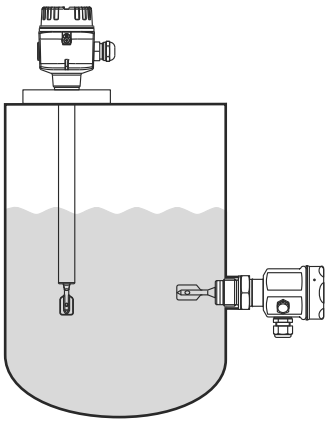
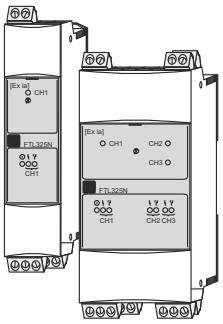
Functional safety manual
Liquiphant M/S with FEL58 and Nivotester FTL325N





Level Limit Measuring System

Application
Minimum detection (also dry running protection) of all types of liquids in tanks to satisfy particular safety systems requirements as per IEC 61508/IEC 61511-1.

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

Your benefits
- For minimum detection 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
- Fault message for circuit break and short-circuit
- Functional test of subsequent devices at the push of a button
- Protected against outside vibration
- Easy commissioning

Endress+Hauser
People for Process Automation

Table of contents

SIL declaration of conformity

SIL-14004a/00

Endress+Hauser
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SIL-Declaration of Conformity

Functional Safety according to IEC 61508 / 61511
Supplement 1 / NE130 Form B.1 and IGR 49-02-15 Datasheet 1

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

declares as manufacturer, that the following type of the

Liquiphant M/S with elelctronic insert FEL58 and Nivotester FTL325N

is suitable for the use in safety-instrumented systems according to IEC61508, if the safety instructions and following parameters are observed.

This declaration of conformity is only valid for the customer listed in the cover letter of the responsible Endress+Hauser sales center and for the listed products in delivery status.

Maulburg, 30.01.2014
Endress+Hauser GmbH+Co. KG

i. V.
Dr. Arno Götz
Dept. Manager Product Safety
Research & Development

i. V.
Dr. Dietmar Frühauf
Dept. Manager Level Limit Switch
Research & Development

1/2

SIL-14004a

SIL-14004a/00

Endress+Hauser
People for Process Automation

General			
Device designation and permissible types	Liquiphant M/S with electronic insert FEL58 and Nivotester FTL325N		
	For more details please have a look at the safety manual SD170F		
Safety-related output signal	NAMUR interface [CONF 1]; Relais [CONF 2]		
Fault current	< 1,2 mA [CONF 1]		
Process variable/function	Dry running protection or operating minimum detection		
Safety function(s)	MIN detection		
Device type acc. to IEC 61508-2	☐ Typ A	☒ Typ B	
Operating mode	☒ Low Demand Mode	☐ High Demand or Continuous Mode	
Valid Hardware-Version	As of delivery date October 2000		
Valid Software-Version	As of 1.0		
Safety manual	SD170F		
Type of evalutation (check only one box)	☐	Complete HW/SW evaluation parallel to development incl. FMEDA and change request acc. to IEC 61508-2, 3	
	☒	Evaluation of "Proven-in-use" performance for HW/SW incl. FMEDA and change request acc. to IEC 61508-2, 3	
	☐	Evaluation of HW/SW field data to verify „prior use" acc. to IEC 61511	
	☐	Evaluation by FMEDA acc. to IEC61508-2 for devices w/o software	
Evaluation through – report no.	exida E+H 02/6-16 R013		
Test documents	Development documents	Test reports	Data sheets

SIL - Integrity			
Systematic safety integrity		☒ SIL 2 capable	☐ SIL 3 capable
Hardware safety integrity	Single channel use (HFT = 0)	☒ SIL 2 capable	☐ SIL 3 capable
	Multi channel use (HFT ≥1)	☒ SIL 2 capable	☐ SIL 3 capable

FMEDA		
	Liquiphant M/S with electronic insert FEL58 [3]	Liquiphant M/S with electronic insert FEL58 and Nivotester FTL325N [4]
Safety function	MIN detection	MIN detection
λ_{DU} *1)	72.7 FIT	84 FIT
λ_{DD} *1)	12.7 FIT	12.7 FIT
λ_{SU} *1)	187 FIT	530 FIT
λ_{SD} *1)	65.6 FIT	65.6 FIT
SFF - Safe Failure Fraction	78 %	88 %
PTC *2)	- %	- %
λ_{total} *1)	338 FIT	692 FIT
Diagnostic test interval	-	-
Fault reaction time	-	-

