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Rosemount 2120

Functional Safety Manual

ROSEMOUNT

EMERSON
Process Management

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Section 1 Introduction

1.1 Scope and purpose of the safety manual

This safety manual contains the information to design, install, verify and maintain a Safety Instrumented Function (SIF) utilizing a Rosemount 2120 level switch.

The manual provides the necessary requirements to enable the integration of the 2120 level switch when showing compliance with the IEC 61508 or IEC 61511 functional safety standards. It indicates all assumptions that have been made on the usage of the Level Switch. If these assumptions cannot be met by the application, the SIL capability of the Product may be adversely affected.

Note
For product support, use the contact details on the back page.

1.2 Skill level requirement

System design, installation and commissioning, and repair and maintenance shall be carried out by suitably qualified personnel.

1.3 Terms, abbreviations, and acronyms

BPCS

Basic Process Control System – a system which responds to input signals from the process, its associated equipment, other programmable systems and/or an operator and generates output signals causing the process and its associated equipment to operate in the desired manner but which does not perform any safety instrumented functions with a claimed SIL greater than or equal to 1.

Fail-safe State

State where switch output is in the state corresponding to an alarm condition. In this condition the switch contacts will normally be open.

Fail Dangerous

Failure that does not respond to an input from the process (i.e. not switching to the fail-safe state).

Fail Dangerous Detected

Failure that is dangerous but is detected.

Fail Dangerous Undetected

Failure that is dangerous and that is not detected.

Fail No Effect

Failure of a component that is part of the safety function but that has no effect on the safety function.

Fail Safe

Failure that causes the switch to go to the defined fail-safe state without an input from the process.

FMEDA

Failure Modes, Effects, and Diagnostics Analysis.

Functional Safety

Part of the overall safety relating to the process and the BPCS which depends on the correct functioning of the SIS and other protection layers.

High demand

Mode of operation where the frequency of demands for operation on a safety-related system is greater than once per year.

HFT

Hardware Fault Tolerance.

Low demand

Mode of operation where the frequency of demands for operation made on a safety-related system is no greater than once per year.

PFDAVG

Average Probability of Failure on Demand.

PFH

Probability of dangerous failure per hour.

Safety Demand Interval

The expected time between safety demands.

SFF

Safe Failure Fraction – a fraction of the overall random failure rate of a device that results in either a safe failure or a detected dangerous failure.

SIF

Safety Instrumented Function – a safety function with a specified SIL which is necessary to achieve functional safety. Typically a set of equipment intended to reduce the risk due to a specified hazard (a safety loop).

SIL

Safety Integrity Level – a discrete level (one out of four) for specifying the safety integrity requirements of the safety instrumented functions to be allocated to the safety instrumented systems. SIL 4 has the highest level of safety integrity, and SIL 1 has the lowest level.

SIS

Safety Instrumented System – an instrumented system used to implement one or more safety instrumented functions. An SIS is composed of any combination of sensors, logic solvers, and final elements.

Type B device

A type B device is a complex device using controllers or programmable logic, as defined by the standard IEC 61508.

1.4 Documentation and standards

This section lists the documentation and standards referred to by this safety manual.

Table 1-1. Associated Documentation

Documents	Purpose of Documents
IEC 61508-2: 2010	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
MOB 08-08-57 R002	FMEDA Report Version V1, Revision R6 and later, for the Rosemount 2120 Level Switch
00813-0100-4030	Rosemount 2120 Product Data Sheet
00809-0100-4030	Rosemount 2120 Reference Manual

Table 1-2. Associated Standards

Standards	Purpose of Standards
IEC 61508: 2010	Functional Safety of electrical/electronic/programmable electronic safety-related systems
IEC 61511 (ANSI/ISA 84.00.01-2004)	Functional safety – Safety instrumented systems for the process industry sector
IEC 60664-1	Insulation coordination for equipment within low voltage systems
IEC 61984	Connectors –Safety requirements and test

Section 2 Product Description

2.1 Operation principle

The Rosemount 2120 level switch consists of a tuned fork with a driver and receiver element, and integral interface electronics. The 2120 level switch is based on the principle that the resonant frequency of a tuned fork changes when it is immersed in a liquid. The frequency change is detected and used to switch an electronic output.

