Functional Safety in the Process Industry

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Safety Instrumented Systems (SIS) in the Process Industry

- Definition of "Risk"
- Risk assessment and Risk reduction by SIS
- Safety Integrity Level (SIL)
- Design of Safety Instrumented Systems
- Safety Parameters and SIL determination
- Structure of Safety Instrumented Systems
- Functional Proof Testing
- Order Code and Documentation

BP AMOCO Refinery Explosion Texas City March 2005

Reason:
- safety systems ignored during maintenance process
- inappropriate design of safety systems
- uncontrolled release of fuel from a vent stack
- inappropriate behavior of workers trying to start and remove a truck
- control room with many workers located close to distillation column

➔ Safety Culture!

Consequence:
- 15 People KILLED
- 180 INJURED
- estimated costs
  US$1,000,000,000

What is “Risk” ?

- Risk = Probability (P) of Event Occurrence x Damage (D)
- Tolerable risk = maximum risk, which is acceptable according to moral concepts (German VDE 2180)
- Risk reduction:
  Reduction of initial risk below tolerable risk by organizational, constructional or protection measures (e.g. Safety Instr. Systems)
- Concept of Functional Safety:

Risk analysis
Quantification of Risk

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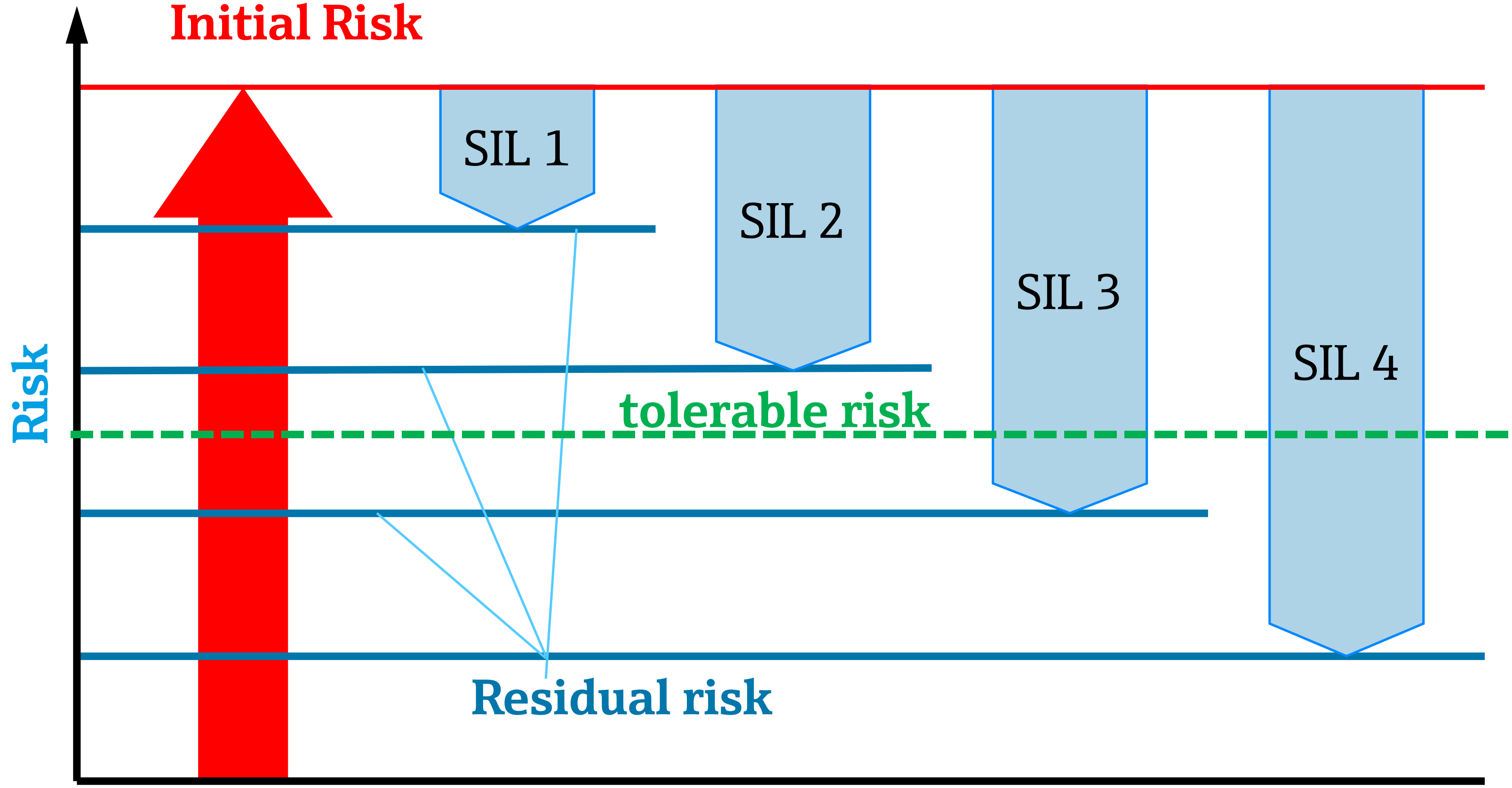
Quantification of required Safety Level of Protection measures
Safety **I**ntegrity **L**evel (SIL)

Risk Reduction by a Safety System



IEC 61508 & IEC 61511: Functional Safety of Electrical/Electronic/Programmable Electronic Systems

Manufacturer

safety related system standards

IEC 61508

7 parts

Manufacturers & suppliers of devices

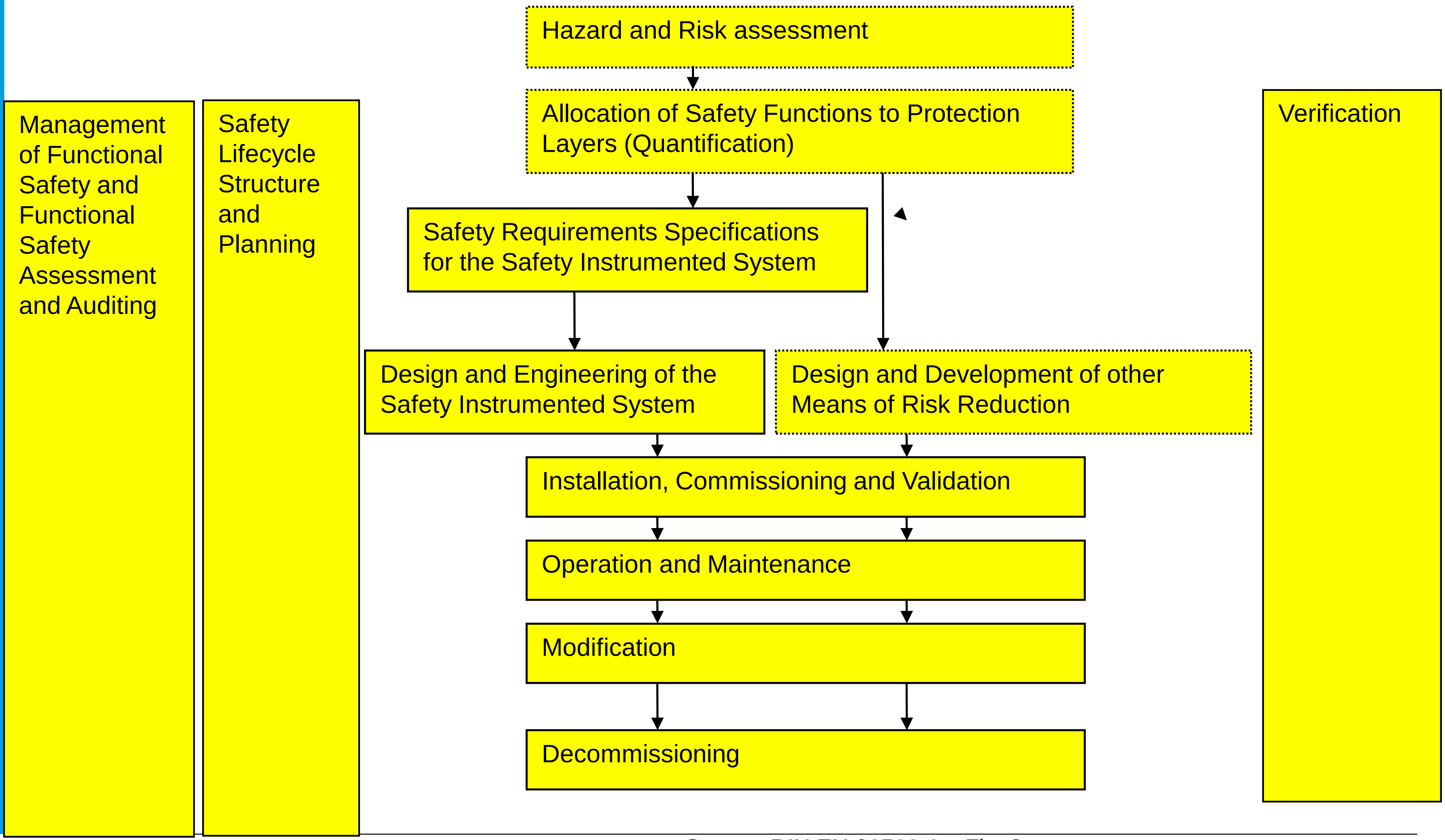
IEC 61511

3 parts

Safety Instrumented Systems Designers, Integrators & Users

American Standard: ANSI/ISA 84.01

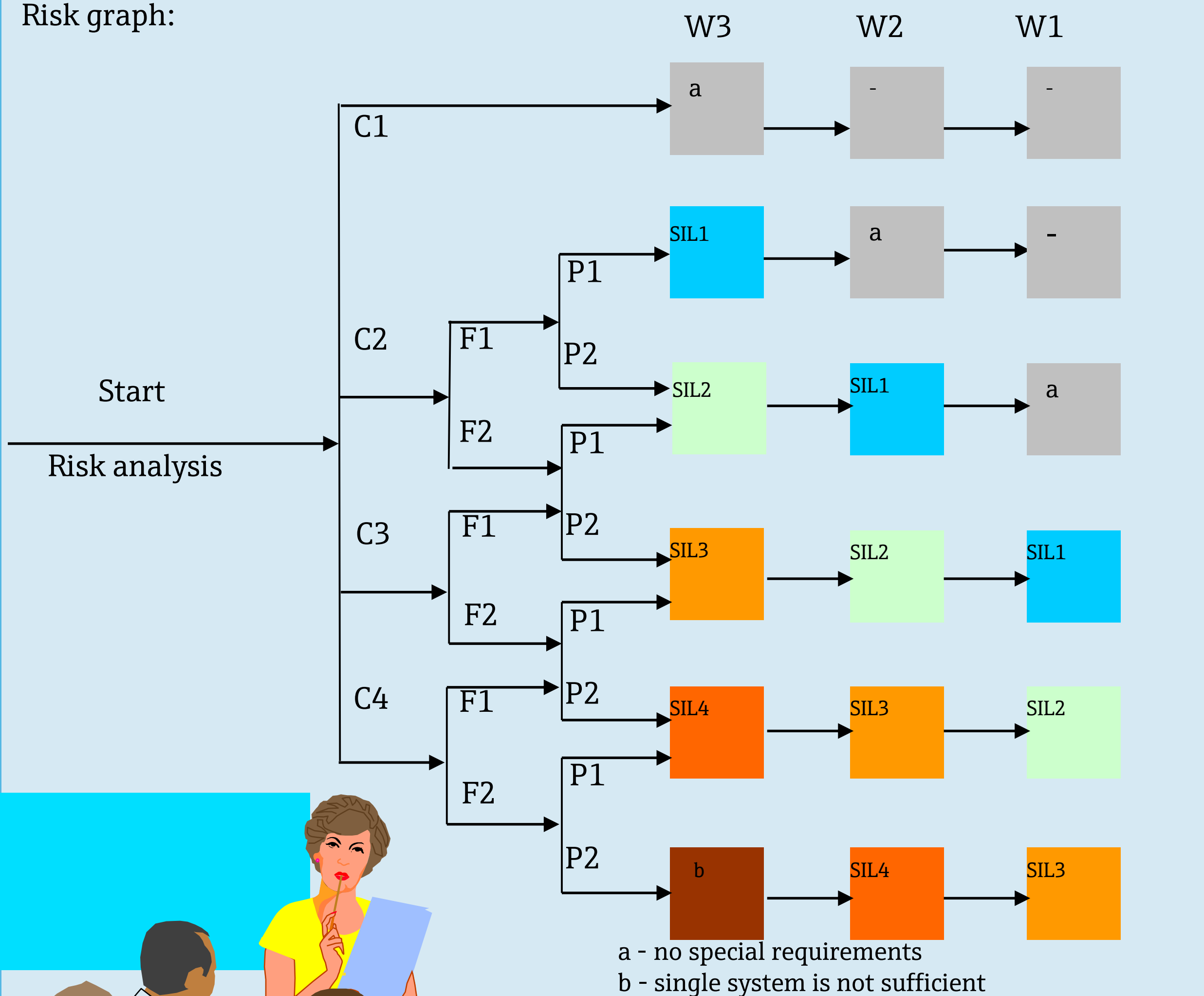
Overall Safety Life-Cycle acc. IEC 61511



Source: DIN EN 61511-1 – Fig. 8

Hazard and Risk Assessment of a Process

Risk graph:



Risk parameters:

W - Occurrence Probability

- W1: very low probability < 0,03/year
- W2: low probability < 0,3 /year
- W3: relative high probability >0,3/ y

C- Extent of damage

- C1: slight injury
- C2: severe irreversible injury to one or more persons or death of a person
- C3: Death of several persons
- C4: Catastrophic consequences, multiple deaths

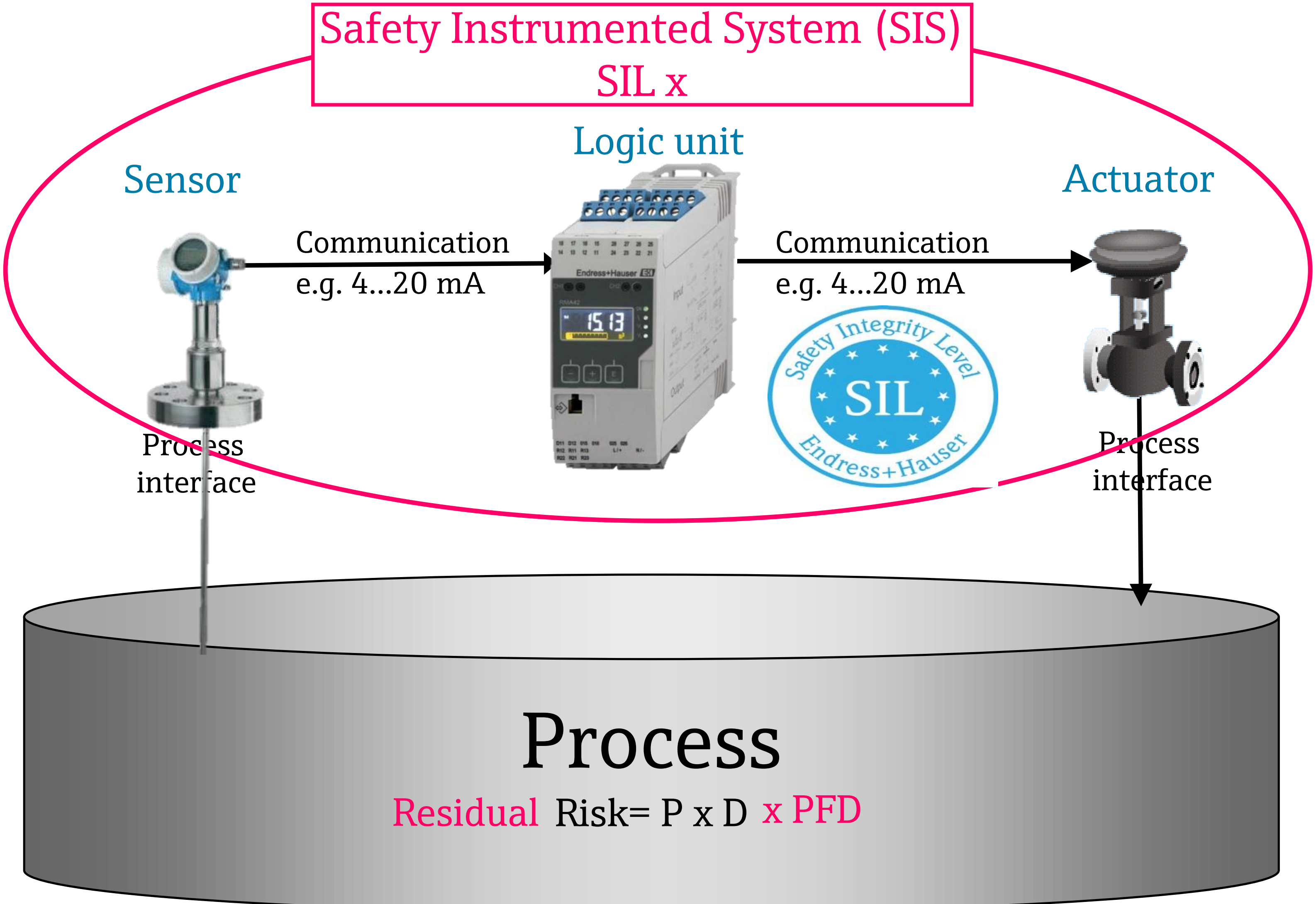
F- Exposure time

- F1: seldom to relatively frequent
- F2: frequent to continuous

P- Hazard Avoidance

- P1: possible under certain conditions
- P2: hardly possible

Risk Reduction by Safety Instrumented Systems



Operational modes of safety systems

High demand mode (HDM)
or continuous mode
demand of the safety function
more than once a year