Comments

[3] This information based on the configuration 1 [CONF 1] in the exida test report
[4] This information based on the configuration 2 [CONF 2] in the exida test report
Other configurations see SD265F under www.endress.com/SIL

Declaration

☒	Our internal company quality management system ensures information on safety-related systematic faults which become evident in the future

*1) FIT = Failure In Time, Number of failures per 10^9 h
*2) PTC = Proof Test Coverage (Diagnostic coverage for proof test)

2/2

SIL-14004a

Introduction

For general informationen 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" (PFDavg), the "Hardware Fault Tolerance" (HFT) and the "Safe Failure Fraction" (SFF) of the safety system. The specific values for the Liquiphant M/S + Nivotester FTL325N measuring system 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. exceeding a defined MIN level/switch point) (Source: IEC 61508, Part 1):

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

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% to < 90%	SIL 1	**SIL 2**	SIL 3
90% to < 99%	SIL 2	SIL 3	
≥ 99%	SIL 3		

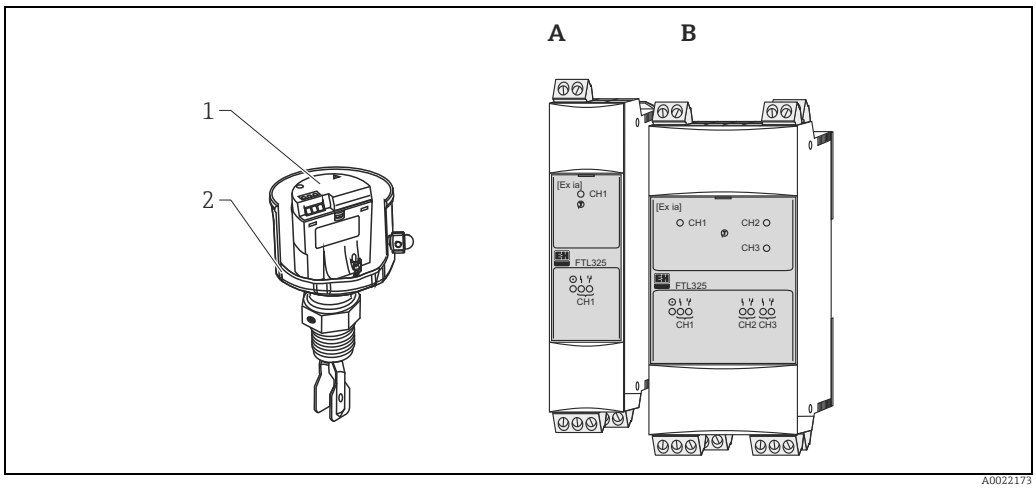
1) In accordance with IEC 61511-1 (FDIS) (Section 11.4.4), the HFT can be reduced by one (values in brackets) if the devices used fulfil the following conditions:
- the device is proven in use,
- only process-relevant parameters can be changed at the device (e.g. measuring range, ...),
- changing the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

All conditions apply to Liquiphant M/S + Nivotester FTL325N.

Structure of the measuring system

Level limit measuring system

The measuring system's devices are displayed in the following diagram (example).



1 *FEL - Electronic insert*
2 *Liquiphant M/S*
A *Nivotester FTL325N (one-channel)*
B *Nivotester FTL325N (three-channel)*

Safety function

The safety function applies to all settings in MIN safety (monitoring of the covered state) and use of the NO contacts of the level relays.

The following settings are permitted for the safety function:

Device	Setting	As-delivered state
Liquiphant	▪ Density switch setting: 0,5 ▪ Density switch setting: 0,7	Density switch setting: 0,7
	"MIN" safety	"MAX" safety
Nivotester FTL325N-#3#3	Error current signal < 1,2 mA	Error current signal < 1,2 mA
	All settings **except** "ΔS function" (see Section "Settings and installation instructions")	Three-channel operation
	The DIL switch for failure indication (short-circuit and cable break-monitoring) must be set into position ON.	Failure switch "ON"
Nivotester FTL325N-#1#1	Error current signal < 1,2 mA	Error current signal < 1,2 mA
		One-channel operation
	The DIL switch for failure indication (short-circuit and cable break-monitoring) must be set into position ON.	Failure switch "ON"

The level relay always works in quiescent current safety; i.e. the relay releases when:
- the switch point is undershot (level falls below response height)
- a fault occurs
- the mains voltage fails

In addition to the level relay, the alarm relay works in quiescent current safety and releases when:
- one of the following faults occurs:
  - the sensor connection is interrupted
  - the sensor connection short circuits
- the mains voltage fails

When the alarm relay releases, the level relay also releases.

