



IECEX Test Report Cover

ATEX Assessment Report Cover



IECEX ExTR Reference Number.....	See Report No. above.
ATEX Assessment Report Number.....	See Report No. above.
Free Reference Number.....	228413200
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Reviewed by + signature (ExTL).....	B.P.O. Meijer (Ex i part) H.J.G. de Wild (Ex d part)
Approved by + signature..... on behalf of the bodies listed below	R. Schuller
Date of issue (yyyy-mm-dd).....	2024-04-15
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IECEX Certification Body (ExCB)	DEKRA Certification B.V.
Address.....	Meander 1051, 6825 MJ Arnhem, The Netherlands
ATEX Notified Body (0344).....	DEKRA Certification B.V.
Per Annex III (EU-Type Examination) or Annex IX (Unit Verification)	
Address	Meander 1051, 6825 MJ Arnhem, The Netherlands
Applicant's name.....	RIKEN KEIKI Co., Ltd.
Address	2-7-6, Azusawa, Itabashi-ku, Tokyo, 174-8744, Japan
Standards associated with this report package	IEC 60079-0 : 2017 (Ed. 7.0) IEC 60079-1 : 2014 (Ed. 7.0) IEC 60079-11 : 2011 (Ed. 6.0)
Clauses considered.....	All clauses considered
Test Report Form Number.....	DEKRA form 256, based on ExTR Cover_9 (released 2021-09)
Related Amendments, Corrigenda or ISHs.....	For ExTAG Decision Sheets see the individual report parts For IEC and ISO Corrigenda, Amendments and Interpretation Sheets see the overview in this IECEX Test Report Cover For EN Corrigenda, Amendments and Interpretation Sheets see the ATEX Assessment Report of National Differences EU (ATEX)
Test item description	Portable gas detector
Model/type reference.....	GX-Force Three different gas sensors are used: Model ESR-A1DP: measures CO/H ₂ S (electrochemical principle) Model ESR-X13P: measures O ₂ (electrochemical principle) Model NCR-6309: measures flammables (catalytic)
Code (e.g. Ex __ II__ T__)	Ex da ia IIC T4 Ga (with catalytic gas sensor) Ex ia IIC T4 Ga (without catalytic gas sensor)

Rating : Battery powered, single secondary cell Panasonic type NCR18650GA.
 Nominal voltage: 3.6 V
 Maximum open circuit voltage: 4.2 V
 The charging terminal is USB TYPE C, and only a use of a charger exclusively specified for it, IEC 60950-certified SELV power supply, or IEC 62368-1-certified ES1 power supply is approved for charging. Charging method is CCCV. (Charging only in non-hazardous area.)
 Charging terminal, Um: 6 V

Report Package Contents

Assembled Report parts and additional reference material:

Report No. NL/DEK/ExTR24.0019/00 Cover
Report No. NL/DEK/ExTR24.0019/00 IEC 60079-0
Report No. NL/DEK/ExTR24.0019/00 IEC 60079-1
Report No. NL/DEK/ExTR24.0019/00 IEC 60079-11 including Appendix A and B
Report No. NL/DEK/ExTR24.0019/00 National Differences EU (ATEX)
Report No. NL/DEK/ExTR24.0019/00 Appendix A; Description of the Test item
Report No. NL/DEK/ExTR24.0019/00 Appendix B; Description of the Tests
Report No. NL/DEK/ExTR17.0047/01 Appendix B; Description of the Tests
Report No. NO/DNV/ExTR21.0088/00

Note: An * is included before the title of documents that are new or revised at an up- issue of the report.

Manufacturer's name..... : Same as Applicant
 Address..... : Same as Applicant
 Trademark..... : N/A

Particulars: Test item vs. Test requirements

Equipment classification of installation and use : Portable (Hand-held)
 Ingress protection : IP20
 Rated ambient temperature range (°C)..... : -20 °C to +60 °C

General remarks:

The test results presented in this report package relate only to the item or product tested.

- "(See Attachment #)" refers to additional information appended to this report package.
- "(See appended table)" refers to a table appended to the report package.
- Throughout this report package, a point is used as the decimal separator.
- *Where the term "N/A" appears in any part of a report package, it indicates that the associated issue was considered "Not applicable" to the involved evaluation.*
- *In accordance with IECEx 02, a Receiving ExCB may request a sample of the Ex equipment and copies of the documentation referred to in an report Cover.*

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Use of uncertainty of measurement for decisions on conformity (Decision rule):

No decision rule is specified by the standards associated with this ExTR package, when comparing the measurement result with the applicable limit according to the specification in these standards. The decisions on conformity are made without applying the measurement uncertainty as described in IECEx OD 012 (i.e. "simple acceptance" decision rule, previously known as "accuracy method").

General product information:

GX-Force is a portable suction type gas detector which can measure 4 kinds of gases.

For gas sensors, electrochemical type and catalytic type are used.

For power, a non-user-replaceable battery, a Panasonic type NCR18650GA is used.

This unit contains 2 buttons, LCD display screen, and LEDs for alarm on both sides and top. Internally, one each pump, buzzer, and vibration motor are mounted. When the power is supplied, the pump will be activated for suction, and the unit starts gas detection. Gas concentration is always displayed on the LCD screen. When a gas is detected, the indicator value on the LCD screen goes up, and when it reaches to the alarm level, LED buzzer, vibration motor will be activated and notify the user that the gas was detected.

The sensors to be mounted are electrochemical type and catalytic type. The electrochemical type sensor detects CO (carbon monoxide), H₂S (hydrogen sulfide), and O₂ (oxygen). The catalytic type sensor detects flammable gases.

Charging shall be done in a non-hazardous location. The charging terminal is USB TYPE C, and only a use of a charger exclusively specified for it, IEC 60950-certified SELV power supply, or IEC 62368-1- certified ES1 power supply is approved for charging. Charging method is CCCV, and a control is performed by a dedicated IC. Rechargeable temperature range is between +10 °C and +40 °C.

Charging circuit:

$U_m = 6.0 \text{ V}$ (SELV circuit)

Report history:

Report	Free Reference Number
NL/DEK/ExTR24.0019/00	228413200

Copy of Marking Plate:

See technical document M4-4777-31-13K.

**Details regarding 'trade agent' / 'local assembler' application in accordance with OD 203:**

N/A, no 'trade agent' / 'local assembler'.

Testing not fully performed by ExTL staff at the above ExTL address:

Tests listed in Appendix B of NL/DEK/ExTR24.0019/00 and Appendix B from part IEC 60079-11 of this Report No. NL/DEK/ExTR24.0019/00 were performed by another ExTL staff, DNV Product Assurance AS, Veritasveien 1, 1363 Høvik, Norway. Results were confirmed in report NO/DNV/ExTR21.0088/00.

National differences considered as part of this evaluation:

For the EU, ATEX: National differences from directive 2014/34/EU and national differences between the applied IEC and EN standards were assessed and reported in the part "National differences for ATEX" of this report.

Specific Conditions of Use:

1. The flameproof joints are not intended to be repaired.
2. When using the product in hazardous areas, take the precautions as listed in safety instructions to safeguard against static electricity hazards.

Routine tests:

N/A

Date(s) of performance for all testing:

See all 3 reports Appendix B for dates of performed tests.

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Technical Document

No.	(*)	Title:	Document No.:	Rev.	Date:
00.		Document package for INDEX GX-Force (documents 1 up to 23).	E4-6991-6235-70-01K	11	2024.3.26

Note: An * is included before the title of documents that are new or revised at an up- issue of the report.

Corrigenda, Amendments and Interpretation Sheets			
Decision	Requirement – Test	Result – Remark	Verdict

IEC 60079-0: 2017 (Edition 7.0)			
IEC 60079-0 : 2017 COR1 : 2020	cl. 26.5.1.1 Temperature tests shall be done in still ambient air and shall be linearly corrected for the rated ambient temperature	Temperature tests are not done for this project.	N/A
IEC 60079-0 : 2017 ISH1 : 2019	cl. 16.6. internal air temperature may represent other temperatures of electrical machines	The internal air temperature is not taken as a representation of other temperatures.	N/A
IEC 60079-0 : 2017 ISH2 : 2019	cl.29. marking of Equipment which includes both an electrical part and a non-electrical part shall have combined marking	The Equipment includes only electrical parts	N/A

IEC 60079-1 : 2014 (Edition 7.0)			
IEC 60079-1 : 2014 / COR1 : 2018	C.2.3.3 the text at bullet point d) is deleted, bullet point e) is renumbered to bullet point d)	No NPT threaded flameproof entry devices in the scope.	N/A
IEC 60079-1 : 2014 / ISH1 : 2020	cl. 13.1: The restriction to NPT and M threaded entries is a major technical change	No entries provided	N/A
	Annex C: a thread adapter fitted and assessed as factory assembled part may use other thread than NPT and M	No factory assembled thread adapter applied	N/A
	cl. 13: blanking elements may be installed in factory assembled thread adapter(s)	The equipment has no blanking elements mounted in factory assembled thread adapter(s).	N/A
	cl. 13 when factory assembled thread adapter are applied, the thread of the field wiring side shall be identified	No factory assembled thread adapter applied	N/A




IEC 60079-11 : 2011 (Edition 6.0)			
IEC 60079-11 : 2011 C1 : 2012	Table 1 cl. 26.4.4 changed Table 3 8 th footnote changed Fig 1b changed cl. 8.2.3 4 th paragraph changed cl. 12.1 5 th , 6 th and 8 th paragraph changed Fig. D.3a changed Fig. G.1 changed	Corrigendum taken into account. For details see EXTR 60079-11	Pass
IEC 60079-11 : 2011 / I-SH 01 : 2014	Significant changes compared to Edition 5	This overview of changes is not used for a gap analysis. The reported assessment covers all actual requirements in the standard.	N/A
IEC 60079-11 : 2011 ISH2 : 2016	clause 6.2.5 clarified. IEC 60079-11 is not applicable for voltage limitation to guarantee U_m .	This interpretation sheet is mainly for the end user and not for the assessment of the product.	N/A

Corrigenda, Amendments and Interpretation Sheets			
Decision	Requirement – Test	Result – Remark	Verdict
IEC 60079-11 : 2011 ISH3 : 2016	guide for level of protection “ic” evaluations	“ic” not applied	N/A
IEC 60079-11 : 2011 / ISH4 : 2019	cl. 6.1.3. group III enclosures	Not group III	N/A
IEC 60079-11 : 2011 / ISH5 : 2019	Table 4 - group III with component(s) immersed in dust	Not group III	N/A
IEC 60079-11 : 2011 / ISH6 : 2019	cl. 10.5.3 b) current limiting devices to be disabled at the determination of the surface temperature of cells.	Only cells are used for testing. See Report Part 60079-11, Appendix B.5.	Pass



Report
IEC 60079-0
Explosive atmospheres –
Part 0: Equipment – General requirements



Report Number	See Report No. above.	  
Free Reference Number.....	See report cover.	
Compiled by + signature (ExTL)	A. Hadak	
Reviewed by + signature (ExTL).....	B.P.O. Meijer (Ex i part) H.J.G. de Wild (Ex d part)	
Date of issue (yyyy-mm-dd)	2024-04-15	
Ex Testing Laboratory (ExTL).....	DEKRA Certification B.V.	
Address	Meander 1051, 6825 MJ Arnhem, The Netherlands	
Applicant's name.....	See report cover.	
Address	See report cover.	
Standard	IEC 60079-0 : 2017, Edition 7.0	
Test procedure.....	IECEX System	
Test Report Form Number.....	See footer, based on ExTR60079-0_7D_DS (released 2021-12)	

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Possible test case verdicts:

- test case does not apply to the test item..... : N/A
- test item does meet the requirement : Pass

General remarks:

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- "(see appended table)" refers to a table appended to this document.
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IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
1 DS 2021/004	Scope	See Appendix A for a detailed description of the Ex d safety concept. See Appendix A from report IEC 60079-11 for a detailed description of the Ex i safety concept. The equipment is intended for standard atmospheric conditions.	Pass
2	Normative references		
3 DS 2020/002	Terms and definitions		
4	Equipment grouping		
4.1	General	The equipment is intended for group II.	Pass
4.2	Group I	This equipment is not intended for group I.	N/A
4.3	Group II	This equipment is intended for use in group II, subdivision IIC.	Pass
4.4	Group III	This equipment is not intended for group III.	N/A
4.5	Equipment for a particular explosive atmosphere	This equipment is not intended for use in a particular explosion atmosphere.	N/A
5 DS 2016/002 DS 2015/011A	Temperatures		
5.1	Environmental influences		
5.1.1	Ambient temperature	The ambient temperature range of -20 °C to +60 °C is marked. See drawing M4-4777-31-01K.	Pass
5.1.2	External source of heating or cooling	No external source of heating or cooling considered.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
5.2 DS 2020/006	Service temperature	<p>The minimum service temperature for all parts is equal to the minimum ambient temperature of -20 °C.</p> <p>The maximum service temperature is based on test results, the maximum ambient temperature and the calculation. See cl. 26.5.1.2</p> <p>Service temperature for Gas Sensor, Type NCR-6309 was determined to +69.3 °C at the ambient temperature +60 °C ($\Delta T=9.3$ K)</p> <p>Current and power consumption in normal use (stated by customer):</p> <ul style="list-style-type: none"> - in normal use <p>Current consumption 85 mA Power consumption 306 mW</p> <ul style="list-style-type: none"> - when alarm is activated <p>Current consumption 110 mA Power consumption 396 mW</p> <p>Service temperature for detector is similar to ambient temperature.</p> <p>$T_{\text{service sensor}} = 69.3$ °C $T_{\text{service detector}} = 60$ °C</p>	Pass

5.3	Maximum surface temperature		
5.3.1	Determination of maximum surface temperature	<p>For detector determined according to clause 5.3.3, 26.5.1 and IEC 60079-11.</p> <p>Maximum surface temperature for Gas Sensor, Type NCR-6309 was determined to +79.4 °C at the ambient temperature +60 °C ($\Delta T=19.4$ K).</p> <p>Taking into the consideration results of thermal tests of IEC 60079-1:</p> <p>$T_{\text{max surface}} = 69.3 + 10.1 = 79.4$ °C (<130 °C for T4)</p>	Pass
5.3.2	Limitation of maximum surface temperature		
5.3.2.1	Group I electrical equipment	This equipment is not intended for group I.	N/A
5.3.2.2	Group II electrical equipment	$T_{\text{max surface}}$ does not exceed the limit for temperature class T4 per table 2 with the 5 K margin per cl. 26.5.1.3 taken into account.	Pass
5.3.2.3	Group III electrical equipment	This equipment is not intended for group III.	N/A
5.3.3	Small component temperature for Group I or Group II electrical equipment	See Appendix A.3 in part IEC 60079-11 for details.	Pass
5.3.4	Component temperature of smooth surfaces for Group I or Group II electrical equipment	Not applied.	N/A

