SD00185F/00/EN/13.19
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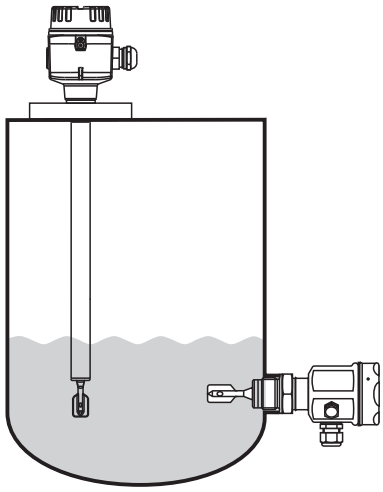
2019-03-05

Special Documentation
Liquiphant M/S with electronic insert FEL51
Functional safety manual



Level Limit Measuring System

Application
Dry running protection or operating minimum detection of all types of liquids in tanks to satisfy particular safety systems requirements to IEC 61508/IEC 61511-1.

The measuring device fulfils the requirements concerning
- Safety functions up to SIL 2
- Explosion protection by flameproof enclosure
- EMC to EN 61326 and NAMUR Recommendation NE 21

Your benefits

- For protection against dry running up to SIL 2
  - Independently assessed (Functional Assessment) by *exida.com* to IEC 61508/IEC 61511-1
- Monitoring for corrosion on the tuning fork of the sensor
- No calibration
- Protected against outside vibration
- Easy commissioning

Endress+Hauser
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Table of contents

SIL declaration of conformity

SIL-04002a/00/a2

SIL Konformitätserklärung
SIL Declaration of Conformity

Funktionale Sicherheit nach IEC 61508/IEC 61511
Functional safety according to IEC 61508/IEC 61511

Endress+Hauser GmbH+Co. KG, Hauptstrasse 1, 79689 Maulburg


Level


Pressure


Flow


Temperature


Liquid Analysis


Registration


Systems Components


Services


Solutions

erklärt als Hersteller, dass der Füllstandgrenzschalter für Flüssigkeiten
declares as manufacturer, that the level limit switch for liquids

Liquiphant M/S FTL5.-, FTL5.H-, FTL51C-, FTL7.-
+Electronic insert FEL51

für den Einsatz in Schutzeinrichtungen entsprechend der IEC 61511-1 geeignet ist, wenn die Sicherheitshinweise und nachfolgende Parameter beachtet werden:
is suitable for the use in safety-instrumented systems according to IEC 61511-1, if the safety instructions and following parameters are observed:

Product	**Liquiphant M/S +FEL51**
Schutzfunktion/Safety Function	Trockenlaufschutz/Minimum Detection
SIL	2
Prüfintervall/Proof test interval	≤ 1 Jahr/year
Gerätetyp/Device Type	B
HFT[1]	0 (einkanalige Verwendung/single channel use)
SFF	> 73 %
PFD_{av}[2]	$< 8{,}4 \times 10^{-4}$
λ_{du}	192 FIT
λ_{dd}	0,34 FIT
λ_{su}	506 FIT
λ_{sd}	40 FIT
$MTBF_{tot}$[3]	155 Jahre/years

[1] gemäß Absatz/according to clause 11.4.4 of IEC 61511-1
[2] die Werte entsprechen SIL 2 nach ISA S84.01/ the values comply with SIL2 according to ISA S84.01.
[3] gemäß Siemens SN29500, einschließlich Fehlern, die außerhalb der Sicherheitsfunktion liegen
according to Siemens SN29500, including faults outside the safety function

Das Gerät einschließlich Software und Änderungsprozess wurde auf Basis der Betriebsbewährung bewertet.
The device including the software and the modification process was assessed on the basis of prior use.