Permitted device types

The details pertaining to functional safety in this manual relate to the device versions listed below and are valid as of the specified firmware and hardware version.
Unless otherwise specified, all subsequent versions can also be used for safety instrumented systems. A modification process according to IEC 61508 is applied for device changes.

Valid device versions for safety-related use:

Liquiphant M FTL50, FTL50H, FTL51, FTL51C, FTL51H+ FEL58

Feature	Designation	Option model	
010	Approval	all	
020	Process connection	all	
030	Probe length; Type	all	
040	Electronics; Output	8	FEL58; SIL NAMUR+test button (H-L signal)
050	Housing; Cable entry	all	
060	Additional option	all	

Valid firmware version: as of 01.00.00
Valid hardware version (electronics): as of 01.00

Valid device versions for safety-related use:

Liquiphant S FTL70, FTL71+ FEL58

Feature	Designation	Option model	
010	Approval	all	
020	Process connection	all	
030	Probe length	all	
040	Electronics; Output	8	FEL58; SIL NAMUR+test button (H-L signal)
050	Housing; Cable entry	all	
060	Additional option	all	
070	Application	all	

Valid firmware version: as of 01.00.00
Valid hardware version (electronics): as of 01.00

Valid device versions for safety-related use:

Nivotester FTL325N

Feature	Designation	Option model	
010	Approval	G H N P T W	ATEX II 3(1)G Ex nC/A (ia) IIC T4, SIL, IECEx Zone 2 ATEX II (1)GD (Ex ia) IIC, WHG, SIL, IECEx (Ex ia) IIC (Liquiphant M / Liquiphant S) NEPSI (Ex ia) IIC, SIL (Liquiphant M / Liquiphant S) FM IS Cl. I, II, III Div. 1 Gr. A-G, SIL (Liquiphant M / Liquiphant S) CSA IS Cl. I, II, III Div. 1 Gr. A-G, SIL (Liquiphant M / Liquiphant S) TIIS Ex ia IIC, SIL, labeling in Japan
020	Housing	all	
030	Power Supply	all	
040	Switch output	all	

Safety function data

- The **mandatory settings** and data for the safety function can be found in chapter "Safety function", → 6 and chapter "Settings and installation instructions", → 10.
- The measuring system reacts in ≤ 0,9 s.

MTTR is set at eight 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

Liquiphant M FTL50, FTL50H, FTL51, FTL51H, FTL51C

Documentation	Contents	Comment
Technical Information ▪ FTL50, FTL50H, FTL51, FTL51H: TI00328F/00/EN ▪ FTL51C: TI00347F/00/EN	– Technical data – Accessories	– The documentation is available on the Internet: → www.endress.com.
Operating Instructions ▪ FTL50, FTL51: KA00143F/00/A6 KA00163F/00/A6[1)] ▪ FTL50H, FTL51H: KA00144F/00/A6 KA00164F/00/A6[1)] ▪ FTL51C: KA00162F/00/A6 KA00165F/00/A6[1)]	– Installation – Wiring – Operation – Commissioning – Troubleshooting – Repair – Maintenance	– The documentation is supplied with the device. – The documentation is also available on the Internet:. → www.endress.com.
Safety instructions depending on the selected version "Approval"	Safety, installation and operating instructions for devices, which are suitable for use in potentially explosive atmospheres or as overfill protection (WHG, German Water Resources Act).	Additional safety instructions (XA, ZE) are supplied with certified device versions. Please refer to the nameplate for the relevant safety instructions.

1) with aluminium housing / separate terminal compartment.

Liquiphant S FTL70, FTL71

Documentation	Contents	Comment
Technical Information TI00354F/00/EN	– Technical data – Accessories	– The documentation is available on the Internet: → www.endress.com.
Operating Instructions KA00172F/00/A6 KA00173F/00/A6[1)]	– Installation – Wiring – Operation – Commissioning – Troubleshooting – Repair – Maintenance	– The documentation is supplied with the device. – The documentation is also available on the Internet:. → www.endress.com.
Safety instructions depending on the selected version "Approval"	Safety, installation and operating instructions for devices, which are suitable for use in potentially explosive atmospheres or as overfill protection (WHG, German Water Resources Act).	Additional safety instructions (XA, ZE) are supplied with certified device versions. Please refer to the nameplate for the relevant safety instructions.

