C)          G = -----------------------
      DI = Indicated Density (KG/M3)        Ratio of Specific Heats
      Dt = Temp.Corrected Density (KG/M3)
                                                    --------------
                                                   | FINAL TEST & |
                                                   |  INSPECTION  |
                                                   |              |
                                                   |              |
                                                   |              |
                                                   |              |
                                                    --------------

Ref No: GD05/V3.32                                  DATE-25NOV10
```

Figure B-1: Example of Prime Nitrogen Certificate

USER GAS - CALIBRATION CERTIFICATE

78121A GAS DENSITY METER

Serial No: 123260
Cylinder No: 5113
Cal Date: 14JAN10

NITROGEN CALIBRATION DATA AT 20 DEG.C

K0 = 4.010560E+02	K18 = -1.590E-05
K1 = -2.028242E+00	K19 = 5.860E-04
K2 = 2.446537E-03	

USER GAS DATA AT 20.0 DEG.C

COMPOSITION BY % VOLUME :- (SINGLE PHASE FLUID IS ASSUMED)

HYDROGEN	.0000
HELIUM	.0000
NITROGEN	.0000
CARBON MONOXIDE	.0000
CARBON DIOXIDE	.0000
OXYGEN	.0000
ARGON	.0000
METHANE	.0000
ETHANE	.0000
ETHYLENE	100.0000
PROPANE	.0000
PROPYLENE	.0000
BUTANE	.0000
PENTANE	.0000
HEXANE +	.0000
TOTAL	100.0000

VELOCITY OF SOUND AND ERROR DATA

DENSITY [KG/M3]	PERIODIC TIME [uS]	V.O.S [M/S]	MAX. ERROR [%density]
1	505.630	329	.118
3	510.020	326	.121
5	514.218	324	.122
6	516.253	323	.124
8	520.206	321	.125
10	524.018	318	.128

DESIGN AUTHORITY	USER GAS COEFFICIENTS	FINAL TEST & INSPECTION
	K0 = 3.938648E+02 K1 = -1.998979E+00 K2 = 2.416783E-03 K18 = 3.116E-05 } DATUM K19 = 5.871E-04 } 20.0 DEG C	

Figure B-2: Example of Gas User Certification

Appendix C
Orifice Metering

The orifice metering system is at present the most commonly used method for accurate flow measurement of natural gas. The orifice meter is a differential pressure type device in which the orifice plate causes a pressure drop between the upstream and downstream sides. The rate of flow is substantially determined from the dimensions of the system and from measurements of differential pressure and fluid density.

The overall uncertainty of the orifice meter, including the error sources of secondary instrumentation, such as a densitometer, can be as low as 1.0%. A typical orifice plate metering system is shown in Figure C-1.

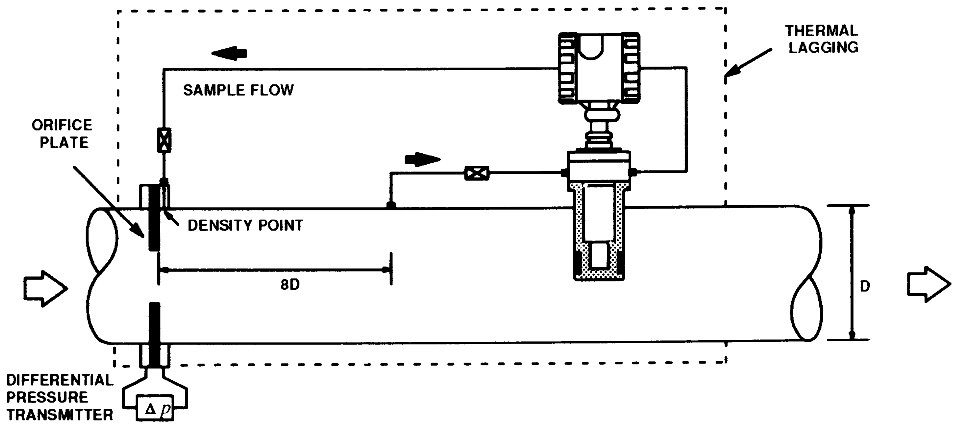


Figure C-1: Typical orifice plate metering system

BASIC FLOW EQUATIONS

In order to establish the volumetric flow or mass flow through an orifice plate, it is necessary to know the density of the fluid at the orifice and the differential pressure across the orifice. However, it should be noted that the gas density will change from upstream of the orifice to downstream due to the pressure drop across the orifice plate. This is illustrated in Figure C-2.

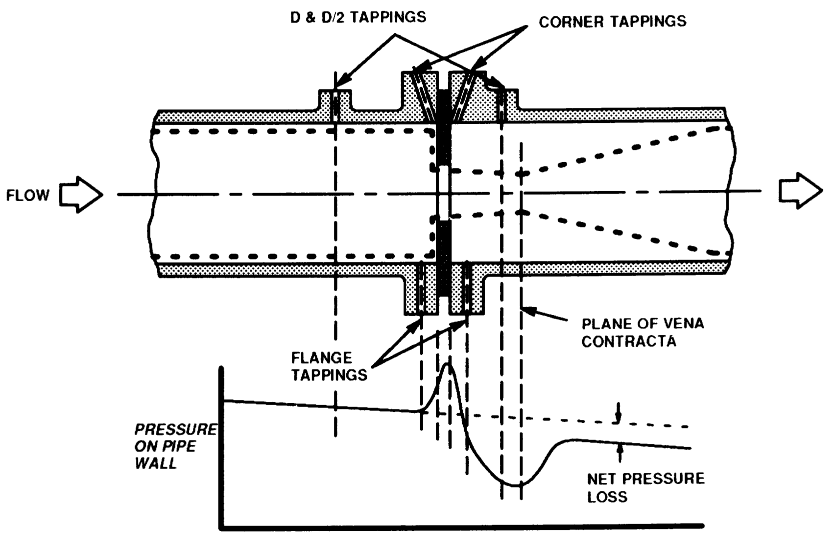


Figure C-2: Pressure variation along pipe wall for square-edged orifice plate

The **mass flow rate, q_m,** is given by:

$$q_m = CE \in_1 \left(\frac{\pi d^2}{4}\right)\sqrt{2\Delta p \rho_1} \quad \text{(D1)}$$

Where:

C = Discharge Coefficient. (Due to the contraction of the gas streamlines downstream of the plate which causes the actual flow rate to be about one third less than the theoretical, ideal value. C = 0.6 approximately.)

E = Velocity of approach factor

$\in_1$ = Expansion factor at upstream orifice tapping

d = Orifice bore diameter

ρ_1 = Density of gas at the plane upstream orifice tapping

Δp = Differential pressure across orifice tappings

It has been determined experimentally that the expansion factor for density measurement at the upstream flange tap is given by the equation:

$$\in_1 = 1 - \left(0.41 + 0.35\beta^4\right)\frac{\Delta p}{P_1 k} \quad \text{(D2)}$$

Where:

β = Orifice diameter ratio

k = Gas isentropic exponent

P_1 = Absolute pressure upstream of orifice

Whilst it is this equation which is quoted in most gas metering standards, it is not practical to measure the gas density at this point without disturbing the gas flow conditions. In consequence, it is necessary to apply corrections which refer the measured density to that which is present at the upstream flange conditions. For most metering upstream, an isothermal and ideal gas condition is assumed in which case this referral is made by simple application of differential pressures.

For example:

$$\rho_1 = \rho_2\left(\frac{P_1}{P_1 - \Delta p}\right) \quad \text{(D3)}$$

Where:

ρ_2 = Density of gas at the plane of the downstream orifice tapping

If isentropic expansion is assumed then this equation becomes:

$$\rho_1 = \rho_2\left(\frac{P_1}{P_1 - \Delta p}\right)^n \quad \text{(D4)}$$

Where:

n = 1 for isothermal expansion, or 1/k for isentropic expansion where *k* = gas isentropic exponent

For a more exact approach it is necessary to consider the real effects on the gas as it passes through the system.

For the Pressure Recovery Method, which is normally recommended, it should be noted that the density measurement is at a temperature condition after full pressure recovery, and the pressure condition is that at the downstream flange tap.

The **volume flow rate**, q_v, is given by:

$$q_v = \left(\frac{q_m}{\rho}\right) \quad \text{..} \quad (D5)$$

Where the density, ρ, in the above equation is at the same temperature and pressure as those at which the volume is stated.

