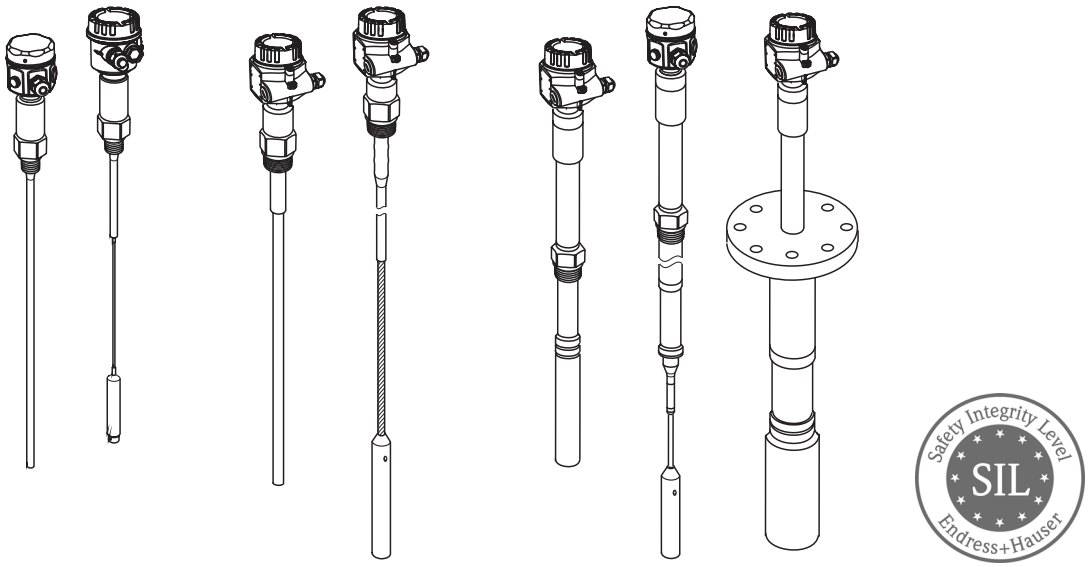
Level | Pressure | Flow | Temperature | Liquid Analysis | Registration | Systems Components | Services | Solutions

Functional Safety Manual

Liquicap M, Solicap M, Solicap S FTI51/52, FTI55/56, FTI77

Capacitive level measurement with 8/16 mA output signal



Application

MIN/MAX safety for liquids and bulk solids, to satisfy the particular requirements for safety-related systems in accordance with IEC 61508.

The measuring system meets the requirements for
- functional safety as per IEC 61508
- explosion protection (depending on version)
- electromagnetic compatibility as per EN 61326 and NAMUR recommendation NE 21
- electrical safety as per IEC/EN 61010-1

Your benefits

- For level limit detection up to SIL 3
  – independently assessed (Functional Safety Assessment) by TÜV Nord as per IEC 61508
- Permanent self-monitoring
- Measurement possible even in the case of turbulent surfaces and foam
- Safe parameter entry concept

SD278F/00/en/10.08
71078014

Endress+Hauser
People for Process Automation

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SIL Declaration of conformity

This binding document is included in the scope of supply when the Liquicap M or Solicap M/S is ordered with the "SIL Declaration of conformity" option.

SIL-08005a/00/a2

SIL-Konformitätserklärung

Funktionale Sicherheit nach IEC 61508

SIL Declaration of Conformity

Functional safety according to IEC 61508

Endress+Hauser GmbH+Co. KG, Hauptstraße 1, 79689 Maulburg
erklärt als Hersteller, dass der Füllstandgrenzschalter (Seriennummer XXXXXXXXXX)
declares as manufacturer, that the level limit switch (Serial number XXXXXXXXXX)

Liquicap M FTI51/52, Solicap M FTI55/56, Solicap S FTI77
+Electronic insert FEI55

für den Einsatz in Schutzeinrichtungen entsprechend der IEC 61508 geeignet ist, wenn das Handbuch zur Funktionalen Sicherheit SD278F/00 und nachfolgende Kenngrößen beachtet werden:
is suitable for the use in safety-instrumented systems according to IEC 61508, if the functional safety manual SD278F/00 and following characteristics are observed:

Gerät / Product	**Liquicap M ; Solicap M/S +FEI55**	
Schutzfunktion/Safety function	MIN	MAX
SIL	2, 3 [3]	
HFT	0	
Gerätetyp/Device type	B	
Betriebsart/Mode of operation	Low demand mode	
SFF	92 %	94 %
PFD_{avg} [1] (T_1 = 1 Jahr/year)	$1{,}85 \times 10^{-4}$	$1{,}46 \times 10^{-4}$
PFD_{avg} [1] (T_1 = 5 Jahre/years)	$9{,}22 \times 10^{-4}$	$7{,}29 \times 10^{-4}$
Prüfintervall/Proof test interval	empfohlen/recommended: T_1 = 1 Jahre/year	
λ_{sd} [2]	2 FIT	1 FIT
λ_{su} [2]	334 FIT	341 FIT
λ_{dd} [2]	187 FIT	188 FIT
λ_{du} [2]	43 FIT	34 FIT
$MTBF_{tot}$ [4]	191 Jahre/years	

[1] Die Werte entsprechen SIL 2 nach ISA S84.01. PFD_{avg}-Werte für andere T_1-Werte siehe Handbuch zur Funktionalen Sicherheit. / The values comply with SIL 2 according to ISA S 84.01. PFD_{avg}-values for other T_1-values see Functional Safety Manual.
[2] Gemäß Siemens SN29500 / according to Siemens SN29500
[3] SIL 3 bei homogen redundantem Einsatz / SIL 3 for homogeneous redundant application
Die Gerätesoftware entspricht SIL 3. / The device software meets SIL 3 requirements.
[4] Gemäß Siemens SN29500, einschließlich Fehlern, die außerhalb der Sicherheitsfunktion liegen / according to Siemens SN29500, including faults outside the safety function

Das Gerät wurde in einem vollständigen Functional Safety Assessment unabhängig bewertet.
The device was assessed independently in a complete Functional Safety Assessment.

