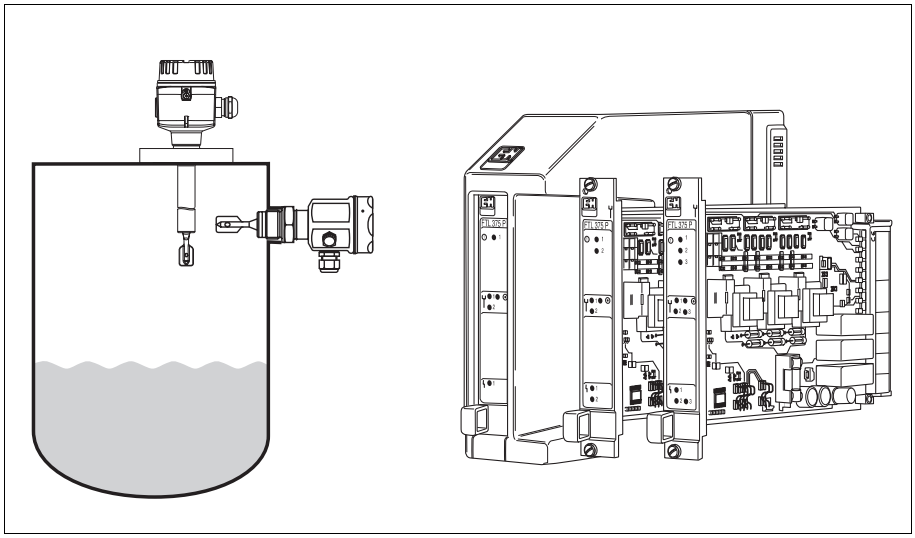
Safety Manual
SD 113F/00/en/11.04
52012410

Limit Level Measuring System
liquiphant M/S + nivotester FTL 375 P

Functional safety manual



Areas of application:
Overspill protection or operating maximum detection of all types of liquids in tanks or piping to satisfy particular safety systems requirements to IEC 61508 or DIN V 19250.

The measuring system fulfils the requirements concerning
- functional safety acc. to IEC 61508 or DIN V 19250
- explosion protection by intrinsic safety and in case of using flameproof enclosures also EEx d (XP)
- EMC to NAMUR Recommendations

Your benefits
- For overspill protection up to SIL 2/AK 4, in redundant versions up to SIL 3/AK 5&6
  - Certified by TÜV Rheinland/ Berlin Brandenburg TÜV Anlagentechnik GmbH Automation, software and IT to IEC 61508
- Permanent self-monitoring
- No calibration
- Protected against outside vibration via optimised drive
- Space-saving switching unit
- Measuring system test by pressing a test-button
- Fail-safety by PFM technology

Endress+Hauser
The Power of Know How

Contents

Introduction

Terms and standards

Abbreviations

PFD	Probability of dangerous Failure on Demand	
PFD_{av}	Probability (average) of a dangerous Failure on Demand	
SIL	Safety Integrity Level *Discrete level (one out of possible four) for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety related systems where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest*	
HFT	Hardware Fault Tolerance *Ability of a functional unit (hardware) to continue to perform a required function in the presence of faults or errors*	
SFF	Safe Failure Fraction *Fraction of failure which do not have the potential to put the safety-related system in a hazardous or fail-to-function state*	
CCF , CC	Common Cause Failure *Failure which is the result of one or more events causing coincident failures of two or more separate channels in a multiple channel system, leading to system failure*	
E/E/PE	Electrical / Electronic / Programmable Electronic System	
XooY	"x out of y“ voting (e.g. 2oo3)	
MTTR	Mean Time To Repair	
MTBF	Mean Time Between Failure	
TI	Test Interval between life testing of the protection function (in years)	

Tab. 1: Definitions from IEC 61508 Part 4

Relevant standards

IEC 61508 Part 1-7	Functional safety of programmable electronic safety-related systems (Target group: Manufacturers & Suppliers of Devices)	
IEC 61511 Part 1-3 Draft	Functional safety instrumented systems for the process industry sector. (Target group: Safety Instrumented Systems Designers, Integrators & Users)	
DIN V VDE 0801 A1	Principles for computers in safety-related systems (including Amendment A1)	
DIN V 19250	Fundamental safety aspects for measurement and control equipment	

Tab. 2: Relevant standards

Terms

Safety system	Complete safety-related measuring chain (protection function)
Safety function	Defined function performed by the system on demand

Tab. 3: Terms

General display of a safety system (protection function)

Version tables for determining Safety Integrity Level (SIL)

The following tables are used to define the reachable SIL or the requirements pertaining to the "Average Probability of a Dangerous Failure On Demand" (PFD_{av}), "Hardware Fault Tolerance" (HFT) and the "Safe Failure Fraction" (SFF) of the safety system. Refer to the tables in the Appendix for the specific values of the measuring systems Liquiphant M/S (FEL 57) and Nivotester FTL 375 P.