The velocity of approach factor, E, corrects the flow equation for the effect of the upstream kinetic energy on the differential pressure across the orifice. The latter is proportional to the square of the velocity, which is inversely proportional to the square of the diameter of the orifice, and thus E and beta are related as follows:

$$E = \left(\frac{1}{\sqrt{1-\beta^4}}\right) \quad \text{..} \quad (D6)$$

Hence, equation *(Dl)* can be written:

$$q_m = \left(\frac{C \in_1}{\sqrt{1-\beta^4}}\right)\left(\frac{\pi d^2}{4}\right)\sqrt{2\Delta p \rho_1} \quad \text{..} \quad (D7)$$

Appendix D
Velocity of Sound Effect

D.1 VOS correction methods

The sensing element within the *7812* Gas Density Meter consists of a thin metal cylinder which is activated so that it vibrates in a hoop mode at its natural frequency. Since the gas being metered is in contact with the vibrating cylinder, it will influence the total vibrating mass and hence change the natural frequency of resonance. The gas density for any particular resonating frequency can therefore be determined.

There is, however, a second but considerably less significant property of the gas which influences the natural frequency of vibration of the sensing element. This second effect is caused by the Velocity of Sound (VOS) in the gas.

The *7812* meters are normally calibrated using pure nitrogen or argon, the density being measured using Transfer Standard Instruments. The accuracy of this calibration is generally better than 0.1% of density.

When using the *7812* on gases other than the calibration gas and where the VOS is different, a small calibration offset may be experienced. Since this offset is accurately predictable, it may be desirable to introduce VOS corrections in order to maintain the best measurement accuracy of the *7812*.

The *7812* is less sensitive to VOS influence than previous models of this instrument and, in consequence, the need to apply VOS correction is less likely. However, when it is necessary, one of the following correction methods are suggested:

D.1.1 User gas equation method

This equation is shown on the nitrogen or argon calibration certificates. The coefficients, which are also listed, are optimised for mixtures of the calibration gas and methane. For other gas mixtures, it is necessary to establish new coefficient values as described in Section D.4. This correction method is recommended for applications where pressure data is not available, but where gas composition and temperature do change.

D.1.2 User Gas Calibration Certificate

For measurement of a gas, which has a reasonably well defined composition, a User Gas Calibration Certificate can be supplied – *if it is required*, *contact the factory using the contact details on the back page*.

This certificate specifies modified values of K0, K1, K2, K18 and K19 that are calculated from the original nitrogen or argon values in order to include the effects of velocity of sound. It should be noted that these modified values are optimised for the specified density range and that K18 and K19 values now include the VOS changes with temperature, and must be applied with respect to a datum temperature which is now the Mean Operating Temperature.

D.1.3 Pressure/Density Method

This correction method is recommended for measurement of different gases at varying operating conditions. It enables the gas velocity of sound to be calculated and corrections applied in an automatic manner and to the best accuracy. For its operation, it is necessary to have a measure of the line pressure and a means of performing the calculation, for example, within a flow computer.

The significance of these correction methods can be better understood by examining the velocity of sound effect in more detail.

D.2 Influence of VOS on the vibrating sensing element

It can be shown from a theoretical examination of the vibrating system that the VOS of the calibration gas and of the measured gas influence the measured density as described by the following equation:

$$\rho_A = \rho_1 \left[\frac{1 + \left(\frac{K}{\tau c_c} \right)^2}{1 + \left(\frac{K}{\tau c_g} \right)^2} \right] \quad \text{.......... (E1)}$$

Where:

ρ_A = True density (kg/m^3)

ρ_1 = Indicated density from calibration gas (kg/m^2)

c_c = Velocity of sound of calibration gas (m/s)

c_g = Velocity of sound of measured gas (m/s)

τ = Periodic time of density sensor output signal (μs}

K = Velocity of Sound constant for density sensor

= 2.10×10^4 for 7812 sensors

This equation which forms the basis of all the correction methods has been verified by extensive testing on many gas mixtures.

An approximate illustration of this effect is shown in Figure D-1.

True density = Indicated density - OFFSET

For ideal gases: $c = \sqrt{\gamma \frac{\delta P}{\delta \rho}}$ and therefore $c \propto \sqrt{\gamma \frac{T}{SG}}$

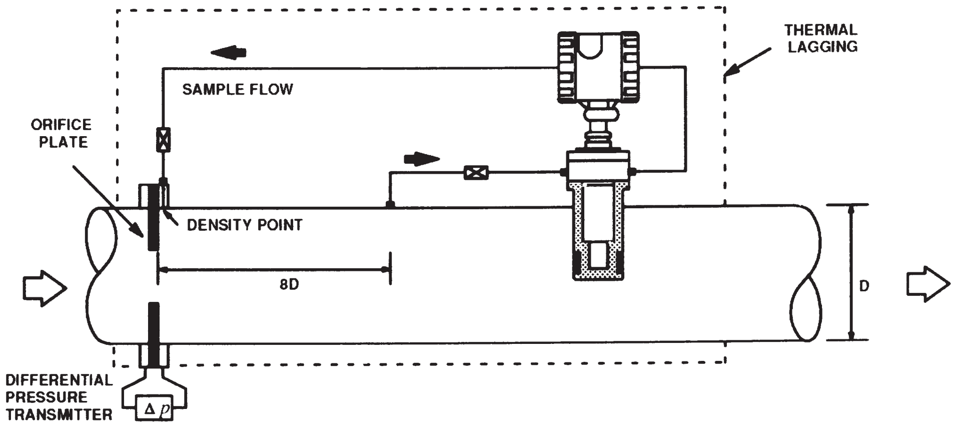


Figure D-1: 7812 velocity of sound offset for Nitrogen and Argon

D.3 Calculation of VOS of gas

In order to apply the correction it is necessary to establish the VOS in both the calibration and measured gases.

Within the procedure for generating User Gas Calibration Certificates there are methods for calculating these velocity of sounds for the specified operating range and thus, with the application of equation E1, the new calibration factors can be established.

Alternatively and from the thermodynamics of a gas, the VOS is given by the equation:

$$c = \sqrt{\gamma\left(\frac{\delta P}{\delta \rho}\right)_T} \quad \text{(E2)}$$

Where: c = Velocity of sound in the gas (m/s)

γ = Ratio of specific heats Cp/Cv

And: $\left(\frac{\delta P}{\delta \rho}\right)_T$ = Ratio of pressure change (Pa) to density change (kg/m^3) at constant temperature

At low pressures and for ideal gases this equation may be simplified to:

$$c = \sqrt{\gamma\left(\frac{P}{\rho}\right)} \quad \text{(E3)}$$

In order to account for the non-ideal situation, equation E2 may be re-written as:

$$c = \sqrt{\gamma_0\left(\frac{P}{\rho}\right)} + K5'\rho^2 + K6'\rho^3 \quad \text{(E4)}$$

Where: c = Velocity of sound in the gas (m/s)

γ_0 = Low pressure ratio of specific heats

P = Pressure (bar A)

$K5', K6'$ = Coefficients which can be established from a knowledge of the actual behaviour of the relevant gas mixtures

It is the combination of equations E1 and either E3 or E4 which form the basis of the **Pressure/Density Method**.

Also, since: $\frac{P}{\rho} = \frac{RT_AZ}{M}$

Where: R = Universal Gas Constant

T_A = Absolute temperature

Z = Compressibility factor

M = Molecular weight

It follows that: $c = \sqrt{\gamma \frac{RT_AZ}{M}}$ .... (E5)

Equations E1 and E5 may be combined and simplified to form the following equation:

$$\rho_A = \rho_1\left[1+\frac{K3}{\rho_1+K4}\left(\left(\frac{SG}{\gamma_0(T+273)}\right)_c-\left(\frac{SG}{\gamma_0(T+273)}\right)_g\right)\right] \text{ ....(E6)}$$

Where:

- ρ_A = True density (kg/m^3)
- ρ_1 = Indicated density from calibration gas (kg/m^3)
- SG = Gas specific gravity
- γ_0 = Low pressure specific heat ratios
- $(\ )_c$ = Relating to calibration gas
- $(\ )_g$ = Relating to measured gas
- K3, K4 = User Gas Equation coefficients
- T = Temperature (°C)

Equation E6 is the basis of the **User Gas Equation Method**.

Note: The User Gas Equation coefficients are calculated to produce minimum error when moving from a specified calibration gas to a typical measured gas over a specified operating density range.

The coefficients shown on the Prime calibration certificate are with respect to the specific conditions on the certificate. Alternative values for the User Gas Equation coefficients can be derived for other gas mixtures and conditions.

D.4 Procedure for K3, K4 derivation

From equation E1, the correction factor for the velocity of sound (VOS) effect is:

$$\text{VOS correction Factor} = \frac{1+\left(\frac{K}{\tau c_c}\right)^2}{1+\left(\frac{K}{\tau c_g}\right)^2} \quad \text{.......... (E7)}$$

Where:

- c_c = Velocity of sound of calibration gas (m/s)
- c_g = Velocity of sound of measured gas (m/s)
- τ = Periodic time of density sensor output signal (μs)
- K = Velocity of sound constant for density sensor
- = 2.10×10^4 for 7812 sensors

Values of τ at defined densities are given on the calibration certificate. The VOS figures are either calculated from the equations given earlier or direct from the gas tables.