Maulburg, 08.07.2008

Endress+Hauser GmbH+Co. KG

i.V. (Dr. Arno Götz)
Leitung Zertifizierung/Manager Certification

i.V. (V.Dreyer)
Leitung Projekt / Project Manager

Endress+Hauser
People for Process Automation

SIL_08005a_00_en

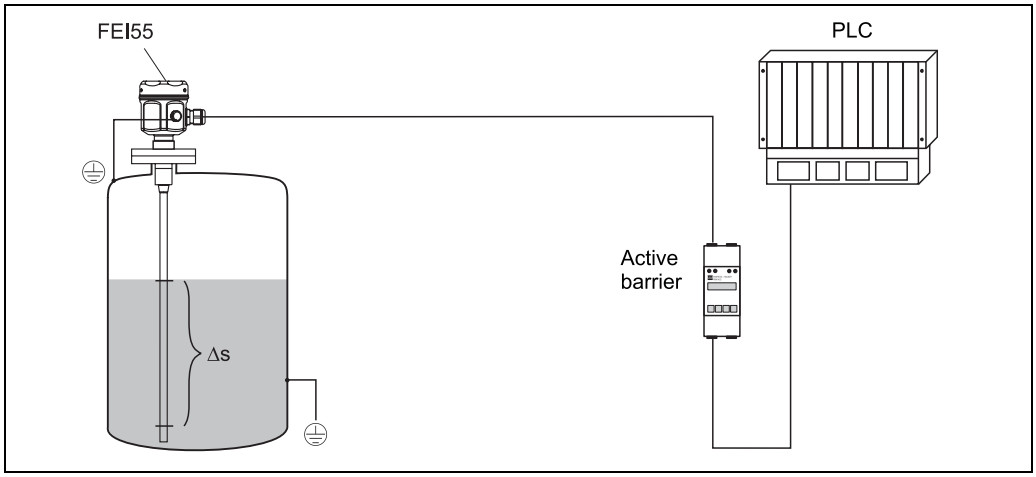
General information

Note!
General information on functional safety (SIL) is available at:
www.de.endress.com/SIL (German) or www.endress.com/SIL (English) and in the Competence Brochure CP002Z "Functional Safety in the Process Industry – Risk Reduction with Safety Instrumented Systems".

Structure of measuring system

System components

The following diagram shows an example of how the measuring system is structured in principle.



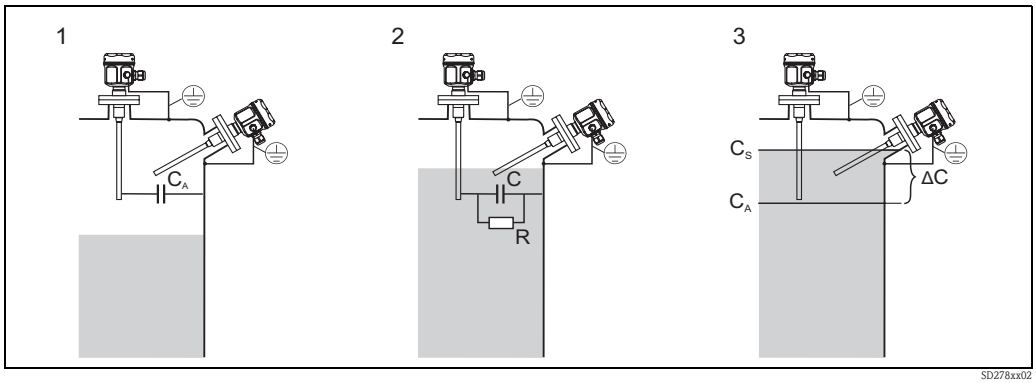
A level-dependent switching signal (8/16 mA) is generated in the transmitter and conveyed to a downstream logic unit (e.g. PLC, limit signal generator, ...) where it is evaluated.
For fault monitoring purposes, the logic unit must identify HI alarms (≥ 21.0 mA) as well as LO alarms (≤ 3.6 mA) as per NE 43.

Description of use as a protective system

The principle of capacitive level limit detection is based on the change in capacitance of a capacitor as a result of the sensor being covered in bulk solids. The sensor and the wall of the vessel (conductive material) form an electrical capacitor. If the sensor is in air (1), a specific low initial capacitance is measured. If the vessel is filled, the capacitance of the capacitor increases as coverage of the sensor increases (2), (3).

The limit switch switches when the switching capacitance determined during calibration is:
- exceeded in the case of MAX application
- undershot in the case of MIN application.

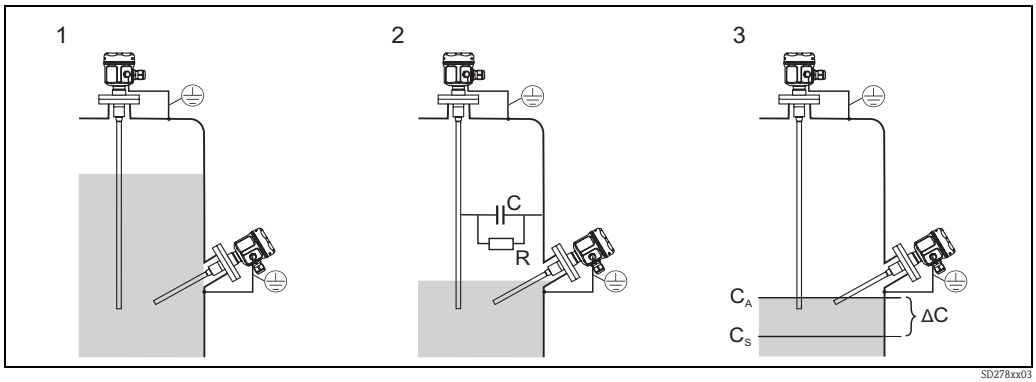
The following diagrams show typical measurement setups when using the devices in protective systems:
MAX application



1 Free
2 Covered (switch point not yet reached)
3 Covered (switch point reached)

R: Conductivity of bulk solids
C: Capacitance of bulk solids
C_A: Initial capacitance (sensor free)
C_S: Switching capacitance
ΔC: Change in capacitance

MIN application



1 Covered
2 Covered (switch point not yet reached)
3 Free (switch point reached)

R: Conductivity of bulk solids
C: Capacitance of bulk solids
C_A: Initial capacitance (sensor covered)
C_S: Switching capacitance
ΔC: Change in capacitance

Note!
Correct installation is essential to the safe operation of the device.
The information relating to installation conditions in the Operating Instructions (→ 🖹 9, "Supplementary device documentation") must be taken into account.

Permitted device types

The information in this manual pertaining to functional safety applies to the device variants listed below and is valid from the software and hardware versions indicated.
Unless otherwise specified, all subsequent versions can also be used for safety functions.

