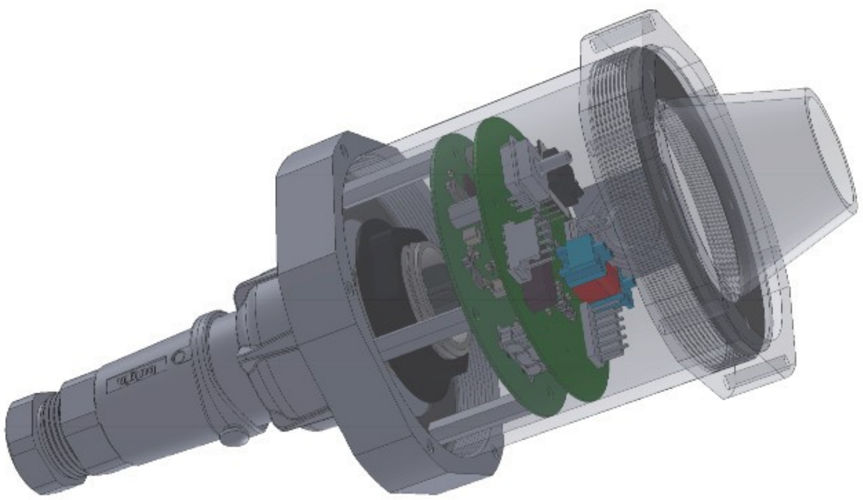
PERCEPTION

SENSORS AND INSTRUMENTATION

PSI-2 FLOW MONITOR

Operation Instructions



PSI2MKII

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1. INTRODUCTION

New Generation PSI2

The new generation PSI2 instrument is fully configured and calibrated by either the RS485 serial communication port operating the Modbus protocol, or via the USB service port. The RS485 allows communication over several kilometres, whilst the USB port is for local use only.

The RS485 is configured for multi-drop installations, allowing up to 32 instruments to be installed on a single bus. Configuration and interrogation of the PSI2 can be performed using the PC based software supplied over the USB or RS485 or via a DCS system over the RS485 provided by the plant.

One analogue output provides isolated 4-20mA current loop which can be configured to output any measured or calculated value from the PSI2.

Mounting

The PSI2MKII is a differential pressure driven measurement system tolerant to both moisture and water droplets. However the installation must take into account that any water droplets or condensate be allowed to drain out of the Pitot tube.

In **horizontal duct** applications the Pitot should be installed such that it is sloping down by a minimum of 5°, that is above 5° from the horizontal as shown below:-

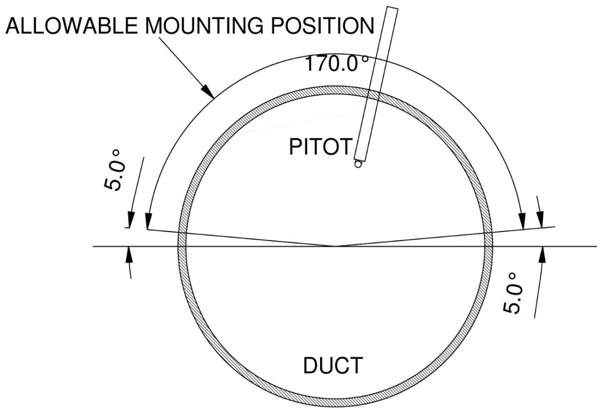

Figure a

Text 1: Horizontal duct applications

In high water content applications the Pitot should be positioned as close to the vertical facing down as practical to ensure that water droplets or condensate will flow out rather than remain in the Pitot. *Note – this is even more important if the gas stream is both wet and aggressive.*

For **vertical ducts** where the flow is rising the aforementioned 5°rule again applies unless the gas stream is dry with no risk of condensate.

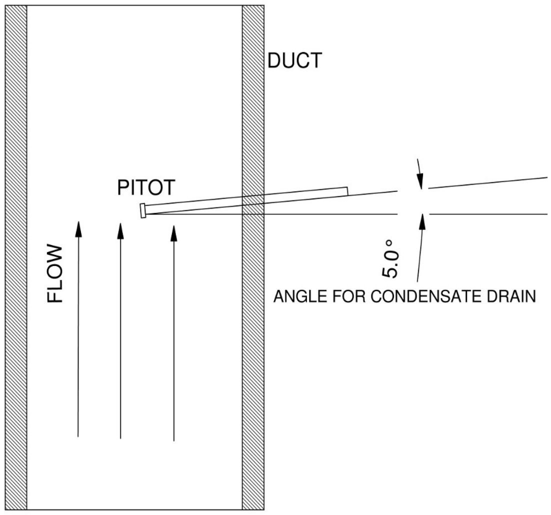

Figure b: Vertical ducts with flow rising

For dry gasses it may be permissible for the probe to be mounted horizontally, however beware as this may causes longer term problems with dust or other foreign bodies.

The most challenging mounting applications are vertical ducts with flow travelling down, driving water and dust into the Pitot entry port and resulting in no available drain. In such applications backpurge must be employed to periodically clean the Pitot tube of condensate. *Note - Contact your local distributor for advice on these applications.*

In **all** installations the Pitot should never be mounted below the horizontal
to prevent the possibility of contaminants flowing into the fine bore impulse tubes within the electronic housing. Should this occur it would result in significant errors which may be unpredictable due to the nature of the surface tension of the water droplets within the tubes.

In very high water content applications with the constant presence of water droplets please consult the local distributor as a wide bore Pitot may be required. This would give the opportunity for additional water drainage from the Pitot tip.

In highly aggressive gas applications, for example sour biogas, additional chemical filtering is required within the PSI2MKII transducer housing. These filters are essential to ensure that the transducer remains non corrosive, they will only need replacing after several years.

Components of the PSI2

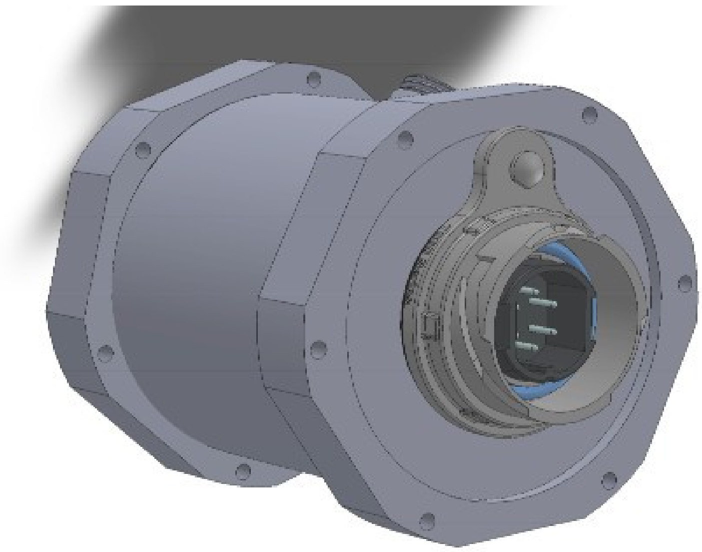

Illustration i: IP69K Stainless Steel Enclosure

The new generation PSI2 is housed in a stainless steel enclosure, sealed to IP69K and the instrument is rated with a continuous ambient temperature rating of 70°C.

An integral pitot tube provides the primary input to the instrument. A range of standard length S type or Averaging pitot tubes are available; if required customer specified length pitots are available to order. The pitot tubes are rated to operate at 700°C continuously but higher temperatures are available on request.

A 6-pole field connector provides connections for power, analogue current loop and RS485 Modbus interface. This connector is rated to IP69K and is screw terminated. A second connector is provided for a USB configuration port but this is not intended for normal operation but purely as an in-the-field service port allowing full service and configuration capabilities without disturbing the field connector.

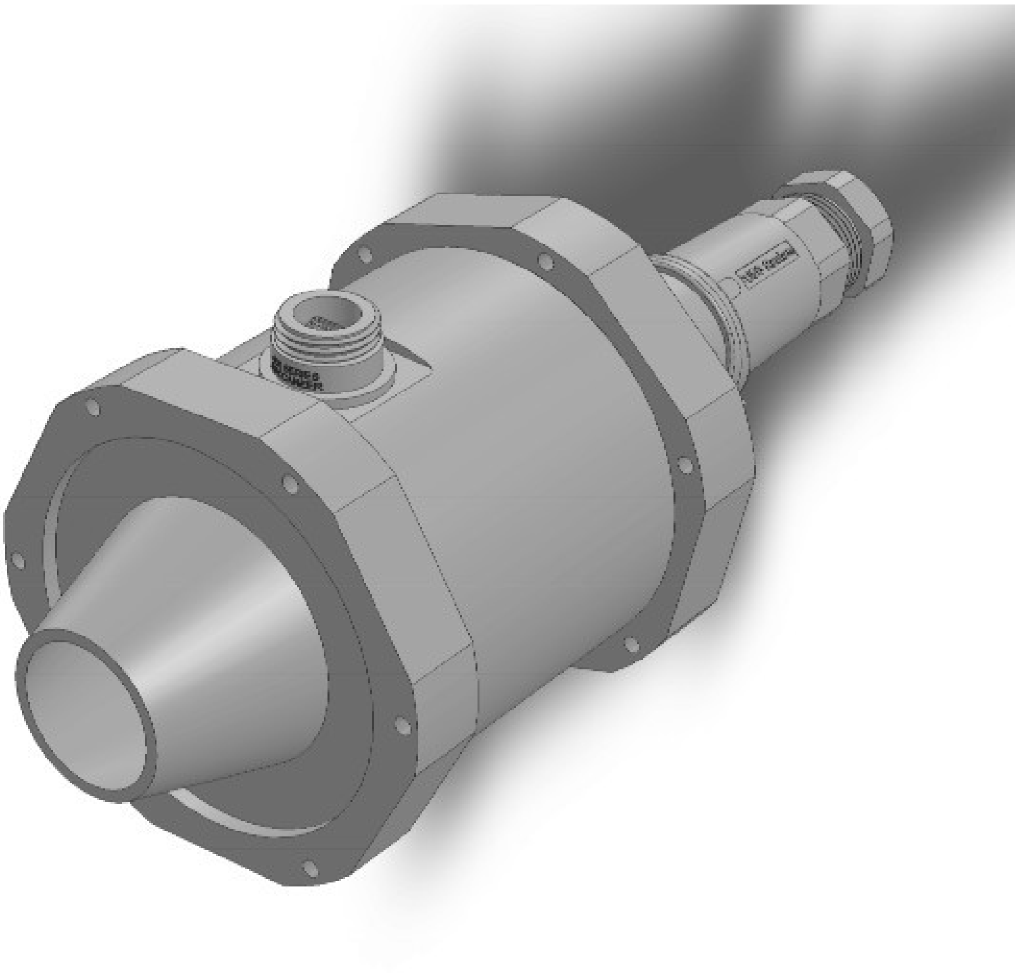

Illustration ii: PSI2MK11 USB Connector

The instrument is partially powered by the USB connector allowing system configuration and transducer testing without the need for external power.