Evaluate the VOS correction factors at minimum and maximum densities and then calculate the K3 and K4 factors as follows:

$$K4 = \frac{(B-1)\rho_b - (A-1)\rho_A}{A-B} \quad \text{.......... (E8)}$$

And:

$$K3 = \frac{(A-1)(\rho_A + K4)}{C} \quad \text{.......... (E9)}$$

Where:

- ρ_A = Minimum density (kg/m^3)
- ρ_B = Maximum density (kg/m^3)
- A = VOS correction factor at minimum density
- B = VOS correction factor at maximum density

$$C = \left(\frac{SG}{\gamma_0(T+273)}\right)_c - \left(\frac{SG}{\gamma_0(T+273)}\right)_g \quad \text{.......... (E10)}$$

D.4.1 Example

For a 7812 sensor calibration using nitrogen at 20°C, determine the K3 and K4 factors for operation on methane at 20°C over a density range of 10kg/m^3 to 60kg/m^3.

Given at 10kg/m3:	τ = 532 μs	c_c = 350m/s	c_g = 441m/s
And at 60kg/m^3:	τ = 633 μs	c_c = 359m/s	c_g = 433m/s

For nitrogen gas: SG = 0.96716 γ_0 = 1.400

$$\left(\frac{SG}{\gamma_0(T+273)}\right)_c = 0.00236$$

For methane gas: SG = 0.55883 γ_0 = 1.292

$$\left(\frac{SG}{\gamma_0(T+273)}\right)_g = 0.00145$$

Note: The periodic time is available from the density sensor calibration certificate while the gas data can be gleaned from the relevant gas reference tables.

From equation E7:

VOS correction factor at 10kg/m^3 A = 1.0046

VOS correction factor at 60kg/m^3 B = 1.0026

From equation E10:

$$\text{Factor C} = 0.00236 - 0.00145 = 9.1 \times 10^{-4}$$

From equation E8:

$$K4 = \frac{(1.0026-1)60-(1.0046-1)10}{1.0046-1.0026} = 55$$

From equation E9:

$$K3 = \frac{(1.0046-1)(10+55)}{9.1\times 10^{-4}} = 328.57$$

In conclusion, the User Gas Equation for this nitrogen/methane gas mixture is:

$$\rho_A = \rho_1\left[1+\frac{328.57}{\rho_1+55}\left(0.00236-\left(\frac{SG}{\gamma_0(T+273)}\right)_g\right)\right]$$

If desirable, this equation can be simplified further with little loss in accuracy by dispensing with the specific heat ratio (γ_0) term. The modified value of the calibration gas VOS factor is known as factor K5' whilst the resultant modified value of K3 is reclassified as factor K6' and is determined as follows:

For nitrogen gas, factor K5' is given by:

$$K5' = \frac{SG}{T+273} = \frac{0.096716}{293} = 0.00330$$

And: $$\text{Factor C} = 0.0033 - \frac{0.5539}{293} = 0.00141$$

With: $K6' = \frac{(1.0046 - 1)(10 + 55)}{0.00141} = 212.0$

The simplified version of the User Gas Equation for this nitrogen/methane gas mixture is:

$$\rho_A = \rho_1 \left[1 + \frac{212}{\rho_1 + 55} \left(0.0033 - \left(\frac{SG}{(T + 273)} \right)_g \right) \right]$$

Appendix E
Ethylene Measurement

E.1 General