Safety function
only active
during demand

Safety function
frequently or
continuously active

Low demand mode (LDM)
demand of the
safety function
once a year or less

E.g. machinery industry

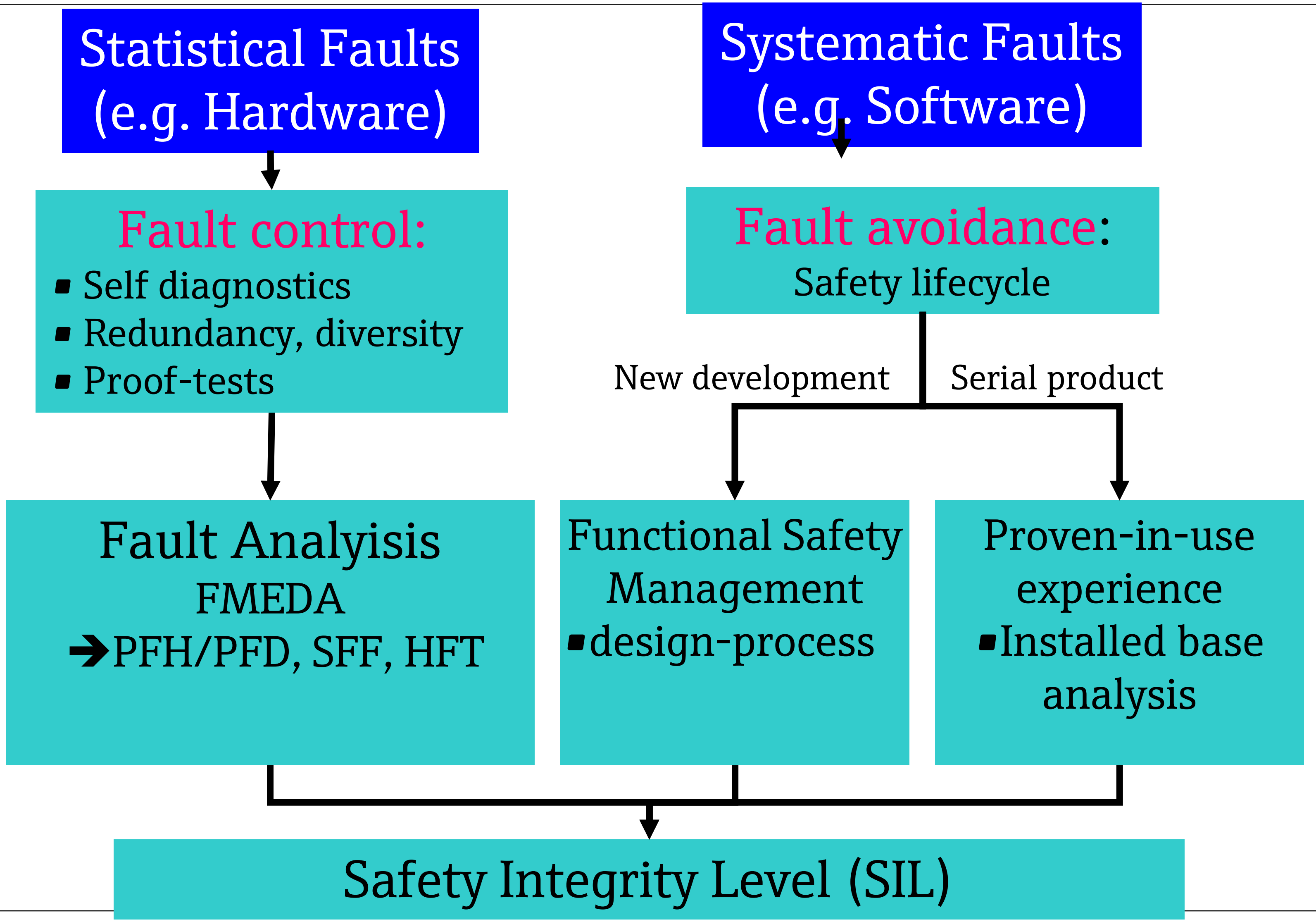
E.g. process industry

„Quantification“ of Risk and Protection Measures

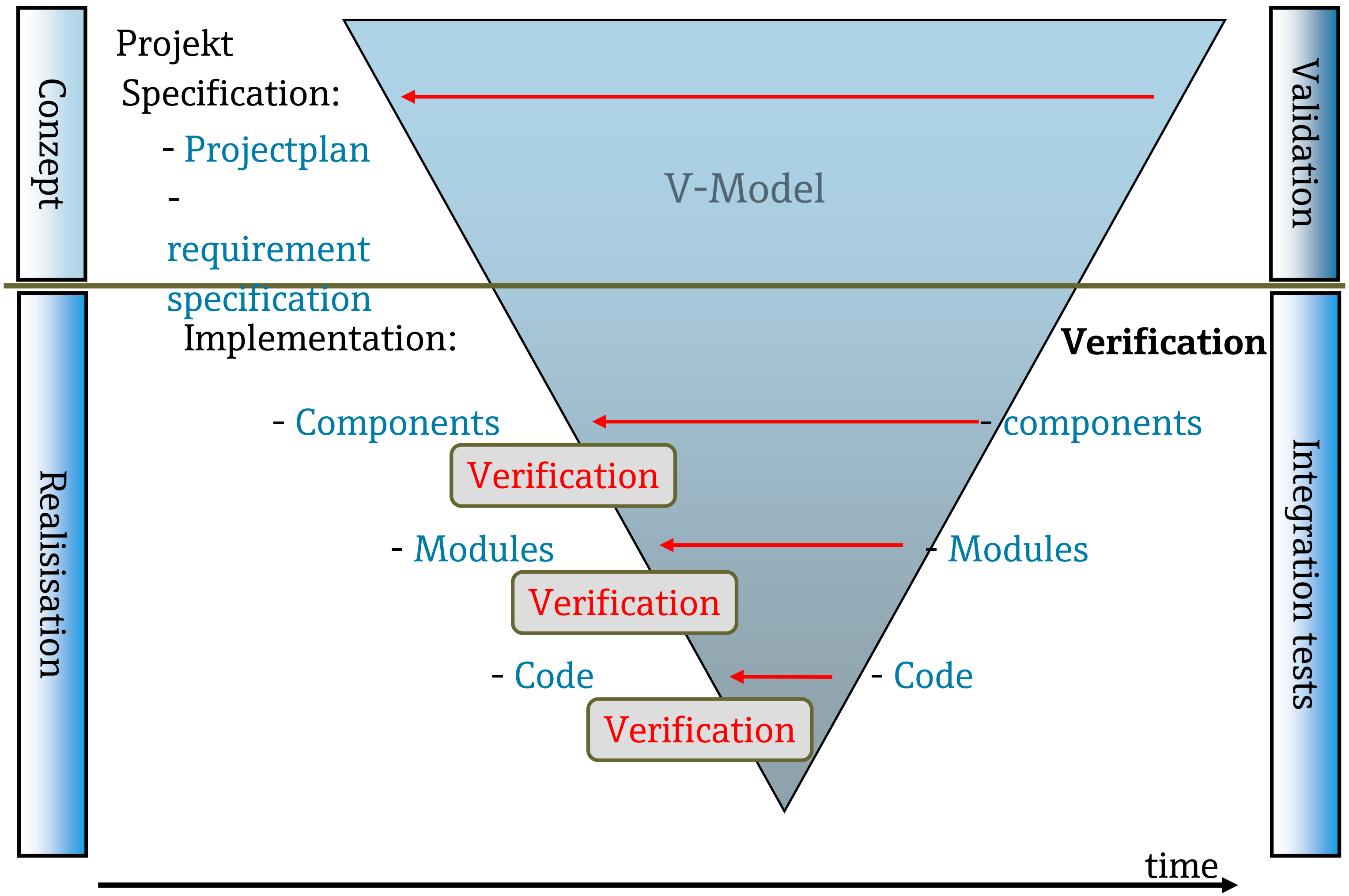
Risk	SIL	Accepted frequency of a failure of the protection measure	Failure rate PFH	Failure probability PFD*
Low	SIL 1	< 1 dangerous fault in 10 years	$<10^{-5}$ 1/h	$<10^{-1}$
Mean	SIL 2	< 1 dangerous fault in 100 years	$<10^{-6}$ 1/h	$<10^{-2}$
High	SIL 3	< 1 dangerous fault in 1000 years	$<10^{-7}$ 1/h	$<10^{-3}$
Very high	SIL 4	< 1 dangerous fault in 10.000 years	$<10^{-8}$ 1/h	$<10^{-4}$

* per demand, assuming 1 demand/year

Reliability of Safety Instrumented Systems



Functional Safety Management - Design Process



Documentation

TÜV Certified Functional Safety Management


TÜVRheinland®

ZERTIFIKAT

CERTIFICATE

FUNCTIONAL SAFETY MANAGEMENT

- IEC 61508 -

No.: 968/FSM 121.00/11

The company

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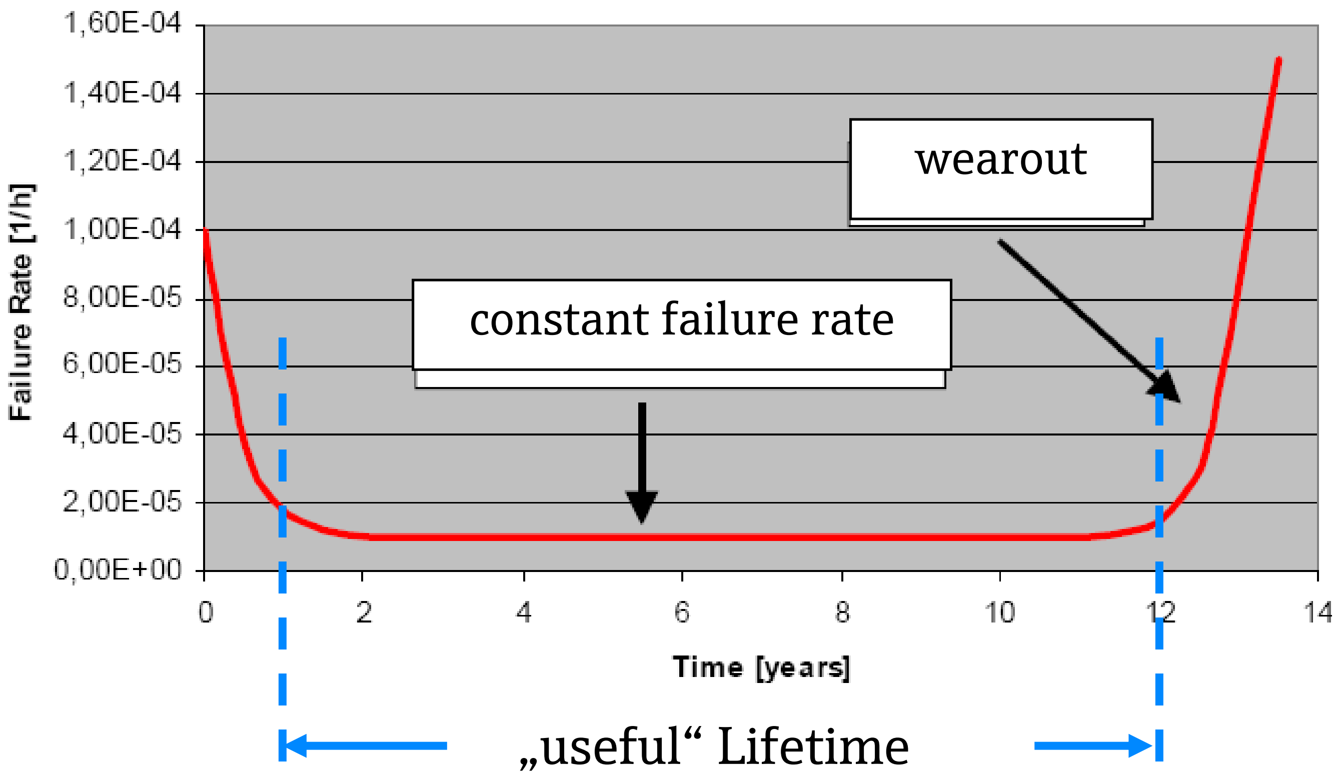
People for Process Automation

TÜVRheinland®
FSM

Safety Level of Safety Instrumented Systems

- Failure Mode and Effect Analysis (FMEA)
- Total Failure Probability (PFD,PFH)
- Architectural Constraints (SFF, HFT)

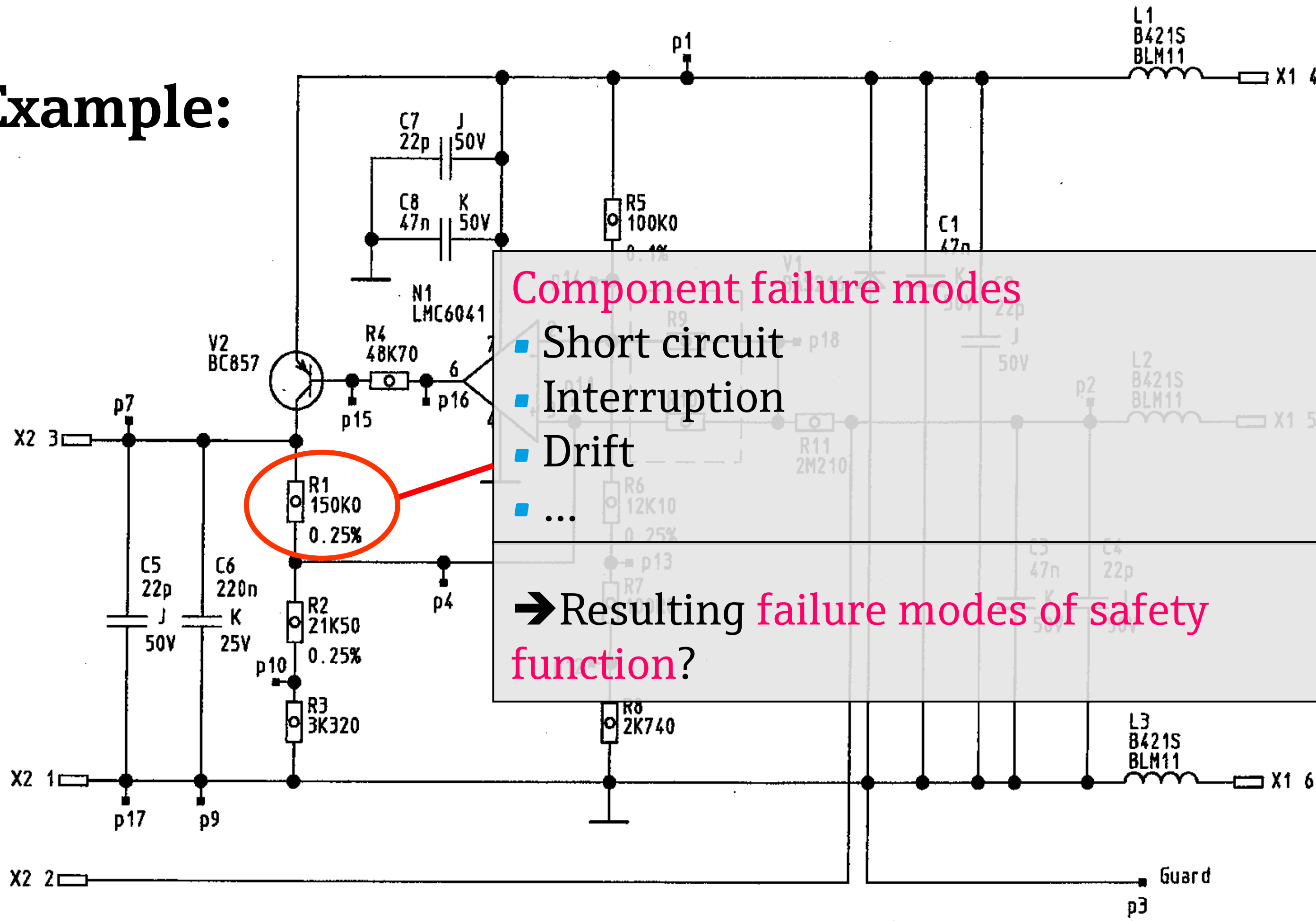
Random Failures of Electronic Components



Note: Failure rate often specified in FIT = 1 Failure/10^9 h = 10^{-9} /h

Failure Mode and Effect Analysis (FMEA)

Example:



Component failure modes

- Short circuit
- Interruption
- Drift
- ...

➔Resulting failure modes of safety function?

Additionally: FMEA of mechanical Components (z. B. Sensor)

Failure Mode Effect Analysis (FMEA)

Pre-condition: - determine safety path (e.g. 4…20 mA output)
- determine accuracy under fault condition (e.g. ± 2 %)

Failure modes:

- dangerous faults
- safe faults
- undetected faults
- detected faults

Probability of Failure Modes	Detected faults	Undetected faults
Safe faults	λ_{sd}	λ_{su}
Dangerous faults	λ_{dd}	λ_{du}

$\lambda_{tot} = \lambda_{su} + \lambda_{sd} + \lambda_{du} + \lambda_{dd} (+\lambda_{\text{not relevant}})$

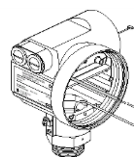
PFD, PFH

$MTBF = 1/\lambda_{tot}$

Failure Modes of Safety Function

λ_{sd} = Safe detected Failure

Example (cont. overfill protection):
Short circuit of 4..20 mA-output
➔ Current >20 mA indicates overfilling and “Alarm”

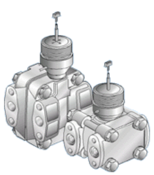


λ_{su} = Safe undetected Failure

Example (limit switch 8/16 mA):
Failure leads to 8 mA output
➔ Safety function activated (fault alarm!)

PFH, PFD

λ_{dd} = Dangerous detected Failure



Example:
Ceramic cell broken in Deltabar
- Broken cell could result in a “valid” measured value but...