The relationship between AK-classes according to DIN V 19250 and the Safety Integrity Level (SIL) according to IEC 61508:

AK-classes (DIN V 19250)		Safety Integrity Level SIL (IEC 61508)
1		–
2 & 3	⇒	1
4	⇒	2
5 & 6	⇒	3
7 & 8	⇒	4

Tab. 4: Relationship between AK and SIL

Permitted failure probability of the complete safety system as a function of SIL for systems which must react on demand (e.g. sensor signal when covered).

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

Tab. 5: Permitted failure probabilities (Source: IEC 61508, Part 1)

The ranges of PFD_{av} are generally distributed as follows for the whole safety system:

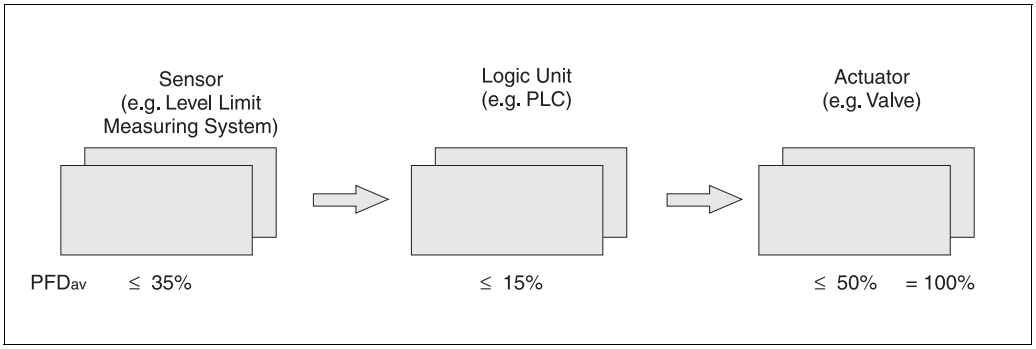


Fig. 1: General distribution of PFD_{av}

The following table shows the achievable Safety Integrity Level (SIL) as a function of the amount of safety-oriented errors and the hardware fault tolerance of the complete safety system for type B systems (complex components, for definition see IEC 61508, Part 2):

SFF		HFT		
		0	1	2
none:	< 60%	not allowed	SIL 1	SIL 2
low:	60 % ...< 90 %	SIL 1	SIL 2	SIL 3
medium:	90 % ...<99%	SIL 2	SIL 3	SIL 4
high:	≥ 99%	SIL 3	SIL 4	SIL 4

Tab. 6: Attainable SIL (Source: IEC 61508, Part 2)

Sensors in the measuring system with Liquiphant M/S (FEL 57) and Nivotester FTL 375 P

Limit level measuring system

Fig. 2 shows the instruments in the measuring system.