Overview of permitted device variants for MIN safety or MAX safety operating modes

		Operation	
		MIN safety	MAX safety
Sensor insulation	Full insulation	Permitted ■ FTI51 ■ FTI52 ■ FTI55	Permitted ■ FTI51 ■ FTI52 ■ FTI55
	Partial insulation	Not permitted	Permitted ■ FTI51 ■ FTI55 ■ FTI56 ■ FTI77

Device variants valid for use in safety-related applications:

Liquicap M FTI51		
Options	**Designation**	**Version**
010	Approval	all
020	Inactive length L3	all
030	Active probe length L1; insulation	all
040	Insulation	1: Fully insulated for MIN and MAX safety 2, 3: Partially insulated only for MAX safety
050	Process connection	all
060	Electronics; output	5: Electronic insert FEI55; 8/16 mA, 11-36 V DC (SIL)
070	Housing	all
080	Cable entry	all
090	Sensor design	1: Compact
100	Additional option	F: SIL Declaration of conformity

Valid software version: 02.00.00 and higher
Valid hardware version (electronics): 02.00 and higher
In the event of device modifications, a modification process compliant with IEC 61508 is applied.

Liquicap M FTI52		
Options	**Designation**	**Version**
010	Approval	all
020	Inactive length L3	all
030	Active probe length L1; insulation	all
040	Insulation	all
050	Process connection	all
060	Electronics; output	5: Electronic insert FEI55; 8/16 mA, 11-36 V DC (SIL)
070	Housing	all
080	Cable entry	all
090	Sensor design	1: Compact
100	Additional option	F: SIL Declaration of conformity

Valid software version: 02.00.00 and higher
Valid hardware version (electronics): 02.00 and higher
In the event of device modifications, a modification process compliant with IEC 61508 is applied.

Solicap M FTI55		
Options	**Designation**	**Version**
010	Approval	all
020	Inactive length L3	all
030	Active probe length L1	all
040	Rod insulation	1: Fully insulated for MIN and MAX safety 2, 3: Partially insulated only for MAX safety
050	Process connection	all
060	Electronics; output	5: Electronic insert FEI55; 8/16 mA, 11-36 V DC (SIL)
070	Housing	all
080	Cable entry	all
090	Sensor design	1: Compact
100	Additional option	F: SIL Declaration of conformity

Valid software version: 02.00.00 and higher
Valid hardware version (electronics): 02.00 and higher
In the event of device modifications, a modification process compliant with IEC 61508 is applied.

Solicap M FTI56		
Options	**Designation**	**Version**
010	Approval	all
020	Inactive length L3	all
030	Active probe length L1; tensioning weight	A, B, C, D: L1 max. 10.000 mm; H, K, M, N: L1 max. 393 in; all
040	Rope insulation	1: Fully insulated for MIN and MAX safety 2: Partially insulated only for MAX safety
050	Process connection	all
060	Electronics; output	5: Electronic insert FEI55; 8/16 mA, 11-36 V DC (SIL)
070	Housing	all
080	Cable entry	all
090	Sensor design	1: Compact
100	Additional option	F: SIL Declaration of conformity

Valid software version: 02.00.00 and higher
Valid hardware version (electronics): 02.00 and higher
In the event of device modifications, a modification process compliant with IEC 61508 is applied.

Solicap S FTI77		
Options	**Designation**	**Version**
010	Approval	all
015	Application	all
020	Inactive length L3	all
030	Active probe length L1	CR, CS, DR, DS: L1 max. 10.000 mm; GR, GS, HR, HS: L1 max. 393 in; all
050	Process connection	all
060	Electronics; output	5: Electronic insert FEI55; 8/16 mA, 11-36 V DC (SIL)
070	Housing	all
080	Cable entry	all
090	Sensor design	1: Compact
100	Additional option	F: SIL Declaration of conformity

Valid software version: 02.00.00 and higher
Valid hardware version (electronics): 02.00 and higher
In the event of device modifications, a modification process compliant with IEC 61508 is applied.

Supplementary device documentation

Liquicap M FTI51, FTI52		
Documentation	**Contents**	**Note**
Technical Information TI417F/00	– Technical data – Information on accessories	– The documentation is also available on the Internet. → www.endress.com.
Operating Instructions BA299F/00	– Identification – Installation – Wiring – Operation – Commissioning – Maintenance – Accessories – Troubleshooting – Technical data – Appendix: illustration of menus	– The documentation is provided with the device. – The documentation is also available on the Internet. → www.endress.com.
Safety information (depending on the type of "Approval" chosen)	– Safety, mounting and operating instructions for devices suitable for use in hazardous areas or as overfill protection (German Water Resources Act).	For certified device versions, additional Safety Instructions (XA, XB, XC, ZE, ZD) are provided. The nameplate indicates which Safety Instructions are relevant.

Solicap M FTI55, FTI56		
Documentation	**Contents**	**Note**
Technical Information TI418F/00	– Technical data – Information on accessories	– The documentation is also available on the Internet. → www.endress.com.
Operating Instructions BA300F/00	– Identification – Installation – Wiring – Operation – Commissioning – Maintenance – Accessories – Troubleshooting – Technical data – Appendix: illustration of menus	– The documentation is provided with the device. – The documentation is also available on the Internet. → www.endress.com.
Safety information (depending on the type of "Approval" chosen)	– Safety, mounting and operating instructions for devices suitable for use in hazardous areas or as overfill protection (German Water Resources Act).	For certified device versions, additional Safety Instructions (XA, XB, XC, ZE, ZD) are provided. The nameplate indicates which Safety Instructions are relevant.

Solicap S FTI77		
Documentation	**Contents**	**Note**
Technical Information TI433F/00	– Technical data – Information on accessories	– The documentation is also available on the Internet. → www.endress.com.
Operating Instructions BA381F/00	– Identification – Installation – Wiring – Operation – Commissioning – Maintenance – Accessories – Troubleshooting – Technical data – Appendix: illustration of menus	– The documentation is provided with the device. – The documentation is also available on the Internet. → www.endress.com.
Safety information (depending on the type of "Approval" chosen)	– Safety, installation and operating instructions for devices suitable for use in hazardous areas or as overfill protection (German Water Resources Act - WHG).	For certified device versions, additional Safety Instructions (XA, XB, XC, ZE, ZD) are provided. The nameplate indicates which Safety Instructions are relevant.

