Failure Modes, Effects and Diagnostic Analysis

Project:
8732 EM Magnetic Flowmeter

Company:
Emerson Rosemount
Eden Prairie, MN
USA

Contract Number: Q12/05-042
Report No.: ROS 12/05-042 R001
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Management Summary

This report summarizes the results of the hardware assessment in the form of a Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the 8732 EM Magnetic Flowmeter. A Failure Modes, Effects, and Diagnostic Analysis is one of the steps to be taken to achieve functional safety certification per IEC 61508 of a device. From the FMEDA, failure rates are determined. The FMEDA that is described in this report concerns only the hardware of the 8732 EM. For full functional safety certification purposes all requirements of IEC 61508 must be considered.

The Rosemount® 8700 Series Magnetic Flowmeter System consists of a flowtube sensor and transmitter, and measures volumetric flow rate by detecting the velocity of a conductive liquid that passes through a magnetic field.

Table 1 gives an overview of the different versions that were considered in the FMEDA of the 8732 EM.

Table 1 Version Overview

External Loop Power	The 4-20mA loop is powered by an external power supply.
Internal Loop Power	The 4-20mA loop is powered by the 8732 EM.

The 8732 EM is classified as a Type B[1] element according to IEC 61508, having a hardware fault tolerance of 0.

The analysis shows that the product has a Safe Failure Fraction between 60% and 90% (assuming that the logic solver is programmed to detect over-scale and under-scale currents) and therefore meets hardware architectural constraints for up to SIL 1 as a single device.

The failure rates for the 8732 EM are listed in Table 2.

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[1] Type B element: "Complex" element (using micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2, ed2, 2010.

Table 2 Failure rates 8732 EM External Loop Power

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		383
Fail Dangerous Detected		1629
Fail Detected (detected by internal diagnostics)	1479	
Fail High (detected by logic solver)	15	
Fail Low (detected by logic solver)	24	
Annunciation Detected	111	
Fail Dangerous Undetected		426
No Effect		470
Annunciation Undetected		30

Table 3 Failure rates 8732 EM Internal Loop Power

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		384
Fail Dangerous Detected		1711
Fail Detected (detected by internal diagnostics)	1495	
Fail High (detected by logic solver)	15	
Fail Low (detected by logic solver)	90	
Annunciation Detected	111	
Fail Dangerous Undetected		434
No Effect		521
Annunciation Undetected		30

These failure rates are valid for the useful lifetime of the product, see Appendix A.

The failure rates listed in this report do not include failures due to wear-out of any components. They reflect random failures and include failures due to external events, such as unexpected use, see section 4.2.2.

Table 4 lists the failure rates for the 8732 EM according to IEC 61508, ed2, 2010.

Table 4 Failure rates according to IEC 61508 in FIT

Device	λ_{SD}	λ_{SU}[2]	λ_{DD}	λ_{DU}	**SFF**[3]
8732 EM External Loop Power	0	383	1629	426	82.5%
8732 EM Internal Loop Power	0	384	1711	434	82.8%

A user of the 8732 EM can utilize these failure rates in a probabilistic model of a safety instrumented function (SIF) to determine suitability in part for safety instrumented system (SIS) usage in a particular safety integrity level (SIL). A full table of failure rates is presented in section 4.4 along with all assumptions.

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[2] It is important to realize that the No Effect failures are no longer included in the Safe Undetected failure category according to IEC 61508, ed2, 2010.

[3] Safe Failure Fraction needs to be calculated on an element level

Table of Contents

1 Purpose and Scope

This document shall describe the results of the hardware assessment in the form of the Failure Modes, Effects and Diagnostic Analysis carried out on the 8732 EM. From this, failure rates and example PFD_{AVG} values may be calculated.

The information in this report can be used to evaluate whether an element meets the average Probability of Failure on Demand (PFD_{AVG}) requirements and if applicable, the architectural constraints / minimum hardware fault tolerance requirements per IEC 61508 / IEC 61511.

An FMEDA is part of the effort needed to achieve full certification per IEC 61508 or other relevant functional safety standard.