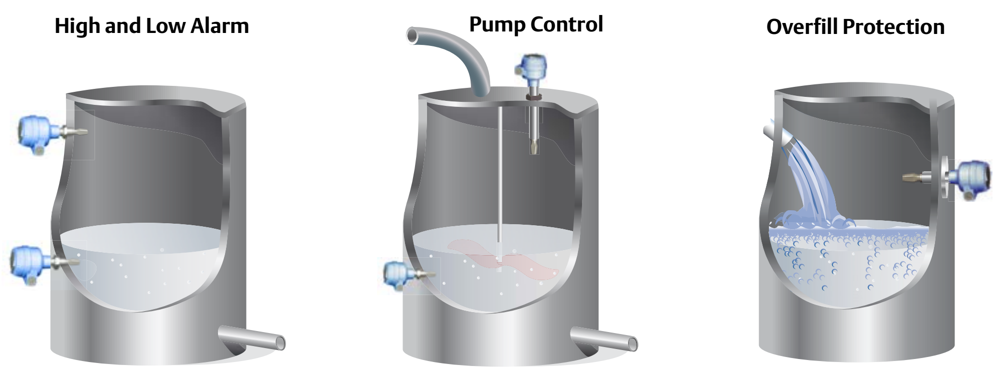
A range of output options are available to suit different applications.

Note
For all product information and documentation downloads, visit www.rosemount.com.

2.2 Level switch purpose

The Level switch indicates, by means of an electronic output, whether the level of a process liquid is above, or below, a certain point (the Switch Point).

Figure 2-1. Example Applications



2.3 Ordering information

Typical Model Number: 2120 D 0A K 1 I1 A 0000 QT

The third option code after “2120” indicates the output type:

- T = Direct Load Switching (Mains two-wire)
- G = PNP/PLC Low Voltage (20 to 60 Vdc, three-wire)
- V = DPCO Relay (standard version)
- K = NAMUR
- H = 8/16 mA
- E = 12 Vdc (nominal) DPCO Relay
- F = 12 Vdc (nominal) PNP/PLC

Output types G, V, K, and H have achieved a SIL rating. Each of these two output types have different Safety Instrumented System (SIS) parameters (see Table 3-1 on page 9).

The other option codes in the model number refer to materials, fittings, and other mechanical options which do not affect SIS parameters.

Versions of the 2120 with the QS option code are supplied with a manufacturer’s prior-use certificate of FMEDA data.

Versions of the 2120 with the QT option, if available, are supplied with a third party certificate of SIL capability.

Section 3 Designing a Safety Function using the Rosemount 2120

3.1 Safety function

A change in liquid level through the *switch point* of the Rosemount 2120 level switch causes it to operate. It may be used in high level or low level safety related applications. It is important that the 2120 is user-configured for the correct application.

3.2 Environmental limits

The designer of the SIF (Safety Instrumented Function) must check that the Rosemount 2120 level switch is rated for use within the expected environmental limits. See the Rosemount 2120 product data sheet for environmental limits.

Note
For all product information and documentation downloads, see the on-line Rosemount 2120 web page at www.rosemount.com.

3.3 Application limits

It is very important that the SIF designer checks for material compatibility by considering process liquids and on-site chemical contaminants. If the Rosemount 2120 level switch is used outside the application limits or with incompatible materials, the reliability data and predicted SIL capability becomes invalid.

The construction materials of a Rosemount 2120 level switch are specified in the product data sheet and the product reference manual (see Table 1-1 on page 3). Use the model code on the product label, and the ordering information table and specification in these product documents, to find out the construction materials.

3.4 Design verification

A detailed Failure Modes, Effects and Diagnostics Analysis (FMEDA) report for the Rosemount 2120 is available from Emerson Process Management. This report details all failure rates and failure modes as well as expected lifetime.

Note
The FMEDA report is available from the Safety quick link at www.rosemount.com. Select Product List, then Level tab, and finally select 2120. In the right-hand panel, there are SIL documents including the FMEDA report (and this safety manual).

The achieved Safety Integrity Level (SIL) of an entire Safety Instrumented Function (SIF) design must be verified by the designer using a PFDAVG calculation considering the architecture, proof test interval, proof test effectiveness, any automatic diagnostics, average repair time, and the specific failures rates of all equipment included in the SIF.

Each subsystem must be checked to assure compliance with minimum Hardware Fault Tolerance (HFT) requirements. When using the Rosemount 2120 level switch in a redundant configuration, a common cause factor of at least 5% should be included in the safety integrity calculations.

The failure rate data listed in the FMEDA report is only valid for the useful lifetime of the Rosemount 2120. The failure rates *increase* after this useful lifetime period has expired. Reliability calculations based on the data listed in the FMEDA report for mission times beyond the lifetime may yield results that are too optimistic, i.e. the calculated SIL will not be achieved.

3.5 SIL capability

3.5.1 Systematic integrity

The Rosemount 2120 level switch with an 8/16 mA, PNP/PLC, or NAMUR electronics cassette has met manufacturer design process requirements of Safety Integrity Level 3 (SIL 3) when it is set to the Dry On mode (see Table 3-1 on page 9).

The Rosemount 2120 level switch with a DPCO Relay (standard version) electronics cassette has met manufacturer design process requirements of Safety Integrity Level 2 (SIL 2) when it is set to the Dry On mode (see Table 3-1 on page 9).