The PSI2 may also be used in conjunction with a Laptop computer to perform flow profile analysis, in this mode only the USB connection is required.

Software and interface functions

Once configured the new generation PSI2 can operate in stand-alone mode where the only output is a simple 4-20mA current loop analogue signal. The simplest method for configuration into this mode is by using the USB port connected to a PC or Laptop computer running the PSI Freeflow software. This allows the instrument to be fully configured on the bench without the requirement of any other connection. Once configured the instrument can be installed and will report any one of the measured parameters, for example, mass flow over the 4-20mA current loop. Once installed the instrument is able to be reconfigured by connection to the USB port.

For installations where either analogue outputs are not required and Modbus systems are available the instrument can be fully configured and operated over the Modbus RTU interface. This provides high speed access to all configuration registers and variables. The maximum distance for the RS485 interface is 1.2Km. The device address, baud rate and parity are programmable with the maximum recommended data rate at 1.2Km of 200K baud. It is possible to configure the capture of the eight primary readings of temperature, pressures and flows with full update rates or approximately 5 updates per second.

All interface types are available concurrently. This allows installation examples were the primary analogue output is assigned to mass flow. The analogue output being used for process control. The Modbus interface is used to gather information on the plant DCS system and provide system configuration. The USB service port is available at all times giving concurrent access to all configuration and measured parameters.

When the USB service port is in operation the Modbus interface is locked into read only mode. The USB interface now acts as the master and provides all of the control and configuration functionality. Disconnection of the USB re establishes full access via the Modbus interface.

2. FUNCTIONS & COMPONENTS

The PSI2 comprises of:

A pitot tube, providing a source of pressure which varies by the square root function with gas velocity and incorporates an embedded thermocouple for the measurement of the process gas temperature. The absolute pressure of the process gas is derived from the absolute pressure of the low pressure pitot port plus a proportion of the elevated pressure on the positive pressure port.

The instrument housing which holds the electronics, comprising of differential pressure transducer, absolute pressure transducer, and thermocouple amplifier, also associated micro electronics for signal processing and communications. A current loop output is provided as the primary output of the instrument.

To derive the velocity of the gas flow, the temperature and pressure of the gas must be known to allow the calculation of the velocity from the differential pressure (see equation 1).

The molecular weight of the gas must also be known. This is calculated from the table j and entered as part of the configuration. Based on the information provided to the PSI2 and it's measured values, the velocity of the gas at the ports of the pitot tube can now be calculated by the instrument.

For volumetric flow the cross sectional area of the duct is entered in the configuration section of the PSI2 allowing volumetric flow to be calculated. In many applications the volumetric flow needs to be reported in a normalised form. This is where the volumetric flow is calculated as if the gas was at a standard temperature and pressure. As the temperature and pressure of the gas is measured the normalised volumetric flow can be calculated by the PSI2.

If required, mass flow can be calculated by the PSI2 using the volumetric flow, temperature, pressure and molecular weight data. All of the aforementioned measurements and calculations are available simultaneously from the PSI2 over the Modbus interface. Any one parameter can be directly outputted over the current loop interface.

In some applications the gas flow rate must be reported on a dry basis. The PSI2 is able to do this by configuring the typical amount of water vapour in the process; the calculations will then be based on the flow rate compensated by removing the water vapour present.

The PSI2 is therefore capable of reporting flow rates in many different forms depending on the end user requirement as either a stand alone transmitter or part of a more complex system.

Units

For end user flexibility several different units of measurement can be selected for the required parameters, i.e., temperatures, pressures, flow rates and areas. For the measurement or configuration of a parameter with a specific unit of measurement then the value comprises of two parts. Firstly the parameter value is held and reported as a floating point number represented as a 32BIT IEEE 754 floating point, and secondly the actual unit of measurement for the reported value is determined in the unit selection register assigned for that specific parameter. Tables a-f show the parameter names and addresses of the register pairs along with the unit selection value.

For example, assume the volumetric flow is to be reported as m3/h and the duct area entered in cm2. The value at Modbus address 121 would be 2 indicating that volumetric flow is to be reported in m3/h and the value at Modbus address 124would be 1 indicating the area unit for the duct size is cm2. A Value of 129 in Modbus address 6 would then indicate to the PSI2 that the duct area is 129cm2. It is therefore important that when configuring the PSI2 over Modbus that both the actual value and the unit selection are taken into account, the parameter value alone does not give all the information. Internally the PSI2 bases all measurements and calculations on SI units, selecting cm2 as a unit only effects the user interface number for user convenience. Selecting the units on such as duct area has no impact on the output units, these are selected independently.

Auto zero

The accuracy of any differential pressure based flow measurement is dominated by the square law nature of the velocity pressure relationship. At low or even moderate flow rates the differential pressure is very low. For this reason the accuracy of low velocity measurements is dominated by transducer zero error. The PSI2 employs both hardware and software temperature compensation for both offset and span, but additionally employs a physical auto zero function. The auto zero employs a pneumatic solenoid that disconnects one of the pressure ports of the differential pressure transducer and connects it to the other. The disconnected pitot port is blanked off to prevent the flow of process gas. The differential pressure transducer is thus connected to the process pressure but without any differential pressure across the transducer. The zero function can then remove any offset errors from the transducer. This method has the advantage that all zero errors are calibrated out including any offset errors that are produced as a result of common mode pressure.

The auto zero can be set to three states, off, timed and auto. In the off state no auto zero will take place. In the timed state the auto zero will be performed based on the time set in the zero interval timer. This timer is set in minutes with a minimum of 1 minute and a maximum of 65536 or just over 45 days. The default is 60 (1 hour). In auto mode the zero calibration is triggered when the PSI2 calculates the optimal time. This is calculated based on the most recent calibration results and the current differential pressure. If the sensor has shown signs of significant changes in zero offset and/or the flow rate is low then the zero calibration can be expected to be performed more frequently. At high flow rates the zero will have little impact on the measurement so will be performed less frequently. In auto mode the interval time sets the minimum interval between calibrations.

During zero calibration the analogue output can be selected to track the results such that as the zero occurs the analogue output follows the result. With this setting the outputs for differential pressure, velocity, volumetric flow, normalised volumetric flow and mass flow will all follow the calibration. Static pressure and temperature measurement will not change. This mode can be useful when the amount of drift needs to be observed for each calibration. If the instrument is used for process control, the analogue output can be locked just before the start of the calibration and released at the end of the calibration. The impact on the control system would then be minimised. In all instances the offset error can be read over the digital communications interfaces.

In order to reduce the calibration time to a minimum the instrument will adjust the calibration duration such that as soon as the transducer has settled the calibration is performed and the instrument returned to normal operation.

A zero calibration can be triggered at any time by setting the zero calibration trigger bit from one of the digital interfaces. This allows control of the calibration from the plant DCS where the DCS can select the most appropriate time for calibration.

Fault indication

In normal operation the analogue output is configured for 4-20mA for 0 to 100% full scale. Under fault conditions the analogue output can be forced to three alternate states 0,2 and 22mA. These alternate states are mapped to the fault mapping registers. For example, an instrument over range can be mapped to 22mA and all other errors mapped to 2mA, leaving 0mA for power fail indication. This is the default setting.

Flow direction

The differential pressure transducer is designed such that one port is more tolerant to over pressure than the other. For this reason one side of the pitot tube is indicated as the positive pressure port and should face into the direction of flow. In some applications flow reversal can occur. For these applications the analogue output can be set to mid scale (12mA)=0 flow rate with negative direction reducing the current to 4mA at full scale and positive flow increasing the current to 20mA full scale. The direction of flow is indicated as a negative value on all digital interfaces for flow flowing in the opposite direction to the normal flow.

Response time

The PSI2 makes several hundred measurement and calculation every second. This allows the instrument to be used in applications where rapid response for control purposes is required. However in many applications the flow is very turbulent and erratic. For these applications the response time of the instrument can be set in ms. This is the time taken to reach 90% of a step change. The filtering is performed with a third order filter which gives significant benefits in removing high frequency turbulence without significantly slowing the overall response of the instrument. The time constant for temperature measurement is fixed and is optimised for fast response while measurement noise is less than 0.1°C. The response time is set by the Damping register.

Linearisation

In ducts, the velocity profile may change with velocity of gas. For most flow measuring devices this change in velocity profile will affect the reported velocity, and is the case for single point measurement systems or line measurements. This is primarily because most flow monitors do not take area into account. The PSI2 employs a linearisation technique to overcome these problems, to ensure that it reports the correct velocity (within the range it has been calibrated in).

Assume the PSI2 reads the velocity with no errors but independent tests performed at low, medium and high flow rates show the total area flows obtained by flow profiling change with respect to the PSI2, as in Fig 5.

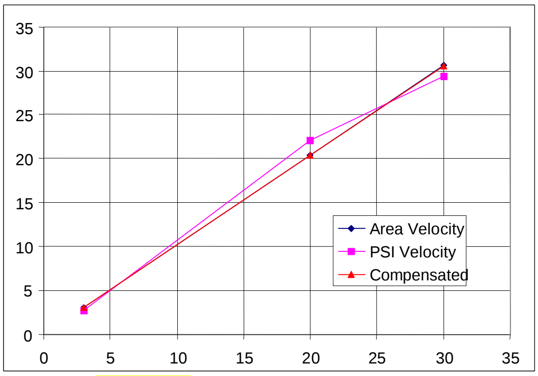

Figure 5 – Linearisation graph

Three error points are then available. In Fig 5 the PSI2 reads low at 3m/s, high at 20m/s and low again at 30m/s.

When all the velocity readings are in-putted to the PSI2, it calculates and applies a spline fit curve correction to the readings such that the three calibration points agree. A forth default condition that zero velocity produces zero flow is used to provide a forth linearisation point at zero.

The table below shows the compensated results generated by this method. The compensation factors a, b and c are displayed in the Linearisation dialogue box, along with the velocity readings.

Measured Area Velocity	Reported PSI2 Velocity	Linearisation Coefficient	Low Coefficient	Mid Coefficient	High Coefficient
3.1	2.7	B	0.839026	0.934851	0.916117
20.4	22.1	C	0	0.0309113	-0.0294752
30.6	29.4	D	0.00332379	-0.00116352	0.000961241

The Linearisation dialogue box allows compensation to be calculated from three different flow rates. As the function of the linearisation compensation is to ensure the velocities reported by the PSI2 are accurate and repeatable over the velocity range of the installation, it is necessary to sample velocities at minimum, maximum and normal running conditions. Although the linearisation compensation cannot be implemented until all three velocity regimes have been sampled, there is no time limit between recording results. For each velocity an average reading from the PSI2 must be stored, along with the actual reading measured by another instrument. Once all three velocities have been measured, the compensation routine can be implemented. The Linearisation dialogue box screen is as shown below in Fig 6.