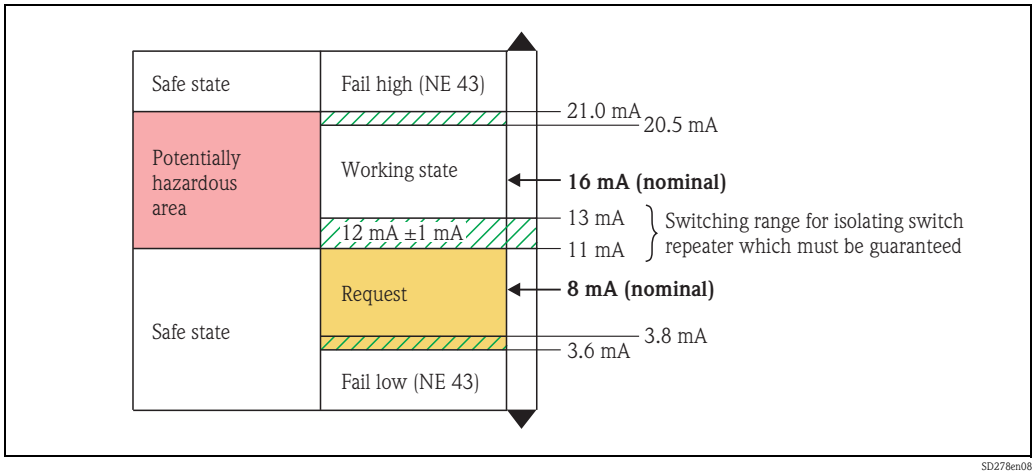
Description of safety requirements and boundary conditions

Safety function

The safety functions of the measuring system are minimum or maximum level limit monitoring (dry running protection or overfill protection).

Note!
To activate the safety functions, the device must be locked directly after calibration (→ 15, "Operation")

Current output



Safety-related signal:

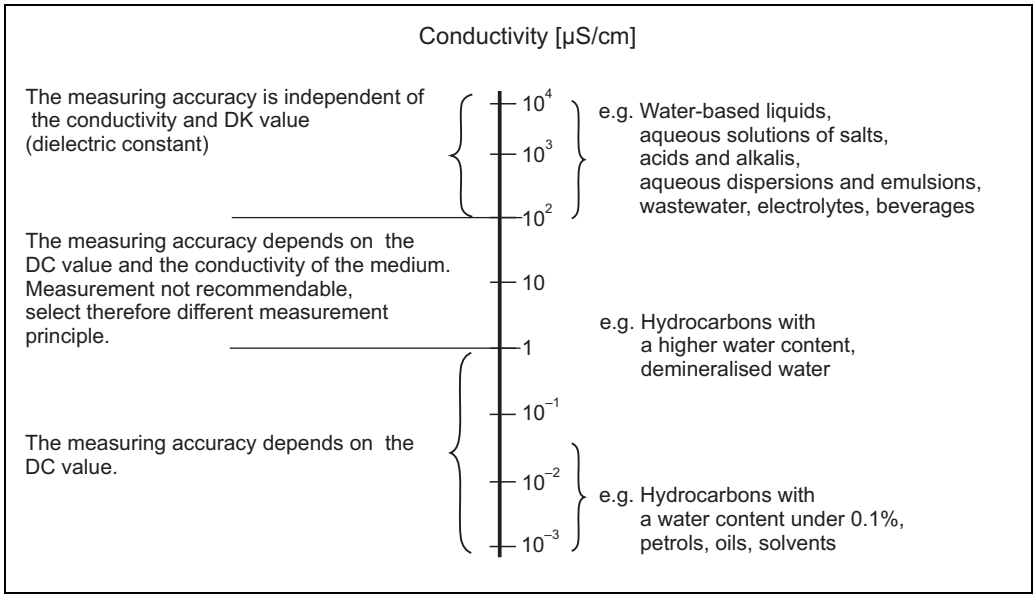
The safety-related output signal is the 8/16 mA switching signal.
All safety measures refer exclusively to this output.

This safety-related output signal is conveyed to a downstream logic unit, such as a programmable logic controller or a limit signal generator, where it is monitored to determine whether:
– a specified level limit has been exceeded (MAX safety, e.g. overfill protection) or undershot (MIN safety, e.g. dry running protection).
– a fault occurs (e.g. error current as per NE 43 (≤ 3.6 mA; ≥ 21.0 mA, interruption or short-circuiting of signal line).

Restrictions for use in safety-related applications

Please ensure that the measuring system is used correctly for the application in question and that the characteristics of the medium and the ambient conditions are taken into account. The instructions for critical process situations and installation conditions, as detailed in the Operating Instructions, must be observed. The specifications in the Operating Instructions (→ 🖹 9, "Supplementary device documentation") must not be exceeded.

In addition, the following restrictions apply to safety-related use:
- In the case of conductive build-up, please follow the steps for commissioning (→ 🖹 15, "Installation").
- Severe build-up (≥100 g/m) is not permitted in applications with vibrations.
- The resistance of wetted parts must be tested with regard to corrosion and diffusion.
- Only compact versions are permitted.
  Separate versions are not permitted due to the additional cable capacitance.
- Overview of permitted device types and variants for MIN safety or MAX safety operating modes (→ 🖹 6, "Permitted device types")
- The relative dielectric constants ε_r (relative permittivity) of the medium must be ≥ 2.5 or the change in capacitance between empty and full calibration must be ≥ 10 pF.



Functional safety indicators

The table shows the specific indicators for functional safety:

Indicator as per IEC 61508	**Value**	
Safety functions	MIN safety	MAX safety
SIL (hardware)	2 (single-channel), 3 (with use of a SIL 3 capable coincidence logic), → 🖹 18, "Appendix"	
SIL (software)	3	
HFT	0	
Device type	B	
Mode of operation	Low demand mode	
SFF	92 %	94 %
MTTR	8 h	
Recommended time interval for proof-testing T_1	1 year	
λ_{sd}	2 FIT	1 FIT
λ_{su}	334 FIT	341 FIT
λ_{dd}	187 FIT	188 FIT
λ_{du}	43 FIT	34 FIT
λ_{tot} *1	566 FIT	564 FIT
PFD_{avg} for T_1 = 1 year *2	1.85×10^{-4}	1.46×10^{-4}
MTBF *1	191 years	
Diagnostic test interval *3	120 s	
Fault reaction time *4	1 s	
System reaction time *5	0.3 to 10 s adjustable	

