Magnetrol®

Failure Modes, Effects, and Diagnostic Analysis

Sealed and Flanged Cage Mechanical Units In Low Level Applications

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A. Description

This report describes the results of the Failure Modes, Effects, and Diagnostic Analysis (FMEDA) of the Magnetrol Sealed and Flanged Cage Mounted Mechanical unit series in low level applications. The FMEDA only applies to the models and switch mechanisms listed in the Model Designation section and wired per one of the methods described in the Wiring Requirements section. The FMEDA performed on these Magnetrol products includes all related hardware. For full certification purposes, the product along with all requirements of IEC 61508 must be considered.

1. Model Designations

The FMEDA analysis in this report is only applicable for the vertical mounted Sealed and Flanged Cage Level Unit model numbers and switch mechanisms listed below.

Models: abc-xxxx-dex

Where "abc" describes basic Model Type
"abc" = A40, A75
B24, B35, B3F, B41, B43, B60, B73, B75,
C24, C29, C35, C60, C75, D30, D75, E75, F75,
G33, G35, G3F, G75, H75,
J52, J30, J31, J33, J75, K35, K3F, K75,
L30, L35, L75, M75, N75,
O30, 075, P75, R75,
S75, V75, Z3F, Z75

"d" describes Switch Type:
"d" = A, B, C, D E, F, M, U, V, W, X, 2 and 3

And "e" describes Single Switch Mechanisms:
"e" = A, K, U, C, F, P for SPDT Switches
D, N, W, B, F, X, I, S for DPDT Switches

Or d & e = LA, LD, LK, LN, LB, LE, LL, LO, SA, SD,
SK, SN, SB, SE, SL, SO

2. Wiring Requirements

The Sealed and Flanged Cage Mechanical Unit is available with either a SPDT or a DPDT switch mechanism. The SPDT switch mechanism contacts can be wired as desired. The DPDT switch mechanism must be wired by one of the three redundant methods

Figure 1. DPDT Wired to be Open on Alarm.

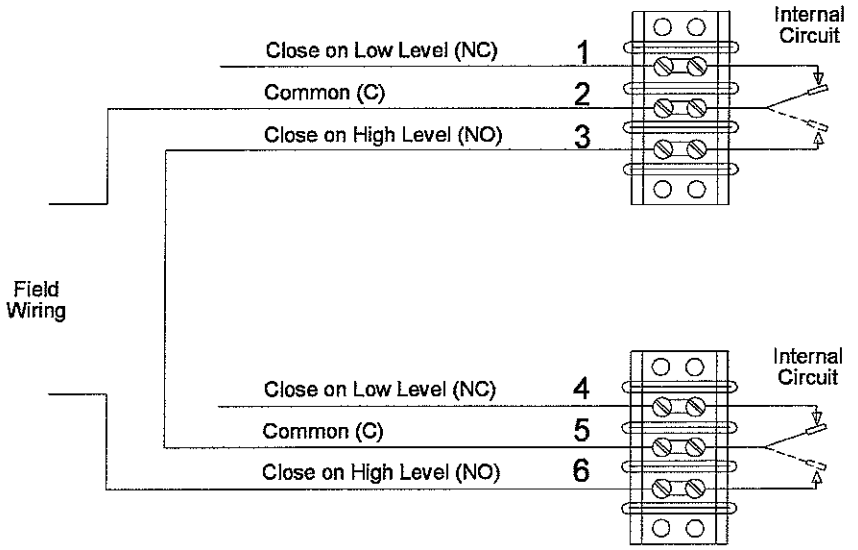
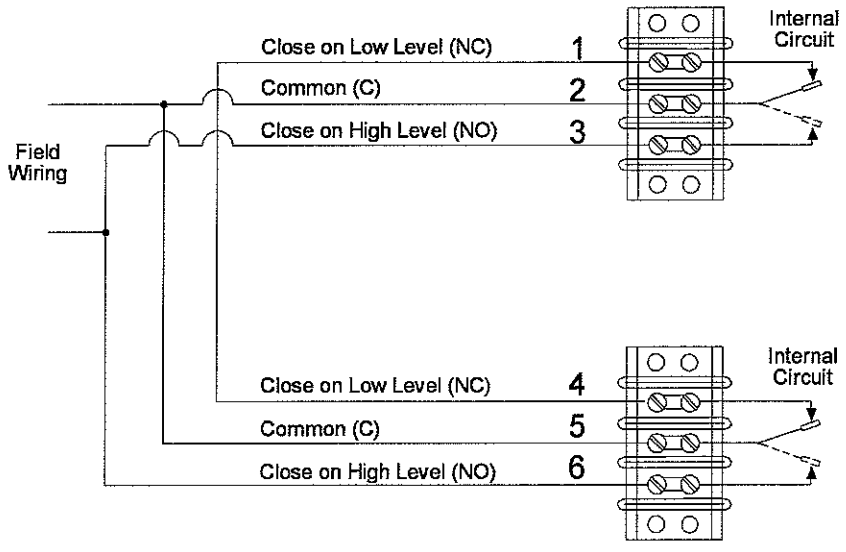


Figure 2. DPDT Wired to be Close on Alarm.