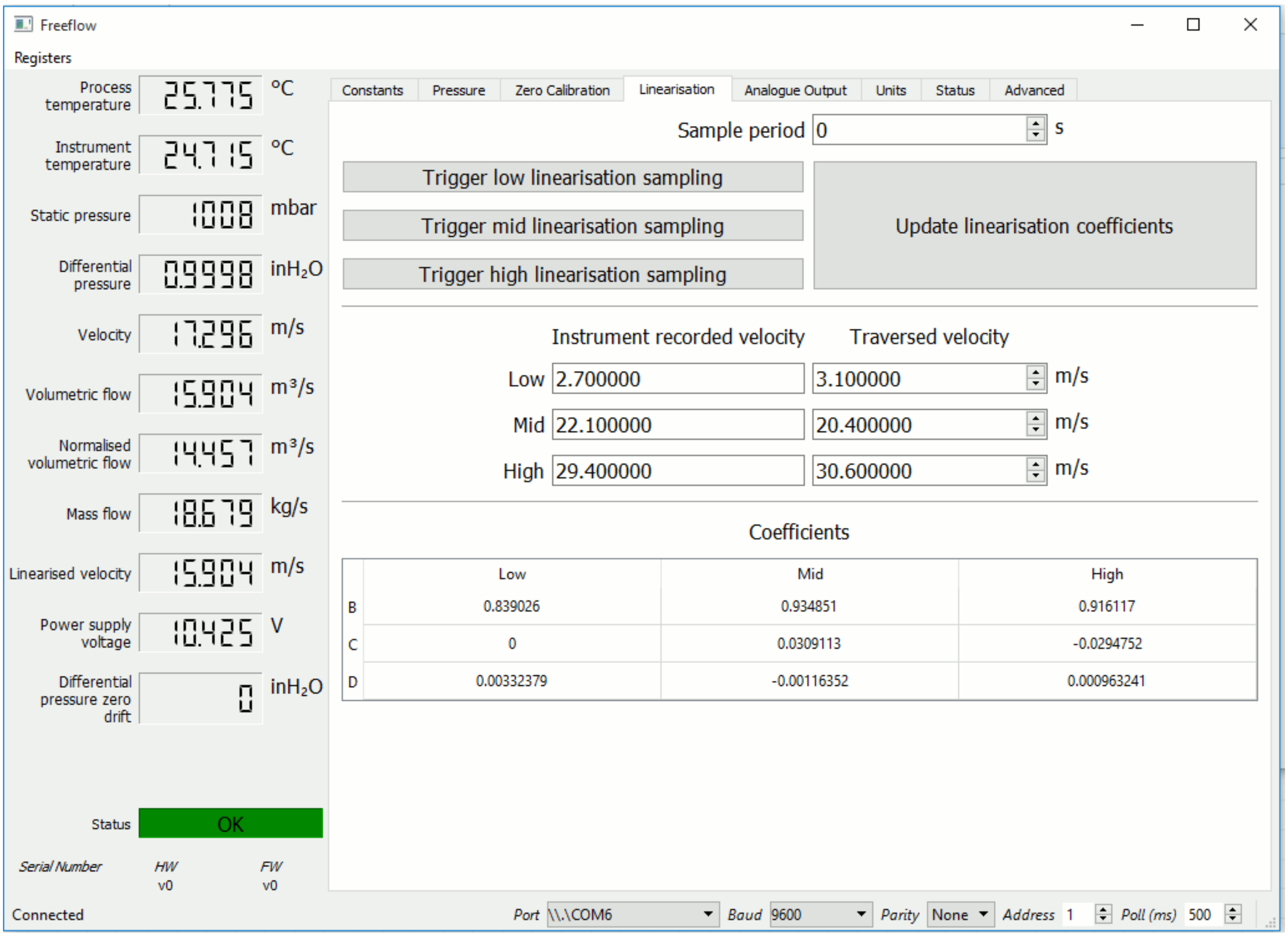

Fig 6 – Linearisation Panel

The Linearisation process;

- Click the “Set Sample Time” box and enter the required sample time, in seconds. This sets how long the velocity will be measured and averaged over.
- When the duct velocity is at its lowest point click the “Start” button. This sets the Time Remaining value to the sample time and starts counting down and logging. When the sample time elapses, the average velocity over the measured time period is displayed.
- Click one of the “Change Low” buttons and enter the velocity as reported by an independent velocity meter.
- Repeat the above for the Med and High velocities.
- Once all the velocities have been entered, click the “Update Calibration Coefficients” button. This performs the linearisation and updates the b, c and d coefficients displayed.

Further alterations to the linearisation compensation can be performed by altering any or all of the velocities and clicking the “Update Calibration Coefficients” button.

3. OPERATION FOR FLOW PROFILING

In order to achieve full accuracy and perform zero calibrations at the start of each measurement the instrument must be powered from an external supply over the field connector. The supply can be anything between 9 volts and 30 volts and only requires a few milliamps. As the PSI2MKII is a self contained unit the Pitot tip can be placed in several positions as outlined in the appropriate guidelines for flow profiling. To take a point reading, place the Pitot in the appropriate position and select the linearising function on the PC. Trigger one of the low, mid or high linearisation samples. Wait for the appropriate time and stop the sampling by pressing the button again. The average velocity for that point in the duct is then displayed in the instruments' recorded velocity for the selected range. Record the result and move the Pitot to the next location. Repeat the process for all the required sampling points.

4. CALCULATIONS

The PSI2 is a powerful flow computer as well as a measuring system for pressures and temperatures. The calculations performed by the PSI2 are as follows:-

Velocity

The basic formula employed by the flow computer is:

$$V = K \times C \times \sqrt{\Delta P} \times \frac{\sqrt{Tp+273}}{\sqrt{M \times P}}$$

Equation 1

where

V	=	Process gas velocity (m/s)
K	=	Pitot tube velocity constant (128.939)
C	=	Velocity pressure coefficient (for S-type Pitot=0.84) (dimensionless)
$\sqrt{\Delta P}$	=	Square root of differential pressure of Process gas (Pascal)
Tp	=	Process temperature (ºC)
P	=	Absolute process gas pressure (Pascal)
M	=	Molecular weight of process gas, wet basis (g/g mole)

Detailed Description of Variables

K is the velocity constant for pitot tubes and is internally set to 128.939

C is the velocity pressure coefficient and for S type pitot tubes is around 0.84. This parameter should be adjusted for the individual pitot tubes used in the specific application. This is normally supplied via a calibration certificate.

ΔP is measured by an on board differential pressure transducer and is reported in Pascal

Tp is the process temperature measured via an external K type thermocouple and is reported in ºC

P is the absolute process pressure and is measured with the on board pressure transducer and is expressed in Pascal

Molecular Weight

M is the molecular weight of the process gas on a wet basis in g/g mole. To calculate this value the components of the process gas must be known. In general the main components are CO_2, O_2 and N_2, plus water. The dry weight is calculated by:

$$Mdry = 44\frac{\%CO_2}{100} + 32\frac{\%O_2}{100} + 28\frac{\%CO}{100} + 28\frac{\%N_2}{100}$$

Equation 2

when

Mdry	=	Dry molecular weight of process gas (g/g mole)
$\%CO_2$	=	Percentage CO_2 in gas stream
$\%O_2$	=	Percentage O_2 in gas stream
%CO	=	Percentage CO in gas stream
$\%N_2$	=	Percentage N_2 in gas stream
44	=	Molecular weight of carbon dioxide (g/g mole)
32	=	Molecular weight of oxygen (g/g mole)
28	=	Molecular weight of carbon monoxide and nitrogen (g/g mole)

This can then be converted to a wet basis by:

$$M = Mdry(1 - B_{wo}) + 18(B_{wo})$$

Equation 3

when

M	=	Wet molecular weight of process gas (g/g mole)
Mdry	=	Dry molecular weight of process gas (g/g mole)
B_{wo}	=	Proportional of water vapour in the gas stream by volume
18	=	Molecular weight of water in (g/g mole)

The resulting value must be entered into the molecular weight parameter

Volumetric Flow

To calculate the volumetric flow in m^3/sec the velocity is multiplied by the cross sectional area

$$Qa = A \times V$$

Equation 4

where A is cross sectional area in m^2
and V is the velocity in m/sec

Normalising to Standard Conditions

The PSI-2 reports the flow output on a dry basis at 0ºC and at standard pressure. To do this, the following equations are used;

The volumetric flow is referred back to standard conditions by the formula

$$Qn = \frac{Qa\ x\ Pa\ x(1 - Bwo)\ x\ Ts}{Ta\ x\ Ps}$$

Equation 5

Bwo	=	Proportion of water vapour in the gas stream by volume
Ps	=	Standard gas pressure (KPa)
Pa	=	Actual gas pressure (KPa)
Qa	=	Volumetric flow at actual conditions (m^3/sec)
Ts	=	Standard gas temperature (°K)
Ta	=	Actual gas temperature (°K)
Qn	=	Normalised volumetric flow (m^3/sec)

Mass Flow

To calculate the mass flow of gas, the volumetric flow is multiplied by the mass of the gas per unit volume. To calculate the mass per m^3 the ideal gas law is used.

Calculating the mass density of a gas at standard temperature and pressure

The ideal gas law states:

$$pV = nRT$$

Equation 6

where

p = Pressure of gas
V_{STD} = Volume of gas
n = Number of moles of gas
R = Universal gas constant (8.314 J/mol.K)
T = Temperature of gas

Rearranging for volume gives:

$$V_{STD} = \frac{nRT}{p}$$

Equation 7

At a standard temperature and pressure (T_{STD}=0°C i.e. 273.15K, 101.325KPa) the volume of 1 mole of gas is thus:

$$V_{STD} = \frac{1 \times 8.314 \times (273.15)}{101.325} = 22.412 m^3$$

Now density is defined as: $\rho = \frac{m}{V_{std}}$

Equation 8

So the mass density of a gas (at STP) = $\frac{Molecular\ weight\ of\ gas(g/gmol)}{22.412}$ In Kg/m^3

So at STP, the instrument then takes the volumetric flow in m^3/sec and multiplies it by

$\frac{Molecular\ weight}{22.412}$ giving the result in kg/sec

However, the standard volume of one mole of gas will be different from that above if a different standard temperature is selected. The PSI-2, therefore, calculates the standard volume based on the chosen standard temperature. This does not change the mass flow result as the V_{STD} is recalculated within the mass flow calculation such that the gas density is the gas density at the chosen standard conditions. In general mass flow is independent of standard condition and is given by

$$\frac{Actual\ volumetric\ flow\ x\ Molecular\ weight\ x\ Pa}{8.314\ x\ Ta}$$

However this does not calculate the mass flow on a dry basis. For this reason, the normalised volumetric flow on a dry basis is used as the input for mass flow calculation. If mass flow is required on a wet basis the normalised volumetric flow should be calculated with water content set to 0 and the molecular weight calculated on a wet basis.