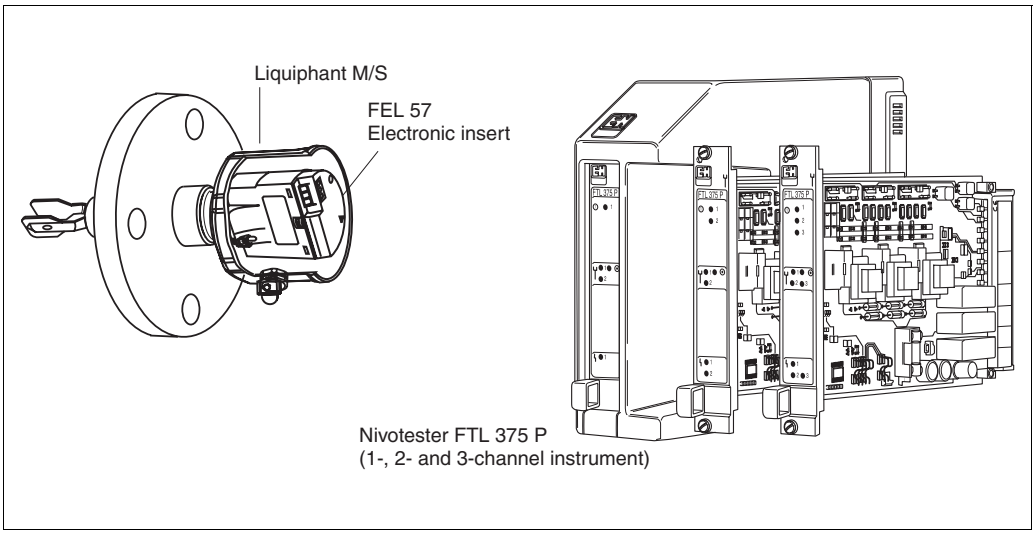


Fig. 2: Measuring system instruments (example)

Safety function

The safety function applies to all settings in MAX safety (monitoring of the covered state) and use of the NO contacts of the level relays or use of transistor outputs in conjunction with an evaluation unit (e.g. PLC).
The following settings are permitted for the safety function:

Instrument	Setting	As-delivered state
Liquiphant	Density switch setting: 0.5 Density switch setting: 0.7	Density switch setting: 0.7
	Test mode "STD" Test mode "EXT"	Test mode "STD"
Nivotester FTL375P-###1 (One-channel instrument)	MAX Safety	MAX Safety
		One-channel operation
Nivotester FTL375P-###2 (Two-channel instrument)	MAX Safety	MAX Safety
	All settings **except** "ΔS function" (see Chap. "Settings and installation instructions")	Two-channel operation
Nivotester FTL375P-###3 (Three-channel instrument)	MAX Safety	MAX Safety
	All settings **except** "ΔS function" (see Chap. "Settings and installation instructions")	Three-channel operation

Tab. 7: Settings

The MAX safety setting has the effect that the level relay or the transistor output always work in quiescent current safety, i.e. the relay releases or the transistor output is disabled when:
- the switch point is exceeded (level exceeds response height)
- a fault occurs
- mains voltage fails

In addition to the level relay, the alarm relay or the alarm transistor output works in quiescent current safety and releases or is disabled when
- one of the following faults occur:
  - the sensor line is interrupted
  - the sensor line short circuits
  - the sensor identifies corrosion at the vibration system
- mains voltage fails

Note!
- When the alarm relay releases or when the alarm transistor output is disabled, the level relays also release or the transistor outputs also are disabled.

Permitted combination of Nivotester with Liquiphant M/S for the safety function

The following instrument combinations are permitted for the measuring system:

Nivotester			Liquiphant M + FEL 57	Liquiphant S + FEL 57
One-channel instrument:	Two-channel instrument:	Three-channel instrument:		
FTL 375 P-H##1*	FTL 375 P-H##2*	FTL 375 P-H##3*	FTL 50-######7###** FTL 51-######7###** FTL 50 H-######7###** FTL 51 H-######7###** FTL 51 C-######7####**	FTL 70-######7####** FTL 71-######7####**
* Approvals for ATEX, WHG and SIL ** 7 = FEL 57				

*Tab. 8: Permitted instrument types (# = all instrument versions permitted); * 7 = FEL 57*

Safety function data

The mandatory settings and data for the safety function can be found in the APPENDIX.

The response time of the measuring system is ≤ 0.9 s.

Note!
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
The following must be available for the measuring system:

	Technical Information	Operating Instructions
Nivotester FTL 375 P	*For all instrument types:* TI 360F	*One-channel instrument FTL 375 P-###1:* KA 174F
		Two-channel instrument FTL 375 P-###2: KA 175F
		Three-channel instrument FTL 375 P-###3: KA 176F
Liquiphant M	*Types: FTL 50, FTL 51, FTL 50 H, FTL 51 H*: TI 328F	*Types: FTL 50, FTL 51:* KA 143F
		Types: FTL 50, FTL 51: KA 163F *(with aluminium housing/separate terminal compartment)*
		Types: FTL 50 H, FTL 51 H: KA 144F
		Types: FTL 50 H, FTL 51 H: KA 164F *(with aluminium housing/separate terminal compartment)*
	Type: FTL 51 C TI 354F	*Type: FTL 51 C:* KA 162F
		Type: FTL 51 C: KA 165F *(with aluminium housing/separate terminal compartment)*
Liquiphant S	*For all instrument types:* TI 354F	*Types FTL 70, FTL 71:* KA 172F
		Types: FTL 70, FTL 71: KA 173F *(with aluminium housing/separate terminal compartment)*
Relevant contend	Connection data Installation instructions	Setting, configuration, remarks, function tests

