BAKER HUGHES
a GE company

PTX 5900 SIL

Pressure Transmitter

Functional Safety Manual

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1. References

The following documents and specifications are referenced by this document:

Table 1-1 - Applicable Documentation

Ref	Number	Revision	Description
[1]	125M0202	-	Product Specification Drawing
[2]	n/a		Calibration Certificate (Shipped with each product)
[3]	IEC 61508-1	Ed 2 2010	Functional safety of electrical/electronic/programmable electronic safety-related systems
[4]	125M0414	-	Independent assessment of PTX 5900 SIL by Method Functional Safety Ltd
[5]	IEC 61508-2	Ed 2 2010	Functional safety of electrical/electronic/programmable electronic safety-related systems
[6]	IEC 61511-2	2Ed 2016	Functional Safety, Safety Instrumented Systems for the Process Industry Sector
[7]	C-A3-1386	01C	PTX 5900 SIL PTX Board Schematic
[8]	C-A3-1407	01B	PTX 5900 SIL Compensation Board Schematic
[9]	K0486	Rev. A	UNIK 5000 Pressure Sensors Equipment Certification ATEX / IECEx Ex ia I/IIC Models – Hazardous Area Installation Instructions
[10]	EN 61326-1	2013	Electrical equipment for measurement, control and laboratory use — EMC requirements
[11]	EN 61326-2-3	2013	(EMC) Particular requirements for transducers
[12]	IEC 61326-3-1	Ed 2 2017	Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 3-1: Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety) – General industrial applications
[13]	IEC 61508-6	Ed 2 2010	Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 6: Guidelines on the application of IEC 61508-1 and IEC 61508-2

2. Abbreviations

λ	Failure rate, the ratio of the total number of failures occurring in a given period of time
λ_D	Failure rate of dangerous failures
λ_{DD}	Failure rate of dangerous failures detected by diagnostics
λ_{DU}	Failure rate of dangerous failures undetected by diagnostics
λ_S	Failure rate of safe failures.
$\propto$	Failure Mode Ratio
1oo1	1 out of 1 voting (Simplex)
1oo2	1 out of 2 voting
bar a	bar absolute (relative to zero)
bar g	bar gauge (relative to atmospheric pressure)
BHGE	Baker Hughes, a GE company
DCS	Distributed Control System
DD	Dangerous Detected
DU	Dangerous Undetected
FAT	Factory Acceptance Test
FMEDA	Failure Modes, Effects and Diagnostics Analysis
FS	Full Scale
HFT	Hardware Fault Tolerance
MFS	Method Functional Safety (consultancy)
MRT	Mean Repair Time (expected overall repair time)
MTTR	Mean Time to Restoration (time to detect the failure + expected overall repair time)
PFD_{AVG}	Average Probability of Failure on Demand
PSI	Pounds per square inch
SFF	Safe Failure Fraction
SIF	Safety Instrumental Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
T_p	Proof Test Interval

Chapter 2. Abbreviations

3. Summary

3.1 Quality Management System

BHGE operates a Quality Management System in accordance with ISO 9001 and the documented procedures for documentation, development and change management are in accordance with the requirements of the IEC 61508.

Lloyd's Register
LRQA

CERTIFICATE OF APPROVAL

Druck Ltd
Fir Tree Lane, Groby, Leicester
United Kingdom

has been approved by Lloyd's Register Quality Assurance
to the following Quality Management System Standard:

ISO 9001:2008

The Quality Management System is applicable to:

Design, development, manufacture and in-house servicing of electronic sensors, digital indicators, controllers and calibrators.

This certificate forms part of the approval identified by certificate number LRQ 0850221

Approval
Certificate No: LRQ 0850221/B

Original Approval: 5 February 1987

Current Certificate: 1 January 2016

Certificate Expiry: 14 September 2018

Issued by: Lloyd's Register Quality Assurance Limited

UKAS
MANAGEMENT SYSTEMS
001

1 Trinity Park, Bickenhill Lane, Birmingham, B37 7ES, United Kingdom

Figure 3-1 - ISO9001 Certificate

3.2 Assessment

Method Functional Safety (Method), an independent external assessor, have reviewed a Hardware Reliability Assessment (performed by BHGE) of the PTX 5900 SIL sensor against the functional safety standard IEC 61508-2 [5]. Based on the assumptions stated in the Method report [4], the PTX 5900 SIL is assessed to be compliant to IEC 61508-1 [3] and IEC 61508-2 [5] for non-redundant use in SIL2 Safety Instrumented Systems (SIS).