Mass flow is therefore calculated as

$$\dot{m} = \frac{Normalised\ volumetric\ flow\ x\ Molecular\ weight\ x\ Ps}{8.314\ x\ Ts} \quad \text{(Kg/sec)}$$

Equation 9

NOTE: As the mass flow is calculated from the normalised volumetric flow, if the water content of the gas is removed from the normalised volumetric flow, it will also be removed from the mass flow.

Worked Example

Based on:

Duct diameter:	1.2m
0% O^2	20%
CO_2	1%
N_2	79%
Moisture content by volume 0.03 (3%)	
Velocity	10m/s
Temperature	200ºC
Pressure	106.258KPa (106258 Pa)

Molecular weight of dry gas:

$$Mdry = 44\frac{\%CO_2}{100} + 32\frac{\%O_2}{100} + 28\frac{\%CO}{100} + 28\frac{\%N_2}{100}$$

$$Md = 44 \times \frac{1}{100} + 32 \times \frac{20}{100} + 28 \times \frac{79}{100} = 28.96 \text{ g/gmol}$$

Molecular weight of process gas wet:

$$M = Mdry(1 - B_{wo}) + 18(B_{wo})$$

Ms = 28.96 (1 – 0.03) + 18 (0.03) = 28.63 g/gmol

Area of duct = $\pi(D / 2)^2$
= $3.142\times (1.2 / 2)^2$
= $1.131 m^2$

If the measured velocity is 10m/sec the reported volumetric flow would be:

Volumetric flow at actual conditions 1.131 x 10 x 60 = 678.6 m^3/min

On a dry basis at standard temperature and pressure this becomes:

$$\frac{678.6\, x\, 273.15\, x\, 106.258\, x\,(1-0.03)}{101.325\, x\,(200+273)}$$ =3.98.5m^3/min @ STP (dry)

The mass would be: $$\frac{398.5\, x\, 28.96\, x\, 101.325}{8.314\, x\, 273.15}$$ =514.9 Kg/min

Note on a wet basis these would be reported as; $410.7 m^3/\min$ and $524.9 kg/\min$ respectively

5. MODBUS COMMUNICATIONS

READ ONLY *(0x04 Read Input Registers)*			
Register Name	**Type**	**Address**	**Units Register**
Process Temperature	float	0	5023
Instrument Temperature	float	2	5024
Static Pressure	float	4	5025
Differential Pressure	float	6	5026
Velocity	float	8	5027
Volumetric Flow	float	10	5028
Normalised Volumetric Flow	float	12	5028
Mass Flow	float	14	5030
Linearised Velocity	float	16	5027
Power Supply Voltage	float	18	N/A
Differential Pressure Average	float	20	5026
Differential Temperature Calibration	float	22	N/A
Static Pressure Temperature Calibration	float	24	N/A
Status Register 1	Int 16	5000	N/A
Status Register 2	Int 16	5001	N/A

Table a: Dynamic Variables (Read Only)

INTEGER READ/WRITE NON VOLATILE *(0x03 Read, 0x06 Write Single, 0x16 Write Multiple)*			
Register Name	**Type**	**Address**	**Units Register**
Number Of Float Registers *(Read Only)*	Int 16	5000	N/A
Number Of Integer Registers *(Read Only)*	Int 16	5001	N/A
Instrument Version *(Read Only)*	Int 16	5002	N/A
Serial Number 0 *(Read Only)*	Int 16	5003	N/A
Serial Number 1 *(Read Only)*	Int 16	5004	N/A
Serial Number 2 *(Read Only)*	Int 16	5005	N/A
Serial Number 3 *(Read Only)*	Int 16	5006	N/A
Serial Number 4 *(Read Only)*	Int 16	5007	N/A
Serial Number 5 *(Read Only)*	Int 16	5008	N/A
Serial Number 6 *(Read Only)*	Int 16	5009	N/A
Serial Number 7 *(Read Only)*	Int 16	5010	N/A
Software Revision *(Read Only)*	Int 16	5011	N/A
ROM CRC Check *(Read Only)*	Int 16	5012	N/A
Linearisation Sample Period	Int 16	5013	N/A
Analogue Output Assignment	Int 16	5014	N/A
Zero Calibration Period	Int 16	5015	N/A
Zero Calibration Duration	Int 16	5016	N/A
Zero Calibration Settling Time	Int 16	5017	N/A
Configuration Register	Int 16	5018	N/A
Instrument Modbus Address	Int 16	5019	N/A
Modbus Baud Rate	Int 16	5020	N/A
Reset Factory Default 1	Int 16	5021	N/A
Reset Factory Default 2	Int 16	5022	N/A
EEROM CRC Check *(Read Only)*	Int 16	5031	N/A

Table b: Integer Read/Write Non-Volatile

BIT VARIABLES NON VOLATILE *(0x01 Read, 0x05 Write Single, 0x0f Write Multiple)*			
Register Name	**Type**	**Address**	**Units Register**
Trigger Zero Calibration	coil	0	N/A
Trigger Low Linearisation Sample	coil	1	N/A
Trigger Mid Linearisation Sample	coil	2	N/A
Trigger High Linearisation Sample	coil	3	N/A
Stop Linearisation Sample	coil	4	N/A
Trigger Linearisation Coefficient Calculation	coil	5	N/A

Table c: Bit Variables Non-Volatile

FLOATING POINT READ/WRITE NON VOLATILE *(0x03 Read, 0x10 Write Multiple)*			
Register Name	**Type**	**Address**	**Units Register**
Pitot Coefficient	float	0	N/A
Water Content %	float	2	N/A
Molecular Weight	float	4	N/A
Duct Size	float	6	5030
Standard Temperature	float	8	5023
Damping	float	10	N/A
Differential Pressure Zero	float	12	N/A
Differential Pressure Span	float	14	N/A
Differential Pressure Zero Temperature Coefficient	float	16	N/A
Differential Pressure Span Temperature Coefficient	float	18	N/A
Differential Pressure ADC Bits @ Zero	float	20	N/A
Absolute Pressure Zero	float	22	N/A
Absolute Pressure Span	float	24	N/A
Absolute Pressure Zero Temperature Coefficient	float	26	N/A
Absolute Pressure Span Temperature Coefficient	float	28	N/A
Absolute Pressure ADC Bits @ Zero	float	30	N/A
Instrument Temperature Zero	float	32	N/A
Instrument Temperature Span	float	34	N/A
Process Temperature Zero	float	36	N/A
Process Temperature Span	float	38	N/A
Linearisation Coefficient B Lower	float	40	N/A
Linearisation Coefficient C Lower	float	42	N/A
Linearisation Coefficient D Lower	float	44	N/A
Linearisation Coefficient B Mid	float	46	N/A
Linearisation Coefficient C Mid	float	48	N/A
Linearisation Coefficient D Mid	float	50	N/A
Linearisation Coefficient B High	float	52	N/A
Linearisation Coefficient C High	float	54	N/A
Linearisation Coefficient D High	float	56	N/A
Instrument Recorded Low Velocity	float	58	5027
Instrument Recorded Medium Velocity	float	60	5027
Instrument Recorded High Velocity	float	62	5027
Traversed Low Velocity	float	64	5027
Traversed Medium Velocity	float	66	5027
Traversed High Velocity	float	68	5027

Table d: Floating Point Read/Write Non-Volatile

FLOATING POINT READ/WRITE NON VOLATILE *(0x03 Read, 0x10 Write Multiple)*			
Register Name	**Type**	**Address**	**Units Register**
Analogue Output Minimum Value	float	70	N/A
Analogue Output Maximum Value	float	72	N/A
Process Temperature Full Scale	float	74	5023
Instrument Temperature Full Scale	float	76	5024
Static Pressure Full Scale	float	78	5025
Differential Pressure Full Scale	float	80	5026
Velocity Full Scale	float	82	5027
Volumetric Flow Full Scale	float	84	5028
Normalised Volumetric Flow Full Scale	float	86	5028
Mass Flow Full Scale	float	88	5029
Linearised Velocity Full Scale	float	90	5027
Process Temperature Minimum Scale	float	92	5023
Instrument Temperature Minimum Scale	float	94	5024
Static Pressure Minimum Scale	float	96	5025
Differential Pressure Minimum Scale	float	98	5026
Velocity Minimum Scale	float	100	5027
Volumetric Flow Minimum Scale	float	102	5028
Normalised Volumetric Flow Minimum Scale	float	104	5028
Mass Flow Minimum Scale	float	106	5029
Linearised Velocity Minimum Scale	float	108	5027

Table e: Analogue Output Scaling Registers Read/Write Non-Volatile

INTEGER READ/WRITE NON VOLATILE *(0x03 Read, 0x06 Write Single, 0x16 Write Multiple)*		
Unit Selection For	**Type**	**Address**
Process Temperature Standard Temperature	INT 16	5023
Instrument Temperature	INT 16	5024
Static Pressure	INT 16	5025
Differential Pressure	INT 16	5026
Velocity Linear Velocity Instrument Recorded Low Velocity Instrument Recorded Medium Velocity Instrument Recorded High Velocity Traversed Low Velocity Traversed Medium Velocity Traversed High Velocity	INT 16	5027
Volumetric Flow	INT 16	5028
Mass Flow	INT 16	5029
Duct Size	INT 16	5030

Table f: Unit Selection Registers

Output Variable	**Code**
Process Temperature	1
Instrument Temperature	2
Static Pressure	3
Differential Pressure	4
Velocity	5
Volumetric Flow	6
Normalised Volumetric Flow	7
Mass Flow	8
Linearised Velocity	9
Power Supply Voltage	10
Differential Pressure Average	11

Table g: Analogue Output Assignment

AVAILABLE UNITS			
Measurement Type	**Unit**	**Code**	**Conversion Factor**
Temperature Conversions	°C	0	*1+0
	K	1	*1 +273.15
	°F	2	*1.8 +32
	°R	3	*1.8 +273.15
Pressure Conversions	Pa	0	1.00000E+00
	kPa	1	1.00000E-03
	atm	2	9.86920E-06
	mbar	3	1.00000E-02
	bar	4	1.00000E-05
	mmHg	5	7.50062E-03
	psi	6	1.45038E-04
	inH_2O	7	4.01463E-03
	inHg	8	2.95300E-04
Velocity	m/s	0	1.00000E+00
	km/h	1	3.60000E+00
	in/s	2	3.93701E+01
	ft/s	3	3.28084E+00
	ft/min	4	1.96850E+02
	mph	5	2.23694E+00
Volumetric Flow	m^3/s	0	1.00000E+00
	m^3/min	1	6.00000E+01
	m^3/h	2	3.60000E+03
	L/s	3	1.00000E+03
	L/min	4	6.00000E+04
	ft^3/s	5	3.53147E+01
	ft^3/min	6	2.11888E+03
	ft^3/h	7	1.27133E+05
Mass Flow	kg/s	0	1.00000E+00
	g/s	1	1.00000E-03
	kg/m	2	6.00000E+01
	kg/h	3	3.60000E+03
	t/h	4	3.60000E+00
	Ib/s	5	2.20462E+00
	Ib/m	6	1.32277E+02
	ft^3/h	7	7.93665E+03
	US ton/h	8	3.96832E+00
	UK ton/h	9	3.54315E+00
Duct Area	m^2	0	1.00000E+00
	cm^2	1	1.00000E+04
	mm^2	2	1.00000E+06
	yd^2	3	1.19599E+00
	ft^2	4	1.07639E+01