➔ Internal “Dia[illegible] in active sensor

λ_{du} = Dangerous undetected fail.

Example:
Output „frozen“ between 4...20 mA independent of the process variable
➔ no warning
[illegible]n not available

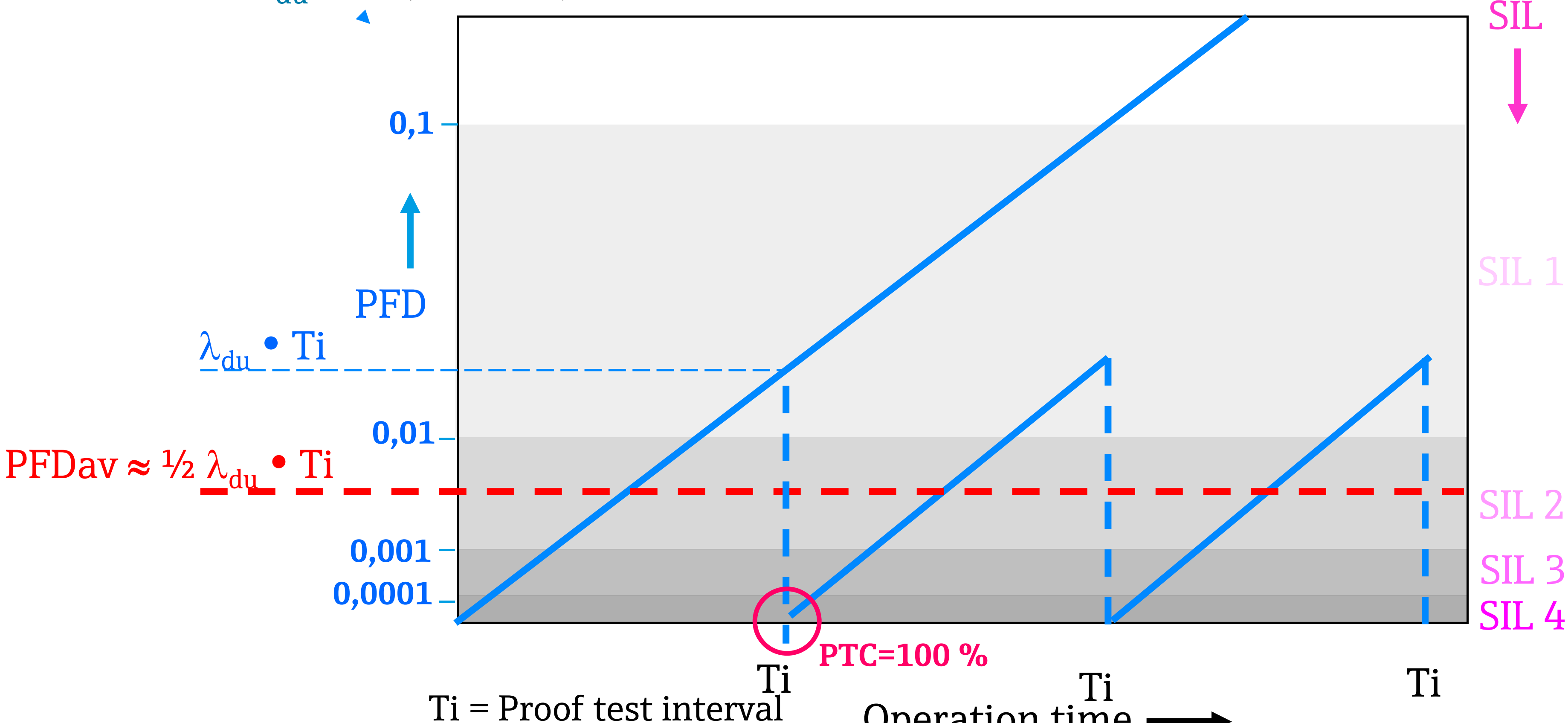
$$\lambda_{tot} = \lambda_{su} + \lambda_{sd} + \lambda_{du} + \lambda_{dd}$$

$$MTBF = 1/\lambda_{tot}$$

Probability of a failure on demand - PFD

Example: Safety component with low demand frequency (~1/a)

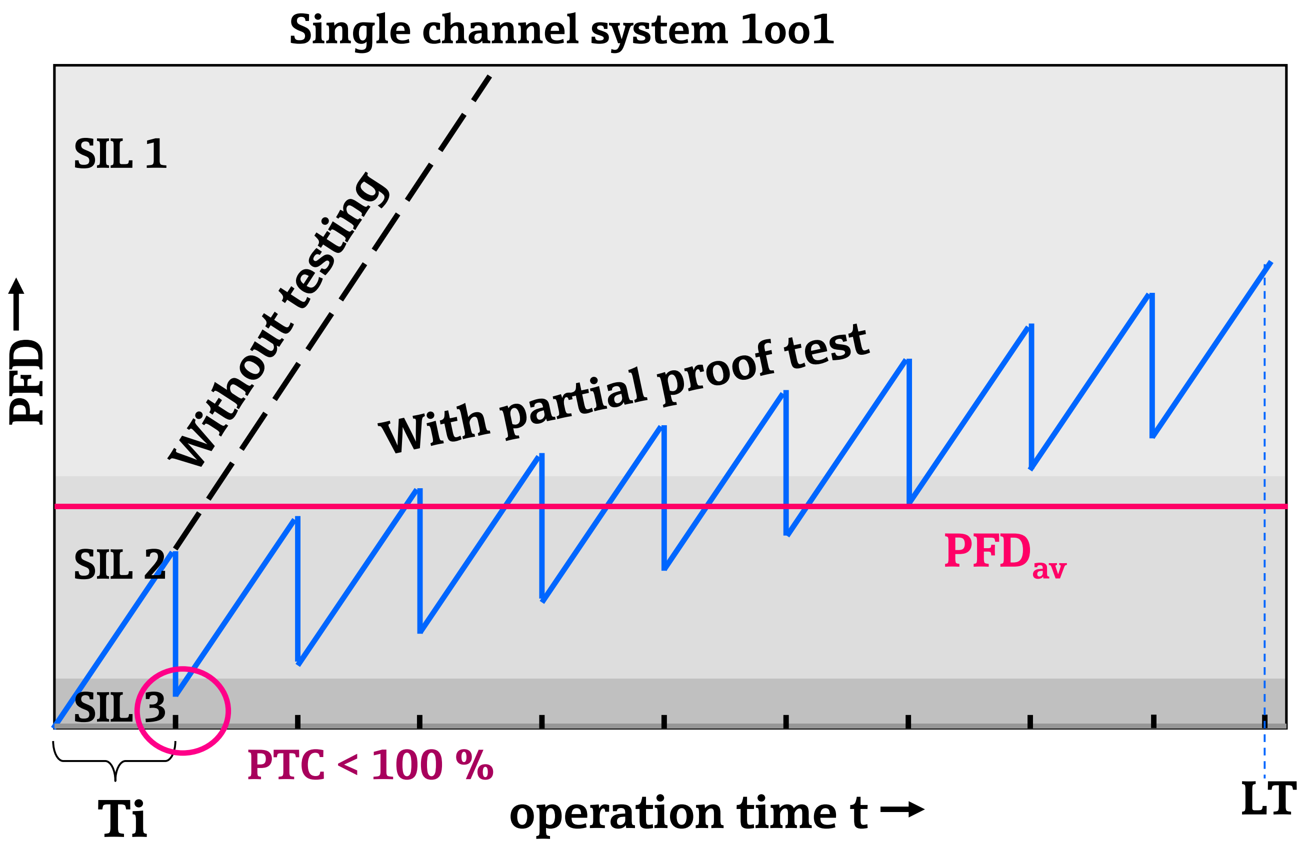
$PFD \approx \lambda_{du} \cdot t \quad (\lambda t << 1)$



Ti = Proof test interval

PTC= Proof test coverage = $\lambda_{du}^{*} / \lambda_{du}$ (λ_{du}^{*}=failures revealed by the proof test)

Partial Proof Testing (PTC < 100%)

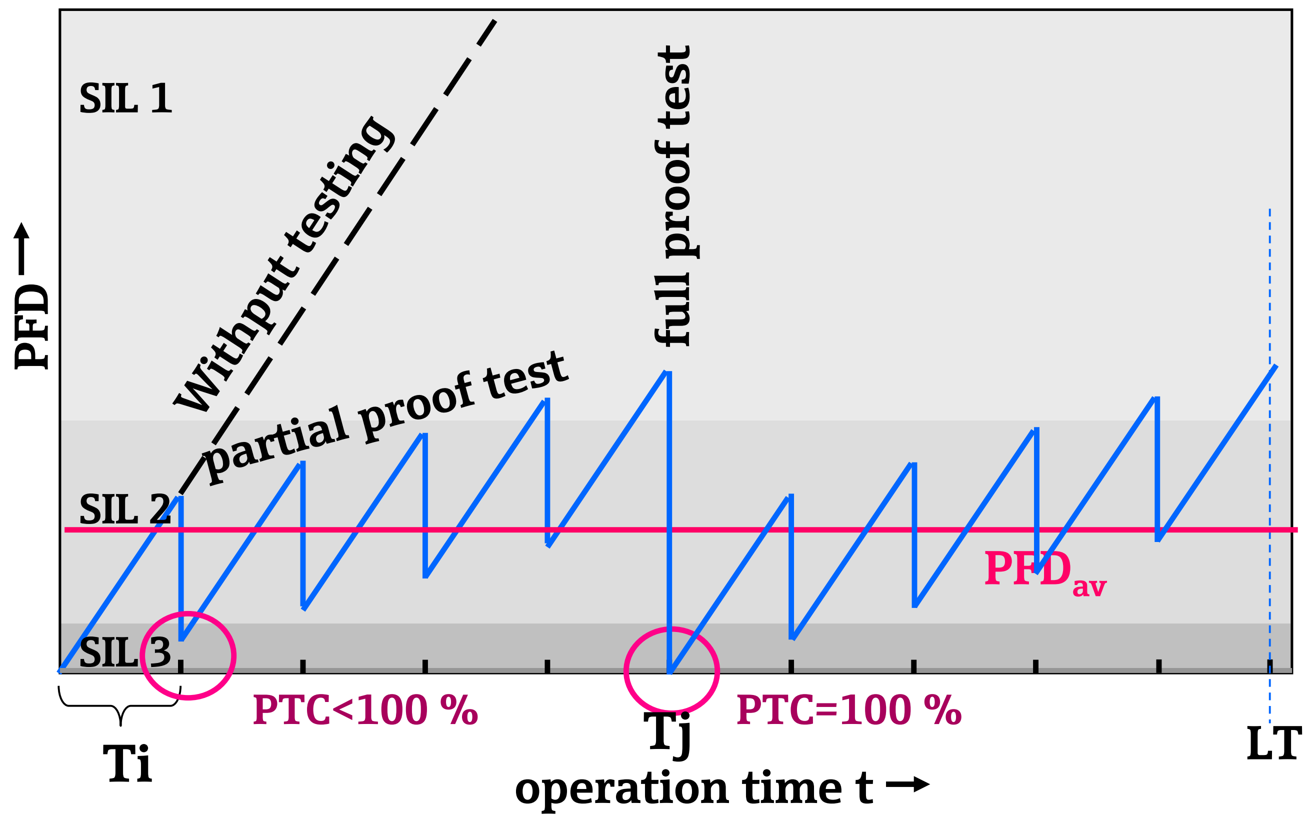


$$PFDav \approx \frac{1}{2}\ \lambda_{du} \times Ti \times PTC + \frac{1}{2}\ \lambda_{du} \times LT \times (1\text{-}PTC)$$

PTC= Proof test coverage (1=100 %)
Ti = Test interval **LT= life time**

Partial Proof Testing + Full Proof Test

Single channel system 1oo1



$$PFDav \approx \tfrac{1}{2}\ \lambda_{du} \times Ti \times PTC + \tfrac{1}{2}\ \lambda_{du} \times Tj \times (1-PTC)$$

PTC= Proof Test Coverage (1=100 %)
Ti = Test interval (<100 %)   Tj = Test interval (100%)

Constraints of the Hardware Architecture

- Device Type (Type)
- Safe Failure Fraction (SFF)
- Hardware-Failure Tolerance (HFT)

Device Types

- Device Type A (simple devices)

  All faults determined
  e.g. analogue electronic devices

- Device Type B (complex devices)
  Not all faults determined
  e.g. µP-controled electrical/electronical devices

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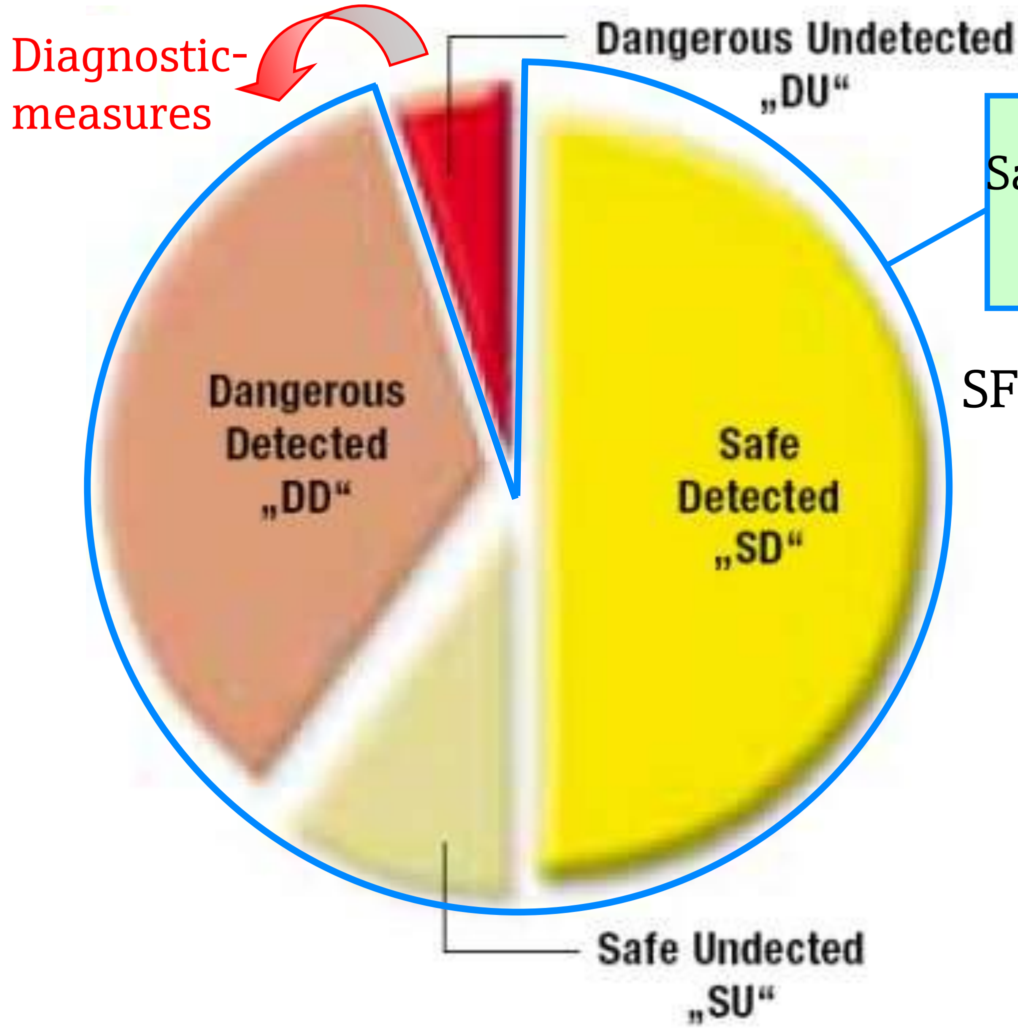
Safe Failure Fraction (SFF)

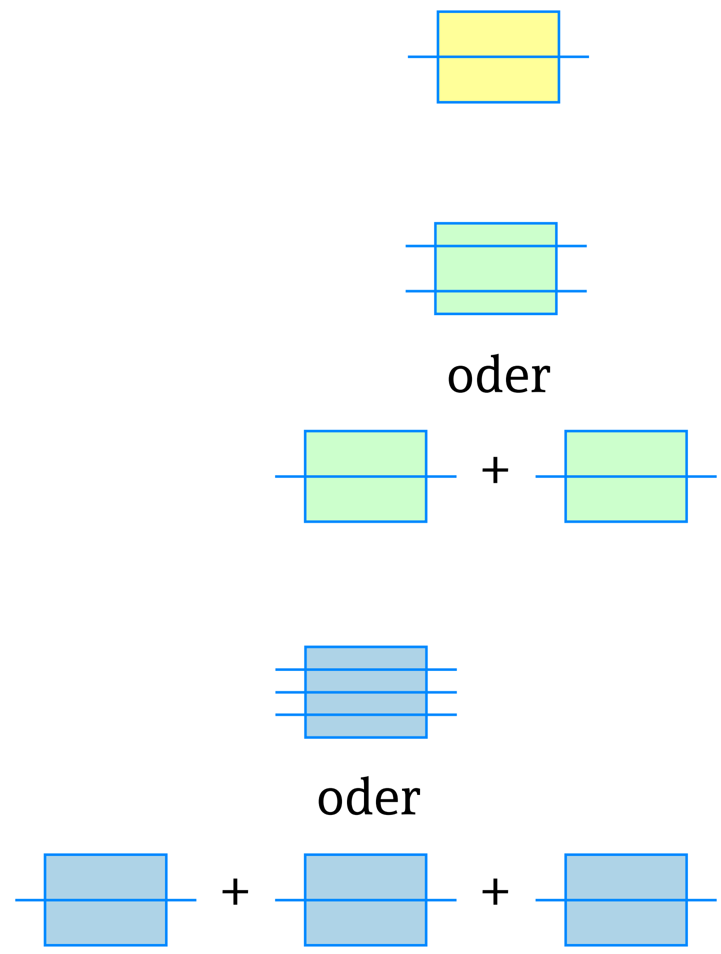


Safe Failure Fraction (SFF)
(in %)

$$SFF = \frac{\Sigma \lambda_{sd} + \Sigma \lambda_{su} + \Sigma \lambda_{dd}}{\Sigma \lambda_{tot}}$$

Hardware-Failure Tolerance (HFT)

- HFT = 0 → no redundancy
  1 fault ➔ loss of safety function
- HFT = 1 → redundant architecture
  2 faults ➔ loss of safety function
- HFT = 2 → 3 channel architecture
  3 faults ➔ loss of safety function



How to determine architectural constraints?