The safety assessment carried out by independent body Method applies to pressure sensors with hardware PCB circuit diagrams C-A3-1386 [7] and C-A3-1407 [8] used on the PTX 5900 SIL sensor. This covers all sensors listed in the Configuration Table 4-1 on page 8.

3.3 Safety Precautions

Special precautions may be required to ensure procedures and instruction in this SIL safety manual are adhered to and to ensure the safety of personnel during the installation, operation and maintenance of the PTX 5900 SIL.

Potential safety issues have been identified and are indicated in by WARNING symbols. It is required that all personnel comprehend these safety messages before any operation is carried out.

WARNING Hazardous area usage: When used in a Hazardous Area then all the instructions given in the Hazardous Area Installation Instructions must be observed.

Although this document is primarily concerned with Functional Safety, other aspects of safety are mentioned where they are relevant to the application, e.g. Hazardous Area cautions in the installation section. If the variant of PTX 5900 SIL being installed does not have Hazardous Area approval (see Table 4-1 on page 8) then these additional cautions do not apply.

3.4 Health and Safety

To ensure that the products listed in this safety manual are of no risk to health, the following must be noted:

- All sections of these instructions must be read carefully before proceeding.
- Warning labels must be observed.
- Installation, operation, maintenance and servicing must only be carried out by suitably trained and BHGE authorized personnel.
- Installation, operation, maintenance and servicing must be in accordance with instruction in Installation manual or other documents referenced in this safety manual. Deviation from these instructions will convey complete liability to the user.
- Adequate safety precautions must be taken to avoid the possibility of an accident occurring when operating in conditions of high pressure and/or temperature.

BHGE will provide advice and any relevant hazard data sheet (where applicable) concerning the use of products listed in this manual. BHGE contact details: sensing.grobyCC@bhge.com

4. Introduction

4.1 Purpose

To convey the functional safety-related information about the product to enable SIF designers, installers, users and maintainers to follow their lifecycle obligations in accordance with IEC 61508/61511.

To provide information to allow the above organisations to return valuable field failure information to the manufacturer so it can follow its lifecycle obligations.

In order to minimise hazardous risks when using this product, all procedures in this manual must be followed.

4.2 Scope

The information in this manual applies to the following Products/Models:

- PTX 5900 SIL SIL-rated 4-20 mA Pressure Sensor Series

4.3 PTX 5900 SIL Sensor Configuration and Identification

The PTX 5900 SIL sensor brings together all mechanical / electrical components to produce a configured product with a very wide range of possible options.

A picture of a typical product configuration is shown below, and the configuration table is shown overleaf in Table 4-1 below.

The full part number is **PTX 59#2-T#-A#-CC-##-##-125M0202** where the # fields are defined in Table 4-1 below.

Figure 4-1 - Typical Sensor Configuration

Table 4-1 - Configuration Table

PTX 59 B 2 - TA - A1 - CC - H4 - RN

Code		Description
Main Product Variant		
PTX	...	PTX 4-20 mA Sensor
Product Diameter and Material		
59	...	59: 60 mm Stainless Steel
Electrical Connector		
B	...	B: M20 Female with Terminal
J	...	J: 1/2NPT Female with Terminal
Output Option		
2	...	2: 4 to 20 mA
Compensated Temperature Range		
TA	...	TA: -10 to +50 °C
TB	...	TB: -20 to +80 °C
TC	...	TC: -40 to +80 °C
TD	...	TD: -40 to +125°C
Accuracy		
A1	...	A1: Industrial
A2	...	A2: Improved
A3	...	A3: Premium
Calibration		
CC	...	CC: Full Thermal
Hazardous Area Approval		
##	...	Various options available – not relevant to Functional Safety of device
Pressure Connector		
#	...	Various options available – not relevant to Functional Safety of device

4.3.1 Ordering Specification

In addition to the options shown above the sensor can be ordered with any configured full-scale span between 2 bar a and 700 bar a, including specifying zero offset (e.g. 10 bar a → 4 mA, 20 bar a → 20 mA). Sensors may be ordered to measure absolute or gauge.