These manufacturer design process requirements are intended to achieve sufficient integrity against systematic errors of design by the manufacturer. A Safety Instrumented Function (SIF) designed with the 2120 must not be used at a SIL higher than the statement without “prior use” justification by the end-user, or verification of diverse technology in the design.

3.5.2 Random integrity

The 2120 level switch is classified as a type B device according to IEC 61508, and the level switch has a Hardware Fault Tolerance (HFT) of zero.

Random Integrity for Type B device:

- Output Types G, H, and K: SIL 2 @ HFT=0 and SIL 3 @ HFT=1
- Output Type V: SIL 1 @ HFT=0 and SIL 2 @ HFT=1

3.5.3 Safety parameters

Table 3-1 on page 9 summarizes the Rosemount 2120 failure rates. For detailed failure rate information, including PFDAVG and MTTR data, see the FMEDA report for the Rosemount 2120.

Note
The FMEDA report is available from the Safety quick link at www.rosemount.com. Select Product List, then Level tab, and finally select 2120. In the right-hand panel, there are SIL documents including the FMEDA report (and this safety manual).

Table 3-1. Rosemount 2120 Failure Rates

Output Type and Model Option Code		Mode	λ_{SD} (1)	λ_{SU}	λ_{DD}	λ_{DU}	SFF %
8/16 mA	H	DRY=On	0.0 FIT	136.0 FIT	152.0 FIT	29.0 FIT	90.9
DPCO Relay(2)	V	DRY=On	0.0 FIT	131.1 FIT	130.3 FIT	101.8 FIT	72.0
NAMUR	K	DRY=On	0.0 FIT	118.0 FIT	131.0 FIT	24.0 FIT	91.1
PNP/PLC	G	DRY=On	0.0 FIT	241.0 FIT	130.0 FIT	41.0 FIT	90.0

(1) FIT is the abbreviation for Failure In Time. One FIT is $1x10^{-9}$ failure per hour.
(2) Standard version of DPCO Relay electronics cassette.

3.6 Connection of the 2120 to the SIS logic solver

The Rosemount 2120 level switch should be connected to the safety-rated logic solver which is actively performing the safety function as well as automatic diagnostics (if any) designed to diagnose potentially dangerous failures within the level switch. In some cases, it may also be connected directly to the final element.

The Rosemount 2120 reference manual gives full installation details for the level switch. The logic solver trip levels must be compatible with (higher than) the sensor alarm levels given in the specifications section of this manual.

Note
For all product information and documentation downloads, see the on-line Rosemount 2120 web page at www.rosemount.com.

3.7 General requirements

- The system and function *response time* shall be less than the *process safety time*

  The 2120 level switch will change to its defined safe state in less than this time with relation to the specific hazard scenario.
- All SIS components, including the 2120 level switch must be operational before process start-up
- The user shall verify that the 2120 level switch is suitable for use in safety applications by confirming the level switch *nameplate* and *model number* are properly marked
- Personnel performing maintenance and testing on the 2120 level switch shall first be assessed as being competent to do so
- Results from periodic proof tests shall be recorded and periodically reviewed
- The 2120 level switch shall not be operated beyond the useful lifetime as listed in the specification section of the product reference manual without undergoing overhaul or replacement

Section 4 Installation and Commissioning

Note
For all product information and documentation downloads, see the on-line Rosemount 2120 web page at www.rosemount.com.

4.1 Installation

The Rosemount 2120 level switch must be installed as described in the installation section of the product reference manual. Check that environmental conditions do not exceed the ratings in the specification section.

The 2120 level switch must be *accessible* for physical inspection.

4.2 Physical location and placement

The Rosemount 2120 level switch shall be *accessible* with sufficient room for cover removal and electrical connections, and allow for manual proof-testing to take place.

The switch point is determined by the location of the 2120 level switch, and consideration must be given to allow the safe proof-testing of the level switch by forcing liquid to put the switch into its Fail-Safe state.

4.3 Electrical connections

Wiring should be adequately rated and not be susceptible to mechanical damage.
Electrical conduit is commonly used to protect wiring.

The wiring to this device must maintain creepage[(1)] and clearance distances. Therefore, the connectable conductors stripping length should be no greater than 6 mm and be free from stray strands.

Wiring used for connection shall have minimum cross-section of AWG 24 to maximum of AWG 14.

The construction of the conductors should be of one of the following:

- Solid – H05(07) V-U minimum 0.2 mm^2, maximum 2.5 mm^2
- Flexible – H05(07) V-K minimum 0.2 mm^2, maximum. 2.5 mm^2
- Wire end ferrule – DIN 46228 pt 1/pt 4, minimum 0.25 mm^2, maximum 1.5 mm^2

(1) Creepage distance is a measurement that is commonly used in determining the conducting path of the flow of electricity.