Example: Device Type B, HFT = 0, SFF =92% ➔ SILmax ?

Safe Failure Fraction (SFF)	Hardware-Failure Tolerance (HFT) (Typ B – complex device)		
	0	1	2
< 60%	Not allowed	SIL 1	SIL 2
60% … < 90%	SIL 1	SIL 2	SIL 3
90% … < 99%	SIL 2	SIL 3	SIL 4
≥ 99%	SIL 3	SIL 4	SIL 4

Basic Safety Parameters

Probability of Failure on Demand:	$PFD_{av} \approx 1/2\ \lambda_{DU} \times T_p$ *
Safe Failure Fraction:	$SFF = \frac{\Sigma \lambda_{sd} + \Sigma \lambda_{su} + \Sigma \lambda_{dd}}{\Sigma \lambda_{tot}}$
Hardware Fault Tolerance:	HFT= No. of tol. Faults
Device Type:	Type= A or B

*** 1 channel System**

↓

Safety Integrity Level
SIL 1...4

Design of Safety Instrumented Systems

- Single Channel System
- Multi-Channel System

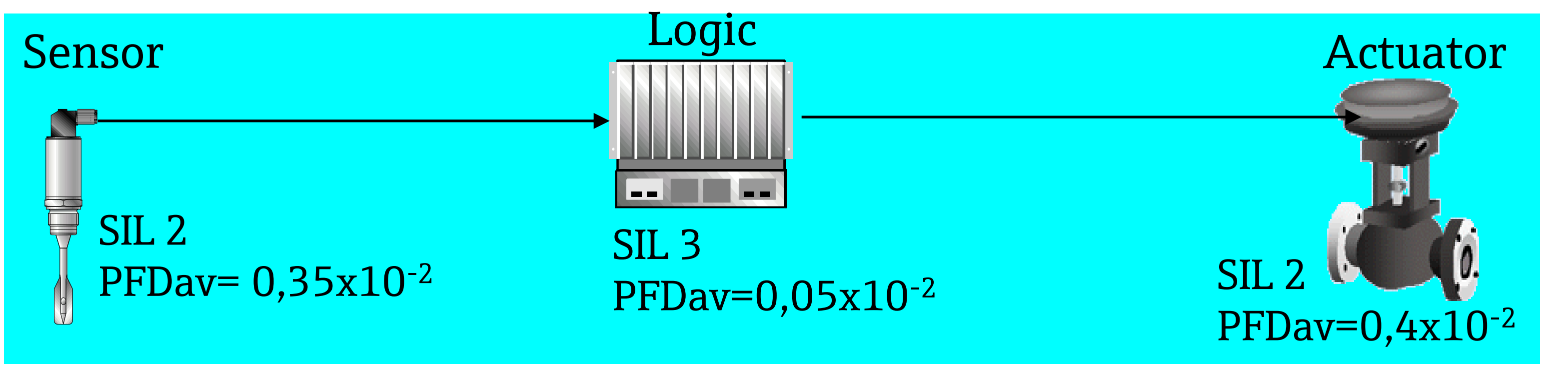
Single Channel System

Design rules

$SIL_S, SIL_L, SIL_A \geq SIL_{system}$

$PFD_S + PFD_L + PFD_A < 10^{-SIL_{system}}$

Example: single channel overfill protection



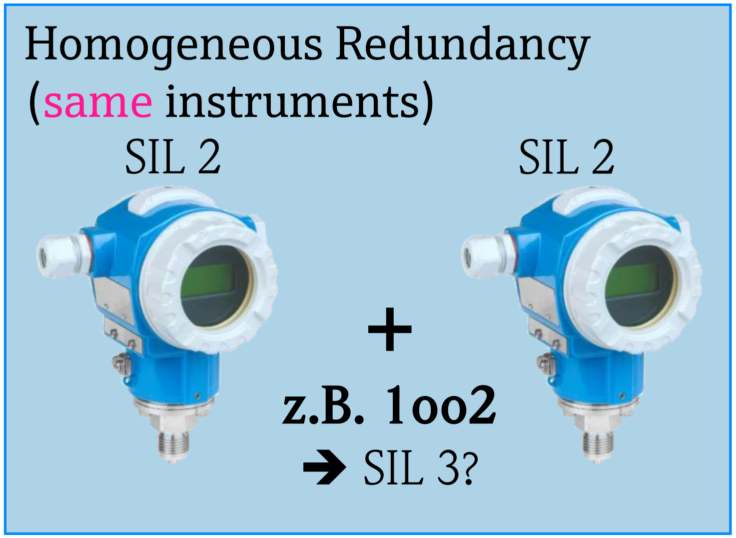
	Sensor	Steuerung	Aktor	System
SIL	2	3	2	≤2
PFD_{av}	$0{,}3\times10^{-2}$	$0{,}05\times10^{-2}$	$0{,}4\times10^{-2}$	$0{,}71 \times 10^{-2}$

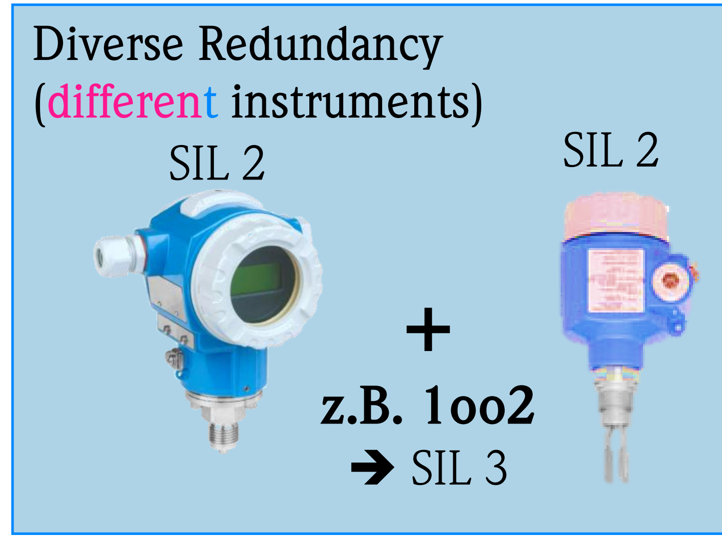
➔ System = SIL 2

Multichannel Architecture

- Homogeneous and diverse Redundancy
- Design rules

Redundancy: Homogeneous or diverse?





Advantage of homogeneous system

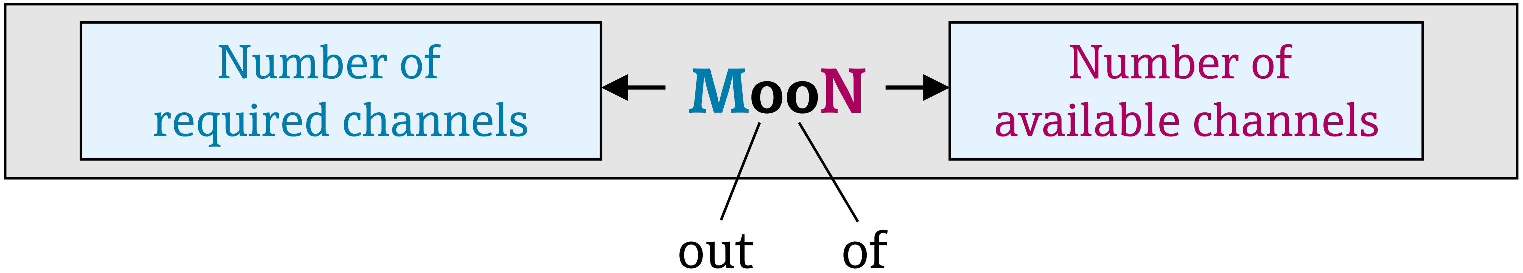
- Control of random faults
- Simple stock management, commissioning, maintenance …

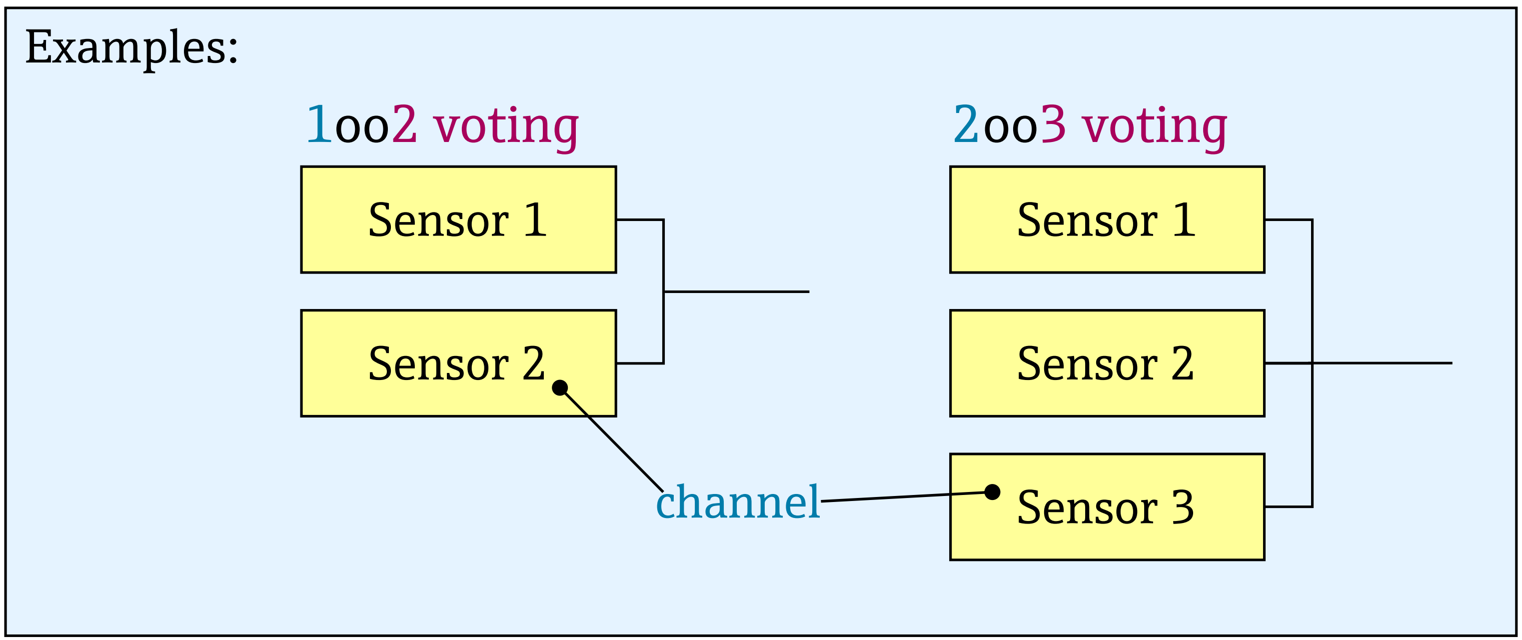
Note: Systematic Integrity (e.g. Software) can not be enhanced!

Advantage of diverse system

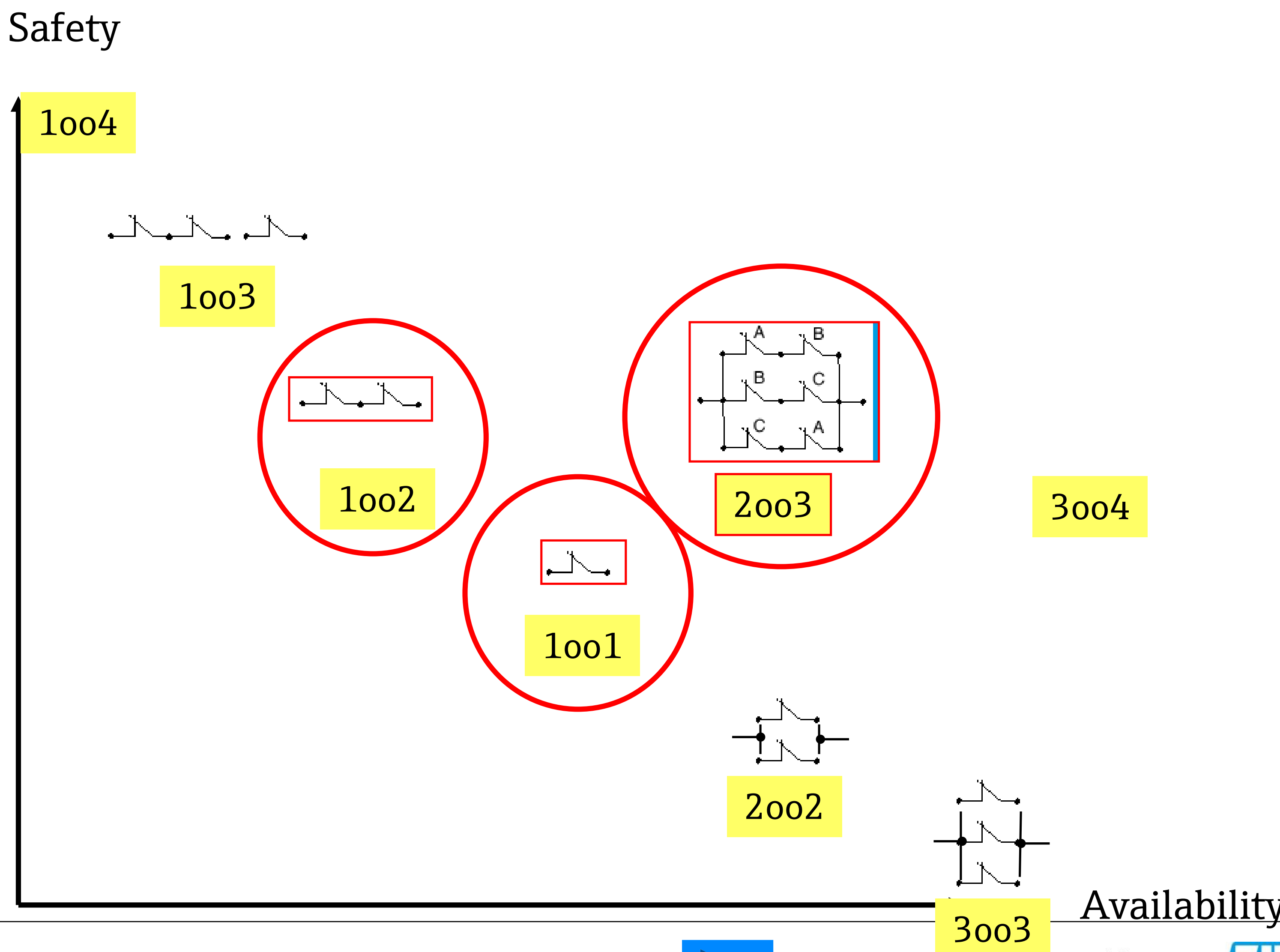
- Control of random and systematic faults (device + process)
- systematic integrity can be enhanced

MooN voting rules



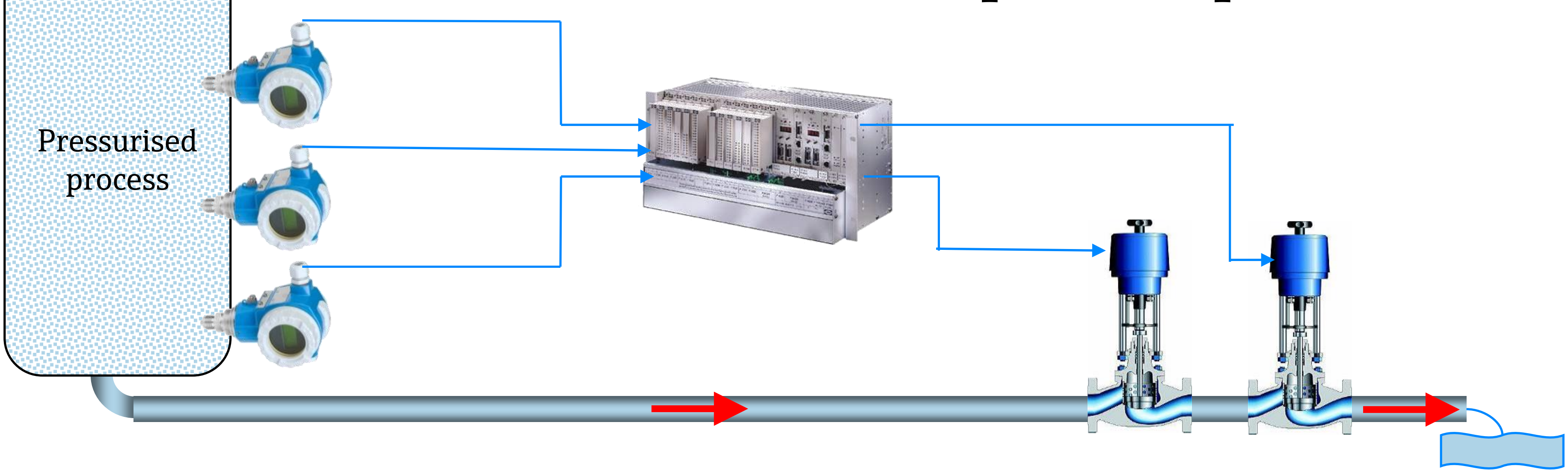


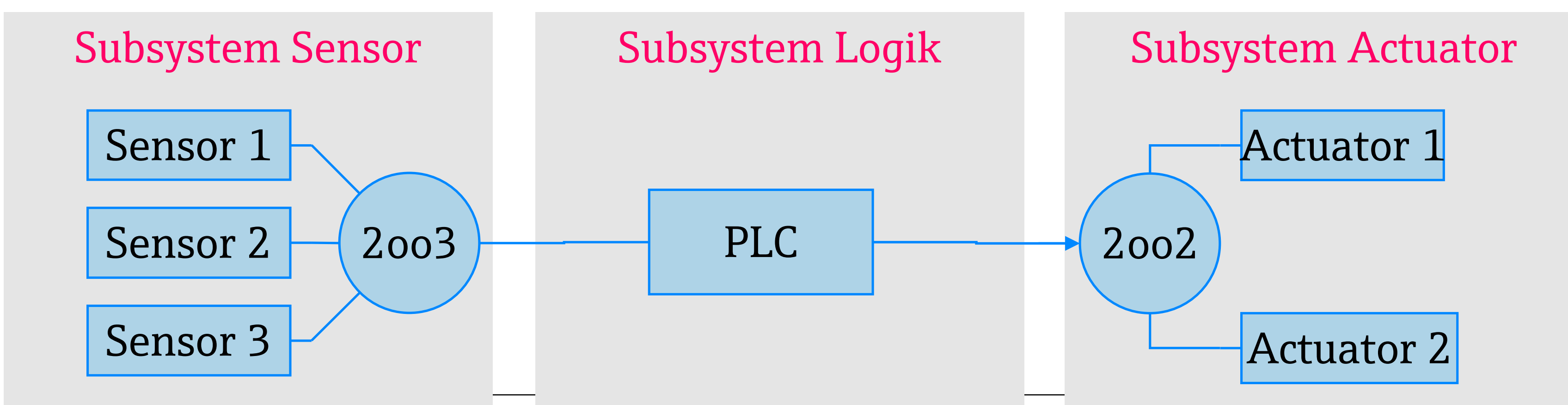
Design of Multi-Channel Systems



Design Rules of Multi-channel Systems

Overpressure protection





$$\underline{PFD_{sub1}} + \underline{PFD_{sub2}} + \underline{PFD_{sub3}} \leq 10^{-SIL}$$