Maulburg, May 03, 2004

Endress+Hauser GmbH+Co. KG

i.V.
Leiter Zertifizierung
Manager Certification

i.V.
Projektleiter
Projectmanager

Endress+Hauser
People for Process Automation

L00-FEL51xxx-01-06-xx-a2-002

Introduction

Note! For general information about SIL please refer to: www.endress.com/sil

General depiction of a safety system (protection function)

Parameter tables for determining Safety Integrity Level (SIL)

The following tables are used to define

- The reachable SIL
- The requirements pertaining to the "Average Probability of Dangerous Failure on Demand" (PFD_{avg})
- The "Hardware Fault Tolerance" (HFT)
- The "Safe Failure Fraction" (SFF)

of a measuring system suitable for the safety function.

The specific values for the Liquiphant M/S measuring system with FEL51 (AC version) can be found in the Appendix.

Permitted probabilities of dangerous failures on demand of the complete safety related system dependent on the SIL (e.g. falling below a defined MIN level/switch point, that is the fork swings free) (Source: IEC 61508, Part 1):

SIL	PFD_{avg}
4	$\geq 10^{-5} \ldots < 10^{-4}$
3	$\geq 10^{-4} \ldots < 10^{-3}$
2	$\geq 10^{-3} \ldots < 10^{-2}$
1	$\geq 10^{-2} \ldots < 10^{-1}$

The following table shows the achievable Safety Integrity Level (SIL) as a function of the probability fraction of safety-oriented failures and the "hardware fault tolerance" of the complete safety system for type B systems (complex components, not all faults are known or can be described).

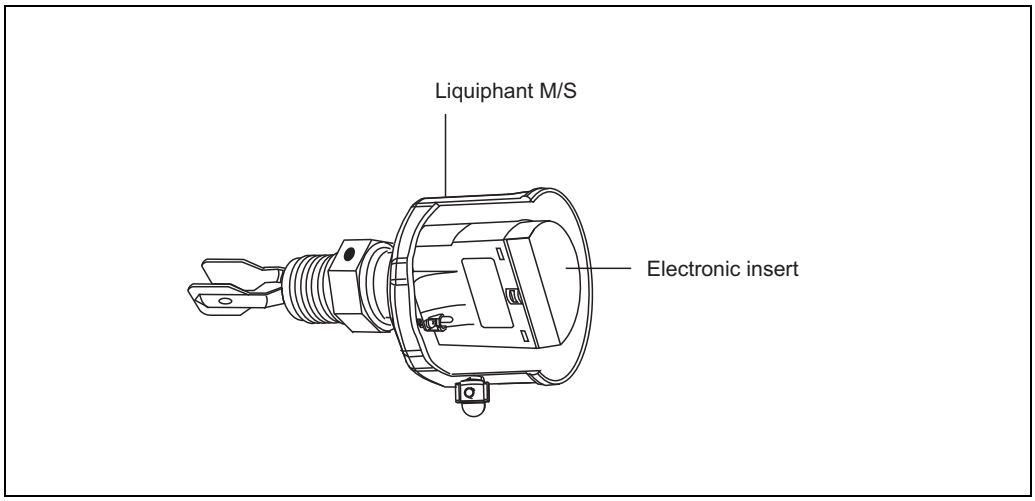
SFF	HFT		
	0	1 (0)[1)]	2 (1)[1]
< 60 %	not allowed	SIL 1	SIL 2
60 % ...< 90 %	SIL 1	SIL 2	SIL 3
90% ...<99%	SIL 2	SIL 3	
≥ 99 %	SIL 3		

1) In accordance with IEC 61511-1 (FDIS) (Section 11.4.4), the HFT can be reduced by one (values in brackets) if the devices used fulfil the following conditions:
- The device is proven in use,
- Only process-relevant parameters can be changed at the device (e.g. measuring range, ...),
- Changing the process-relevant parameters is protected (e.g. password, jumper, ...),
- The safety function requires less than SIL 4.

Structure of the measuring system with Liquiphant M/S with FEL51

Level limit measuring system

The measuring system is displayed in the following diagram (example).



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Safety function

The safety function only applies to MIN safety (protection against dry running).