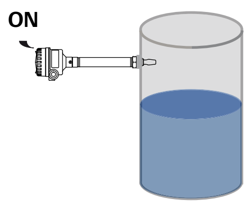
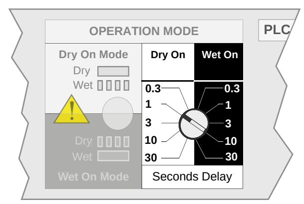
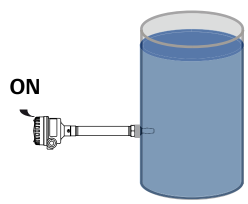
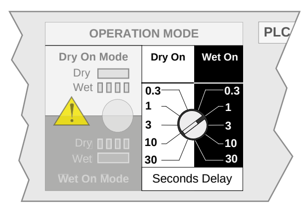
4.4 Configuration

4.4.1 Output mode setting

The Rosemount 2120 level switch must be user-configured for an application so that the output is ON in the Safe or Normal condition (see Table 4-1).

The response time (seconds delay) may be set to a convenient value to prevent trips that are spurious i.e. not due to a real condition. Note that the Safety Response Time is the greater of 10 seconds and the selected seconds delay using the switch setting (see Table A-1 on page 15).

Table 4-1. Output Mode Setting

<table>
<tr><th>Application</th><th>Switch Setting
(Normal or Safe Condition)</th></tr>
<tr><td>High Level Alarm
</td><td>Dry = On
</td></tr>
<tr><td>Low Level Alarm
</td><td>Wet = On
</td></tr>
</table>

Section 5 Operation and Maintenance

5.1 Proof-test requirement

During operation, a low-demand mode SIF must be proof-tested. The objective of proof-testing is to detect failures within the equipment in the SIF that are not detected by any automatic diagnostics of the system. Undetected failures that prevent the SIF from performing its function are the main concern.

Periodic proof-tests shall take place at the frequency (or interval) defined by the SIL verification calculation. The proof-tests must be performed more frequently than or as frequently as specified in the SIL verification calculation in order to maintain the required safety integrity of the overall SIF. A sample procedure is provided in Appendix B: Proposed Full Proof-test Procedure.

Results from periodic proof tests shall be recorded and periodically reviewed.

5.2 Repair and replacement

Repair procedures in the Rosemount 2120 level switch reference manual must be followed.

5.3 Notification of failures

In case of malfunction of the system or SIF, the Rosemount 2120 level switch shall be put out of operation and the process shall be kept in a safe state by other measures.

Emerson Process Management must be informed when the Rosemount 2120 level switch is required to be replaced due to failure. The occurred failure shall be documented and reported to Emerson Process Management using the contact details on the back page of this safety manual. This is an important part of Emerson Process Management's SIS management process.

Appendix A Specifications

A.1 General

In Table A-1, the safety response time for all output types is the greater of 10 seconds or the selected seconds delay using the switch setting.

Note
See Table 4-1 on page 12 for the switch setting feature.

Table A-1. General Specification

Output Type	Supply voltage	Safety Alarm Levels (leakage currents)(1)	Safety Response time(2)	Switch Point – Water(3)	Switch Point – Other Liquid(4)
8/16 mA (Code K)	11 to 36 Vdc	< 8.5 mA	10 s minimum	11 to 15 mm	0 to 30 mm
DPCO Relay (Code V)(5)	20 to 60 Vdc 20 to 264 Vac	Not applicable	10 s minimum	11 to 15 mm	0 to 30 mm
NAMUR (Code H)	7 to 9 Vdc	1.0 mA	10 s minimum	11 to 15 mm	0 to 30 mm
PNP/PLC (Code G)	20 to 60 Vdc	< 100 μA	10 s minimum	11 to 15 mm	0 to 30 mm

(1) Logic solver trip levels should be set higher than these values in order to ensure reliable trips.
(2) The safety response time is the greater of 10 seconds or the selected seconds delay using the switch setting. See Table 4-1 on page 12 for the switch setting feature.
(3) Operating (Switch) Point measured from lowest point of fork when liquid is water.
(4) Operating (Switch) Point measured from lowest point of fork when liquid is not water.
(5) Standard version of DPCO Relay electronics cassette.

A.2 Useful life

Based on general field failure data and manufactures component data, a useful life period of approximately 32 years is expected for the Rosemount 2120 level switch at an ambient temperature of 55 °C. This decreases by a factor of two for every increase of 10 °C, and increases by a factor of two for every decrease of 10 °C.

A.3 Useful lifetime

According to the standard IEC 61508-2, a useful lifetime based on experience should be assumed.