Proof-testing with Endress+Hauser Instruments

- The Liquiphant Family
- Level Continuous
- Pressure
- Flow Instruments and Fieldcheck
- Overview of test procedures and parameters

Example 1- Level switch

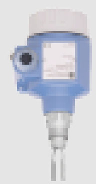




Liquiphant M FTL 50/51
Liquiphant S FTL 70/71
Liquiphant S FDL 80/81/85 + FTL 825 Fail Safe

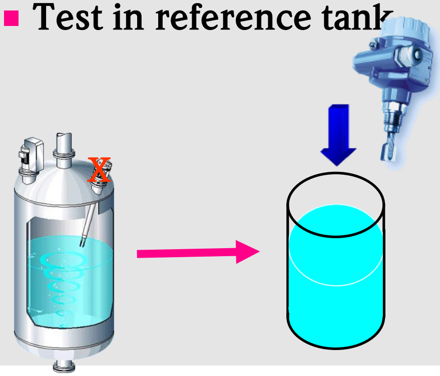
The Liquiphant Family – SIL qualified

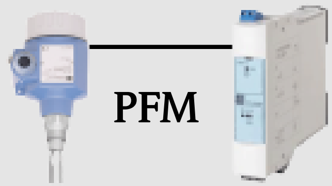
SIL2 MIN/MAX



Liquiphant M FTL 50/51
Liquiphant S FTL 70/71
Electronic:
FEL51, 2-Wire AC
FEL52, 3-Wire DC-PNP
FEL54, AC/DC DPDT
FEL55, 8/16 mA

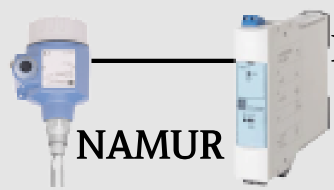
Peridic proof testing
- **Wet testing or**
- **Test in reference tank**





Liquiphant M FTL50/51
Liquiphant S FTL70/71
+ FEL 57+ FTL3x5 P

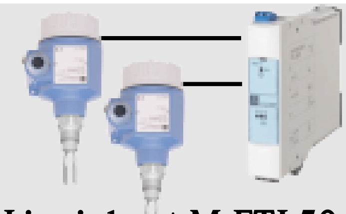
Peridic proof testing
- **Testgenerator (push-button)**



Liquiphant M FTL50/51
Liquiphant S FTL70/71
+FEL 56/58 + FTL325N

Peridic proof testing
- **Wet testing or**
- **Test in reference tank**
- **Alarm simulation (push-but)**

SIL3 MAX



Liquiphant M FTL50/51
Liquiphant S FTL70/71
+FEL 57 + FTL3x5 P

Periodic proof testing
- **Testgenerator (push-button)**

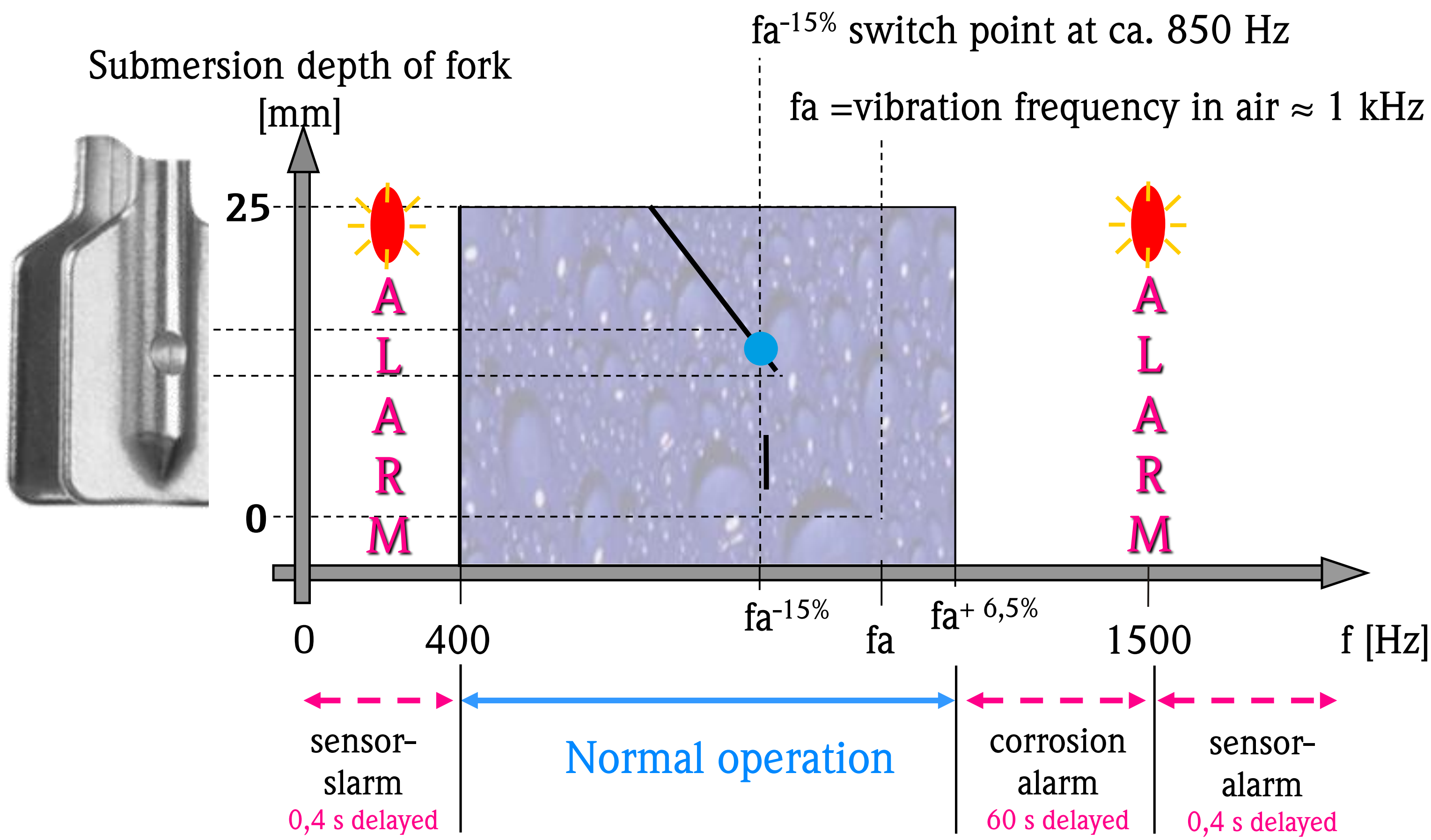
SIL 3 MIN/MAX

Liquiphant S Failsafe FTL8x
Nivotester FTL825

Periodic proof testing
- **Continuous self-diagnostic**
- **Testgenerator (push-button)**
- **Proof test interval ≤ 12 years!**

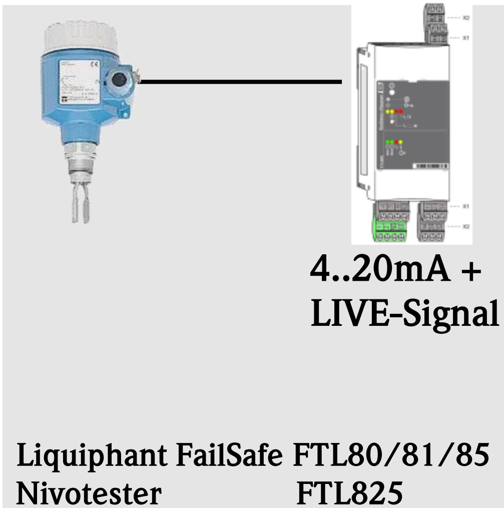
Self Diagnostics Liquiphant M/S (FEL 51... 67)

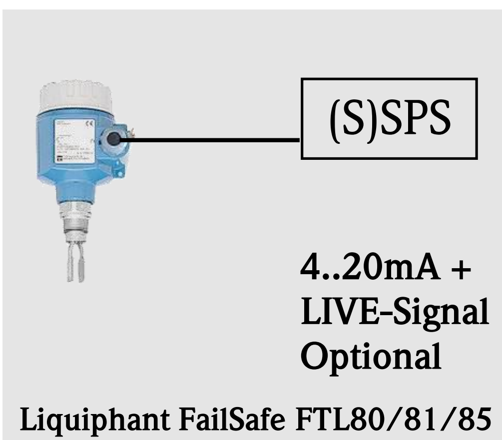
- Continuous monitoring of vibration frequency
- Reliable alarm funktion with each elektronic insert!



New: Liquiphant Fail Safe FTL 80/81/85 + FTL 825

SIL3 MIN/MAX





Safety function

- SIL 3 capable with single device
- min/max safety function
- 2 safety relay outputs (FTL 825)
- proof test generator with push-button
- proof test interval ≤ 12 years !

Total Proof test coverage (DC+PTC) according to IEC 61508

Total coverage (DC+PTC)	FTL80/81/85+ FTL825	FTL 80/81/85+ SSPS
Wet test	99% (Procedure IA MAX/MIN)	99% (Procedure IIA MAX/MIN)
Simulation (in situ testing!)	98 % (Procedure IB) (Testbutton: FEL85 od. FTL825)	95 % (Procedure IIB MAX/MIN) (Testbutton: FEL85)

Endress+Hauser

Example 2 – Level Continuous

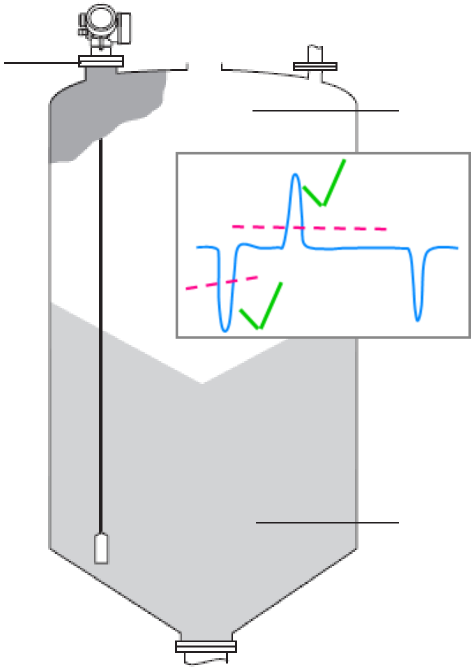
Levelflex FMP 4x, FMP 5x

Micropilot M/S FMR xxx

Levelflex FMP 5x

Safety Function:

- Level of liquid or bulk solid material (4..20 mA)
- Interface between 2 liquids (4..20 mA)
- Min, max, range
- SIL 2 (1oo1), SIL 3 (1oo2)
- LDM, HDM



Proof test procedures:

Test criterion: Trip level ±2 %

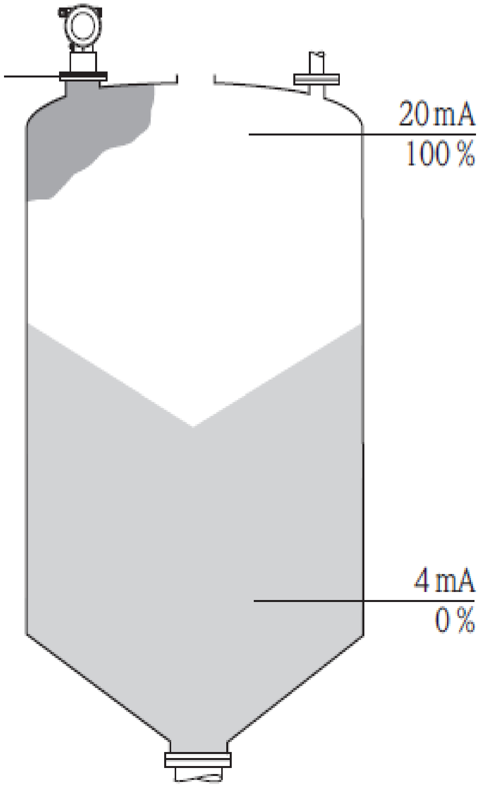
a) Wet testing in the application/reference tank (PTC≈ 98 %, Ti= 3 years)

b) In-situ level simulation (PTC≈ 92 %, Ti= 1 year)
(no process shutdown required!)

Micropilot FMR 5x

Safety Function:

- Level of liquid or bulk solid material (4..20 mA)
- Min, max, range
- SIL 2/3
- LDM, HDM



Proof test procedures:

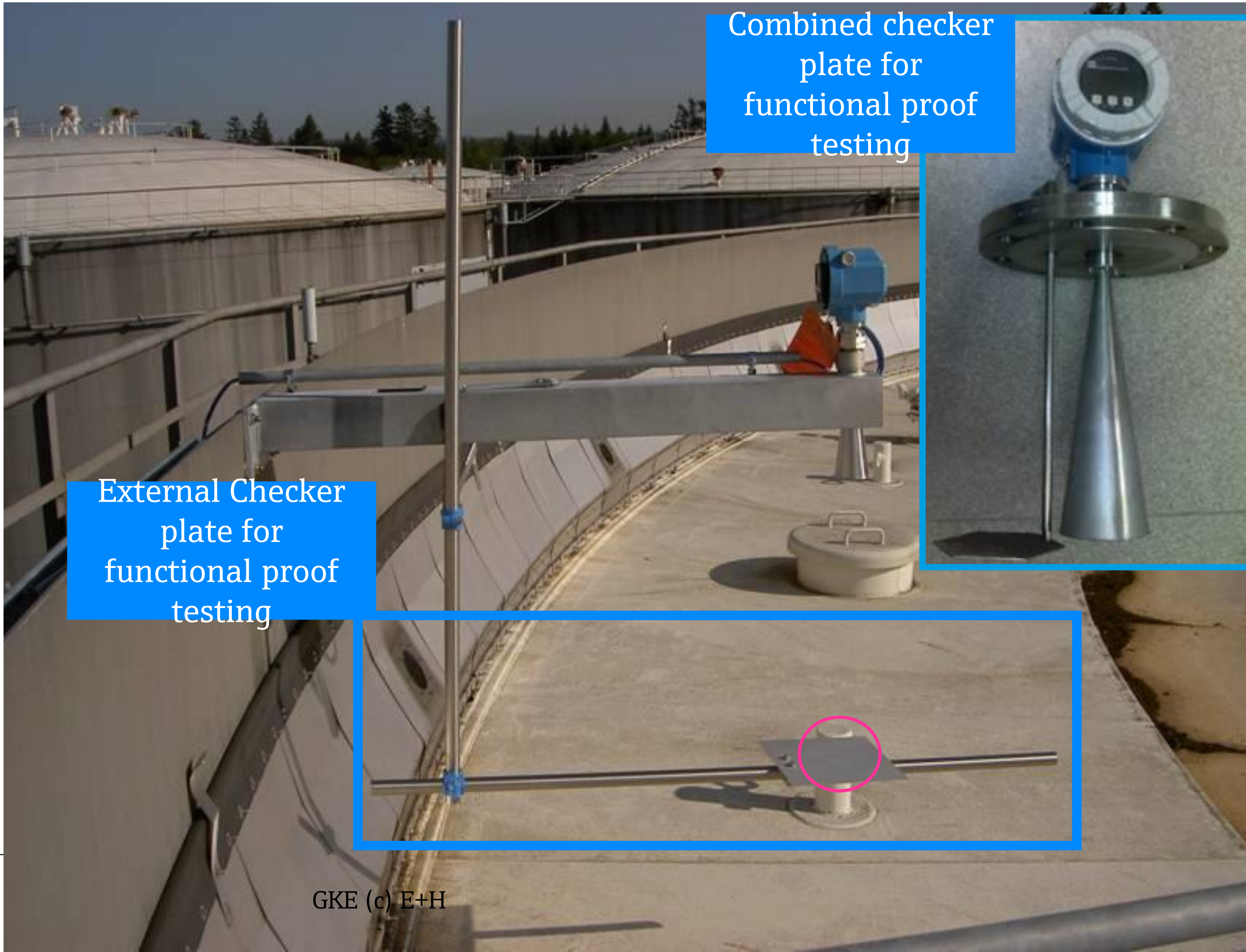
Test criterion: Trip level ±2 %

a) Wet testing in the application (PTC≈ 98 %, Ti=2 years)

b) Simulation (PTC≈ 55 %, Ti=1 year)