1) with aluminium housing / separate terminal compartment

Nivotester FTL325N

Documentation	Contents	Comment
Technical Information TI00353F/00/EN	– Technical data – Accessories	– The documentation is available on the Internet: → www.endress.com.
Operating Instructions ▪ One-channel device: KA00170F/00/A6 ▪ Three-channel device: KA00171F/00/A6	– Installation – Wiring – Operation – Commissioning – Troubleshooting – Repair – Maintenance	– The documentation is supplied with the device. – The documentation is also available on the Internet:. → www.endress.com.
Safety instructions depending on the selected version "Approval"	Safety, installation and operating instructions for devices, which are suitable for use in potentially explosive atmospheres or as overfill protection (WHG, German Water Resources Act).	Additional safety instructions (XA, ZE) are supplied with certified device versions. Please refer to the nameplate for the relevant safety instructions.

Settings and installation instructions

Installation instructions

Please refer to the Operating Instructions (KA) for information regarding the correct installation of Liquiphant M/S + Nivotester FTL325N.
Since the application conditions have an effect on the safety of the measurement, pay attention to the notes in the Technical Information (TI) and Operating Instructions (KA).

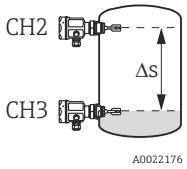
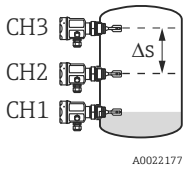
The ambient conditions for the Nivotester FTL325N must correspond to IP54 (in accordance with EN 60529).

The manuals on setting the devices can be found in the section "Supplementary device documentation", → 8.

Settings for Liquiphant M/S (FEL58):

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

Settings for Nivotester FTL325N-#3#3 (three-channel version):

Setting	Description	Caution!
	Channel 2+3 in ΔS function	This setting ist not permitted for the safety function!
	Channel 1, independent	Channel 1 is permitted for the safety function. The DIL switch for fault messaging (short-circuit and cable break-monitoring) must be set into possition ON.
	Channel 2+3 in ΔS function	Channel 2 and 3 in this setting are not permitted for the safety function!

Observe the following for the Nivotester FTL325N:
The operator must use suitable measures (e.g. current limiter, fuse) to ensure the relay contact characteristics are not exceeded:
- U ≤ 253 V AC 50/60 Hz , I ≤ 2 A, P ≤ 500 VA at cos φ ≥ 0,7 or
- U ≤ 40 V DC, I ≤ 2 A, P ≤ 80 W

Changes to the measuring system and settings after start-up can impair the protection function!

Response in operation and failure

The response in operation and failure is descriped in the documentation, which can be found in the section "Supplementary device documentation", → 8.

Repair

In the event of failure of a SIL-labeled Endress+Hauser device, which has been operated in a protection function, the "Declaration of Contamination and Cleaning" with the corresponding note "Used as SIL device in protection system" must be enclosed when the defective device is returned

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.

Note the following points for the function test:
- Each individual channel must be checked e.g. by lowering the level.
- Relay contact switching can be checked by using a hand multimeter at the terminals or by observing the minimum detection components (e.g. horn, adjuster).
- In multi-channel devices, all channels which do not carry out a safety function must be included in the recurrent function tests if faulty functioning cannot be detected by any other means.
- As a positive test result, an uncovered tuning fork must be detected and trigger the alarm for minimum detection.
- **If fork uncovering 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

The tables show the specific values and wiring options for the measuring system.

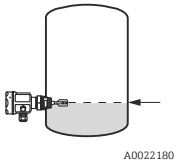
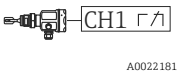
Note the following points on the tables below:
- The PFD_{avg} values for multichannel systems already contain common cause failures for the associated wiring scheme.
- The PFD_{avg} values are only valid for the associated wiring scheme. Wiring schemes other than those shown in the Appendix were not assessed and thus do not bear any information relevant to safety. Using NC contacts instead of NO contacts requires further consideration of the installation means.
- The wiring scheme shows the number of devices (Liquiphant and Nivotester) and the limit relay contact circuits (open, when the sensor signals uncovering).
- For every channel, which performs a safety function, the failure indication (cable break/short circuit) must be switched on.
- With several devices in a wiring scheme, they all indicate the same displayed settings.

