OPTIBAR 7060 SERIE

Supplementary Instructions

Safety Handbook according to IEC 61508:2010

2-wire 4...20 mA HART with SIL-qualification

SIL 2/3
Safety Integrity Level

KROHNE

1.1 Device Version

This safety handbook applies for the OPTIBAR DP 7060 differential pressure transmitter with capillary diaphragm seals and the OPTIBAR DP 7060 with OPTIBAR DS diaphragm seals.

Electronics types:

- 2-wire 4...20 mA / HART ®with SIL-qualification
- 2-wire 4...20 mA / HART® with SIL qualification and supplementary electronics "Additional current output 4...20 mA"

Valid Versions:

- from HW Version 1.0.0
- from SW Version 1.2.2

The following versions are excluded from safety-relevant applications

- none

1.2 Field of application

A differential pressure transmitter can be used to measure the following process parameters in a safety-related system according to IEC 61508 in modes "low demand mode" or "high demand mode":

- Hydrostatic level measurement
- Differential pressure measurement
- Flow measurement
- Density measurement
- Interface measurement

Due to systematic suitability SC3 this is possible up to:

- SIL2 in a single-channel architecture
- SIL3 in a multiple-channel architecture

The following interface should be used to output the measured value:

- Current output = 4...20 mA.

The following interfaces are only permitted for parameter adjustment and for informative use:

- HART®
- Display and Adjustment module
- Additional current output 4...20 mA
  Only with the device version with additional electronics "additional current output 4...20 mA"

1.3 SIL conformity

The SIL conformity was independently judged and certified by the TÜV Rhineland according to IEC 61508:2010 (Ed.2).

The certificate is valid for the entire service life of all devices that were sold before the certificate expired!

2.1 Safety function

The converter generates a signal at its current output between 3.8 mA and 20.5 mA corresponding with the process parameter. This analog signal is fed to a connected processing system to monitor the following conditions:

- Exceeding a defined threshold of the process parameter
- Falling below a defined threshold of the process parameter
- Monitoring a defined range of the process parameter

Safety tolerance

For the interpretation of the safety function, the following aspects must be considered in respect to the tolerances:

- Due to a dangerous undetected failure in the range between 3.8 mA and 20.5 mA, an incorrect output signal can be generated which deviates from the real measured value by up to 4%
- Due to the special application conditions, increased measurement deviations can be caused (see technical data in the operating instructions)

2.2 Safe state

The safe state of the current output depends on the safety function and the characteristics set on the sensor.

Characteristics	Monitoring upper limit value	Monitoring lower limit value
4...20 mA	Output current ≥ Switching point	Output current ≤ Switching point
20...4 mA	Output current ≤ Switching point	Output current ≥ Switching point

Output signals in case of malfunction

Possible fault currents:

- ≤ 3.6 mA ("fail low")
- ≥ 21 mA ("fail high")

2.3 Prerequisites for operation

- The measuring system should be used appropriately taking pressure, temperature, density and chemical properties of the medium into account. The application-specific limits must be observed.
- The specifications according to the operating instructions manual, particularly the current load on the output circuits, must be kept within the specified limits.
- Existing communication interfaces (e.g. HART®, USB) are not used for transmission of the safety-relevant measured value.
- The instructions in chapter "Safety-related characteristics" must be noted.
- All parts of the measuring chain must correspond to the planned "Safety Integrity Level (SIL)".

3.1 Key figures according to IEC 61508

OPTIBAR 7060 Serie

Parameter	Value
Safety Integrity Level	SIL2 in single-channel architecture
	SIL3 in multiple-channel architecture ①
Hardware failure tolerance	HFT = 0
Device Type	Type B
Mode	Low demand mode, High demand mode
SFF	> 90%
MTBF ②	0.31 x 10^6 h (35 years)
Diagnosis test interval ③	< 30 min

① Homogeneous redundancy possible
② Including errors outside the safety function
③ Time during which all internal diagnoses are carried out at least once

Failure rates

λ_S	λ_{DD}	λ_{DU}	λ_H	λ_L	λ_{AD}
0 FIT	2412 FIT	47 FIT	9 FIT	59 FIT	34 FIT

PFD_{AVG}	0.041 x 10^{-2}	(T1 = 1 Year)
PFD_{AVG}	0.059 x 10^{-2}	(T1 = 2 Years)
PFD_{AVG}	0.115 x 10^{-2}	(T1 = 5 Years)
PFH	0.047 x 10^{-6} 1/h	

