# FUNCTIONAL SAFETY CERTIFICATE

This is to certify that the

## *X5000 & S5000 Fixed Gas Detector Range*

manufactured by

***MSA – The Safety Company***
1000 Cranberry Woods Drive
Cranberry Township
16066-5296, PA, USA

***General Monitors***
26776 Simpatica Cir
Lake Forest
CA 92630, USA

have been assessed by Sira Certification Service with reference to the CASS methodologies and found to meet the requirements of

**IEC 61508:2010**
**Routes $1_H$ & $1_S$**
**Systematic Capability (SC3)**

as an element/subsystem suitable for use in safety related systems performing safety functions up to and including

**SIL 2 capable with HFT=0 (1oo1)***
**SIL 3 capable with HFT=1 (1oo2)***

when used in accordance with the scope and conditions of this certificate.

* This certificate does not waive the need for further functional safety verification to establish the achieved Safety Integrity Level (SIL) of the safety related system

Certification Manager:
Wayne Thomas

Initial Certification : 31/01/2018
This certificate re-issued : 31/01/2018
Renewal date : 30/01/2023





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## Product description and scope of certification

**X5000:**

Main Transmitter – The main transmitter unit consists of an explosion proof aluminum or stainless steel enclosure that houses the main unit electronics. Functionality includes the unit power supply, microprocessor and digital interface, 4-20mA drivers, user interface and (optional) relays. Up to two sensors in any combination can be used with a single Main Transmitter.

XIR Plus Sensor – The XIR Plus sensor is an infrared sensor designed to measure many combustible and toxic gasses. It is based on the existing MSA XIR sensor but with an updated digital interface so that it can communicate with the main transmitter.

Digital Sensors – The Digital Sensor modules include either an MSA XCell electrochemical sensor (currently CO, H2S and Oxygen) or an MSA XCell catalytic bead combustible sensor, a pre-amp board and a board that digitizes the gas measurement for communication with the main transmitter. The CO and H2S sensor modules also includes MSA's patented Life and Health algorithm that automatically compensates for sensor drift and sensitivity loss.

**S5000:**

The S5000 main transmitter supports either one or two sensors, depending on sensor selection and is assembled with one of three sensor interface specific boards; Digital interface sensors, MOS sensors or Passive Catalytic bead combustible sensors.

IR400 Sensor – The IR400 sensor is an infrared sensor designed to measure many combustible and toxic gasses. It communicates with the main transmitter via a 4-20mA loop.
Passive Catalytic Sensor – The passive catalytic sensor is simply a catalytic bead sensor with no additional electronics. All signal amplification and processing is handled by a special version of the main board in the S5000 main transmitter.

Passive MOS Sensor – The passive MOS (metal oxide semiconductor) sensor is a high performance / high concentration H2S sensor which includes a small heating element. All signal amplification and processing is handled by a special version of the main board in the S5000 main transmitter.

Digital Sensors – The Digital Sensor modules include either an MSA XCell electrochemical sensor (currently CO, H2S and Oxygen) or an MSA XCell catalytic bead combustible sensor, a pre-amp board and a board that digitizes the gas measurement for communication with the main transmitter. The CO and H2S sensor modules also includes MSA's patented Life and Health algorithm that automatically compensates for sensor drift and sensitivity loss.


**Figure 1: Typical Assembly of the X5000 (left) and S5000 (right) Gas Detectors**



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## Element Safety Function

The element safety functions of the **Error! Reference source not found.** is defined as follows:

To provide the host system with a predefined 4-20mA alarm signal output and de-energise a relay (if included) in the event of a dangerous or explosive atmosphere depending on the sensor type configuration.

## Certified Data in support of use in safety functions

The assessment has been carried out with reference to the *Conformity Assessment of Safety-related Systems* (CASS) methodology using the Route $1_H$ approach.

Based on the document submitted by MSA the Failure Mode and Effect Analysis (FMEA) of the X5000 & S5000 Gas Detectors has verified the documents as evidence of conformity to IEC 61508-2:2010 in respect of 'hardware safety integrity'. The results in tables 1 & 2 summarize the X5000 & S5000 Gas Detectors FMEA assessment and achieved safety integrity level.