The pressure offset and span are typically specified on the order for the product, in any pressure units of the customer's choosing (as long as they fall into the ranges defined above). The final configuration including pressure range are laser marked onto the body of the device, see example label definition below.

Note that due to the available Accuracy and Compensated Temperature Range options there is a range of values for the Safety Accuracy. These are listed in Table 5-1 on page 11.

	UNIK 5900 PRESSURE SENSOR PTX 59B2-TA-A2-CC-H4-RN-125M0202 IMPROVED ACCURACY		1180
0 - 35 bar a		4-20 mA	
7 - 28 Vdc 22 mA		S/N 3736378	21/08/14
IECEx BAS 10.0103X Baseefa 10ATEX0204X			
☐ Ex ia IIC T5 Ga (-40°C <= Ta <= 80°C)			II 1 G
☐ Ex ia I Ma (-40°C <= Ta <= 80°C)			I M1
☐			
DRUCK LTD. GROBY, LE6 0FH, UK		MADE IN UK	

Figure 4-2 - Example Marking Details

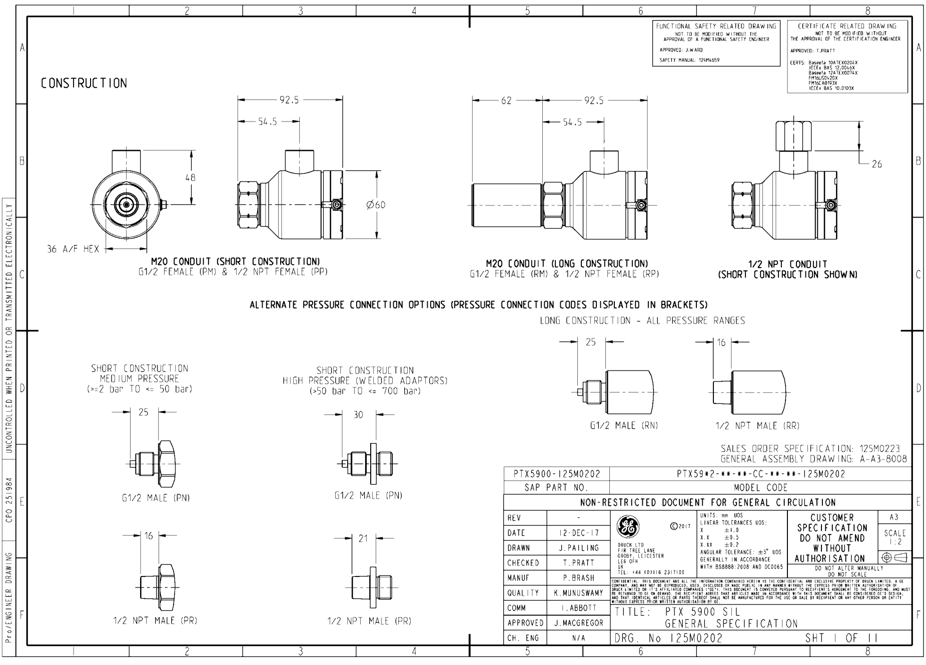

Figure 4-3 – PTX 5900 SIL Specification Drawing (front page)

Chapter 4. Introduction

5. Safety Specifications

5.1 Safety Related Parameters

The following variables and interfaces are attributes of the PTX 5900 SIL:

- Variable: Pressure
- Interface: 4 to 20 mA analogue current
- Pressure to loop current function: see section 4.3.1 on page 8
- Output Current Operating Range: 3.8 mA to 20.5 mA
- Safety Accuracy (see section 8.1 on page 21 for details of what these figures include)

Table 5-1 - Safety Accuracy

<table>
<tr><th>Compensated Temperature Range</th><th>TA
-10 to +50 °C</th><th>TB
-20 to +80 °C</th><th>TC
-40 to +80 °C</th><th>TD
-40 to +125 °C</th></tr>
<tr><td>Accuracy A1 (Industrial)</td><td>2.95% FS</td><td>3.70% FS</td><td colspan="2">4.45% FS</td></tr>
<tr><td>Accuracy A2 (Improved)</td><td rowspan="2">2.00% FS</td><td rowspan="2">2.50% FS</td><td colspan="2" rowspan="2">3.00% FS</td></tr>
<tr><td>Accuracy A3 (Premium)</td></tr>
</table>