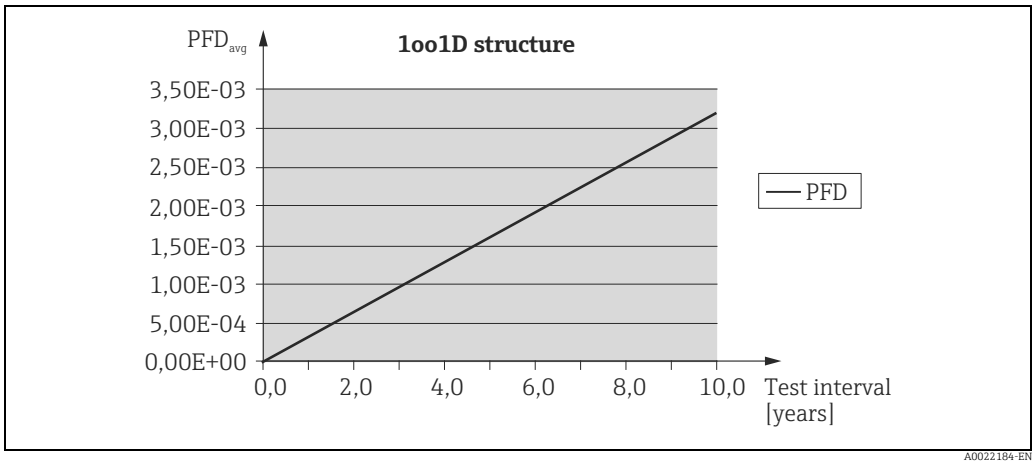
For safety related use for MIN detection, the following application errors must be excluded:

Liquiphant M/S:
- Permanent and/or heavy build-up or "non-Newtonian media".
- Solid proportions of the medium with a diameter > 5.0 mm. (0.2 in).
- Corrosion: The Liquiphant may only be used in media to which the process-wetted parts are resistant. If coated sensors are used, measures must therefore be taken to ensure that there is no damage during installation and operation.

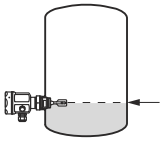
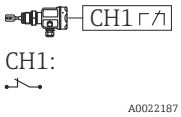
The errors may cause that the demand mode of the safety function is not detected and the Liquiphant will not switch as intended.

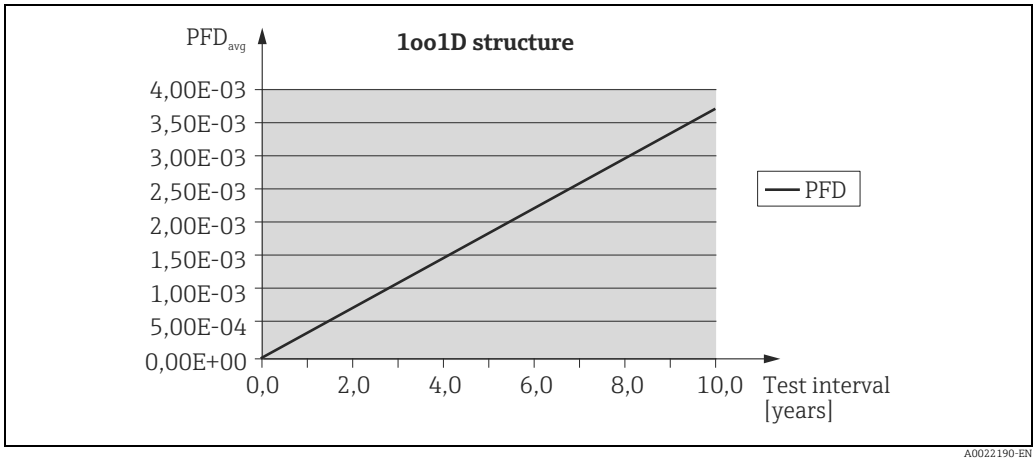
Liquiphant S:
- Hydrogen diffusion at temperatures over 180 °C (356 °F) and over 64 bar (928 psi).

1oo1 architecture (CONF 1)	
Liquiphant (FEL58) Settings	1) Density 0,7 / 0,5 2) MIN safety
Evaluated NAMUR transmitter	 A0022180 Error current signal < 1,2 mA
SIL	SIL 2
HFT	0
SFF	78.5%
PFD_{avg} **	3.2×10^{-4}
Wiring scheme	 A0022181 Ask the manufacturer in question for the NAMUR transmitter parameters relevant to safety.
Recurrent test e.g. lowering the level	** TI (test interval) = annual

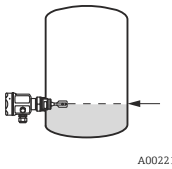
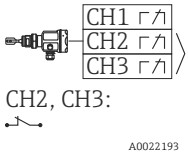