Proof Test Coverage (PTC)

Test type ①	Remaining failure rate of dangerous undetected failures	PTC
Test 1	24 FIT	49%
Test 2	2 FIT	96%

① See section Proof test

OPTIBAR 7060 series with OPTIBAR DS series diaphragm seal on one side

Failure rates

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	λ_{H}	λ_{L}	λ_{AD}
0 FIT	0 FIT	2412 FIT	115 FIT	9 FIT	59 FIT	34 FIT

PFD_{AVG}	0.098×10^{-2}	(T1 = 1 Year)
PFD_{AVG}	0.143×10^{-2}	(T1 = 2 Years)
PFD_{AVG}	0.278×10^{-2}	(T1 = 5 Years)
PFH	0.115×10^{-6} 1/h	

Proof Test Coverage (PTC)

Test type ①	Remaining failure rate of dangerous undetected failures	PTC
Test 1	92 FIT	20%
Test 2	2 FIT	98%

① See section Proof test

OPTIBAR 7060 series with OPTIBAR DS series diaphragm seals on two sides

Failure rates

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	λ_{H}	λ_{L}	λ_{AD}
0 FIT	0 FIT	2412 FIT	183 FIT	9 FIT	59 FIT	34 FIT

PFD_{AVG}	0.154×10^{-2}	(T1 = 1 Year)
PFD_{AVG}	0.226×10^{-2}	(T1 = 2 Years)
PFD_{AVG}	0.442×10^{-2}	(T1 = 5 Years)
PFH	0.183×10^{-6} 1/h	

Proof Test Coverage (PTC)

Test type ①	Remaining failure rate of dangerous undetected failures	PTC
Test 1	160 FIT	12%
Test 2	2 FIT	99%

① See section Proof test

3.2 Key figures according to ISO 13849-1

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Derived from the safety-related characteristics, the following figures result according to ISO 13849-1 (machine safety): (ISO 13849-1 was not part of the certification of the device.)

Parameter	Value
$MTTF_d$	45 years
DC	98%
Performance Level	4.67×10^{-8} 1/h

OPTIBAR 7060 series with OPTIBAR DS series diaphragm seal on one side

Parameter	Value
$MTTF_d$	43 years
DC	96%
Performance Level	1.15×10^{-7} 1/h

OPTIBAR 7060 series with OPTIBAR DS series diaphragm seals on two sides

Parameter	Value
$MTTF_d$	42 years
DC	93%
Performance Level	1.83×10^{-7} 1/h

3.3 Supplementary information

Determination of the failure rates

The failure rates of the device were determined by a FMEDA according to IEC 61508. Basis for the calculations are the component failure rates according to SN 29500.

All figures refer to an average ambient temperature of 40°C / 104°F during the operating time. For higher temperatures, the values should be corrected:

- Continuous operating temperature > 50°C / 122°F by factor 1.3
- Continuous operating temperature > 60°C / 140°F by factor 2.5

Similar factors apply if frequent temperature fluctuations are expected.

Assumptions of the FMEDA

- Failure rates are constant. Take note of the useful service life of the components according to IEC 61508-2.
- Multiple failures are not considered.
- Wear on mechanical parts is not considered.
- Failure rates of external power supplies are not considered.
- The environmental conditions correspond to an average industrial environment.

Calculation of PFD_{AVG}

The values for PFD_{AVG} specified above were calculated as follows for a 1oo1 architecture:

$PFD_{AVG} = (PTC \times \lambda_{DU} \times T1 / 2) + \lambda_{DD} \times MTTR + ((1-PTC) \times \lambda_{DU} \times LT / 2)$

- T1 = Proof Test Interval
- MTTR = 8
- PTC = 90%
- LT = 10 Years

Boundary conditions relating to the configuration of the processing unit

A connected control and processing unit must have the following properties:

- The output circuit of the signal converter is judged according to the idle current principle
- "fail low" and "fail high" signals are interpreted as a failure, which triggers a fault message

If this is not the case, the respective shares of the failure rates must be assigned to the dangerous failures and the values stated in chapter "Safety-related characteristics" redetermined!

Multiple channel architecture

Due to systematic suitability SC3, this device can also be used in a homogeneously redundant configuration in multiple channel systems up to SIL 3.
The safety-related characteristics must be calculated especially for the selected structure of the measuring chain using the stated failure rates. In doing this, a suitable Common Cause Factor (CCF) must be considered (see IEC 61508-6, appendix D).