- Response Time: <0.1 s to 95% of step input
- Measurement Updates: continuous, settles to 95% within 100 ms
- Supply Voltage Sensitivity <0.005% FS/V
- Low Alarm level: <3.6 mA
- High Alarm Level: >21 mA

WARNING To ensure safe fault monitoring, the safety system logic solver (or DCS) must be capable of recognising both the Fail High and Fail Low conditions as fault indicator.

5.2 Reliability Data

5.2.1 Environmental Limits

- Storage Temperature: -55 °C to +100 °C
- Compensated Temperature Range: depends on option. See Table 4-1 on page 8.
- Relative Humidity: 0 to 100%
- Power Consumption: 616 mW (22 mA @ 28 Vdc) max
- Terminal Voltage: 7 to 28 Vdc
- Loop Resistance: 954 Ω maximum at 22 mA (28 Vdc supply) – see graph below:

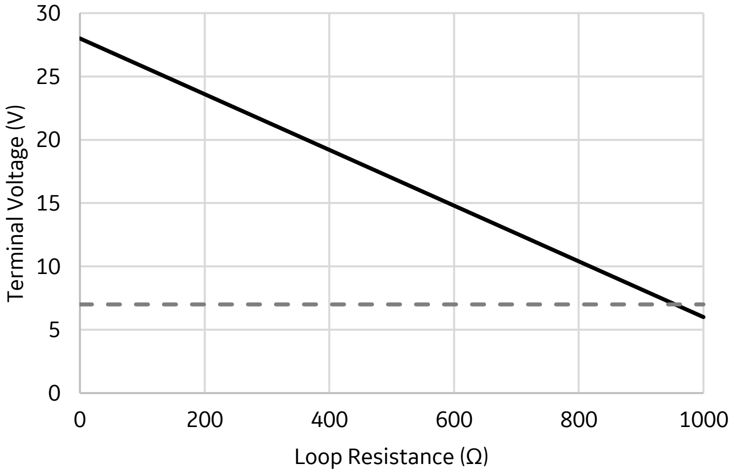

Figure 5-1 - Loop Resistance / Terminal Voltage Graph

- Inverse Polarity protected to -33 Vdc
- Insulation Resistance: >100 MΩ at 500 Vdc (except H0 approval option)
- Vibration: MIL-STD-810C, 514.2, Table 514.2-11: 5-14 Hz 0.1inch, 14-23 Hz 1g, 23-52 Hz 0.036inch, 52-2000 Hz 5g, 1 octave per minute, 3 axes
- Shock: half-sine 100g 0.4 ms and 100g 11 ms, 3 shocks per axis, 3 axes

5.2.2 Over-Pressure Limits

Table 5-2 refers to the PTX 5900 SIL Pressure Sensor Full-Scale (FS) limits and maximum over-range pressure data. This refers to the maximum pressure that can be applied without changing the performance of (i.e. damaging) the sensor.

Table 5-2 – Maximum Over-range Pressure Limits

FS up to (bar a)	Over-range Pressure Limit (bar a)
2	3.5
3.5	5.25
5	7.5
7	10.5
10	15
15	22.5
25	37.5
35	52.5
50	75
70	105
135	202.5
200	300
350	525
500	750
700	1050

5.2.3 Electromagnetic Compatibility

The PTX 5900 SIL Pressure Sensor conforms to the following EMC requirements:

- EMC directive 2014/30/EU
- EN 61326-1:2013 [10]
- EN 61326-2-3:2013 [11]
- IEC 61326-3-1 [12] (from EN 61508 for SIL equipment)

5.2.4 Design Life

The PTX 5900 SIL pressure sensors have a useful design life of greater than 25 years when operated within design parameters.

5.3 Assessment Data

5.3.1 Safety function

The device has the following safety function: To provide a continuous calibrated 4-20 mA output that corresponds to the pressure applied at the sensing interface.