2 Project Management

2.1 *exida*

exida is one of the world's leading accredited Certification Bodies and knowledge companies specializing in automation system safety and availability with over 300 years of cumulative experience in functional safety. Founded by several of the world's top reliability and safety experts from assessment organizations and manufacturers, *exida* is a global company with offices around the world. *exida* offers training, coaching, project oriented system consulting services, safety lifecycle engineering tools, detailed product assurance, cyber-security and functional safety certification, and a collection of on-line safety and reliability resources. *exida* maintains a comprehensive failure rate and failure mode database on process equipment.

2.2 Roles of the parties involved

Emerson Rosemount	Manufacturer of the 8732 EM
exida	Performed the hardware assessment
Emerson Rosemount	contracted *exida* in May 2012 with the hardware assessment of the above-mentioned device.

2.3 Standards and Literature used

The services delivered by *exida* were performed based on the following standards / literature.

[N1]	IEC 61508-2: ed2, 2010	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
[N2]	Electrical Component Reliability Handbook, 3nd Edition, 2012	exida LLC, Electrical Component Reliability Handbook, Third Edition, 2012, ISBN 978-1-934977-04-0
[N3]	Mechanical Component Reliability Handbook, 3nd Edition, 2012	exida LLC, Electrical & Mechanical Component Reliability Handbook, Third Edition, 2012, ISBN 978-1-934977-05-7
[N4]	Safety Equipment Reliability Handbook, 3rd Edition, 2007	exida LLC, Safety Equipment Reliability Handbook, Third Edition, 2007, ISBN 978-0-9727234-9-7
[N5]	Goble, W.M. 1998	Control Systems Safety Evaluation and Reliability, ISA, ISBN 1-55617-636-8. Reference on FMEDA methods
[N6]	IEC 60654-1:1993-02, second edition	Industrial-process measurement and control equipment – Operating conditions – Part 1: Climatic condition

2.4 *exida* Tools Used

[T1]	7.1.18	FMEDA Tool
[T2]	3.0.9.785	exSILentia

2.5 Reference documents

2.5.1 Documentation provided by Emerson Rosemount

[D1]	Doc # 00813-0100-4727, Rev RA, December 2007	Data Sheet
[D2]	Doc # 00809-0100-4662, Rev BA, March 2008	Reference Manual
[D3]	Doc # 08732-0270, Rev AE, 2012-07-17	Schematic Drawing, 8732 EM TRANSMITTER REMOTE JUNCTION BOX BOARD
[D4]	Doc # 08732-0302, Rev AA, 2012-04-02	Schematic Drawing, 8732 EM TUBE REMOTE JUNCTION BOX TERMINAL BLOCK BOARD
[D5]	Doc # 08732-0314, Rev AA, 2012-03-29	Schematic Drawing, 8732 EM I.S. SOCKET MODULE BOARD
[D6]	Doc # 08732-0857, Rev AB, 2012-06-15	Schematic Drawing, 8732 EM IS, SERIAL LOI
[D7]	Doc # 08732-0860, Rev AA, 2012-10-03	Schematic Drawing, 8732 EM IS RFI
[D8]	Doc # 08732-0863, Rev AA, 2012-10-18	Schematic Drawing, 8732 EM IS MAGMETER POWER SUPPLY/COIL DRIVER
[D9]	Doc # 08732-0866, Rev AD, 2012-10-05	Schematic Drawing, 8732 EM I.S. ELECTRODE SIRF BOARD

2.5.2 Documentation generated by *exida*

[R1]	Rosemount 8732E Magmeter FMEDA V0R2 - 12-28-12.efm	Failure Modes, Effects, and Diagnostic Analysis – 8732 EM
[R2]	8732E.exi, 2013-01-16	exSILentia File (used to calculate PFD_{AVG})
[R3]	ROS 12-05-042 R001 V1 R3 FMEDA 8732 EM MagMeter.doc, 11/11/2013	FMEDA report, 8732 EM (this report)

3 Product Description

The Rosemount® 8700 Series Magnetic Flowmeter System consists of a flowtube sensor and transmitter, and measures volumetric flow rate by detecting the velocity of a conductive liquid that passes through a magnetic field.

There are four Rosemount magnetic flowmeter flowtube sensors:

- Flanged Rosemount 8705
- Flanged High-Signal Rosemount 8707
- Wafer-Style Rosemount 8711
- Sanitary Rosemount 8721

The flowtube sensor is installed in-line with process piping. Coils located on opposite sides of the flowtube sensor create a magnetic field. Electrodes located perpendicular to the coils make contact with the process fluid. A conductive liquid moving through the magnetic field generates a voltage at the two electrodes that is proportional to the flow velocity. The transmitter drives the coils to generate a magnetic field, and electronically conditions the voltage detected by the electrodes to provide a flow signal. The transmitter can be integrally or remotely mounted from the flowtube sensor.