Tab. 9: Supplementary documentation

Settings and installation instructions

Installation
The Nivotester FTL 375 P is installed in the Endress+Hauser Racksyst II assembly rack (FXG 1) or in the Monorack II. The ambient conditions for the assembly rack or the Monorack must correspond to IP54 (as per EN 60529). Please pay special attention to the instructions and requirements stated in TI 183F (Monorack II) or TI 224 F (assembly rack).
All components which are used in conjunction with the FTL 375 P in the assembly rack must observe EMC standards 89/336/EEC or equivalent national regulations. The measuring system must undergo a functional test after installation.

Caution!
Please note the following for the Nivotester FTL 375 P-####:
The operator must use suitable measures (e.g. current limiter, fuses) to ensure the relay contact characteristics of
- U ≤ 253 V AC 50/60 Hz , I ≤ 2.5 A, P ≤ 300 VA at cos φ ≥ 0.7 or
- U ≤100 V DC, I ≤ 2.5 A, P ≤ 100 W

are not exceeded and the permitted transistor output connection characteristics of
- U_{ext} ≤ 20...30 V DC
- I_{max} = 500 mA

are observed.

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

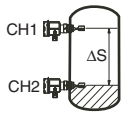
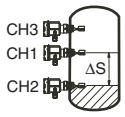
Refer to the following documentation for instructions on setting the instruments:

Instrument	Setting description in documentation:
Liquiphant M + FEL 57	KA 143F, KA 163F, KA 144F, KA 164F*, KA 165F, KA 162F*
Liquiphant S + FEL 57	KA 172F, KA 173F
Nivotester FTL 375 P-###1 (one-channel)	KA 174 F
Nivotester FTL 375 P-###2 (two-channel)	KA 175 F
Nivotester FTL 375 P-###3 (three-channel)	KA 176 F

Tab. 10: Instrument documentation (type-dependent, see Tab. 9)*

Settings for Liquiphant M/S (FEL 57):
- The **density switch setting** has an influence on probability of failure and function test type (refer to the APPENDIX for details).
- The **test mode** setting has influence on the function test (refer to the Tab. 13 for details).

Settings for Nivotester FTL 375 P-###3 (3-channel version) and FTL 375 P-###2 (2-channel version)

Instrument	Setting	Description	⚠ Caution!
FTL 375 P-###2 FTL 375 P-###3		Channels 1+2 in Delta-S function	THIS SETTING IS NOT PERMITTED FOR THE SAFETY FUNCTION
FTL 375 P-###3		Channel 3 independent	Channel 3 is permitted for the safety function
		Channels 1+2 in Delta-S function	CHANNELS 1 AND 2 IN THIS SETTING ARE NOT PERMITTED FOR THE SAFETY FUNCTION

Tab. 11: Settings of the Nivotester

Response in operation and failure

Response in operation and failure is described in the following documentation:

Instrument	Description in documentation:
Liquiphant M + FEL 57	KA 143F, KA 163F, KA 144F, KA 164F*, KA 165F, KA 162F*
Liquiphant S + FEL 57	KA 172F, KA 173F
Nivotester FTL 375 P-###1 (one-channel)	KA 174 F
Nivotester FTL 375 P-###2 (two-channel)	KA 175 F
Nivotester FTL 375 P-###3 (three-channel)	KA 176 F

Tab. 12: Instrument documentation (type-dependent, see Tab. 9)*

Recurrent function test of the measuring system

The measuring system should be checked as follows:

Liquiphant M/S		Nivotester	Test	
Setting Density switch	Test mode setting	Setting	Test interval	Description of test procedure
Setting 0.7	STD or EXT	Any permitted setting	Annual function test**	KA 174F * KA 175F * KA 176F *
Setting 0.5	STD or EXT	Any permitted setting	Annual function test** and complete test*: Covered signal monitoring, e.g. by approaching the level, at least every 5 years	

