KLAY-INSTRUMENTS

SAFETY MANUAL

SERIES 8000 and HYDROBAR

SAFETY INTEGRITY LEVEL
SIL2
KLAY INSTRUMENTS

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1. Functional Safety

1.1 Scope

This safety manual applies to measuring systems consisting of Klay Instruments pressure transmitter in a two wire 4-20 mA loop.

This functionally safety manual applies for:

- **Series 8000, 8000-SAN, CER-8000, 8000-SAN Cable, Hydrobar Cable and Hydrobar Cable-FR.** With a serial number of the transmitter > 10509426

1.2 Application area

The measuring system can be used for process pressure or level measurement of gases, vapours and liquids which meet the specific requirements of the safety technology.

1.3 Safety function

The device generates an analogue output signal of 4-20 mA that is proportional to the current pressure. This has to be controlled by a downstream logical unit (e.g. PLC). For the malfunction detection, the logical unit has to distinguish between 4-20 mA-signals and the fault current < 3.3 mA or > 20.8 mA. Observe with the conception of the system, that the technical data of the product-specific as well as Functional Safety Data Sheet may not be exceeded. Especially the permissible operating condition (permissible temperatures, etc.) have to be ensured.

- Make sure that the entire interconnection of different components fulfills the requirements of the application. The operator is responsible for correct construction of the overall system.
- After installation a validation of the safety function is required.
- The installation, maintenance and cleaning of the devices must be performed exclusively by persons specifically trained and authorized for this purpose as far as they are familiar with the devices !
- The operability of the measuring device should be checked via proof test in regularly intervals. For defining the scope and interval of tests, the following table can be used as a reference. However each application has its own unique properties and exceptions. Klay Instruments is not an expert in the customer's process (technical field) and does not accept liability for consequential damage of any kind due to use or misuse of the Series 8000 and Hydrobar.

Industry	Application	Frequency of proof test		
		Twice a year	Yearly	Every two years
Food and Dairy	Fluids		●	
	Steam and Air			●
	Homogenisors	●		
Brewery and Beverage	Fluids		●	
	Steam and Air			●
	Homogenisors	●		
Pharmaceutical	Fluids		●	
	Steam and Air			●
Pulp and Paper	Fluids		●	
	Steam and Air			●
Industry	**Application**	**Frequency of proof test**		
		Twice a year	**Yearly**	**Every two years**
Shipbuilding and Marine	Fluids		●	
	Steam and Air			●
Water and Wasted Water	Fluids		●	
	Air			●
Chemical and Petrochemical	Fluids		●	
	Steam, Air and Gasses		●	
Oil and Gas	Fluids		●	
	Steam, Air and Gasses		●	
	Drilling systems	●		
Others (Machinebuilding)	Fluids		●	
	Steam, Air and Gasses		●	

- Modifications on devices and connections void Functional Safety and the warranty !

- It is the responsibility of the user to verify whether the chosen version of the device is suitable for the intended application and the existing environmental conditions. Klay Instruments does not assume any liability for an incorrect selection and its consequences.

2. Compliance

2.1 Assumptions

- The average ambient temperature during the operating time is 20°C - 40 °C (68 °C - 104 °F).
- The environmental conditions correspond to an industrial environment.
- The lifetime of the components is around 10 to 14 years (IEC 61508-2, 7.4.7.4, remark 3).

2.2 Product identification

Make sure the device has been ordered with SIL-conformity and has been delivered accordingly.
The transmitter is clearly marked with a special SIL marking on the enclosure.

2.3 SIL conformity

The SIL conformity is confirmed by the verification documents in the appendix.
It is the conclusion of Risknowlogy that the products meet the proven in use requirements of IEC 61508 and are more conservative considering the prior use requirements of IEC 61511. The table below show the IEC 61508 requirements based on the architectural constraints of route 1_H.
Final results:

HFT	IEC 61508	IEC 61511
HFT = 0	SIL 2	SIL 2
HFT = 1	SIL 3	SIL 3

Abbreviations, terms:

SIL	Safety Integrity Level
HFT	Hardware Fault Tolerance
SFF	Safe Failure Fraction
PFD_{AVG}	Average Probability of dangerous Failure on Demand
PFH	Probability of a dangerous Failure per Hour
FMEDA	Failure Mode, Effects and Diagnostics Analysis
λ_{sd}	Rate for safe detected failure
λ_{su}	Rate for safe undetected failure
λ_{dd}	Rate for dangerous detected failure
λ_{du}	Rate for dangerous undetected failure
DC_S	Diagnostic Coverage of safe failures; $DC_S = \lambda_{sd}/(\lambda_{sd}+\lambda_{su})$
DC_D	Diagnostic Coverage of dangerous failures; $DC_D = \lambda_{dd}/(\lambda_{dd}+\lambda_{du})$
FIT	Failure In Time (1 FIT = 1 failure/10^9 h)
MTBF	Mean Time Between Failure
MTTF	Mean Time To Failure
MTTR	Mean Time To Repair

Further abbreviations and terms are stated in IEC 61508-4.