Figure 1 8732 EM, Parts included in the FMEDA

Table 5 gives an overview of the different versions that were considered in the FMEDA of the 8732 EM.

Table 5 Version Overview

External Loop Power	The 4-20mA loop is powered by an external power supply.
Internal Loop Power	The 4-20mA loop is powered by the 8732 EM.

The 8732 EM is classified as a Type B[4] element according to IEC 61508, having a hardware fault tolerance of 0.

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[4] Type B element: “Complex” element (using micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2, ed2, 2010.

4 Failure Modes, Effects, and Diagnostic Analysis

The Failure Modes, Effects, and Diagnostic Analysis as performed based on the documentation obtained from Emerson Rosemount and is documented in [R1].

4.1 Failure categories description

In order to judge the failure behavior of the 8732 EM, the following definitions for the failure of the device were considered.

Fail-Safe State	Failure that deviates the process signal or the actual output by more than 2% of span, drifts toward the user defined threshold (Trip Point) and that leaves the output within active scale.
Fail Safe	Failure that causes the device to go to the defined fail-safe state without a demand from the process.
Fail Detected	Failure that causes the output signal to go to the predefined alarm state (3.75 or 23.25 mA).
Fail Dangerous	Failure that deviates the process signal or the actual output by more than 2% of span, drifts away from the user defined threshold (Trip Point) and that leaves the output within active scale.
Fail Dangerous Undetected	Failure that is dangerous and that is not being diagnosed by automatic diagnostics.
Fail Dangerous Detected	Failure that is dangerous but is detected by automatic diagnostics.
Fail High	Failure that causes the output signal to go to the over-range or high alarm output current (> 21 mA).
Fail Low	Failure that causes the output signal to go to the under-range or low alarm output current(< 3.6 mA).
No Effect	Failure of a component that is part of the safety function but that has no effect on the safety function.
Annunciation Detected	Failure that does not directly impact safety but does impact the ability to detect a future fault (such as a fault in a diagnostic circuit) and that is detected by internal diagnostics. A Fail Annunciation Detected failure leads to a false diagnostic alarm.
Annunciation Undetected	Failure that does not directly impact safety but does impact the ability to detect a future fault (such as a fault in a diagnostic circuit) and that is not detected by internal diagnostics.

The failure categories listed above expand on the categories listed in IEC 61508 which are only safe and dangerous, both detected and undetected. In IEC 61508, Edition 2010, the No Effect failures cannot contribute to the failure rate of the safety function. Therefore they are not used for the Safe Failure Fraction calculation needed when Route 2H failure data is not available.

Depending on the application, a Fail High or a Fail Low failure can either be safe or dangerous and may be detected or undetected depending on the programming of the logic solver. Consequently, during a Safety Integrity Level (SIL) verification assessment the Fail High and Fail Low failure categories need to be classified as safe or dangerous, detected or undetected.

The Annunciation failures are provided for those who wish to do reliability modeling more detailed than required by IEC61508. It is assumed that the probability model will correctly account for the Annunciation failures. Otherwise the Annunciation Undetected failures have to be classified as Dangerous Undetected failures according to IEC 61508 (worst-case assumption).

4.2 Methodology – FMEDA, Failure Rates

4.2.1 FMEDA

A Failure Modes and Effects Analysis (FMEA) is a systematic way to identify and evaluate the effects of different component failure modes, to determine what could eliminate or reduce the chance of failure, and to document the system in consideration.

A FMEDA (Failure Mode Effect and Diagnostic Analysis) is an FMEA extension. It combines standard FMEA techniques with the extension to identify automatic diagnostic techniques and the failure modes relevant to safety instrumented system design. It is a technique recommended to generate failure rates for each important category (safe detected, safe undetected, dangerous detected, dangerous undetected, fail high, fail low, etc.) in the safety models. The format for the FMEDA is an extension of the standard FMEA format from MIL STD 1629A, Failure Modes and Effects Analysis.