The following settings are permitted for the safety function:

Instrument	Setting	As-delivered state
Liquiphant M/S	Density switch setting: 0.5 Density switch setting: 0.7	Density switch setting: 0.7
	"MIN" safety	"MAX" safety

The thyristor output is blocked (residual current < 6 mA) when:

- Falling below the switch point (level below response height, fork free)
- A detected fault occurs
- The mains voltage fails

In addition to the thyristor output, a red LED indicates the following:

- Level alarm (fork free) - red LED illuminated
- Corrosion alarm or detected electrical fault - red LED flashes (1 Hz)

Permitted versions of the Liquiphant M/S with FEL51 for the safety function

The following combinations are permitted for the measuring system:

Liquiphant M with FEL51	Liquiphant S with FEL51
FTL50-######1###* FTL51-######1###* FTL50H-######1###* FTL51H-######1###* FTL51C-######1####*	FTL70-######1####* FTL71-######1####*

*Permitted instrument types (# = all instrument versions permitted); * 1 = FEL51*

Safety function data

The **mandatory settings** and data for the safety function can be found in the Appendix (Page 9).

The measuring system reacts in ≤ 1.4 s.

Note!

MTTR is set at 8 hours.

Safety systems **without a self-locking function** must be monitored or set to an otherwise safe state after carrying out the safety function within MTTR.

Supplementary device documentation

The following must be available for the measuring system:

	Technical Information	Operating Instructions	Special version documentation
Liquiphant M	Types FTL50, FTL51, FTL50H, FTL51H: TI00328F	Types FTL50, FTL51: KA00143F, KA00220F	Technical special products (TSP) with remote electronics: SV01222F
		Types FTL50, FTL51: KA00163F (with aluminium housing/ separate terminal compartment)	
		Types FTL50H, FTL51H: KA00144F, KA00220F	
		Types FTL50H, FTL51H: KA00164F (with aluminium housing/ separate terminal compartment)	
	Type FTL51C: TI00347F	Type FTL51C: KA00162F	
		Type FTL51C: KA00165F (with aluminium housing/ separate terminal compartment)	
Liquiphant S	For all instrument types: TI00354F	Types FTL70, FTL71: KA00172F	
		Types FTL70, FTL71: KA00173F (with aluminium housing/ separate terminal compartment)	
Relevant contents	Connection data, Installation instructions	Setting, configuration, remarks, function tests	Additional installation instructions

Settings and installation instructions

Installation instructions

Please refer to the Compact Instructions (KA) for information regarding the correct installation of Liquiphant M/S with FEL51.
Since the application conditions have an effect on the safety of the measurement, pay attention to the notes in the Technical Information (TI) and Compact Instructions (KA).

Refer to the following documentation for instructions on setting the instruments:

Instrument	Setting description in documentation:
Liquiphant M/S with FEL51	KA00143F, KA00163F, KA00144F, KA00164F, KA00220F, KA00162F, KA00165F, KA00172F, KA00173F, *

(type-dependent, see Table: Supplementary device documentation, Page 6)*

Settings for Liquiphant M/S with FEL51:

- The **density switch setting** must be configured according to the density range of the medium.
- The setting of the **safety mode** has an effect on the function. The DIL switch must be set to MIN in a SIL application.

Caution!
Load (connectable)
Load switched via thyristor directly in power circuit.
Transient (40 ms) max. 1.5 A, max. 375 VA at 253 V or max. 36 VA at 24 V
(Not short-circuit proof);
continuous max. 89 VA at 253 V, max. 8.4 VA at 24 V
min. 2.5 VA at 253 V (10 mA), min. 0.5 VA at 24 V (20 mA);
voltage drop via FEL51 max. 12 V;
residual current with blocked thyristor max. 6 mA.
Overvoltage protection FEL51: overvoltage category III

Caution!
Changes to the settings at the electronic insert FEL51 after measuring system start-up can impair the protection function!

