SIL Safety Manual for External Cage Float Level Switches

Functional Safety Manual

External Cage Float Level Switches

This manual complements and is intended to be used with the Magnetrol® *External Cage Float Level Switches.*

Application

The MAGNETROL External Cage level switches are float operated units suitable for use on clean liquid applications for level alarm, pump control and safety shutdown functions. Units are designed and fabricated using industry standards and best practices, and can be certified to compliance with ASME B31.1 and ASME B31.3 specifications.

Benefits

- 14-inch (356 mm) side/side process connections available as standard
- Choice of sealed or flanged float chamber design
- Process temperatures up to +1000 °F (+538 °C)
- Specific gravity ratings as low as 0.33
- Choice of TYPE 4X/7/9, Group B, C & D or EEx d IIC T6 housings
- Agency approvals include FM, CSA, ATEX and SAA
- ASME B31.1, B31.3 or NACE Certificate of Conformance supplied

Magnetrol®

SIL – External Cage Float Level Switches

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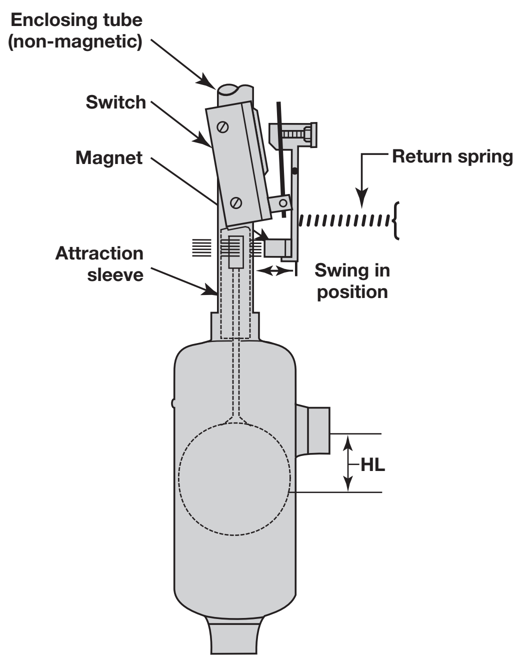

Figure 1
Switch Tripped

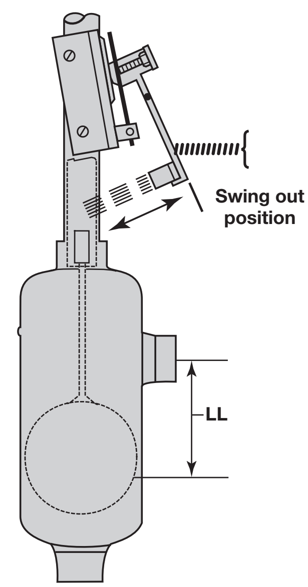

Figure 2
Switch Released

1.0 Introduction

1.1 Product Description

The MAGNETROL External Cage level switches are float operated units suitable for use on clean liquid applications for level alarm, pump control and safety shutdown functions. Units are designed and fabricated using industry standards and best practices, and can be certified to compliance with ASME B31.1 and ASME B31.3 specifications.

External Cage float level switches are suitable for use in Safety Integrity Level (SIL) 2 loops.

1.2 Theory of Operation

The design of MAGNETROL float-operated level switches is based upon the principle that a magnetic field will penetrate non-magnetic materials such as 316 stainless steel. The float moves a magnetic attraction sleeve within a non-magnetic enclosing tube and actuates a switch mechanism. The enclosing tube provides a pressure seal to the chamber and therefore to the process.

As the liquid level rises in the chamber (refer to Figure 1), the float moves the magnetic attraction sleeve up within the enclosing tube and into the field of the switch mechanism magnet. As a result, the magnet is drawn in tightly to the enclosing tube causing the switch to trip, “making” or “breaking” an electrical circuit. As the liquid level falls, the float drops and moves the attraction sleeve out of the magnetic field, releasing the switch at a predetermined “low level” (refer to Figure 2). The tension spring ensures the return of the switch in a snap action.