4.2.2 Failure Rates

The failure rate data used by *exida* in this FMEDA is from the Electrical and Mechanical Component Reliability Handbooks [N2] and [N3] which was derived using over fifty billion unit operational hours of field failure data from multiple sources and failure data from various databases. The rates were chosen in a way that is appropriate for safety integrity level verification calculations. The rates were chosen to match *exida* Profile 3, see Appendix C. The *exida* profile chosen was judged to be the best fit for the product and application information submitted by Emerson Rosemount. It is expected that the actual number of field failures due to random events will be less than the number predicted by these failure rates.

For hardware assessment according to IEC 61508 only random equipment failures are of interest. It is assumed that the equipment has been properly selected for the application and is adequately commissioned such that early life failures (infant mortality) may be excluded from the analysis.

Failures caused by external events however should be considered as random failures. Examples of such failures are loss of power, physical abuse, or problems due to intermittent instrument air quality.

The assumption is also made that the equipment is maintained per the requirements of IEC 61508 or IEC 61511 and therefore a preventative maintenance program is in place to replace equipment before the end of its "useful life". The user of these numbers is responsible for determining their applicability to any particular environment. Accurate plant specific data may be used for this purpose. If a user has data collected from a good proof test reporting system such as *exida* SILStat^{TM} that indicates higher failure rates, the higher numbers shall be used. Some industrial plant sites have high levels of stress. Under those conditions the failure rate data is adjusted to a higher value to account for the specific conditions of the plant.

4.3 Assumptions

The following assumptions have been made during the Failure Modes, Effects, and Diagnostic Analysis of the 8732 EM.

- Only a single component failure will fail the entire 8732 EM.
- Failure rates are constant, wear-out mechanisms are not included.
- Propagation of failures is not relevant.
- All components that are not part of the safety function and cannot influence the safety function (feedback immune) are excluded.
- Failures caused by maintenance capability are site specific and therefore cannot be included.
- The stress levels are average for an industrial environment and can be compared to the *exida* Profile 3 with temperature limits within the manufacturer's rating. Other environmental characteristics are assumed to be within manufacturer's rating.
- Practical fault insertion tests can demonstrate the correctness of the failure effects assumed during the FMEDA and the diagnostic coverage provided by the automatic diagnostics.
- The HART protocol is only used for setup, calibration, and diagnostics purposes, not for safety critical operation.
- The application program in the logic solver is constructed in such a way that Fail High and Fail Low failures are detected regardless of the effect, safe or dangerous, on the safety function.
- Materials are compatible with process conditions.
- The device is installed per manufacturer's instructions.
- External power supply failure rates are not included.
- Worst-case internal fault detection time is 1 hour.

4.4 Results

Using reliability data extracted from the *exida* Electrical and Mechanical Component Reliability Handbook the following failure rates resulted from the 8732 EM FMEDA.

Table 6 Failure rates 8732 EM External Loop Power

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		383
Fail Dangerous Detected		1629
Fail Detected (detected by internal diagnostics)	1479	
Fail High (detected by logic solver)	15	
Fail Low (detected by logic solver)	24	
Annunciation Detected	111	
Fail Dangerous Undetected		426
No Effect		470
Annunciation Undetected		30

Table 7 Failure rates 8732 EM Internal Loop Power

Failure Category	Failure Rate (FIT)	
Fail Safe Undetected		384
Fail Dangerous Detected		1711
Fail Detected (detected by internal diagnostics)	1495	
Fail High (detected by logic solver)	15	
Fail Low (detected by logic solver)	90	
Annunciation Detected	111	
Fail Dangerous Undetected		434
No Effect		521
Annunciation Undetected		30

These failure rates are valid for the useful lifetime of the product, see Appendix A.

Table 8 lists the failure rates for the 8732 EM according to IEC 61508.

According to IEC 61508 the architectural constraints of an element must be determined. This can be done by following the 1_H approach according to 7.4.4.2 of IEC 61508 or the 2_H approach according to 7.4.4.3 of IEC 61508.

The 1_H approach involves calculating the Safe Failure Fraction for the entire element.

The 2_H approach involves assessment of the reliability data for the entire element according to 7.4.4.3.3 of IEC 61508.