**Table 1: FMEDA Analysis Results of the X5000 Gas Detector (single mode)**

| Parameter name | Symbol | Equation / source | Result |
|---|---|---|---|
| Proof Test Interval | T1 | IEC 61508-4 clause 3.8.5 | **4380 hrs** |
| Mean Time To Repair | MTTR | IEC 61508-4 clause 3.6.21 | **72 hrs** |
| Mean Repair Time (once revealed) | MRT | IEC 61508-4 clause 3.6.22 | **72 hrs** |
| Type A/B | Type | IEC 61508-2 clause 7.4.4.1.2 & 7.4.4.1.3 | **Type B** |
| Total failures: | $\lambda$ | IEC 61508-4 clause 3.6.4 | See annex 1 of this certificate for results |
| Safe diagnosed failures: | $\lambda_{SD}$ | IEC 61508-4 clause 3.6.8 | |
| Safe undiagnosed failures: | $\lambda_{SU}$ | | |
| Dangerous diagnosed failures: | $\lambda_{DD}$ | IEC 61508-4 clause 3.6.7 | |
| Dangerous undiagnosed failures: | $\lambda_{DU}$ | | |
| Diagnostic coverage: | $DC$ | $DC = \frac{\lambda_{DD}}{\lambda_{DU} + \lambda_{DD}}$ | |
| Safe Failure Fraction: | $SFF$ | $SFF = \frac{\lambda_{SD} + \lambda_{SU} + \lambda_{DD}}{\lambda}$ | |
| Channel equivalent down time | $t_{CE}$ | $t_{CE} = \frac{\lambda_{DU}}{\lambda_D}\left(\frac{T}{2} + MRT\right) + \frac{\lambda_{DD}}{\lambda_D} MTTR$ | |
| $PFD_{AVG}$ (using simplified equation) | $PFD_{AVG}$ | $PFD_{AVG} = \lambda_{DU}\left(\frac{T}{2} + MTTR\right) + \lambda_{DD} MTTR$ | |
| SIL capability (Low demand mode) | **SIL** | | |



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**Table 2: FMEDA Analysis Results of the S5000 Gas Detector (single mode)**

| Parameter name | Symbol | Equation / source | Result |
|---|---|---|---|
| Proof Test Interval | T1 | IEC 61508-4 clause 3.8.5 | **2190 hrs** |
| Mean Time To Repair | MTTR | IEC 61508-4 clause 3.6.21 | **4 hrs** |
| Mean Repair Time (once revealed) | MRT | IEC 61508-4 clause 3.6.22 | **4 hrs** |
| Type A/B | Type | IEC 61508-2 clause 7.4.4.1.2 & 7.4.4.1.3 | **Type B** |
| Total failures: | $\lambda$ | IEC 61508-4 clause 3.6.4 | See annex 2 of this certificate for results |
| Safe diagnosed failures: | $\lambda_{SD}$ | IEC 61508-4 clause 3.6.8 | |
| Safe undiagnosed failures: | $\lambda_{SU}$ | | |
| Dangerous diagnosed failures: | $\lambda_{DD}$ | IEC 61508-4 clause 3.6.7 | |
| Dangerous undiagnosed failures: | $\lambda_{DU}$ | | |
| Diagnostic coverage: | $DC$ | $DC = \frac{\lambda_{DD}}{\lambda_{DU} + \lambda_{DD}}$ | |
| Safe Failure Fraction: | $SFF$ | $SFF = \frac{\lambda_{SD} + \lambda_{SU} + \lambda_{DD}}{\lambda}$ | |
| Channel equivalent down time | $t_{CE}$ | $t_{CE} = \frac{\lambda_{DU}}{\lambda_D}\left(\frac{T}{2} + MRT\right) + \frac{\lambda_{DD}}{\lambda_D} MTTR$ | |
| $PFD_{AVG}$ (using simplified equation) | $PFD_{AVG}$ | $PFD_{AVG} = \lambda_{DU}\left(\frac{T}{2} + MTTR\right) + \lambda_{DD} MTTR$ | |
| SIL capability (Low demand mode) | **SIL** | | |

**Note 1**: The failure data:

1) The $PFD_{AVG}$ figure shown is for illustration only. Refer to IEC 61508-6 for guidance on $PFD_{AVG}$ calculations from the failure data.