Although a constant failure rate is assumed by the probabilistic estimation method (see FMEDA report), this only applies provided that the useful lifetime[1] of components is not exceeded. Beyond their useful lifetime, the result of the probabilistic calculation method is therefore meaningless as the probability of failure significantly increases with time.

The useful lifetime is highly dependent on the subsystem itself and its operating conditions. Specifically, the equipment contains electrolytic capacitors which have a useful life which is highly dependent on ambient temperature (see Safety Data in the FMEDA report).

This assumption of a constant failure rate is based on the bath-tub curve. Therefore, it is obvious that the PFDAVG calculation is only valid for components that have this constant domain and that the validity of the calculation is limited to the useful lifetime of each component.

It is the responsibility of the end-user to maintain and operate the Rosemount 2120 level switch according to the manufacturer's instructions. Furthermore, regular inspection should show that all components are clean and free from damage.

For high-demand mode applications, the useful lifetime of the mechanical parts is limited by the number of cycles. The useful lifetime of the mechanical and electrical parts is greater than 200000 operations. When plant experience indicates a shorter useful lifetime than indicated, the number based on plant experience should be used.

(1) Useful lifetime is a reliability engineering term that describes the operational time interval where the failure rate of a device is relatively constant. It is not a term which covers product obsolescence, warranty, or other commercial issues.

Appendix B Proposed Full Proof-test Procedure

B.1 Suggested proof-test

According to the standard IEC 61508-2, proof-tests shall be undertaken to reveal dangerous faults which are undetected by diagnostic tests. This means that it is necessary to specify how dangerous undetected faults which have been noted during the Failure Modes, Effects, and Diagnostic Analysis can be detected during proof-testing.

The suggested proof-tests in Table B-1 consist of switch operation tests at the site.

Note

- A Rosemount 2120 with 8/16 mA, NAMUR, or PNP/PLC electronics, and also set to the Dry On mode, is for high level SIL2 applications
- A Rosemount 2120 with DPCO Relay (standard version) electronics, and also set to the Dry On mode, is for high level SIL1applications

Table B-1. Suggested Full Proof-test (High Level Alarm)

Step	Action
1	Inspect the accessible parts of the level switch for any leaks or damage.
2	Bypass the safety function and take appropriate action to avoid a false trip.
3	Verify the Mode Switch is set to the required mode of operation.
4	Disable any **drain** mechanism and fill the vessel to force the switch to the fail-safe state and confirm that the Safe State was achieved and within the correct time as indicated by the Mode Switch setting. **INDEPENDENT PRECAUTIONS MUST BE TAKEN TO ENSURE THAT NO HAZARD CAN RESULT FROM THIS OPERATION**.
5	Reinstate the **drain** mechanism so that the vessel refills and confirm that the normal operating state of the switch was achieved.
6	Remove the safety function bypass and otherwise restore normal operation.

B.2 Full proof-test coverage

Table B-2 shows the percentage of coverage achieved by using the full proof-test for the Rosemount 2120 with a SIL rating.

Table B-2. Full Proof-test Coverage Percentages

Output Type	Proof-test Coverage (%)
8/16 mA (Code H)	89
NAMUR (Code K)	88
PNP/PLC (Code G)	74
DPCO Relay (Code V)	75

B.3 Impact on SIF and process

In order to achieve the product safe state, the sensor must be either removed from or immersed in the process medium, depending on the operating mode. The process cannot be allowed to operate whilst the proof test is being performed.

B.4 Duration of full proof-test

The full proof test takes several hours to perform with all safety measures being followed.

B.5 System elements tested

The full proof test performs a complete test of the system elements. The sensor, measuring electronics and output stage are all checked by virtue of changing of the sensor condition and observation of the output.

B.6 Tools and data required

If the Rosemount 2120 is being removed from the vessel, the tools required depend upon the process connection. If being tested by manually raising and lowering the process medium level, no tools are required.

The date, time and name of the operator that performed the proof-test, the response time and result of the proof-test will be documented for maintaining the proof-test history of the device for PFDAVG calculations.

B.7 Personal safety concerns

As stated in the section Impact on SIF and process , the process must not be allowed to run during the proof test procedure.

Appendix C Proposed Partial Proof-test Procedure

C.1 Suggested proof-test

According to the standard IEC 61508-2, proof-tests shall be undertaken to reveal dangerous faults which are undetected by diagnostic tests. This means that it is necessary to specify how dangerous undetected faults which have been noted during the Failure Modes, Effects, and Diagnostic Analysis can be detected during proof-testing.

The suggested proof-tests in Table C-1 consist of switch operation tests at the site.

