



H250 Supplementary instructions

Variable area flowmeter
Safety manual



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1.1 Fields of application

Measurements of volume flow rate of liquids, gases and vapor that shall meet the special safety requirements according to IEC 61508.

The measuring unit meets the requirements regarding

- Functional safety in accordance with IEC 61508-2:2000
- EMC in accordance to EN 60947-5-2, EN 60947-5-6 and NAMUR recommendation NE 21
- ATEX compliance in accordance to EN 1127-1, EN 13463-1, EN 50014, EN 50020, EN 50021 and EN 50281-1-1
- PED in accordance to EN 13445-2 and EN 729-2

For further information please refer to the CE declaration of conformity which is available at the Download Center at www.krohne.com.

1.2 User benefits

Use for

- Volume flow monitoring up to SIL 2 (see Exida FMEDA report Krohne 05/06-20 R007)
- Continuous measurement
- Easy commissioning

1.3 Relevant standards / literature

[N1]	IEC 61508-2:2000 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
[N2]	ISBN: 0471133019 John Wiley & Sons Electronic Components: Selection and Application Guidelines by Victor Meeldijk
[N3]	FMD-91, RAC 1991 Failure Mode / Mechanism Distributions
[N4]	FMD-97, RAC 1997 Failure Mode / Mechanism Distributions
[N5]	NPRD-95, RAC Non-electronic Parts - Reliability Data 1995
[N6]	SN 29500 Failure rates of components
[N7]	NSWC-98/LE1 Handbook of Reliability Prediction Procedures for Mechanical Equipment
[N8]	IEC 60654-1:1993-02, second edition, Industrial-process measurement and control equipment - operating conditions - Part 1: Climatic condition

Terms and definitions

DC _D	Diagnostic Coverage of dangerous failures
FIT	Failure In Time (1x10 ⁻⁹ failures per hour)
FMEDA	Failure Modes, Effects and Diagnostic Analysis
HFT	Hardware Fault Tolerance
Low demand mode	Mode, where the frequency of demand for operation made on a safety-related system is not greater than one per year and not greater than twice in the proof test frequency.
PFD _{AVG}	Average Probability of Failure on Demand
SFF	Safe Failure Fraction summarizes the fraction of failure, which lead to a safe state and the fraction of failures which will be detected by diagnostic measures and lead to a defined safety action.
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
Type A component	"Non-complex" subsystem (all failure modes are well defined); for details see 7.4.3.1.2 of IEC 61508-2.
Type B component	"Complex" subsystem (all failure modes are well defined); for details see 7.4.3.1.2 of IEC 61508-2.
T[Proof]	Proof Test Interval

3.1 Functional principle

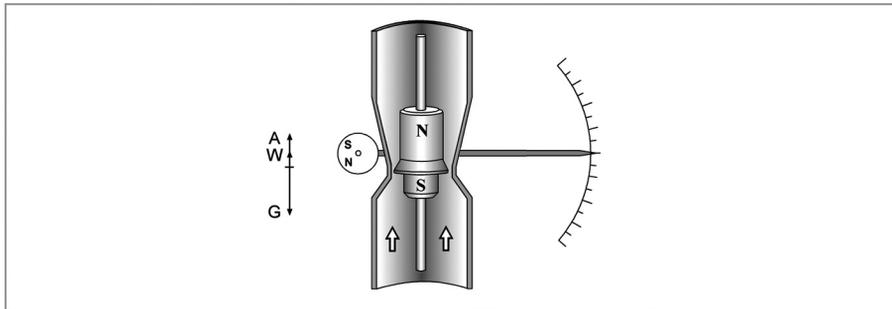


Figure 3-1: Functional principle

The flowmeter operates in accordance with the float measuring principle.

A metal cone is installed in the measuring unit H250, in which a suitably shaped float can move freely up and down.

The flowmeter is inserted into a vertical pipeline and the medium flows through it from bottom to top.

The guided float adjusts itself so that the buoyancy force A acting on it, the form drag W and weight G are in equilibrium ($G = A + W$).

An annular gap results which width depends on the current flow rate.

The height of the float in the measuring unit, which depends on the float, is transmitted by a magnetic coupling and displayed on a scale.

Strong deflecting magnetic fields can lead to deviations in the measured value.

4.1 Description of the failure categories

In order to judge the failure behavior of the variable-area flowmeter H250/M9 with limit switch output, the following definitions for the failure of the product were considered.