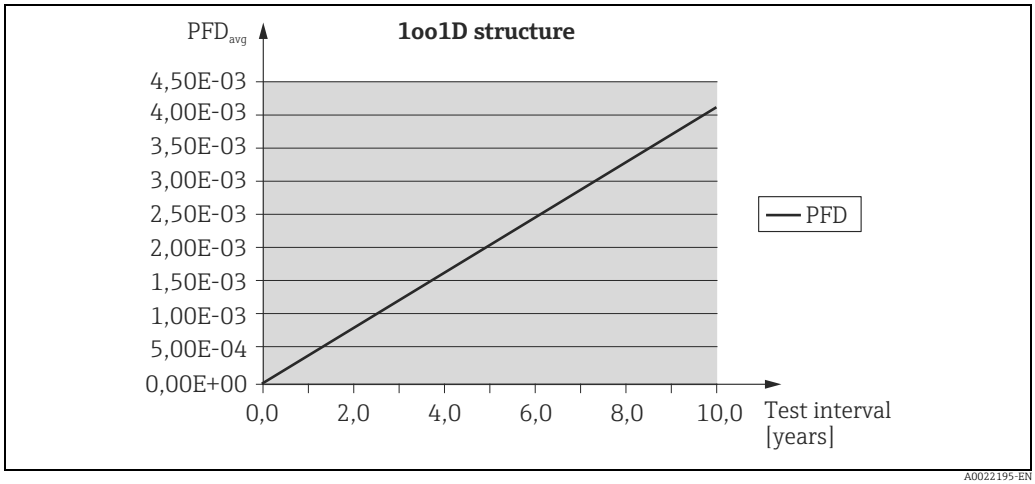
A0022184-EN

1oo1 architecture (CONF 2)	
Liquiphant (FEL58) Settings	1) Density 0,7 / 0,5 2) MIN safety
Nivotester FTL325N-#1#1 Settings (One-channel device)	 A0022180 Error current signal < 1,2 mA
SIL	SIL 2
HFT	0
SFF	87.9%
PFD_{avg} **	3.7×10^{-4}
Wiring scheme	 A0022187
Recurrent test e.g. lowering the level	** TI (test interval) = annual

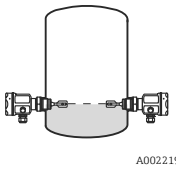
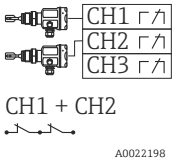


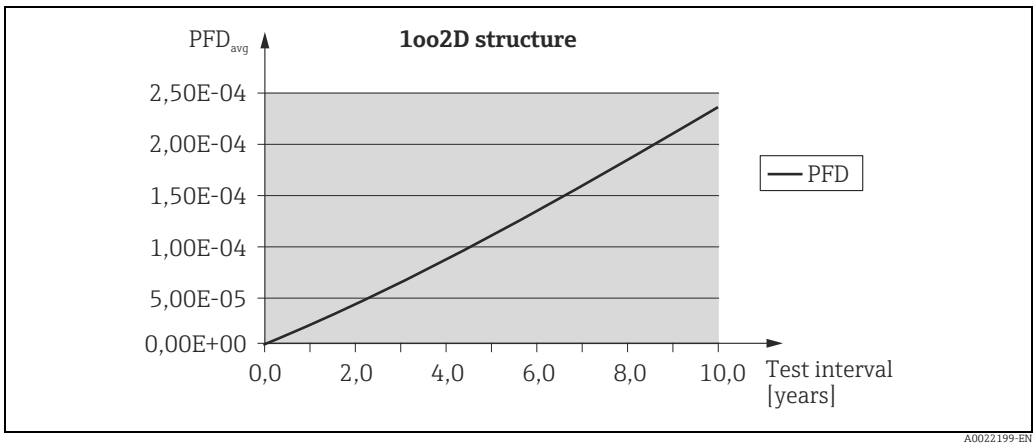
A0022190-EN

1oo1 architecture (CONF 3)	
Liquiphant (FEL58) Settings	1) Desnity 0,7 / 0,5 2) MIN safety
Nivotester FTL325N-#3#3 Settings (Three-channel device)	 A0022180 Error current signal < 1,2 mA
SIL	SIL 2
HFT	0
SFF	87.7%
PFD_{avg} **	4.1×10^{-4}
Wiring scheme	 A0022193
Recurrent test e.g. lowering the level	** TI (test interval) = annual

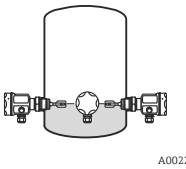
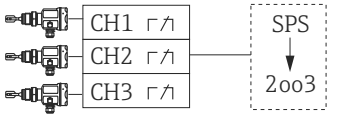