Note

- A Rosemount 2120 with 8/16 mA, NAMUR, or PNP/PLC electronics, and also set to the Dry On mode, is for high level SIL2 applications
- A Rosemount 2120 with DPCO Relay (standard version) electronics, and also set to the Dry On mode, is for high level SIL1applications

Table C-1. Suggested Partial Proof-test (High Level Alarm)

Step	Action
1	Inspect the accessible parts of the level switch for any leaks or damage
2	Bypass the safety function and take appropriate action to avoid a false trip
3	Verify the Mode Switch is set to the required mode of operation
4	Apply a bar magnet to the Magnetic Test Point to force the switch to the fail-safe state and confirm that the Safe State was achieved within 2 seconds. **INDEPENDENT PRECAUTIONS MUST BE TAKEN TO ENSURE THAT NO HAZARD CAN RESULT FROM THIS OPERATION**.
5	Remove the bar magnet from the Magnetic Test Point and confirm that the normal operating state of the switch was achieved after 1 second.
6	Remove the safety function bypass and otherwise restore normal operation

C.2 Partial proof-test coverage

Table C-2 shows the percentage of coverage achieved by using the partial proof-test for the Rosemount 2120 with a SIL rating.

Table C-2. Full Proof-test Coverage Percentages

Output Type	Proof-test Coverage (%)
8/16 mA (Code H)	81
NAMUR (Code K)	76
PNP/PLC (Code G)	68
DPCO Relay (Code V)[(1)]	69

(1) Standard version of DPCO Relay electronics cassette.

C.3 Impact on SIF and process

In order to achieve the product safe state, the sensor must be either removed from or immersed in the process medium, depending on the operating mode. The process cannot be allowed to operate whilst the proof test is being performed.

C.4 Duration of partial proof-test

The partial proof test takes less than an hour to perform with all safety measures being followed.

C.5 System elements tested

The partial proof test performs a partial test of the system elements. The output stage is checked by triggering the safety function using the Magnetic Test Point of the Rosemount 2120.

C.6 Tools and data required

A bar magnet is required to trigger the Magnetic Test Point on the Rosemount 2120.

The date, time and name of the operator that performed the proof-test, the response time and result of the proof-test will be documented for maintaining the proof-test history of the device for PFDAVG calculations.

C.7 Personal safety concerns

As stated in the section Impact on SIF and process , the process must not be allowed to run during the proof test procedure.

Appendix D PFDAVG Calculation

D.1 Average probability of failure on demand (PFDAVG)

This Average probability of failure on demand (PFDAVG) calculations for a single (1oo1) Rosemount 2120 Point Level Switch are shown in this appendix.

The failure rate data used in this calculation is available in the product FMEDA report. A mission time of 10 years has been assumed with a Mean Time To Restoration of 24 hours.

PFDAVG figures can only be used for Low Demand applications. For High Demand applications, refer to Appendix E: PFH Calculation.

The PFDAVG calculations using full proof-test coverage figures are shown in Table D-1 and Figure D-1. For partial proof-test coverage figures, see Table D-2 and Figure D-2 on page 22.

Table D-1. PFDAVG Calculations for Full Proof-test Interval

Proof-test Interval	PFDAVG			
	NAMUR (Code K)	8/16 mA (Code H)	PNP/PLC (Code G)	Relay (Code V)(1)
1	2.2E-04	2.5E-04	6.0E-04	1.5E-03
2	3.1E-04	3.7E-04	7.3E-04	1.8E-03
3	4.0E-04	4.8E-04	8.7E-04	2.1E-03
4	5.0E-04	5.9E-04	1.0E-03	2.5E-03
5	5.9E-04	7.0E-04	1.1E-03	2.8E-03
6	6.8E-04	8.2E-04	1.3E-03	3.1E-03
7	7.7E-04	9.3E-04	1.4E-03	3.5E-03
8	8.7E-04	1.0E-03	1.5E-03	3.8E-03
9	9.6E-04	1.2E-03	1.7E-03	4.1E-03
10	1.1E-03	1.3E-03	1.8E-03	4.5E-03

(1) Standard version of DPCO Relay electronics cassette.