6	Requirements for all electrical equipment		
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IEC 60079-0																																																																																	
Clause	Requirement – Test	Result – Remark	Verdict																																																																														
6.1	General	The equipment complies with the requirements of this standard and IEC 60079-1 and IEC 60079-11. Compliance with the relevant industrial standards is the manufacturer responsibility.	Pass																																																																														
6.2	Mechanical strength of equipment	For “ia”: Excluded by table 1 of IEC 60079-11. The gas sensor, Type NCR-6309, is protected from impact by enclosure parts which are considered as “guard”.	Pass																																																																														
6.3	Opening times	For “ia”: Excluded by table 1 of IEC 60079-11. Sensor, Type NCR-6309, cannot be opened.	N/A																																																																														
6.4	Circulating currents in enclosures (e.g. of large electric machines)	This equipment is not a large electric machine.	N/A																																																																														
6.5	Gasket retention	For “ia”: Excluded by table 1 of IEC 60079-11. Sensor, Type NCR-6309, cannot be opened, Ex protection doesn’t rely on the gasket.	N/A																																																																														
6.6	Electromagnetic and ultrasonic energy radiating equipment																																																																																
6.6.1	General	Energy levels do not exceed the levels as stated in the standard, see remarks below.	Pass																																																																														
6.6.2	Radio frequency sources	Frequency: 2.4 GHz Maximum output RF power: 6 dBm = 4 mW 4 mW < 2 W Component IC16 is a BLE Module EYSHJN [TAIYO YUDEN]. Chip : Nordic nRF52832 Internal C = 1.5 µFmax, L=0 (nano Henry range) <table><tr><th>Symbol</th><th>Description</th><th>Min.</th><th>Typ.</th><th>Max.</th><th>Units</th></tr><tr><td>F_{op}</td><td>Operating frequencies</td><td>2402</td><td></td><td>2480</td><td>MHz</td></tr><tr><td>PLL_{CH1}</td><td>PLL channel spacing</td><td></td><td>1</td><td></td><td>MHz</td></tr><tr><td>DF_{BLE1M}</td><td>Frequency deviation @ BLE 1Mbps</td><td></td><td>+/-250</td><td></td><td>kHz</td></tr><tr><td>DF_{BLE2M}</td><td>Frequency deviation @ BLE 2Mbps</td><td></td><td>+/-500</td><td></td><td>kHz</td></tr><tr><td>P_{RF}</td><td>Maximum output power</td><td></td><td>4</td><td>6</td><td>dBm</td></tr><tr><td>P_{RF-C}</td><td>RF power control range</td><td></td><td>24</td><td></td><td>dB</td></tr><tr><td>P_{RF-CH}</td><td>RF power accuracy</td><td></td><td></td><td>+/-4</td><td>dB</td></tr><tr><td>P_{AC1}</td><td>1st Adjacent Channel Transmit Power 1 MHz</td><td></td><td>-25</td><td></td><td>dBc</td></tr><tr><td>P_{AC2}</td><td>2nd Adjacent Channel Transmit Power 2 MHz</td><td></td><td>-50</td><td></td><td>dBc</td></tr><tr><td>PRX_{MAX}</td><td>Maximum received signal strength at < 0.1% PER</td><td></td><td>0</td><td></td><td>dBm</td></tr><tr><td>P_{SENS.IT,1M BLE}</td><td>Receiver sensitivity 1Mbps BLE Ideal transmitter <=37bytes (0.1% BER)</td><td></td><td>-94</td><td></td><td>dBm</td></tr><tr><td>P_{SENS.IT,2M BLE}</td><td>Receiver sensitivity 2Mbps BLE Ideal transmitter Packet length<=37bytes</td><td></td><td>-91</td><td></td><td>dBm</td></tr></table>	Symbol	Description	Min.	Typ.	Max.	Units	F _{op}	Operating frequencies	2402		2480	MHz	PLL _{CH1}	PLL channel spacing		1		MHz	DF _{BLE1M}	Frequency deviation @ BLE 1Mbps		+/-250		kHz	DF _{BLE2M}	Frequency deviation @ BLE 2Mbps		+/-500		kHz	P _{RF}	Maximum output power		4	6	dBm	P _{RF-C}	RF power control range		24		dB	P _{RF-CH}	RF power accuracy			+/-4	dB	P _{AC1}	1st Adjacent Channel Transmit Power 1 MHz		-25		dBc	P _{AC2}	2nd Adjacent Channel Transmit Power 2 MHz		-50		dBc	PRX _{MAX}	Maximum received signal strength at < 0.1% PER		0		dBm	P _{SENS.IT,1M BLE}	Receiver sensitivity 1Mbps BLE Ideal transmitter <=37bytes (0.1% BER)		-94		dBm	P _{SENS.IT,2M BLE}	Receiver sensitivity 2Mbps BLE Ideal transmitter Packet length<=37bytes		-91		dBm	Pass
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F _{op}	Operating frequencies	2402		2480	MHz																																																																												
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6.6.3	Ultrasonic sources	The equipment does not contain ultrasonic sources.	N/A																																																																														

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
6.6.4 DS 2018/004	Lasers, luminaires, and other non-divergent continuous wave optical sources	LEDs for alarm on both sides and top. These LEDs are divergent and not continuous. According to IEC 60079-28 ISH1:2019 divergent light sources are not applicable to IEC 60079-28.	N/A


7	Non-metallic enclosures and non-metallic parts of enclosures		
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7.1	General		
7.1.1	Applicability	For “ia”: Excluded by table 1 of IEC 60079-11. (plastic materials from gas detector are relevant only for electrostatic) Enclosure of the gas sensor, Type NCR-6309, made from two plastic parts with - cemented joint (in between).	Pass
7.1.2	Specification of materials		
7.1.2.1	General	The materials are specified see technical document M2-4777-31-01K for gas detector and M3-4463-10-02K for gas sensor.	Pass
7.1.2.2	Plastic materials	Gas Sensor, Type NCR-6309, enclosure: a) DIC Corporation b) PPS FZ1130-D5 (PPS GF30%), natural color. c) no surface treatment d) RTI: +130 °C e) N/A (not exposed to UV)	Pass
7.1.2.3	Elastomers	There are no elastomers relevant for the type of protection.	N/A
7.1.2.4	Materials used for cementing	Sensor, Type NCR-6309: The joints between the in-casted breather and the Cap and between the electrical contacts and Base are cemented joints. Since the joints are formed by injection molding (from the same material as enclosure) the molding parameters are relevant (specified in drawing M3-4463-10-02K). See 7.1.2 for details. Cementing is not used for the external enclosure.	Pass

7.2	Thermal endurance		
7.2.1	Tests for thermal endurance	See cl. 26.8 and 26.9	Pass
7.2.2	Material selection	All materials used for cementing are rated for the maximum service temperature +20 K or better.	Pass
7.2.3	Alternative qualification of elastomeric sealing O-rings	The alternative qualification is not used.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
7.3	Resistance to ultraviolet light	For “ia”: Excluded by table 1 of IEC 60079-11. Sensor, Type NCR-6309, protected from UV by detectors enclosure.	Pass

7.4	Electrostatic charges on external non-metallic materials		
7.4.1	Applicability	Applicable non-metallic materials: - enclosure	Pass
7.4.2	Avoidance of a build-up of electrostatic charge for Group I or Group II	Sign X in certificate regarding static electricity hazards. In manual: When using the product in hazardous areas, take the following precautions to safeguard against static electricity hazards: 1. Wear anti-static clothing and conductive shoes (anti-static work shoes). 2. When using the product indoors, stand on a conductive work floor (with a leakage resistance of 10 MΩ or less).	Pass
7.4.3	Avoidance of a build-up of electrostatic charge for Group III	This equipment is not intended for group III.	N/A

7.5	Attached external conductive parts	<p>The capacitance of nipple is determined, for details see Appendix B. The capacitance is 1.4 pF which is acceptable for EPL Ga, group IIC (3 pF). Nipple is metallic material and conductive.</p>  <p>Screws and metallic parts less the size of the screws will present a capacitance of not more than 3 pF, according to NOTE 1. These parts are also situated such that discharges to approaching earthed objects are not expected.</p>	Pass
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8	Metallic enclosures and metallic parts of enclosures	No metallic enclosures or metallic parts of enclosures	N/A
9	Fasteners	No fasteners applied.	N/A
10	Interlocking devices	This equipment does not contain interlocking devices.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
11	Bushings	This equipment does not contain bushings.	N/A
12	(Reserved for future use)		
13 DS 2014/001 DS 2021/006	Ex Components	No Ex Components included	N/A
14	Connection facilities	For “ia”: Excluded by table 1 of IEC 60079-11. No external connections to gas sensor, Type NCR-6309.	N/A
15	Connection facilities for earthing or bonding conductors	For “ia”: Excluded by table 1 of IEC 60079-11. Battery powered equipment.	N/A
16 DS 2017/001	Entries into enclosures	For “ia”: Excluded by table 1 of IEC 60079-11. No entries to gas sensor, Type NCR-6309.	N/A
17	Supplementary requirements for electric machines	The equipment is no rotating machine.	N/A
18	Supplementary requirements for switchgear	The equipment does not contain switchgear.	N/A
19	Reserved for future use		
20 DS 2020/007	Supplementary requirements for external plugs, socket outlets and connectors for field wiring connection	The equipment does not contain external plugs, socket outlets or connectors for field wiring connection.	N/A
21	Supplementary requirements for luminaires	The equipment is no and does not contain luminaires.	N/A
22	Supplementary requirements for cap lights and hand lights	The equipment is no and does not contain cap lights and hand lights.	N/A
23	Equipment incorporating cells and batteries		

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
23.1	General	EUT is powered by a single secondary cell. The cell is tested in partial test report NO/PRE/ExTR20.0043/00. See Appendix B of IEC 60079-11 report for details.	Pass
23.2	Interconnection of cells to form batteries	Only a single cell is used.	Pass
23.3 DS 2019/002	Cell types	According to table 14: Type system: Lithium ion Positive electrode: (NCA) Li(NiCoAl)O ₂ Electrolyte: Liquid solution Negative electrode: Carbon Voltage: 3.6 V Maximum open circuit voltage: 4.2 V	Pass
23.4	Cells in a battery	Single cell.	Pass
23.5	Ratings of batteries	Ambient temperature discharge: -20 °C to +60 °C Ambient temperature charge: +10 °C to +45 °C Ambient temperature for EUT: -20 °C to +60 °C Max discharge current for the battery is 8 A. Nominal discharge for EUT is: 85 mA Discharge when alarm is activated: 110 mA	Pass
23.6	Interchangeability	Only one single battery in EUT.	Pass
23.7	Charging of primary batteries	Primary cells are not used.	N/A
23.8	Leakage	Tested according to clause 10.5.2 of IEC 60079-11. No leakage occurred.	Pass
23.9	Connections	Connections according to manufacturer's recommendations.	Pass
23.10	Orientation	Battery orientation is not important for safe operation.	N/A
23.11	Replacement of cells or batteries	User shall never replace the battery.	N/A
23.12	Replaceable battery pack	The battery is not replaceable.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
24	Documentation	The documents listed in the report Cover give a full and correct specification of the explosion safety aspects.	Pass

25	Compliance of prototype or sample with documents	The samples used for testing comply with the documents. See Appendix B of this report, Appendix B of part IEC 60079-11 of this report and Appendix B of Report NL/DEK/ExTR17.0047/01. Note: When only Appendix B is mentioned, all 3 reports are relevant.	Pass
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26 DS 2017/005	Type tests		
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26.1	General	Tests have been carried out, See Appendix B. Impact test on sensor enclosure was omitted. The same sensor is used for both detectors: GX-Force and GX-3R. Reasons why GX-Force can be exempted from thermal endurance and impact tests: - The GX-Force enclosure materials are the same as that used in the other application (GX-3R), which has been tested for thermal endurance and impact with positive result. (The GX-3R enclosure is made of two types of materials, and the GX-Force is made of one of them. The RTI value of container (Material PC L-1225Z100M) is 115 °C, which is 55 °C higher than the maximum service temperature of +60 °C.) - The Ex da sensors are better mechanically protected and more deep inside the enclosure in GX-Force type than in GX-3R, see evidence folder.	Pass
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26.2	Test configuration	Most unfavourable test configuration was tested, see Appendix B.	Pass
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26.3	Tests in explosive test mixtures	Tests in explosive mixtures have been carried out, See Appendix B of this report and Appendix B of Report NL/DEK/ExTR17.0047/01.	Pass
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26.4	Tests of enclosures		
26.4.1	Order of tests		
26.4.1.1	Metallic enclosures, metallic parts of enclosures and glass parts of enclosures	Tests have been conducted in sequence according to clause 26.4.1.2.	N/A
26.4.1.2	Non-metallic enclosures or non-metallic parts of enclosures		
26.4.1.2.1	General	Tests have been conducted in the given sequence according to this clause. See Appendix B of this report and of Report No. NL/DEK/ExTR17.0047/01.	Pass

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
26.4.1.2.2	Group I equipment	The equipment is not intended for group I.	N/A
26.4.1.2.3	Group II and Group III equipment	Tests have been conducted in the given sequence according to this clause. See Appendix B of this report and of Report No. NL/DEK/ExTR17.0047/01.	Pass
26.4.2 DS 2020/001	Resistance to impact	This test was omitted, see cl. 26.1.	Pass
26.4.3	Drop test	Equipment is handheld equipment. See Appendix B of this report.	Pass
26.4.4	Acceptance criteria	The equipment passed the tests. For details see Appendix B of this report.	Pass
26.4.5 See also DS 2012/003	Degree of protection (IP) by enclosures		
26.4.5.1	Test procedure	The equipment was tested for IP20. After drop test, IP test was performed. For details see Appendix B of this report.	Pass
26.4.5.2	Acceptance criteria	The equipment passed the tests. For details see Appendix B of this report.	Pass

26.5	Thermal tests		
26.5.1	Temperature measurement		
26.5.1.1	General	For details see Appendix B of NL/DEK/ExTR17.0047/01.	Pass
26.5.1.2	Service temperature	The service temperature rise is measured on the (plastic) enclosure of the of the gas sensor, Type NCR-6309, $\Delta T=9.3$ K. For details see Appendix B of this report.	Pass
26.5.1.3	Maximum surface temperature	For detector see Appendix A and B of the IEC 60079-11 report for details. Maximum surface temperature determined to $+79.4$ °C, for the gas sensor, Type NCR-6309, taking in to the consideration results of the thermal testing x 1.2 (acc. to 60079-1, cl. 15.4.3.1) For details see Appendix B of this report.	Pass
26.5.2	Thermal shock test	For "ia": Excluded by table 1 of IEC 60079-11. Not applicable for gas sensor, Type NCR-6309.	N/A
26.5.3	Small component ignition test (Group I and Group II)		
26.5.3.1	General	This test was not done, see cl. 5.3.3.	N/A
26.5.3.2	Procedure	This test was not done, see cl. 5.3.3.	N/A
26.5.3.3	Acceptance criteria	This test was not done, see cl. 5.3.3.	N/A

26.6	Torque test for bushings		
26.6.1	Test procedure	This test was not required, see cl. 11.	N/A
26.6.2	Acceptance criteria	This test was not required, see cl. 11.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
26.7	Non-metallic enclosures or non-metallic parts of enclosures		
26.7.1	General	Non-metallic materials of sensor enclosure are considered, the appropriate tests were done. For details see Appendix B of this report and Appendix B of Report NL/DEK/ExTR17.0047/01.	Pass
26.7.2	Test temperatures	Non-metallic materials and test temperatures are considered. For details see Appendix B of this report and Appendix B of Report NL/DEK/ExTR17.0047/01.	Pass
26.8 DS 2020/003	Thermal endurance to heat	The equipment passed the tests. For details see Appendix B of this report and Appendix B of Report NL/DEK/ExTR17.0047/01.	Pass
26.9	Thermal endurance to cold	The equipment passed the tests. For details see Appendix B of this report and Appendix B of Report NL/DEK/ExTR17.0047/01 (tested for $T_{amb\ min} = -40\ ^\circ C$).	Pass
26.10	Resistance to UV light	This test was not required, see cl. 7.3.	N/A
26.11	Resistance to chemical agents for Group I equipment	This equipment is not intended for group I.	N/A
26.12	Earth continuity	This test was not required, see cl. 15.7.	N/A
26.13	Surface resistance test of parts of enclosures of non-metallic materials	This test was not required, see cl. 7.4.2.	N/A
26.14	Measurement of capacitance		
26.14.1	General	The equipment passed the tests. For details see Appendix B of this report.	Pass
26.14.2	Test procedure		Pass
26.15	Verification of ratings of ventilating fans	The equipment does not contain ventilating fans.	N/A
26.16	Alternative qualification of elastomeric sealing O-rings	The alternative qualification was not used.	N/A
26.17	Transferred charge test	This test was not required, see cl. 7.4.2.	N/A
27	Routine tests	Routine tests are not required.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
28 DS 2020/002 DS 2021/005	Manufacturer's responsibility	No part of the product evaluation.	N/A
29 DS 2012/005A DS 2017/007 DS 2021/006	Marking		
DS 2021/005	Ex Equipment that includes Ex auxiliary equipment and Ex component	Equipment with Ex auxiliary equipment assessed and marked according to the decision sheet. General product information defines that sensor is designed in "Ex da" type of protection.	Pass
29.1	Applicability	Equipment is marked and complies with the applicable standards.	Pass
29.2	Location	Equipment is legibly marked on the main part. See drawing M2-4777-31-01K.	Pass
29.3	General	The marking includes the following: a) Name of manufacturer or the trade mark: b) Type identification c) Serial number d) The certificate number: IECEX: DEK 24.0016 and ATEX: DEKRA 24ATEX0018. e) symbol X, f) The specific Ex marking per cl. 29.4 g) Additional marking required by other standards See drawing M4-4777-31-01K.	Pass
29.4	Ex marking for explosive gas atmospheres	Ex da ia IIC T4 Ga (with NCR-6309) Ex ia IIC T4 Ga (without NCR-6309) See drawing M4-4777-31-01K.	Pass
29.5	Ex marking for explosive dust atmospheres	The equipment is not intended for group III.	N/A
29.6	Combined types (or levels) of protection	The symbols of all types of marking are included.	Pass
29.7	Multiple types of protection	No Multiple types of protection applied.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
29.8	Ga equipment using two independent Gb types (or levels) of protection	Equipment does not contain two independent Gb types of protection.	N/A
29.9	Boundary wall	No boundary wall applied.	N/A
29.10 DS 2004/006A DS 2012/006A DS 2012/008	Ex Components	Not applicable for equipment.	N/A
29.11	Small Ex Equipment and small Ex Components	Equipment is not small.	N/A
29.12	Extremely small Ex Equipment and extremely small Ex Components	Equipment is not extremely small.	N/A
29.13	Warning markings	No warning markings applied.	N/A
29.14	Cells and batteries	This equipment contains batteries that cannot be replaced by end user.	N/A
29.15	Electric machines operated with a converter	This equipment is not a converter-fed electrical machine.	N/A
29.16	Examples of marking	The examples of marking are informative.	N/A
30 DS 2021/006	Instructions		
30.1	General	<p>The manual (document safety information Rev.6) contains:</p> <ul style="list-style-type: none"> - A recapitulation of marking, - Instructions for safety use, - Specific conditions of uses, - Additional information for use, - A list of standards including the issue date. 	Pass
30.2	Cells and batteries	The equipment contains cells or batteries that cannot be replaced by the end user.	N/A
30.3	Electrical machines	The equipment is no electrical machine.	N/A

IEC 60079-0			
Clause	Requirement – Test	Result – Remark	Verdict
30.4	Ventilating fans	Equipment does not contain ventilating fans.	N/A

30.5	Cable glands	The equipment is no cable gland.	N/A
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Annex A (Normative) See also DS 2017/001	Supplementary requirements for cable glands	Entry devices are not in the scope and to be selected by the end user.	N/A
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Annex B (Normative)	Requirements for Ex Components		
Table B.1	Clauses with which Ex Components shall comply	Not applicable for Ex Equipment.	N/A

Annex C (Informative)	Example of rig for resistance to impact test		
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Annex D (Informative)	Electric machines connected to converters		
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Annex E (Informative)	Temperature evaluation of electric machines		
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Annex F (Informative)	Guideline flowchart for tests of non-metallic enclosures or non-metallic parts of enclosures (26.4)		
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Annex G (Informative)	Guidance flowchart for tests of cable glands		
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Annex H (Informative)	Shaft voltages resulting in motor bearing or shaft brush sparking Discharge energy calculation		
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Measurement Section, including Additional Narrative Remarks (as deemed applicable)

Temperature determination:

The minimum service temperature for all parts is equal to the minimum ambient temperature of -20 °C.

