DK46 - DK800 Supplementary Instructions

Variable area flowmeter

Safety manual according to IEC 61508:2010

SIL 2
Safety Integrity Level

KROHNE

1.1 General notes

These additional instructions apply to the SIL compliant versions of variable area flowmeters. They complete the standard manual and the supplementary Ex manual.

This supplement only contains the data applicable to functional safety.
The technical data and instructions given in the standard manual remain unchanged unless they will be excluded or replaced by these supplementary instructions.

1.2 Field of application

Measurement of flow rate of liquids, gases and vapours that shall meet the special safety requirements according to IEC 61508.

The measuring device meets the requirements regarding

- Functional safety in accordance with IEC 61508-2:2010 (Edition 2)
- EMC Directive 2014/30/EC
- ATEX Directive 2014/34/EC
- Pressure Equipment Directive 2014/68/EC

For further information please refer to the DK46 - DK47 - DK48 - DK800 declaration of conformity on the manufacturer's website.

1.3 User benefits

Use for

- Flow monitoring
- Easy commissioning
- Excellent price/performance ratio

1.4 Relevant standards / Literature

[N1]	IEC 61508-2:2010 - Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
[N2]	Electrical & Mechanical Component Reliability Handbook, 4nd Edition 2017, exida L.L.C.
[N3]	IEC 60654-1:1993-02 2nd edition, Industrial process measurement and control equipment - Operating conditions - Part 1: Climatic conditions

Table 1-1: Relevant standards

2.1 Description of the used terms

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
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.
T[Proof]	Proof Test Interval

Table 2-1: Description of the used terms

2.2 Description of the considered environmental profile

exida profile	3
Description (Electrical)	General field mounted; self-heating
Description (Mechanical)	General field mounted
IEC 60654-1 profile	C3; also applicable for D1
Average ambient temperature	25°C
Average internal temperature	45°C
Daily temperature excursion (pk-pk)	25°C
Seasonal temperature excursion (winter average vs. summer average)	40°C
Exposed to elements / weather conditions	Yes
Humidity (rating per IEC 60068-2-3)	0...100% condensing
Shock (rating per IEC 60068-2-27)	15 g
Vibration (rating per IEC 60068-2-6)	3 g
Chemical corrosion (rating per ISA 71.04)	G3
Surge (rating per IEC 61000-4-5)	Line-Line: 0.5 kV
	Line-Ground: 1kV
EMI susceptibility (rating per IEC 61000-4-3)	80 MHz...1.4 GHz: 10 V/m
	1.4 GHz...2.0 GHz: 3 V/m
	2.0 GHz...2.7 GHz: 1 V/m
ESD (air) (rating per IEC 61000-4-2)	6 kV

Table 2-2: Description of the considered environmental profile

3.1 Description of the subsystem

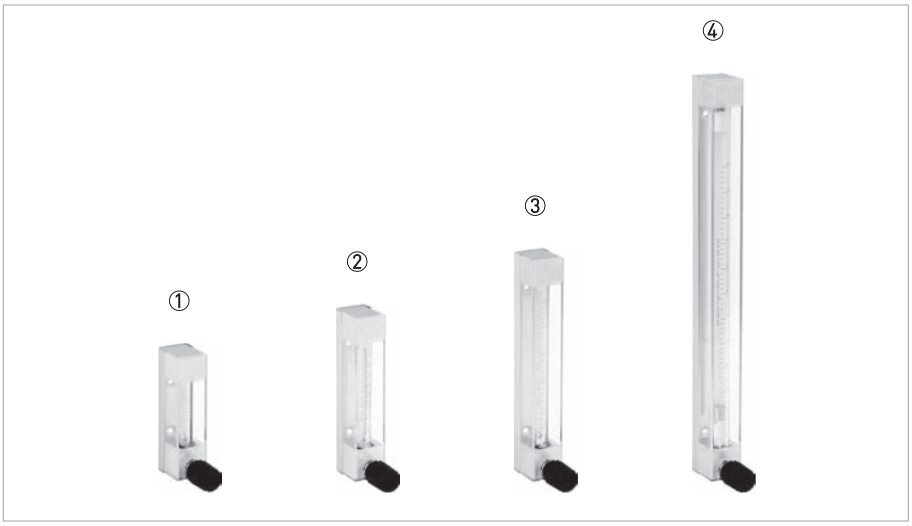

Figure 3-1: Standard versions

① DK46 with valve and an overall length of 111 mm / 4.4"
② DK800 with valve and an overall length of 146 mm / 5.7"
③ DK47 with valve and an overall length of 196 mm / 7.7"
④ DK48 with valve and an overall length of 346 mm / 13.6"

Figure 3-2: Optional versions

① DK device with flow regulator for fluctuating inlet and outlet pressures
② DK device with limit switch and connection box
③ DK device with valve at top and calibrated to inlet pressure

3.2 Functional principle

The flowmeter operates in accordance with the float measuring principle.