Figure D-1. PFDAVG Calculation for Full Proof-test Interval

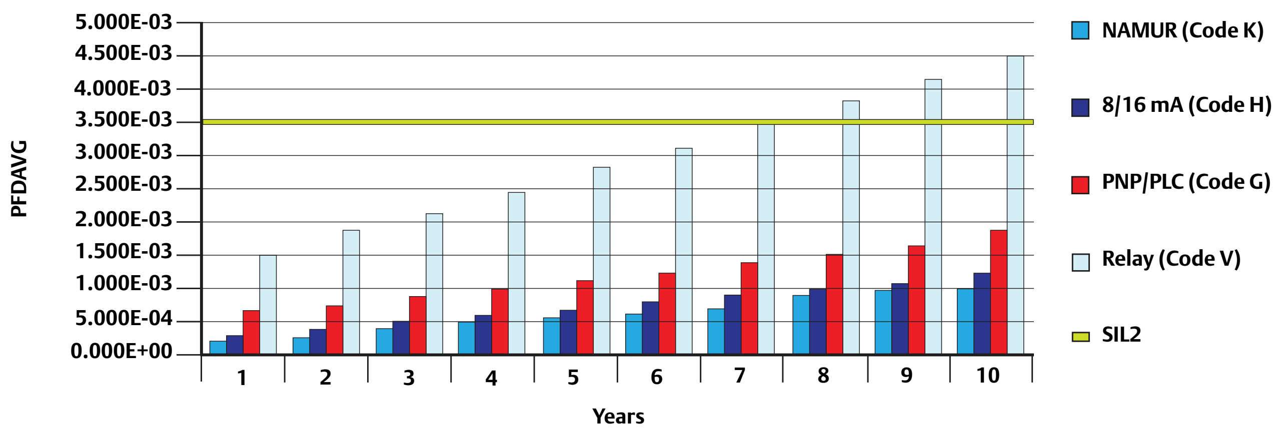
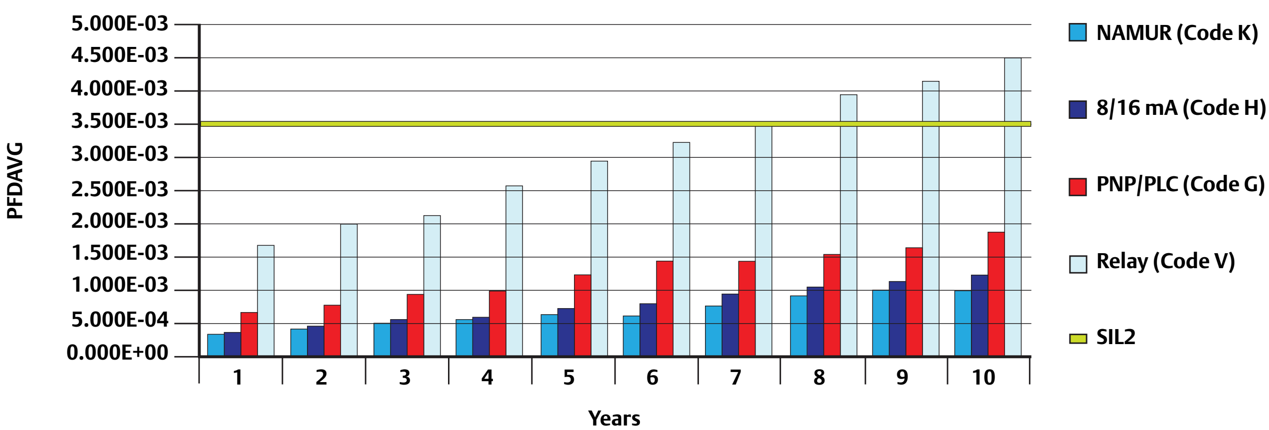


Table D-2. PFDAVG Calculations for Partial Proof-test Interval

Proof-test Interval	PFDAVG			
	NAMUR (Code K)	8/16 mA (Code H)	PNP/PLC (Code G)	Relay (Code V)[(1)]
1	3.3E-04	3.4E-04	7.0E-04	1.7E-03
2	4.1E-04	4.5E-04	8.2E-04	2.0E-03
3	4.9E-04	5.5E-04	9.4E-04	2.3E-03
4	5.7E-04	6.5E-04	1.1E-03	2.6E-03
5	6.5E-04	7.6E-04	1.2E-03	2.9E-03
6	7.3E-04	8.6E-04	1.3E-03	3.2E-03
7	8.1E-04	9.6E-04	1.4E-03	3.5E-03
8	8.9E-04	1.1E-03	1.6E-03	3.9E-03
9	9.7E-04	1.2E-03	1.7E-03	4.2E-03
10	1.1E-03	1.3E-03	1.8E-03	4.5E-03

(1) Standard version of DPCO Relay electronics cassette.

Figure D-2. PFDAVG Calculation for Partial Proof-test Interval



Appendix E PFH Calculation

E.1 Probability of dangerous failure per hour (PFH)

For High Demand applications, PFH values for the Rosemount 2120 must be used to determine the suitability of the Rosemount 2120 within a SIF.

For a SIF where the safety demand interval is greater than 100[1] times the diagnostic interval, the SIF PFH value is calculated with the following equation:

$PFH = \Sigma\lambda_{DU}$

With all equipment that is part of the safety system contributing to the final PFH value. As the safety demand interval approaches the diagnostic test rate, on-line diagnostics become increasingly less useful for detecting dangerous failures. In this case, dangerous detected failures are not included in the PFH calculation.

