5485C

HIGH TEMPERATURE VELOCITY TRANSDUCER

SAFETY MANUAL

02.27.2017 – Rev. 0

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1. PURPOSE

The purpose of this safety manual is to establish the safety aspect of the Metrix - 5845C High Temperature Velocity transducer and to enable the integration of this device into a safety related system, with the objective to be in compliance with the requirements of the IEC 61508-2 Annex D. The information contained in this Safety Manual are valid for the model indicated in the paragraph 4.1.

When the 5845C High Temperature Velocity transducer is in included in a Safety Instrumented Function, the integrator shall evaluate the performance of the device into the SIF loop, in order to ensure its proper implementation.

2. TERMS, DEFINITIONS AND ABBREVIATIONS

2.1. TERMS AND DEFINITIONS

Architecture

Arrangement of hardware and/or software elements in a system.

Architectural constraint

This reports the maximum SIL achievable based on the SIF's subsystems architecture alone. This is calculated solely on the basis of Type A or Type B device selection, redundancy (hardware fault tolerance), and the safe failure fraction (calculated or conservatively assumed if no data is provided). It does not pertain to Systematic Capability or certification. This is calculated as indicated, using respective IEC 61508 or IEC 61511 tables.

Architectural Type

- Type A equipment or (sub)system: "Non –complex" (sub)system or equipment according 7.4.3.1.2 of IEC 61508-2;

- Type B equipment or (sub)system: "Complex" (sub)system or equipment according 7.4.3.1.3 of IEC 61508-2.

Diagnostic Coverage

Fraction of dangerous failures rates detected by diagnostics. Diagnostics coverage does not include any faults detected by proof tests.

Mean Repair Time

Expected overall repair time

Mean Time to Restoration

Expected time to achieve restoration.

Mode of operation

Way in which a SIF operates which may be either low demand mode, high demand mode or continuous mode:

• Low Demand Mode: mode of operation where the SIF is only performed on demand, in order to transfer the process into a specified safe state, and where the frequency of demands is no greater than one per year;

- High Demand Mode: mode of operation where the SIF, is only performed on demand, in order to transfer the process into a specified safe state, and where the frequency of demands is greater than one per year;

- Continuous Mode: where the mode of operation where the SIF retains the process in a safe state as part of normal operation.

MooN

SIS, or part thereof, made up of "N" independent channels, which are so connected, that "M" channels are sufficient to perform the SIF.

Hardware Fault Tolerance

A hardware Fault Tolerance of N means that N+1 is the minimum number of faults that could cause a loss of the safety function. In determining the hardware fault tolerance no account shall be taken of other measures that may control the effects of faults such as diagnostics.

Probability of dangerous Failure on demand PFD

Average probability of dangerous failure on demand.

Probability of dangerous Failure per Hour PFH

Average probability of dangerous failure within 1 h.

Proof Test

Periodic test performed to detect dangerous hidden faults in a SIS so that, if necessary, a repair can restore the system to an "as new" condition or a close as practical to this condition.

Safe Failure Fraction

Property of a safety related element that is defined by the ratio of the average failure rates of safe plus dangerous detected failures and safe plus dangerous failures.

Safety instrumented function (SIF)

Safety Function to be implemented by a safety instrumented system (SIS)

Safety instrumented system (SIS)

Instrument system used to implement one or more SIFs.

Safety Integrity

Ability of the SIS to perform the required SIF as and when required.

Safety Integrity Level (SIL)

Discrete level (one out of four) allocated to the SIF for specifying the safety integrity requirements to be achieved by the SIS.

Safe State

State of process when safety is achieved.

Systematic Capability

Measure (expressed on a scale of SC 1 to SC 4) of the confidence that the systematic safety integrity of a device meets the requirements of the specified SIL, in respect of the specified safety function, when the device is applied in accordance with the instructions specified in the device safety manual.

λ

Failure rate (per hour) of a channel in a subsystem.

λ_D

Dangerous failure rate (per hour) of a channel in a subsystem.

λ_S

Safety failure rate (per hour) of a channel in a subsystem.

λ_{DU}

Dangerous undetected failure rate (per hour) of a channel in a subsystem.