The measuring unit consists of a glass cone in which a float can move freely up and down. The flow goes from bottom to top.

The 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.

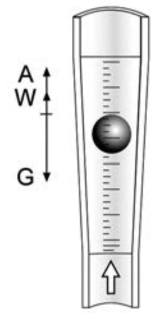

Figure 3-3: Operating principle

The height of the float is read on the scale of the measuring glass and indicates the flow rate.

The top edge of the float marks the reading line for flow values.

3.3 Intended use

CAUTION!
Responsibility for the use of the measuring devices with regard to suitability, intended use and corrosion resistance of the used materials against the measured fluid lies solely with the operator.

INFORMATION!
This device is a Group 1, Class A device as specified within CISPR11:2009. It is intended for use in industrial environment. There may be potential difficulties in ensuring electromagnetic compatibility in other environments, due to conducted as well as radiated disturbances.

INFORMATION!
The manufacturer is not liable for any damage resulting from improper use or use for other than the intended purpose.

The variable area flowmeters are suitable for measuring gases and liquids.

The devices are particularly suitable for the measurement of small quantities of:

- Process or carrier gases
- Nitrogen, CO_2 or other industrial gases
- Sample flows for process analysers
- Sealing gas or sealing liquid measurement on sealing systems
- Purge fluids for measuring systems
- Air or water
- Chemicals and additives
- Lubricating, cooling and anti-corrosive agents

DANGER!
For devices used in hazardous areas, additional safety notes apply; please refer to the Ex documentation.

WARNING!
Do not use any abrasive or highly viscous media.

4.1 Description of the failure categories

In order to judge the failure behaviour of the variable area flowmeters DK800/DK4*, the following definitions for the failure of the flowmeter were considered:

Fail-Safe	Failure that causes the subsystem to go to the defined fail-safe state without a demand from process.
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)
Fail No Effect	Failure of a component that is part of the safety function but is neither a safe failure nor a dangerous failure and has no effect on the safety function.

Table 4-1: Description of the failure categories

Fail-Safe State	The fail-safe state is defined as the output being de-energised
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)

Table 4-2: DK46, DK47, DK48, DK800 with inductive limit switch output

The demand response time of DK46, DK47, DK48, DK800 is < 2 seconds.

5.1 Applicable device documentation

[D1]	TD DK46_800-Rxx-xx Technical datasheet DK32, DK34, DK37 - Variable area flowmeter
[D2]	MA DK46_800-Rxx-xx Handbook including installation and operating instructions
[D3]	exida FMEDA report: KROHNE 18/07-119 R013 version 1

Table 5-1: Applicable device documentation

5.2 Project planning, behaviour during operation and malfunction

- The stress levels shall be average for an industrial outdoor environment and shall be similar to exida Profile 3 (for details refer to *Description of the considered environmental profile* on page 5) with temperature limits within the manufacture's rating.
  Other environmental characteristics are assumed to be within the manufacturer's ratings.
- Under normal conditions the maximum operating time will be 10 years.
- Requirements made in the operating manual have to be kept.
- Repair and inspection intervals have to be based on the safety calculations.
- Follow the repair instructions of the manufacturer in the printed manual.
- Modifications made without specific authorisation of the manufacturer are strictly prohibited.
- Follow the installation and operating instructions.
- The application program in the safety logic solver is configured to detect under-range and over-range failures and does not automatically trip on these failures; therefore these failures have been classified as dangerous detected failures. The failure rates of the safety logic solver are not included in the listed failures rates.
- The parameters given by the FMEDA are considered as planning support.
  The end user is responsible for the overall functional safety of the application.
- For help to find the correct order text refer to annex 1.

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 7.4.9.5 of IEC 61508-2, a useful lifetime, based on experience, should be assumed.
According to section 7.4.9.5 note 3 of IEC 61508-2 experience has shown that the useful lifetime often lies within a range of 8 to 12 years.

We recommend 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 in chapter 7.2.

6.2 Proof tests

The following proof tests (initial test during start-up) to detect dangerous undetected faults must be carried out:

Proof test for DK46, DK47, DK48, DK800 with inductive limit switches

1. Take appropriate action to avoid a false trip.
2. Inspect the device for any visible damage, corrosion or contamination.
3. Force the variable area flowmeter DK46, DK47, DK48, DK800 to reach a defined "MAX" threshold value and verify that the inductive limit switch goes into the safe state.
4. Force the variable area flowmeter DK46, DK47, DK48, DK800 to reach a defined "MIN" threshold value and verify that the inductive limit switch goes into the safe state.
5. Restore the loop to full operation.
6. Restore the normal operation.