With the increasing importance of ethylene gas in the petrochemical industry, coupled with the continuing rise in its manufacturing costs, it is becoming financially apparent that an accurate flow measurement system is necessary for this gas. The favoured system is that of a turbine flowmeter and densitometer, from which the volumetric flow and density are used to compute the mass flow. However, the accuracy to which the densitometer and flowmeter are calibrated is of prime significance.

The characteristics of ethylene gas are illustrated in Figure E-1. Within the saturated zone the ethylene takes the form of liquid and saturated vapour, the relative quantities per unit volume being dependent upon the pressure/temperature conditions existing. In this zone no attempt is made to determine the density to any reasonable accuracy. Outside the saturated zone the fluid is single phased, displaying the characteristics of a gas in the low density/low pressure area whilst in the high density/high pressure area the characteristics are those of a liquid. The shaded area of Figure E-1 represents the normal operating range, where the highest accuracy of measurement is essential. Since this area borders on the supercritical region of the gas, density calculations using the pressure and temperature method are extremely difficult to obtain with any reasonable degree of accuracy.

Micro Motion has created the 78125 meter specifically for the measurement of supercritical ethylene gas.

The new calibration is performed using high purity argon, with correction for the velocity of sound characteristics of the sensing element taken into account. These calibrations can be verified by comparison with the NPL certified transfer standard instruments; in general the agreement is better than 0.1% of reading.

Figure E-2 shows the graph from Figure E-1 with an overlay illustrating the velocity of sound correction as a percentage of reading.

Figure E-3 illustrates the rigorous procedure adopted to assure the standard of accuracy of the 78125 meter.

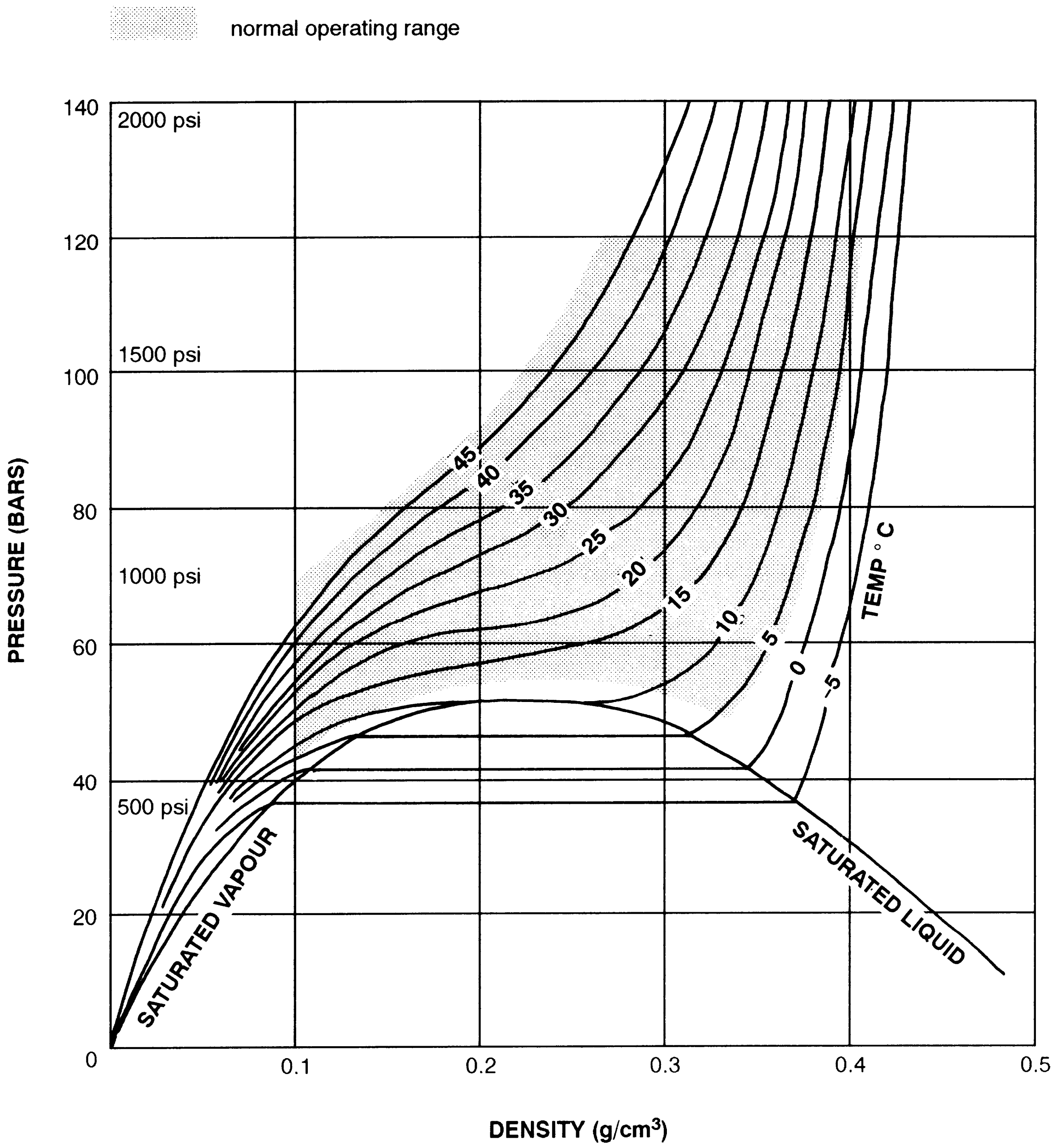


Figure E-1: Ethylene gas characteristics

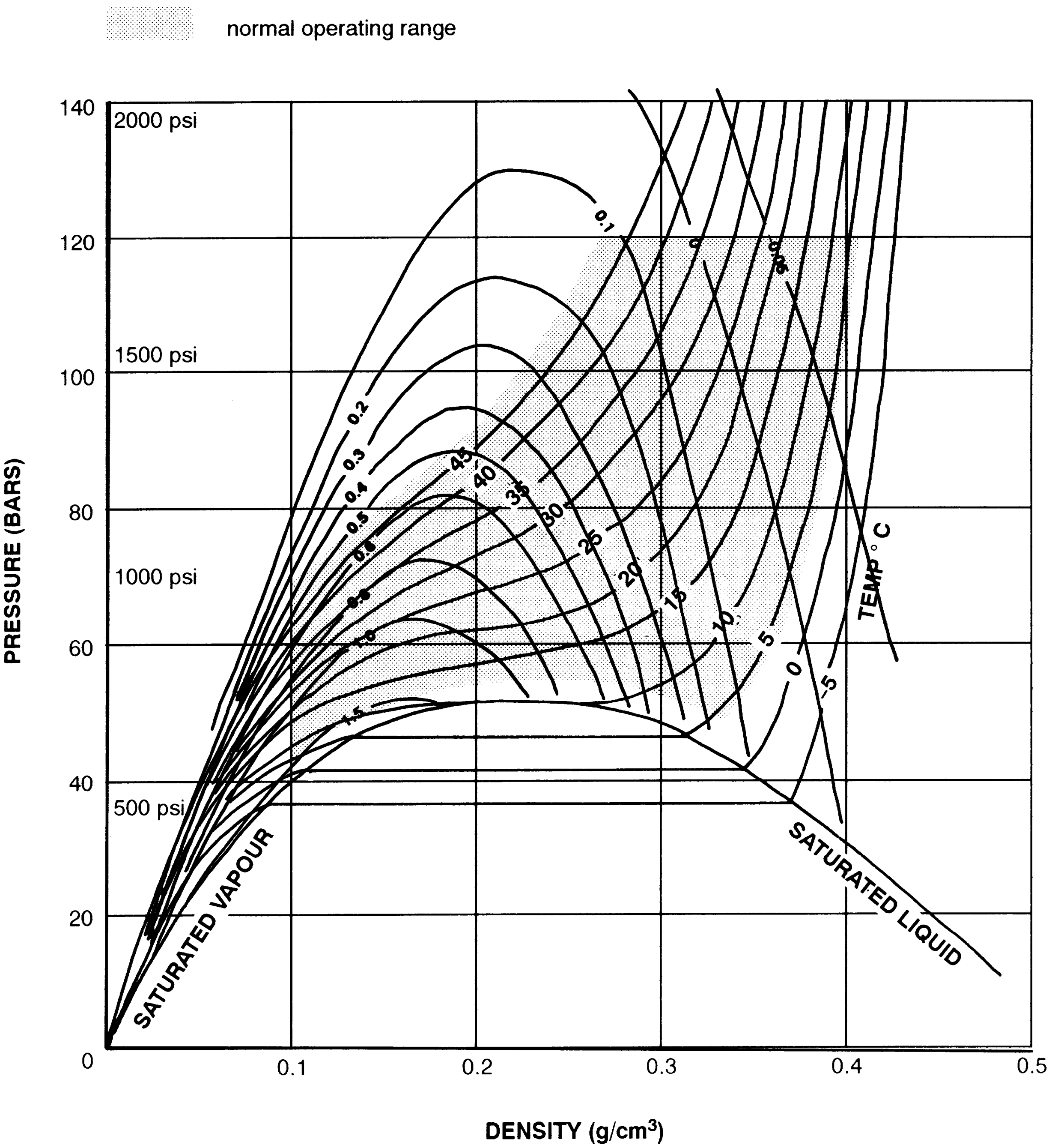


Figure E-2: Ethylene gas characteristics with VOS correction overlaid

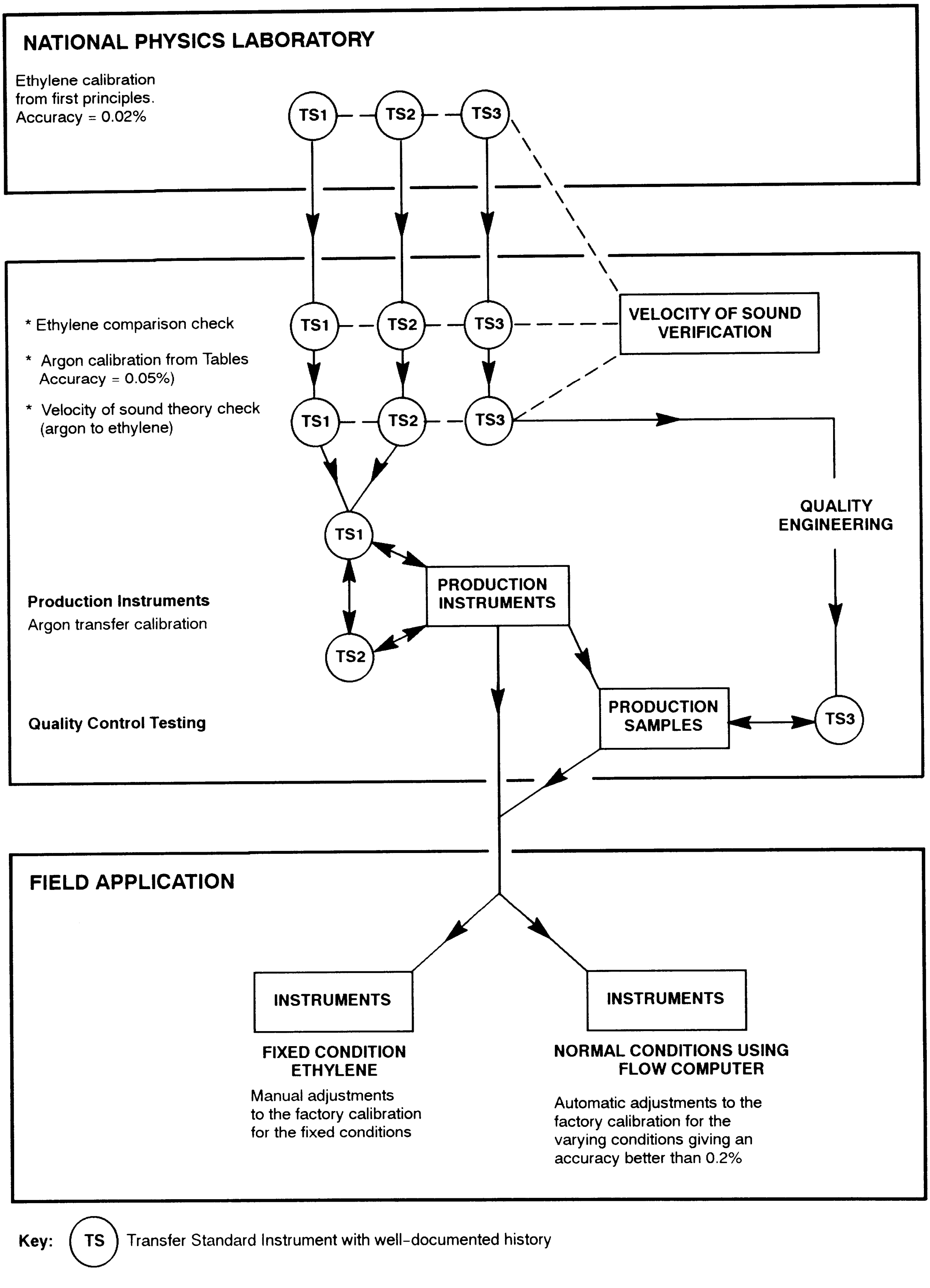


Figure E-3: Verification procedure for calibration of instruments

E.2 Worked example

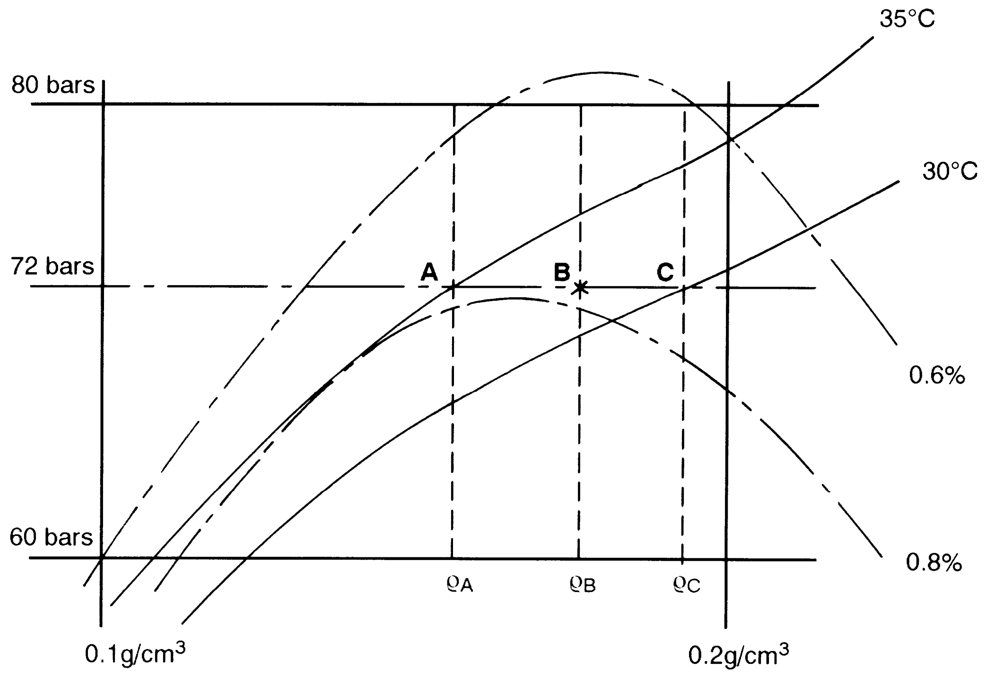


Figure E-4: Magnified area of graph in Figure E-1

The ethylene gas is at a constant pressure of 72bar and the expected temperature variation is 30°C to 35°C. Calculate the true density variation and derive a set of modified constants KO, K1 and K2 for the *7812*.