Table 1
SIL vs. PFDavg

Safety Integrity Level (SIL)	Target Average Probability of Failure on Demand (PFDavg)
4	$\geq 10^{-5}$ to $<10^{-4}$
3	$\geq 10^{-4}$ to $<10^{-3}$
2	$\geq 10^{-3}$ to $<10^{-2}$
1	$\geq 10^{-2}$ to $<10^{-1}$

Table 2
Minimum Hardware Fault Tolerance

SFF	Hardware Fault Tolerance (HFT)		
	0	1	2
<60%	SIL 1	SIL 2	SIL 3
60% to <90%	SIL 2	SIL 3	SIL 4
90% to <99%	SIL 3	SIL 4	SIL 4
≥99%	SIL 3	SIL 4	SIL 4

1.3 Determining Safety Integrity Level (SIL)

Tables 1 and 2 define the criteria for the achievable SIL against the target mode of operation in Demand Mode Operation.

Table 1 shows the relationship between the SIL and the Probability of Failure on Demand Average (PFDavg).

Table 2 can be used to determine the achievable SIL as a function of the Hardware Fault Tolerance (HFT) and the Safe Failure Fraction (SFF) for the complete safety system (Type A, simple device as per IEC 61508 Part 2) of which the level switch is one component.

2.0 Applicable Models

Model designations for Exida FMEDA – Sealed and Flanged External Cage Float Switches

Model: a b c – x x x x – d e x

Basic Model Type – Flanged Cage Models	
abc=	A40, B24, B25, B3F, B41, B43, B60, C24, C25, C29, C60, D30, G33, G3F, J30, J31, J33, K3F, L30, O30, W24, W25, W29, W60, Z3F
Basic Model Type – Sealed Cage Models	
abc=	A75, B35, B72, B73, B75, C35, C75, D75, E75, F75, G35, J52, J75, K35, K75, L35, L75, M75, N75, O75, P75, R75, S75, V35, V75, Z35, Z75

Switch Type	
d=	B, C, D, F, R, S, U, W, X, 8, 9

Single Switch Mechanism – SPDT	
e=	K, C, A, 1
Single Switch Mechanism – DPDT	
e=	N, F, D

Switch Type & Switch Mechanism – SPDT	
de=	SB, SE
Switch Type & Switch Mechanism – DPDT	
de=	SL, SO

3.0 Mean Time To Repair (MTTR)

SIL determinations are based on a number of factors including the Mean Time To Repair (MTTR). The analysis for the External Cage float level switch is based on a MTTR of 24 hours.

4.0 Supplementary Documentation

Refer to the following documents as supplements to this External Cage Float Switch SIL Safety Manual:

- 46-605 Flanged External Cage Float-actuated Liquid Level Switches Installation and Operating Manual
- 46-620 B73 & Series 75 Sealed External Cage Liquid Level Switches Installation and Operating Manual
- 46-622 Series 3 Liquid Level Switches ASME B31.3 Construction Installation and Operating Manual
- 46-624 Series 3 Liquid Level Switches ASME B31.1 Construction Installation and Operating Manual
- 46-630 Boiler Controls – External Cage Float-actuated Liquid Level Switches Installation and Operating Manual
- 46-627 Model J52 Refrigerant Level Switches Instruction Manual and Parts List
- 42-683 Electric Switch Mechanisms Installation and Operating Manual
- 42-799 High-temperature Electric Switch Mechanisms Installation and Operating Manual
- 46-350 FMEDA External Cage Float Switch, Failure Modes, Effects, and Diagnostic Analysis

5.0 Instructions

5.1 Systematic Limitations

The following application and environmental limitations must be observed to avoid systematic failures.

5.1.1 Application Locations

The External Cage float level switch should be located for easy access for service, configuration, and monitoring. There should be sufficient headroom to allow installation and removal of the unit. Special precautions should be made to prevent exposure to corrosive atmosphere, excessive vibration, shock, or physical damage.

5.1.2 Operating Temperature

The operating temperature for the External Cage float level switch is based on ambient temperature of +100 °F (+38 °C). The operating temperature for the switch mechanism is dependent on the model selected. The switches are listed below.