Note: the pressure to loop current function is specified by the customer order and is marked on the unit body. This includes the zero-pressure output current and the pressure span, see section 4.3.1 on page 8. As such the pressure corresponding to a fixed "trip" current (e.g. 12 mA typical) must be calculated from the specification which has been ordered.

The safety function is either to regularly transmit valid measurement data with measurement uncertainty within the Safety Accuracy percentage (see Table 5-1 on page 11) of full-scale (FS) or to enter into a fault state that is either above 21 mA or below 3.6 mA.

The output current should be used in the overall system to ensure the safe state of the EUC in accordance with the application.

Dangerous failure modes are considered those that transmit measurement data that look plausible, but which nevertheless has measurement uncertainty outside the tolerance detailed as Safety Accuracy.

5.3.2 Realisable Safety Function Within an Over Pressure System

The following overall safety function can be realized with the pressure measurement system:

The function supported by the sensor is to indicate pressure above the specified trip pressure as part of an over pressure protection system.

Any failure which prevents indication of pressure over the specified trip point (e.g. 12 mA) is considered to be dangerous and undetected unless the current is below 3.6 mA or above 21 mA. Failures which result in over indication of pressure are considered safe.

Failures which result in an output current >21 mA are considered detected.

Failures which result in an output current <3.6 mA are considered detected.

These considerations are taken as a base for the failure mode effect and diagnostics analysis.

5.3.3 Analysis

The PTX 5900 SIL Pressure Sensor is classified as a Type A device according to IEC 61508 [5], because of the deterministic failure modes of the constituent components.

A hardware analysis [4] was carried out using Failure Modes, Effects and Diagnostic Analysis (FMEDA) for pressure alarm configurations of the sensor.

In compliance with IEC 61508-2 [5] (clause 7.4.9.5 a), Table 5-3 lists the estimated failure rates using component failure data from a recognised industry source Telcordia SR232 version 3 where estimated failure rates have 90% confidence level. Prediction methodology parameters used were Quality 'Level 1', Environment 'Ground, Fixed, Uncontrolled', Ambient Temperature 50°C (lifetime average), Failure Mode Distribution from IEC TR 62380:2004.

Based on FMEDA the Pressure Sensor has a Safe Failure Fraction (SFF) of 73.7%.

Table 5-3 - Failure Data (failures / 10^9 operating hour)

Device	λ	λS	λDD	λDU	SFF	HFT required for SIL2	Diagnostic Coverage
PTX 5900 SIL	75.85	1.58	58.2	16.07	78.8%	0	78%

Table 5-4 shows the corresponding calculated PFD_{AVG} values. The following assumptions were used in this calculation:

- Proof Test Interval (T_1): 25 years = 219,000 hours
- Proof Test Coverage: 100%
- Mean Time to Repair (MTTR): 1 week = 168 hours
- Mean Repair Time (MRT): 1 week = 168 hours
- Mode of Demand: Low Demand

Channel equivalent mean down time (hour) IEC 61508-6 [13] B.3.2.2.1 (TCE) calculation:

$$TCE = \lambda DU/\lambda D*(\tfrac{1}{2}T_1+MRT) + \lambda DD/\lambda D*MTTR = 23{,}849 \text{ hours}$$

PFD_{AVG} calculation (for 1oo1):

$$PFD_{AVG} = \lambda D*TCE = 1.8E\text{-}03$$

Other configuration architectures are possible however a specific assessment would be required and this is not included in this document.

Table 5-4 - Hardware Reliability Assessment

Example Configuration	PFD_{AVG} Target (30% of SIL2 band)	Achieved PFD_{AVG}	Achieved SIL (Architecture)	Overall Achieved SIL
1oo1	3.0E-03	1.8E-03	2	2

The results of the assessment illustrate that the PTX 5900 SIL meets the hardware reliability (PFD of less than 3.0E-03), and architectural requirements of SIL2 in accordance with IEC 61508 [5] and IEC 61511 [6], in 1oo1 voting configuration (i.e. with a HFT of 0, Mode of Operation: Low Demand, as stated in Table 5-3 on page 15.) The Systematic Capability is SC2 based on the techniques and measures used in the realisation lifecycle as verified by the independent assessment body.