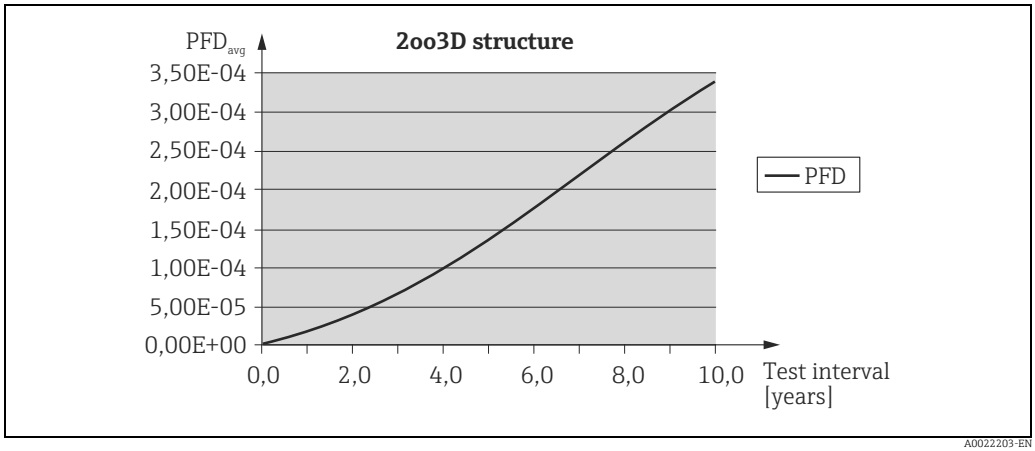
A0022195-EN

1oo2 architecture (CONF 4)	
Liquiphant (FEL58) Settings	1) Density 0,7 / 0,5 2) MIN safety
Nivotester FTL325N-#3#3 Settings (Three-channel device)	 A0022197 Error current signal < 1,2 mA
SIL	SIL 2
HFT	1
SFF	87.9%
PFD_{avg} **	2.1×10^{-5}
Wiring scheme	 A0022198
Recurrent test e.g. lowering the level	** TI (test interval) = annual

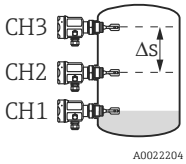
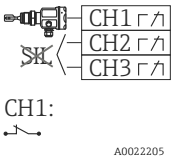


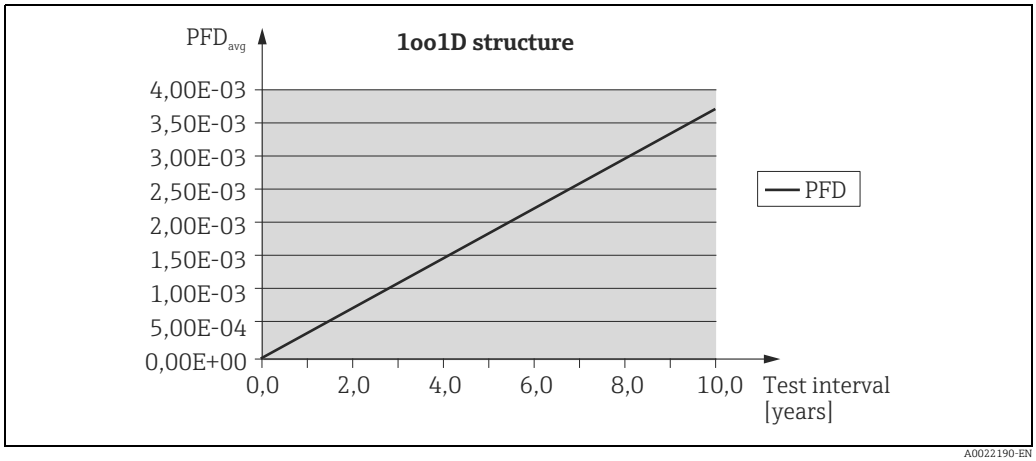
A0022199-EN

2oo3 architecture (CONF 5)	
Liquiphant (FEL58) Settings	1) Denisty 0,7 / 0,5 2) MIN safety
Nivotester FTL325N-#3#3 Settings (Three-channel device)	 A0022201 Error current signal < 1,2 mA
SIL	SIL 2
HFT	1
SFF	87.3%
PFD_{avg} **	2.4×10^{-5}
Wiring scheme	 A0022202
Recurrent test e.g. lowering the level	** TI (test interval) = annual



A0022203-EN

1oo1 architecture (CONF 6)	
Liquiphant (FEL58) Settings	1) Density 0,7 / 0,5 2) MIN safety
Nivotester FTL325N-#3#3 Settings (Three-channel device)	 Error current signal < 1,2 mA
SIL	SIL 2
HFT	0
SFF	87.9%
PFD_{avg} **	3.7×10^{-4}
Wiring scheme	
Recurrent test e.g. lowering the level	** TI (test interval) = annual



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FMEDA including SFF determination and PFD_{AVG} calculation

Project:

Level limit switch Liquiphant M/S
with NAMUR output FEL 58 and Nivotester FTL325N
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 R013
Version V1, Revision R1.1, May 2003
Stephan Aschenbrenner

Management summary

This report summarizes the results of the hardware assessment with proven-in-use consideration according to IEC 61508 / FDIS IEC 61511 carried out on Liquiphant M/S with NAMUR output FEL 58 with software version V1.0 and Nivotester FTL325N for applications with MIN detection. Table 1 gives an overview of the different configurations which have been assessed.