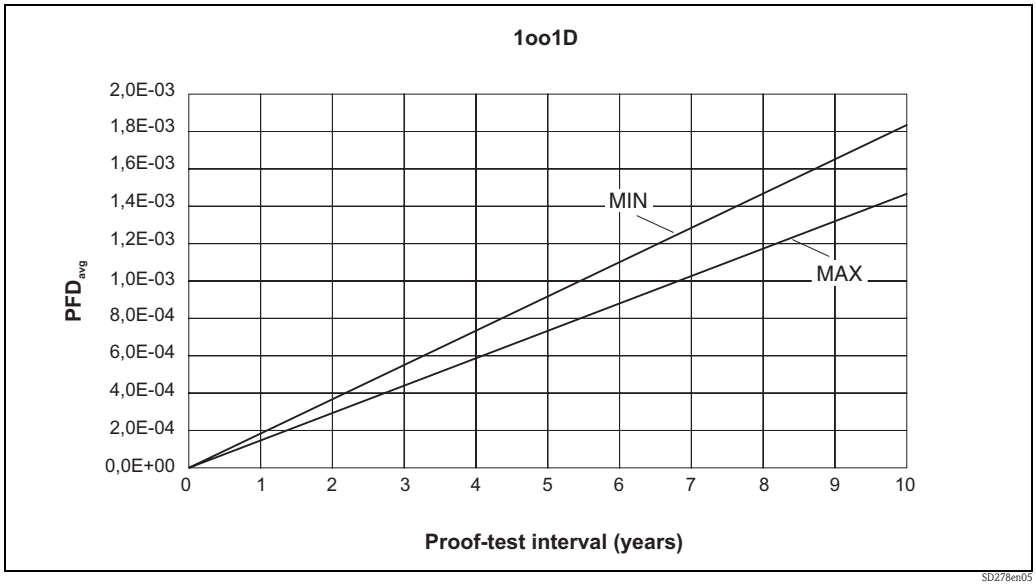
*1 As per Siemens SN29500. This value takes all failure types into account (→ 🖹 20, "Management Summary").

*2 When the average temperature when in continuous use is in the region of 50 °C, a factor of 1.3 should be taken into account. Additional information → 🖹 20, "Management Summary".

* 3 During this time, all diagnostic functions are executed at least once.

*4 Time between fault detection and fault reaction.

*5 Step response time as per DIN EN 61298-2.



Proof-test interval

Dangerous undetected failures in this scenario:

A dangerous, undetected failure is defined as an incorrect output signal which deviates from the real measured value by more than 2%, with the output signal remaining at 8 or 16 mA.

Operating life of electrical components:

The underlying failure rates of electrical components apply within the usable operating life as per IEC 61508-2 Section 7.4.7.4 Note 3.

Behavior of device during operation and in case of error

Behavior of device during power-up

Once a device has powered up, the output signal can be regarded as safe after 3 seconds.
During this time, the output current is ≤ 8 mA.

Behavior of device on demand

Once the limit value being monitored has been reached, the output current switches from 16 mA to 8 mA within the reaction time of the system.

Behavior of device in the event of alarms and warnings

Error current

The output current in the event of an alarm is fixed at a value ≤ 3.6 mA.

In some cases (e.g. short-circuit of signal line), where the error current ≤ 3.6 mA cannot be set, output currents are output in the "safe state" range (→ 🖹 11, "Current output").
For alarm monitoring, the logic unit must be configured in accordance with this table.

Alarm and warning messages

In addition to signaling a fault, a status LED flashes red cyclically.

Note!
This signaling is simply an additional piece of diagnostic information and does not form part of the safety-related output signal.

Installation

Installation, wiring and commissioning

Installation, wiring and commissioning of the device is described in the relevant Operating Instructions (→ 🖹 9, "Supplementary device documentation").

To ensure the safe functioning of the sensor, an electrical connection between the sensor and the counter electrode (e.g. tank) is required.

In the case of installations with media which have a tendency towards build-up, measures must be taken to ensure that the build-up does not result in an inaccuracy which is outside the permitted range. This can be done by performing proof-testing in accordance with test procedure A (→ 🖹 16).

Orientation

The permitted orientations of the device are described in the Operating Instructions.
If there are obvious sensor deflections in applications with long sensors and increased vibrations, it is recommended that the sensor be anchored in a suitable way.

Operation

Calibrating the measuring point

Calibration of the measuring point is described in the Operating Instructions.

Method for parameter entry

Parameter entry is described in the Operating Instructions.
When parameter entry is complete, the device must be switched to SIL mode. This automatically locks the device.
An iterative test must be performed after each parameter entry.

Maintenance

Maintenance instructions can be found in the relevant Operating Instructions (→ 🖹 9, "Supplementary device documentation").
During parameter entry, proof-testing and maintenance work on the device, alternative monitoring measures must be taken to ensure process safety.

Proof-test

Proof-test

Safety functions must be tested at appropriate intervals to ensure that they are functioning correctly and are safe. The time intervals must be defined by the operator.
The "Proof-test interval" diagram, → 14 can be used here.

Caution!
Proof-testing can be performed only when the device is in operation (output current = 16 mA).

Proof-testing of the device may be carried out as follows:
– Approach level (→ test procedure A).
– Remove and immerse in a medium of comparable conductivity (→ test procedure B).

Caution!
This test procedure is permitted only in the case of media with a conductivity greater than 100 µS/cm!

– Simulation using the electronic insert FEI55 by activating the self-test function (functional test) function switch pos. 6 (→ test procedure C).

In addition, checks must be carried out to ensure that all cover seals and cable entries are sealing correctly.

Procedure for proof-testing

Test procedure A

Preparation

1. Connect a suitable measuring device (recommended accuracy better than ±0.1 mA) to the current output.
2. Establishing fail-safe mode (SIL-MIN or SIL-MAX). Operating Instructions (→ 9, "Supplementary device documentation"), Section 5.

Procedure in the case of MIN fail-safe mode

1. Check sensor state (free/covered). Please ensure that the switch point during the test procedure corresponds to the desired calibration.
2. Read current value for electrical current (free = 8 mA ±0.5 mA, covered = 16 mA ±0.8 mA).
3. Log current value and evaluate.
4. Change level so that the other switching state is expected.
5. Read current value for electrical current (free = 8 mA ±0.5 mA, covered = 16 mA ±0.8 mA).
6. Log current value and evaluate.
7. Restore original system status.
8. Read current value (expected value: original current value from point 2).
9. Log current value and evaluate.