6. Personnel

Personnel with involvement in installation, operation and maintenance of products listed in this Safety Manual must be adequately trained and qualified.

It is the responsibility of the system systems integrator, installer and user organisations to ensure and enforce any required training. For further information contact BHGE Customer Support Services at sensing.grobyCC@bhge.com

7. Installation

In order to ensure plant safety and safety of all other parties involved it is essential that installation is carried out by suitably trained personnel. The installation procedure of the UNIK 5900 family of Pressure Sensors (that includes the PTX 5900 SIL rated sensor) can be found in Instruction for Installation, Operation, and Maintenance documents as listed in reference documents [2]. After installation, a proof test shall be conducted to verify correct operation of the safety function. Refer to section 11.1 for details.

Connect the earth / ground connections applicable to the installation. If applicable, make sure the cable screen is isolated from the pressure sensor.

8. Configuration and Setup

8.1 Service / Proof Test Interval

It should be noted that the analysis in section 5.3.3 on page 14 shows that routine proof testing is not required during the lifetime of the product (25 years). However, proof testing is required following installation and after any zero/span adjustments if performed.

It should also be noted that that the Safety Accuracy figures quoted in Table 5-1 on page 11 include of all the following contributions:

- Initial accuracy
- Thermal errors/drift
- Zero/span setting accuracy
- Lifetime stability/drift

Given the very high accuracy of the factory zero/span setting and the low drift it is not recommended that any field recalibration is carried out during the sensor lifetime. However, if required for operational reasons a procedure is given below.

8.2 Zero and Span Adjustment

To adjust zero and span the enclosure can be opened and the zero and span potentiometers adjusted. Use an insulated potentiometer adjustment tool.

WARNING Do not open the enclosure when an explosive atmosphere is present.

The Safety Function may be affected during adjustment – ensure that the equipment being protected is in a safe shut-down state before starting work.

After adjustment a proof test shall be performed to prove that the Safety Function is working as expected.

Take care to disassemble and assemble the electrical connector correctly.

Make sure items such as O-rings and gaskets are properly located when re-assembling sensor.

Before connecting a pressure calibrator, make sure it is certified “intrinsically safe” and that all the electrical connections are intrinsically safe. Stay within the permitted limits for the electrical system.

The pressure calibrator used must be (a) in calibration and (b) have an accuracy of better than 0.04% FS (i.e. 5 times better than Zero/Span setting error contribution) otherwise the safety accuracy of the SIF may be compromised.

8.2.1 Disassembly and Adjustment

Locate and loosen the security bolt using an M3 hex key:

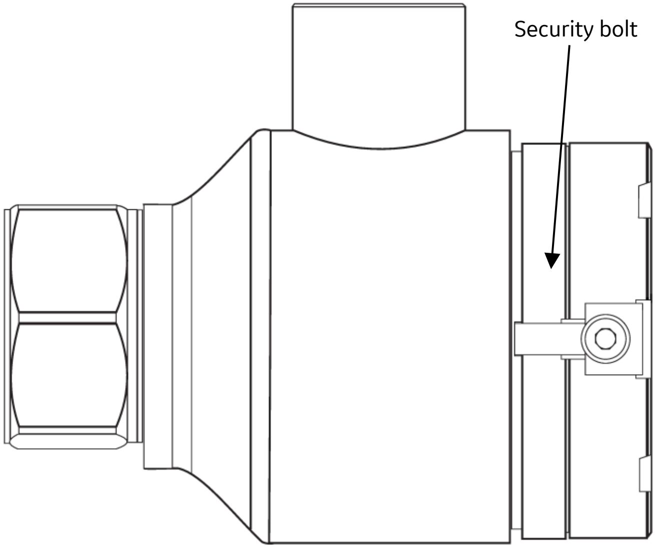

Figure 8-1 - Security Bolt

Unscrew the lid by turning anti-clockwise:

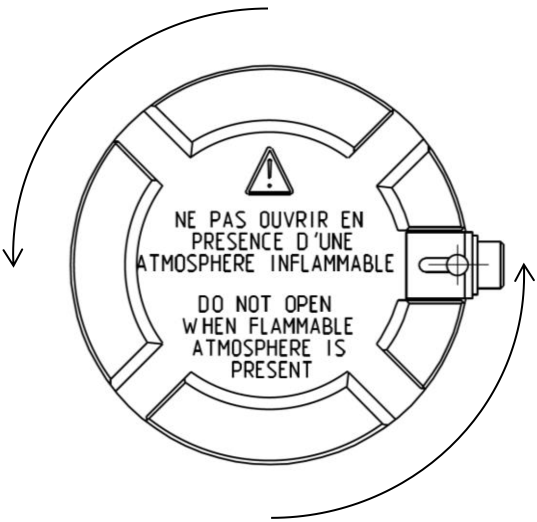

Figure 8-2 – Lid Removal

Lift or remove (will require removing earth screw) the protective black rubber cover to access the zero and span adjustment potentiometers:

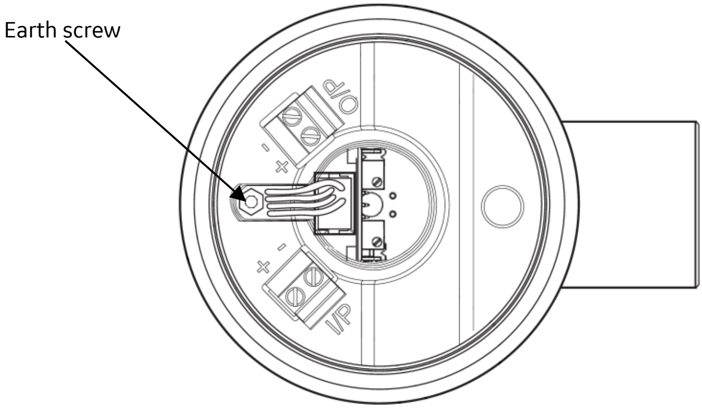

Figure 8-3 – Earth Screw

The Zero adjustment and Span adjustment potentiometers will now be visible. These are multi-turn devices to facilitate fine adjustment:

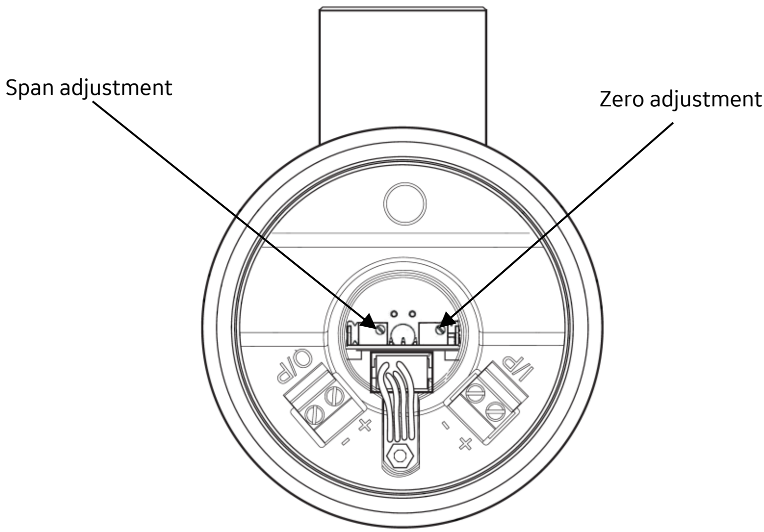

Figure 8-4 - Zero and Span Adjustment

Follow local procedure for adjusting zero and span, noting the Warnings above.

Reassemble unit following reverse of these instructions.

9. Sensor Replacement

If a sensor is replaced it must be installed in accordance with the Instruction for Installation, Operation, and Maintenance documents as listed in reference documents [2]. A proof test must be performed on the sensor after replacement.

10. Decommissioning

There are no specific requirements for the decommissioning of the PTX 5900 SIL sensor.

11. Preventive Maintenance

11.1 Periodic Proof Testing

Dangerous undetected (DU) faults can occur during the operation of the sensor and lead to failure of the safety function.

The analysis in section 5.3.3 on page 14 shows that the required proof test interval is greater than 25 years to meet the PFD_{AVG} requirements, so proof testing need only be performed at installation and following any zero/span adjustments if performed (section 8.2 on page 21).

A suggested proof test procedure is described below.