Table h: Available Units

6. SPECIFICATIONS

Instrument

Static pressure input	*0 to 207kPa absolute*	
Operating differential pressure	*+/-1000Pa*	*Approx 32m/s at STP* (NOTE 1)
Max. differential pressure	*25kPa (250mbar)*	*No damage*
Max. differential pressure	*50kPa*	*Burst limit*
Max. common mode pressure	*207KPa Gauge all inputs*	*Burst limit of differential pressure transducer*
Repeatability (transducers)	*0.1% FS*	(Note 2)
Span drift differential & static pressure	*+/-0.25% FS (25°C change)*	(Note 2)
Zero drift differential & static pressure	*+/-0.2% FS (25°C change)*	(Note 2, 3)
Ambient temperature range	*-20°C to 70°C*	
Supply	*8V to 30V 150mA maximum*	
Process temperature range	*-20°C to 700°C*	*Higher temperature ranges available on request*

Pitot

S-type style Pitot tube	*300mm to 2mtre*	
Averaging style Pitot tube	*300mm to 2mtre*	
Material available	*316 stainless steel*	
Temperature range	-40°C to +700°C	*Higher temperature ranges available on request*

Note 1:

Specification based on standard differential transducer.
Higher ranges are available but the burst common mode pressure remains at 207KPa gauge.

Note 2:

As the velocity calculation is based on the square root of differential pressure, velocity errors are non liner.
For low velocity accuracy the actual error must be calculated based on the transducer performance applied to the velocity calculation formula.

Note 3:

The zero drift on the differential pressure is quoted with auto zero switched off.
Improved zero performance will result if the auto zero is enabled and configured for the application.

Illustration iii: PSI2 S-Type Pitot

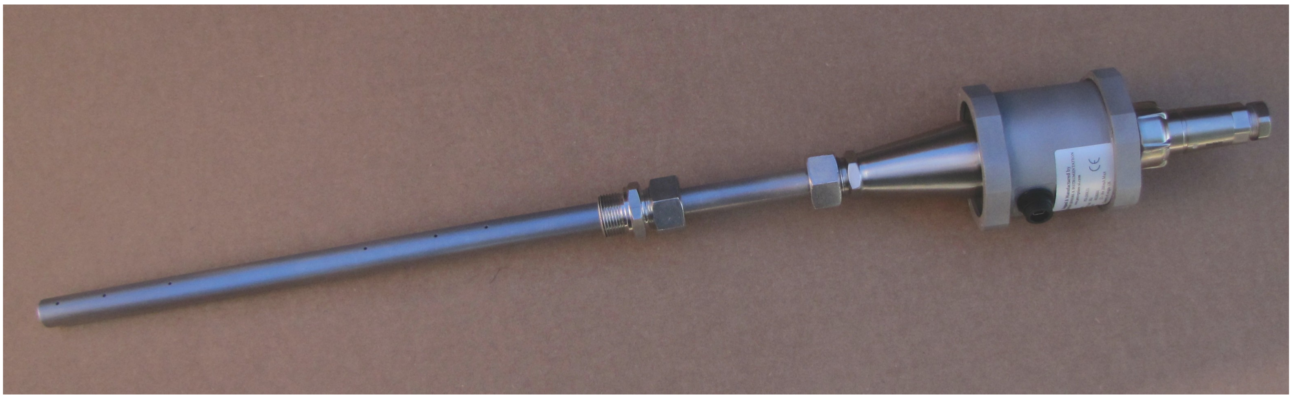

Illustration iv: PSI2 Averaging Pitot

Outputs

Configurable analogue output assignable to any measured or calculated parameter

Outputs are 4 – 20mA isolated

Serial Interface

RS485 MODBUS RTU Selectable Baud,parity, and Stop bit
USB

Dimension

IP Rating

IP69K

Connections

IP69K 6-pole field connectors
IP69K USB mini-B service connector

FIELD CONNECTIONS	
Pin	**Function**
1	Supply +V
2	Supply OV
3	Analogue O/P OV
4	Analogue O/P +V
5	RS485 A
6	RS485 B

Table i

BREAKDOWN OF THE MOLECULAR WEIGHT OF DRY AIR		
Gas	%	Weight
N_2	78.08	21.88
O_2	20.95	6.704
Ar	0.93	0.372
CO_2	0.03	0.014
	Total Dry Air	**28.97**

Table j

MOLECULAR WEIGHT OF AIR		
Dry		28.97
10%	H_2O	27.87
20%	H_2O	26.78

Table k

MOLECULAR WEIGHT		
Gas		Molecular weight
H	Hydrogen	1
H2O	Water	18
O2	Oxygen	32
CO	Carbon Monoxide	28
NO	Nitric Oxide	30
NO2	Nitrogen Dioxide	46
N2	Nitrogen	28
SO2	Sulphur Dioxide	64
CO2	Carbon Dioxide	48
CH4	Methane	16

Table l

7. FREEFLOW PC BASED SOFTWARE GUIDE

The PSI2MKII flow measurement system provides two digital communications paths, long hall RS485 port and a USB service port.

The PC based software Freeflow provides a convenient means of accessing all measurement and configuration parameters to both commission, test and calibrate the PSI2MKII.

To install Freeflow go to the link http://downloads.emergent-design.co.uk/freeflow/ and download the freeflow file. This is a compressed folder using 7-zip. If 7-zip is required this may be installed from http://www.7-zip.org/download.html . The folder can be placed in any convenient location on the computer. When installing software from any external source it is strongly advised that the downloaded files are scanned with an up-to-date virus checker. PSI has taken extensive precautions to protect our downloads from attack but it remains the responsibility of the user to check the software installed on their computer. Once extracted, the Freeflow software will run without further installation except for the USB virtual comport, if this is required see below. In some versions of Windows, verification will be requested to run the software for the first time.

There are two communications ports both of which employ the MODBUS RTU protocol, with the RS485 port supporting several baud rates with parity of non, odd and even, together with a programmable field address. For USB port communications the PSI2MKII behaves as a virtual comport using standard Windows and Linux comport drivers. A key difference between the USB and RS485 ports is that the USB port ignores the baud rate, parity and address. This is to ensure that communication to the PSI2MKII can always be established irrespective of the communications configuration. The serial port configuration for the RS485 port can therefore always be configured or queried over the USB port. This is important for commissioning as it allows the RS485 Modbus communications to be configured to match existing plant configurations without the risk of loosing communication with the device.

As Freeflow communicates exclusively over communication ports, even when using the USB port, Freeflow does not need special driver installation. However as the PSI2MKII will have a new vendor and product ID for the USB vitual comport the PC will require the comport to be configured.

Should the USB virtual comport be required, when the instrument is first connected open the Freeflow file directory and double click on the “psi2-cdc-setup.exe” file. This will install the PSI CDC class inf file for the Windows CDC class comport driver. When this has been installed the PSI2MKII will appear as a standard comport on the Windows operating system. For the RS485 communications channel use the comport installation guide from the comport providers installation guide.

The PSI2MKII does not need any external power for establishing USB communications. All configurations and device integration can be undertaken using the instrument as a USB powered device. However the internal precision references do not operate when powered solely from the USB port. The accuracy of the instrument will be severely degraded in this mode and no calibration of the instrument should be performed without external power. In addition the USB port is unable to provide power for the Analogue Output or the Zero Calibration system and these will be disabled in USB powered mode.

When the instrument is externally powered the USB port can be used to perform full calibration procedures and the analogue output and zero calibration hardware will be fully operational. However to avoid command conflicts, when the USB communications are active the RS485 port is set to 'Read Only' mode. No configuration changes are possible over the RS485 port while the USB port is connected. Disconnecting the USB port automatically restores 'Write Access' to the instrument over the RS485 port.

Within the Freeflow directory run the file 'freeflow.exe.' Fig1 below shows shows the start-up screen.