2.4 Relevant standards

- **IEC 61508:2010**
  Functional safety of electrical/electronic/programmable electronic safety-related systems

- **IEC 61511-1:2016**
  Functional safety - safety instrumented systems for the process industry sector - Part 1: Framework, definitions, system, hardware and software requirements

3. Safety

3.1 Safety requirements

Failure limit values for a safety function, depending on the SIL class (of IEC 61508-1, 7.6.2)

Safety integrity level	Low demand mode
SIL	PFD_{avg}
4	$\geq 10^{-5} \ldots < 10^{-4}$
3	$\geq 10^{-4} \ldots < 10^{-3}$
2	$\geq 10^{-3} \ldots < 10^{-2}$
1	$\geq 10^{-2} \ldots < 10^{-1}$

Safety integrity of hardware for safety-related subsystems of type A (IEC 61508-2, 7.4.3)

Safe failure fraction	Hardware fault tolerance		
SFB	HFT = 0	HFT = 1 (0)	HFT = 2
< 60 %	SIL1	SIL2	SIL3
60 % … < 90 %	SIL2	SIL3	SIL4
90 % … < 99 %	SIL3	SIL4	SIL4
≥ 99 %	SIL3	SIL4	SIL4

3.2 Service Proven

According to IEC 61511-1, paragraph 11.4.4, the failure tolerance HFT can be reduced by one for service-proven subsystems if the following conditions are met:

- The hardware of the device is selected on the basis of prior use (see IEC 61511-1 Cl. 11.5.3)
- The device allows adjustment of process-related parameters only, for example, measuring range, upscale or downscale failure direction.
- The adjustment of the process-related parameters of the device is protected.
- The function has a SIL requirement of less than 4.

SIL	Minimum hardware fault tolerance (see 11.4.3 and 11.4.4)
1	0
2	1
3	2
4	Special requirements apply (see IEC 61508)

The user must have experience with this process, and must be in compliance by the requirements of IEC 61511-1 clause 11.5.3. The operating experience must be recorded in the user's list of equipment approved for use in their facilities.

4. Safety-related characteristics

4.1 Basics

The failure rates of the electronics, the mechanical parts of the transmitter as well as the process fitting are determined by an FMEDA according to IEC 61508. The calculations are based on component failure rates according to SN 29500. All values refer to an average ambient temperature during the operating time of 55 °C (104 °F). For a higher average temperature of 60 °C (140 °F), the

failure rates should be multiplied by a factor of 2.5. A similar factor applies if frequent temperature fluctuations are expected.

4.2 Safe function

A measurement of absolute and relative pressure or level within the specified safety accuracy of 0.2 % from full span.
The safety function response time is 50 ms.

4.3 Specific characteristics

Failure Rate

Type of rating	Failure in time (FIT)
λ_{sd} (safe detected failure)	0.00
λ_{su} (Safe undetected failure)	104.14
λ_{dd} (Dangerous detected failure)	0.00
λ_{du} (Dangerous undetected failure)	36.38

Single channel architecture (1oo1D)

SIL	SIL2
HFT	0
Instrument type	A

SFF	**74 %**
PFD_{avg}	
T_{Proof} = 1 Year	$< 0.161 \times 10^{-3}$
T_{Proof} = 2 years	$< 0.321 \times 10^{-3}$
T_{Proof} = 5 years	$< 0.799 \times 10^{-3}$
T_{Proof} = 10 years	$< 0.159 \times 10^{-2}$
T_{Proof} = 15 years	$< 0.239 \times 10^{-2}$
T_{Proof} = 20 years	$< 0.319 \times 10^{-2}$

4.4 Time-dependent process of PFD_{avg}

The chronological sequence of PFDavg is nearly linear to the operating time over a period up to 10 years. The above values apply only to the TProof interval after which a recurring function test must be carried out

4.5 Service life

After 10 to 14 years, the failure rates of the electronic components will increase, whereby the derived PFD values will deteriorate (IEC 61508-2, 7.4.7.4, note 3).