The third method is to wire the two sets of DPDT contacts independently to the Logic Solver. The Logic Solver can then arbitrate between the information on the two sets of contacts. If both sets agree, the measurement is as indicated. If they disagree, then there is a fault in the device. The user can decide the appropriate logic required for the particular application.

3. Management Summary

This report summarizes the results of the Failure Modes, Effects and Diagnostic Analysis (FMEDA) of the Magnetrol Sealed and Flanged Cage Mounted Mechanical unit series in low level applications. The FMEDA was performed to determine failure rates, and the Safe Failure Fraction (SFF), which can be used to achieve functional safety certification per IEC 61508 of a device.

The Magnetrol Sealed and Flanged Cage Mounted Mechanical unit series are devices classified as Type A according to IEC 61508, having a hardware fault tolerance of 0. The FMEDA analysis assumes the device is installed in a Low Level Alarm application when considering the state of the device for the various failure mechanisms. The units are available with either DPDT or SPDT switches. The switches must be wired by one of the methods shown in the Wiring Requirements section. If a DPDT switch is used then both sets of contacts are wired redundantly. Using these assumptions, the analysis shows that these devices have a safe failure fraction between 60 and 90% and therefore may be used up to SIL 2 as a single device.

The failure rate for the Sealed and Flanged Cage Mechanical Units with a SPDT switch is:

$\lambda^{DU} = 11. * 10^{-9}$ failures per hour

The failure rate for the Sealed and Flanged Cage Mechanical Units with a DPDT switch wired redundantly is:

$\lambda^{DU} = 8. * 10^{-9}$ failures per hour

Table 1: Failure rates according to IEC 61508 for the Magnetrol Sealed and Flanged Cage Mounted Mechanical Unit series

Switch Type	Failure Category	λ_{sd}	λ_{su}	λ_{dd}	λ_{du}	SFF
SPDT	Low Trip	0 FIT	35 FIT	0 FIT	11 FIT	76.1%
DPDT	Low Trip	0 FIT	38 FIT	0 FIT	8 FIT	82.6%

The failure rates in Table 1 assume the switches are wired open to indicate an alarm condition.

These failure rates can be used in a probabilistic model of a Safety Instrument Function (SIF) to determine suitability in part for Safety Instrumented System (SIS) usage in a particular Safety Integrity Level (SIL). A more complete listing of failure rates is provided in Table 2.

B. Failure Modes, Effects, and Diagnostic Analysis

1. Standards

This evaluation is based on the following:

IEC 61508:2000 Functional Safety of Electrical/Electronic/Programmable Electronic Safety Related Systems

SILVER (FMEDA Tool V4R0.6a), a failure rate database developed by exida.com. The rates have been chosen in a way that is appropriate for safety integrity level verification calculations. Actual field failure results with average environmental stress are expected to be superior to the results predicted by these numbers. The user of this information is responsible for determining the applicability to a particular environment.

2. Definitions

FMEDA	A Failure Modes Effect and Diagnostic Analysis is a technique which combines online diagnostic techniques and the failure modes relevant to safety instrumented system design with traditional FMEA techniques which identify and evaluate the effects of isolated component failure modes.
Fail-Safe State	The Fail–Safe state is equivalent to the condition of the output of the device if it stopped operating entirely. For switch outputs this is the normally open contacts.
Safe Failure	A failure that causes the device or system to go to the defined fail-safe state without a demand from the process. Safe failures are either detected or undetected.
Dangerous Failure	A failure that does not respond to a demand from the process (i.e. is unable to go to the defined fail-safe state). Dangerous Failures are either detected or undetected.
Hardware Fault Tolerance	The ability of a component / subsystem to continue to be able to undertake the required SIF in the presence of one or more dangerous faults in hardware.
FITs	Failures in time. 1 FIT = 1 x 10^{-9} failures per hour.
PFD_{AVG}(1yr)	Average Probability of Failure on Demand for a one year proof test interval. Probability the unit will fail in the period of one year between functional checks of the unit. The percentage of the range indicates how much of the total allowed PFD range for a particular SIL level for the SIF is consumed by the device.