4.1 General

Take note of the mounting and installation instructions in the operating instructions manual.
Start-up must take place in process conditions.

Functional check

When locking the adjustment, the device checks the data of the measurement loop and decides based on the evaluation results if it is necessary to check the level. Hence the following actions must be carried out at the time of every startup:

- Unlock adjustment
- if necessary, change parameters
- Lock adjustment and verify modified parameters, if necessary

4.2 Device parameter adjustment

The following adjustment units are permitted for parameterization of the safety function:

- Display and Adjustment module
- The DTM suitable for OPTIBAR 7060 in conjunction with an adjustment software according to the FDT/DTM standard, e.g. PACTware
- The device description EDD suitable for OPTIBAR 7060

A wireless connection is also possible if the Bluetooth function is available.

The parameter adjustment is described in the operating instructions manual.

Safety-relevant parameters

For protection against unwanted or unauthorised adjustment, the set parameters must be protected against unauthorised access. For this reason, the device is shipped in locked condition. The PIN in delivery status is "0000".
The default values of the parameters are listed in the operating instructions. When shipped with customer-specific parameter settings, the device is accompanied by a list of the values differing from the default values.

Safe parameterisation

To avoid or detect possible errors during parameter adjustment for unsafe operating environments, a verification procedure is used that allows the safety-relevant parameters to be checked.
Parameter adjustment proceeds according to the following steps:

- Unlock adjustment
- Change parameters
- Lock adjustment and verify modified parameters

The exact process is described in the operating instructions.

The device is shipped in locked condition.

For verification, all modified, safety-relevant and non-safety-relevant parameters are shown. The verification texts are displayed either in German or, when any other menu language is used, in English.

Unsafe device status

WARNING!
When adjustment is unlocked, the safety function must be considered as unreliable. This applies until the parameters are verified and the adjustment is locked again. If the parameter adjustment process is not carried out completely, the device statuses described in the operating instructions must be taken into consideration. If necessary, you must take other measures to maintain the safety function.

Device reset

WARNING!
In case a reset to "Delivery status" or "Basic adjustment" is carried out, all safety-relevant parameters must be checked or set anew.

5.1 Behaviour in case of failure

The device is permanently monitored by an internal diagnostic system. If a malfunction is detected, an error signal is output at the safety-relevant output (see the "Safe State" section). The diagnosis interval is specified in chapter "Safety-related characteristics".

A fault message coded according to the type of fault is outputted.
The fault messages are listed in the operating instructions.

5.2 Repair

Behaviour in case of faults

If faults are detected, the entire measuring system must be shut down and the process held in a safe state by other measures.
The manufacturer must be informed of the occurrence of a dangerous, undetected error (incl. fault description).

Electronics exchange

The procedure is described in the operating instructions manual. Note the instructions for parameter adjustment and setup.

Software update

The procedure is described in the operating instructions manual. Note the instructions for parameter adjustment and setup.

6.1 General

WARNING!
During the function test, the safety function must be treated as unreliable.
Consider that the function test influences downstream connected devices. If necessary, you must take other measures to maintain the safety function. After the function test, the status specified for the safety function must be restored.

To identify possible undetected, dangerous failures, the safety function must be checked in adequate intervals by a proof test.
It is the user's responsibility to choose the type of testing.
The time intervals are subject to the PFD_{AVG} (see chapter "Safety-related characteristics"). If one of the tests proves negative, the entire measuring system must be taken out of service and the process held in a safe state by means of other measures.

In a multiple channel architecture this applies separately to each channel.

- Determine safety function (mode, switching points).
- If necessary, remove the device from the safety chain and maintain the safety function by other means.
- Provide an approved adjustment unit.

6.2 Test 1 - without checking the process parameter

Conditions

- Device can be left in installed condition
- Output signal corresponds to the process pressure or the level.
- Device status in the menu Diagnosis is "OK".

Procedure

1. Perform a restart (disconnect the device under test from the power supply for at least 10 seconds).
2. Simulate high error current >21 mA and check current output (test line resistor).
3. Simulate low error current ≤3.6 mA and check current output (test closed current).