2) The verified failure rates used in the safe failure fraction and diagnostic coverage do not include (λ no parts or no effect) failures in the calculation.

The failure data above is supported by the base information given in Table 3 below.

**Table 3: Base information for the X5000 & S5000 Gas Detectors**

| | | |
|---|---|---|
| 1 | Product identification: | X5000 & S5000 Gas Detectors |
| 2 | Functional specification: | To provide the host system with a predefined 4-20mA alarm signal output and de-energise a relay (if included) in the event of a dangerous or explosive atmosphere depending on the sensor type configuration. |
| 3-5 | Random hardware failure rates: | Refer to table 1 & 2 of this certificate. |
| 6 | Environment limits: | Operating temperature:<br>X5000 up to +60°C, S5000 up to +75°C |
| 7 | Lifetime/replacement limits: | 20 years |
| 8 | Proof Test requirements: | Refer to safety manuals:<br>X5000_Safety Manual<br>S5000_Safety Manual |
| 9 | Maintenance requirements: | Refer to safety manuals:<br>X5000_Safety Manual<br>S5000_Safety Manual |
| 10 | Diagnostic coverage: | 95% - 99% depending on the model |
| 11 | Diagnostic test interval: | Refer to safety manuals: |



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| | | |
|---|---|---|
| | | X5000_Safety Manual<br>S5000_Safety Manual |
| 12 | Repair constraints: | Refer to safety manuals:<br>X5000_Safety Manual<br>S5000_Safety Manual |
| 13 | Safe Failure Fraction: | 90% - 99% depending on the model |
| 14 | Hardware fault tolerance (HFT): | See Tables 1 & 2 of this certificate |
| 15 | Highest SIL (architecture/type A/B): | Type B, SIL2 (HFT=0) & Type B, SIL3 (HFT=1). |
| 16 | Systematic failure constraints: | Refer to safety manuals:<br>X5000_Safety Manual<br>S5000_Safety Manual |
| 17 | Evidence of similar conditions in previous use: | Not applicable. |
| 18 | Evidence supporting the application under different conditions of use: | Not applicable. |
| 19 | Evidence of period of operational use: | Not applicable. |
| 20 | Statement of restrictions on functionality: | See systematic report R70164637B. |
| 21 | Systematic capability (SC1, SC2, SC3) | SC3 - See systematic report R70164637B. |
| 22 | Systematic fault avoidance measures: | Compliance with techniques and measures from IEC 61508-2 Annex B. See systematic report R70164637B. |
| 23 | Systematic fault tolerance measures: | Compliance with techniques and measures from IEC 61508-2 Annex A to support the SFF achieved – see hardware safety integrity report R70164637A. |
| 24 | Validation records: | All documents that have been used in support of the hardware have been documented in section 5.24 of report R70164637A; this includes the FMEA document and insertion tests. |

**Management of functional safety**

The assessment has demonstrated that the product is supported by an appropriate functional safety management system that meets the relevant requirements of IEC 61508-1:2010 clause 6, see report R70164637B.

**Software Lifecycle compliance to IEC 61508-3**

The assessment did not cover the systematic software lifecycle to IEC 61508-3:2010. The certificate only covers parts 1 (FSM) and 2 (hardware lifecycle) of the IEC 61508 and the software techniques and measures (Annex A & B of IEC61508-3).

**Identification of certified equipment**

The certified equipment and it's safe use is defined in the manufacturer's documentation listed in Table 4 below.