According to 3.6.15 of IEC 61508-4, the Safe Failure Fraction is the property of a safety related element that is defined by the ratio of the average failure rates of safe plus dangerous detected failures and safe plus dangerous failures. This ratio is represented by the following equation:

$SFF = (\Sigma\lambda_S \text{ avg} + \Sigma\lambda_{DD} \text{ avg})/(\Sigma\lambda_S \text{ avg} + \Sigma\lambda_{DD} \text{ avg}+ \Sigma\lambda_{DU} \text{ avg})$

When the failure rates are based on constant failure rates, as in this analysis, the equation can be simplified to:

$SFF = (\Sigma\lambda_S + \Sigma\lambda_{DD})/(\Sigma\lambda_S + \Sigma\lambda_{DD} + \Sigma\lambda_{DU})$

Where:

$\lambda_{S\,=}$ Fail Safe
$\lambda_{DD\,=}$ Fail Dangerous Detected
$\lambda_{DU=}$ Fail Dangerous Undetected

Table 8 Failure rates according to IEC 61508 in FIT

Device	λ_{SD}	λ_{SU}[5]	λ_{DD}	λ_{DU}	**SFF**[6]
8732 EM External Loop Power	0	383	1629	426	82.5%
8732 EM Internal Loop Power	0	384	1711	434	82.8%

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[5] It is important to realize that the No Effect failures are no longer included in the Safe Undetected failure category according to IEC 61508, ed2, 2010.

[6] Safe Failure Fraction needs to be calculated on an element level

5 Using the FMEDA Results

The following section(s) describe how to apply the results of the FMEDA.

5.1 PFD$_{AVG}$ calculation 8732 EM

An average Probability of Failure on Demand (PFD$_{AVG}$) calculation is performed for a single (1oo1) 8732 EM with *exida's* exSILentia tool. The failure rate data used in this calculation is displayed in section 4.4. A mission time of 15 years has been assumed and a Mean Time To Restoration of 24 hours. Table 9 lists the proof test coverage (see Appendix B) used for the various configurations as well as the results when the proof test interval equals 1 year.

Table 9 Sample PFD$_{AVG}$ Results

Device	**Proof Test Coverage**	**PFD$_{AVG}$**	**% of SIL 1 Range**
8732 EM External Loop Power	77%	2.75E-02	27.5%
8732 EM Internal Loop Power	75%	2.80E-02	28.0%

The resulting PFD$_{AVG}$ Graphs generated from the exSILentia tool for a proof test of 1 year are displayed in Figure 2.

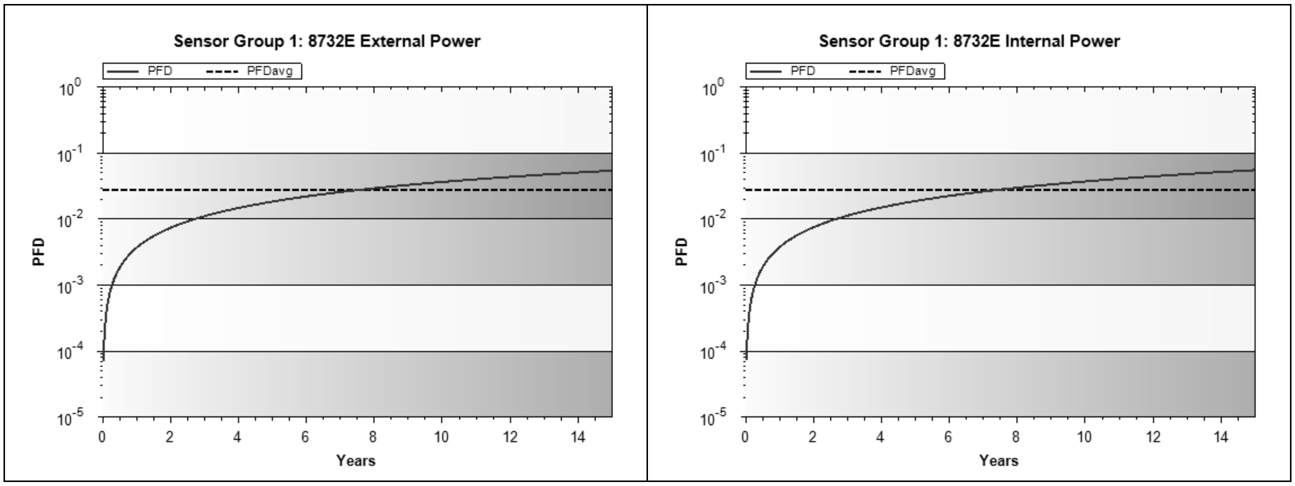

Figure 2 PFD$_{AVG}$ value for a single, 8732 EM with proof test intervals of 1 year.