Proof testing with Level Radar

Independent High Level Alarms / Radar – Proof Testing external



Example 3 - Pressure Measurement

Cerabar S PMC 71, PMP 71/72/75

Deltabar S PMD 70/75, FMD 76/77/78

Cerabar S, Deltabar S

Safety function

- Pressure, Level (4… 20 mA)
- min, max, range
- SIL 2 (1oo1), SIL 3 (1oo2)
- LDM, HDM

Proof test procedures:

- test with reference pressure (Ti ≤ 5 years, PTC≈99 %)
- in-situ test with signal simulation (Ti=1 year, PTC ≈ 50 %)
  tool: HART communication or Display keyboards

Test criterion: trip level ±2%

Example 4 – Flow Measurement

Promass 80, 83 [Coriolis]
Promag 50, 53 [MID]
Prowirl 72, 73 [Vortex]

Promass 80, 83 Promag 50, 53 Prowirl 72,73

Safety function:

- Volume flow, Mass flow[1], density[1] (4…20 mA) [1]Promass only!
- Min, max, range
- SIL 2 (1oo1), SIL 3 (1oo2) [1]

Proof test procedures:

Test criterion: Trip level ± 2%

1. in- or off-line test with a calibration rig (PTC≈98 %, Ti ≤ 5 years)
   mobile or factory calibration: volume flow, mass flow or density
2. in- or off-line test with the integrated totaliser (PTC≈ 98 %, Ti ≤ 5 years)
   measuring a reference volume or mass
3. in-line test of density by reference liquids[1] (PTC≈ 98 %)
4. in-line test with the Field Check (PTC ≈ 90 %, Ti = 1 year)
   (volume flow, mass flow, density)
   „Field Care“ ➔ automatised data recording

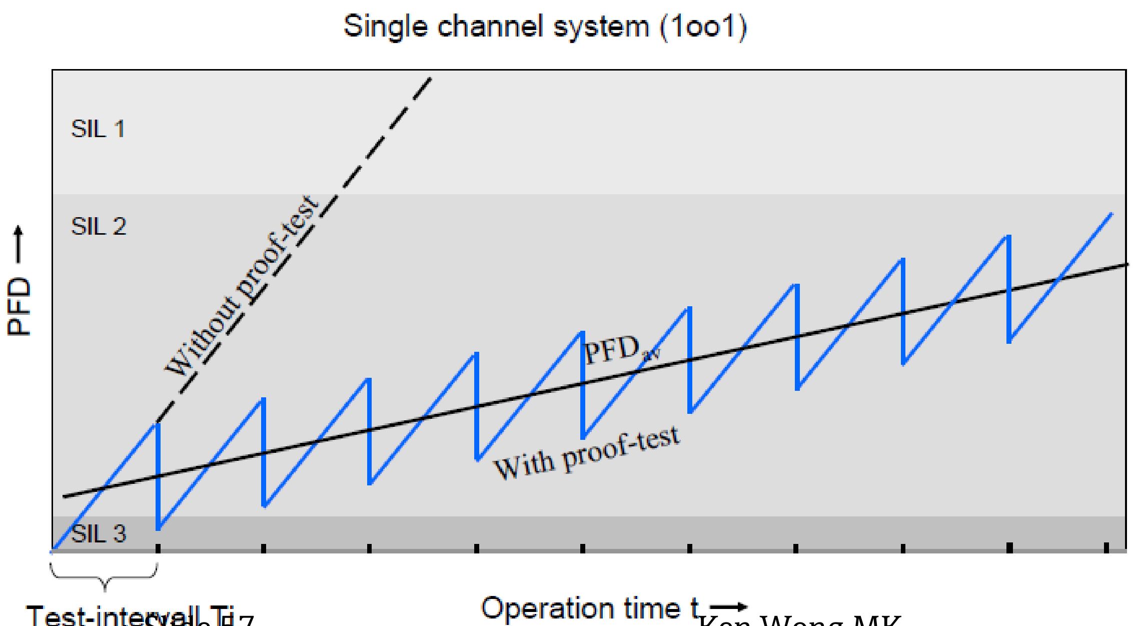
➔ calibration rig/totalizer test: ≤ 10 years

Flow Measurement - Easy proof testing

Example: Promag 50, 53 , Promass 80, 83

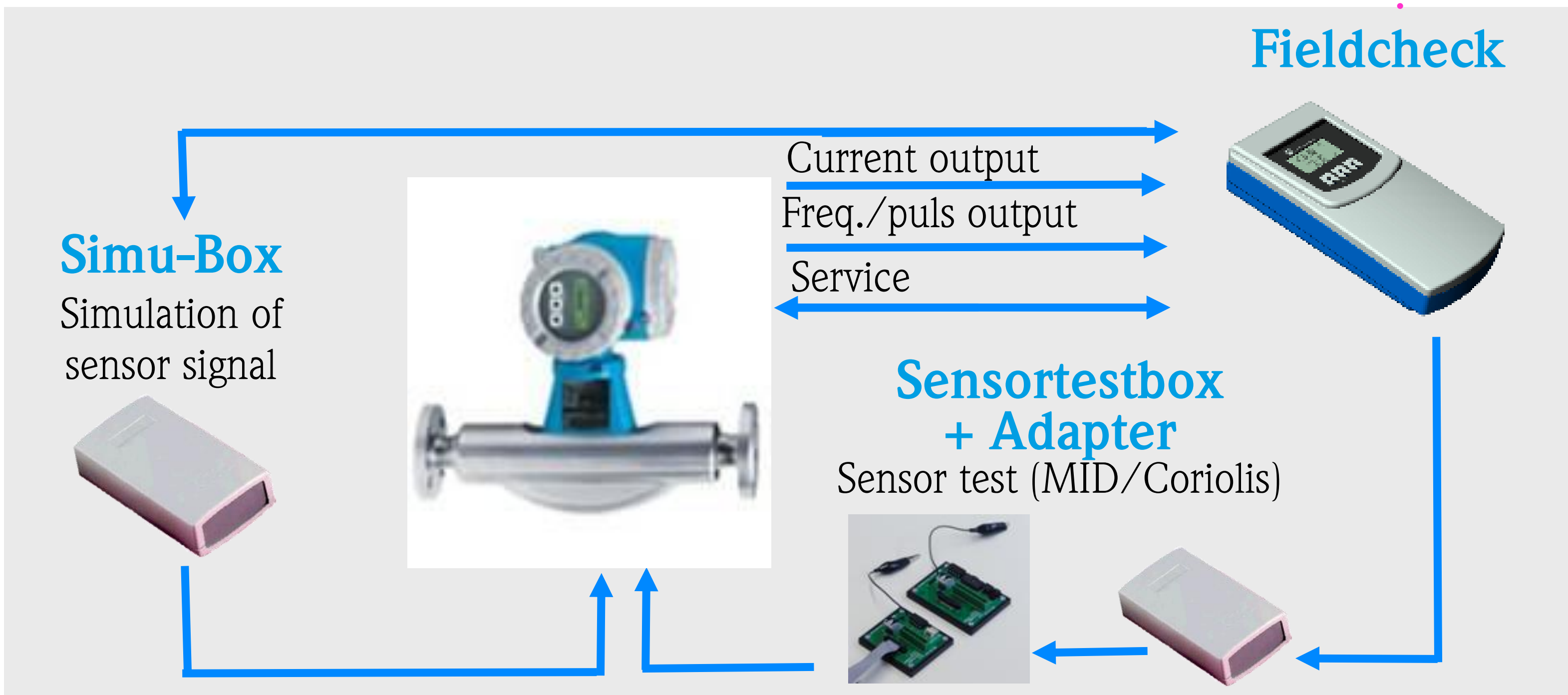
Proof-test methods, either

- Off-line proof test with calibration rig
- In-line proof test using the totalizer with balancing method
- In-line proof test by simulating partial proof-test with fieldcheck

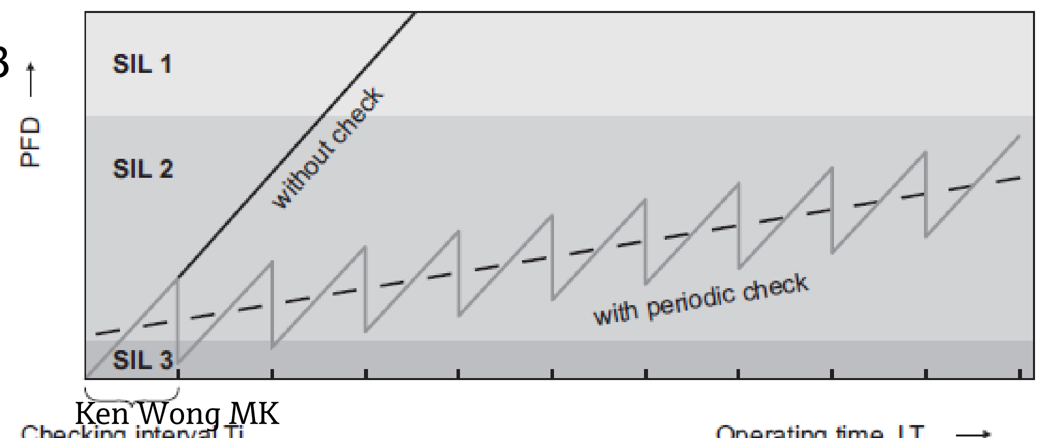


Principle of the verification of an electromagnetic flowmeter with FieldCheck.

Partial proof test with Fieldcheck (PTC≈ 90 %)



Promass 80, 83



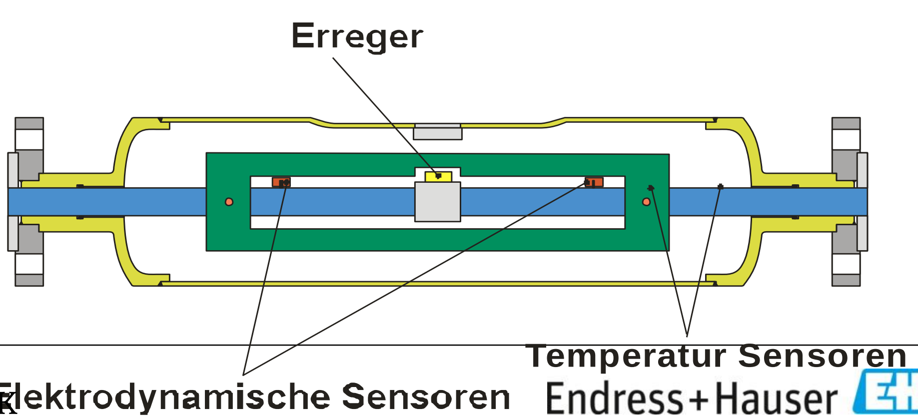
Fieldcheck: In-Line Verification Promass, Promag, Prowirl

Transformer...

- Zero point verification of outputs
- Verification of signal processing
- Linearity check of measuring amplifier
- Linearity check of output signals

...sensor verification suitable to measuring principle, e.g. Promass

- Stimulating coils
- Signal coils
- Temperatur sensors



Example 5 - Temperature

iTEMP TMT 112/122/162/182

TMT 112

TMT 122

TMT 162

TMT 182

iTEMP TMT 112/122/162/182

Safety function:

- Temperature measurement (4…20 mA)
- Min, max, range
- SIL 2

Proof test procedures:

Test criterion: trip level ± 2%

- test with reference temperature measurement (PTC ≈ 98 %)
- simulation with input restistor incl. short circuit/ interruption

Test interval:

- ≤ 1 year with 2/3-wire RTD or thermocouple („low stress“ ≤0,1 g)
- ≤ 5 years with 4-wire RTD („low stress““ ≤0,1 g)

Environmental Effect on Thermocouples/RTDs

Effect on Thermocouples/RTDs

- Failure rates for separate elements with „high stress““ >0,1 g 20x higher!

Example:

Thermocouple Failure Mode Distribution (close coupled)	Low Stress Fit	Percentage	High Stress	Percentage
Open Circuit (Burn-out)	95	95%	1900	95%
Short Circuit (Temperature measurement in error)	4	4%	80	4%
Drift (Temperature measurement in error)	1	1%	20	1%
	total	*total*	*total*	*total*
	100	100%	2000	100%

Overview Proof-tests E+H Instruments

Device	Type	Electronic	SIL	Safety function	Prooftest procedure	Proof test interval	Proof test coverage	Tolerance
Liquiphant M/S	FTL 5x FTL 7x	FEL51,52, 54,55,56,58	2	min/max	Wet test Test-button[1]	≤ 5 years On request	98 % --	--
Liquiphant M/S	FTL 5x FTL 7x	FEL57 (PFM)	2 (3)	min/max max	Wet test Test-button[2]	≤ 5 years[3] ≤1 year	98 % 90 %	--
Liquiphant FS	FTL 8x		3	min/max	Wet test Test-button[1]	≤12 years On request	98 %	--
Levelflex	FMP 5x		2 (3)	min/max/ range Interface	Wet test Test simulation	≤3 years ≤1 year	98 % 92 %	±2 %
Micropilot	FMR 5x		2 (3)	min/max/ range	Wet test Test simulation	≤2 years ≤1 year	98 % 55 %	±2 %
Cerabar S Deltabar S	PMC PMP		2 (3)	min/max/ range	Wet test Test simulation	≤ 5 years	98 % 50 %	±2 %

[1] test only subsequent safety loop
[2] complete test simulation
[3] only low density media (<0,7)

Overview Proof-tests E+H Instruments

Device	Type	Electronic	SIL	Safety function	Prooftest procedure	Proof test interval	Proof test coverage	Tolerance
Promass	80,83		2 (3)	volume mass/density Min/max/ range	Calibration Totalizer Field check	≤ 5 years ≤ 5 years ≤ 1 year	98 % 98 % 90 %	Reference accurracy
Promass 200	E200 F200		2 (3)	volume mass/density Min/max/ range	Calibration Totalizer	≤ 5 years ≤ 5 years ≤ 1 year	98 % 98 % 90 %	Reference accurracy
Promag Prowirl	50/53 72/73		2	Min/max/ range	Calibration Fieldcheck	≤ 5 years ≤ 1 year	98 % 90 %	Reference accurracy
Temperatur iTemp	TMT 1x2		2	min,/max/ range	Calibration with reference resistor	≤ 1 year[4)] ≤ 5 years[5)]	98 %	±2 %

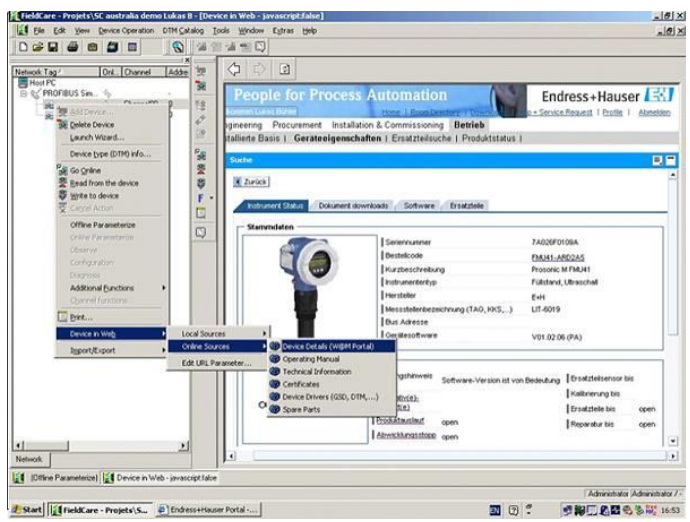
[4]) 2/3 wire RTD or thermocouple (low stress environment ≤ 0,1 g)
[5)] 4 wire RTD (low stress environment ≤ 0,1 g)

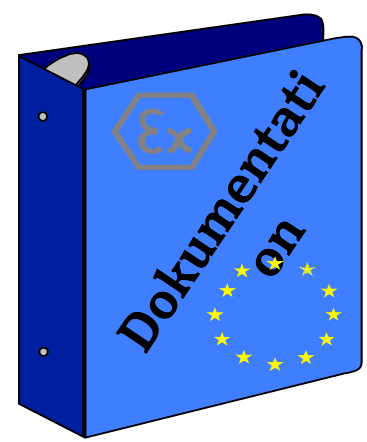
Proof-Test Documentation
W@M Lifecycle Management