Figure E-4 illustrates the appropriate area of the graph in Figure F-l, magnified to show the range of conditions existing for this example.

From Figure E-4, the following values of indicated density are obtained ($1g/cm^3 = 1000kg/m^3$):

$\rho_A = 156.42kg/m^3$ $\rho_B = 177kg/m^3$ $\rho_C = 193.24kg/m^3$

From the *7812* calibration certificate the meter constants are:

K0 = -84.991388 K1 = -0.02516094 K2 = 0.00045766

and the relevant periodic times are obtained using the equation:

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

Or: $\tau = \dfrac{-K1 + \sqrt{K1^2 - 4K2(K0 - \rho)}}{2K2}$

τ_A = 754.2942367

τ_B = 784.5977854

τ_C = 807.6803586

Now from Figure F-4 and deriving the mean velocity of sound offsets at points A, B and C, the corrected values of density for ethylene gas at these points are:

ρ'_A = 156.42(1 + 0.007714) = 157.6266239kg/m^3

ρ'_B = 177(1 + 0.007834) = 178.386618kg/m^3

ρ'_C = 193.24(1 + 0.00737) = 194.6641788kg/m^3

i.e. The velocity of sound offsets are 0.7714%, 0.7834% and 0.737% respectively

Since there must now be a different density indication for the time periods τ_A, τ_B and τ_C then a modified set of constants K0, K1 and K2 are required. These are derived using the following equations:

Constant K2

$$K2 = \frac{(\rho'_C - \rho'_A)(\tau_B - \tau_A) - (\rho'_B - \rho'_A)(\tau_C - \tau_A)}{(\tau_C^2 - \tau_A^2)(\tau_B - \tau_A) - (\tau_B^2 - \tau_A^2)(\tau_C - \tau_A)} = 0.0003768812$$

Constant K1

$$K1 = \frac{(\rho'_B - \rho'_A) - K2(\tau_B^2 - \tau_A^2)}{(\tau_B - \tau_A)} = 0.1050886138$$

Constant K0

$$K0 = \rho'_A - K1\tau_A - K2\tau_A^2 = -136.0713623$$

The modified constants are only applicable over the density range of ρ_A to ρ_C and within the temperature and pressure conditions stated and should be set into the electronic read-out device.

When using 7950/7951/7955 (Signal Converters / Flow Computers), the changes in calibration characteristics from argon to ethylene are performed within the instrument. This may be done continuously over the complete operating range by the addition of a line pressure input to the computer.

The argon calibrations, combined with the 7950/7951/7955 (which can automatically correct for the systematic errors of the *7812*), offer the highest level of measurement accuracy over a wide range of operating conditions on both pure ethylene and gas mixtures.

Appendix F
Reference Data

F.1 Conversion tables

Parameter	Units	Converted Units
Length	1 inch 1 foot	= 25.4 mm = 0.3048 m
Mass	1 lb 1 ton	= 0.45359237 kg = 1016.05 kg
Density	lb/f^3 1 lb/gal 1 lb/US gal	= 16.0185 kg/m^3 = 99.7763 kg/m^3 = 119.8264 kg/m^3
Pressure	1 lb/in^2 1 atm 1 MPa 1 N/m^2 1 mm Hg (0°C) 1 mm WG (4°C) 1 in Hg (0°C) 1 in WG (4°C	= 68.9476 mbar = 1.01325 bar = 10 bar = 10 E-5 bar = 1.33322 E-3 bar = 98.0665 E-6 oar = 33.8639 E-3 bar = 2.49089 E-3 bar
Volume/Capacity	1 in^3 1 ft^3 1 gal 1 US gal 1 US barrel	= 16.8371 cm^3 = 0.0283168 m^3 = 4.54609 dm^3 = 3.78541 cm^3 = 0.158987 m^3
Volume Flow	1 ft^3/min 1 gal/min 1 US gal/min 1 US barrel/hr MCFM (USA) MMCFH (USA)	= 40.776 m^3/day = 6.5463 m^3/day = 5.4510 m^3/day = 3.8157 m^3/day = 679.6 m^3/day = 679.6 E3 m^3/day
Mass Flow	1 lb/hr 1 ton/hr	= 10.886 kg/day = 1016.05 kg/hr
Energy	1 BTU 1 kWh 1 therm	= 1.05506 kJ = 3.6 MJ = 105.506 MJ
Temperature	0°C x 1.8	= °F - 32
Viscosity (dynamic)	1 P 1 lb/ft/s or 1 pdl s/ft^2 1 slug/ft/s or 1 lbf s/ft^2	= 0.1 Pa s = 1.48816 Pa s = 47.8803 Pa s
Viscosity (kinematic)	1 St 1 ft^2/s	= 1 cm^2/s = 9.29030 dm^2/s

Notes: The **dynamic viscosity** (η) of a Newtonian fluid is given by: $\eta = \tau$ x dv/dr where r = shearing stress between two planes parallel with the direction of flow; dv/dr = velocity gradient at right angles to the direction of flow.

The dimensions of dynamic viscosity are $M L^{-1} T^{-1}$ and the SI unit is Pascal seconds (Pa s).

The **kinematic viscosity** (υ) is the ratio of the dynamic viscosity to the density ρ.