3. Assumptions

- The failure categories listed are only safe and dangerous, both detected and undetected.
- Failure of one part will fail the entire unit.
- Failure rates are constant; normal wear and tear is not included.
- Increase in failures is not relevant.
- Failure rates are based on actual field information and field failures. Only field failures are considered.
- The average temperature over a long period of time is 40°C.
- The stress levels are typical for an industrial environment and can be compared to the Ground Benign classification of MIL-HNBK-217F.
- This report only applies to the models and switch mechanisms listed in the Model Designations section of this report.
- The unit is installed as a Low Level Alarm.
- The unit must be wired according to the Wiring Requirements section of this report.

4. Failure Rates

Table 2: Sealed and Flanged Cage Mounted Mechanical Unit Failure Rates

Failure Category	Failure Rate (in Fits)	Failure Rate (in Fits)
	SPDT	**DPDT**
Fail High (detected by the logic solver)	0	0
Fail Low (detected by the logic solver)	0	0
Fail Dangerous Undetected	11	8
No Effect	35	38

5. Safe Failure Fraction

Table 3: Sealed and Flanged Cage Mounted Mechanical Unit Safe Failure Fraction

Switch Type	SFF
SPDT Switch	76.1 %
DPDT Switch	82.6 %

For Sealed and Flanged Cage Unit Switches, because the SFF is between 60 and 90%, and the switch is a Type A device, it is suitable for SIL 2 with a hardware fault tolerance of 0.

6. (PFD)ave

Sealed and Flanged Cage Mounted Mechanical units average Probability of Failure on Demand (PFD_{ave}) for a one year Proof Test is:

For SPDT units

PFD(avg)(1yr) = (λ^{DU} /2)* 1 yr = $11*10^{-9}$ /2 * 8760 hr = $4.82*10^{-5}$

PFD(avg)(1yr) = 0.0000482

This PFD_{ave} value is less than 0.01 and suitable for a Type A SIL 2 application.

SIL range (max) 0.01

PFD(avg)(1yr) % of SIL Range 0.482%

For DPDT units

PFD(avg)(1yr) = (λ^{DU} /2)* 1 yr = 8*10^{-9} /2 * 8760 hr = 3.50*10^{-5}

PFD(avg)(1yr) = 0.000035

This PFD_{ave} value is less than 0.01 and suitable for Type A SIL 2 application.

SIL range (max) 0.01

PFD(avg)(1yr) % of SIL Range % 0.35%

C. Proven in Use for Sealed Cage Units with DPDT Switches

1. Standards

This evaluation is based on the following:

IEC 61511-1:2003 Functional safety: Safety instrumented systems for the process industry sector. Part 1: Framework, definitions, system, hardware and software requirements

2. Definitions

RMA A Return Material Authorization is Magnetrol's mechanism for customers to return material to Magnetrol for evaluation and repair.

3. Assumptions

Sealed and Flanged Cage units with DPDT switches wired redundantly and used as Low Level Alarms may be considered as meeting the criteria for Proven in Use when considering the following:

- Time in Use – Devices exceed 2 years with no significant change; devices exceed 1 year with no minor revisions.
- Hours in Use – This device exceeds 10,000,000 Hours of Operation for at least 2 years in a minimum of 10 applications.
- Operating Conditions – This device may only be installed per the Installation and Operations Manual and specified installation constraints.
- Failure Rate Calculations - Calculated based on RMA data. All returns are examined and evaluated. Failures are categorized.
- Failure Rate SFF - Sealed and Flanged Cage units with DPDT switches wired redundantly and installed as Low Level Switches have a SFF > 80%.

- Safety Manual - Information required for safe and proper installation is provided in the safety section of the instruction manual provided with each unit.

- Quality Systems - These units are manufactured as part of an ISO 9000 Quality Assurance System.

- Process Parameters - All Process Parameters are calibrated at the factory and are inherent to the particular device. No operator adjustments exist in mechanical units. Password protection is provided in electrical units.

4. Hardware Fault Tolerance

Sealed and Flanged Cage units with DPDT switches with the models and wiring as described in this report may be considered suitable for SIL 3 applications per IEC 61511-1 clause 11.4.4 with a reduced hardware fault tolerance of 0.

D. Release Signatures

The FMEDA analysis is based on *exida.com's SILVER* Tool. Magnetrol and *exida.com* accept no liability whatsoever for the use of these numbers or for the correctness of the standards on which the general calculation methods are based.

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