Procedure in the case of MAX fail-safe mode

1. Check sensor state (free/covered). Please ensure that the switch point during the test procedure corresponds to the desired calibration.
2. Read current value for electrical current (free = 16 mA ±0.8 mA, covered = 8 mA ±0.5 mA).
3. Log current value and evaluate.
4. Change level so that the other switching state is expected.
5. Read current value for electrical current (free = 16 mA ±0.8 mA, covered = 8 mA ±0.5 mA).
6. Log current value and evaluate.
7. Restore original system status.
8. Read current value (expected value: original current value from point 2).
9. Log current value and evaluate.

Note!
If there is a deviation in the expected current value for a particular sensor state, this results in the iterative test being failed. For troubleshooting → Operating Instructions (→ 9, "Supplementary device documentation"), Section 9.
This test exposes 98 % of dangerous undetected failures.

Test procedure B

Preparation

1. Prepare test container with medium (conductivity greater than 100 µS/cm) and suitable counter electrode.
   Installation instructions → Operating Instructions (→ 🖹 9, "Supplementary device documentation"), Section 3.
2. Remove device and mount it in test container. (Note: Connect functional earth).
3. Connect a suitable measuring device (recommended accuracy better than ±0.1 mA) to the current output.
4. Establishing fail-safe mode (SIL-MIN or SIL-MAX).
   → Operating Instructions (→ 🖹 9, "Supplementary device documentation"), Section 5.

Procedure in the case of MIN fail-safe mode
– → Test procedure A

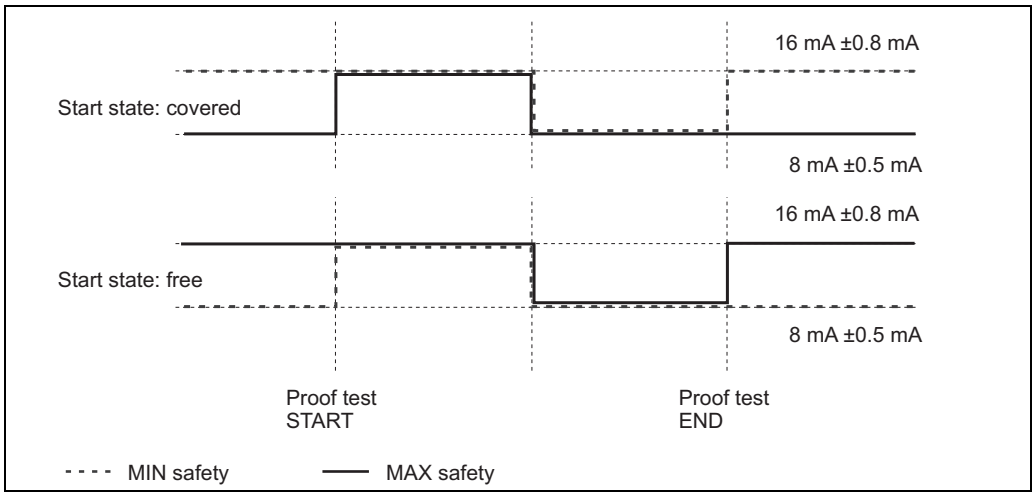
Procedure in the case of MAX fail-safe mode
– → Test procedure A

✎ Note!
If there is a deviation in the expected current value for a particular sensor state, this results in the iterative test being failed. For troubleshooting → Operating Instructions (→ 🖹 9, "Supplementary device documentation"), Section 9.
This test exposes 98 % of dangerous undetected failures.

Test procedure C

1. Connect a suitable measuring device (recommended accuracy better than ±0.1 mA) to the current output.
2. Establishing fail-safe mode (SIL-MIN or SIL-MAX).
   → Operating Instructions (→ 🖹 9, "Supplementary device documentation"), Section 5.
3. Function switch in pos. 6.
4. Press – key and + key simultaneously for min. 2 s.

   ✎ Note!
   The start of the proof test is indicated when LED 5 flashes.
5. Observe output current, expected characteristics → Drawing. Test duration approx. 30 s.



Note!
If there is a deviation in the expected current value for a particular sensor state, this results in the iterative test being failed. For troubleshooting → Operating Instructions (→ 🖹 9, "Supplementary device documentation"), Section 9.
This test exposes approx. 35 % of dangerous undetected failures.

This test procedure does not test the probe rod or the sensor's electrical connection.
These device components are covered only by test procedures A or B.

Note!
If one of the test criteria in the test procedures described above is not fulfilled, the device can no longer be used as part of a protective system.
Proof-testing is used to detect random device failures. The effect of systematic errors on the safety function is not covered by this test and must be examined separately.
Systematic errors may be caused, for example, by material properties, operating conditions, build-up or corrosion.

Repair

Repair

All repairs to the devices must be carried out by Endress+Hauser only.

Exception:
The customer is permitted to replace the electronic insert FEI55 if the member of staff responsible has been trained by Endress+Hauser to do so.
The replaced electronic insert FEI55 must be sent to Endress+Hauser for fault analysis.
Once the electronic insert has been replaced, proof-testing using procedure A or B must be carried out.

In the event of failure of a SIL-labeled Endress+Hauser device, which has been operated in a protective system, the "Declaration of contamination and cleaning" with the note "Used as SIL device in protective system" must be enclosed when the defective device is returned
Please note the Operating Instructions ("Supplementary device documentation"), "Return" section.

Appendix

Notes on the redundant connection of multiple sensors for SIL 3

With redundant connection with HFT = 1 (e.g. coincidence logic 1oo2 or 2oo3), the device meets the requirements for SIL 3.

The common cause factors β and β_D listed in the table below are minimum values for the devices. These must be used when calculating the probability of failure of redundantly connected Liquicap M or Solicap M/S devices in accordance with IEC 61508-6.
System-specific observation can return higher values depending on the actual installation and the use of other components (e.g. Ex barriers).