Response in operation and failure

The response in operation and failure is described in the following documentation:

Instrument	Setting description in documentation:
Liquiphant M/S with FEL51	KA00143F, KA00163F, KA00144F, KA00164F, KA00220F, KA00162F, KA00165F, KA00172F, KA00173F, *

(type-dependent, see Table: Supplementary device documentation, Page 6)*

Recurrent function tests of the measuring system

The operativeness of the minimum detection must be checked annually if the PFD_{avg} values given in the Appendix are used.
The check must be carried out in such a way that it is proven that the minimum detection functions perfectly in interaction with all components. This is guaranteed when the response height is lowered in an emptying process. If it is not practical to empty to the response height, suitable simulation of the level or of the physical measuring effect must be used to make the level sensor respond. If the operativeness of the level sensor/transmitter can be determined otherwise (exclusion of faults that impair function), the check can also be completed by simulating the corresponding output signal.

In the case of recurrent tests, each permitted setting must be checked, especially whether all the alarm switches are set to ON.

Caution!
Note the following points for the function test:
- Thyristor output switching can be checked by using a hand multimeter at the terminals or by observing the dry running protection elements (e.g. horn, actuating element).
- As a positive test result, a free tuning fork must be detected and trigger the alarm for dry running protection.
- **If free fork is not detected during the recurrent test, the monitored process must be set to a safe state by means of additional or other measures and/or kept in the safe state until the safety system is repaired.**

Appendix

Specific values and wiring options for the measuring system Liquiphant M/S with FEL51

The tables show values and wiring options relevant to safety for the measuring system.

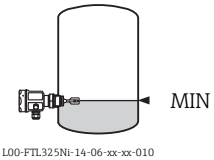
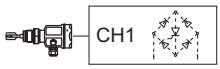
Note!
Note the following points on the table below:

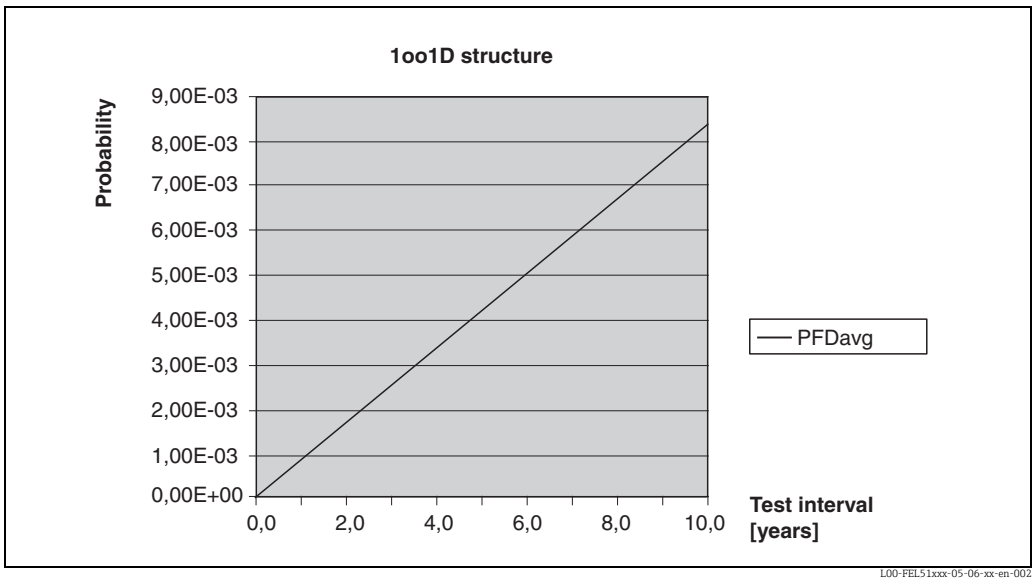
- The PFD_{avg} value applies to alarms with blocked thyristor switching (high impedance). The use of open thyristor switching (low impedance) requires further consideration.

Warning!
For safety related use for MIN detection, the following application errors must be excluded:

Liquiphant M/S:
- Permanent and/or heavy build-up or "non-Newtonian media"
- Solid proportions of the medium with a diameter > 5.0 mm
- Corrosion within the scope of the media compatibility with regard to fork material and coating.