The maximum service temperature is based on the following consideration:

This type of sensor acts on catalytic gas excitation, with a small internal gas hotspot, resulting in limited heating of the casing. The expected temperature increase is 5 K, this is the same as measured by Riken Keiki, for safety reasons we added a margin of 50%, resulting in ΔT by the catalytic process of 7.5 K

The max. rated power of the monitor unit is 396 mW or 436 mW at 110% (= max. rated power for GX-Force, drawing E3-6991-6230-10-01K).

For 1 W a ΔT at the surface of max. 5 K is considered to be a safe assumption.

$T_{\text{service max.}} = T_{\text{ambient}} + \Delta T_{\text{housing}} + \Delta T_{\text{sensor}} = 60 + 4.3 + 5 = 69.3 \text{ °C.}$

Maximum surface temperature for Gas Sensor, Type NCR-6309 was determined to +79.4 °C at the ambient temperature +60 °C.

($\Delta T = 19.4$ K) taking into the consideration
results of thermal tests (see 60079-1 report).

$$(T_{\text{max surface}} = 69.3 + 8.4 \times 1.2 = 79.4 < 135-5 (T_4) [^{\circ}\text{C}]$$



Report
IEC 60079-1
Explosive atmospheres – Part 1:
Equipment protection by flameproof enclosures "d"



Report Number : See Report No. above.

Free Reference Number : See report cover.

Compiled by + signature (ExTL)..... : A. Hadak

Reviewed by + signature (ExTL) ... : H.J.G. de Wild

Date of issue (yyyy-mm-dd) : 2024-04-15

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Ex Testing Laboratory (ExTL) : DEKRA Certification B.V.

Address : Meander 1051, 6825 MJ Arnhem, The Netherlands

Applicant's name : See report cover.

Address : See report cover.

Standard..... : IEC 60079-1 : 2014, Edition 7.0 + C1 : 2018

Test procedure : IECEx System

Test Report Form Number : See footer, based on ExTR60079-1_7B_DS (released 2021-10)

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Possible test case verdicts:

- test case does not apply to the test item : N/A
- test item does meet the requirement..... : Pass

General remarks:

The test results presented in this Ex Test Report relate only to the item or product tested.

- "(see Attachment #)" refers to additional information appended to this document.
- "(see appended table)" refers to a table appended to this document.
- Throughout this document, a point "." is used as the decimal separator.

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IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
1	Scope		
2 DS2010/006A	Normative references		
3 DS 2015/015	Terms and definitions		
4	Level of protection (equipment protection level, EPL)		
4.1	General	The level of protection of this equipment is da. Applicable to catalytic sensor type NCR-6309 only.	Pass
4.2 DS2015/016A	Requirements for level of protection “da”	<p>The sensor assessed is a catalytic sensor to be used in a portable gas detector</p> <ul style="list-style-type: none"> - Internal volume < 1 cm³ - The electrical conductors are potted in the enclosure and assessed for clause 6, -The breather is assessed for clause 10 and casted in the sensor housing, leaving no gap. Both sensor's halves are secured with a metal clamp (caulking cap) around. See drawing M3-4463-10-02K -Supply is by an Ex ia circuit. Maximum dissipated power < 1.3 W (DC 1V, 100 mA) -The non-transmission tests were performed for group IIC with 50 ignitions for each test gas. 	Pass
4.3	Requirements for level of protection “db”	“db” not applied	N/A
4.4	Requirements for level of protection “dc”	“dc” not applied	N/A
5	Flameproof joints		
5.1	General requirements	<p>All joints comply with the requirements in Clause 5. A limitation and advisory marking are applied: "This product is an explosion-proof product and is not to be disassembled or modified with the exception of specified parts." Plastic enclosure, which does not require corrosion protection. For more details see drawing: M3-4463-10-02K.</p>	Pass

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
5.2 DS 2015/018	Non-threaded joints	The multi-step joint between enclosure halves. For details see Appendix A.	Pass
5.2.1	Width of joints (<i>L</i>)	The multi-step joint requirements applied, see cl. 5.2.9 below.	Pass
5.2.2	Gap (<i>i</i>)	The multi-step joint requirements applied, see cl. 5.2.9 below.	Pass
5.2.3 DS 2015/018	Spigot joints	No spigot joints.	N/A
5.2.4	Holes in joint surfaces	No holes in joint surfaces.	N/A
5.2.5	Conical joints	No conical joints.	N/A
5.2.6	Joints with partial cylindrical surfaces (not permitted for Group IIC)	No such joints.	N/A
5.2.7	Flanged joints for acetylene atmospheres	No flanged joint	N/A
5.2.8	Serrated joints	No serrated joints.	N/A
5.2.9	Multi-step joints	<p>The joint 1 between enclosure halves assessed as multi-step joint consists of three adjacent segments where path changes direction two times by 90°.</p> <p>Length of the joint $L_{\min} = 2.65 + 0.48 + 3.35 = 6.48 \text{ mm}$</p> <p>For details see Appendix A.</p> <p>Tested per clause 15.3 with the length of each segment reduced to not more than 75 %.</p> <p>An advisory mark is applied see drawing M4-4777-31-01K - "This product is an explosion-proof product and is not to be disassembled or modified with the exception of specified parts."</p>	Pass
5.3	Threaded joints	No threaded joints	N/A
5.4	Gaskets (including O-rings)	The gasket is no part of the flameproof joint and does not interrupt it.	Pass
5.5	Equipment using capillaries	No capillaries applied.	N/A
6	Sealed joint		
6.1 DS 2015/015 DS 2020/005	Cemented joints		

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
6.1.1	General	The joints between the in-casted breather and the Cap and between the electrical contacts and Base are cemented joints. Since the joint is formed by injection moulding, the molding parameters are defined on drawing M3-4463-10-02K.	Pass
6.1.2	Mechanical strength	The breather is fixed with a rim on top and under it. The contacts are fixed by their multiturn shape. These joints are not intended to be opened. Overpressure test of the enclosure with cemented joints is performed before and after the tests per IEC 60079-0 and the test result is judged satisfactory. For details see Appendix B of report NL/DEK/ExTR17.0047/01.	Pass
6.1.3	Width of cemented joints	Internal volume is $<< 10 \text{ cm}^3$. The width of the cemented joints: Joint 2. Contacts -specified: min. 3.9 mm > 3 mm Joint 3. Breather -specified: min. 3.66 mm > 3 mm For details see Appendix A.	Pass
6.2	Fused glass joints	No Fused glass joints	N/A
7	Operating rods	No operating rod applied.	N/A
8	Supplementary requirements for shafts and bearings	No shafts and bearings	N/A
9	Light-transmitting parts	No light transmitting part.	N/A
10	Breathing and draining devices which form part of a flameproof enclosure		
10.1	General	Breather device is part of enclosure used for exchange of hazardous atmosphere for gas sampling. Types of breather: pressed metal wire elements The breathing and draining devices withstand the dynamic effects and pressure from an internal explosions and prevent flame transmission as tested per cl. 15 and 16. For details see Appendix B.	Pass
10.2	Openings for breathing or draining	No such openings.	N/A

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
10.3	Composition limits	The material is specified in drawing M3-4463-10-02K. The elements of breathing devices comprise of stainless steel only. (Cu content < 0.1%)	Pass
10.4	Dimensions	The dimensions are specified in drawing M3-4463-10-02K. Press metal wire element -diameter: 10 ± 0.1 , thickness: 1.66 ± 0.1 mm	Pass
10.5	Elements with measurable paths	The sintered metal element has no measurable paths.	N/A
10.6	Elements with non-measurable paths	The elements have a specified max. density and max. pore size and comply with the relevant requirements of Annex B. For details see Annex B.	Pass
10.7	Removable devices	The device cannot be dismantled.	N/A
10.8	Mechanical strength	Impact test was waived, see explanation in report IEC 60079-0 cl. 26.4.2. for the impact test.	Pass
10.9	Breathing devices and draining devices when used as Ex components	Breathing devices and draining devices are not used as Ex components.	N/A
11	Fasteners and openings	The Sensor does not have fasteners or openings, it is completely closed with an in-casted breather and cemented electrical contacts.	N/A
12 DS 2012/004	Materials		
12.1	Tests prescribed by Clauses 14 to 16	The equipment withstood the applicable tests in Clauses 14 through 16. For details see Appendix B.	Pass
12.2	Assembly of multiple flameproof enclosures	One flameproof enclosure is used.	N/A
12.3	Intercommunicating enclosure compartments	No intercommunicating compartments.	N/A
12.4	Use of cast iron	No cast Iron used.	N/A
12.5	Use of liquids	No liquids used.	N/A

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
12.6	Insulating materials for Group I apparatus	The equipment is not intended for Group I.	N/A
12.7	Zinc content	This equipment is not made of zinc or zinc alloy with more than 80% zinc.	Pass
12.8	Copper or copper alloys in explosive gas atmospheres containing acetylene	No copper or copper alloys used.	Pass
13	Entries for flameproof enclosures	No entries into the enclosure	N/A
14	Verification and tests	This product complies with IEC 60079-0 and this standard. See IEC 60079-0 and Appendix B report for maximum surface temperature determination.	Pass
15	Type tests		
15.1	General	The required sequence is followed. Breather element and cemented joints were tested as part of previous project, for details about results see Appendix B of NL/DEK/ExTR17.0047/01. Subject of the additional testing was flameproof joint 1 (multi step joint). For details about results see Appendix B of this report. Note: where a reference is made to Appendix B, Appendix B of this ExTR is intended.	Pass
15.2	Tests of ability of the enclosure to withstand pressure		
15.2.1 DS 2021/003	General	The equipment has been tested according to the requirements in clauses 15.2.3 and 15.3. No permanent deformation was observed. The units tested according to clause 15.2.3 was also subjected to the test for flame non-transmission with satisfactory result. For details see Appendix B.	Pass
15.2.2	Determination of explosion pressure (reference pressure)		
15.2.2.1	General	Determination of explosion pressure considered impracticable due to extremely small internal volume of the gas sensor.	N/A
15.2.2.2	Test procedure	See cl. 15.2.2.1 above.	N/A
15.2.2.3	Rotating electrical machines	The equipment is no rotating machine.	N/A
15.2.2.4	Pressure-piling	Clause not applied.	N/A
15.2.2.5	Apparatus intended for use in a single gas	This equipment is not intended to be used in a single specified gas.	N/A

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
15.2.3	Overpressure test		
15.2.3.1	General	First method (static) is used for the overpressure test.	Pass
15.2.3.2	Overpressure test - First method (static)	Tested acc. value from Table 8 (Relative pressures for small equipment) Volume < 10 cm ³ gas group IIC, for low ambient temperature: - 40 °C: value 1 MPa x 1.45 = 1.45 MPa applied. For details see Appendix B.	Pass
15.2.3.3	Overpressure test - Second method (dynamic)	See clause 15.2.3.1.	N/A
15.3	Test for non-transmission of an internal ignition		
15.3.1	General	For details see Appendix B.	Pass
15.3.2	Electrical equipment of groups I, IIA and IIB	The equipment is for IIC.	N/A
15.3.3	Electrical apparatus of group IIC		
15.3.3.1	General	Tested by the second method.	Pass
15.3.3.2	First method – Testing by increased test gap	Second method applied.	N/A
15.3.3.3	Second method – Testing by increased pressure	Fifty ignitions (according to cl. 4.2) have been done with each test gas at pre-compression pressure (1.510-1.530 kPa) at normal ambient temperature. The test was satisfactory; the internal ignitions were not transmitted to the test chamber. For details see Appendix B.	Pass
15.3.3.4	Third method – Testing by oxygen enrichment of test gases	Second method applied.	N/A
15.3.3.5	Number of tests for single piece production	The equipment is not a single piece production.	N/A
15.4	Tests of flameproof enclosures with breathing and draining devices		
15.4.1	General	The tests in accordance with 15.4.2 to 15.4.4 were conducted after the impact test. For details see Appendix B of NL/DEK/ExTR17.0047/01. Determined maximum test pore size of the breather elements was min. 85 % of the specified maximum bubble test pore size.	Pass
15.4.2	Tests of ability of the enclosure to withstand pressure		
15.4.2.1	General	Additions and modifications made see below.	Pass
15.4.2.2	Replacement of breathing and draining devices	Because of the small size reference pressure measurement is waived.	N/A
15.4.2.3	Overpressure test	The breather is sealed for the overpressure test.	Pass
15.4.3	Thermal tests		

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
15.4.3.1	Test procedure	Tested per 15.4.4.2, 5 times with both gases, surface temperature measure. Because of the small size of the Sensor ignition on one location. No forced flow. No ventilating or sampling system. See also Appendix B of NL/DEK/ExTR17.0047/01.	Pass
15.4.3.2	Acceptance criterion	No continuous burning observed. Temperature increase measured: 8.4 K (with C ₂ H ₂) $T_{\max \text{ surface}} = 69.3 \text{ °C} + 8.4 \times 1.2 = 79.4 \text{ °C}$ ($<130 \text{ °C}$ for T4) See also Appendix B of NL/DEK/ExTR17.0047/01.	Pass
15.4.4	Tests for non-transmission of an internal ignition		
15.4.4.1	General	The additions and modifications are made to 15.3	Pass
15.4.4.2	Test procedure	Tested. Because of the small size of the Sensor ignition on one location.	Pass
15.4.4.3	Non-transmission test for breathing and draining devices		
15.4.4.3.1	General	Tested for IIC, with non-measurable paths, tested per 15.4.4.3.3	Pass
15.4.4.3.2	Method A – Testing by increased pressure	See 15.4.4.3.1	N/A
15.4.4.3.3	Method B – Testing by oxygen enrichment of test gases	The non-transmission tests are performed with: 40% H ₂ , 20% O ₂ and N ₂ 10% C ₂ H ₂ , 24% O ₂ and N ₂ See 15.3.3.4	Pass
15.4.4.4	Acceptance criterion	No flame transmission occurred.	Pass
15.5	Tests for “dc” devices	“dc” not applied.	N/A
16	Routine tests		
16.1	General	Routine tests are not required. See cl.16.2	N/A
16.2 DS 2015/015	Enclosures not incorporating a welded construction	The enclosure does not have a welded construction and has an internal volume $< 10 \text{ cm}^3$, so a routine test is not required.	Pass
16.3 DS 2015/015	Enclosures incorporating a welded construction	The enclosure is not a welded construction	N/A
16.4	Bushings not specific to one flameproof enclosure	No such bushing applied.	N/A
16.5 DS 2021/003	Acceptance criteria	See cl.16.2	N/A

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
16.6	Batch testing	No batch testing required	N/A
17	Switchgear for Group I	The equipment is not intended for Group I.	N/A
18	Lampholders and lamp caps	The product does not include lampholders and lamp caps.	N/A
19	Non-metallic enclosures and non-metallic parts of enclosures		
19.1	General	The cemented joint complies with cl. 6 (since small leakage through cemented joint, non-transmission test was performed). Flameproof joint (multi step joint) includes two non-metallic faces of the joint.	Pass
19.2	Resistance to tracking and creepage distances on internal surfaces of the enclosure walls	Sensor is supplied by Ex i circuit, see also cl. 4.2.	N/A
19.3	Requirements for type tests	a) Due to small size ref. pressure determination is impracticable. b) Overpressure tests performed on samples after tests per 60079-0, see 15.2.3 c) Non-transmission tests performed on samples after tests per 60079-0, see 15.3.3.4 d) Erosion by flame not required, see 19.4 e) Not required, see above.	Pass
19.4	Test of erosion by flame	The internal volume < 50 cm ³ .	N/A
20	MARKING		
20.1	General	The marking includes 'da'	Pass
20.2	Caution and warning markings	No caution or warning markings required based on the clauses referenced in Table 14.	N/A
20.3	Informative markings	No informative markings applied.	N/A



IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
21	Instructions	The instructions per IEC 60079-0 are assessed in that ExTR part. A limitation is added indicating that the flamepaths are not intended to be repaired.	Pass
Annex A (Normative)	Additional requirements for crimped ribbon elements and multiple screen elements of breathing and draining devices	This equipment has no crimped ribbon elements and multiple screen elements of breathing and draining devices.	N/A
Annex B (Normative)	Additional requirements for elements, with non-measurable paths, of breathing and draining devices		
B.1	Sintered metal elements	The breather is a pressed metal wire element.	N/A
B.2	Pressed metal wire elements		
B.2.1	Construction	Matrix consists of five layers made from different combination of stainless steel wire braid mesh and diameter. (FP100 and FP75) FP100 is test sample, while FP75 is used in product. The pore size of FP100 is larger than FP75. Therefore the maximum pore size of pressed metal wire elements for products is always smaller than for test sample. FP100 and FP75 have same structure other than 2nd layer. Tests performed on FP100 can be used for acceptance of FP75.	Pass
B.2.2	Specifications	The wire diameter and mesh size of each gauze layer is specified. See drawing M3-4463-10-02K. Density of st.st. 316: 7.95 g/cm^3 . The specific density of the breather is 5.2 g/cm^3 . Resulting in a ratio of 0.65. This is accepted since the pressed wire element is also sintered which will give an increase of density.	Pass
B.2.3	Bubble test pore size	Performed on three samples. Design: $139.3 \mu\text{m}$. All samples $> 85\%$ Test per 15.4.3 performed with $133 \mu\text{m}$. See Appendix B of NL/DEK/ExTR17.0047/01.	Pass
B.2.4	Density	Performed on 8 pieces being 5.041 g in total. Result: 5.139 g/cm^3 , this is regarded within the margin. See B.2.2 and Appendix B of NL/DEK/ExTR17.0047/01.	Pass
B.2.5	Open porosity and or fluid permeability	With the defined and checked pore size and density of the breather the functionality is sufficiently secured.	N/A

IEC 60079-1			
Clause	Requirement – Test	Result – Remark	Verdict
B.2.6	Identification	a. Stainless steel SUS316 b. Max. pore size: 139.3 μm c. Min. density: 5.2 g/cm^3 d. Thickness: 1.66 \pm 0.1 mm Diameter: 10 mm e. Wire diameter, see B.2.2 f. N/A see B.2.5	Pass
B.3	Metal foam elements	The breather is a pressed metal wire element.	N/A
Annex C (Normative)	Additional requirements for flameproof entry devices	Flameproof entry devices are not in the scope of this assessment. Equipment has no openings.	N/A
Annex D (Normative)	Empty flameproof enclosures as ex components	The enclosure is part of Ex equipment.	N/A
Annex E (Normative)	Cells and batteries used in flameproof “d” enclosures	Battery is part of Ex i protection.	N/A
Annex F (Informative)	Mechanical properties for screws and nuts		
Annex G (Normative) DS 2019/003	Additional requirements for flameproof enclosures with an internal source of release (containment system)	This equipment has no internal source of release (containment system).	N/A
Annex H (Normative)	Requirements for machines with flameproof “d” enclosures fed from converters	This equipment is no machines with flameproof “d” enclosures fed from converters.	N/A
Measurement Section, including Additional Narrative Remarks			N/A



Report
IEC 60079-11 Explosive atmospheres –
Part 11: Equipment protection by intrinsic safety "i"



Report Number..... :	See Report No. above.
Free Reference Number..... :	See report cover.
Compiled by + signature (ExTL).... :	A. Hadak 
Reviewed by + signature (ExTL) ... :	B.P.O. Meijer 
Date of issue (yyyy/mm/dd) :	2024-04-12
Ex Testing Laboratory (ExTL) :	DEKRA Certification B.V.
Address..... :	Meander 1051, 6825 MJ Arnhem, The Netherlands
Applicant's name..... :	See report cover.
Address..... :	See report cover.
Standard :	IEC 60079-11:2011, Edition 6.0
Test procedure :	IECEx System
Test Report Form Number..... :	See footer, based on ExTR60079-11_6B_DS (released 2021-10)

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Possible test case verdicts:

- test case does not apply to the test item : N/A
- test item does meet the requirement..... : Pass

General remarks:

The test results presented in this Ex Test Report relate only to the item or product tested.

- "(see Attachment #)" refers to additional information appended to this document.
- "(see appended table)" refers to a table appended to this document.
- Throughout this document, a point "." is used as the decimal separator.

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IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
1	Scope		
2 DS 010/006A	Normative references		
3	Terms and definitions		
4	Grouping and classification of intrinsically safe apparatus and associated apparatus	Ex ia IIC T4 Ga	Pass
5	Levels of protection and ignition compliance requirements of electrical apparatus		
5.1	General	Battery powered handheld equipment. The EUT has a USB-C contact for charging of the single secondary cell. U_m for the USB-C is 6.0 V.	Pass
5.2	Level of protection "ia"	Refer to Appendix A.1 for details.	Pass
5.3	Level of protection "ib"	Level of protection "ia".	N/A
5.4	Level of protection "ic"	Level of protection "ia".	N/A
5.5	Spark ignition compliance	Refer to Appendix A.2 for details.	Pass
5.6	Thermal ignition compliance		
5.6.1	General	Refer to Appendix A.3 for details.	Pass
5.6.2 DS 2015/016A DS 2015/009	Temperature for small components for Group I and Group II	Refer to Appendix A.3.1 for details.	Pass
5.6.3	Wiring within intrinsically safe apparatus for Group I and Group II	Refer to Appendix A.3.2 for details.	Pass
5.6.4	Tracks on printed circuit boards for Group I and Group II	Refer to Appendix A.3.3 for details.	Pass
5.6.5 DS 2020/006	Intrinsically safe apparatus and component temperature for Group III	Not for Group III.	N/A
5.7	Simple apparatus	Not simple apparatus	N/A

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict


6	Apparatus construction		
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6.1	Enclosures		
6.1.1	General	IP20 based on performed test	Pass
6.1.2	Enclosures for Group I or Group II apparatus		
6.1.2.1	General	Complies with table 5	Pass
6.1.2.2	Apparatus complying with Table 5	Refer to Appendix A.6 for details. > IP20, EUT is drop tested prior to IP test.	Pass
6.1.2.3 DS 2019/006	Apparatus complying with Annex F	Annex F not applied	N/A
6.1.3	Enclosures for Group III apparatus	Not group III	N/A

6.2	Facilities for connection of external circuits		
6.2.1	Terminals	No terminals for connection of external circuits.	N/A
6.2.2	Plugs and sockets	USB-C socket for charging of the battery in non-hazardous area.	Pass
6.2.3	Determination of maximum external inductance to resistance ratio (L_o/R_o) for resistance limited power source	L_o/R_o is not applied	N/A
6.2.4	Permanently connected cable	No cable for external circuits	N/A
6.2.5	Requirements for connections and accessories for IS apparatus when located in the non-hazardous area	USB-C socket for charging of the battery in non-hazardous area. U_m : 6.0 V. Internally this connection is named CN1. The U_m voltage will not take the safety components beyond 2/3 of their ratings.	Pass

6.3	Separation distances		
6.3.1	General	See 6.3.2 to 6.3.14	Pass
6.3.2	Separation of conductive parts	Refer to Appendix A.6 for details. Separation distances between different parts of the intrinsically safe circuit. The requirements of this clause are considered during the evaluation of the circuit and layout.	Pass
6.3.2.1	Distances according to Table 5	Refer to Appendix A.6 and Appendix B.1 for details.	Pass
6.3.2.2	Distances according to Annex F	Annex F not applied	N/A

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
6.3.3	Voltage between conductive parts	Max voltage for the battery powered circuits are: From single battery cell: 4.2 V maximum open circuit voltage. After step-up circuit to buzzer circuit: 4.2 V x 3 = 12.6 V Zener diodes ZD1 to ZD4 from buzzer circuit: max. 4.8 V.	Pass
6.3.4	Clearance	No partitions	N/A
6.3.5	Separation distances through casting compound	Casting compound is not used.	N/A
6.3.6	Separation distances through solid insulation	Solid insulation is not used.	N/A
6.3.7	Composite separations	No composite separations considered	N/A
6.3.8	Creepage distance	Refer to Appendix A.6 and Appendix B.1 for details.	Pass
6.3.9	Distance under coating	No conformal coating applied	N/A
6.3.10	Requirements for assembled printed circuit boards	a) and b) No conformal coating applied c) Considered in the evaluation of separation distances.	Pass
6.3.11	Separation by earthed screens	No earthed screen	N/A
6.3.12	Internal wiring	Internal wiring will not affect the separation distances due to its layout.	N/A
6.3.13	Dielectric strength requirement	Battery powered equipment with non-metallic enclosure.	N/A
6.3.14	Relays	No relays	N/A
6.4	Protection against polarity reversal	Polarity reversal need not be considered because the secondary battery cell is fixed and shall not be replaced by customer.	N/A
6.5	Earth conductors, connections and terminals	Battery powered equipment.	N/A
6.6	Encapsulation	Encapsulation is not used.	N/A
7	Components on which intrinsic safety depends		
7.1 DS 2018/005A DS 2004/003	Rating of components	Refer to Appendix A.4 for details. Resistors and zener diodes are used as safety components. The safety factor of at least 1.5 is satisfied.	Pass

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
7.2	Connectors for internal connections, plug-in cards and components	<p>Incorrect connections are not possible</p> 	Pass

7.3	Fuses	<p>The fuse, F1, is used in the charging circuit. A current of 0.75 A x 1.7 is considered to flow continuously when the equipment is located in the non-hazardous area.</p> <p>The cold resistance of the fuse is not used.</p> <p>The fuse is connected to the USB-C socket and will not carry current when the EUT is located in the hazardous area. Therefore encapsulation of the fuse is not required.</p> <p>Thin film chip fuse not for replacement (soldered to the circuit board).</p> <p>Um = 6.0 V</p> <p>Breaking capacity for the fuse: 50 V / 63 A.</p> <p>In = 0.75 A</p>	Pass
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7.4	Primary and secondary cells and batteries		
7.4.1	General	<p>One single cell of Panasonic NCR18650GA. Battery has been tested in NO/PRE/ExTR20.0043/00. Test data are copied. The battery shall not be replaced by the user or be charged in hazardous area.</p>	Pass
7.4.2 DS 2010/003	Battery construction	The battery is sealed (gas-tight).	Pass
7.4.3	Electrolyte leakage and ventilation	<p>No electrolyte spillage. The battery has been tested according to clause 10.5.2. Encapsulation is not used.</p> <p>EUT satisfy the requirements for ia and Group IIC. Requirement for hydrogen concentration does not apply.</p> <p>The enclosure of the EUT is not sealed, but lid and enclosure is fixed together with four screws. Only one single cell inside enclosure. The cell is sealed.</p>	Pass

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
7.4.4	Cell voltages	According to table 14: Type system: Lithium ion Positive electrode: (NCA) $\text{Li}(\text{NiCoAl})\text{O}_2$ Electrolyte: Liquid solution Negative electrode: Carbon Voltage: 3.6 V Maximum open circuit voltage: 4.2 V	Pass
7.4.5	Internal resistance of cell or battery	Internal resistance: 24 m Ω	Pass
7.4.6	Batteries in equipment protected by other types of protection	No other types of protection. Only intrinsic safety.	N/A
7.4.7	Batteries used and replaced in explosive atmospheres	The battery shall not be replaced	N/A
7.4.8	Batteries used but not replaced in explosive atmospheres	The battery does not need current-limiting devices to ensure the safety of the battery itself.	Pass
7.4.9	External contacts for charging batteries	<p>a) The current from the battery to the external charging contact is limited by the safety resistors RS2, RS3, RS4 and RS5. These resistors are mounted in parallel.</p> $R_p = (30 \parallel 30 \parallel 470 \parallel 470) \times 0.99 = 13.96 \Omega$ <p>Maximum voltage from EUT to charging contact is 4.8 V (ZD1, ZD2, ZD3, ZD4 buzzer circuit). $I = 4.8 \text{ V} / 13.96 = 344 \text{ mA}$ According to Table A.1: 3.33 A @ 12.1 V is permitted. $344 \text{ mA} < 3.33 \text{ A}$</p> <p>If the current should be made from the maximum voltage in the buzzer circuit ($4.2 \text{ V} \times 3 = 12.6 \text{ V}$) named VBZ it will be reduced by the serial safety resistors RS11 and RS12.</p> $R = (8.2 + 8.2) \times 0.99 = 16.2 \Omega$ $I = 12.6 \text{ V} / 16.2 \Omega = 776 \text{ mA}$ <p>According to Table A.1: 2.51 A @ 12.6 V is permitted. $776 \text{ mA} < 2.51 \text{ A}$</p> <p>In addition one parallel track has three serial connected blocking diodes (D1, D2 and D3). This is the buzzer circuit.</p> <p>b) N/A, EUT satisfies sub-clause a).</p>	Pass

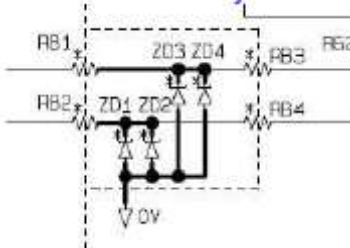
7.5 DS 2015/007	Semiconductors		
7.5.1	Transient effects	Battery powered equipment. No transient effects	N/A
7.5.2	Shunt voltage limiters	<p>a) D1, D2, D3 are diodes connected in series. 1.5 in safety factor is applied. See appendix A.4.3 for details.</p> <p>b) Zener diodes are used in the buzzer circuit to clamp the voltage to a maximum of 4.8 V. 1.5 in safety factor is applied. See appendix A.4.2 for details.</p>	Pass

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
7.5.3	Series current limiters	Three series blocking diodes D1, D2, D3 Refer to Appendix A.2 for details. See sub-clause 7.5.2.a above and appendix A.4.3 for details.	Pass
7.6 DS 2016/002 DS 2012/009	Failure of components, connections and separations	Faults per this clause are considered	Pass
7.7	Piezo-electric devices	There is one piezo-electric device in the circuit (BZ1). It is used as a buzzer. This device is tested according to clause 10.7. $E = 0.5 \times 42.9 \text{ nF} \times 18.9\text{V}^2 = 7.67 \text{ }\mu\text{J}$ $7.67.\mu\text{J} < 50.\mu\text{J} \rightarrow \text{IIC}$ See appendix B.2 for details.	Pass

IEC 60079-11									
Clause	Requirement – Test	Result – Remark		Verdict					
7.8	Electrochemical cells for the detection of gases	Different types of electrochemical cells for the detection of different gases are used.		Pass					
		<table><tr><td>Detection Principle</td><td>Electrochemical</td><td>Electrochemical</td></tr><tr><td>Model</td><td>ESR-A1DP</td><td>ESR-X13P</td></tr><tr><td>Measured Gas</td><td>CO/H₂S</td><td>O₂</td></tr></table>	Detection Principle		Electrochemical	Electrochemical	Model	ESR-A1DP	ESR-X13P
Detection Principle	Electrochemical	Electrochemical							
Model	ESR-A1DP	ESR-X13P							
Measured Gas	CO/H ₂ S	O ₂							
		<p>There are no circuit board or electronic components in these cells. Ref. document M4-4482-02-01K and M4-4488-19-01K.</p> <p>DOES NOT CONTAIN PCB NOR ELECTRONIC COMPONENTS.</p> <p>No Inductors No Capacitors No Resistors are contained.</p> <p>⚠</p> <p>Electrochemical evaluation: With reference to ExTAG DS 2002/001A 2007 09 25: Typical values under worst-case-condition have been reported to be: 1.25 V – 50 mA - 1 A (short circuit peak / capacitive) 300 mW Sometimes the maximum output values for sensors for toxic gases can only be reached with lethal concentrations. It is recommended to assess the characteristics only in the range of warning levels If the sensors are stand-alone-equipment they could be assessed to be simple apparatus. According to this clause the addition of power shall not be considered for thermal assessment. Voltage and current for 100 % conditions (most severe condition) for these two cells are: Voltage: 0.1 V Current 0.5 mA Data are conformed by measurement. No further evaluation for these cells are considered.</p>							

8	Infallible components, infallible assemblies of components and infallible connections on which intrinsic safety depends		
8.1	Level of Protection “ic”	Level of protection ia .	N/A
8.2	Mains transformers	No mains transformers. Battery powered equipment.	N/A
8.3	Transformers other than mains transformers	No transformers in the equipment.	N/A
8.4	Infallible windings	No infallible windings in EUT.	N/A