Expected result

- To 1: Output signal corresponds to the assigned process parameter and the device status in the menu Diagnosis is "OK".
- To 2: Output signal corresponds to >21
- To 3: Output signal corresponds to ≤3.6 mA

Coverage of the test

See "Safety-related characteristics"

6.3 Test 2 - with checking the process parameter

Conditions

- Device can be left in installed condition
- Output signal corresponds to the assigned process parameter.
- Device status in the menu Diagnosis is "OK".
- A reference pressure measurement is performed on the high-pressure side.
- The low-pressure side is vented to atmospheric pressure or acted upon with the static pressure corresponding to the application.

Procedure

1. Perform a restart (disconnect the device under test from the power supply for at least 10 seconds).
2. Simulate high error current >21 mA and check current output (test line resistor).
3. Simulate low error current ≤3.6 mA and check current output (test closed current).
4. Reference pressure measurement at 0%, 50% and 100% of the measuring range (4 mA, 12 mA and 20 mA)
5. If necessary, calibrate sensor through service log-in and perform another reference pressure measurement as described in point 4.

Expected result

- To 1: Output signal corresponds to the process pressure or the level and the device status in the menu Diagnosis is "OK".
- To 2: Output signal corresponds to >21
- To 3: Output signal corresponds to ≤3.6 mA
- To 4: and 5: Output signal corresponds to the reference pressure.

Coverage of the test

See "Safety-related characteristics"

7.1 Appendix 1 - Test report

Identification

Company/Tester	
Plant/Device TAG	
Meas. loop TAG	
Device type/Order code	
Device serial number	
Date, setup	
Date, last function test	

Test reason/Test scope

	Start-up without checking the process parameter
	Start-up with checking the process parameter
	Proof test without checking the process parameter
	Proof test with checking the process parameter

Mode

	Monitoring a maximum limit
	Monitoring a minimum limit
	Range monitoring

Adjusted parameters of the safety function are documented

	Yes
	No

Test result

Test point	Process parameter e.g. point level detection, level, interface, pressure, flow, density	Expected measured value	actual value	Test result
Value				
Value				
Value				
Value				
Value				

Confirmation

Date:	Signature:

7.2 Appendix B - Term definitions

Term	description
SC	Systematic Capability (SC1, SC2, SC3, SC4)
SIL	Safety Integrity Level
HFT	Hardware Fault Tolerance
SFF	Safe Failure Fraction
PFD_{AVG}	Average Probability of dangerous Failure on Demand
PFH	Average frequency of a dangerous failure per hour (Ed.2)
FMEDA	Failure Mode, Effects and Diagnostics Analysis
FIT	Failure in Time (1 FIT = 1 failure/109 hours)
λ_{SD}	Rate for safe detected failure
λ_{SU}	Rate for safe undetected failure
λ_S	$\lambda_S = \lambda_{SD} + \lambda_{SU}$
λ_{DD}	Rate for dangerous detected failure
λ_{DU}	Rate for dangerous undetected failure
λ_H	Rate for failure, who causes a high output current (> 21 mA)
λ_L	Rate for failure, who causes a low output current (≤ 3.6 mA)
λ_{AD}	Rate for diagnostic failure (detected)
λ_{AU}	Rate for diagnostic failure (undetected)
DC	Diagnostic Coverage
PTC	Proof Test Coverage (Diagnostic coverage for manual proof tests)
T1	Proof Test Interval
LT	Useful Life Time
MTBF	Mean Time Between Failure = MTTF + MTTR
MTTF	Mean Time To Failure
MTTR	IEC 61508, Ed1: Mean Time To Repair IEC 61508, Ed2: Mean Time To Restoration
$MTTF_d$	Mean Time To dangerous Failure (ISO 13849-1)
PL	Performance Level (ISO 13849-1)

7.3 SIL Manufacturer's declaration NE 130: Form B.1

SIL manufacturer's declaration NE 130: Form B.1

Manufacturer	
Manufacturer	KROHNE Pressure Solutions GmbH
Address	Gewerbepark 14, D-32423 Minden, Germany