λ_{DD}

Dangerous detected failure rate (per hour) of a channel in a subsystem.

functional safety

part of the overall safety relating to the EUC and the EUC control system that depends on the correct functioning of the E/E/PE safety-related systems and other risk reduction measures

safe state

state of the EUC when safety is achieved

2.2. SYMBOLS AND ABBREVIATIONS

BPCS	Basic Process Control System
DC	Diagnostic Coverage
E/E/PE	Electrical / Electronic / Programmable Electronic
EUC	Equipment Under Control
FIT	Failure In Rate
HFT	Hardware Fault Tolerance
IEC	International Electro-Technical Commission
MRT	Mean Repair Time
MTTR	Mean Time to Restoration
PFD	Probability of Failure on Demand
PLC	Programmable Logic Controller
PTC	Proof Test Coverage
SC	Systematic Capability
SFF	Safe Failure Fraction
SIL	Safety Integrity Level
SIS	Safety Instrumented System

3. INTRODUCTION

The Metrix 5485C is a moving-coil velocity transducer, specifically designed for continuous use in elevated temperatures. A permanent magnet moving back and forth within a coil winding induces and electromagnetic field in the windings. This electromagnetic field is proportional to the velocity of oscillation of the magnet: the magnet shall be mounted on the vibration object to measure its velocity.

A zero-friction coil suspension provides accurate, repeatable vibration measurements over a wide range of amplitude and frequency and is built to withstand the high-g environments and cross-axis vibrations typical of gas turbines. The coil bobbin is suspended by two non-twisting, circular spider springs that provide a clean frequency response.

Purely viscous electromagnetic damping is employed and eliminates friction-prone air damping. This allows improved detection of small vibration amplitudes at low frequencies.

The sensor is available in two configurations: with integral armored cable or removable armored cable via a 2-pin MIL-style threaded connector. The case is constructed of stainless steel and its robust internals are hermetically sealed to ensure durability in the most hostile environments. The product is approved for use in Zone 2 / Div 2 hazardous areas without use of intrinsic safety barriers. It is also approved for use in Zone 0/1 and Div. 1 areas with use of an appropriate intrinsic safety barrier.

The Metrix 5485C Velocity Sensor shall be used in application where there is a continuous vibration of the unit to be supervised and where the target is the vibration detection over the assigned threshold.

4. REFERENCE DOCUMENTS

The following table shows the document useful the Safety Manual realization:

Doc ID	Project Document Name	Document Code	Version
[D1].	Datasheet	Doc# 1004251	Rev J – June 2015
[D2].	Installation Manual	Doc# M8109	Rev K – Feb 2015
[D3].	SIL Certificate	MIC-5485-E01-ESLC-S01	Rev. A – Feb. 28th 2017
[D4].	Safety Assessment Report	C306-105-021600_ESLC-S01_01	Rev. 0 – Feb. 27th 2017

4.1. PRODUCTS FAMILY IDENTIFICATION

This Safety Manual is valid for each product listed in this paragraph. In the following table are listed the family models for the sensor 5485C with Removable Cable. Each sensor is differentiated one from the other by the internal coil resistance: the latter allows a differential measure sensitivity.

5485C-AAA Velocity Sensor with Removable Cable				
AAA				**Output Type**
	0	0	2	105 mV/in/s (4.14 mm/sec), 73 Ω coil resistance
	0	0	4	145 mV/in/s (5.71 mm/sec), 102 Ω coil resistance
	0	0	6	200 mV/in/s (7.87 mm/sec), 135 Ω coil resistance
	0	0	8	150 mV/in/s (5.91 mm/sec), 105 Ω coil resistance

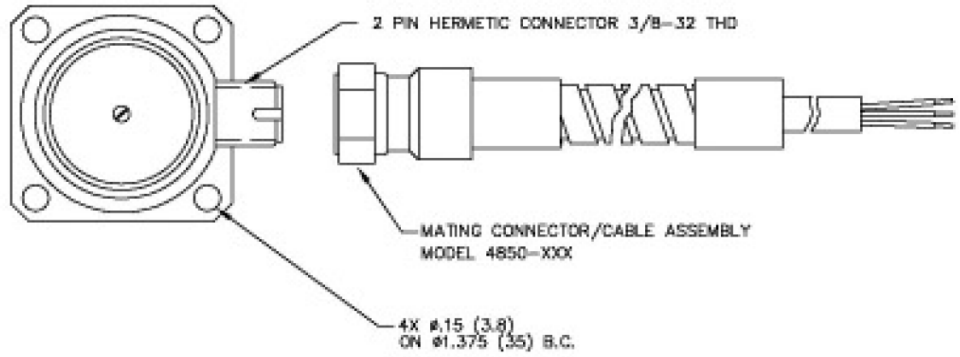

Figure 1 Removable Cable Configuration

The types of removable cable for the above products are listed in the following table:

4850-AAA High Temperature Armored Cable Assembly					
AAA				**Cable Length (feet and meters)**	
	0	1	0	10 feet (3 m)	
	0	2	0	20 feet (6.1 m)	
	0	6	0	60 feet (18.3 m)	
	x	x	x	Other lengths in feet; min length 2 feet; max length 60 feet; must be ordered in 2-foot increments (e.g., AAA=042 for 42’ length is allowed; AAA=043 for 43’ length is not allowed)	
				Cable Length	**Allowable Increments**
				2 – 20 feet	1 foot (e.g., AAA=018 for 18’ and AAA=019 for 19’)
				20 – 60 feet	2 feet (e.g., AAA=042 for 42’ and AAA=044 for 44’)
				60 – 100 feet	5 feet (e.g., AAA=075 for 75’ and AAA=080 for 80’)

Whereas, in the following table are listed the sensors 5485C with Integral Cable (Cable 4850 is not required):

5485C-AAA-BBB Velocity Sensor with Integral Cable (Cable 4850 not required)				
AAA				**Output Type**
	0	0	1	105 mV/in/s (4.14 mm/sec), 73 Ω coil resistance
	0	0	3	145 mV/in/s (5.71 mm/sec), 102 Ω coil resistance
	0	0	5	200 mV/in/s (7.87 mm/sec), 135 Ω coil resistance
	0	0	7	150 mV/in/s (5.91 mm/sec), 105 Ω coil resistance
BBB				**Cable Length (feet and meters)**
	0	1	0	10 feet (3 m)
	0	2	0	20 feet (6.1 m)
	0	6	0	60 feet (18.3 m)
	x	x	x	Other lengths in feet; minimum length 2 feet; max length 60 feet; must be ordered in 1, 2 or 5-foot increments

Summarizing, the 5485C High Temperature Velocity Sensor is available with the Armored Cable integrated and removable as shown in Figure 2 and Figure 1.

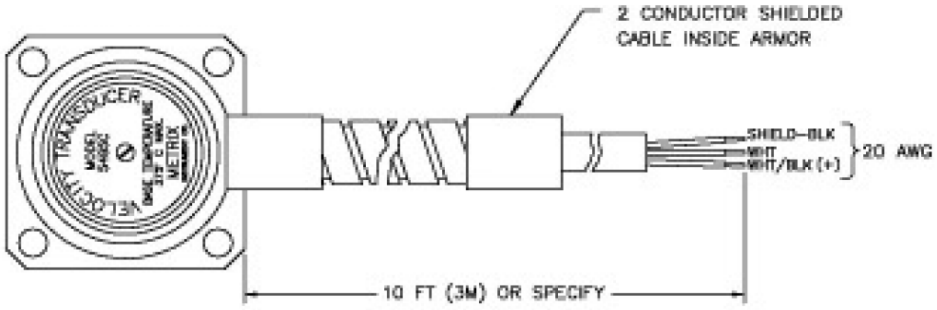

Figure 2 Fixed Cable Configuration

4.2. SPECIFICATIONS

Axis Orientation	Any*
Sensitivity	105, 145, 150, or 200 mV/in/sec
Sensitivity vs Temperature	Less than 0.02%/°C
Cross-Axis Sensitivity	Less than 10%
Service Temperature	-54° to + 375°C (-65° to +707°F)
Frequency Response (+\- 3dB Passband)	15 Hz to 2000 Hz
Maximum G-Level	50 g
Maximum Displacement	1.8 mm (70 mils) pk-pk
Case-To-Coil Isolation (Min)	- 100 MΩ @ 20°C - 10 MΩ @ 200°C - 1 MΩ @ 375°C
Case Sealing	Welded; hermetically sealed
Material	- Housing: 416 Stainless Steel - Connector: 316 Stainless Steel - Cable Armor: 302 Stainless Steel
Weight	- Sensor: 0.2 kg (0.5 lb) - Armored Cable: 0.2 kg/m (0.13 lb/ft)
Connector Type	- Sensor: 2-pin MIL-style (male) - 4850 Cable: 2-pin MIL-style (female) - Integral Cable: none (cable is not detachable)

NOTICE

The device can be installed in each orientation, but if it installed upside-down, the BPCS software shall be configurated to compensate the gravity force.