Endress+Hauser
People for Process Automation

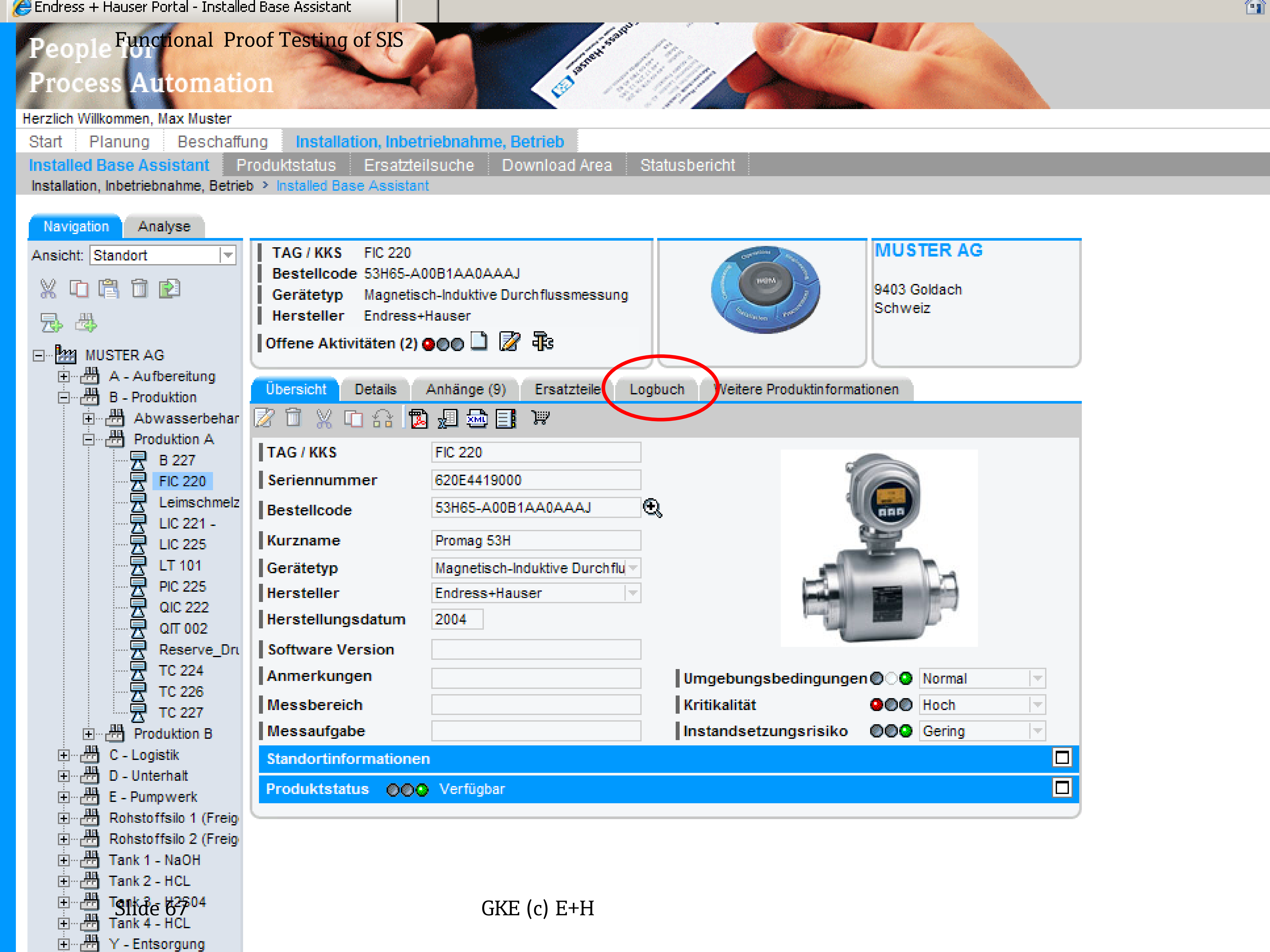
Proof-Test Documentation with Fieldcare

- Electronic data recording and documentation on PC
- W@M Life cycle management
  - Upload of Data with Fieldcare/Fieldtool into Common Equipment Record (CER)
  - Integration into computer based maintainance systems e.g. SAP Plant Maintenance, IBM Maximo, Datastream7i, Comos PT





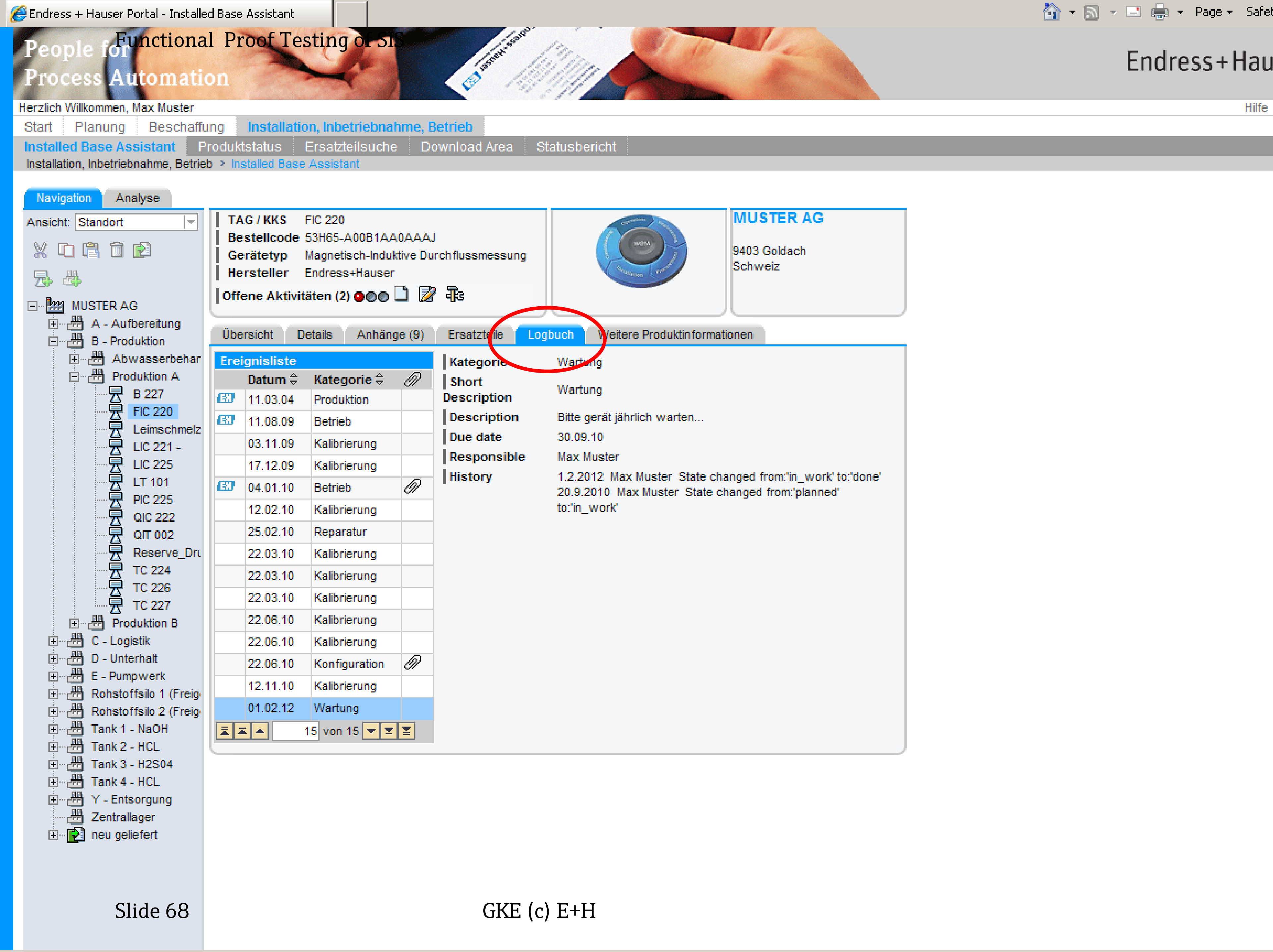
Functional Proof Testing of SIS



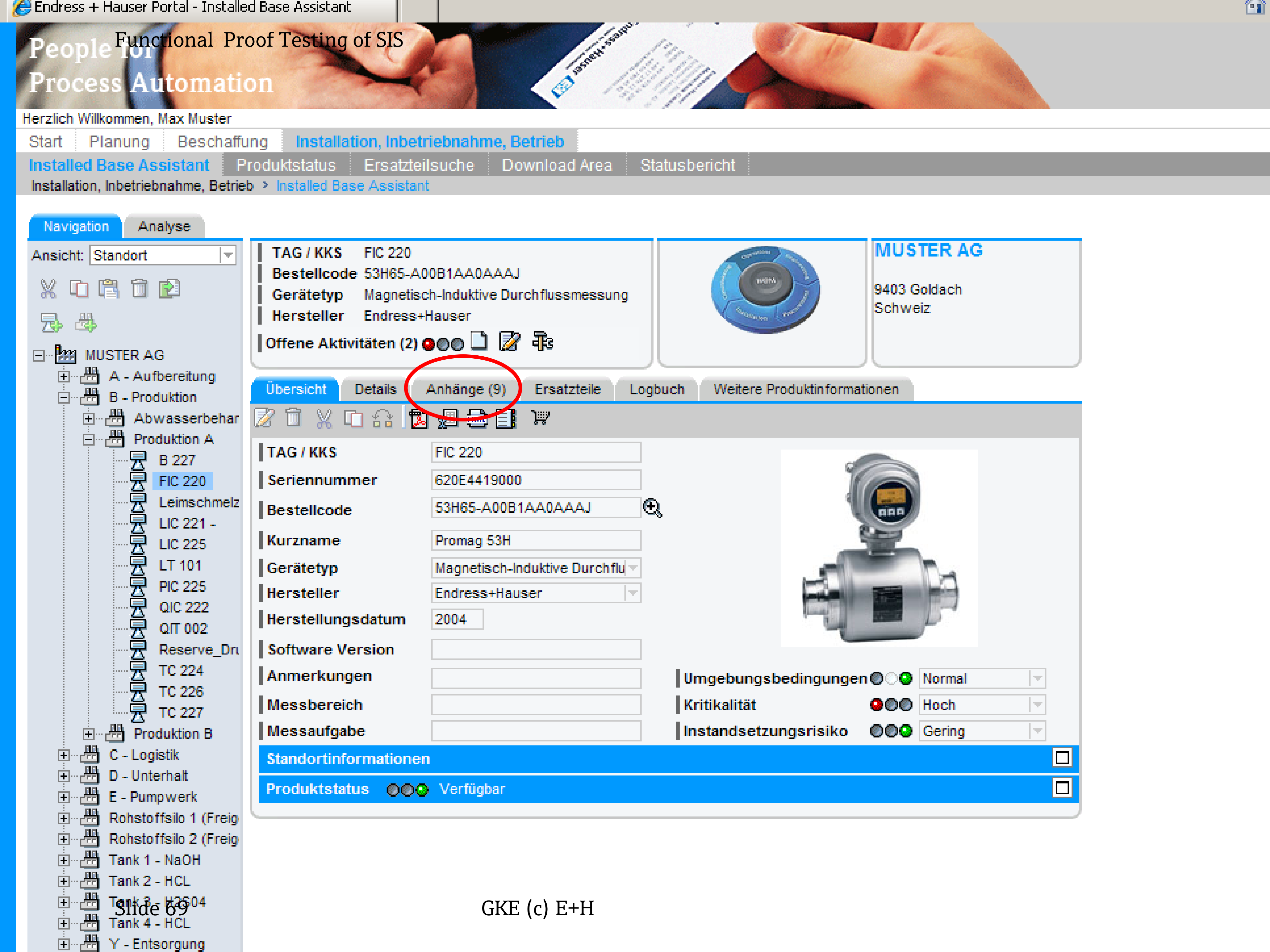
Slide 67

GKE (c) E+H

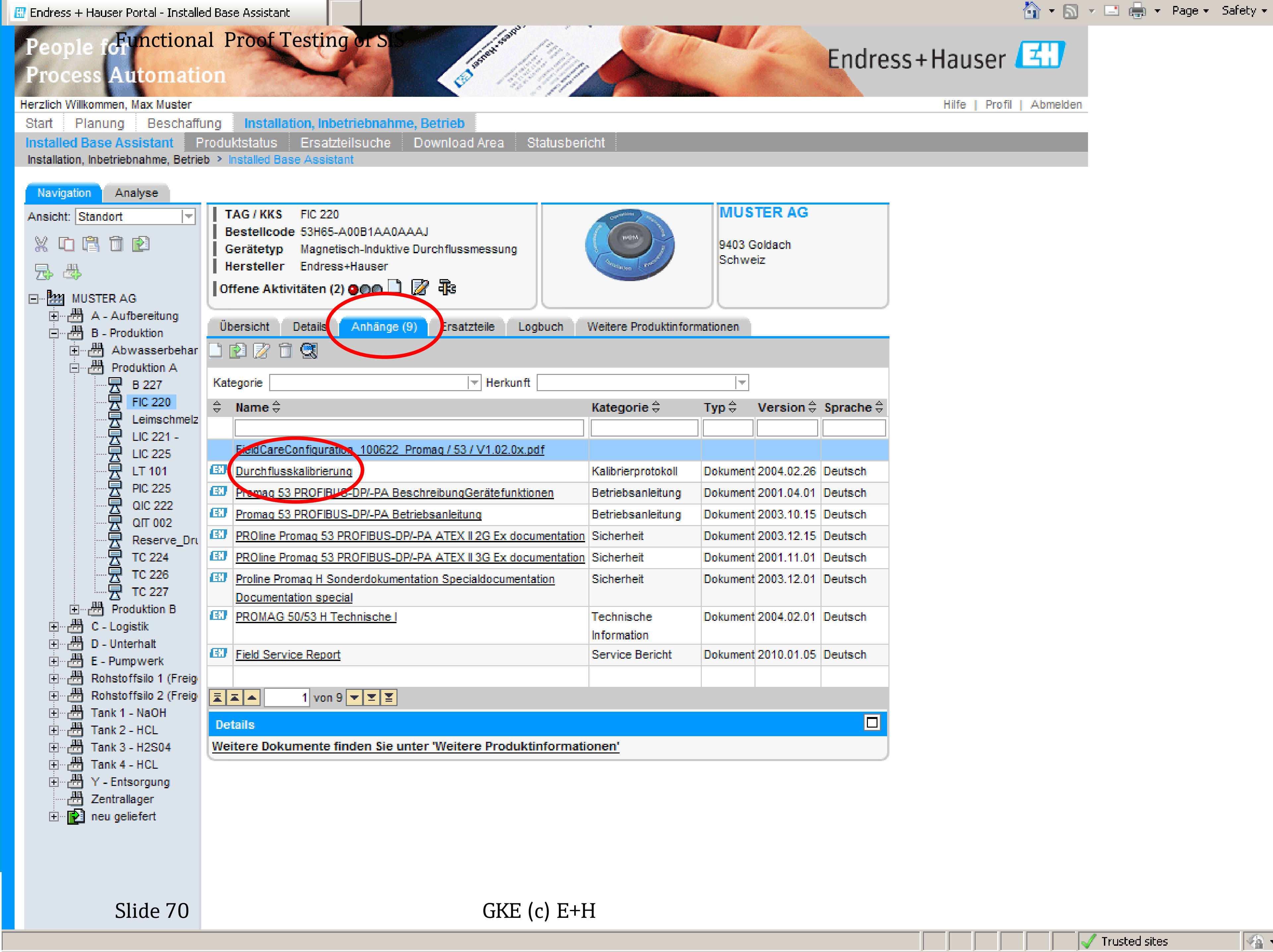
Functional Proof Testing of SIS



Functional Proof Testing of SIS



Functional Proof Testing of SIS



GKE (c) E+H

Proof-Test protocol: Example Micropilot S

System-specific data		
Company	Mustermann AG	
Measuring points / TAG no.		
System		
Device type / Order code		
Serial number of device		
Name		
Date		
Signature		
Device-specific commissioning parameters		
Empty calibration		
Full calibration		
Proof-test protocol		
Test stage	Set point	Actual value
1. Current value 1		
2. Current value 2		
3. If necessary current value 3		
4. If necessary current value 4		
5. If necessary current value 5		

Endress+Hauser Service

- Periodic Proof-tests
- Calibration Service

Endress+Hauser Verification and Proof-Test Service

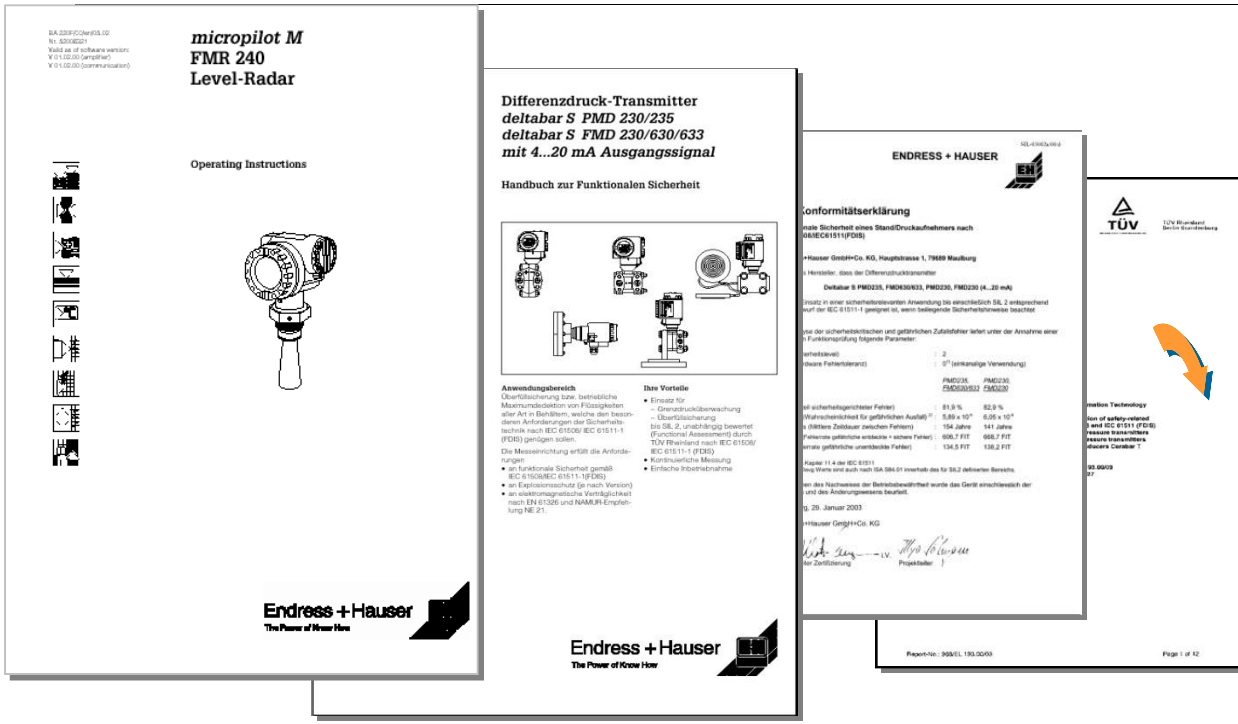
- Periodic verification with Fieldcheck
  - Promass
  - Promag
  - Prowirl
- Proof-Test via Calibration Service
- Electronic data recording and Documentation

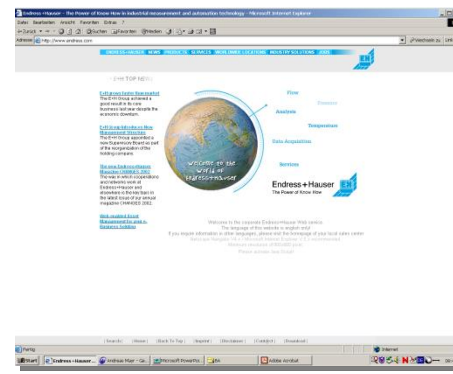
Order Code Structures for SIL devices

3 Options:

1. Older devices assessed by proven-in-use experience
   (e.g. Levelflex FMP 4x, Promass 80)
   - order standard device 4…20 mA
   - order safety manual separately or
   - download safety manual from www.endress.com/SIL
2. Cerabar, Deltabar
   - order standard device with SIL –Declaration of conformity (back-pack)
   - device is delivered with safety manual, SIL Declaration of Conformity with serial No. of product, SIL marking
3. New products developed acc. to IEC 61508
   (e.g. Levelflex FMP 5x, Promass 200)
   - order SIL device (separate order code)
   - device is delivered with safety manual, declaration of conformity/Certificate, SIL marking

Functional Safety - Related documentation





Safety Manual

includes:
- manufacturer declaration
- fundamental safety parameters
- assessment report
- application information
- parameter settings

- www.endress.com/SIL
- Engine

SIL-Approval – Who may issue it?