Fail-Safe State	The fail-safe state is defined as the output being de-energized or one of the 2 limit switches is triggered. Fail Safe Failure that causes the module / (sub) system to go to the defined fail-safe state without a demand from the process.
Fail Dangerous	Failure that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state).
Fail Dangerous Undetected	Failure that is dangerous and that is not being diagnosed by internal diagnostics.
Fail Dangerous Detected	Failure that is dangerous but is detected by internal diagnostics. (These failures may be converted to the selected fail-safe state.)
Not Effect	Failure of a component that is part of the safety function but that has no effect on the safety function. For the calculation of the SFF it is treated like a safe undetected failure.
Not part	Failures of a component which is not part of the safety function but part of the circuit diagram and is listed for completeness. When calculating the SFF this failure mode is not taken into account. It is also not part of the total failure rate.

The "No Effect" failures are provided for those who wish to do reliability modeling more detailed than required by 61508. In IEC 61508 the "No Effect" failures are defined as safe undetected failures even though they will not cause the safety function to go to a safe state. Therefore they need to be considered in the Safe Fraction calculation.

5.1 Applicable device documentations

- [D1] TD H250 Rxx en
Technical datasheet H250 – Variable area flowmeter
- [D2] MA H250 Rxx en
Handbook including installation and operating instructions
- [D3] exida FMEDA report: KROHNE 05/06-20 R007

5.2 Project planning, behaviour during operation and malfunction

- Average temperature for the parts in the display section M9 has to be $+40^{\circ}\text{C}$ over a long period of time. The max. allowed process temperature in relation to max. ambient temperature is shown in Figure 5-1.
- Under normal conditions the maximum operating time will be 10 years.
- Requirements made in the Handbook have to be kept.
- Repair and inspection intervals have to be based on the safety calculations.
- Follow the KROHNE repair instructions in the printed Handbook
- Modifications made without specific authorisation of the manufacturer are strictly prohibited.
- For help to find the correct Description code see ANNEX 1.

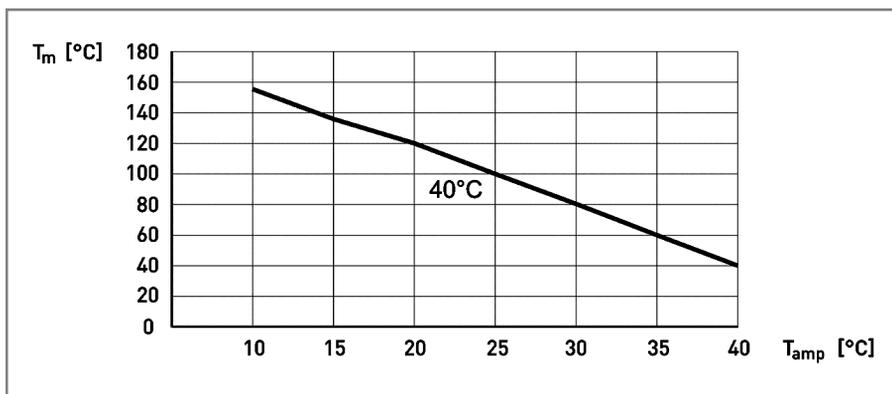


Figure 5-1: Relation between process temperature, ambient temperature and temperature of display section M9

6.1 Life time

Although a constant failure rate is assumed by the probabilistic estimation method this only applies provided that the useful lifetime of components is not exceeded. Beyond their useful lifetime, the result of the probabilistic calculation method is meaningless, as the probability of failure significantly increases with time. The useful lifetime is highly dependent on the component itself and its operating conditions – temperature in particular (for example, electrolyte capacitors can be very sensitive). This assumption of a constant failure rate is based on the bathtub curve, which shows the typical behaviour for electronic components. Therefore it is obvious that the PFD_{AVG} calculation is only valid for components which have this constant domain and that the validity of the calculation is limited to the useful lifetime of each component.

It is assumed that early failures are detected to a huge percentage during the installation period and therefore the assumption of a constant failure rate during the useful lifetime is valid.

According to section 7.4.7.4 of IEC 61508-2, a useful lifetime, based on experience, should be assumed.

According to section 7.4.7.4 note 3 of IEC 61508-2 experience has shown that the useful lifetime often lies within a range of 8 to 12 years.

KROHNE recommends an operational life time for variable area flowmeters no longer than 10 years in SIL rated applications. However, if the user is monitoring the instruments over their life time demonstrating the required results (e.g. constant failure rate), this can allow safety capability exceeding this period on the user's own responsibility.