IEC 60079-11																																																											
Clause	Requirement – Test	Result – Remark	Verdict																																																								
8.5	Current-limiting resistors	All resistors on which intrinsic safety depends are metal film type. Refer to Appendix A.4 for ratings.	Pass																																																								
8.6 DS 2003/003	Capacitors																																																										
8.6.1	Blocking capacitors	No blocking capacitors.	N/A																																																								
8.6.2	Filter capacitors	No filter capacitors.	N/A																																																								
8.7	Shunt safety assemblies																																																										
8.7.1	General	Voltage limitation with 2 zener diodes per infallible assembly. The Zener diodes ZD1, ZD2, ZD3 and ZD4 are used as safety components. These are coupled 2 and 2 in parallel on the two tracks to buzzer circuit. See appendix A.4.2 for details.	Pass																																																								
8.7.2	Safety shunts	The Zener diodes ZD1, ZD2, ZD3 and ZD4 are used as safety shunts. In the buzzer circuit it is a piezo driver, IC4, (charge pump) which multiplies the input voltage. Ref. datasheet: <table><tr><th colspan="6">■RECOMMENDED OPERATING CONDITION (T=25°C)</th></tr><tr><th>PARAMETER</th><th>SYMBOL</th><th>CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr><tr><td rowspan="2">Operating Voltage</td><td rowspan="2">VIN</td><td>1x Mode, 2x Mode</td><td>2.3</td><td>3.0</td><td>5.0</td><td rowspan="2">V</td></tr><tr><td>1x Mode, 2x Mode, 3x Mode</td><td>2.3</td><td>3.0</td><td>3.4</td></tr></table> <table><tr><th colspan="6">■ELECTRICAL CHARACTERISTICS (T=25°C, VIN=3V, CL=100nF, CIN=100nF, COUT=15nF, fIN=4kHz)</th></tr><tr><th>PARAMETER</th><th>SYMBOL</th><th>CONDITIONS</th><th>MIN</th><th>TYP</th><th>MAX</th><th>UNIT</th></tr><tr><td rowspan="3">Output Voltage</td><td>VOUT</td><td>1x Mode</td><td>2.8</td><td>-</td><td>3</td><td>V</td></tr><tr><td>VOUT</td><td>2x Mode</td><td>5.2</td><td>-</td><td>6</td><td>V</td></tr><tr><td>VOUT</td><td>3x Mode</td><td>7.2</td><td>-</td><td>9</td><td>V</td></tr></table> Maximum output voltage is 9 V. The Zener diodes limit the voltage to the circuits connected to the buzzer circuit, to a maximum voltage of 4.8 V.	■RECOMMENDED OPERATING CONDITION (T=25°C)						PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT	Operating Voltage	VIN	1x Mode, 2x Mode	2.3	3.0	5.0	V	1x Mode, 2x Mode, 3x Mode	2.3	3.0	3.4	■ELECTRICAL CHARACTERISTICS (T=25°C, VIN=3V, CL=100nF, CIN=100nF, COUT=15nF, fIN=4kHz)						PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT	Output Voltage	VOUT	1x Mode	2.8	-	3	V	VOUT	2x Mode	5.2	-	6	V	VOUT	3x Mode	7.2	-	9	V	Pass
■RECOMMENDED OPERATING CONDITION (T=25°C)																																																											
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT																																																					
Operating Voltage	VIN	1x Mode, 2x Mode	2.3	3.0	5.0	V																																																					
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	VOUT	2x Mode	5.2	-	6	V																																																					
	VOUT	3x Mode	7.2	-	9	V																																																					
8.7.3	Shunt voltage limiters	No shunt voltage limiters.	N/A																																																								

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
8.8	Wiring, printed circuit board tracks, and connections	<p>Refer to Appendix A.5 for infallible connections</p> <p>a) Wires are not used as infallible connections in EUT.</p> <p>b) 2: Infallible tracks (single tracks) are used in the safety shunt assembly.</p>  <p>See appendix B.3 for details.</p> <p>3: Infallible vias (single) are used in the safety shunt assembly. The vias connect the anodes of the Zener diodes to GND layer.</p> <p>See appendix B.4 for details.</p> <p>c) 3: The soldered joints of the Zener diodes to the PCB are according to the component's manufacturer recommendations.</p>	Pass

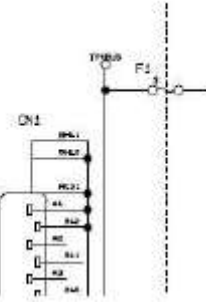
8.9	Galvanically separating components	No galvanically separating components	N/A
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9	Supplementary requirements for specific apparatus		
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9.1	Diode safety barriers	Not such apparatus	N/A
9.2	FISCO apparatus	Not such apparatus	N/A
9.3	Handlights and caplights	Not such apparatus	N/A

10	Type verifications and type tests		
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10.1 DS 2013/002	Spark ignition test		
10.1.1	General	Assessment using reference curves and tables Refer to Appendix A.2 for details.	Pass
10.1.2	Spark test apparatus	Assessment using reference curves and tables	N/A
10.1.4	Tests with the spark test apparatus	Assessment using reference curves and tables	N/A
10.1.5	Testing considerations		
10.1.5.1	General	Assessment using reference curves and tables	Pass
10.1.5.2	Circuits with both inductance and capacitance	Refer to Appendix A.2.4 for details.	Pass
10.1.5.3	Circuits using shunt short-circuit (crowbar) protection	Refer to Appendix A.2.5 for details.	N/A

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
10.2	Temperature tests	See appendix B for temperature tests and appendix A for temperature assessment of small components.	Pass
10.3	Dielectric strength tests	EUT is battery powered. No use of blocking capacitors, optocouplers or transformers.	N/A
10.4	Determination of parameters of loosely specified components	Clause not applied	N/A
10.5	Tests for cells and batteries		
10.5.1	General	The battery cells are tested in IECEx test report NO/PRE/ExTR20.0043. Test results for electrolyte leakage test are copied from that report.	Pass
10.5.2	Electrolyte leakage test for cells and batteries	See appendix B.5 for details.	Pass
10.5.3	Spark ignition and surface temperature of cells and batteries	See appendix B.5 for details.	Pass
10.5.4	Battery container pressure tests	The battery cell is sealed.	N/A
10.6	Mechanical tests		
10.6.1	Casting compound	Casting compound is not used	N/A
10.6.2	Determination of the acceptability of fuses requiring encapsulation	<p>The fuse, F1, is mounted close to the USB-C charging contact (CN1), and is a part of the charging circuit. The fuse will only carry current when located in non-hazardous area.</p> 	N/A
10.6.3	Partitions	No such partitions	N/A
10.7	Tests for intrinsically safe apparatus containing piezoelectric devices	The buzzer, BZ1, is a piezo electric device. See appendix B.2 for details.	Pass
10.8	Type tests for diode safety barriers and safety shunts	No such components	N/A

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
10.9	Cable pull test	See 6.2.4	N/A
10.10	Transformer tests	No transformers	N/A
10.11	Optical isolators tests	No optical isolator	N/A
10.12	Current carrying capacity of infallible printed circuit board connections	Clause not applied	N/A
11	Routine verifications and tests		
11.1	Routine tests for diode safety barriers		
11.1.1	Completed barriers	Not such apparatus	N/A
11.1.2	Diodes for 2-diode “ia” barriers	Not such apparatus	N/A
11.2	Routine tests for infallible transformers	Not such apparatus	N/A
12	Marking		
12.1	General	Marked according to IEC 60079-0. No intrinsically safe parameters to be marked.	Pass
12.2	Marking of connection facilities	Only charging connection facility for use in non-hazardous area. Label on AC ADAPTER defines correct connection (USC Type-C).	Pass
12.3	Warning markings	a) Secondary cells. b) Battery is not to be replaced. c) Warning Read manual for safety info on equipment, In manual: Do not charge in a hazardous location. d) N/A, battery is not replaceable	Pass
12.4	Examples of marking	The examples of marking are informative.	Pass

IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
13	Documentation	<p>According to IEC 60079-0.</p> <p>a) No parameters for entity concept.</p> <p>b) N/A</p> <p>c) Um: 6 VDC.</p> <p>d) The battery should be charged with the dedicated AC adapter or by power from IEC60950-certified SELV power source, or IEC62368-1-certified ES1 power source. The maximum voltage from the charger shall not exceed 6.0 Vdc.</p> <p>e) N/A (battery powered).</p> <p>f) N/A</p> <p>g) Ambient temperature is part of certification.</p> <p>h) Annex F is not used.</p>	Pass

Annex A (Normative)	Assessment of intrinsically safe circuits		
A.1	Basic criteria	Applied	Pass
A.2	Assessment using reference curves and tables	Applied	Pass
A.3	Examples of simple circuits	Informative	Pass
A.4	Permitted reduction of effective capacitance when protected by a series resistance	Clause is not used	N/A

Annex B (Normative)	Spark test apparatus for intrinsically safe circuits	Assessment using curves and tables	N/A
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Annex C (Informative)	Measurement of creepage distances, clearances and separation distances through casting compound and through solid insulation		
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Annex D (Normative)	Encapsulation	Encapsulation is not used.	N/A
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Annex E (Informative)	Transient energy test		
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Annex F (Normative)	Alternative separation distances for assembled printed circuit boards and separation of components	Annex F is not used.	N/A
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Annex G (Normative)	Fieldbus intrinsically safe concept (FISCO) – Apparatus requirements	Not for FISCO certification	N/A
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IEC 60079-11			
Clause	Requirement – Test	Result – Remark	Verdict
Annex H (Informative)	Ignition testing of semiconductor limiting power supply circuits		

Measurement Section, including Additional Narrative Remarks

APPENDIX A: Description of product

A.1 General overview

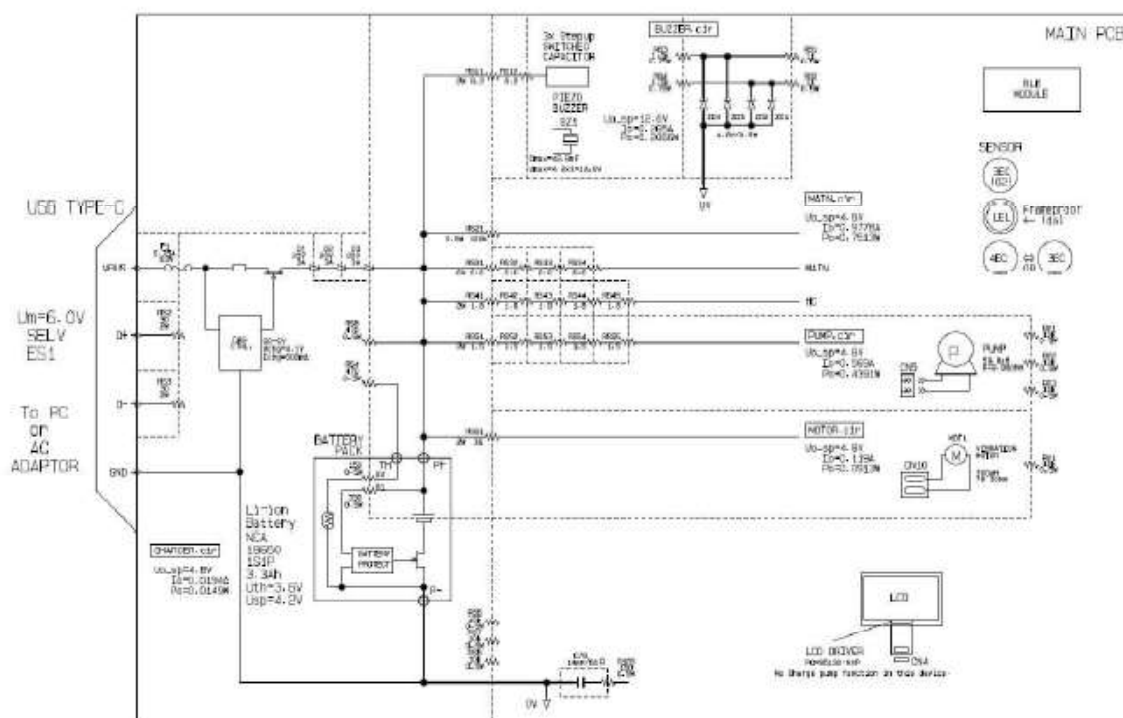
Equipment under test (EUT) is a gas detector named GX-Force. It is hand-held, powered by 1 secondary cell, and comes with three different gas detection cells. EUT is equipped with a buzzer (piezo-electric), pump, vibration motor, low energy Bluetooth module (BLE), LCD screen and LEDs for alarm.

Additional information:

- Pump, RIKEN KEIKI RP-12, is already certified in [IECEX PRE 17.0070/Presafe 17ATEX11584](#).
- Battery, Panasonic NCR18650GA, is already tested in NO/PRE/ExTR20.0043.
- Vibration motor, LEXIN LE4A3GS1G4, is already certified in [IECEX DEK 17.0050X/DEKRA 17ATEX0103X](#).

All relevant data are copied from above mentioned test reports.

IS safety diagram (overview):



A detailed explanation for the different circuits see below.

AC adapter:

This specific AC adapter (Mass Power Electronic Limited S018) can be used for charging the battery. Copy of certificates are stored in project folder at ExTL.

2.5 Safety Standards

The power supply shall be certified by following international regulatory standards.

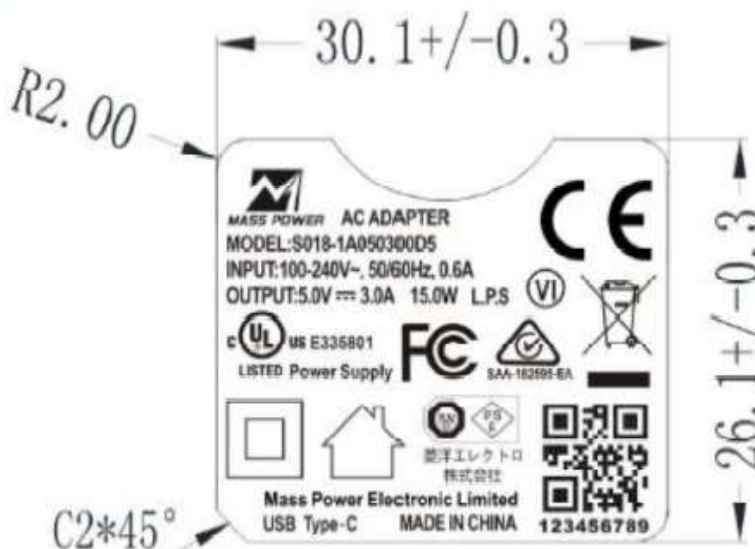
Item	Country	Status	Safety standard
CE	Europe	Approved	EN62368-1
GS	Germany	Approved	EN62368-1
UL/cUL	America / Canada	Approved	UL 62368 and CAN/CSA
SAA	Australia/New Zealand	Approved	AS/NZS 62368.1
CCC	China	Approved	GB4943
TUV Mark	United Kingdom	---	BS EN60950-1
PSE	Japan	Approved	J60950-1
KCC	Korea	---	K60950
CB	Global	Approved	IEC62368-1

2.2.1 Output voltage and current

Rated output voltage (V)	Nominal output voltage (V)	Voltage range (V)	No load (A)	Min load (A)	Rated load(A)	Max. load (A)	Rated output power(W)
5	5.2	4.9-5.5	0	0	3	*	15

The output voltage must stay within the limits specified in table 2 when operating at steady state.

5.2 Label Drawing



Charging circuit:

The battery shall only be charged in non-hazardous area, and not replaced. It shall be charged with the dedicated AC adapter (Mass Power S018), by power from IEC 60950 (Information technology equipment Safety) certified SELV power source or IEC 62368-1 (Audio/video, information and communication technology equipment - Part 1: Safety requirements) certified ES1 (ES1 equal to SELV) power source. The maximum voltage from the charger shall not exceed 6.0 VDC (U_m : 6.0 VDC). The charging contact is USB-C. The charging circuit will only be operative in the non-hazardous area.

The USB-C contact is named CN1 by RIKEN KEIKI. It has 3 tracks going to the circuit in addition to GND. Track 1 is protected by fuse F1 (0.75 A x 1.7 = 1.275 A), track 2 protected by resistor RS2 (30 x 0.99 = 29.7 Ω) and track 3 protected by resistor RS3 (30 x 0.99 = 29.7 Ω). Track 4 is GND.

After the charging circuit there are 6 tracks going to the battery pack and the remaining circuits. So the non-active charging circuit in hazardous area is protected by the parallel coupled resistors RS4, RS5, RS6, RS7 and RS8. These resistors are also in parallel with three serial coupled blocking diodes, D1, D2 and D3. The current to the buzzer circuit, main circuit, pump circuit and motor circuit is further reduced with safety resistors. By this construction the USB-C contact is not capable of delivering hazardous spark energy to the environment in hazardous area.

See appendix A.2 for details.

Battery circuit/pack:

Contains one secondary cell. Maximum voltage is 4.2 V. Nominal voltage is 3.6 V. This circuit has its own pcb named protect pcb. Protect pcb is connected to main pcb with the contact CN2 (3 pins).