It is the responsibility of the Safety Instrumented Function designer to do calculations for the entire SIF. *exida* recommends the accurate Markov based exSILentia tool for this purpose.

For SIL 1 applications, the PFD$_{AVG}$ value needs to be ≥ 10^{-2} and < 10^{-1}. This means that for a SIL 1 application, the PFD$_{AVG}$ for a 1-year Proof Test Interval of the 8732 EM is approximately equal to 28% of the range.

These results must be considered in combination with PFD_{AVG} values of other devices of a Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL).

6 Terms and Definitions

FIT	Failure In Time (1x10-9 failures per hour)
FMEDA	Failure Mode Effect and Diagnostic Analysis
HFT	Hardware Fault Tolerance
Low demand mode	Mode, where the demand interval for operation made on a safety-related system is greater than twice the proof test interval.
Automatic Diagnostics	Tests performed on line internally by the device or, if specified, externally by another device without manual intervention.
PFD_{AVG}	Average Probability of Failure on Demand
SFF	Safe Failure Fraction, summarizes the fraction of failures which lead to a safe state plus the fraction of failures which will be detected by automatic diagnostic measures and lead to a defined safety action.
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s).
Type A element	"Non-Complex" element (using discrete components); for details see 7.4.4.1.2 of IEC 61508-2
Type B element	"Complex" element (using complex components such as micro controllers or programmable logic); for details see 7.4.4.1.3 of IEC 61508-2

7 Status of the Document

7.1 Liability

exida prepares FMEDA reports based on methods advocated in International standards. Failure rates are obtained from a collection of industrial databases. *exida* accepts no liability whatsoever for the use of these numbers or for the correctness of the standards on which the general calculation methods are based.

Due to future potential changes in the standards, best available information and best practices, the current FMEDA results presented in this report may not be fully consistent with results that would be presented for the identical product at some future time. As a leader in the functional safety market place, *exida* is actively involved in evolving best practices prior to official release of updated standards so that our reports effectively anticipate any known changes. In addition, most changes are anticipated to be incremental in nature and results reported within the previous three year period should be sufficient for current usage without significant question.

Most products also tend to undergo incremental changes over time. If an *exida* FMEDA has not been updated within the last three years and the exact results are critical to the SIL verification you may wish to contact the product vendor to verify the current validity of the results.

7.2 Releases

Version:	V1	
Revision:	R3	
Version History:	V1, R3:	updated product name; 11/11/13 TES
	V1, R2:	updated product designation and client address, 2013-06-12
	V1, R1:	Released to Emerson Rosemount; Feb. 8, 2013
	V0, R1:	Draft; 2013 January 16
Author(s):	Rudolf Chalupa	
Review:	V0, R1:	William M. Goble, February 8, 2013
Release Status:	Released to Emerson Rosemount	

7.3 Future Enhancements

At request of client.

7.4 Release Signatures

William M Goble

Dr. William M. Goble, Principal Partner

Rudolf P. Chalupa

Rudolf P. Chalupa, Senior Safety Engineer

John C. Grebe Jr., Principal Engineer

Appendix A Lifetime of Critical Components

According to section 7.4.9.5 of 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 section 4.2.2) this only applies provided that the useful lifetime[7] 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.

This assumption of a constant failure rate is based on the bathtub curve. Therefore it is obvious that the $\mathrm{PFD}_{\mathrm{AVG}}$ 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.

Table 17 shows which components are contributing to the dangerous undetected failure rate and therefore to the $\mathrm{PFD}_{\mathrm{AVG}}$ calculation and what their estimated useful lifetime is.

Table 10 Useful lifetime of components contributing to dangerous undetected failure rate

Component	Useful Life
Capacitor (electrolytic) – Aluminum electrolytic, non-solid electrolyte	Approx. 90,000 hours

It is the responsibility of the end user to maintain and operate the 8732 EM per manufacturer's instructions. Furthermore regular inspection should show that all components are clean and free from damage.