7.1 Assumptions

The following assumptions have been made during the Failure Modes, Effects and Diagnostic Analysis of the variable area flowmeter DK46, DK47, DK48, DK800.

- Failure rates are constant, wear out mechanisms are not included.
- Propagation of failures is not relevant.
- Failures resulting from incorrect use of the flowmeters DK46, DK47, DK48, DK800, in particular humidity entering through incompletely closed housings or inadequate cable feeding through the inlets, are not considered.
- Sufficient tests are performed prior to shipment to verify the absence of vendor and/or manufacturing defects that prevent proper operation of specified functionality to product specifications or cause operation different from the design analysed.
- The mean time to restoration (MTTR) after safe failure is 24 hours.
- All modules are operated in the low demand mode of operation.
- External power failure rates are not included.
- Practical fault insertion test can demonstrate the correctness of the failure effects assumed during FMEDAs.
- The stress levels are average for an industrial outdoor environment and can be compared to exida Profile 3 (for details refer to *Description of the considered environmental profile* on page 5) with temperature limits within the manufacture’s rating.
  Other environmental characteristics are assumed to be within the manufacturer’s ratings.
- The failure rates of the amplifier are not included in the listed failure rates.

All components that are not part of the safety function and cannot influence the safety function (feedback immune) are excluded.

The variable area flowmeters DK46, DK47, DK48, DK800 with inductive limit switches are classified as type A subsystems (non-complex subsystem according 7.4.3.1.2. of IEC 61508-2) with hardware fault tolerance HFT=0.

7.2 Safety-related characteristics for devices with NAMUR limit switch

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

7.2.1 DK46/DK47/DK48/DK800 with 1 NAMUR limit switch

DK4x/K1 and DK800/K1 with 1 NAMUR limit switch ①

Environmental profile	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	MTBF	SIL AC ②
Profile 3 (general field mounted)	0 FIT	57 FIT	10 FIT	131 FIT	251 years	SIL2

Table 7-1: Environmental profile

T[Proof] ③	1 year	5 years	10 years
PFD_{AVG} ④	$6.28E^{-4}$	$2.91E^{-3}$	$5.76E^{-3}$

Table 7-2: T[Proof] and PFD_{AVG}

① The switching contact output is connected to a standard NAMUR amplifier (e.g. Pepperl+Fuchs KF**-SR2-Ex1). The failure rates of the amplifier are not included in the listed failure rates.

② SIL AC (Architectural Constraints) means that the element meets the hardware architectural constraints up to SIL 2 at HFT=0 for low demand mode applications to route 2H.

③ It is assumed that proof testing is performed with a proof test coverage of 99%.

④ The PFD_{AVG} was calculated for exida profile 3 (general field mounted) using the Markov modelling. The results must be considered in combination with PFD_{AVG} values of other devices of the Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL)
For SIL1 applications, the PFD_{AVG} value needs to be $< 10^{-1}$.
For SIL2 applications, the PFD_{AVG} value needs to be $< 10^{-2}$.

7.2.2 DK46/DK47/DK48/DK800 with 1 NAMUR limit switch and flow regulator

DK4x/Rx/K1 and DK800/Rx/K1 with 1 NAMUR limit switch ① and flow regulator

Environmental profile	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	MTBF	SIL AC ②
Profile 3 (general field mounted)	0 FIT	57 FIT	10 FIT	219 FIT	169 years	SIL2

Table 7-3: Environmental profile

T[Proof] ③	1 year	5 years	10 years
PFD_{AVG} ④	$1.04E^{-3}$	$4.84E^{-3}$	$9.57E^{-3}$

Table 7-4: T[Proof] and PFD_{AVG}

① The switching contact output is connected to a standard NAMUR amplifier (e.g. Pepperl+Fuchs KF**-SR2-Ex1). The failure rates of the amplifier are not included in the listed failure rates.

② SIL AC (Architectural Constraints) means that the element meets the hardware architectural constraints up to SIL 2 at HFT=0 for low demand mode applications to route 2H.

③ It is assumed that proof testing is performed with a proof test coverage of 99%.

④ The PFD_{AVG} was calculated for exida profile 3 (general field mounted) using the Markov modelling. The results must be considered in combination with PFD_{AVG} values of other devices of the Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL)
For SIL1 applications, the PFD_{AVG} value needs to be < 10^{-1}.
For SIL2 applications, the PFD_{AVG} value needs to be < 10^{-2}.