General			
Device designation and permissible types	OPTIBAR DP 7060 Series, 2-wire 4-20mA HART with SIL; VGK7 **********A_		
Safety-related output signal	4…20mA		
Fault current	≥ 21mA; ≤ 3,6mA		
Process variable/function	Differential Pressure Transmitter or pressure, flow, density, interface and level measurement		
Safety function(s)	Generation of a measured value to monitor Min / Max / Range		
Device type acc. to IEC 61508-2	☐ Type A	☒ Type B	
Operating mode	☒ Low Demand Mode	☒ High Demand Mode	☒ Continuous Mode
Valid Hardware-Version	HW ≥ 1.0.0		
Valid Software-Version	SW ≥ 1.2.2		
Safety manual	AD_OPTIBAR_7060_Safety_Manual		
Type of evaluation (check only <u>one</u> box)	☒ Complete HW/SW evaluation parallel to development incl. FMEDA and change request acc. to IEC 61508-2, 3		
	☐ Evaluation of "prior use" performance for HW/SW incl. FMEDA and change request acc. to IEC 61508-2, 3		
	☐ Evaluation of HW/SW field data to verify „prior use" acc. to IEC 61511		
	☐ Evaluation by FMEDA acc. to IEC61508-2 for devices w/o software		
Evaluation through – report no.	TÜV Rheinland Industry Service GmbH, No.: 968/FSP 1674.00/18		
Test documents	Development documents	Test reports	Data sheets
SIL-Integrity			
Systematic safety integrity		☐ SIL 2 capable	☒ SIL 3 capable
Hardware safety integrity	Single channel use(HFT=0)	☒ SIL 2 capable	☐ SIL 3 capable
	Multi channel use (HFT≥1)	☐ SIL 2 capable	☒ SIL 3 capable

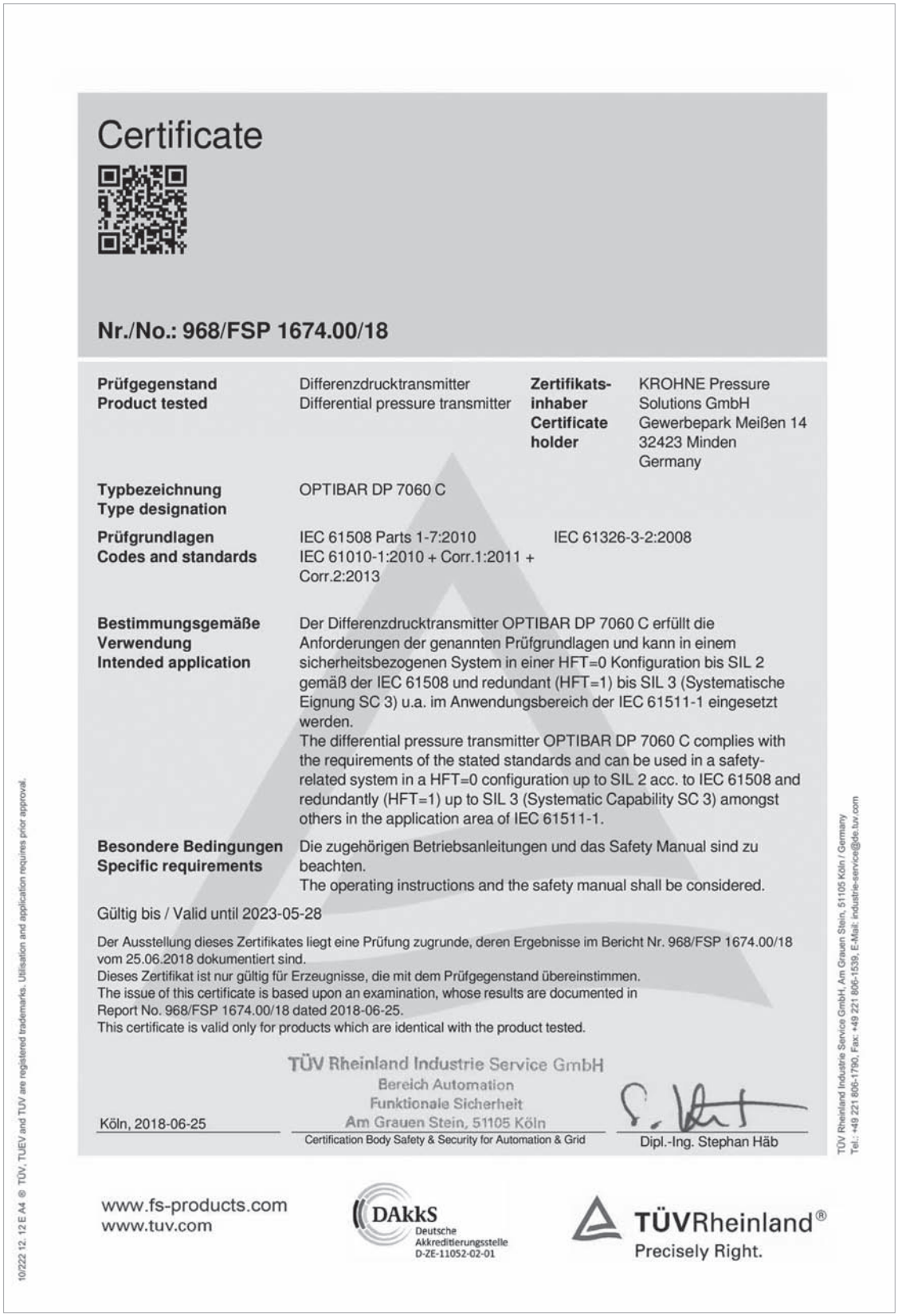
FMEDA			
	OPTIBAR DP 7060	**OPTIBAR DP 7060 with 1x OPTIBAR DS diaphragm seal**	**OPTIBAR DP 7060 with 2x OPTIBAR DS diaphragm seals**
Safety function	Min / Max / Range	Min / Max / Range	Min / Max / Range
λ_{DU} *1)	47 FIT	115 FIT	183 FIT
λ_{DD} *1).	2514 FIT	2514 FIT	2514 FIT
λ_{SU} *1)	0 FIT	0 FIT	0 FIT
λ_{SD} *1)	0 FIT	0 FIT	0 FIT
SFF – Safe Failure Fraction	> 90%	> 90%	> 90%
PTC *2)	Test1: 49% Test2: 96% with pressure reference	Test1: 20% Test2: 98% with pressure reference	Test1: 12% Test2: 99% with pressure reference
FMEDA data source	SN 29500		