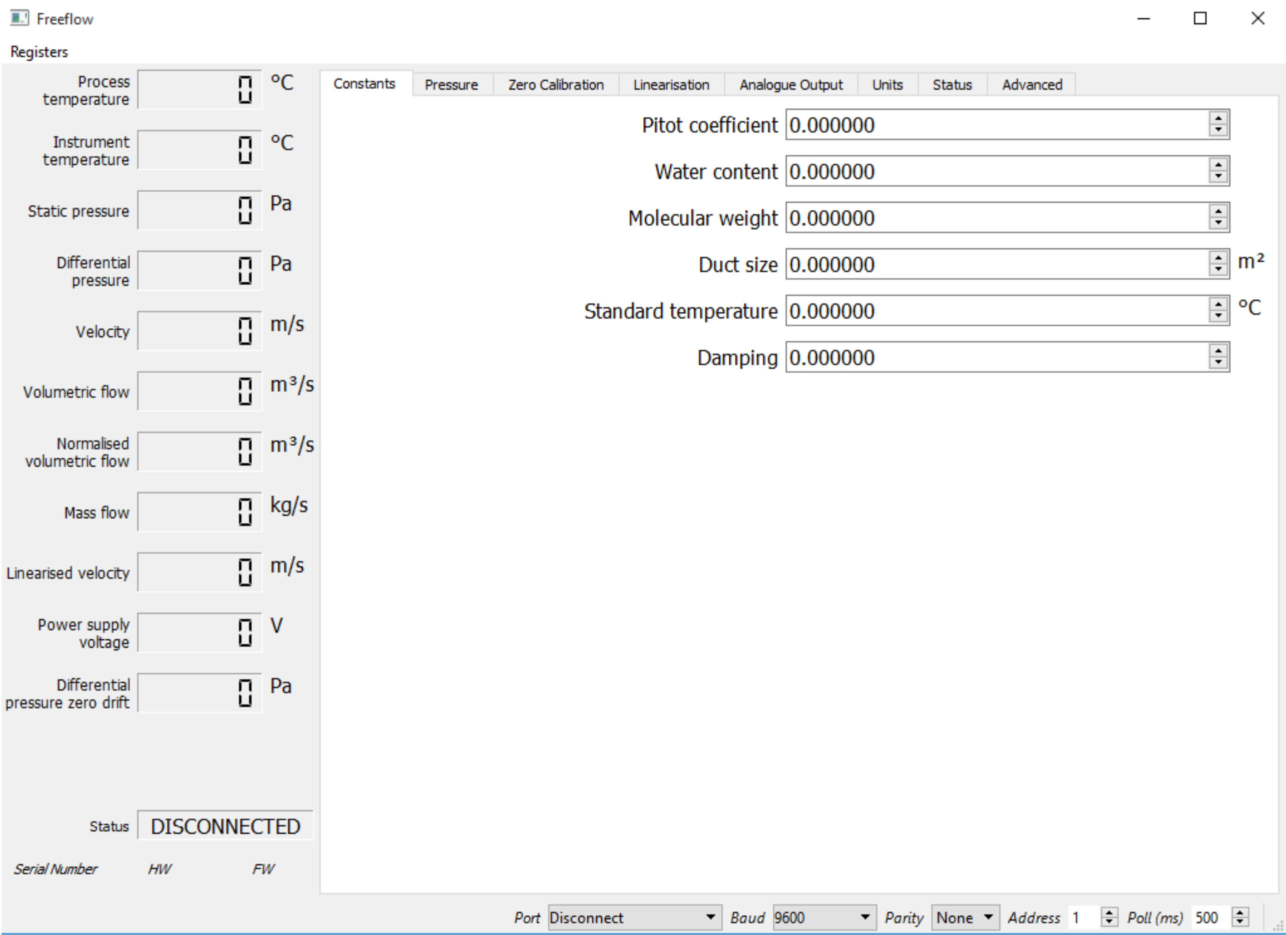

Figure c: FreeFlow Start-Up Screen

To connect to the PSI2MKII, in the 'Port' dialog box at the bottom of the screen, select the comport for either the USB comport or the RS485 comport. This will establish communications and the status will changed from 'DISCONNECTED' to 'CONNECTED'. If the PSI2MKII is only USB powered the 'Status' box at the lower left of the screen will read 'ERROR' and is indicating that the instrument is connected but not fully operational. Selecting the 'Status' tab on the top bar will show the main status panel. This panel will indicate any problems with the power supply and analogue output: providing power to the instrument will remove these errors.

Saving Instrument settings

On the top right hand side of the instrument display panel is the Registers button. Clicking on this button reveals the file save and restore functions. The Instrument settings can be saved or restored by selecting the appropriate action from the list. The file is saved as a semicolon delimited plain text file for easy importing into external spread sheets such as Microsoft excel or LibreOffice calc.

The top of the Freeflow panel has the following tabs:

Constants

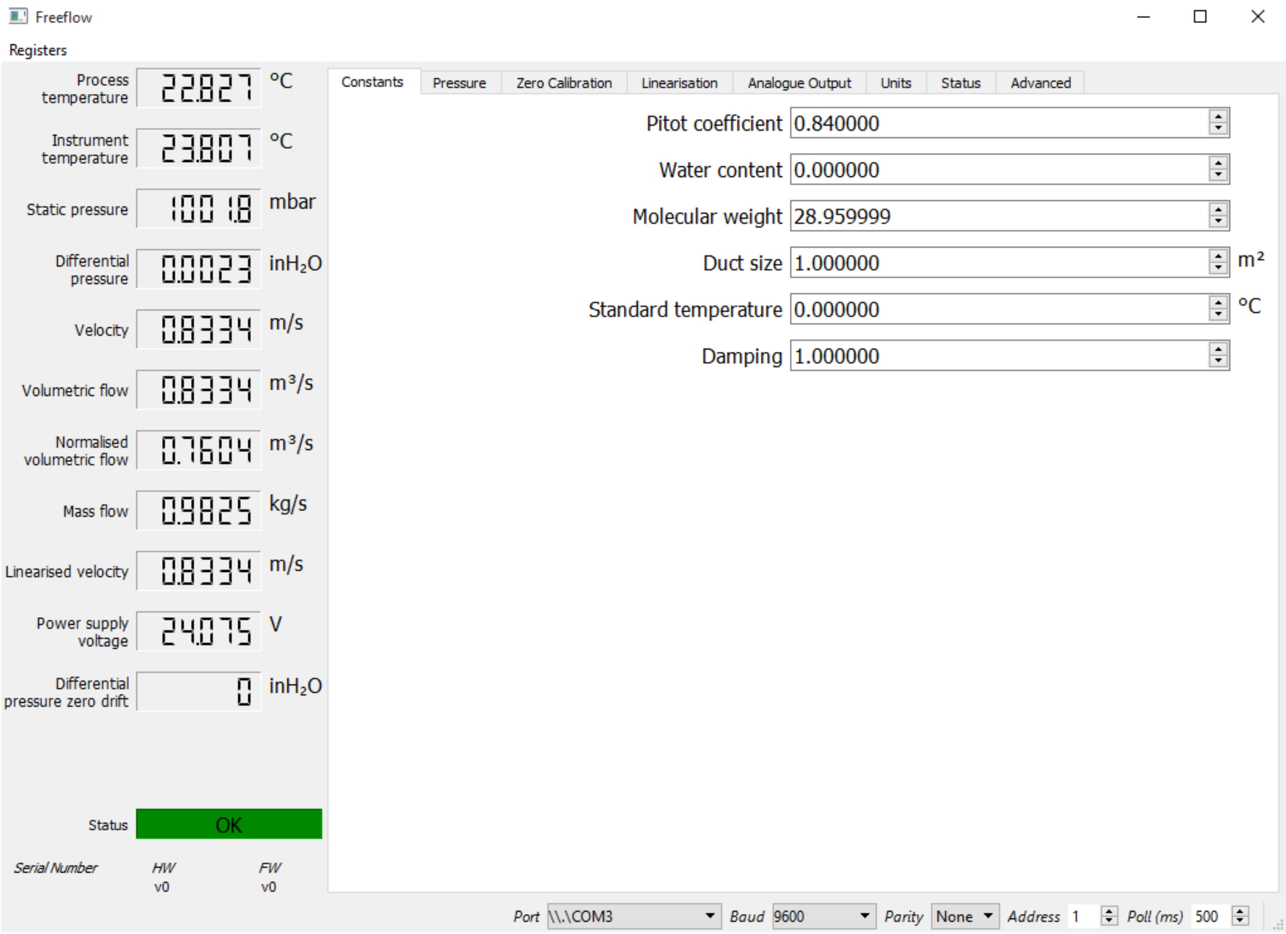

Figure d: FreeFlow Constants Screen

This is used for configuration of the instruments' physical constants such as molecular weight and Pitot coefficient.

Pressure

The Pressure tab is reserved for future use.

Zero Calibration

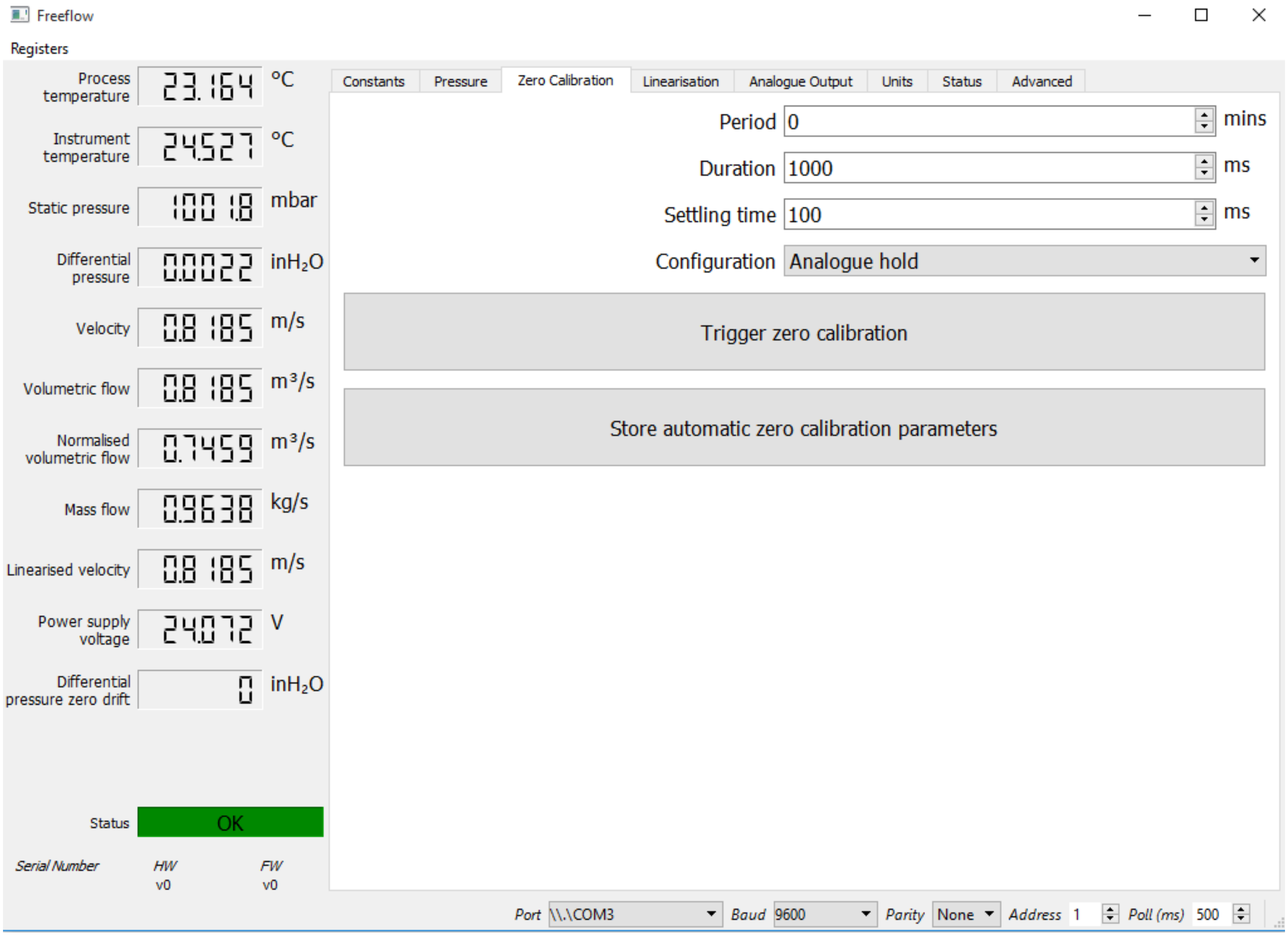

Figure e: FreeFlow Zero Calibration Screen

This configures the zero characteristics of the instrument.

- Period sets the time between auto zero calibrations.
- Duration sets the length of time the zero calibration takes.
- Settling time sets the time after the zero calibration is complete, before the system returns to normal functionality.
- Configuration selects between analogue output tracking the zero calibration and being held during zero calibration.

Note – setting the Period to zero switches auto calibration off and enables the manual calibration trigger. In normal operation, the auto zero does not change the zero calibration coefficient of the differential transducer but shows the total drift since the zero calibration result was last saved. Selecting 'Store Automatic Zero' calibration parameter modifies the zero calibration coefficient and zeros the differential pressure zero drift. This is provided so that zero drift performance can be monitored between service intervals.