The limiting factors with regard to the useful lifetime of the system are the aluminum electrolytic capacitors. The aluminum electrolytic capacitors have an estimated useful lifetime of about 10 years.

When plant experience indicates a shorter useful lifetime than indicated in this appendix, the number based on plant experience should be used.

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[7] 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 Proof tests to reveal dangerous undetected faults

According to section 7.4.5.2 f) of IEC 61508-2 proof tests shall be undertaken to reveal dangerous faults which are undetected by automatic 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.

B.1 Suggested Proof Test

The suggested proof test consists of a setting the output to the min and max, and a calibration check, see Table 11.

Table 11 Suggested Proof Test

Step	Action
1.	Bypass the safety function and take appropriate action to avoid a false trip.
2.	Use HART communications to retrieve any diagnostics and take appropriate action.
3.	Cycle power to the transmitter[8].
4.	Send a HART command to the transmitter to go to the high alarm current output and verify that the analog current reaches that value[9].
5.	Send a HART command to the transmitter to go to the low alarm current output and verify that the analog current reaches that value[10].
6.	Perform a two-point calibration[11] of the transmitter over the full working range.
7.	Remove the bypass and otherwise restore normal operation.

B.2 Proof Test Coverage

The Proof Test Coverage for the various product configurations is given in Table 12.

Table 12 Proof Test Coverage – 8732 EM

Device	PTC
8732 EM External Loop Power	77%
8732 EM Internal Loop Power	75%

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[8] This clears the RAM of any acculated soft errors.

[9] This tests for compliance voltage problems such as a low loop power supply voltage or increased wiring resistance. This also tests for other possible failures.

[10] This tests for possible quiescent current related failures.

[11] If the two-point calibration is performed with electrical instrumentation, this proof test will <u>not</u> detect any failures of the sensor

Appendix C *exida* Environmental Profiles

***exida* Profile**	**1**	**2**	**3**	**4**	**5**	**6**
Description (Electrical)	Cabinet mounted/ Climate Controlled	Low Power Field Mounted no self-heating	General Field Mounted self-heating	Subsea	Offshore	N/A
Description (Mechanical)	Cabinet mounted/ Climate Controlled	General Field Mounted	General Field Mounted	Subsea	Offshore	Process Wetted
IEC 60654-1 Profile	B2	C3 also applicable for D1	C3 also applicable for D1	N/A	C3 also applicable for D1	N/A
Average Ambient Temperature	30C	25C	25C	5C	25C	25C
Average Internal Temperature	60C	30C	45C	5C	45C	Process Fluid Temp.
Daily Temperature Excursion (pk-pk)	5C	25C	25C	0C	25C	N/A
Seasonal Temperature Excursion (winter average vs. summer average)	5C	40C	40C	2C	40C	N/A
Exposed to Elements/Weather Conditions	No	Yes	Yes	Yes	Yes	Yes
Humidity[12]	0-95% Non-Condensing	0-100% Condensing	0-100% Condensing	0-100% Condensing	0-100% Condensing	N/A
Shock[13]	10 g	15 g	15 g	15 g	15 g	N/A
Vibration[14]	2 g	3 g	3 g	3 g	3 g	N/A
Chemical Corrosion[15]	G2	G3	G3	G3	G3	Compatible Material
Surge[16]						
Line-Line	0.5 kV	0.5 kV	0.5 kV	0.5 kV	0.5 kV	N/A
Line-Ground	1 kV	1 kV	1 kV	1 kV	1 kV	
EMI Susceptibility[17]						
80MHz to 1.4 GHz	10V /m	10V /m	10V /m	10V /m	10V /m	N/A
1.4 GHz to 2.0 GHz	3V/m	3V/m	3V/m	3V/m	3V/m	
2.0Ghz to 2.7 GHz	1V/m	1V/m	1V/m	1V/m	1V/m	
ESD (Air)[18]	6kV	6kV	6kV	6kV	6kV	N/A

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[12] Humidity rating per IEC 60068-2-3
[13] Shock rating per IEC 60068-2-6
[14] Vibration rating per IEC 60770-1
[15] Chemical Corrosion rating per ISA 71.04
[16] Surge rating per IEC 61000-4-5
[17] EMI Susceptibility rating per IEC 6100-4-3
[18] ESD (Air) rating per IEC 61000-4-2