Minimum value β in the case of homogeneous redundant use	5 %
Minimum value β_D in the case of homogeneous redundant use	2 %

Commissioning or proof-test protocol

System-specific data				
Company				
Measuring points / TAG no.				
System				
Device type / Order code				
Serial number of device				
Name				
Date				
Signature				
Device-specific commissioning parameters				
Medium (if necessary conductivity, DK, similar test medium)				
Measuring range [pF]				
Switching delay [s]				
Empty / Full calibration Switch point adjustment [pF]				
Operating mode/ Fail-safe mode	MIN	SIL MIN	SIL MAX	MAX
Please check				
Proof-test protocol				
Test procedure	A Approach level	B Remove device	C Simulation	
Please check				
Test stage	Set point	Actual value		
1. Determine sensor state (free / covered)				
2. Read current value for electrical current				
3. Evaluate: OK / failed				
4. Change level				
5. Read current value for electrical current				
6. Evaluate: OK / failed				
7. Restore original system status				
8. Read current value for electrical current				
9. Evaluate: OK / failed				
Result: Proof test passed: (yes / no) (3. + 6. + 9. = OK)				

SD278en07

Failure Modes, Effects and Diagnostic Analysis

Project:

Capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56
and Solicap S FTI77 with electronic insert FEI55
Applications with level limit detection (MIN / MAX detection)

Customer:

Endress+Hauser GmbH+Co. KG
Maulburg
Germany

Contract No.: E+H 03/03-22
Report No.: E+H 03/03-22 R048
Version V1, Revision R0, June 2008
Stephan Aschenbrenner

Management summary

This report summarizes the results of the hardware assessment carried out on the capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56 and Solicap S FTI77 with electronic insert FEI55 with software version V01.00.01-19.

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.

For safety applications only the 8/16 mA output was considered. All other possible output variants or electronics are not covered by this report.

The failure rates used in this analysis are the basic failure rates from the Siemens standard SN 29500.

The capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56 and Solicap S FTI77 with electronic insert FEI55 are considered to be Type B[1] subsystems with a hardware fault tolerance of 0. For Type B subsystems with a hardware fault tolerance of 0 the SFF shall be > 90% for SIL 2 subsystems according to table 3 of IEC 61508-2.

Endress+Hauser GmbH+Co. KG together with *exida* performed a qualitative analysis of the mechanical parts of the capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56 and Solicap S FTI77 with electronic insert FEI55. This analysis was used to calculate the failure rates of the sensor element using different failure rate databases ([N5], [N6], [N7] and *exida*'s experienced-based data compilation) for the different components of the sensor element (see [D7] to [D11]). The results of the quantitative analysis were used for the calculations described in sections 4.5.1 and 4.5.2.

The listed SN29500 failure rates are valid for operating stress conditions typical of an industrial field environment similar to IEC 60654-1 class C (sheltered location) with an average temperature over a long period of time of 40°C (25°C ambient temperature plus internal self heating). For a higher average temperature of 60°C, the failure rates should be multiplied with an experience based factor of 2,5. A similar multiplier should be used if frequent temperature fluctuation (daily fluctuation of > 15°C) must be assumed.

The failure rates listed below do not include failures resulting from incorrect use of the capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56 and Solicap S FTI77 with electronic insert FEI55, in particular humidity entering through incompletely closed housings or inadequate cable feeding through the inlets.

The following tables show how the above stated requirements are fulfilled.

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

Table 1: Summary for MIN detection – Failure rates

Failure category	Failure rates (in FIT)
Fail Safe Detected (λ_{SD})	**2**
Fail safe detected	2
Fail Safe Undetected (λ_{SU})	**334**
Fail safe undetected	240
Residual	86
Annunciation undetected (95%)	8
Fail Dangerous Detected (λ_{DD})	**187**
Fail dangerous detected	176
Fail high	11
Annunciation detected	0
Fail Dangerous Undetected (λ_{DU})	**43**
Fail dangerous undetected	42
Annunciation undetected (5%)	1
No part	30

Total failure rate (safety function)	**566 FIT**
SFF	**92%**
DC_S [2]	**0%**
DC_D [2]	**81%**
MTBF	**191 years**

SIL AC [3]	**SIL2**

[2] DC means the diagnostic coverage (safe or dangerous) by the safety logic solver.

[3] SIL AC (architectural constraints) means that the calculated values are within the range for hardware architectural constraints for the corresponding SIL but does not imply all related IEC 61508 requirements are fulfilled.

Table 2: Summary for MAX detection – Failure rates

Failure category	Failure rates (in FIT)
Fail Safe Detected (λ_{SD})	**1**
Fail safe detected	1
Fail Safe Undetected (λ_{SU})	**341**
Fail safe undetected	250
Residual	83
Annunciation undetected (95%)	8
Fail Dangerous Detected (λ_{DD})	**188**
Fail dangerous detected	176
Fail high	12
Annunciation detected	0
Fail Dangerous Undetected (λ_{DU})	**34**
Fail dangerous undetected	33
Annunciation undetected (5%)	1
No part	32

Total failure rate (safety function)	**564 FIT**
SFF	**94%**
DC_S [2]	**0%**
DC_D [2]	**84%**
MTBF	**191 years**

SIL AC [3]	**SIL2**

A user of the capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56 and Solicap S FTI77 with electronic insert FEI55 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 sections 4.5.1 and 4.5.2 along with all assumptions.

It is important to realize that the “residual” failures are included in the “safe undetected” failure category according to IEC 61508. Note that these failures on their own will not affect system reliability or safety, and should not be included in spurious trip calculations.

The failure rates are valid for the useful life of the capacitive level limit switches Liquicap M FTI51/52, Solicap M FTI55/56 and Solicap S FTI77 with electronic insert FEI55 (see Appendix 2).

Certificate

TÜV NORD

Zertifikat

Certificate

Registrier-Nr.
Registration No.
44 207 08 360698-001

Zeichen des Auftraggebers *Customer's reference*	Auftragsdatum *Date of order*	Aktenzeichen *File reference*	Prüfbericht Nr. *Test report no.*
	30.05.2008	8000360698	08 207 360698-001

Name und Anschrift des Auftraggebers
Endress+Hauser GmbH + Co. KG
Hauptstrasse 1
79689 Maulburg
Customer's name and address

Geprüft nach — **IEC 61508:1998 + corrigendum 1999** — **Funktionale Sicherheit sicherheitsbezogener elektrischer/elektronischer/ programmierbarer elektronischer Systeme Anforderungen an SIL 2 (HW) / SIL 3 (SW)**
Functional safety of electrical/electronic/programmable electronic safety-related systems Requirements according to SIL 2 (HW) / SIL 3 (SW)
Tested in accordance with

Beschreibung des Produktes (Details siehe Anhang 1)
Kapazitive Füllstandsensoren mit Elektronikeinsatz FEI55
Capacitive level sensors with electronic FEI55
Description of product (Details see Annex 1)

Typenbezeichnung
Liquicap M-FTI51, FTI52
Solicap M-FTI55, FTI56
Solicap S-FTI77
Type Description

Bemerkung
Remark

Dieses Zertifikat bescheinigt das Ergebnis der Prüfung an dem vorgestellten Prüfgegenstand. Eine allgemein gültige Aussage über die Qualität der Produkte aus der laufenden Fertigung kann hieraus nicht abgeleitet werden.
This certifies the result of the examination of the product sample submitted by the manufacturer. A general statement concerning the quality of the products from the series manufacture cannot be derived there from.