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.

Table 1: Configuration overview

	Configurations
[CONF 1]	FEL 58
[CONF 2]	FEL 58 with Nivotester FTL325N as single channel device
[CONF 3]	FEL 58 with Nivotester FTL325N as three channel device in single channel mode with two output relays in parallel
[CONF 4]	FEL 58 with Nivotester FTL325N as three channel device in dual channel mode with one channel having two output relays in parallel
[CONF 5]	FEL 58 with Nivotester FTL325N as three channel device in three channel mode
[CONF 6]	FEL 58 with Nivotester FTL325N as three channel device in single channel mode

FEL 58 has a current output interface according to EN 60947-5-6 / IEC 60947-5-6.

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 NAMUR output FEL 58 is considered to be a Type B[1] component having a hardware fault tolerance of 0. Nivotester FTL325N is considered to be a Type A[2] component. In the following both sub-systems are considered to be Type B components for simplification reasons and as a worst-case assumption.

For Type A components with a SFF of 60% to < 90% a hardware fault tolerance of 0 according to table 2 of IEC 61508-2 is sufficient for SIL 2 (sub-) systems.

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.

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

Type A component: "Non-complex" component (all failure modes are well defined); for details see 7.4.3.1.2 of IEC 61508-2.

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As Liquiphant M/S with NAMUR output FEL 58 and Nivotester FTL325N are supposed to be proven-in-use devices, 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 FDIS Ed.1 27-09-02 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 2: Summary for [CONF 1]

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 3,18E-04	PFD_{AVG} = 1,59E-03	PFD_{AVG} = 3,17E-03	> 78 %

λ_{sd} = 6,56E-08 1/h
λ_{su} = 1,87E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 7,27E-08 1/h

Table 3: Summary for [CONF 2]

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 3,68E-04	PFD_{AVG} = 1,84E-03	PFD_{AVG} = 3,66E-03	> 87 %

λ_{sd} = 6,56E-08 1/h
λ_{su} = 5,30E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 8,40E-08 1/h

Table 4: Summary for [CONF 3]

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 4,09E-04	PFD_{AVG} = 2,04E-03	PFD_{AVG} = 4,07E-03	> 87 %

λ_{sd} = 6,56E-08 1/h
λ_{su} = 5,87E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 9,33E-08 1/h

Table 5: Summary for [CONF 4]

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 2,07E-05	PFD_{AVG} = 1,10E-04	PFD_{AVG} = 2,35E-04	> 87 %

Leg 1 (consisting of [CONF 2]):
λ_{sd} = 6,56E-08 1/h
λ_{su} = 5,30E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 8,40E-08 1/h

Leg 2 (consisting of [CONF 3]):
λ_{sd} = 6,56E-08 1/h
λ_{su} = 5,87E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 9,33E-08 1/h

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Table 6: Summary for [CONF 5]

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 2,37E-05	PFD_{AVG} = 1,42E-04	PFD_{AVG} = 3,40E-04	> 87 %

λ_{sd} = 6,56E-08 1/h
λ_{su} = 6,25E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 1,03E-07 1/h

Table 7: Summary for [CONF 6]

T[Proof] = 1 year	T[Proof] = 5 years	T[Proof] = 10 years	SFF
PFD_{AVG} = 3,68E-04	PFD_{AVG} = 1,84E-03	PFD_{AVG} = 3,66E-03	> 87 %

λ_{sd} = 6,56E-08 1/h
λ_{su} = 5,30E-07 1/h
λ_{dd} = 1,27E-08 1/h
λ_{du} = 8,40E-08 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.

The functional assessment according to IEC 61508 has shown that Liquiphant M/S with NAMUR output FEL 58 and Nivotester FTL325N has a PFD_{AVG} 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 a Safe Failure Fraction (SFF) of > 80%. Based on the verification of "prior use" they can be used as a single device for SIL2 Safety Functions in terms of IEC 61511-1 FDIS Ed.1 27-09-02.

A user of Liquiphant M/S with NAMUR output FEL 58 and Nivotester FTL325N 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 for different operating conditions is presented in section 5.2 to 5.7 along with all assumptions.

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Supplementary Documentation	Safety in the Process Industry - reducing risks with SIL CP01008Z/11/EN.

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