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**Table 4: Certified documents**

| Document no. | Rev. | Date | Document description |
|---|---|---|---|
| 324130 | 2 | 11 Feb 2017 | S5000 Main Transmitter Schematic |
| 324140 | 0 | 16 Jun 2014 | X5000 Main Transmitter Schematic |
| 324170 | 0 | 20 Jul 2015 | Digital Cat Bead Preamp Schematic |
| 324180 | 0 | 22 Jul 2015 | Oxygen Preamp Puck Schematic |
| 324230 | 2 | 04 May 2016 | Tox Life & Health Preamp Schematic |
| SK3073-1122 | 4 | 05 Dec 2013 | Toxic & Oxygen ASIC Schematic |
| SK3073-1134 | 0 | 23 Sep 2016 | X5000 Relay Schematic |
| SK3073-1143 | 0 | 23 Sep 2016 | XIR Main Schematic |
| SK3073-1144 | 0 | 23 Sep 2016 | XIR Power Schematic |
| SK3073-1146 | 1 | 23 Sep 2016 | X5000 Main Schematic |

**Conditions of Certification**

The validity of the certified base data is conditional on the manufacturer complying with the following conditions:

1. The manufacturer shall analyse failure data from returned products on an on-going basis. Sira Certification Service shall be informed in the event of any indication that the actual failure rates are worse than the certified failure rates. (A process to rate the validity of field data should be used. To this end, the manufacturer should co-operate with users to operate a formal field-experience feedback programme).
2. Sira shall be notified in advance (with an impact analysis report) before any modifications to the certified equipment or the functional safety information in the user documentation is carried out. Sira may need to perform a re-assessment if modifications are judged to affect the product's functional safety certified herein.
3. On-going lifecycle activities associated with this product (e.g., modifications, corrective actions, field failure analysis) shall be subject to surveillance by Sira in accordance with 'Regulations Applicable to the Holders of Sira Certificates'.

**Conditions of Safe Use**

The validity of the certified base data in any specific user application is conditional on the user complying with the following conditions:

1. The user shall comply with the requirements given in the manufacturer's user documentation in regard to all relevant functional safety aspects such as application of use, installation, operation, maintenance, proof tests, maximum ratings, environmental conditions, and repair.
2. Selection of this product for use in safety function and the installation, configuration, overall validation, maintenance and repair shall only be carried out by competent personnel, observing all the manufacturer's conditions and recommendations in the user documentation.
3. All information associated with any field failures of this product should be collected under a dependability management process (e.g., IEC 60300-3-2) and reported to the manufacturer.
4. The safety device is to have an independent power supply, it must not share the same power supply as non-safety devices that may cause a fault to the safety device.
5. This certificate is subject to review once MSA have submitted evidence of the full compliance against the software requirements of IEC61508-3.



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## General Conditions and Notes

1. This certificate is based upon a functional safety assessment of the product described in Sira Test & Certification Assessment Report R70164637A and R70164637B.
2. If the certified product or system is found not to comply, Sira Certification Service should be notified immediately at the address shown on this certificate.
3. The use of this Certificate and the Sira Certification Mark that can be applied to the product or used in publicity material are subject to the 'Regulations Applicable to the Holders of Sira Certificates' and 'Supplementary Regulations Specific to Functional Safety Certification'.
4. This document remains the property of Sira and shall be returned when requested by the issuer.
5. No part of the Functional safety related aspects stated in the instruction manual shall be changed without approval of the certification body.
6. This certificate will remain valid subject to completion of two surveillance audits within the five year certification cycle, and upon receipt of acceptable response to any findings raised during this period. This certificate can be withdrawn if the manufacturer no longer satisfies scheme requirements.

## Certificate History

| Issue | Date | Report no. | Comment |
|---|---|---|---|
| 0 | 31/01/2018 | R70164637A<br>R70164637B | The release of prime certificate. |
| | | | |



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## Annex 1: X5000 Full FMEA Results

### FMEA Summary for the X5000 Gas Detector in Single Mode (1oo1) without Relay (Low Demand of Operation)

**Safety Function:**
To provide the host system with a predefined 4-20mA alarm signal output and de-energise a relay (if included) in the event of a dangerous or explosive atmosphere depending on the sensor type configuration.