Tab. 13: Recurrent functional tests (depending on type, see Tab. 9)*

**Note the following points for the function test:
- Test each channel individually by pressing the associated test key.
- The electrical switching of the relay contacts and the transistor outputs must be checked:
  – Relay contacts: Electrical check, e.g. using a hand multimeter connected to the terminals.
  – Transistor outputs: Electrical check at the outputs or check with connected evaluation unit (e.g. PLC).
  – In multi-channel instruments, 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 - e.g. by means of independent protective measures or changing the response of the measuring point.
- A positive test result is obtained when the system reaction corresponds to the description.
- **If the system reaction does not correspond to the described procedure, the monitored process must be kept in a safe state by additional or different measures until the safety system is repaired.**

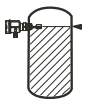
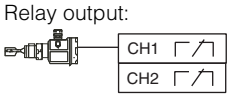
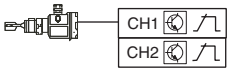
APPENDIX

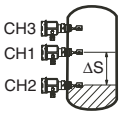
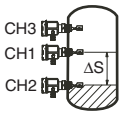
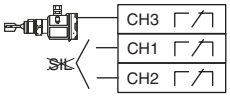
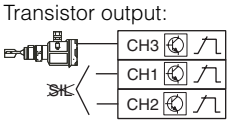
Specific values and wiring options for the measuring system Liquiphant M/S (FEL 57) and Nivotester FTL 375 P

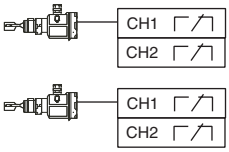
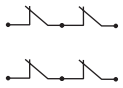
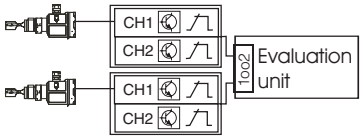
The tables show the specific values and wiring options for the measuring system.

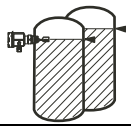
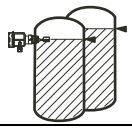
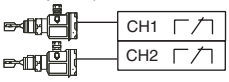
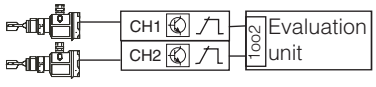
Note!
Note the following points on the tables below:

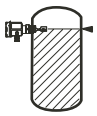
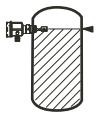
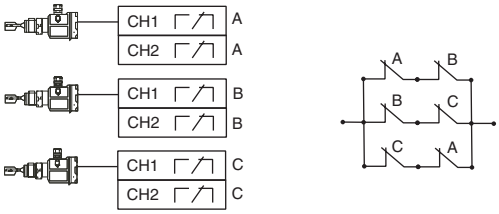
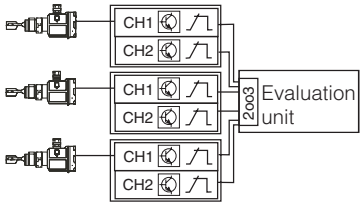
- The PFD_{av} values for multichannel systems already contain common cause errors for the associated wiring scheme. The PFD_{av} values of the evaluation units are not contained in these values.
- The PFD_{av} values are only valid for associated wiring scheme. They are not suitable for deriving calculations for other wiring schemes.
  Using NC contacts instead of NO contacts requires further consideration of the installation means.
- The wiring scheme shows the number of instruments (Liquiphant and Nivotester) and the switching of the limit level relay contacts (open, if sensor reports covered) or the switching of the transistor outputs (disabled, if sensor reports covered).
- If there are several instruments in a wiring scheme they all have the same settings shown.
- The evaluation units used must not effect the system and the design must comply with IEC 61508.
- The transistor outputs are not suitable for series switching using external wiring.