In event of the safety demand interval being less than 100[1] times the diagnostic interval, the SIF PFH value is calculated with the following equation:

$PFH = \Sigma(\lambda_{DU} + \lambda_{DD})$

Again, with all equipment that is part of the safety system contributing to the final PFH value, but in this case dangerous detected failure figures are allowed to contribute to the final PFH value.

(1) The figure of 100 is used here for illustrative purposes only, and is variable depending on user experience and available knowledge of the SIF.

Appendix F Diagnostic Intervals

F.1 Diagnostic checks and intervals

Table F-1 is a summary of the diagnostic checks that are performed by the system software, including at which intervals they are performed. All diagnostic checks are performed together and complete within 1 hour.

Table F-1. Diagnostic Checks and Intervals

Diagnostic	Description	Interval	System Reaction
Calibration data	Ensures that the data loaded from non-volatile memory is as expected.	Once at system power-up, and every 5 seconds thereafter	On system power-up, if blank non-volatile data is detected, the system sets its calibration data for default values, and indicates to the user, via the Heartbeat LED, that the system is uncalibrated.
			If the data loaded from non-volatile memory is found not to match expected values, it is reloaded from non-volatile memory.
			If the data on the non-volatile memory is found to be corrupted, the output is switched off and the system will reset itself within 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
Calibration state	Checks that all necessary steps have been performed for either a site or factory calibration.	During a calibration routine.	The calibration routine must be restarted.
Continuous RAM check (PNP/PLC only)	Checks that system RAM is functioning as expected.	Every 25 mill-seconds	The output is switched off and the system will reset itself within 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
Continuous ROM check (PNP/PLC only)	Checks the content of the system ROM is valid.	Every 25 mill-seconds	The output is switched off and the system will reset itself within 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
Invalid frequency (Enhanced/Self-Check mode only)	The time for which the sensor frequency must be out of limits and determined to be an invalid frequency, indicating a sensing system fault.	At least 5 seconds from a valid frequency condition.	The system indicates, via the Heartbeat LED, the sensing system fault condition and the output is switched off.
			Excursions to the invalid frequency range are permitted, but must be consistent for 5 seconds before being determined to be a invalid frequency.

Diagnostic	Description	Interval	System Reaction
Mode Switch setting integrity	Checks that the Mode Switch setting is recognized as within the valid range.	Every 25 milli-seconds.	If invalid for 5 seconds, the output is switched off and the system will reset itself with 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
Output change delay	Sets the time in seconds before the output state is changed according to the condition of the sensor.	According to the setting of the Mode Switch.	The output is switched to the user configured state after the time delay has expired.
Program flow	Checks that all expected parts of the system software have been executed and that the order of execution is correct.	Every 25 milli-seconds.	The output is switched off and the system will reset itself within 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
RAM check (all electronic types except PNP/PLC)	Checks that each byte of system RAM can be written to and the same value recalled.	Once at system power-up.	The output is not switched on until the test has completed, the system will reset itself within 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
ROM check (all electronic types except PNP/PLC)	Checks that the system program memory matches its expected contents.	Once at system power-up.	The output is not switched on until the test has completed, the system will reset itself within 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
Sensor measurement	Reads the frequency being generated by the sensor.	Every 25 milli-seconds.	The sensor state is determined from the frequency data.
Short circuit detection on Mode Switch electronics (PNP/PLC only)	Checks that a short circuit has not occurred on the Mode Switch electronics	Every 25 milli-seconds.	If invalid for 5 seconds, the output is switched off and the system will reset itself with 500 milli-seconds, giving two rapid flashes of the Heartbeat LED to indicate the fault.
Site calibration	The time within which the combination of turns of the Mode Switch must be completed for a site calibration to be initiated.	Within 4 seconds.	The site calibration routine must be restarted.
System configuration	Ensures the system micro controller Input/Output ports and peripherals are configured as expected.	Once at system power-up, and every 25 milli-seconds thereafter.	None.
Test Mode disable	Checks that the Magnetic Test Point has had the bar magnet removed for disabling Test Mode.	For at least 1 second.	Test Mode is not disabled if the bar magnet is not removed for at least 1 second.
Test Mode enable	Checks that Magnetic Test Point has had the bar magnet applied for enabling Test Mode.	For at least 1 second.	Test Mode is not enabled if the bar magnet is not applied for at least 1 second.

Diagnostic	Description	Interval	System Reaction
Valid frequency	The time for which the sensor frequency must be within limits and determined to be a valid frequency indicating a functional sensing system.	At least 5 seconds from an invalid frequency condition.	The Heartbeat LED operates as normal. Excursions to the invalid frequency range are permitted, but must be consistent for 5 seconds before being determined to be a valid frequency.
Watchdog reset	The maximum time permissible before the system watchdog triggers a reset of the system software.	Within 500 milli-seconds.	The system performs a reset.

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