| Sensor 1 | Sensor 2 | Relay | $\lambda_{SD}$ | $\lambda_{SU}$ | $\lambda_{DD}$ | $\lambda_{DU}$ | SFF | DC | $t_{CE}$ | PFD | SIL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Xcell Toxic | No Sensor | No | 2.99E-08 | 1.20E-06 | 1.54E-06 | 4.14E-08 | 98.53% | 97.39% | 1.29E+02 | 2.05E-04 | 2 |
| Xcell Toxic | Xcell Toxic | No | 3.05E-08 | 1.53E-06 | 2.03E-06 | 6.80E-08 | 98.14% | 96.76% | 1.43E+02 | 3.00E-04 | 2 |
| Xcell Toxic | Xcell Oxygen | No | 3.06E-08 | 1.60E-06 | 2.02E-06 | 4.30E-08 | 98.83% | 97.91% | 1.18E+02 | 2.42E-04 | 2 |
| Xcell Toxic | Cat Bead Combustible | No | 3.00E-08 | 1.31E-06 | 1.61E-05 | 1.64E-06 | 91.40% | 90.75% | 2.75E+02 | 4.88E-03 | 2 |
| Xcell Toxic | XIR Plus | No | 2.99E-08 | 1.82E-06 | 2.54E-06 | 5.21E-08 | 98.83% | 97.99% | 1.16E+02 | 3.01E-04 | 2 |
| Xcell Oxygen | No Sensor | No | 3.00E-08 | 1.28E-06 | 1.53E-06 | 1.65E-08 | 99.42% | 98.94% | 9.53E+01 | 1.48E-04 | 2 |
| Xcell Oxygen | Xcell Oxygen | No | 3.07E-08 | 1.68E-06 | 2.00E-06 | 1.81E-08 | 99.52% | 99.11% | 9.16E+01 | 1.85E-04 | 2 |
| Xcell Oxygen | Cat Bead Combustible | No | 3.01E-08 | 1.39E-06 | 1.61E-05 | 1.62E-06 | 91.55% | 90.87% | 2.72E+02 | 4.82E-03 | 2 |
| Xcell Oxygen | XIR Plus | No | 3.00E-08 | 1.89E-06 | 2.53E-06 | 2.71E-08 | 99.39% | 98.94% | 9.52E+01 | 2.43E-04 | 2 |
| Cat Bead Combustible | No Sensor | No | 2.94E-08 | 9.83E-07 | 1.56E-05 | 1.62E-06 | 91.15% | 90.63% | 2.77E+02 | 4.78E-03 | 2 |
| Cat Bead Combustible | Cat Bead Combustible | No | 2.95E-08 | 1.09E-06 | 3.02E-05 | 3.22E-06 | 90.69% | 90.38% | 2.83E+02 | 9.46E-03 | 2 |
| Cat Bead Combustible | XIR Plus | No | 2.94E-08 | 1.60E-06 | 1.66E-05 | 1.63E-06 | 91.82% | 91.09% | 2.67E+02 | 4.88E-03 | 2 |
| XIR Plus | No Sensor | No | 2.93E-08 | 1.49E-06 | 2.06E-06 | 2.55E-08 | 99.29% | 98.78% | 9.88E+01 | 2.06E-04 | 2 |
| XIR Plus | XIR Plus | No | 2.93E-08 | 2.11E-06 | 3.05E-06 | 3.61E-08 | 99.31% | 98.83% | 9.76E+01 | 3.02E-04 | 2 |

The above results are based on the following:

- Proof Test Interval (PTI) = 4380 hours (6 months)
- Mean Time to Restoration (MTTR) = 72 hours
- Mean Repair Time (MRT) = 72 hours

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**FMEA Summary for the X5000 Gas Detector in Single Mode (1oo1) with Relay (Low Demand of Operation)**

**Safety Function:**
To provide the host system with a predefined 4-20mA alarm signal output and de-energise a relay (if included) in the event of a dangerous or explosive atmosphere depending on the sensor type configuration.