Linearisation

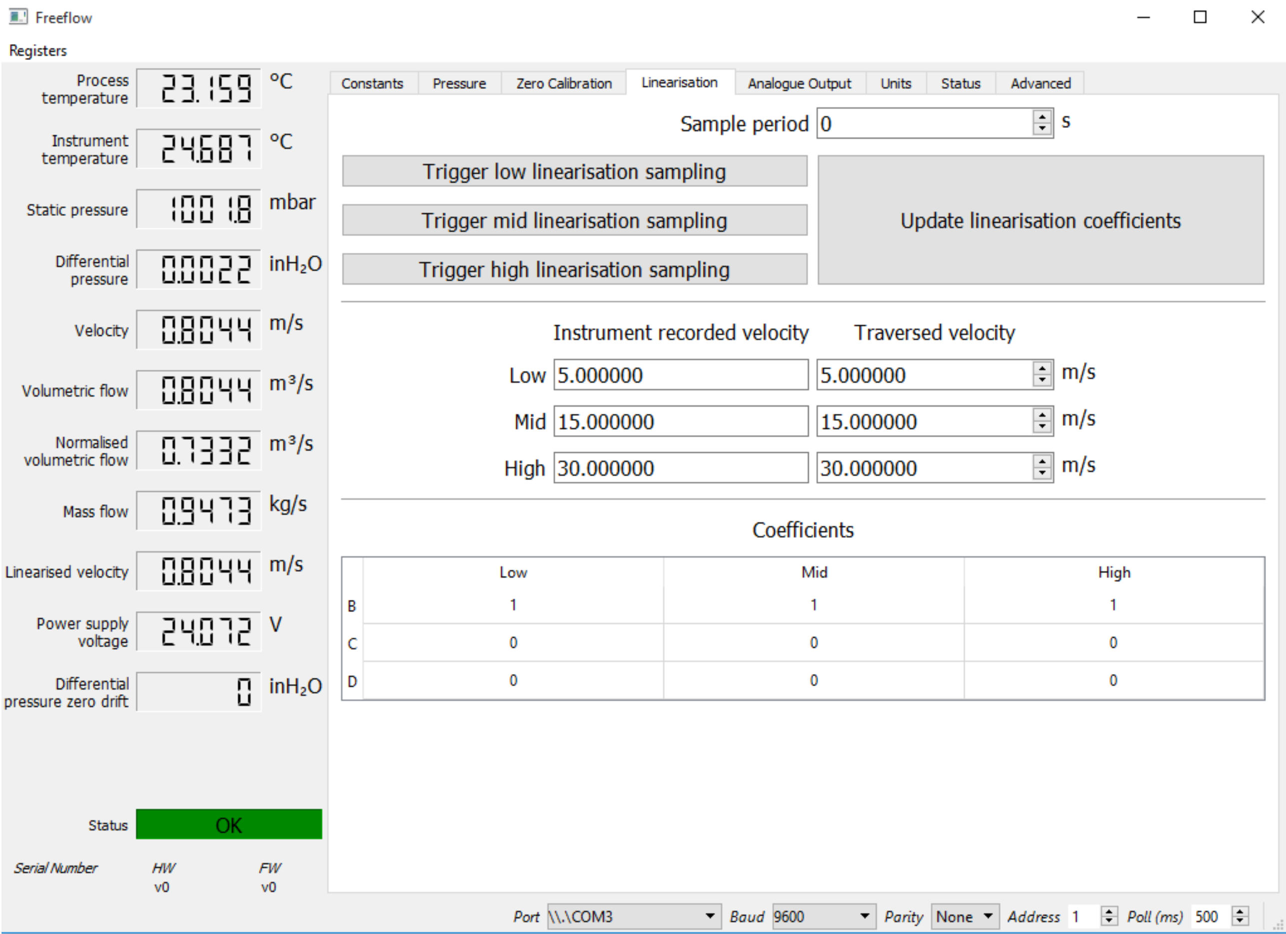

Figure f: FreeFlow Linearisation Screen

The linearisation panel is used for performing a 4-point linearisation of the flow profile. Only three data points are entered as the 0 point is implicit in that at zero flow, the instrument should read zero. When doing a low velocity traverse the 'Trigger Low' linearisation sampling should be selected, at which the instrument will commence taking a measurement of the average velocity as seen by the PSI2MKII until the trigger is cancelled. The PSI2MKIIs recorded velocity will then show the 'Average Velocity' taken during this period. The result of the traverse should then be entered manually into the 'Traverse Velocity Panel' for the low reading. This process is then repeated for the mid and high readings. On completion, select the update linearisation coefficients. Once done, this will then calculate the coefficients required for the spline curve fit i.e., linearised flow readings are compensated for changes in flow profile with changes in velocity.

Analogue Output

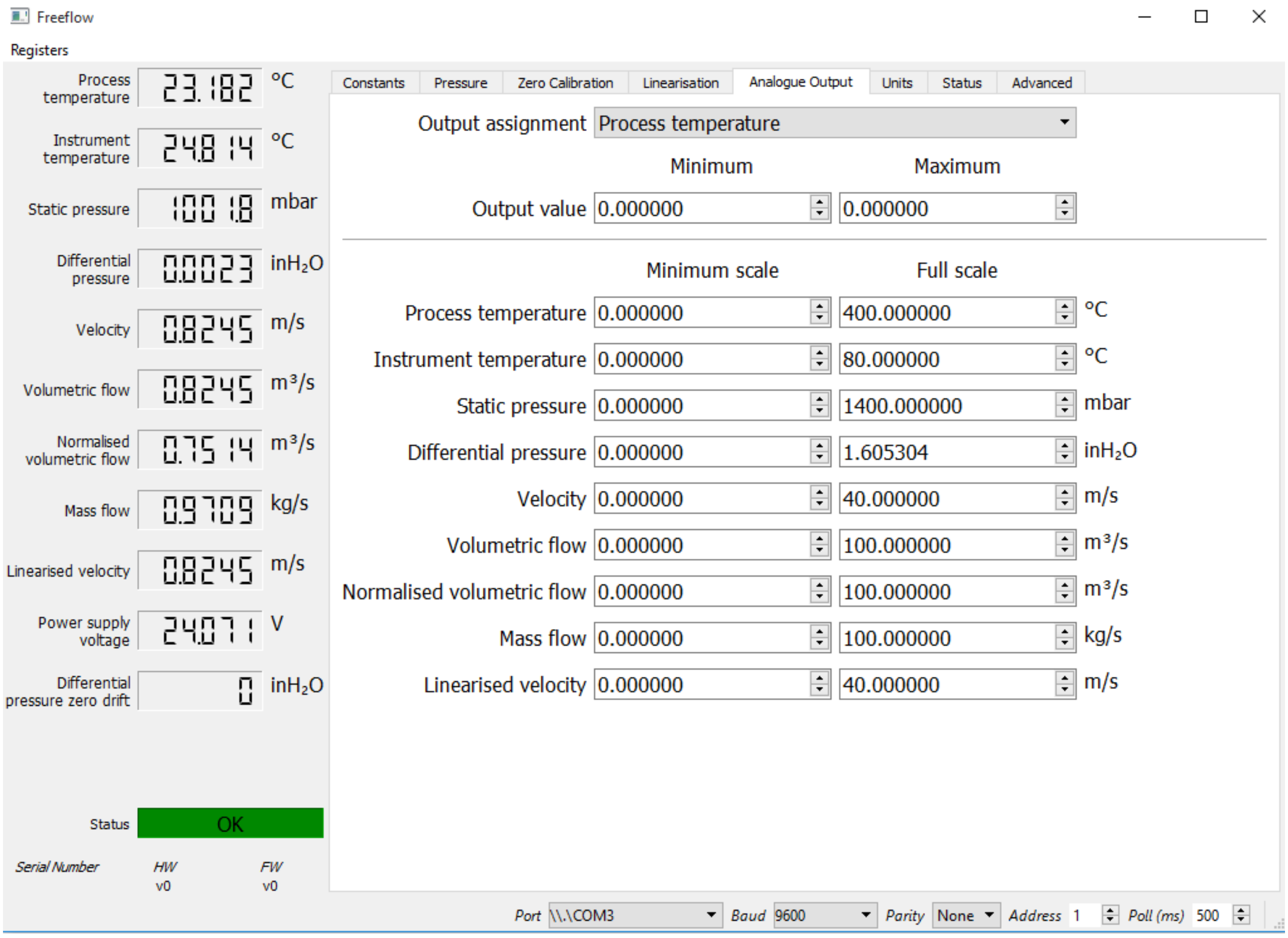

Figure g: FreeFlow Analogue Output Screen

The output assignment is used to select the parameter required as the analogue output parameter. Each individual parameter able to be output can be set to a minimum and maximum for 4-20mA, however only one parameter can be active on the analogue output at any one time.