The dimensions of kinematic viscosity are $L^2 T^{-1}$ and the SI unit is square metres per second (m^2/s)

F.2 Product data

F.2.1 Platinum resistance law (to DIN 43 760)

°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms	°C	Ohms
-200	18.53	-210	14.36	-220	10.41				
-150	39.65	-160	35.48	-170	31.28	-180	27.05	-190	22.78
-100	60.20	-110	56.13	-120	52.04	-130	47.93	-140	43.90
-50	80.25	-60	76.28	-70	72.29	-80	68.28	-90	64.25
0	100.00	-10	96.07	-20	92.13	-30	88.17	-40	84.21
0	100.00	10	103.90	20	107.79	30	111.67	40	115.54
50	119.40	60	123.24	70	127.07	80	130.89	90	134.70
100	138.50	110	142.28	120	146.06	130	149.82	140	153.57
150	157.32	160	161.05	170	164.76	180	168.47	190	172.16
200	175.84	220	183.17	240	190.46	260	197.70	280	204.88

°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms	°F	Ohms
-200	18.53	-210	14.36	-220	10.41				
-150	39.65	-160	35.48	-170	31.28	-180	27.05	-190	22.78
-100	60.20	-110	56.13	-120	52.04	-130	47.93	-140	43.90
-50	80.25	-60	76.28	-70	72.29	-80	68.28	-90	64.25
0	100.00	-10	96.07	-20	92.13	-30	88.17	-40	84.21
0	100.00	10	103.90	20	107.79	30	111.67	40	115.54
50	119.40	60	123.24	70	127.07	80	130.89	90	134.70
100	138.50	110	142.28	120	146.06	130	149.82	140	153.57
150	157.32	160	161.05	170	164.76	180	168.47	190	172.16
200	175.84	220	183.17	240	190.46	260	197.70	280	204.88

F.2.2 Density of ambient air (in kg/m^3)

Air pressure (mb)	Air Temperature °C (°F)						
	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

Taken at a relative humidity of 50%

F.2.3 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									

Use pure, bubble free water

F.3 Physical properties of gas compounds

Compound	Formula	Molecular Weight (1)	Specific Gravity (2)
Hydrogen	H_2	2.01594	0.069600
Helium	He	4.00260	0.138189
Water Vapour	H_20	18.01534	0.621976
Nitrogen	N_2	28.01340	0.967157
Carbon Monoxide	CO	28.01055	0.967058
Oxygen	O_2	31.99880	1.104752
Argon	Ar	39.94800	1.379197
Carbon Dioxide	$C0_2$	44.00995	1.519435
Air (3)	-	28.96469	1.000000
Hydrogen Sulphide	H_2S	34.07994	1.176603
Methane	CH_4	16.04303	0.553882
Ethane	C_2H_6	30.07012	1.038165
Propane	C_3H_8	44.09721	1.522447
I-Butane	C_4H_{10}	58.12430	2.006730
N-Butane	C_4H_{10}	58.12430	2.006730
I-Pentane	C_5H_{12}	72.15139	2.491012
N-Pentane	C_5H_{12}	72.15139	2.491012
Hexane	C_6H_{14}	86.17848	2.975294
Heptane	C_7H_{16}	100.20557	3.459577
Octane	C_8H_{18}	114.23266	3.943859

Notes:

1. Based upon 1961 atomic weights, referred to Carbon-12 Isotope (12 AMU), recommended by the International Commission of Atomic Weights and the International Union of Pure and Applied Chemistry.

2. Perfect gas specific gravity represents the ratio of molecular weight of compounds to the molecular weight of air.

3. Molecular weight of air based upon components of atmospheric air given *in Handbook of Chemistry and Physics*, 53rd Edition (1972-1973). Value of 28.96469 differs from Figure 28.966 provided by NBS Circular 564 due to minute differences in component content and changes in atomic weights of the elements given in 1961; (NBS value based upon 1959 atomic weights).

The **Relative Density** of mixed hydrocarbon gases at 14.735 lb/in^2 absolute and 60°F by empirical equation is:

$$\rho_\gamma = 0.995899G = 0.010096G^2$$

Where: $G = \frac{M_G}{M_A}$

M_G = Molecular weight of gas (or gas mixture)

M_A = Molecular weight of dry air

F.4 Useful equations

If $\rho = K0 + K1\tau + k2\tau^2$

Then $\tau = \dfrac{-K1 + \sqrt{K1^2 - 4K2(K0 - \rho)}}{2K2}$

Derivation of the constants K0, K1 and K2 given three points,

ρ_A at τ_A, ρ_B at τ_B, ρ_c at τ_c.

$$K2 = \frac{(\rho_C - \rho_A)(\tau_B - \tau_A) - (\rho_B - \rho_A)(\tau_C - \tau_A)}{(\tau_C{}^2 - \tau_A{}^2)(\tau_B - \tau_A) - (\tau_B{}^2 - \tau_A{}^2)(\tau_C - \tau_A)}$$

$$K1 = \frac{(\rho_B - \rho_A) - K2(\tau_B{}^2 - \tau_A{}^2)}{(\tau_B - \tau_A)}$$

$$K0 = \rho_A - K1\tau_A - K2\tau_A{}^2$$

Appendix G
Return Policy

G.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.

G.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.

G.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.

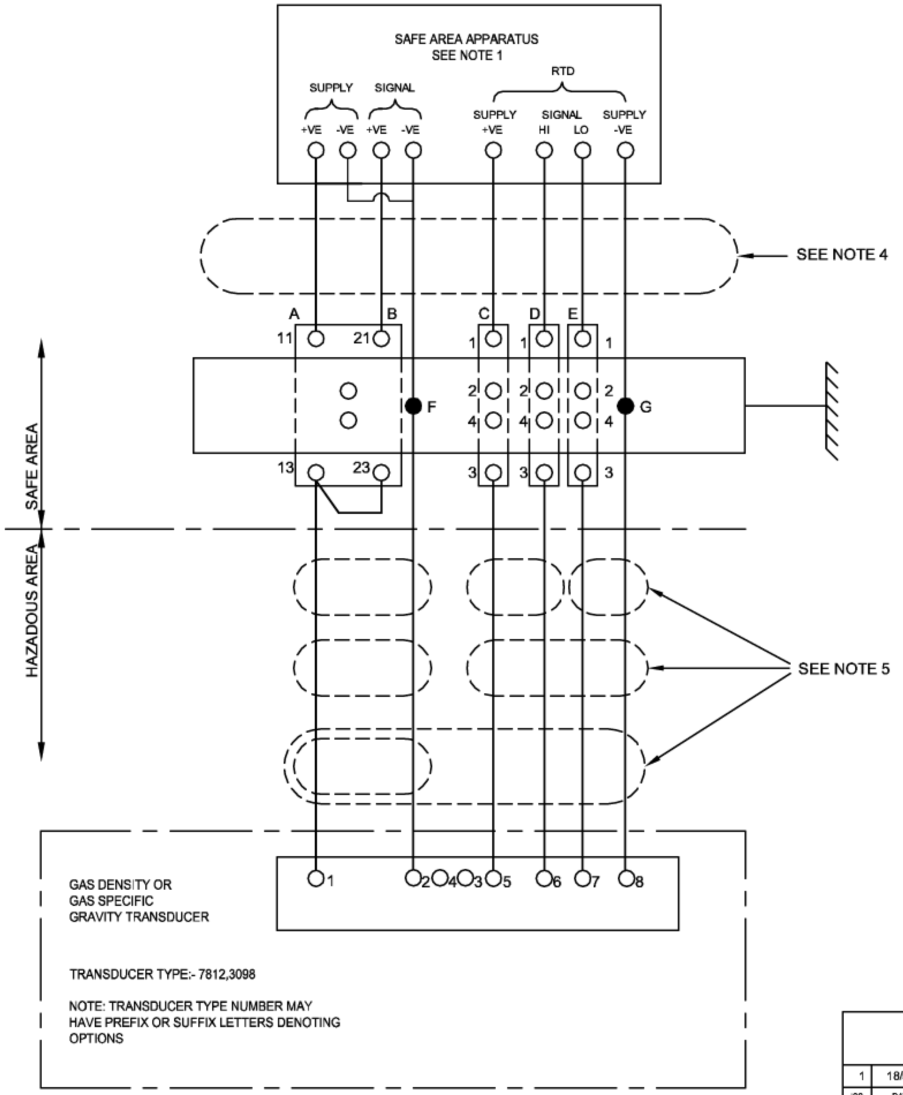
Used equipment must be accompanied by a completed Return Materials Authorization form and a Decontamination Statement for all process fluids that have been in contact with the equipment. If a Decontamination Statement cannot be completed (for example, for food-grade process fluids), you must include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

Appendix H Certified System Drawings

H.1 GENERAL

All certified drawings in this manual are given here for planning purposes only. Before commencing with implementation, reference should always be made to the **current issue** of the certified drawings. Contact the factory for further details.

No.	Drawing Reference	Description
1.	78125039A Sheet 1 of 4	CSA System Drawing, Gas Groups A, B, C and D (2-Wire Option) Shunt Diode Barrier
2.	78125039A Sheet 2 of 4	CSA System Drawing, Gas Groups A, B, C and D (3-Wire Option) Shunt Diode Barrier
3.	78125039A Sheet 4 of 4	CSA System Drawing, Gas Groups A, B, C and D (2-Wire Option) Isolated Interface Units
4.	78125039A Sheet 4 of 4	CSA System Drawing, Gas Groups A, B, C and D (3-Wire Option) Isolated Interface Units



NOTES

1. SAFE AREA APPARATUS IS UNSPECIFIED EXCEPT THAT IT MUST NOT BE SUPPLIED FROM NOR CONTAIN IN NORMAL OR ABNORMAL CONDITIONS A SOURCE OF POTENTIAL WITH RESPECT TO EARTH IN EXCESS OF 250 VOLTS RMS OR 250 VOLTS DC.
2. BARRIERS C,D AND E ARE ALL OPTIONAL. REMOVAL OF THESE AND THE ASSOCIATED CABLING DOES NOT EFFECT THE SYSTEM SAFETY.
3. THIS INSTALLATION MUST COMPLY WITH CANADIAN ELECTRICAL CODE (CEC) PART 1.
4. IN AN ELECTRICALLY NOISY ENVIRONMENT THE CABLE IN THE SAFE MAY BE SCREENED.
5. A MULTI-CORE CABLE, MAY BE USED FOR GAS GROUPS A,B,C PROVIDED THE CABLE IS SCREENED IN ACCORDANCE WITH THE FOLLOWING METHOD.