| Sensor 1 | Sensor 2 | Relay | $\lambda_{SD}$ | $\lambda_{SU}$ | $\lambda_{DD}$ | $\lambda_{DU}$ | SFF | DC | $t_{CE}$ | PFD | SIL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Xcell Toxic | No Sensor | Yes | 2.99E-08 | 1.34E-06 | 1.68E-06 | 5.25E-08 | 98.31% | 96.96% | 1.39E+02 | 2.39E-04 | 2 |
| Xcell Toxic | Xcell Toxic | Yes | 3.05E-08 | 1.67E-06 | 2.16E-06 | 7.91E-08 | 97.99% | 96.47% | 1.49E+02 | 3.34E-04 | 2 |
| Xcell Toxic | Xcell Oxygen | Yes | 3.06E-08 | 1.75E-06 | 2.15E-06 | 5.41E-08 | 98.64% | 97.54% | 1.26E+02 | 2.77E-04 | 2 |
| Xcell Toxic | Cat Bead Combustible | Yes | 3.00E-08 | 1.45E-06 | 1.63E-05 | 1.65E-06 | 91.47% | 90.76% | 2.74E+02 | 4.91E-03 | 2 |
| Xcell Toxic | XIR Plus | Yes | 2.99E-08 | 1.96E-06 | 2.67E-06 | 6.31E-08 | 98.66% | 97.69% | 1.23E+02 | 3.35E-04 | 2 |
| Xcell Oxygen | No Sensor | Yes | 3.00E-08 | 1.42E-06 | 1.66E-06 | 2.75E-08 | 99.12% | 98.37% | 1.08E+02 | 1.82E-04 | 2 |
| Xcell Oxygen | Xcell Oxygen | Yes | 3.07E-08 | 1.82E-06 | 2.13E-06 | 2.91E-08 | 99.28% | 98.65% | 1.01E+02 | 2.20E-04 | 2 |
| Xcell Oxygen | Cat Bead Combustible | Yes | 3.01E-08 | 1.53E-06 | 1.62E-05 | 1.63E-06 | 91.62% | 90.89% | 2.72E+02 | 4.85E-03 | 2 |
| Xcell Oxygen | XIR Plus | Yes | 3.00E-08 | 2.04E-06 | 2.66E-06 | 3.82E-08 | 99.20% | 98.59% | 1.03E+02 | 2.78E-04 | 2 |
| Cat Bead Combustible | No Sensor | Yes | 2.94E-08 | 1.13E-06 | 1.58E-05 | 1.63E-06 | 91.23% | 90.65% | 2.77E+02 | 4.82E-03 | 2 |
| Cat Bead Combustible | Cat Bead Combustible | Yes | 2.95E-08 | 1.24E-06 | 3.04E-05 | 3.23E-06 | 90.73% | 90.38% | 2.83E+02 | 9.49E-03 | 2 |
| Cat Bead Combustible | XIR Plus | Yes | 2.94E-08 | 1.74E-06 | 1.68E-05 | 1.64E-06 | 91.88% | 91.10% | 2.67E+02 | 4.91E-03 | 2 |
| XIR Plus | No Sensor | Yes | 2.93E-08 | 1.63E-06 | 2.19E-06 | 3.66E-08 | 99.06% | 98.36% | 1.08E+02 | 2.40E-04 | 2 |
| XIR Plus | XIR Plus | Yes | 2.93E-08 | 2.25E-06 | 3.19E-06 | 4.72E-08 | 99.14% | 98.54% | 1.04E+02 | 3.36E-04 | 2 |

The above results are based on the following:

- Proof Test Interval (PTI) = 4380 hours (6 months)
- Mean Time to Restoration (MTTR) = 72 hours
- Mean Repair Time (MRT) = 72 hours

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## Annex 2: S5000 Full FMEA Results

### FMEA Summary for the S5000 Gas Detector in Single Mode (1oo1) without Relay (Low Demand of Operation)

**Safety Function:**
To provide the host system with a predefined 4-20mA alarm signal output and de-energise a relay (if included) in the event of a dangerous or explosive atmosphere depending on the sensor type configuration.