TÜV NORD CERT GmbH
Zertifizierungsstelle für Produktsicherheit
Certification body for product safety

Gültig bis / *Valid to*: **29.08.2013**

Ralf Laborenz

Hannover, 29.08.2008

Bitte beachten sie auch die umseitigen Hinweise
Please also pay attention to the information stated overleaf

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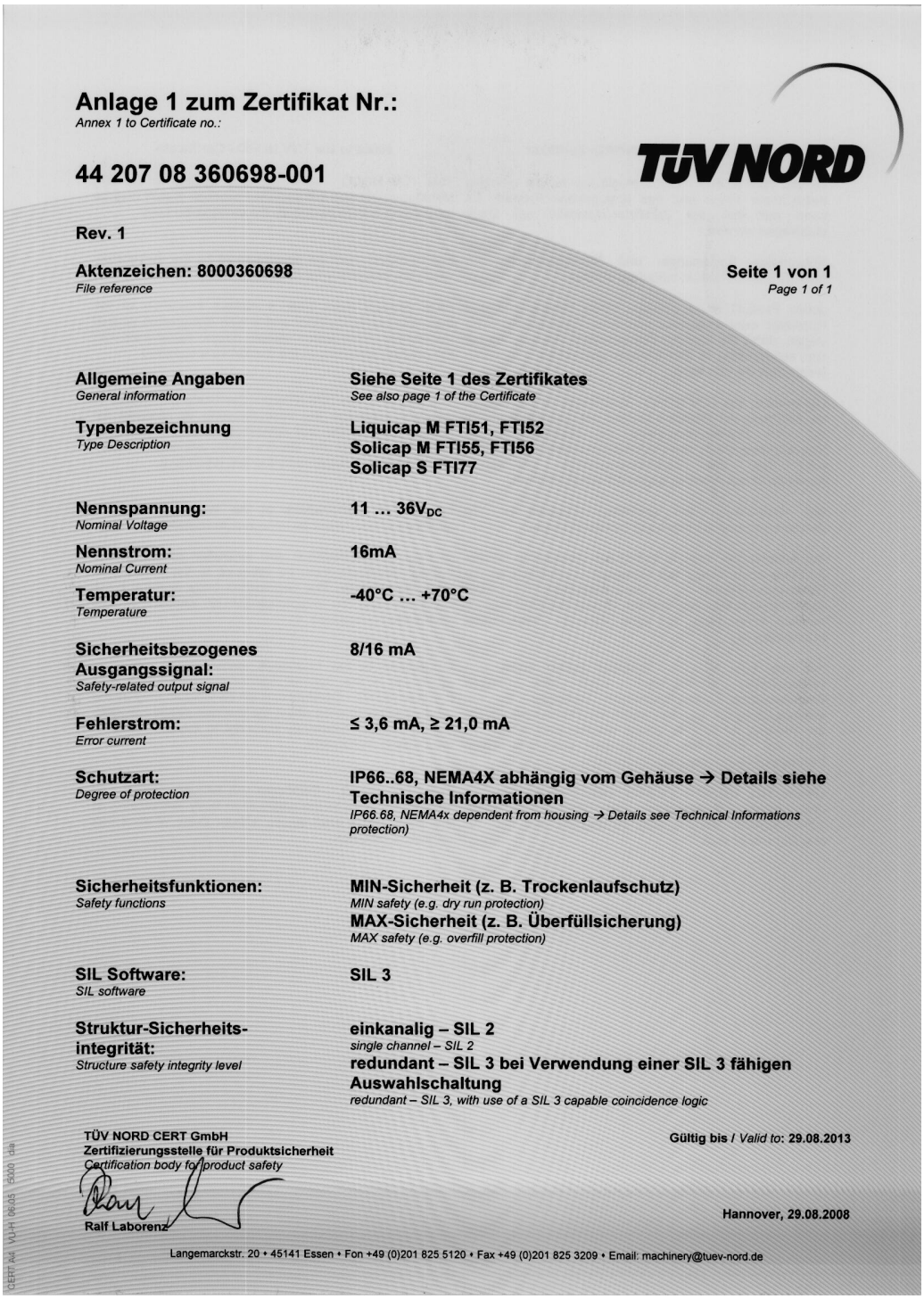

Anlage 1 zum Zertifikat Nr.:
Annex 1 to Certificate no.:

44 207 08 360698-001

TÜV NORD

Rev. 1

Aktenzeichen: 8000360698
File reference

Seite 1 von 1
Page 1 of 1

Allgemeine Angaben *General information*	**Siehe Seite 1 des Zertifikates** *See also page 1 of the Certificate*
Typenbezeichnung *Type Description*	**Liquicap M FTI51, FTI52** **Solicap M FTI55, FTI56** **Solicap S FTI77**
Nennspannung: *Nominal Voltage*	**11 … 36V_{DC}**
Nennstrom: *Nominal Current*	**16mA**
Temperatur: *Temperature*	**-40°C … +70°C**
Sicherheitsbezogenes Ausgangssignal: *Safety-related output signal*	**8/16 mA**
Fehlerstrom: *Error current*	**≤ 3,6 mA, ≥ 21,0 mA**
Schutzart: *Degree of protection*	**IP66..68, NEMA4X abhängig vom Gehäuse → Details siehe Technische Informationen** *IP66.68, NEMA4x dependent from housing → Details see Technical Informations protection)*
Sicherheitsfunktionen: *Safety functions*	**MIN-Sicherheit (z. B. Trockenlaufschutz)** *MIN safety (e.g. dry run protection)* **MAX-Sicherheit (z. B. Überfüllsicherung)** *MAX safety (e.g. overfill protection)*
SIL Software: *SIL software*	**SIL 3**
Struktur-Sicherheits-integrität: *Structure safety integrity level*	**einkanalig – SIL 2** *single channel – SIL 2* **redundant – SIL 3 bei Verwendung einer SIL 3 fähigen Auswahlschaltung** *redundant – SIL 3, with use of a SIL 3 capable coincidence logic*

TÜV NORD CERT GmbH
Zertifizierungsstelle für Produktsicherheit
Certification body for product safety

Gültig bis / *Valid to*: 29.08.2013

Ralf Laborenz

Hannover, 29.08.2008

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