Pin 1 (P+): Connection to positive signal from charger, + polarity on battery and main circuit. The connection to the charger goes through the three diodes, D1, D2 and D3. There is also a connection to the protect IC through the resistor R1 (330 $\Omega \pm 1\%$).

Pin 2 (TH): Connection to negative signal from charger through R4 (150 $\Omega \pm 1\%$) and to the protect IC and negative polarity on battery. There is also a thermistor in series with R4 (RT1).

Pin 3 (P-): Connection to negative pole on battery and to the 0 V on main pcb. It is connected to the same tracks as pin 2 (TH), but after the safety resistor and thermistor.

Maximum current between P+ and P- will be through the safety resistor R1.

See appendix A.2 for details.

Buzzer circuit:

Connection between Buzzer circuit (VBZ) and battery is through the resistors RS11 and RS12 (8.2 Ω x 0.99 x 2 = 16.2 Ω). Between buzzer and main circuit (IC12) there are connection named PB4 and PB5.

These connections are protected by resistors $(RB1 + RB3) \parallel (RB2 + RB4) = (1 \text{ k}\Omega \times 0.99 + 1.5 \text{ k}\Omega \times 0.99) \parallel (1 \text{ k}\Omega \times 0.99 + 1.5 \text{ k}\Omega \times 0.99) = 1237.5 \text{ }\Omega$, and parallel coupled Zener diodes ZD1, ZD2, ZD3 and ZD4, $U = \max 4.8 \text{ V}$. The buzzer circuit include a step-up piezo driver ($3 \times U = 3 \times 4.2 \text{ V} = 12.6 \text{ V}$).

Pump circuit:

This circuit contains a pump (RP-12) for suction of gas in the surrounding atmosphere to be used in the gas analyses. The pump is connected to the pump circuit with the connection CN5.

Pump circuit is connected to the battery through the resistors RS51, RS52, RS53, RS54 and RS55 ($R = 1.5 \text{ }\Omega \times 0.99 \times 5 = 7.4 \text{ }\Omega$).

In addition the pump circuit is connected to the main circuit through the parallel coupled resistors RP1, RP2 and RP3 ($R = (10 \text{ k}\Omega \times 0.995) / 3 = 3316 \text{ }\Omega$)

Pump, RIKEN KEIKI RP-12, is already certified in IECEx PRE 17.0070/Presafe 17ATEX11584. All results for the specific pump are copied from that project.

Motor circuit:

Vibration motor, LEXIN LE4A3GS1G4, is already certified in IECEx DEK 17.0050X/DEKRA 17ATEX0103X. All results for the vibration motor are copied from that project.

The circuit itself is powered by the battery through the resistor RS61 ($36 \text{ }\Omega \times 0.99 = 35.64 \text{ }\Omega$). In addition the circuit is connected to main circuit through the resistor RV1 ($10 \text{ k}\Omega \times 0.995 = 9950 \text{ }\Omega$).

LCD:

There is a LCD screen connected to the main board (CN4). There is none charge pump function in the LCD driver. The polarity is not reversed.

BLE Module (IC16): Bluetooth 5.0 low energy module. It uses the chip Nordic nRF52832 (512kB Flash, 64kB RAM). The chip itself contains maximum $1.5 \text{ }\mu\text{F}$ and negligible inductance. It is connected to main circuit by CN9. The module itself is named IC16.

Main circuit:

The main circuit is connected to all of the other circuits, but the current is reduced by the use of safety resistors. There are mainly three tracks from the battery to the main circuit.

V_{BAT} : RS21 $\rightarrow 100 \text{ k}\Omega \times 0.99 = 99000 \text{ }\Omega$

V_{MAIN} : RS31, RS32, RS33, RS34 in series $\rightarrow 2.2 \text{ }\Omega \times 0.99 \times 4 = 8.71 \text{ }\Omega$

V_{HC} : RS41, RS42, RS43, RS44, RS45 in series $\rightarrow 1.8 \text{ }\Omega \times 0.99 \times 5 = 8.91 \text{ }\Omega$

The three different tracks must be considered to be in parallel. $R_{\text{p3}} = 99000 \text{ }\Omega \parallel 8.71 \text{ }\Omega \parallel 8.91 \text{ }\Omega = 4.4 \text{ }\Omega$

In addition the main circuit connection to the other circuits:

Buzzer circuit: $RB1 \parallel RB2 = 1 \text{ k}\Omega \times 0.99 \parallel 1 \text{ k}\Omega \times 0.99 = 495 \text{ }\Omega$

Pump circuit: RP1, RP2 and RP3 ($R = (10 \text{ k}\Omega \times 0.995) / 3 = 3316 \text{ }\Omega$)

Motor circuit: RV1 ($10 \text{ k}\Omega \times 0.995 = 9950 \text{ }\Omega$).

$R_{\text{total}} = 4.4 \text{ }\Omega \parallel 495 \text{ }\Omega \parallel 3316 \text{ }\Omega \parallel 9950 \text{ }\Omega = 4.35 \text{ }\Omega$

The connections to the other circuits (buzzer, pump and motor) are negligible.

A.2 Spark ignition considerations

A.2.1 Resistive spark ignition

Charging circuit:

(This evaluation is for the USB-C contact not to deliver hazardous spark energy in Ex zone.)

Maximum voltage from battery is, U : 4.2 V (maximum open circuit voltage).

Minimum resistance to limit the current is, $R = RS4 \parallel RS5 \parallel RS6 \parallel RS7 \parallel RS8 = 470 \text{ }\Omega \times 0.99 \parallel 470 \text{ }\Omega \times 0.99 \parallel 10 \text{ k}\Omega \times 0.995 \parallel 10 \text{ k}\Omega \times 0.995 \parallel 10 \text{ k}\Omega \times 0.995 = 217.4 \text{ }\Omega$

Maximum current, $I = 4.2 \text{ V} / 217.4 = 19.4 \text{ mA}$.

In addition the current will be limited by the cold resistance of F1 in parallel with RS2 and RS3, but this resistance is negligible, and is not considered in this evaluation.

According to table A.1 a current of 3.33 A is permitted @ 12.1 V and 1.5 safety factor.

$3.33 \text{ A} > 19.4 \text{ mA}$

$12.1 \text{ V} > 4.2 \text{ V}$

Battery circuit/pack:

Maximum voltage from battery is, U : 4.2 V (maximum open circuit voltage).

Minimum resistance to limit the current is, $R = R1 = 330 \text{ }\Omega \times 0.99 = 326.7 \text{ }\Omega$

Maximum current, $I = 4.2 \text{ V} / 326.7 \text{ }\Omega = 12.9 \text{ mA}$.

According to table A.1 a current of 3.33 A is permitted @ 12.1 V and 1.5 safety factor.

$3.33 \text{ A} > 12.9 \text{ mA}$

12.1V > 4.2 V

Maximum voltage between P+ and Th is, U: 4.2 V (maximum open circuit voltage).

Minimum resistance to limit the current is, $R = R4 = 150 \Omega \times 0.99 = 148.5 \Omega$

Maximum current, $I = 4.2 \text{ V} / 148.5 \Omega = 28.3 \text{ mA}$.

According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

3.33 A > 28.3 mA

12.1 V > 4.2 V

P + is limited by the resistors connected to the other circuits.

Buzzer circuit:

Maximum voltage to buzzer circuit from battery, U = 4.2 V

Minimum resistance between buzzer circuit and battery, $R = RS11 + RS12 = 8.2 \Omega \times 0.99 \times 2 = 16.2 \Omega$

Maximum current to buzzer from battery, $I = 4.2 \text{ V} / 16.2 \Omega = 260 \text{ mA}$

According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

3.33 A > 260 mA

12.1V > 4.2 V

Maximum voltage due to the step-up driver, $U = 4.2 \text{ V} \times 3 = 12.6 \text{ V}$.

Maximum current if 100% efficiency of step-up converter, $I = 260 \text{ mA} / 3 = 86.7 \text{ mA}$

According to table A.1 a current of 2.51 A is permitted @12.6 V and 1.5 safety factor.

2.51 A > 86.7 mA

Maximum voltage from buzzer to main circuit, U (ZD1, ZD2, ZD3 and ZD4) = 4.8 V + 1.0 V (VR) = 5.8 V

Minimum resistance from buzzer to main circuit @ 5.8 V, $R = RB1 \parallel RB2 = 1 \text{ k}\Omega \times 0.99 \parallel 1 \text{ k}\Omega \times 0.99 = 495 \Omega$

Maximum current from buzzer circuit and main circuit, $I = 5.8 \text{ V} / 495 \Omega = 11.8 \text{ mA}$

According to table A.1 a current of 3.33 A is permitted @12.1V and 1.5 safety factor.

3.33 A > 11.8 mA

12.1 V > 5.8 V

Total current to the buzzer circuit will be current from battery + current from main circuit = 260 mA + 4.2 V / (495 Ω x 2) = 260 mA + 5 mA = 265 mA

According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

3.33 A > 265 mA

12.1 V > 4.2 V

Pump circuit:

Maximum voltage to pump circuit from battery, U = 4.2 V

Minimum resistance between pump circuit and battery is RS51, RS52, RS53, RS54 and RS55 in series ($R = 1.5 \Omega \times 0.99 \times 5 = 7.4 \Omega$). In addition current from the main circuit through the parallel coupled resistors RP1, RP2 and RP3 ($R = (10 \text{ k}\Omega \times 0.995) / 3 = 3316 \Omega$).

$R_p = 7.4 \Omega \parallel 3316 \Omega = 7.38 \Omega$

Maximum current to the pump circuit, $I = 4.2 \text{ V} / 7.38 \Omega = 569 \text{ mA}$

According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

3.33 A > 569 mA

12.1V > 4.2 V

Motor circuit:

Maximum voltage to motor circuit from battery, U = 4.2 V

Minimum resistance from battery and main circuit is, $R = RS61 \parallel RV1 = 36 \Omega \times 0.99 \parallel 10 \text{ k}\Omega \times 0.995 = 35.51 \Omega$.

Maximum current, $I = 4.2 \text{ V} / 35.51 \Omega = 119 \text{ mA}$

According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

3.33 A > 119 mA

12.1 V > 4.2 V

Main circuit:

Maximum voltage to main circuit from battery, U = 4.2 V

Minimum resistance, $R = 4.35 \Omega$

Maximum current, $I = 4.2 \text{ V} / 4.35 \Omega = 966 \text{ mA}$

Maximum current from buzzer circuit and main circuit, $I = 5.8 \text{ V} / 495 \Omega = 11.8 \text{ mA}$

Total, $I = 966 \text{ mA} + 11.8 \text{ mA} = 977.8 \text{ mA}$

(Current from motor and pump circuits are negligible.)

According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

3.33 A > 978 mA

12.1 V > 4.2 V

A.2.2 Inductive spark ignition

Charging circuit:

No inductors. Inductance from components such as ferrite bead, ICs and tracks is negligible @19.4 mA and 1.5 safety factor.

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (19.4 \text{ mA} \times 1.5)^2) = 94.4 \text{ mH}$.

Battery circuit/pack:

No inductors. Inductance from components and tracks is negligible @28.3 mA and 1.5 safety factor.

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (28.3 \text{ mA} \times 1.5)^2) = 44.4 \text{ mH}$.

Buzzer circuit:

No inductors. Inductance from components and tracks is negligible @265 mA and 1.5 safety factor.

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (265 \text{ mA} \times 1.5)^2) = 506 \mu\text{H}$.

Pump circuit:

No inductance in the pump circuit except for the inductance in the pump itself.

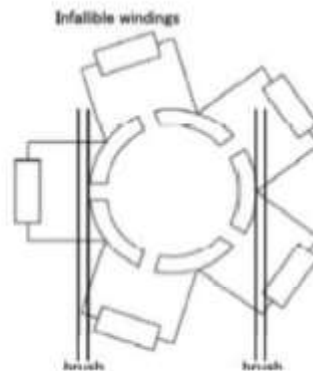
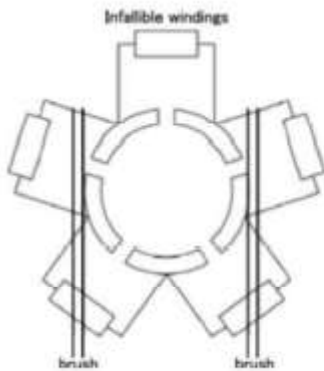
Pump motor:

Micro pump type RP-12: (Internal motor of pump is type A12B-09-SS). The pump type was used in other product from manufacturer whereof it was assessed and already certified in [IECEx PRE 17.0070](#)/Presafe 17ATEX11584.

The pump's motor has windings. The motor coil resistance is taken as an resistance to protect it's inductance. The minimum motor coil resistance and maximum motor coil inductance of A12B-09-SS are as follows.

case1: one commutator segment active.

case2: two commutator segments active.



Rmin 13.1 Ω / Lmax 59.8 μH

Rmin 11.0 Ω / Lmax 49.8 μH

The range of the motor coil resistance and the motor coil inductance are as follows.

Rmin = 11.0 Ω - 13.1 Ω , Lmax = 49.8 μH - 59.8 μH (9.98 Ω stated by RIKEN KEIKI.)

The worst value is Rmin = 11.0 Ω and Lmax = 59.8 μH respectively

The effective internal inductance of a pump motor coil is Lmax = 59.8 μH max. And the minimum resistance of a pump motor coil is Rmin = 9.98 Ω

Minimum resistance, $R = 7.38 \Omega$ (pump circuit) + 9.98 $\Omega = 17.36 \Omega$

Maximum current in coil, $I = 4.2 \text{ V} / 17.36 \Omega = 242 \text{ mA}$.

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (242 \text{ mA} \times 1.5)^2) = 607 \mu\text{H}$.
607 μH > 59.8 μH

Motor circuit:

No inductance in the motor circuit except for the inductance in the motor itself.

Vibration motor, LEXIN LE4A3GS1G4, is already certified in IECEx DEK 17.0050X/DEKRA 17ATEX0103X.

According to datasheet:

* 温度20℃, 相対湿度65%の条件下にて測定のこと。

4-7	Terminal Resistance 端子間抵抗	+65℃	133 Ω ± 10%
		+20℃	115 Ω ± 10%
		-25℃	93 Ω ± 10%
		-40℃	87 Ω ± 10%
4-8	Inductance インダクタンス	+65℃	240 μH以下
		+20℃	275 μH以下
		-25℃	295 μH以下
		-40℃	300 μH以下

Maximum inductance in the motor: 300 μH.

Minimum cold resistance in motor: 78.3 Ω (defined by Riken Keiki)

Total resistance in the circuit is, $R = 78.3 \Omega + 35.51 \Omega = 113.81 \Omega$

Maximum current through the motor coil, $I = 4.2 \text{ V} / 113.81 \Omega = 36.9 \text{ mA}$

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (36.9 \text{ mA} \times 1.5)^2) = 26.1 \text{ mH}$.

26.1 mH > 300 μH

BLE module:

The BLE module has a inductance of 10.8 nH (L3 and L4). Maximum current to the BLE module is, $I = 978 \text{ mA}$.

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (978 \text{ mA} \times 1.5)^2) = 37 \mu\text{H}$.

37 μH > 10.8 nH

Main circuit:

No inductance in the main circuit board except for ferrite beads (NF2, NF21, NF22, NF23, NF31, NF32, NF33 and NF41). In addition the inductance in BLE module, 10.8 nH.

Maximum inductance permitted according to figure A.6, $L = 40 \mu\text{J} / (0.5 \times (978 \text{ mA} \times 1.5)^2) = 37.2 \mu\text{H}$.

37 μH > 10.8 nH

A.2.3 Capacitive spark ignition

Charging circuit:

$C_{\text{total}} = C1 + C2 + C3 + C11 + C12 + C13 + C14 + C15 + C16 + C17 + C18 + IC2 + IC3 = 120 \mu\text{F} + 7 \text{ pF} + 26 \text{ pF} = 120 \mu\text{F}$ (including tolerances)

According to table A.2 a maximum capacitance of 136 μF is permitted at a voltage of $4.8 \text{ V} \times 1.5 = 7.2 \text{ V}$.

136 μF > 120 μF

Battery circuit/pack:

$C_{\text{total}} = C1 + C2 + C3 = 1.6 \mu\text{H}$ (including tolerances)

According to table A.2 a capacitance of 420 μF is permitted @ $4.2 \text{ V} \times 1.5 = 6.3 \text{ V}$.

420 μF > 1.6 μH.

Buzzer circuit:

$C_{\text{total}} = C51 + C52 + C53 + BZ1 = 1 \mu\text{H} + 42.9 \text{ nH} = 1.04 \mu\text{H}$ (including tolerances)

According to table A.2 a capacitance of 1.15 μF is permitted @ $12.6 \text{ V} \times 1.5 = 18.9 \text{ V}$.

1.15 μF > 1.04 μF

Pump circuit:

$C_{\text{total}} = C31 + C32 + C33 + C34 + C35 + C36 = 8 \mu\text{H}$ (including tolerances)

According to table A.2 a capacitance of 136 μF is permitted @ $4.8 \times 1.5 = 7.2 \text{ V}$.