   - 5.a. ALL WIRES ARE INDIVIDUALLY SCREENED.
   - 5.b. WIRES ARE SCREENED AS PAIRS/THREES AS SHOWN.
   - 5.c. WIRES ARE SCREENED AS A PAIR AND QUAD AS SHOWN.
   - 5.d. THE OUTPUTS FROM BARRIERS 'A' & 'B', MAY BE INDIVIDUALLY SCREENED OR SCREENED TOGETHER WITH AN OVERALL SCREEN AS SHOWN.

   IN ALL CASES THE CABLE SCREENS MUST BE EARTHED ONLY AT THE BARRIER.
   THE INSULATION MATERIAL BETWEEN SCREENS MUST BE OF SUFFICIENT QUALITY TO WITHSTAND A BREAKDOWN WHEN A VOLTAGE OF 500VDC IS APPLIED ACROSS THEM.
6. ALL BARRIERS TO BE CSA CERTIFIED.

BARRIER	VOLTAGE RATING	POLARITY
A	28V 300 Ω	POSITIVE
B	28V DIODE	POSITIVE
C	12V 1KΩ	POSITIVE
D	12V 1KΩ	POSITIVE
E	12V 1KΩ	POSITIVE

   INSTALLATION SHALL ALSO MEET BARRIER INSTALLATION DRAWING
7. EARTH GROUND IS TO BE LESS THAN 1 OHM.
8. THE ELECTRICAL CIRCUITS IN THE HAZARDOUS AREA MUST BE CAPABLE OF WITHSTANDING AN AC TEST VOLTAGE OF 500 VOLTS RMS TO EARTH OR FRAME OF THE EQUIPMENT, FOR A PERIOD OF 1 MINUTE WITHOUT BREAKDOWN.
9. SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.

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MICRO MOTION DIVISION

DIMENSIONS IN MM UNLESS STATED OTHERWISE
DIMENSIONS IN BRACKETS [ ] ARE INCHES

TITLE:- SYSTEM DRAWING (CSA)
GAS GROUPS A,B,C,D
(2 WIRE OPTION)SHUNT DIODE BARRIERS

ISS	DATE	CHANGE NOTE	NAME
1	18/5/07	ST5540	GP

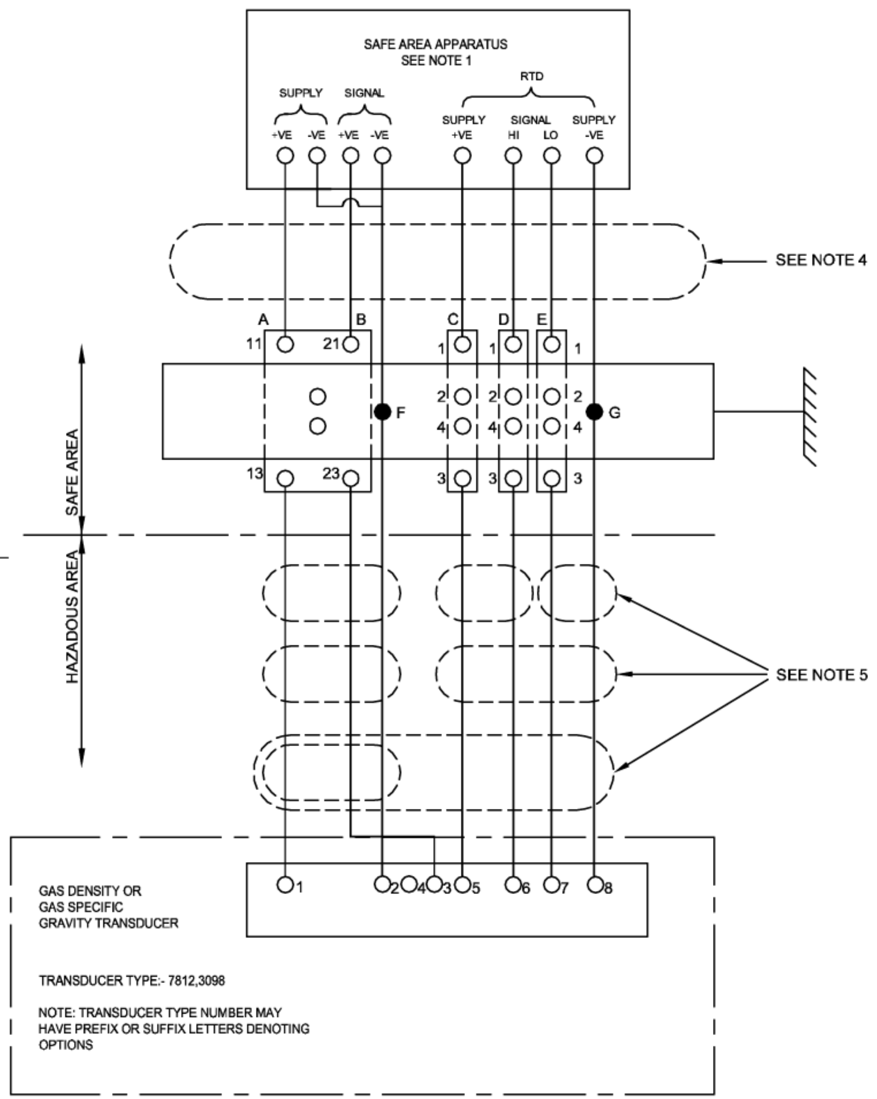
THIRD ANGLE PROJECTION

MODEL NUMBER: 78125039A

SIZE A3 | DRAWN | NAME GP | DATE 18/5/07

DO NOT SCALE DRAWING | SHEET 1 OF 4

Drawing 78125039A Sheet 1 of 4: CSA System Drawing, Gas Groups A, B, C and D (2-Wire Options) Shunt Diode Barriers



NOTES

1. SAFE AREA APPARATUS IS UNSPECIFIED EXCEPT THAT IT MUST NOT BE SUPPLIED FROM NOR CONTAIN IN NORMAL OR ABNORMAL CONDITIONS A SOURCE OF POTENTIAL WITH RESPECT TO EARTH IN EXCESS OF 250 VOLTS RMS OR 250 VOLTS DC.

2. BARRIERS C,D AND E ARE ALL OPTIONAL. REMOVAL OF THESE AND THE ASSOCIATED CABLING DOES NOT EFFECT THE SYSTEM SAFETY.

3. THIS INSTALLATION MUST COMPLY WITH CANADIAN ELECTRICAL CODE (CEC) PART 1.

4. IN AN ELECTRICALLY NOISY ENVIRONMENT THE CABLE IN THE SAFE AREA MAY BE SCREENED.

5. A MULTI-CORE CABLE, MAY BE USED FOR GAS GROUPS A,B,C PROVIDED THE CABLE IS SCREENED IN ACCORDANCE WITH THE FOLLOWING METHOD.

   5.a. ALL WIRES ARE INDIVIDUALLY SCREENED.
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   5.d. THE OUTPUTS FROM BARRIERS 'A' & 'B', MAY BE INDIVIDUALLY SCREENED OR SCREENED TOGETHER WITH AN OVERALL SCREEN AS SHOWN.

   IN ALL CASES THE CABLE SCREENS MUST BE EARTHED ONLY AT THE BARRIER.
   THE INSULATION MATERIAL BETWEEN SCREENS MUST BE OF SUFFICIENT QUALITY TO WITHSTAND A BREAKDOWN WHEN A VOLTAGE OF 500VDC IS APPLIED ACROSS THEM.

6. ALL BARRIERS TO BE CSA CERTIFIED.

BARRIER	VOLTAGE RATING	POLARITY
A	28V 300Ω	POSITIVE
B	28V DIODE	POSITIVE
C	12V 1K Ω	POSITIVE
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9. SUBSTITUTION OF COMPONENTS MAY IMPAIR INTRINSIC SAFETY.