Units

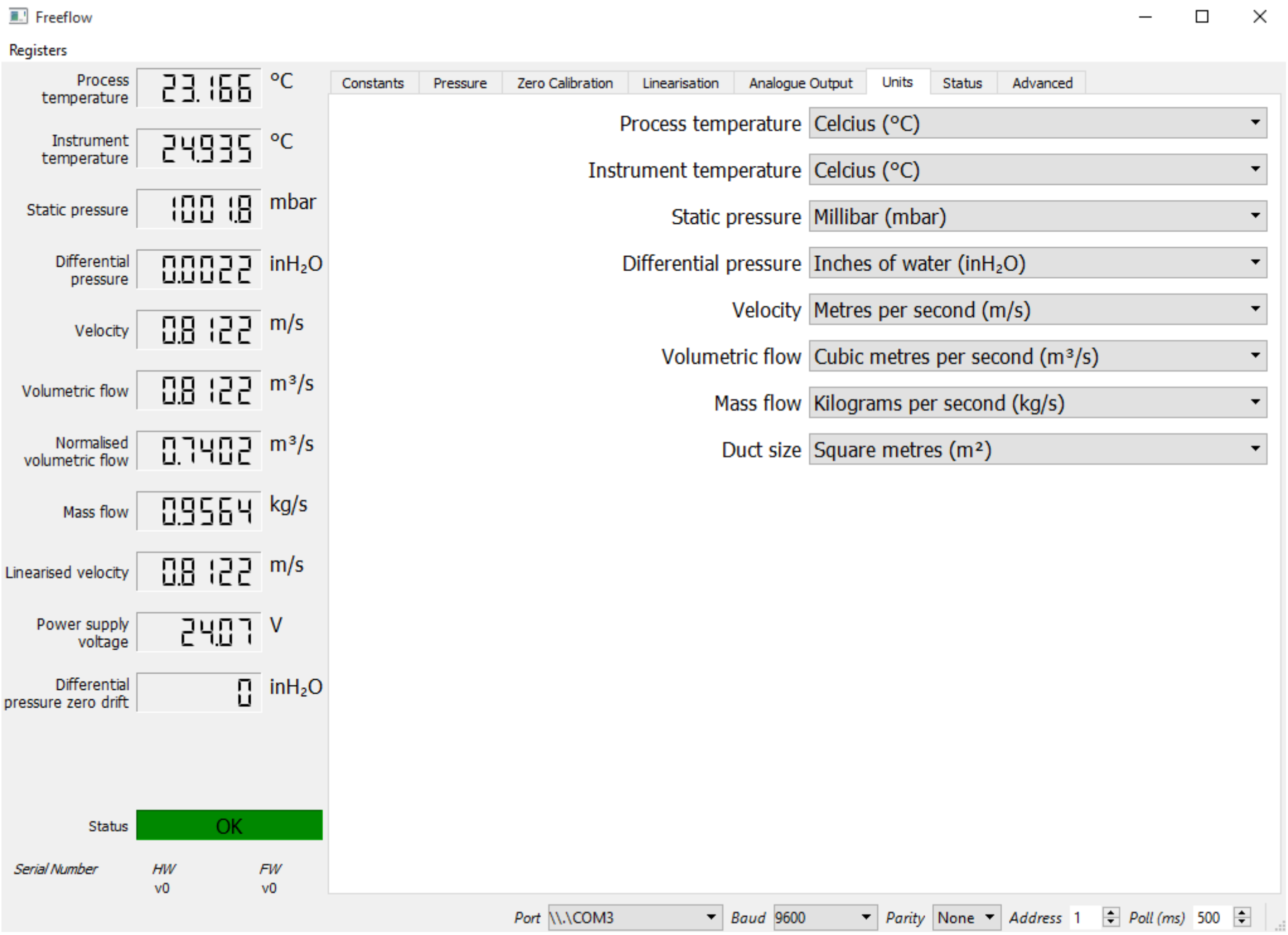

Figure h: FreeFlow Units Screen

The PSI2MKII can output data in many different units. The instrument itself always works in SI units but data entered and outputted can be any of the predefined units. For each data type, select the unit required. All references by the instrument will then be in the selected unit. As this effects all displayed data and analogue output settings it is advisable to select the units at the start of any configuration process. However if the analogue output was assigned 'Differential Pressure in Pascal', selecting a different unit will automatically change the analogue output scaling to the new units but maintaining the same range in Pascal.

Status

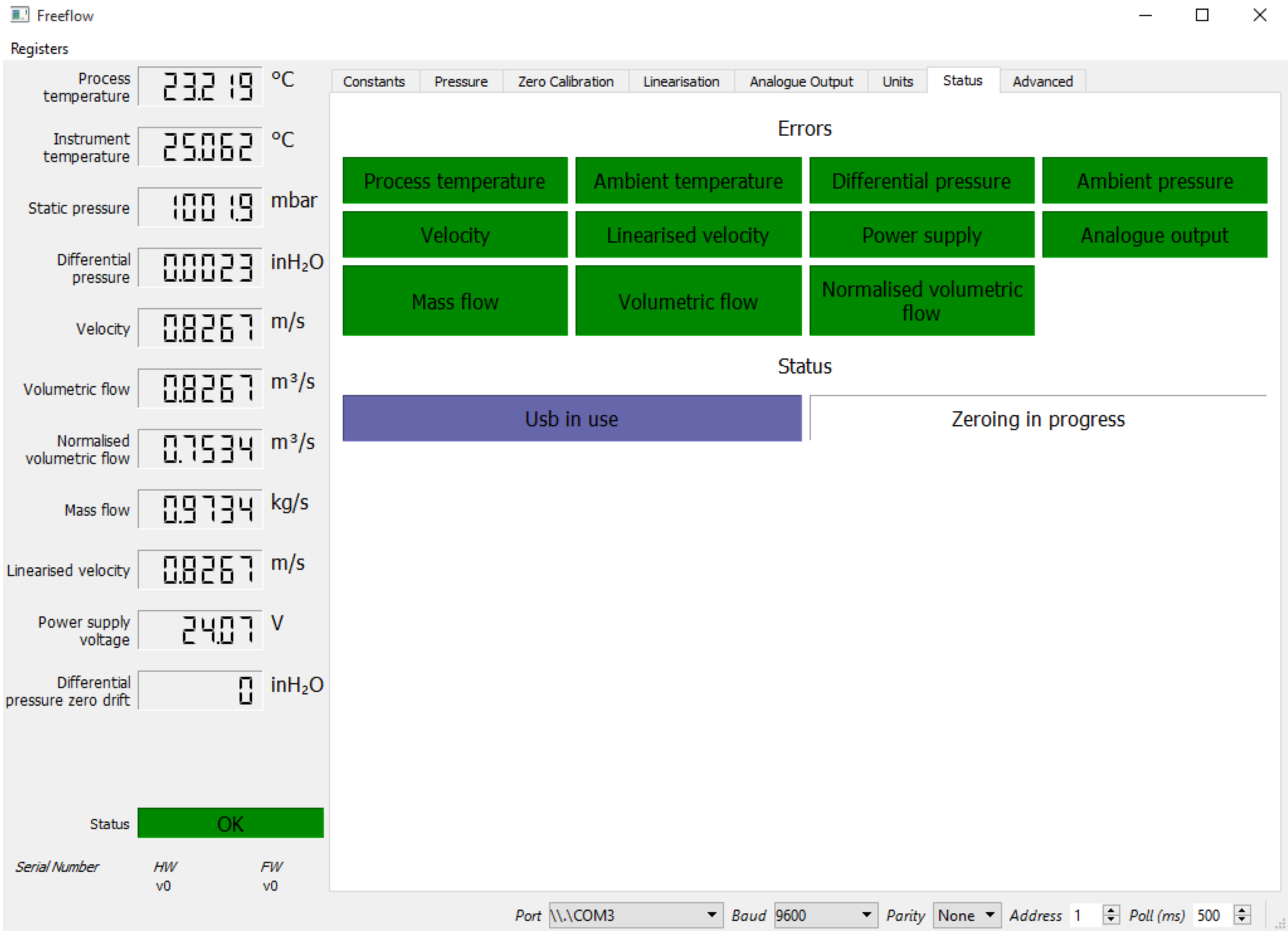

Figure i: FreeFlow Status Screen

The error status displays the status of several internal and external functions. In a number of instances these are determined by limits set in firmware for satisfactory operation of the instrument. If a thermocouple is open circuit then the process temperature will display a fault. As many other parameters are dependent on knowing the process temperature these will also be flagged as in error. An example of this would be:-

If the process temperature is faulty the velocity, volumetric flow, mass flow and normalised volumetric flow will all be in error as they are dependent on knowing the process temperature. The 'USB in Use' and 'Zeroing in Progress' will show the status of these functions.

PSI2MKII

Advanced

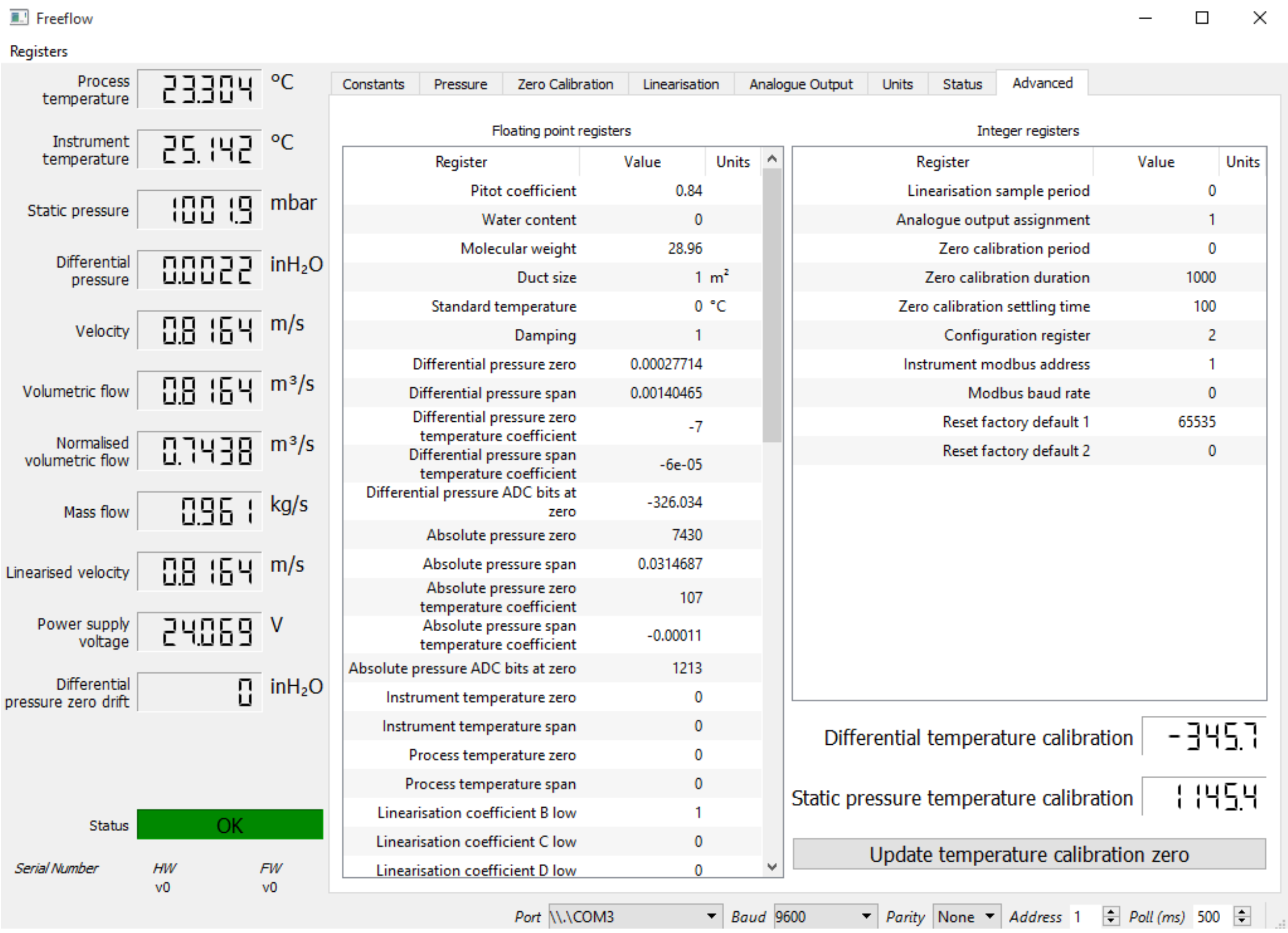

Figure j: FreeFlow Advanced Screen

The Advanced Tab provides low level access to all functions. This panel is for use by service personnel only. It is specifically to aid field personnel resolving issues in the field and for factory calibration and service.