136 μF > 8 μH

Motor circuit:

$C_{\text{total}} = C54 + C55 = 5 \mu\text{H}$ (including tolerances)

According to table A.2 a capacitance of 136 μF is permitted @ $4.8 \times 1.5 = 7.2 \text{ V}$.
 $136 \mu\text{F} > 5 \mu\text{F}$

BLE module:

Maximum capacitance in the chip, $C = 1.5 \mu\text{F}$.

Main circuit:

$C_{\text{total}} = C19 + C21 + C22 + C23 + C24 + C25 + C26 + C41 + C42 + C43 + C44 + C45 + C61 + C62 + C63 + C64 + C65 + C66 + C67 + C68 + C69 + C71 + C72 + C73 + C74 + C75 + C76 + C77 + C78 + C81 + C82 + C83 + C84 + C85 + C86 + C87 + C91 + C92 + C93 + C94 + C95 + C96 + C97 + C98 + C101 + C102 + C103 + C104 + C105 + C106 + C107 + C110 + C111 + C112 + C113 + C114 + C115 + C116 + C117 + C118 + C120 + C121 + C122 + C123 + C124 + C125 + C126 + C130 + C131 + C132 + C133 + C134 + C135 + C136 + C140 + C141 + C142 + C143 + C144 + C145 + C151 + C152 + C153 + C155 + C160 + C161 + C162 + C163 + C164 + C165 + C166 + C167 + C171 + C172 + C173 + C174 = 120 \mu\text{H}$
(including tolerances)

In addition the capacitance from IC16 (BLE module), $1.5 \mu\text{F}$

According to table A.2 a capacitance of 136 μF is permitted @ $4.8 \times 1.5 = 7.2 \text{ V}$.

$136 \mu\text{F} > 121.5 \mu\text{F}$

In addition there will be capacitance from other circuits. The current is reduced by safety resistors:

Buzzer circuit: $\text{RB1} \parallel \text{RB2} = 1 \text{ k}\Omega \times 0.99 \parallel 1 \text{ k}\Omega \times 0.99 = 495 \Omega \rightarrow I = 4.8 \text{ V} / 495 \Omega = 9.7 \text{ mA}$

Pump circuit: $\text{RP1}, \text{RP2}$ and RP3 ($R = (10 \text{ k}\Omega \times 0.995) / 3 = 3316 \Omega \rightarrow I = 4.8 \text{ V} / 3316 \Omega = 1.5 \text{ mA}$

Motor circuit: RV1 ($10 \text{ k}\Omega \times 0.995 = 9950 \Omega$) $\rightarrow I = 4.8 \text{ V} / 9950 \Omega = 0.5 \text{ mA}$

Charger circuit: The current will be limited by the resistors to the main circuit, $R = 4.4 \Omega \rightarrow$

$I = 4.8 \text{ V} / 4.4 \Omega = 1.091 \text{ A}$

In addition $C79$ (14 mF) that must be discharged through $R105 \rightarrow I = 4.8 \text{ V} / (150 \Omega \times 0.99) = 4.8 \text{ V} / 148.5 \Omega = 32.4 \text{ mA}$

Total, $I = 9.7 \text{ mA} + 1.5 \text{ mA} + 0.5 \text{ mA} + 1.091 \text{ A} + 32.4 \text{ mA} = 1.136 \text{ A}$ @4.8V. According to table A.1 a current of 3.33 A is permitted @12.1 V and 1.5 safety factor.

$3.33 \text{ A} > 1.136 \text{ A}$

$12.1 \text{ V} > 4.8 \text{ V}$

Information for $C79$: This is a small supercapacitor with a nominal and discharge capacity of 4.0 μAh and an electrostatic capacity of maximum 14 mF. The minimum internal resistance of the capacitor is 50 Ω .

$I = 4.8 \text{ V} / 50 = 96 \text{ mA} \rightarrow 96 \text{ mA} < 3.33 \text{ A}$. In addition the current will be reduced by safety resistor $R105$.

Due to the very small capacitance of the capacitor (4.0 μAh) and the high impedance it is considered not necessary to do temperature measurements on the component. The unique ceramic packaging with superior air-tightness is used. As the result, it offers leakage resistance and humidity resistance. Total weight of the capacitor is 0.025 g.

A.2.4 Combination of inductive and capacitive spark ignition

Charging circuit:

No combination of inductance and capacitance.

Battery circuit/pack:

No combination of inductance and capacitance.

Buzzer circuit:

No combination of inductance and capacitance.

Main circuit:

No inductance in the main circuit board except for ferrite beads (NF2, NF21, NF22, NF23, NF31, NF32, NF33 and NF41). BLE module has an inductance of 10.8 nH. Maximum permitted inductance is 37 μH . 10.8 nH is only 0.35 % of permitted inductance.

Pump circuit:

Capacitance: $136 \mu\text{F} > 8 \mu\text{F} \rightarrow 5.9 \%$

Inductance: $607 \mu\text{H} > 59.8 \mu\text{H} \rightarrow 9.9 \%$

Both inductance and capacitance are below 50% of permitted values. No further assessment is necessary.

Motor circuit:

Capacitance: $136 \mu\text{F} > 5 \mu\text{F} \rightarrow 3.7 \%$

Inductance: $26.1 \text{ mH} > 300 \mu\text{H} \rightarrow 1.2 \%$

Both inductance and capacitance are below 50 % of permitted values. No further assessment is necessary.

A.2.5 Shunt short-circuit (crowbar) spark ignition

N/A

A.2.6 Other spark ignition considerations

N/A

A.3 Thermal ignition consideration

Maximum nominal voltage from the battery pack, U : 3.6 V

Maximum open circuit voltage: 4.2 V

Maximum voltage from the buzzer circuit, U : 5.8 V. (As the charge pump does not have 100% efficiency this is not considered.)

Maximum ambient temperature, $T_a = +60^\circ\text{C}$ is equal to a maximum service temperature.

A.3.1 Temperature for small components for Group I and Group II

Charging circuit:

The power to the charging circuit is limited by the resistors RS4, RS5, RS6, RS7 and RS8 in parallel.

$R = 470 \Omega \times 0.99 \parallel 470 \Omega \times 0.99 \parallel 10 \text{ k}\Omega \times 0.995 \parallel 10 \text{ k}\Omega \times 0.995 \parallel 10 \text{ k}\Omega \times 0.995 = 217.4 \Omega$

Voltage from battery is, U : 3.6 V

Maximum power, $P = (3.6 \text{ V}^2 / 217.4 \Omega) / 4 = 14.9 \text{ mW}$

For components $>20 \text{ mm}^2$: $14.9 \text{ mW} < 1.2 \text{ W} \rightarrow \text{T4}$

For components $<20 \text{ mm}^2$: $R_{th} = (275^\circ\text{C} - 60^\circ\text{C}) / 14.9 \text{ mW} = 14429 \text{ K/W} \rightarrow \text{Actual } R_{th} \text{ for a component is much less than } 14429 \text{ K/W} \rightarrow \text{T4}$

Battery circuit/pack:

Voltage from battery is, U : 3.6 V

Minimum resistance to limit the current is, $R = R1 = 330 \Omega \times 0.99 = 326.7 \Omega$

Maximum power, $P = (3.6 \text{ V}^2 / 326.7 \Omega) / 4 = 10.0 \text{ mW}$.

Voltage between P+ and Th is, U : 3.6 V

Minimum resistance to limit the current is, $R = R4 = 150 \Omega \times 0.99 = 148.5 \Omega$

Maximum power, $P = (3.6 \text{ V}^2 / 148.5 \Omega) / 4 = 21.9 \text{ mW}$.

For components $>20 \text{ mm}^2$: $21.9 \text{ mW} < 1.2 \text{ W} \rightarrow \text{T4}$

For components $<20 \text{ mm}^2$: $R_{th} = (275^\circ\text{C} - 60^\circ\text{C}) / 21.9 \text{ mW} = 9818 \text{ K/W} \rightarrow \text{Actual } R_{th} \text{ for a component is much less than } 9818 \text{ K/W} \rightarrow \text{T4}$

P + is limited by the resistors connected to the other circuits.

Buzzer circuit:

Voltage to buzzer circuit from battery, $U = 3.6 \text{ V}$

Minimum resistance between buzzer circuit and battery, $R = RS11 + RS12 = 8.2 \Omega \times 0.99 \times 2 = 16.2 \Omega$

Maximum power to buzzer from battery, $P = (3.6 \text{ V}^2 / 16.2 \Omega) / 4 = 200 \text{ mW}$

Maximum power from buzzer circuit to main circuit, $P = (3.6 \text{ V}^2 / (16.2 \Omega + 495 \Omega)) / 4 = 6.4 \text{ mW}$

or

Maximum power from main circuit to buzzer circuit, $P = (3.6 \text{ V}^2 / 495 \Omega) / 4 = 6.6 \text{ mW}$

Total power to the buzzer circuit will be power from battery + power from main circuit = $200 \text{ mW} + 6.6 \text{ mW} = 206.6 \text{ mW}$

For components $>20 \text{ mm}^2$: $206.6 \text{ mW} < 1.2 \text{ W} \rightarrow \text{T4}$

For components $<20 \text{ mm}^2$: $R_{th} = (275^\circ\text{C} - 60^\circ\text{C}) / 206.6 \text{ mW} = 1041 \text{ K/W}$. R_{th} for R62 (0603) is 350 K/W . $350 \text{ K/W} < 1041 \text{ K/W} \rightarrow \text{T4}$

Pump circuit:

Voltage to pump circuit from battery, $U = 3.6 \text{ V}$

Minimum resistance between pump circuit and battery is RS51, RS52, RS53, RS54 and RS55 in series ($R = 1.5 \Omega \times 0.99 \times 5 = 7.4 \Omega$). In addition current from the main circuit through the parallel coupled resistors RP1, RP2 and RP3 ($R = (10 \text{ k}\Omega \times 0.995) / 3 = 3316 \Omega$).

$R_p = 7.4 \Omega \parallel 3316 \Omega = 7.38 \Omega$

Maximum power to the pump circuit, $P = (3.6V^2 / 7.38 \Omega) / 4 = 439.1 \text{ mW}$

For components $>20\text{mm}^2$: $439.1 \text{ mW} < 1.2 \text{ W} \rightarrow T4$

For components $<20\text{mm}^2$: $R_{th} = (275^\circ\text{C} - 60^\circ\text{C}) / 439.1 \text{ mW} = 490 \text{ K/W}$. R_{th} for Q6 (1.6 mm x 1.6 mm > 0603) is approx. $350 \text{ K/W} \rightarrow 350 \text{ K/W} < 490 \text{ K/W} \rightarrow T4$

Motor circuit:

Voltage to motor circuit from battery, $U = 3.6 \text{ V}$

Minimum resistance from battery and main circuit is, $R = RS61 \text{ II RV1} = 36 \Omega \times 0.99 \text{ II } 10 \text{ k}\Omega \times 0.995 = 35.51 \Omega$.

Maximum power, $P = (3.6V^2 / 35.51\Omega) / 4 = 91.3 \text{ mW}$

(Power from main circuit and RV1 (10 k Ω) is negligible.)

For components $>20\text{mm}^2$: $91.3 \text{ mW} < 1.2 \text{ W} \rightarrow T4$

For components $<20\text{mm}^2$: $R_{th} = (275^\circ\text{C} - 60^\circ\text{C}) / 91.3 \text{ mW} = 2354 \text{ K/W}$. R_{th} for Q6 (1.6mm x 1.6mm > 0603) is approx. 350 K/W . $\rightarrow 350 \text{ K/W} < 2354 \text{ K/W} \rightarrow \text{Actual } R_{th} \text{ for a component is much less than } 2354 \text{ K/W} \rightarrow T4$

Main circuit:

Voltage to main circuit from battery, $U = 3.6 \text{ V}$

Minimum resistance, $R = 4.35 \Omega$

Maximum power, $P = (3.6V^2 / 4.35 \Omega) / 4 = 744.9 \text{ mW}$

In addition power from the buzzer circuit, $P = 6.4 \text{ mW}$

(Power from pump and motor circuits are negligible.)

Total power, $P = 744.9 \text{ mW} + 6.4 \text{ mW} = 751.3 \text{ mW}$

For components $>20\text{mm}^2$: $751.3 \text{ mW} < 1.2 \text{ W} \rightarrow T4$

For components $<20\text{mm}^2$: $R_{th} = (275^\circ\text{C} - 60^\circ\text{C}) / 751.3 \text{ mW} = 286 \text{ K/W}$. Components in size 1206, 0805 and SOT-23 have R_{th} less than $286 \text{ K/W} \rightarrow T4$

R21, R22, R23, R24, R25, R26, R31, R32, R33, R34, R35, R36, R51, R52, R53, R54, R55, R56, R71, R72, R73, R74, R75, R76, R77, R78, R79, R80, R81, R82, R83, R84, R85, R86, R87, R88, R89, R90, R91, R92, R93, R94, R95, R96, R101, R102, R103, R104, R106, R107, R108, R109, R111, R112, R121, R122, R123, R124, R125, R126, R127, R128, R129, R130, R131, R132, R141, R142, R143, R144, R145, R151, R152, R153, R154, R155, R156, R157, R158, R159, R160, R161, R162, R163, R164, R165, R166, R167, R168, R169, R170, R171, R172, R173, R174, R175, R176, R178, R181, R182, R183, R184, R185, R186, R191, R192, R193, R194, R195, R196, R201, R202, R203, R204, R206, R211, R212, R213, R214, R215, R216, R217, R220, R221, R222, R223, R224, R225, R226, R227, R231, R232, R233, R234: 1608 /0603. See appendix B.6 for test details $\rightarrow T4$

PS1: Pressure sensor. The measuring bridge resistors are $>10 \text{ k}\Omega$ each.

D5, D6, D7, D8, D9, D10, D11: Schottky diode, VR 30 V, VF 0.37 V, 0.8 mm x 1.2 mm. Maximum power, $P = 0.37 \text{ V} \times (3.6 \text{ V} / 4.35 \Omega) = 307 \text{ mW}$. Package size is between 0402 and 0603, $R_{th} \approx 600 \text{ K/W}$. $T = 60^\circ\text{C} + 600 \text{ K/W} \times 307 \text{ mW} = 245^\circ\text{C} \rightarrow T4$

Q3: 1.6 mm x 1.6 mm is larger than a 0603 component, so the test in appendix B.6 will be representative.

Q4: 2 mm x 2 mm, this component is larger than a 0805 component, and will have a R_{th} less than 250 K/W .

Q8, Q9, Q10, Q11, Q14, Q15, Q16: 2 mm x 2.1 mm, this component is larger than a 0805 component, and will have a R_{th} less than 250 K/W .

Q13: 2 mm x 2 mm, this component is larger than a 0805 component, and will have a R_{th} less than 250 K/W .

IC3, IC6, IC7, IC9, IC11: SOT-23

IC5: 2.9 mm x 1.6 mm, this component is larger than a 0805 component, and will have a R_{th} less than 250 K/W .

IC10: 3.1 mm x 3.1 mm, this component is larger than a 0805 component, and will have a R_{th} less than 250 K/W .

IC12: $>20 \text{ mm}^2$

IC13: 3.9 mm x 5.05 mm (footprint) $> 20 \text{ mm}^2$ surface area.

IC14: 3.81 mm x 4.8 mm (footprint) $> 20 \text{ mm}^2$ surface area.

IC15: $27 \text{ mm}^2 > 20 \text{ mm}^2$

IC16: Hybrid circuit, including 0201 inductors. See appendix B.7 for temperature measurement test.

IC17: 5 mm x 5 mm (footprint) $> 20 \text{ mm}^2$ surface area.

IC18, IC22: larger than a SOT-23 package component, and will have a R_{th} less than 250 K/W .

IC19, IC20: 3 mm x 3 mm (footprint) $> 20 \text{ mm}^2$ surface area.

IC21: 2 mm x 2 mm, this component is larger than a 0805 component, and will have a R_{th} less than 250 K/W .

NF21, NF22, NF23, NF31, NF32, NF33, NF41: 0402, beads, jumper or resistors: Maximum supply to

main circuit is 751.3 mW and 3.6 V. For beads DC resistance is 2.2 Ω and current rating is 200mA@125 °C.

The component is already tested in RIKEN KEIKI project NO/PRE/ExTR15.0012/00, results are copied in this project. The surface temperature of the small components < 20 mm² measured while dissipating 1.137 W. This resulted in a maximum temperature rise is 204 °C (SENSOR_PCB NF3_BLM15HD182 - 0402). At

ambient temperature of 60 °C the maximum surface temperature would hence be 264 °C which is below the 275 °C limit. Also 0402 resistor is tested in the same project @807 mW → ΔT 105.9 K.

TH1: 1608 = 0603 component, so the test in appendix B.6 will be representative.