Comments

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

*1) FIT: Failure In Time, Number of breakdown per 109 h
*2) PTC: Proof Test Coverage (Diagnostic coverage for manual proof tests)

7.4 SIL Zertifikat



Certificate

Nr./No.: 968/FSP 1674.00/18

Prüfgegenstand **Product tested**	Differenzdrucktransmitter Differential pressure transmitter	**Zertifikats-inhaber** **Certificate holder**	KROHNE Pressure Solutions GmbH Gewerbepark Meißen 14 32423 Minden Germany
Typbezeichnung **Type designation**	OPTIBAR DP 7060 C		
Prüfgrundlagen **Codes and standards**	IEC 61508 Parts 1-7:2010 IEC 61010-1:2010 + Corr.1:2011 + Corr.2:2013	IEC 61326-3-2:2008	
Bestimmungsgemäße Verwendung **Intended application**	Der Differenzdrucktransmitter OPTIBAR DP 7060 C erfüllt die Anforderungen der genannten Prüfgrundlagen und kann in einem sicherheitsbezogenen System in einer HFT=0 Konfiguration bis SIL 2 gemäß der IEC 61508 und redundant (HFT=1) bis SIL 3 (Systematische Eignung SC 3) u.a. im Anwendungsbereich der IEC 61511-1 eingesetzt werden. The differential pressure transmitter OPTIBAR DP 7060 C complies with the requirements of the stated standards and can be used in a safety-related system in a HFT=0 configuration up to SIL 2 acc. to IEC 61508 and redundantly (HFT=1) up to SIL 3 (Systematic Capability SC 3) amongst others in the application area of IEC 61511-1.		
Besondere Bedingungen **Specific requirements**	Die zugehörigen Betriebsanleitungen und das Safety Manual sind zu beachten. The operating instructions and the safety manual shall be considered.		

Gültig bis / Valid until 2023-05-28

Der Ausstellung dieses Zertifikates liegt eine Prüfung zugrunde, deren Ergebnisse im Bericht Nr. 968/FSP 1674.00/18 vom 25.06.2018 dokumentiert sind.
Dieses Zertifikat ist nur gültig für Erzeugnisse, die mit dem Prüfgegenstand übereinstimmen.
The issue of this certificate is based upon an examination, whose results are documented in Report No. 968/FSP 1674.00/18 dated 2018-06-25.
This certificate is valid only for products which are identical with the product tested.

Köln, 2018-06-25

TÜV Rheinland Industrie Service GmbH
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Am Grauen Stein, 51105 Köln
Certification Body Safety & Security for Automation & Grid

Dipl.-Ing. Stephan Häb

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KROHNE – Process instrumentation and measurement solutions

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