11.1.1 Steps for Proof Testing

After venting and isolating the pipeline, personnel must ensure that pressure sensor output is continuously monitored while the following steps, illustrated in Figure 11-1, are carried out.

For the proof test to be most effective, it is recommended to check the pressure sensor output against a calibrated pressure source. It is also recommended to repeat the steps in Figure 11-1 with different pressure rise and fall rates, within the specified range, as many times as possible.

1. Gradually increase the pressure by injecting the input, for a period of T1, until causing a trip condition.
2. Maintain stable pressure above the trip point for a period of T2.
3. Gradually vent the pressure in the pipeline to a minimum for a period of T3.
4. Maintain vented minimum pressure for a period of T4.
5. Increase the pressure at higher rate than the previous rise in T1, for a period of T5, until causing a trip condition.
6. Maintain stable pressure above the trip point for a period of T6.
7. Vent the pressure at higher rate than that in period T3, for a period of T7.

The periods T1 to T7 are to be determined by customers based on their safety system capabilities.

The maximum rate of pressure increase or decrease during proof test shall not exceed 1000 psi/sec (68.9 bar/sec) to prevent damage to the sensor.

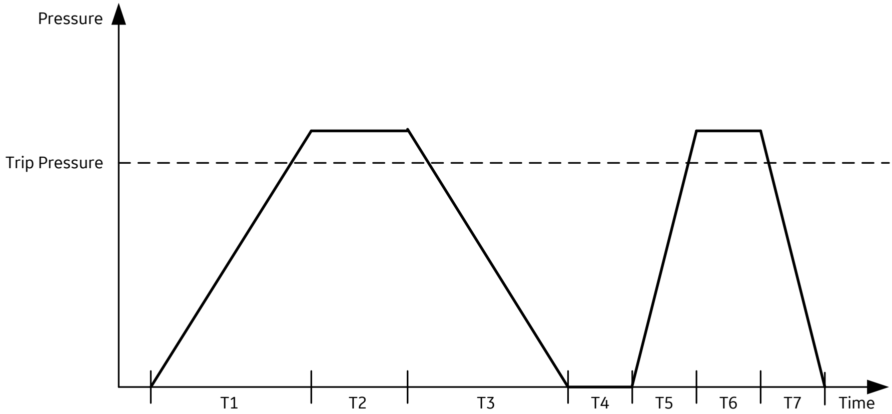

Figure 11-1 - Proof Test Pressure Steps

12. Fault Handling

12.1 How to Detect a Fault

Fault detection on the PTX 5900 SIL Pressure Sensor needs to be achieved by monitoring the sensor output, and detecting fail high (>21 mA) and fail low (<3.6 mA) conditions. When a fault is detected the 4-20 mA output will be set to an alarm state immediately.

The sensor has been configured so that for some internal faults the output of the sensor will be forced Low (<3.6 mA), while other faults may be revealed if the sensor output is High (>21 mA). These faults are declared DD. Other faults (including DU) may also be detected at system level by monitoring for frozen or incorrect (inconsistent with other sensors) pressure indications.

12.2 Repair, Replacement and Revalidation

No attempt to repair failed sensor without first informing BHGE Customer Support Services at sensing.grobyCC@bhge.com.

A proof test must be performed on the sensor after any repair.

12.3 Fault Reporting Requirements

If for any reason a functional failure of the sensor is revealed, the manufacturer should be informed directly by notifying them with:

- The serial number(s) of the affected unit(s)
- A brief description of the fault (e.g. no/incorrect output when pressure applied)
- When the fault was discovered or occurred, in particular:
- Prior to commissioning (i.e. transit, storage or during initial installation)
- Post commissioning (during the operational phase)

Fault reports should be marked for the attention of the FS authority (or c/o Quality Manager) and sent via:

- Email to: sensing.grobyCC@bhge.com
- Telephone: +44 116 231 7100

Note: the above is required to fulfil lifecycle obligations in accordance with IEC 61508 or 61511 of both the user and device manufacturer; it is required independent of contractual warranty arrangements.

12.4 Sensor Fault Reset

The fault detection mechanism is not latching within the PTX 5900 SIL, so there is no fault reset mechanism required.

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124M4659 Revision A | English