The required cyclic proof test interval can be found in the table chapter 7.2.

6.2 Proof tests

Possible proof tests to detect dangerous undetected faults

Proof test 1 consists of the following steps:

1. Take appropriate action to avoid a false trip.
2. Force the variable-area flowmeter H250/M9 to reach a defined "MAX" threshold value and verify that the inductive limit switch goes into the safe state.
3. Restore the loop to full operation.
4. Restore normal operation.

Proof test 2 consists of the following steps:

1. Take appropriate action to avoid a false trip.
2. Force the variable-area flowmeter H250/M9 to reach a defined "MIN" threshold value and verify that the inductive limit switch goes into the safe state.
3. Restore the loop to full operation.
4. Restore normal operation.



INFORMATION!

Both tests together will detect approximately 90% of possible "du" failures.



INFORMATION!

It is necessary to open the casing of the device in order to do the electrical connection and to set the limit switch set points.

*Special attention is required when the casing is open. **Avoid a deformation of the precision mechanics indicator system.** By deforming the pointer or the balance vane the ease-of-movement can be influenced leading to a wrong measurement.*

By performing the mandatory proof-test after installation and closing the casing the ease-of-movement has to be verified

7.1 Assumptions

The following assumptions have been made during the Failure Modes, Effects and Diagnostic Analysis of the variable-area flowmeter H250/M9 with switching contact output.

- Failure rates are constant, wear out mechanisms are not included.
- Propagation of failures is not relevant.
- The time to restoration after a safe failure is 8 hours.
- All modules are operated in low demand mode of operation.
- External power supply failure rates are not included.
- The stress levels are average for an industrial outdoor environment and can be compared to the Ground Fixed classification of MIL-HNBK-217F.

Alternatively, the assumed environment is similar to:

IEC 60654-1, Class C (sheltered location) with temperature limits within the manufacturer's rating and an average temperature over a long period of time of 40°C.

- Humidity levels are assumed within manufacturer's rating.
- Only the switching contact output is used for safety applications.

7.2 Specific safety-related characteristics

Under the assumptions described in 7.1 and the definitions given in section 4 the following tables show the failure rates according to IEC 61508:

Based on the construction of the H250/M9 this device is specified as a type A device according to IEC 61508 with a HFT (Hardware Failure Tolerance) = 0 and a classification as SIL (Safety Integrity Level): 2.

System	SFF	T _{PROOF}	PFD _{AVG}	λ _{SAFE}	λ _{DANGEROUS}
H250/M9 connected to a standard switching amplifier	63%	1 year	5.04E-04	197 FIT	115 FIT
		5 years	2.52E-03		
		10 years	(5.03E-03)		
H250/M9 connected to a fail-safe switching amplifier ①	68%	1 year	3.35E-04	166 FIT	77 FIT
		5 years	1.67E-03		
		10 years	3.34E-03		

① The switching contact output is connected to a fail-safe NAMUR amplifier (e.g. Pepperl + Fuchs KF**-SH-Ex1). Failure rates of the amplifiers are not included.

PFD_{AVG} was calculated for three different proof test times using the Markov modeling.

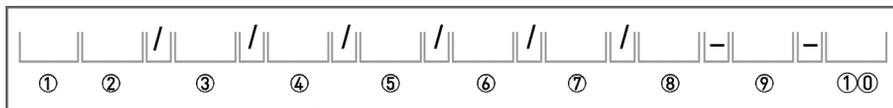
The PFD_{AVG} value in brackets mean, that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 but do not fulfil the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3.50E-03.

The PFD_{AVG} value (not in brackets) mean, that the calculated PFD_{AVG} values are within the allowed range for SIL 2 according to table 2 of IEC 61508-1 and do fulfil the requirement to not claim more than 35% of this range, i.e. to be better than or equal to 3.50E-03.

8.1 Annex 1

Constricted Description Code for H250 Functional Safety Equipment acc. to EN 61508

The description code for H250 consists of the following elements ①



① Device type H250 - standard version

② Materials / versions

RR - Stainless Steel

HC - Hastelloy®

Ti - Titanium

③ Heating jacket version

B - with heating jacket

④ Series of indicators

M9 - Indicator M9 standard indicator

M9S - Indicator with added impact and corrosion protection

M9R - Indicator in Stainless Steel housing

⑤ Position not needed for SIL 2 applications

⑥ Position not needed for SIL 2 applications

⑦ Position not needed for SIL 2 applications

⑧ Limit switch

K1 - One limit switch

K2 - Two limit switches

S1 - One SIL2 Limit switch acc. to IEC 61508

S2 - Two SIL2 Limit switches acc. to IEC 61508

⑨ Explosion protection

Ex - Explosion-protected equipment

⑩ SIL

SK - SIL2 compliance of limit switches acc. to IEC 61508

① positions which are not needed are omitted (no blank positions)

The variable-area flowmeter H250/M9 (SIL) can be equipped with a maximum of two electronic limit switches.