Switch	Temperature Range
B	-40 to +250 °F -40 to +121 °C
C	-40 to +450 °F -40 to +232 °C
D	-40 to +250 °F -40 to +121 °C
F	-40 to +750 °F -40 to +399 °C
R	-40 to +1000 °F -40 to +538 °C
S	-40 to +550 °F -40 to +288 °C

Switch	Temperature Range
U	-40 to +550 °F -40 to +288 °C
W	-40 to +450 °F -40 to +232 °C
X	-40 to +450 °F -40 to +232 °C
8	-40 to +750 °F -40 to +399 °C
9	-40 to +1000 °F -40 to +538 °C

5.1.3 Operating Pressure

Maximum operating pressures are dependent on the float. Refer to the chart below for maximum operating pressures.

Bulletin	46-605	46-620	46-622	46-624	46-630
Section	7.0	7.0	5.4	5.4	7.0

5.2 Skill Level of Personnel

Personnel following the procedures of this safety manual should have technical expertise equal to or greater than that of a qualified instrument technician.

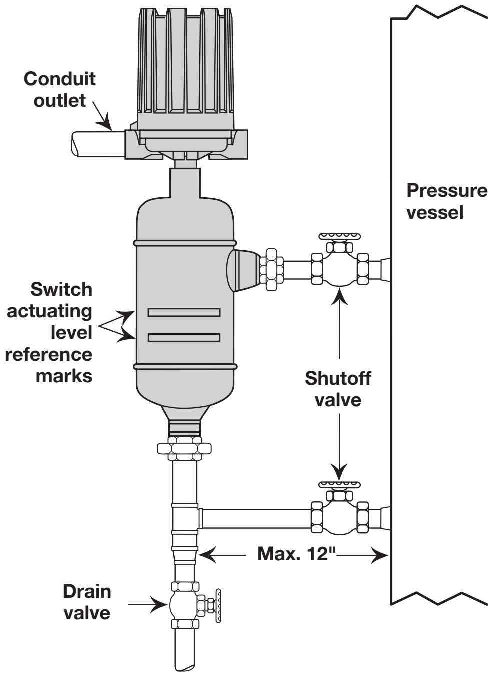

Figure 3
Typical Piping Arrangement

5.3 Necessary Tools

No special equipment or tools are required to install an External Cage float level switch. The following items are recommended:

- Wrenches, flange gaskets, and flange bolting appropriate for process connection(s)
- Screwdrivers and assorted tools for making conduit and electrical connections
- Digital multimeter or DVM for troubleshooting

5.4 Storage

External Cage liquid level switches should be stored in its original shipping box and not be subjected to temperatures outside the storage temperature range -40 to +160 °F (-40 to +70 °C).

5.5 Installation

Caution: This instrument is intended for use in Installation Category II, Pollution Degree 3.

Adjust piping as required to bring control to a vertical position. MAGNETROL controls must be mounted within 3° of vertical in all directions. A three degree slant is noticeable by eye, but installation should be checked with a spirit level on top and/or sides of float chamber.

Controls should be mounted as close to the vessel as possible. This will result in a more responsive and accurate level change in the control. Liquid in a long line may be cooler and more dense than liquid in the vessel causing lower level indication in the control than actual level in the vessel.

Caution: Never insulate the switch housing of the level control.

Installation and maintenance of tandem float models are accomplished in much the same manner as described for standard models. Additional consideration must be given to the piping arrangement to allow for alignment of the two switch actuating level marks on the float chamber with the desired levels in the vessel.

Caution: Operation of all buoyancy type level devices should be done in such a way as to minimize the action of dynamic forces on the float or displacer sensing element. Good practice for reducing the likelihood of damage to the control is to equalize pressure across the device slowly.

5.6 Site Acceptance Testing

To ensure proper operation after installation and configuration, a site acceptance test should be completed. This procedure is identical to the Proof Test Procedure described in Section 6.1.4.

6.0 Recurrent Function Tests

6.1 Proof Testing

6.1.1 Introduction

Following are the procedures utilized to detect Dangerous Undetected (DU) failures. The procedure will detect possible DU failures in the External Cage float level switch per table at left.

Proof Test Coverage

Device	λ_{DU} PT (FIT)	Proof Test Coverage
High Alarm, DPDT Switch, NC	7	98%
Low Alarm, DPDT Switch, NC	18	94%
High Alarm, DPDT Switch, NO	7	98%
Low Alarm, DPDT Switch, NO	17	91%
High Alarm, SPDT Switch, NC	8	98%
Low Alarm, SPDT Switch, NC	17	94%
High Alarm, SPDT Switch, NO	8	98%
Low Alarm, SPDT Switch, NO	17	94%

Where λ_{DU} PT is the dangerous failures not covered by proof test.