Who is authorised to qualify the functional safety?

IEC 61508 recommendation:

SIL	Minimum degree of independence
SIL 1	Independent Person
SIL 2	Independent department
SIL 3	Independent organisation
SIL 4	Independent organisation

SIL approvals

- SIL-Declaration of Conformity (Manufacturer)
- SIL-Certificate (Approval body, e.g. TÜV, Exida)

Level Pressure Flow Temperature Liquid Analysis Registration Systems Components Services Solutions

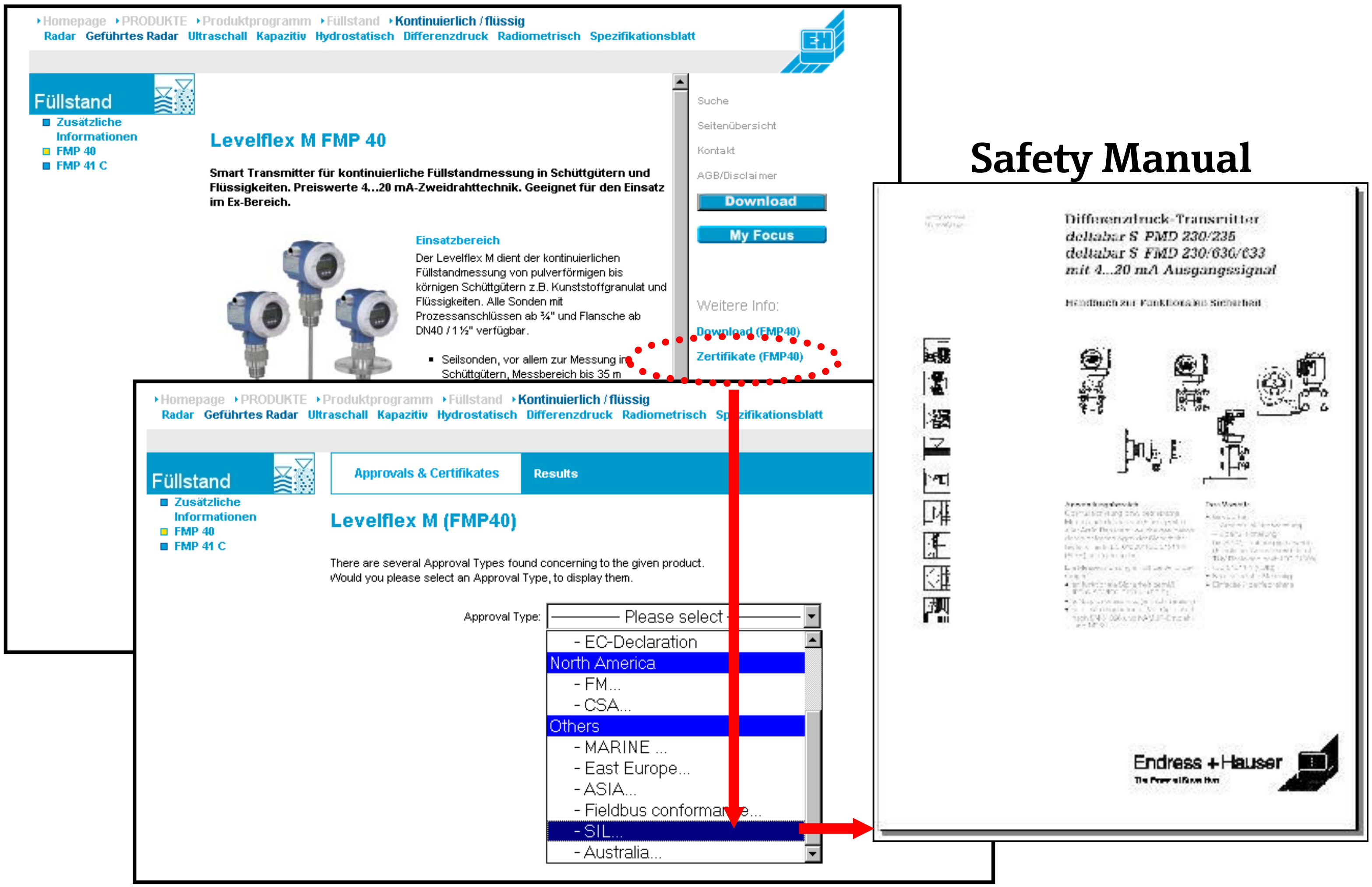
SIL-12132a/00/A2

SIL-Konformitätserklärung

Funktionale Sicherheit nach IEC 61508

Gerät/Device	Micropilot FMR50/51/52/53/54/56/57
Handbuch zur Funktionalen Sicherheit/ Functional safety manual	SD001087F/00
Sicherheitsfunktion/Safety function	MIN, MAX, Bereich/Range
SIL	2, 3 *3
HFT	0
Gerätetyp/Device type	B
Betriebsart/Mode of operation	Low demand mode, High demand mode
SFF	92 %
PFD_{avg} *1 T_1 = 1 Jahr/year (einkanalig/single channel)	1.09×10^{-3}
PFD_{avg} *1 T_1 = 2 Jahre/years (einkanalig/single channel)	2.17×10^{-3}
PFH	2.45×10^{-7} 1/h
λ_{sd} *2	15 FIT
λ_{su} *2	520 FIT
λ_{dd} *2	2438 FIT
λ_{du} *2	245 FIT
λ_{tot} *2	3218 FIT
MTBF *4	50 Jahre/years

Safety Manual at “www.endress.com/SIL”

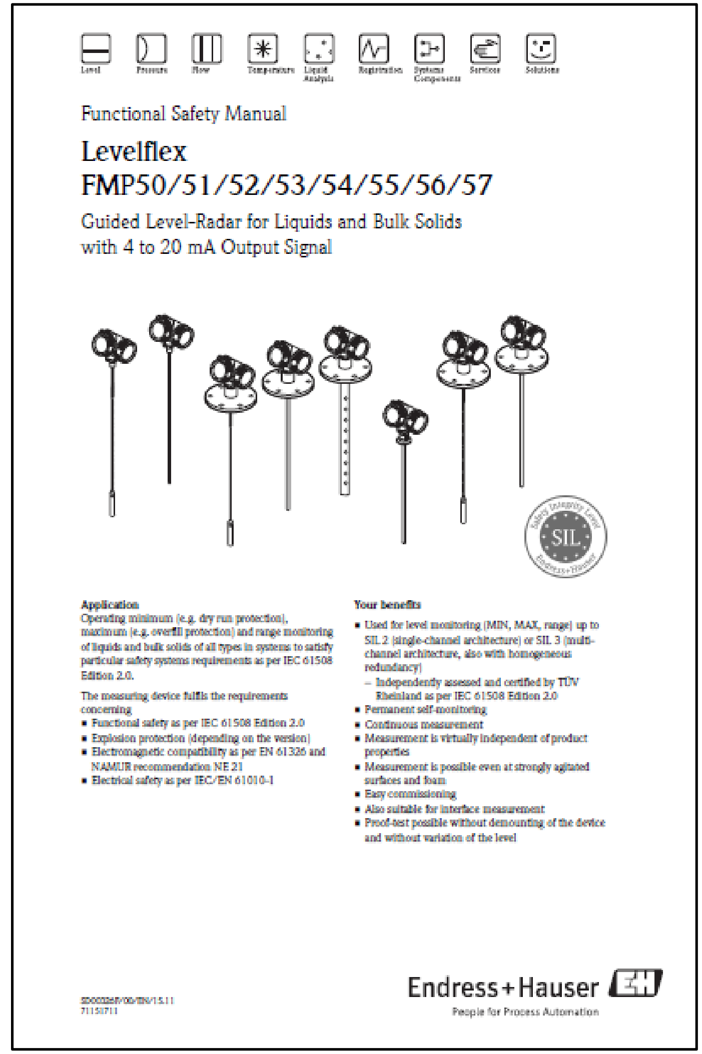


Endress+Hauser

The Functional Safety Manual

Contents

- Set-up of the safety system
- Description of the safety function
- Safety Parameters
- Ambient conditions, tolerance, restrictions
- Behavoir under normal and fault operation
- Installation and comissioning
- Parametrisation
- Functional proof test
- Maintenance and repair



Level Pressure Flow Temperature Liquid Analysis Registration Systems Components Services Solutions

Functional Safety Manual

Levelflex
FMP50/51/52/53/54/55/56/57

Guided Level-Radar for Liquids and Bulk Solids
with 4 to 20 mA Output Signal

Application
Operating minimum (e.g. dry run protection), maximum (e.g. overfill protection) and range monitoring of liquids and bulk solids of all types in systems to satisfy particular safety systems requirements as per IEC 61508 Edition 2.0.

The measuring device fulfils the requirements concerning
- Functional safety as per IEC 61508 Edition 2.0
- Explosion protection (depending on the version)
- Electromagnetic compatibility as per EN 61326 and NAMUR recommendation NE 21
- Electrical safety as per IEC/EN 61010-1

Your benefits
- Used for level monitoring (MIN, MAX, range) up to SIL 2 (single-channel architecture) or SIL 3 (multi-channel architecture, also with homogeneous redundancy)
  – Independently assessed and certified by TÜV Rheinland as per IEC 61508 Edition 2.0
- Permanent self-monitoring
- Continuous measurement
- Measurement is virtually independent of product properties
- Measurement is possible even at strongly agitated surfaces and foam
- Easy commissioning
- Also suitable for interface measurement
- Proof-test possible without demounting of the device and without variation of the level

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People for Process Automation

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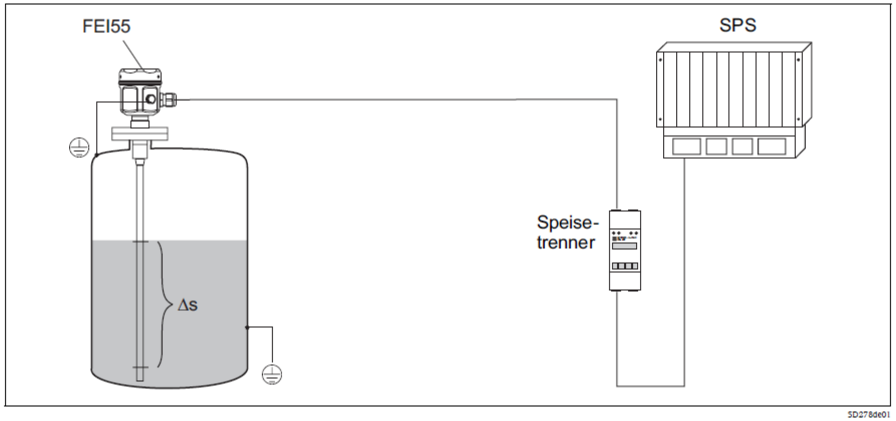
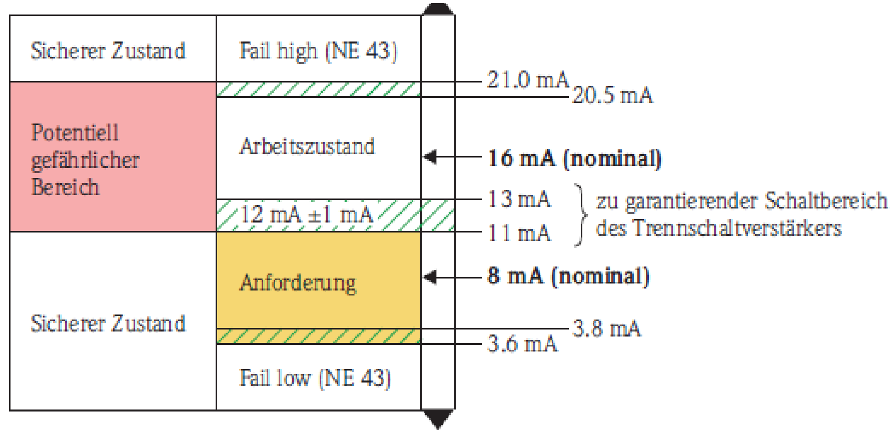
The Functional Safety Manual- contents

Set-up of the safety system

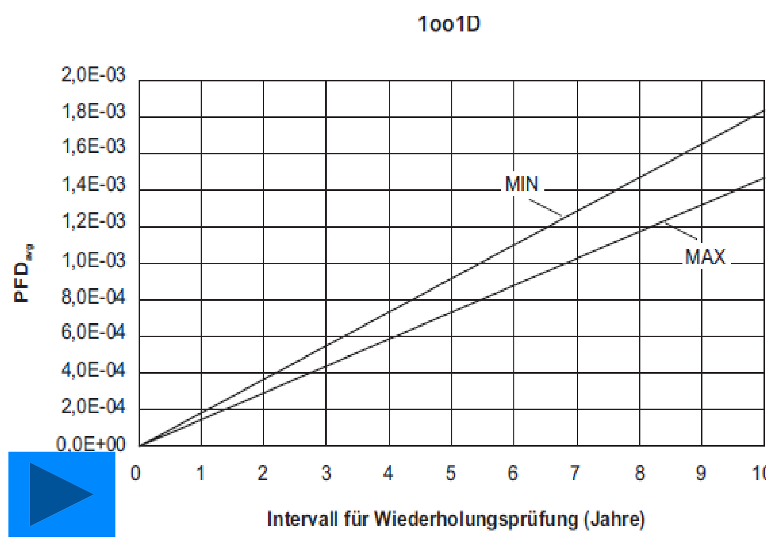


Safety related output signal:



Kenngröße gemäß IEC 61508	Wert	
Sicherheitsfunktionen	MIN-Sicherheit	MAX-Sicherheit
SIL (Hardware)	2 (einkanalig), 3 (mit SIL 3-fähiger Auswahlschaltung), → 18, "Anhang"	
SIL (Software)	3	
HFT	0	
Gerätetyp	B	
Betriebsart	Low demand mode	
SFF	92 %	94 %
MTTR	8 h	
Empfohlenes Zeitintervall für Wiederholungsprüfung T_1	1 Jahr	
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	[illegible]
PFD_{avg} für T_1 = 1 Jahr *2	$1{,}85 \times 10^{-4}$	$1{,}46 \times 10^{-4}$

Proof test interval



Safety by Choice, not by Chance!

Micropilot

Levelflex

Product	Type	Assessment	Rating
Cerabar S	PMC71, PMP71,72,75	EN 61508	SIL 2/3
Cerabar M	PMC 5x	prior use	SIL 2
Deltabar S	PMD 75, 76,77, 78	EN 61508	SIL 2/3
Deltapilot S	FMB 70	EN61508	SIL 2/3
Liquiphant M/S	FTL 5x, 7x FEL 5x	EN 61508	SIL 2
Liquiphant M/S	FTL 5x 7x, FEL 57 (PFM)	EN 61508	SIL 2/3
Liquiphant FS	FTL 8x	EN 61508	SIL 3
Liquicap M	FMI 50, 51	EN 61508	SIL 2
Levelflex M	FMP 40, 41C, 45	prior use	SIL 2
Levelflex M	FMP 5x	IEC 61508	SIL 2/3
Micropilot M	FMR 230, 231, 240, 244, 245	prior use	SIL 2
Micropilot	FMR 5x	EN 61508	SIL 2/3
Gammapilot M	FMG 60 (limit switch)	EN 61508	SIL 2/3
Promass	80, 83	prior use	SIL 2
Promag	50, 53	prior use	SIL 2
Prowirl	72, 73	prior use	SIL 2
Liquiline	CM 42	IEC 61508	SIL 2
iTEMP	TMT 112, 122, 182, 162	prior use	SIL 2
Transmitter	RMA 422, RMA 42	prior use	SIL 2

Liquiphant FS

Cerabar S Deltabar S

Promag

RMA 42

Promass 80/83

Thank you very much and much success!
Good Bye!