The limit switch function with a slot-type indicator which is operated inductively through the semicircular metal vane belonging to the measuring pointer.

The correct ordering text for switches with different contact types and the fitting isolating switching amplifier are found in the right column of the two tables "option 1" and "option 2" (see next page).

Option 1: H250/M9 connected to a standard switching amplifier

Type code	Technology
SC3,5-N0-Y47819-ATEX-Dub.	2-wire technology (NAMUR)

Appropriate Isolating Switching Amplifiers:

Type code	Supply voltage	Channel	Output	Ordering No.
KFA6-SR2-Ex1.W	230 VAC	1	relay	5015262000
KFA5-SR2-Ex1.W	115 VAC	1	relay	5015262100
KFD2-SR2-Ex1.W	24 VDC	1	relay	5015262200
KFA6-SR2-Ex2.W	230 VAC	2	relay	5015262300
KFA5-SR2-Ex2.W	115 VAC	2	relay	5015262400
KFD2-SR2-Ex2.W	24 VDC	2	relay	5015262500

Option 2: H250/M9 connected to a fail-safe switching amplifier

Type code	Technology
SJ3,5-SN-ATEX	2-wire technology safety-oriented
SJ3,5-S1N-ATEX	2-wire technology safety-oriented

Appropriate Isolating Switching Amplifiers:

Type code	Supply voltage	Channel	Output	Ordering No.
KFD2-SH-Ex1	20...35 VDC	1	redundant relay	501526800
KFD2-SH-Ex1.T.OP	20...35 VDC	1	Electronic and relay	optional
KHA6-SH-Ex1	85...253 VAC	1	redundant relay	optional

8.2 Annex 2

Declaration of conformity for Functional Safety (SIL)




DECLARATION OF CONFORMITY

KONFORMITÄTSEKLRÄRUNG

DECLARATION DE CONFORMITE

KROHNE Messtechnik GmbH & Co. KG, Ludwig-Krohne-Str. 5, D-47058 Duisburg Germany

We declare herewith under sole responsibility:

Wir erklären hiermit unter alleiniger Verantwortung:

Nous déclarons sous notre seule responsabilité:

H250/M9/K*...-SK

variable area flowmeters for measuring volume flow rates of gases and liquids are suitable for the use in a safety-related application up to SIL2 according IEC 61508-2:2000 provided that the safety instructions are observed (see safety manual). IEC61508-3 is not part of this declaration because there is no software implemented in these devices. The assessment of the safety critical and dangerous random errors lead to the following parameters:

Schwebekörper-Durchflussmessgeräte zur Volumendurchflussmessung von Gasen und Flüssigkeiten sind unter Beachtung der Sicherheitshinweise im Sicherheitshandbuch für den Einsatz in sicherheitsgerichteten Applikationen bis SIL2 nach IEC 61508-2:2000 geeignet. IEC61508-3 ist nicht Bestandteil der Erklärung, da in den Geräten keine Software implementiert ist. Die Untersuchung der sicherheitsrelevanten und gefährlichen, zufälligen Fehler führt zu folgenden Kenndaten:

débitmètres à section variable pour mesurer les débits volumiques de gaz ou liquides peuvent être utilisés pour des applications de sécurité fonctionnelle jusqu'à SIL2 selon IEC 61508-2:2000 en respectant les consignes de sécurité spécifiées dans le Safety Manual. La norme IEC61508-3 n'est pas applicable à cette déclaration sachant qu'il n'y a aucun logiciel intégré dans ces appareils. L'évaluation des défaillances aléatoires et dangereuses pour la sécurité donne les valeurs suivantes :

Type A device | Hardware Fault Tolerance HFT=0 | Low demand mode

H250/M9/K*...-SK with 1 or 2 fail-safe limit switches (MIN/MAX)

λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	SFF	SIL Level
0 FIT	111 FIT	55 FIT	77 FIT	68%	SIL2

T[Proof]	1 year	5 years	10 years
PFD _{AVG}	3,35E-04	1,67E-03	3,34E-03

Reference: *exida* FMEDA report "KROHNE 05/06-20 R007"