6.1.2 Interval

To maintain the Safety Integrity Level of a Safety Instrumented System, it is imperative that the entire system be tested at regular time intervals (referred to as TI in the appropriate standards). The SIL for the External Cage float switch is based on the assumption that the operator will carry out these tests and inspection at least once (1x) per year. The onus is on the owner/operator to select the type of inspection and the time period for these tests.

6.1.3 Recording results

Results of the Proof Test should be recorded for future reference.

6.1.4 Proof Test Procedure (To be performed annually at a minimum)

1. Bypass the logic controller or take other action to avoid a false trip.
2. Perform a detailed inspection of the unit inside and out for physical damage that may impact the structural integrity, and for evidence of environmental or process leaks. Repair or replace the unit if needed.
3. Using a calibrated multimeter set to measure electrical resistance (ohms), at the field connections measure and record the resistances across the Common (C) and the Normally Closed (NC) contacts, and the Common (C) and the Normally Open (NO) contacts.
4. Change the process level to cause the switch mechanism to change states.
5. Again, measure and record the resistances across the Common (C) and the Normally Closed (NC) contacts, and the Common (C) and the Normally Open (NO) contacts.
6. Ensure with the multimeter readings that the switch mechanism did in fact change states. A closed switch contact should measure less than 1 ohm, and an open contact should measure greater than 5 megaohms.
7. Repeat steps 3 through 6 for all other sets of switch contacts (if any).
8. Restore the installation to normal operation.

6.2 Troubleshooting

Report all failures to Magnetrol Technical Support. Refer to bulletins in Section 4.0, based on the type of External Cage level switch, for troubleshooting instructions.

7.0 Appendices

7.1 FMEDA Report: Exida Management Summary

exida®

Failure Modes, Effects and Diagnostic Analysis

Project:
Sealed and Flanged External Cage Float Switches

Company:
Magnetrol International, Inc.
Aurora, IL
USA

Contract Number: Q16/12-101
Report No.: MAG 16/12-101 R001
Version V1, Revision R2, May 8, 2017
Rudolf Chalupa

4.4 Results

Using reliability data extracted from the *exida* Electrical and Mechanical Component Reliability Handbook the following failure rates resulted from the External Cage Float Switches FMEDA.

Table 3 Failure rates External Cage Float Switches

Application/Device/Configuration	λ_{SD}	λ_{SU}[3]	λ_{DD}	λ_{DU}	#	SFF
Hi Alarm, DPDT Switch, NC	0	289	0	455	403	39%
Low Alarm, DPDT Switch, NC	0	417	0	295	405	59%
Hi Alarm, DPDT Switch, NO	0	188	0	469	403	29%
Low Alarm, DPDT Switch, NO	0	517	0	197	406	72%
High Alarm, SPDT, NC	0	194	0	523	334	27%
Low Alarm, SPDT, NC	0	401	0	312	338	56%
High Alarm, SPDT, NO	0	161	0	555	335	22%
Low Alarm, SPDT, NO	0	435	0	278	338	61%

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

According to IEC 61508-2 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 61508-2 or the 2_H approach according to 7.4.4.3 of IEC 61508-2 (see Section 5.2).

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.

The failure rate data used for this analysis meets the *exida* criteria for Route 2_H. Therefore, the External Cage Float Switches meets the hardware architectural constraints for up to SIL 2 at HFT=0 (or SIL 3 @ HFT=1) when the listed failure rates are used.

[3] 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.

7.2 SIL Declaration of Conformity

Hardware functional safety according to Section 7.4.4 of IEC 61508-2 (Edition 2.0, 2010 Edition)

Magnetrol International, Incorporated, 705 Enterprise Street, Aurora, Illinois 60504 declares as the manufacturer, that the level switches:

External Cage Float Level Switches

are suitable for use in safety-instrumented loops according to IEC 61508 on condition that "the good practice of engineering rules" as described in the IEC standards, the appropriate parts of IEC 61508/61511, and the following parameters of the instrument are applied.