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DIMENSIONS IN BRACKETS [ ] ARE INCHES

ISS	DATE	CHANGE NOTE	NAME
1	18/5/07	ST5540	GP

THIRD ANGLE PROJECTION

SIZE A3 | DRAWN | NAME GP | DATE 18/5/07

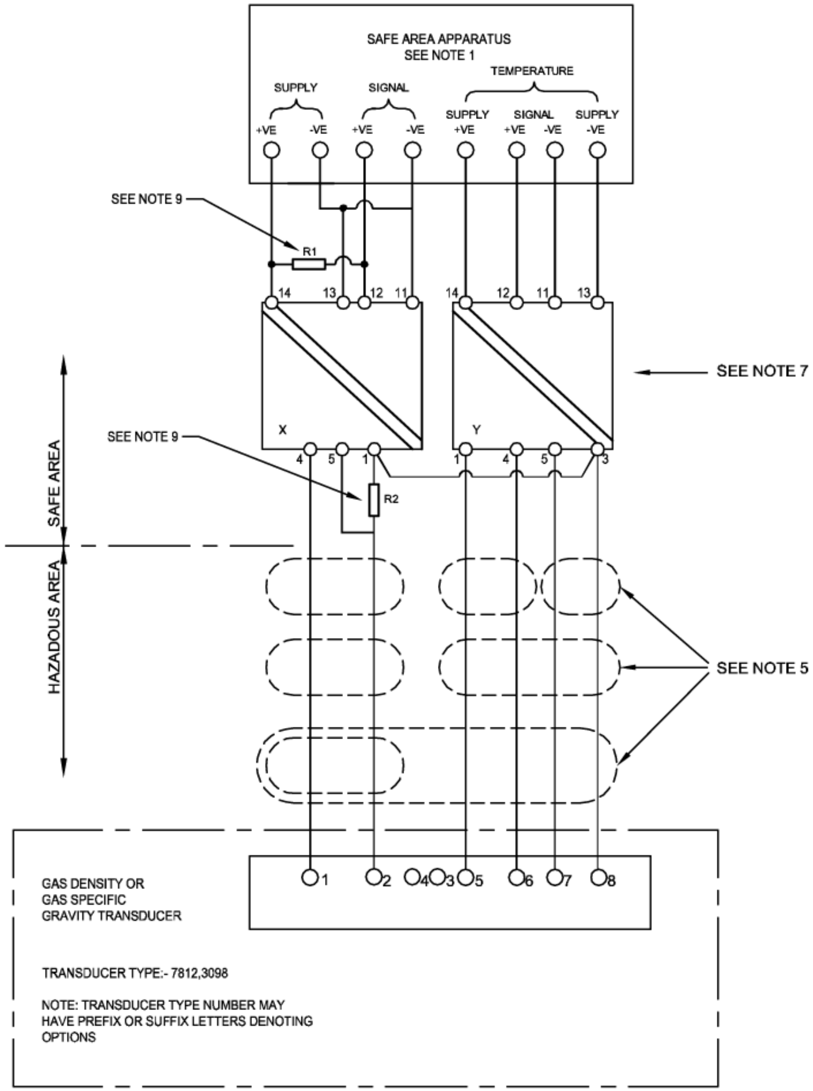
TITLE:- SYSTEM DRAWING (CSA)
GAS GROUPS A,B,C,D
(3 WIRE OPTION)SHUNT DIODE BARRIERS

MODEL NUMBER: 78125039A

DO NOT SCALE DRAWING

SHEET 2 OF 4

Drawing 78125039A Sheet 2 of 4: CSA System Drawing, Gas Groups A, B, C and D (3-Wire Options) Shunt Diode Barriers



NOTES

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2. INTERFACE UNIT Y IS OPTIONAL. REMOVAL OF THIS AND THE ASSOCIATED CABLING DOES NOT AFFECT THE SYSTEM SAFETY.

3. THIS INSTALLATION MUST COMPLY WITH CANADIAN ELECTRICAL CODE (CEC) PART 1.

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6. ALL INTERFACE UNITS TO BE CSA CERTIFIED.

UNIT	CIRCUIT	SAFETY DESCRIPTION
X	SIGNAL	28V 94mA
Y	PRT	6.6V 76mA

INSTALLATION SHALL ALSO MEET BARRIER INSTALLATION DRAWING

7. EARTH GROUND IS TO BE LESS THAN 1 OHM.

8. BECAUSE THE POWER SUPPLIES HAVE ISOLATION THE ELECTRICAL CIRCUIT INTHE HAZARDOUS AREA NEED NOT BE CAPABLE OF WITHSTANDING AN AC TEST VOLTAGE OF 500 VOLTS RMS TO EARTH OR FRAME OF THE EQUIPMENT, FOR A PERIOD OF 1 MINUTE WITHOUT BREAKDOWN.

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10. TYPICAL RESISTOR VALUES: R1=2K, R2=200R.

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TITLE:- SYSTEM DRAWING (CSA)
GAS GROUPS A,B,C,D
(2 WIRE OPTION)ISOLATING I'FACE UNITS

ISS	DATE	CHANGE NOTE	NAME
1	18/5/07	ST5540	GP

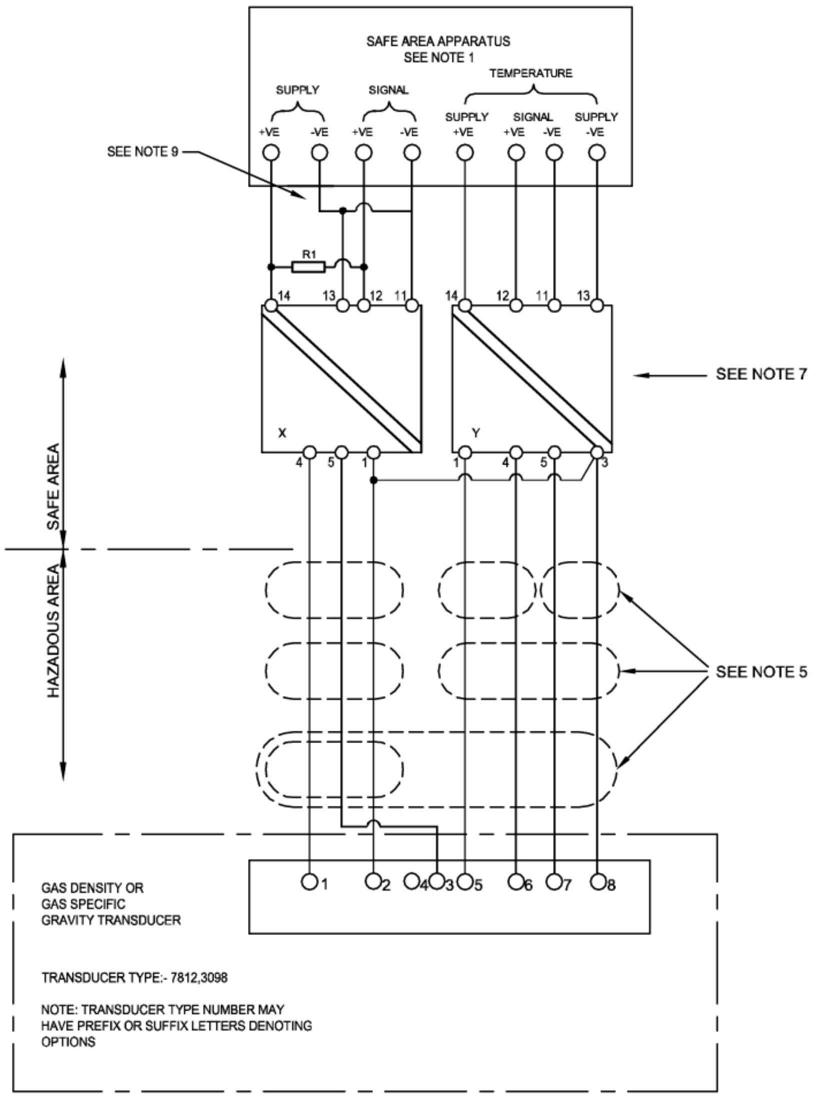
THIRD ANGLE PROJECTION

MODEL NUMBER: 78125039A

SIZE A3 | DRAWN | NAME GP | DATE 18/5/07

DO NOT SCALE DRAWING | SHEET 3 OF 4

Drawing 78125039A Sheet 3 of 4: CSA System Drawing, Gas Groups A, B, C and D (2-Wire Options) Isolating Interface Units



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INSTALLATION SHALL ALSO MEET BARRIER INSTALLATION DRAWING

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1	18/5/07	ST5540	GP

THIRD ANGLE PROJECTION

MODEL NUMBER: 78125039A

SIZE A3 | DRAWN | NAME GP | DATE 18/5/07

DO NOT SCALE DRAWING

SHEET 4 OF 4

Drawing 78125039A Sheet 4 of 4: CSA System Drawing, Gas Groups A, B, C and D (3-Wire Options) Isolated Interface Units

Micro Motion® 7812

P/N MMI-20018377, Rev. AA

Micro Motion Inc. USA
Worldwide Headquarters
7070 Winchester Circle
Boulder, CO 80301
T +1 303-527-5200
+1 800-522-6277
F +1 303-530-8459
www.micromotion.com

Micro Motion Slough
Emerson Process Measurement
158 Edinburgh Avenue,
Slough, Berks, SL1 4UE, UK
T +44 1753 756600
F +44 1753 823589

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Process Management