5. SAFETY CHARACTERISTICS

Safety Function	Generate an emf directly proportional to the oscillatory velocity applied to the sensor body by the external environment, suitable to vibration monitoring of rotating machinery.
Installation	Refer to [D2]
Lifetime	When using in the prescribed manner indicated in the [D2], the device can operate in safety applications up to 10 years.
Diagnostic	No internal diagnostics are present. The diagnostic can be performed by the SIS logic solver, revealing easily the open and short circuit of the device. In case of short circuit or open circuit, the output voltage drop to zero.
Interface	Being an intrinsically safe device, the interface towards the SIS shall be implemented with an isolating barrier as specified in [D2].
Response Time	The response time of the device is 30·ms. This value does not consider any adapting device that can be interfaced to the Velocity Sensor.
MRT	8 hours (considering the worst case for high temperature application)

NOTICE

No modification is allowed on the device. Any modification compromises the function of the device and safety-related characteristics.

NOTICE

During the installation, shall be paid attention to the armed cable, avoiding repeated twisting which can compromise the device health state.

6. SAFETY PARAMETERS

Specific activities necessary to investigate and reach a judgment on the adequacy of the functional safety achieved by the E/E/PE safety-related system or compliant items (elements/subsystems) has been conducted by an independent assessor.

The following failure rates data shall be used to the PFDAVG estimation, taking into consideration all parameters such as redundancy, architectural constraints, diagnostic capability, also introduced by the whole system, including the considerations about the proof test and its effectiveness, mean time of restoration, up to the maintenance capability and its minimum characteristics.

NOTICE

The design of each Safety Instrumented Function shall meet the requirements listed in the reference standards that shall be selected by taking into account the specific application.

The estimated safety integrity, for each safety function, due to random hardware failures (including soft-errors) and random failures of data communication processes. The following table shows the failure rates of the device listed in para. 4.1.

5485C-AAA Velocity Sensor with 4850-AAA High Temperature Armored Cable Assembly (Removable Cable)			
λ_{SU} (FIT)	**λ_{SD} (FIT)**	**λ_{DU} (FIT)**	**λ_{DD} (FIT)**
0	0	98	716
Systematic Capability [SC]:		3 (Route 1_S)	
Hardware Safety Integrity:		Type A	Route 1_H

5485C-AAA-BBB Velocity Sensor with Integral Cable			
λ_{SU} (FIT)	**λ_{SD} (FIT)**	**λ_{DU} (FIT)**	**λ_{DD} (FIT)**
0	0	104	712
Systematic Capability [SC]:		3 (Route 1_S)	
Hardware Safety Integrity:		Type A	Route 1_H

NOTICE

The failures rates are distributed considering the ability of the SIS logic solver to detect short circuit and open circuit, as described in para. 7.

7. REQUIREMENTS FOR IMPLEMENTATION INTO A SIS

The SIS logic solver shall be able to detect the sensor fault through its signal. The most critical failure modes, open circuit and short, give as a result an output signal equal to zero.

The logic solver used to acquire the 5485C output signal shall have a high internal impedance (not less than 100kΩ).

In order to maintain the safety capability of the sensor, the logic solver shall activate a proper feedback when a zero-voltage signal is detected. This proper feedback shall be used as fault condition of the sensor. The fault condition shall be properly managed as per each specific safety function.

NOTICE

The sensor isn't designed to impulsive vibration. It shall be used in application having a natural vibration frequency in the range of the sensor in order to allow a proper diagnostic of the correct functionality of the sensor.

NOTICE

The natural vibration of the equipment under control shall not exceed the transducer maximum displacement of 1,8mm (70 mils).

After the first installation, and after any replacing or proof test, the right functionality of the sensor through verifying of coil-to-case insulation. The electrical test shall be used to discover possible wire damage able to increase the resistance of the connecting cable.

8. PROOF TEST

The proof test is not necessary, since for the entire lifetime, the correct functioning according to the specifications indicated in the para. 4.2 are satisfied. However, the proof test can be performed in order to satisfy the requirement coming from the demand rate of the Safety Instrumented Function, where the Metrix 5845C is involved.

SENSOR VERIFICATION CALIBRATION PROCEDURE

Mount the 5845C on a shaker table and verify the RMS output per table below. The table is divided according to the different types of Sensitivity.

CALIBRATION VERIFICATION TABLE 1 ips (0.0254 m/s) peak @ 150 Hz		
Calibrated Sensitivity mV/in/s	**Calibrated Sensitivity mV/mm/s**	**RMS Output mV Min/Max**
105	4.14	67/81
145	5.71	93/112
150	5.91	95/167
200	7.87	127/156

NOTICE

The test detailed in this paragraph shall be carried out by competent and trained personnel.

WARNING!

Maintenance may compromise the sensor. Follow the instruction listed into the user manual is mandatory to ensure the correct operability of SIS.