7.2.3 DK46/DK47/DK48/DK800 with 2 NAMUR limit switches

DK4x/K2 and DK800/K2 with 2 NAMUR limit switches ①

Environmental profile	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	MTBF	SIL AC ②
Profile 3 (general field mounted)	0 FIT	114 FIT	10 FIT	181 FIT	202 years	SIL2

Table 7-5: Environmental profile

T[Proof] ③	1 year	5 years	10 years
PFD_{AVG} ④	$8.66E^{-4}$	$4.01E^{-3}$	$7.95E^{-3}$

Table 7-6: T[Proof] and PFD_{AVG}

① The switching contact output is connected to a standard NAMUR amplifier (e.g. Pepperl+Fuchs KF**-SR2-Ex1). The failure rates of the amplifier are not included in the listed failure rates.

② SIL AC (Architectural Constraints) means that the element meets the hardware architectural constraints up to SIL 2 at HFT=0 for low demand mode applications to route 2H.

③ It is assumed that proof testing is performed with a proof test coverage of 99%.

④ The PFD_{AVG} was calculated for exida profile 3 (general field mounted) using the Markov modelling. The results must be considered in combination with PFD_{AVG} values of other devices of the Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL)
For SIL1 applications, the PFD_{AVG} value needs to be < 10^{-1}.
For SIL2 applications, the PFD_{AVG} value needs to be < 10^{-2}.

7.2.4 DK46/DK47/DK48/DK800 with 2 NAMUR limit switches and flow regulator

DK4x/Rx/K2 and DK800/Rx/K2 with 2 NAMUR limit switches ① and flow regulator

Environmental profile	λ_{SD}	λ_{SU}	λ_{DD}	λ_{DU}	MTBF	SIL AC ②
Profile 3 (general field mounted)	0 FIT	114 FIT	10 FIT	269 FIT	146 years	SIL2

Table 7-7: Environmental profile

T[Proof] ③	1 year	5 years	10 years
PFD_{AVG} ④	$1.28E^{-3}$	$5.94E^{-3}$	$1.18E^{-2}$

Table 7-8: T[Proof] and PFD_{AVG}

① The switching contact output is connected to a standard NAMUR amplifier (e.g. Pepperl+Fuchs KF**-SR2-Ex1). The failure rates of the amplifier are not included in the listed failure rates.

② SIL AC (Architectural Constraints) means that the element meets the hardware architectural constraints up to SIL 2 at HFT=0 for low demand mode applications to route 2H.

③ It is assumed that proof testing is performed with a proof test coverage of 99%.

④ The PFD_{AVG} was calculated for exida profile 3 (general field mounted) using the Markov modelling. The results must be considered in combination with PFD_{AVG} values of other devices of the Safety Instrumented Function (SIF) in order to determine suitability for a specific Safety Integrity Level (SIL)
For SIL1 applications, the PFD_{AVG} value needs to be $< 10^{-1}$.
For SIL2 applications, the PFD_{AVG} value needs to be $< 10^{-2}$.

8.1 Annex 1

Constricted description code for DK46, DK47, DK48, DK800 functional safety equipment according to EN 61508.

The description code consists of the following elements*:

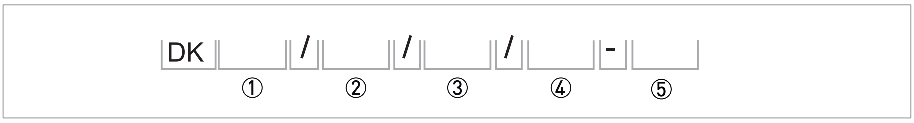

Figure 8-1: Description code

① Device type
46 - Overall length of measuring cone 65 mm / 2.6"
47 - Overall length of measuring cone 150 mm / 5.9"
48 - Overall length of measuring cone 300 mm / 11.8"
800 - Overall length of measuring cone 100 mm / 3.9"
② Material for top and bottom fittings
N - brass
R - stainless steel
③ Flow regulator
RE - flow regulator for variable inlet pressure
RA - flow regulator for variable outlet pressure
④ Limit switches
K1 - one limit switch
K2 - two limit switches
⑤ SIL compliance
SK - SIL conformity according to IEC 61508 of the limit switch

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

8.2 Annex 2

Bistable NAMUR contact types, used for DK46, DK47, DK48, DK800

I7R2010-NL, I7R2015-NL (ifm electronic)

RC10-14-N3, RC15-14-N3 (Pepperl+Fuchs)

Recommended NAMUR isolated switching amplifiers

Type code	Manufacturer	Supply voltage	Channel	Output
KFA6-SR2-Ex1.W	Pepperl+Fuchs	207...253 VAC	1 channel	Relay
KFA5-SR2-Ex1.W	Pepperl+Fuchs	103.5...126 VAC	1 channel	Relay
KFD2-SR2-Ex1.W	Pepperl+Fuchs	20...30 VDC	1 channel	Relay

Table 8-1: Recommended NAMUR isolated switching amplifiers

KROHNE – Process instrumentation and measurement solutions

- Flow
- Level
- Temperature
- Pressure
- Process Analysis
- Services

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