| Sensor 1 | Sensor 2 | Relay | $\lambda_{SD}$ | $\lambda_{SU}$ | $\lambda_{DD}$ | $\lambda_{DU}$ | SFF | DC | $t_{CE}$ | PFD | SIL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Xcell Toxic | No Sensor | No | 8.00E-08 | 1.21E-06 | 1.38E-06 | 2.66E-08 | 99.01% | 98.11% | 2.47E+01 | 3.48E-05 | 2 |
| Xcell Toxic | Xcell Toxic | No | 8.06E-08 | 1.53E-06 | 1.87E-06 | 5.32E-08 | 98.49% | 97.23% | 3.44E+01 | 6.59E-05 | 2 |
| Xcell Toxic | Xcell Oxygen | No | 8.07E-08 | 1.61E-06 | 1.85E-06 | 2.83E-08 | 99.21% | 98.50% | 2.04E+01 | 3.85E-05 | 2 |
| Xcell Toxic | IR 400 | No | 8.00E-08 | 3.31E-06 | 3.63E-06 | 5.30E-08 | 99.25% | 98.56% | 1.98E+01 | 7.28E-05 | 2 |
| Xcell Oxygen | No Sensor | No | 8.01E-08 | 1.28E-06 | 1.37E-06 | 1.71E-09 | 99.94% | 99.88% | 5.36E+00 | 7.36E-06 | 2 |
| Xcell Oxygen | Xcell Oxygen | No | 8.08E-08 | 1.69E-06 | 1.84E-06 | 3.34E-09 | 99.91% | 99.82% | 5.98E+00 | 1.10E-05 | 2 |
| Xcell Oxygen | IR 400 | No | 8.01E-08 | 3.38E-06 | 3.62E-06 | 2.81E-08 | 99.60% | 99.23% | 1.24E+01 | 4.54E-05 | 2 |
| IR 400 | No Sensor | No | 7.93E-08 | 2.98E-06 | 3.15E-06 | 2.65E-08 | 99.58% | 99.17% | 1.31E+01 | 4.17E-05 | 2 |
| Digital Cat Bead | No Sensor | No | 7.94E-08 | 9.89E-07 | 1.55E-05 | 1.60E-06 | 91.17% | 90.62% | 1.07E+02 | 1.82E-03 | 2 |
| Digital Cat Bead | Digital Cat Bead | No | 7.96E-08 | 1.10E-06 | 3.01E-05 | 3.20E-06 | 90.70% | 90.37% | 1.09E+02 | 3.64E-03 | 2 |
| Digital Cat Bead | Xcell Oxygen | No | 8.02E-08 | 1.39E-06 | 1.60E-05 | 1.60E-06 | 91.57% | 90.87% | 1.04E+02 | 1.83E-03 | 2 |
| Digital Cat Bead | Xcell Toxic | No | 8.01E-08 | 1.32E-06 | 1.60E-05 | 1.63E-06 | 91.42% | 90.74% | 1.05E+02 | 1.85E-03 | 2 |
| Digital Cat Bead | IR 400 | No | 7.94E-08 | 3.09E-06 | 1.77E-05 | 1.63E-06 | 92.77% | 91.59% | 9.61E+01 | 1.86E-03 | 2 |
| Passive Cat Bead | No Sensor | No | 4.14E-08 | 6.35E-07 | 1.52E-05 | 1.60E-06 | 90.82% | 90.44% | 1.09E+02 | 1.82E-03 | 2 |
| Passive MOS | No Sensor | No | 5.09E-08 | 6.57E-07 | 1.67E-05 | 1.34E-08 | 99.92% | 99.92% | 4.87E+00 | 8.16E-05 | 2 |

The above results are based on the following:

- Proof Test Interval (PTI) = 2190 hours (3 months)
- Mean Time to Restoration (MTTR) = 4 hours
- Mean Repair Time (MRT) = 4 hours

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**FMEA Summary for the S5000 Gas Detector in Single Mode (1oo1) with Relay (Low Demand of Operation)**