Liquiphant S:
- Hydrogen diffusion at temperatures over 180 °C and over 64 bar.

1oo1 architecture	
Liquiphant M/S with FEL51 Settings	1) density 0.7 / 0.5 2) MIN safety
Evaluated transmitter (FEL51)	 L00-FTL325Ni-14-06-xx-xx-010
SIL	SIL 2
HFT	0
SFF	> 73 %
PFD_{avg}	< 0,084 x 10^{-2}
Wiring scheme	 L00-FEL51xxx-04-06-xx-xx-001
Recurrent test e.g. approaching level	TI (test interval) = annual



L00-FEL51xxx-05-06-xx-en-002

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FMEDA and Proven-in-use Assessment

Project:
Level limit switch Liquiphant M/S with thyristor output FEL 51
Applications with level limit detection in liquids (MIN detection)

Customer:
Endress+Hauser GmbH+Co.KG
Maulburg
Germany

Contract No.: E+H 02/6-16
Report No.: E+H 02/6-16 R009
Version V1, Revision R1.0, August 2003
Stephan Aschenbrenner

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Management summary

This report summarizes the results of the hardware assessment with proven-in-use consideration according to IEC 61508 / IEC 61511 carried out on Liquiphant M/S with thyristor output FEL 51 with software version V1.0 for applications with MIN detection.

The hardware assessment consists of a Failure Modes, Effects and Diagnostics Analysis (FMEDA). A FMEDA is one of the steps taken to achieve functional safety assessment of a device per IEC 61508. From the FMEDA, failure rates are determined and consequently the Safe Failure Fraction (SFF) is calculated for the device. For full assessment purposes all requirements of IEC 61508 must be considered.

The failure rates used in this analysis are based on the Siemens standard SN 29500.

According to table 2 of IEC 61508-1 the average PFD for systems operating in low demand mode has to be $\geq 10^{-3}$ to $< 10^{-2}$ for SIL 2 safety functions. A generally accepted distribution of PFD_{AVG} values of a SIF over the sensor part, logic solver part, and final element part assumes that 35% of the total SIF PFD_{AVG} value is caused by the sensor part. For a SIL 2 application the total PFD_{AVG} value of the SIF should be smaller than 1,00E-02, hence the maximum allowable PFD_{AVG} value for the sensor part would then be 3,50E-03.

Liquiphant M/S with thyristor output FEL 51 is considered to be a Type B[1] component having a hardware fault tolerance of 0.

Type B components with a SFF of 60% to < 90% must have a hardware fault tolerance of 1 according to table 3 of IEC 61508-2 for SIL 2 (sub-) systems.

As Liquiphant M/S with thyristor output FEL 51 is supposed to be a proven-in-use device, an assessment of the hardware with additional proven-in-use demonstration for the device and its software was carried out. Therefore according to the requirements of IEC 61511-1 First Edition 2003-01 section 11.4.4 and the assessment described in section 5.1 a hardware fault tolerance of 0 is sufficient for SIL 2 (sub-) systems being Type B components and having a SFF of 60% to < 90%.

Table 1: Summary for Liquiphant M/S with thyristor output FEL 51

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 8,42E-04	PFD_{AVG} = 4,19E-03	PFD_{AVG} = 8,35E-03	> 73 %

λ_{sd} = 3,99E-08 1/h

λ_{su} = 5,06E-07 1/h

λ_{dd} = 3,38E-10 1/h

λ_{du} = 1,92E-07 1/h

The boxes marked in yellow (▭) mean that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 but do not fulfill the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3,50E-03. The boxes marked in green (▭) mean that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 and table 3.1 of ANSI/ISA–84.01–1996 and do fulfill the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3,50E-03. Figure 4 shows the time dependent curve of PFD_{AVG}.

Type B component: "Complex" component (using micro controllers or programmable logic); for details see 7.4.3.1.3 of IEC 61508-2.

L00-FEL51xxx-01-06-xx-en-004

Supplementary Documentation	Safety in the Process Industry – reducing risks with SIL CP002Z/11

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