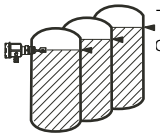
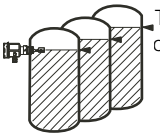
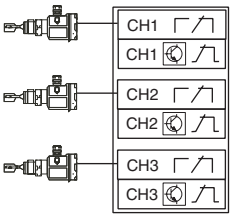
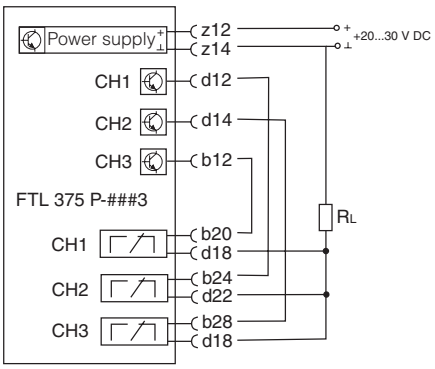
X out of Y: 1oo1		
Liquiphant M/S setting	Density 0.7	Density 0.5
Nivotester FTL 375 P-###1 Setting one-channel instrument	 One-channel operation	 One-channel operation
SIL / AK	SIL 2 / AK 4	SIL 2 / AK 4
HFT	0	0
SFF	> 90 %	> 90 %
PFDav	< 0.15 x10^{-2}	< 0.20 x 10^{-2}
Wiring scheme	Relay output:  CH1/CH2:  Transistor output:  CH1/CH2: 	
Function test with test key	annual	annual
Complete function test, e.g. by approaching level	not required within normal life	at least every 5 years

X out of Y: 1oo1		
Liquiphant M/S setting	Density 0.7	Density 0.5
Nivotester FTL 375 P-###3- Setting three-channel instrument	 CH3 in one-channel operation CH1/CH2 in Δ S function	 CH3 in one-channel operation CH1/CH2 in Δ S function
SIL / AK	SIL 2 / AK 4	SIL 2 / AK 4
HFT	0	0
SFF	> 90 %	> 90 %
PFDav	< 0.15 x 10^{-2}	< 0.20 x 10^{-2}
Wiring scheme	Relay output:  CH3 :  Transistor output:  CH3 : 	
Function test with test key	annual	annual
Complete function test, e.g. by approaching level	not required within normal life	at least every 5 years

X out of Y: 1oo2		
Liquiphant setting	Density 0.7	Density 0.5
Nivotester FTL 375 P-###1- Setting one-channel instrument	 One-channel operation	 One-channel operation
SIL / AK	SIL 3 / AK 5&6	SIL 3 / AK 5&6
HFT	1	1
SFF	> 90 %	> 90 %
PFDav	< 0.10 x 10^{-3}	< 0.15 x 10^{-3}
Wiring scheme	Relay outputs:  CH1 + CH1 : or CH2 + CH2 :  Transistor outputs:  CH1 or CH2 : CH1 or CH2 :	
Function test with test key	annual	annual
Complete function test, e.g. by approaching level	not required within normal life	at least every 5 years

X out of Y: 1oo2		
Liquiphant setting	Density 0.7	Density 0.5
Nivotester FTL 375 P-###2- Setting two-channel instrument	 Two-channel operation	 Two-channel operation
SIL / AK	SIL 3 / AK 5&6	SIL 3 / AK 5&6
HFT	1	1
SFF	> 90 %	> 90 %
PFDav	< 0.10 x 10^{-3}	< 0.15 x 10^{-3}
Wiring scheme	Relay outputs:  CH1 + CH2 :  Transistor outputs:  CH1 : CH2 :	
Function test with test key	annual	annual
Complete function test, e.g. by approaching level	not required within normal life	at least every 5 years

X out of Y: 2oo3		
Liquiphant setting	Density 0.7	Density 0.5
Nivotester FTL 375 P-###1- Setting one-channel instrument	 One-channel operation	 One-channel operation
SIL / AK	SIL 3 / AK 5&6	SIL 3 / AK 5&6
HFT	1	1
SFF	> 90 %	> 90 %
PFDav	< 0.10 x 10^{-3}	< 0.20 x 10^{-3}
Wiring scheme	Relay outputs:  Transistor outputs:  	
Function test with test key	annual	annual
Complete function test, e.g. by approaching level	not required within normal life	at least every 5 years

X out of Y: 2oo3		
Liquiphant setting	Density 0.7	Density 0.5
Nivotester FTL 375 P-###3- Setting three-channel instrument		
SIL / AK	SIL 3 / AK 5&6	SIL 3 / AK 5&6
HFT	1	1
SFF	>90 %	>90 %
PFDav	< 0.20 x 10^{-3}	< 0.20 x 10^{-3}
Wiring scheme	Relay outputs wired with transistor outputs:  	
Function test with test key	annual	annual
Complete function test, e.g. by approaching level	not required within normal life	at least every 5 years

Notes

Subject to modification

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