**Safety Function:**
To provide the host system with a predefined 4-20mA alarm signal output and de-energise a relay (if included) in the event of a dangerous or explosive atmosphere depending on the sensor type configuration.

| Sensor 1 | Sensor 2 | Relay | $\lambda_{SD}$ | $\lambda_{SU}$ | $\lambda_{DD}$ | $\lambda_{DU}$ | SFF | DC | $t_{CE}$ | PFD | SIL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Xcell Toxic | No Sensor | Yes | 1.03E-07 | 1.24E-06 | 1.40E-06 | 2.92E-08 | 98.95% | 97.96% | 2.63E+01 | 3.77E-05 | 2 |
| Xcell Toxic | Xcell Toxic | Yes | 1.04E-07 | 1.56E-06 | 1.89E-06 | 5.57E-08 | 98.46% | 97.13% | 3.54E+01 | 6.88E-05 | 2 |
| Xcell Toxic | Xcell Oxygen | Yes | 1.04E-07 | 1.64E-06 | 1.87E-06 | 3.08E-08 | 99.16% | 98.38% | 2.17E+01 | 4.13E-05 | 2 |
| Xcell Toxic | IR 400 | Yes | 1.03E-07 | 3.34E-06 | 3.65E-06 | 5.56E-08 | 99.22% | 98.50% | 2.04E+01 | 7.57E-05 | 2 |
| Xcell Oxygen | No Sensor | Yes | 1.03E-07 | 1.31E-06 | 1.39E-06 | 4.23E-09 | 99.85% | 99.70% | 7.32E+00 | 1.02E-05 | 2 |
| Xcell Oxygen | Xcell Oxygen | Yes | 1.04E-07 | 1.72E-06 | 1.86E-06 | 5.86E-09 | 99.84% | 99.69% | 7.44E+00 | 1.39E-05 | 2 |
| Xcell Oxygen | IR 400 | Yes | 1.03E-07 | 3.41E-06 | 3.64E-06 | 3.06E-08 | 99.57% | 99.17% | 1.31E+01 | 4.82E-05 | 2 |
| IR 400 | No Sensor | Yes | 1.03E-07 | 3.01E-06 | 3.17E-06 | 2.90E-08 | 99.54% | 99.09% | 1.39E+01 | 4.45E-05 | 2 |
| Digital Cat Bead | No Sensor | Yes | 1.03E-07 | 1.02E-06 | 1.55E-05 | 1.60E-06 | 91.20% | 90.62% | 1.07E+02 | 1.82E-03 | 2 |
| Digital Cat Bead | Digital Cat Bead | Yes | 1.03E-07 | 1.13E-06 | 3.01E-05 | 3.21E-06 | 90.71% | 90.37% | 1.09E+02 | 3.64E-03 | 2 |
| Digital Cat Bead | Xcell Oxygen | Yes | 1.03E-07 | 1.42E-06 | 1.60E-05 | 1.61E-06 | 91.59% | 90.86% | 1.04E+02 | 1.83E-03 | 2 |
| Digital Cat Bead | Xcell Toxic | Yes | 1.03E-07 | 1.35E-06 | 1.60E-05 | 1.63E-06 | 91.45% | 90.74% | 1.05E+02 | 1.86E-03 | 2 |
| Digital Cat Bead | IR 400 | Yes | 1.03E-07 | 3.12E-06 | 1.77E-05 | 1.63E-06 | 92.79% | 91.59% | 9.61E+01 | 1.86E-03 | 2 |
| Passive Cat Bead | No Sensor | Yes | 6.47E-08 | 6.68E-07 | 1.52E-05 | 1.60E-06 | 90.84% | 90.44% | 1.09E+02 | 1.82E-03 | 2 |
| Passive MOS | No Sensor | Yes | 7.42E-08 | 6.89E-07 | 1.67E-05 | 1.59E-08 | 99.91% | 99.91% | 5.04E+00 | 8.44E-05 | 2 |

The above results are based on the following:

- Proof Test Interval (PTI) = 2190 hours (3 months)
- Mean Time to Restoration (MTTR) = 4 hours
- Mean Repair Time (MRT) = 4 hours

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