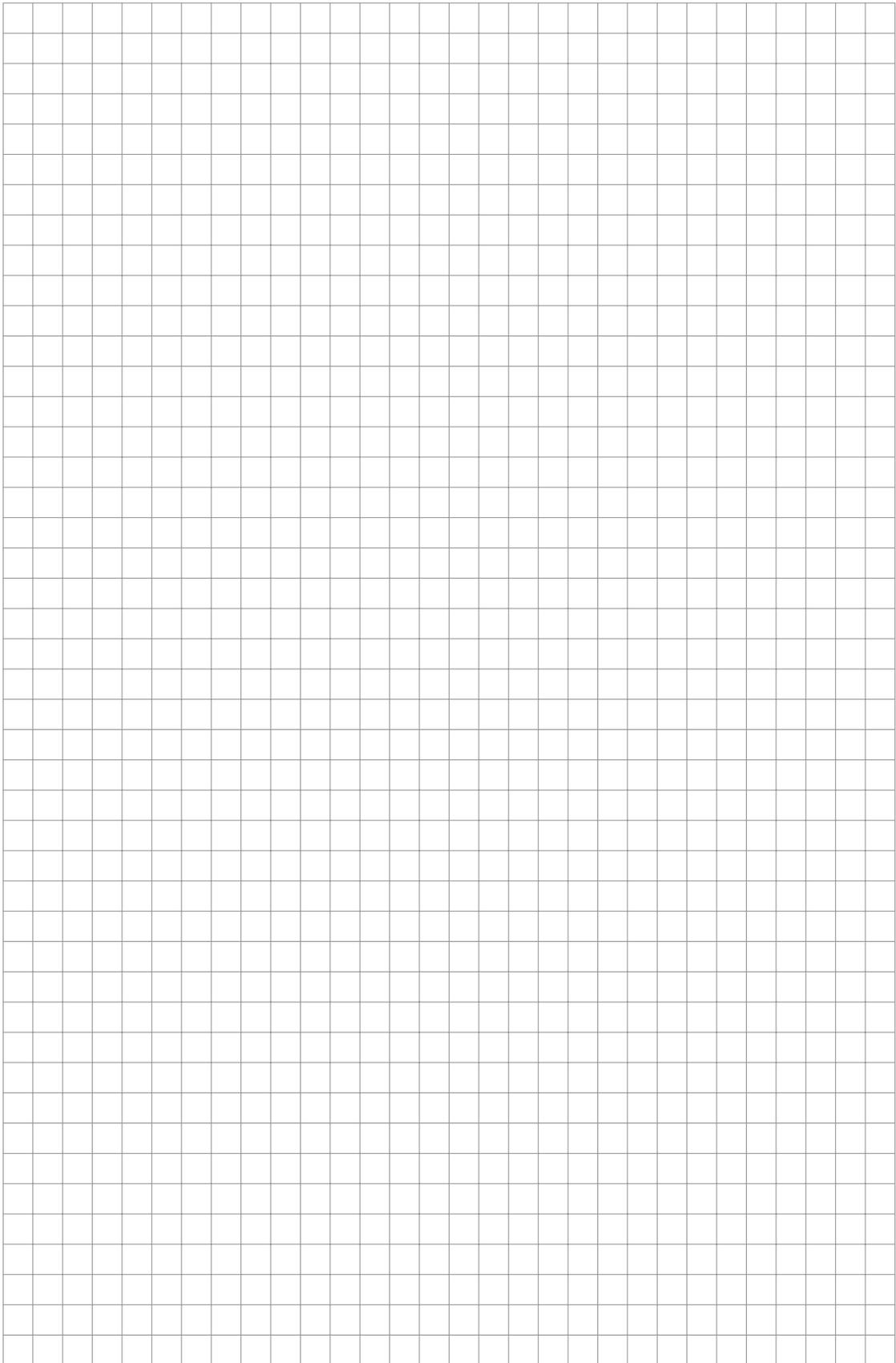
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The actual declaration of conformity (H250 M9 DoC SIL) is available at the Download Center at www.krohne.com.







KROHNE product overview

- Electromagnetic flowmeters
- Variable area flowmeters
- Ultrasonic flowmeters
- Mass flowmeters
- Vortex flowmeters
- Flow controllers
- Level meters
- Temperature meters
- Pressure meters
- Analysis products
- Products and systems for the oil & gas industry
- Measuring systems for the marine industry

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