FIT = Failure in Time (1×10-9 failures per hour)

Application/Device/ Configuration	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF
High Alarm, DPDT Switch, NC	0	289	0	455	39%
Low Alarm DPDT Switch, NC	0	417	0	295	59%
High Alarm, DPDT Switch, NO	0	188	0	469	29%
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Low Alarm, SPDT Switch, NO	0	435	0	278	61%

The failure rate data used for this analysis meets the ***exida*** criteria for Route 2_H. Therefore, the External Cage float level switch meets the hardware architectural constraints for up to SIL 2 at HFT=0 (or SIL 3 @ HFT=1) when the listed failure rates are used.

Refer to Section 5.0 and Appendix D of FMEDA for PFD_{avg} information.

The External Cage level switch is classified a Type A* element according to IEC 61508, having a hardware fault tolerance of 0.

7.3 Report – Lifetime of Critical Components

According to section 7.4.9.5 of IEC 61508-2, a useful lifetime, based on experience, should be determined and used to replace equipment before the end of useful life.

Although a constant failure rate is assumed by the exida FMEDA prediction method (see Section 4.2.2 of FMEDA), this only applies provided that the useful lifetime** of components is not exceeded. Beyond their useful lifetime, the result of the probabilistic calculation method is likely optimistic, as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the subsystem itself and its operating conditions.

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

Based on general field failure data, a useful life period of approximately 10 to 15 years is expected for the External Cage level switch.

When plant experience indicates a shorter useful lifetime than indicated in Appendix A of FMEDA, the number based on plant experience should be used.

** 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.

NOTES

NOTES

References

- ANSI/ISA-84.00.01-2004 Part 1 (IEC 61511-1Mod) "Functional Safety: Safety Instrumented Systems for the Process Industry Sector–Part 1 Hardware and Software Requirements"
- ANSI/ISA-84.00.01-2004 Part 2 (IEC 61511-2Mod) "Functional Safety: Safety Instrumented Systems for the Process Industry Sector–Part 2 Guidelines for the Application of ANSI/ISA84.00.01-2004 Part 1 (IEC 61511-1 Mod)–Informative"
- ANSI/ISA-84.00.01-2004 Part 3 (IEC 61511-3Mod) "Functional Safety: Safety Instrumented Systems for the Process Industry Sector–Part 3 Guidance for the Determination of the Required Safety Integrity Levels– Informative"
- ANSI/ISA-TR84.00.04 Part 1 (IEC 61511 Mod) "Guideline on the Implementation of ANSI/ISA-84.00.01-2004"

Disclaimer

The SIL values in this document are based on an FMEDA analysis using exida's SILVER Tool. MAGNETROL accepts no liability whatsoever for the use of these numbers of for the correctness of the standards on which the general calculation methods are based.

ASSURED QUALITY & SERVICE COST LESS

Service Policy

Owners of Magnetrol controls may request the return of a control or any part of a control for complete rebuilding or replacement. They will be rebuilt or replaced promptly. Controls returned under our service policy must be returned by prepaid transportation. Magnetrol will repair or replace the control at no cost to the purchaser (or owner) other than transportation if:

1. Returned within the warranty period; and
2. The factory inspection finds the cause of the claim to be covered under the warranty.

If the trouble is the result of conditions beyond our control; or, is NOT covered by the warranty, there will be charges for labor and the parts required to rebuild or replace the equipment.

In some cases it may be expedient to ship replacement parts; or, in extreme cases a complete new control, to replace the original equipment before it is returned. If this is desired, notify the factory of both the model and serial numbers of the control to be replaced. In such cases, credit for the materials returned will be determined on the basis of the applicability of our warranty.

No claims for misapplication, labor, direct or consequential damage will be allowed.

Return Material Procedure

So that we may efficiently process any materials that are returned, it is essential that a "Return Material Authorization" (RMA) number be obtained from the factory prior to the material's return. This is available through Magnetrol's local representative or by contacting the factory. Please supply the following information:

1. Company Name
2. Description of Material
3. Serial Number
4. Reason for Return
5. Application

Any unit that was used in a process must be properly cleaned in accordance with OSHA standards, before it is returned to the factory.

A Material Safety Data Sheet (MSDS) must accompany material that was used in any media.

All shipments returned to the factory must be by prepaid transportation.

All replacements will be shipped F.O.B. factory.

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