A.3.2 Wiring within intrinsically safe apparatus for Group I and Group II

Maximum power to the different circuits:

Buzzer circuit: 206.6 mW

Pump circuit: 439.1 mW

Motor circuit: 91.3 mW

Main circuit: 751.3 mW

Maximum ambient temperature: +60 °C.

According to NOTE 5 of Table 2: When the maximum power does not exceed 1.2 W (ref. Table 4 of IEC 60079-0) the wiring can be assigned a temperature classification of T4.

Wiring from battery to pcb is AWG 22 = 0.34 mm². According to table 2, a current of 7.7 A is permitted @+40°C with a cross-sectional area of 0.196 mm². Maximum current to all circuits added together is 978 mA + 12.9 mA + 28.3 mA + 260 mA + 569 mA + 119 mA = 1.97 A. 7.7 A > 1.97 A

Wiring to pump from pcb is AWG 28 = 0.08 mm². According to table 2, a current of 3.7 A is permitted @+40°C with a cross-sectional area of 0.0314 mm². Maximum current to the pump is, $I = 3.6 \text{ V} / 7.38 \Omega = 488 \text{ mA}$.

488 mA < 3.7 A and 0.08 mm² > 0.0314 mm²

A.3.3 Tracks on printed circuit boards for Group I and Group II

Maximum power to the different circuits:

Buzzer circuit: 206.6 mW

Pump circuit: 439.1 mW

Motor circuit: 91.3 mW

Main circuit: 751.3 mW

Maximum ambient temperature: +60 °C.

According to clause 5.6.4: When the maximum power does not exceed 1.2 W (ref. Table 4 of IEC 60079-0) the wiring can be assigned a temperature classification of T4.

The current from the battery will be reduced by the current limiting resistors, and the track width is 1 mm → $5.9 \text{ A} / 2 / 1.2 = 2.45 \text{ A}$ permitted current → $2.45 \text{ A} > 1.97 \text{ A}$ (see calculation in A.3.2 above).

A.3.4 Intrinsically safe apparatus and component temperature for Group III

Not group III equipment.

A.4 Rating of components

A.4.1 Resistors

Um when charging: 6.0 V

Charging circuit:

RS2, RS3: 30 Ω , 1%, 2W, 200 V → $P = (6V^2 / (30 \Omega \times 0.99)) \times 1.5 = 1.82 \text{ W} \rightarrow 2 \text{ W} > 1.82 \text{ W}$

RS4, RS5: 470 Ω , 1%, 0.5 W, 200 V → $P = (6V^2 / (470 \Omega \times 0.99)) \times 1.5 = 116 \text{ mW} \rightarrow 0.5 \text{ W} > 116 \text{ mW}$

RS6, RS7, RS8: 10 k Ω , 0.5%, 0.5 W, 200 V → $P = (6V^2 / (10 \text{ k}\Omega \times 0.995)) \times 1.5 = 6 \text{ mW} \rightarrow 0.5 \text{ W} > 6 \text{ mW}$

Buzzer circuit:

RS11, RS12: 8.2 Ω , 1%, 2 W, 200 V → These two resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0.43 V) maximum voltage will be, $V = (6 \text{ V} - 0.43 \text{ V}) / 2 = 2.79 \text{ V}$ over each resistor. $P = (2.79 \text{ V}^2 / (8.2 \Omega \times 0.99)) \times 1.5 = 1.44 \text{ W} \rightarrow 2 \text{ W} > 1.44 \text{ W}$

RB1, RB2: 1 k Ω , 0.5%, 0.5 W, 200 V → $P = (6V^2 / (1 \text{ k}\Omega \times 0.995)) \times 1.5 = 55 \text{ mW} \rightarrow 0.5 \text{ W} > 55 \text{ mW}$

RB3, RB4: 1.5 k Ω , 1%, 0.75 W, 200 V → $P = (4.8 \text{ V}^2 / (1.5 \text{ k}\Omega \times 0.99)) \times 1.5 = 8 \text{ mW} \rightarrow 0.75 \text{ W} > 8 \text{ mW}$

Pump circuit:

RS51, RS52, RS53, RS54, RS55: 1.5 Ω , 1%, 2 W, 200V → These five resistors are connected in series.

Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0.43 V) maximum voltage will be, $V = (6 \text{ V} - 0.43 \text{ V}) / 5 = 1.12 \text{ V}$ over each resistor. $P = (1.12 \text{ V}^2 / (1.5 \Omega \times 0.99)) \times 1.5 = 1.27 \text{ W} \rightarrow 2 \text{ W} > 1.27 \text{ W}$

RP1, RP2, RP3: 10 k Ω , 0.5 %, 0.5 W, 200 V $\rightarrow P = (6V^2 / (10 \text{ k}\Omega \times 0.995)) \times 1.5 = 6 \text{ mW} \rightarrow 0.5 \text{ W} > 6 \text{ mW}$

Motor circuit:

RS61: 36 Ω , 1%, 2 W, 200 V \rightarrow Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0.43 V) maximum voltage will be, $V = 6 \text{ V} - 0.43 \text{ V} = 5.57 \text{ V}$ over the resistor. $P = (5.57V^2 / (36 \Omega \times 0.99)) \times 1.5 = 1.31 \text{ W} \rightarrow 2 \text{ W} > 1.31 \text{ W}$

RV1: 10 k Ω , 0.5 %, 0.5 W, 200 V $\rightarrow P = (6V^2 / (10 \text{ k}\Omega \times 0.995)) \times 1.5 = 6 \text{ mW} \rightarrow 0.5 \text{ W} > 6 \text{ mW}$

Main circuit:

RS21: 100 k Ω , 1%, 0.5 W, 200 V \rightarrow This resistor is connected in series with the serial coupled diodes, D1, D2 and D3 (with a VF of 0.43 V) maximum voltage will be, $V = 6 \text{ V} - 0.43 \text{ V} = 5.57 \text{ V}$ over resistor. $P = (5.57V^2 / (100 \text{ k}\Omega \times 0.99)) \times 1.5 = 0.47 \text{ mW} \rightarrow 0.5 \text{ W} > 0.47 \text{ mW}$

RS31, RS32, RS33, RS34: 2.2 Ω , 1%, 2 W, 200 V \rightarrow These four resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0.43 V) maximum voltage will be, $V = (6 \text{ V} - 0.43 \text{ V}) / 4 = 1.40 \text{ V}$ over each resistor. $P = (1.40V^2 / (2.2 \Omega \times 0.99)) \times 1.5 = 1.35 \text{ W} \rightarrow 2 \text{ W} > 1.35 \text{ W}$

RS41, RS42, RS43, RS44, RS45: 1.8 Ω , 1%, 2 W, 200 V \rightarrow These five resistors are connected in series. Due to the serial coupled diodes, D1, D2 and D3 (with a VF of 0.43 V) maximum voltage will be, $V = (6 \text{ V} - 0.43 \text{ V}) / 5 = 1.12 \text{ V}$ over each resistor. $P = (1.12V^2 / (1.8 \Omega \times 0.99)) \times 1.5 = 1.06 \text{ W} \rightarrow 2 \text{ W} > 1.06 \text{ W}$

R105 (in series with capacitor C79): 150 Ω , 1%, 0.5 W, 200 V $\rightarrow P = (6V^2 / (150 \Omega \times 0.99)) \times 1.5 = 364 \text{ mW} \rightarrow 0.5 \text{ W} > 364 \text{ mW}$

Battery circuit:

R1: 330 Ω , 1%, 0.5 W, 200 V $\rightarrow P = (6V^2 / (330 \Omega \times 0.99)) \times 1.5 = 166 \text{ mW} \rightarrow 0.5 \text{ W} > 166 \text{ mW}$

R4: 150 Ω , 1%, 0.5 W, 200 V $\rightarrow P = (6V^2 / (150 \Omega \times 0.99)) \times 1.5 = 364 \text{ mW} \rightarrow 0.5 \text{ W} > 364 \text{ mW}$

A.4.2 Shunt voltage limiters

Zener diodes are used in the buzzer circuit to clamp the voltage to a maximum of 4.8 V (two and two parallel coupled).

P/N	Symbol						
	Zener Voltage $V_Z(V)$		Dynamic Impedance $Z_{dZ}(\Omega)$		Reverse Current $I_{RZ}(\mu A)$		
	MIN.	MAX.	$I_Z(mA)$	MAX.	$I_Z(mA)$	MAX.	$V_R(V)$
TFZV 2.0B	2.020	2.200	20	140	20	120	0.5
TFZV 2.2B	2.220	2.410	20	120	20	120	0.7
TFZV 2.4B	2.430	2.630	20	100	20	120	1.0
TFZV 2.7B	2.660	2.910	20	100	20	100	1.0
TFZV 3.0B	3.010	3.220	20	80	20	50	1.0
TFZV 3.3B	3.320	3.530	20	70	20	20	1.0
TFZV 3.6B	3.600	3.845	20	60	20	10	1.0
TFZV 3.9B	3.890	4.160	20	50	20	5	1.0
TFZV 4.3B	4.170	4.430	20	40	20	5	1.0
TFZV 4.7B	4.550	4.800	20	25	20	5	1.0
TFZV 5.1B	4.930	5.190	20	20	20	5	1.0

They are rated 0.5 W. The current to the zener diodes are limited by safety resistors RB1 II RB3 for ZD3 II ZD4 and RB2 II RB4 for ZD1 II ZD2. 1.5 safety factor is applied.

ZD1, ZD2, ZD3, ZD4: 4.8 V, 0.5 W $\rightarrow P = ((6V / (1 \text{ k}\Omega \times 0.995 \text{ II } 1.5 \text{ k}\Omega \times 0.99)) \times U_Z) \times 1.5 = (6 \text{ V} / 595.7 \Omega) \times 4.8 \text{ V} \times 1.5 = 73 \text{ mW} \rightarrow 0.5 \text{ W} \times 0.71 \text{ (considering derating at } 60^\circ\text{C)} = 355 \text{ mW} > 73 \text{ mW}$. Due to the large safety factor ($SF = 355 \text{ mW} / 73 \text{ mW} = 4.8$) rating test is considered not to be necessary.

A.4.3 Series current limiter (semiconductor based)

D1, D2, D3 are diodes connected in series. Maximum current in lead direction is secured by the fuse F1. 1.5 safety factor is applied.

If diodes = 3 A

V_r diodes = 20 V

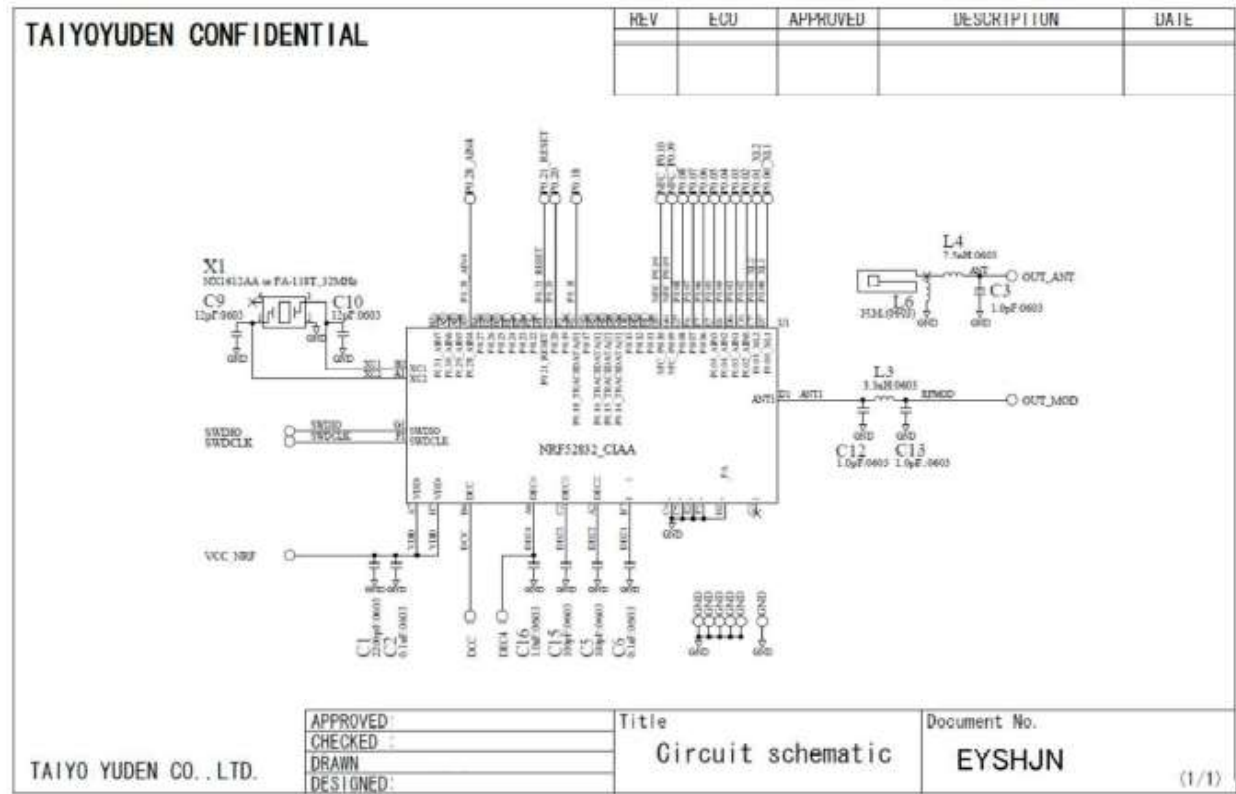
Ifuse = 0.75 A $\times 1.7 = 1.275 \text{ A}$

Maximum voltage in circuit = 12.6 V

3 A $> 1.275 \text{ A} \times 1.5 = 1.92 \text{ A}$

20 V $> 12.6 \text{ V} \times 1.5 = 18.9 \text{ V}$

A.4.4 IC16
IC16 (hybrid circuit) circuit diagram and bom:



Parts No.	Description	Parts name and standard	Supplier	Remark
C1	CAPACITOR	LMK063 BJ222 KP-F or Equivalent	TAIYO YUDEN or other supplier	
C2 C6	CAPACITOR	JMK063 BJ104 KP-F or Equivalent	TAIYO YUDEN or other supplier	
C3 C12 C13	CAPACITOR	GRM0334C1E or Equivalent	MURATA or other supplier	
C5 C15	CAPACITOR	UMK063 CH101JI-F or Equivalent	TAIYO YUDEN or other supplier	
C9 C10	CAPACITOR	TMK063 CH120 JP-F or Equivalent	TAIYO YUDEN or other supplier	
C16	CAPACITOR	JMK063ABJ105MP-F or Equivalent	TAIYO YUDEN or other supplier	
L3	INDUCTOR	HK 0603 or Equivalent	TAIYO YUDEN or other supplier	
L4	INDUCTOR	HK 0603 or Equivalent	TAIYO YUDEN or other supplier	
X1	CRYSTAL	FCX-07L (32MHz) or Equivalent	RIVER ELETEC or other supplier	
U1	IC	nRF52832	NORDIC	
PCB1	PCB	PB-150197	MEIKO	
CASE1	CASE	GTC097-KFT	KOBAYASHI SPRING	

A.5 Infallible Connections, wires and PCB tracks

The connections have been measured on sample and verified to comply with clause 6.5 and 8.8 of IEC 60079-11. For more details see Appendix B.3 and 4.

A.6 Separation distances

The separation distances were measured on the sample. For more details see Appendix B.1.

APPENDIX B: Tests

B.1 Separation distances (creepage and clearance)

Equipment Tested:	Layout of circuit board
Date of Test (yyyy/mm/dd):	2022/02/03 and 2022/02/28
Clause and Standards:	6.3.4 and 6.3.8 of IEC 60079-11: 2011

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

B.1.1 Test procedures

Separation distances are measured by the use of microscope and micrometers on circuit board.



B.1.2 Results

Creepage and clearance separation distances

Designation	Distance [mm]	Requirement [mm]		Designation	Distance [mm]	Requirement [mm]
Charging circuit:				RV1	2,2	≥1,5
RS2	1,8	≥1,5		Main circuit:		
RS3	1,8	≥1,5		RS21	2,2	≥1,5
RS4	2,4	≥1,5		RS31	1,8	≥1,5
RS5	2,5	≥1,5		RS32	1,8	≥1,5
RS6	2,4	≥1,5		RS33	1,8	≥1,5
RS7	2,4	≥1,5		RS34	1,8	≥1,5
RS8	2,4	≥1,5		RS41	1,7	≥1,5
D1	1,5	≥1,5		RS42	1,7	≥1,5
D2	1,5	≥1,5		RS43	1,7	≥1,5
D3	1,5	≥1,5		RS44	1,7	≥1,5
Buzzer circuit:				RS45	1,8	≥1,5
RS11	1,9	≥1,5		R105	2,0	≥1,5
RS12	2,7	≥1,5		Battery/protect circuit:		
RB1	2,1	≥1,5		R1	2,0	≥1,5
RB2	2,2	≥1,5		R4	2,0	≥1,5
RB3	2,4	≥2				

RB4	2,2	≥ 2				
Pump circuit:						
RS51	3,1	$\geq 1,5$				
RS52	2,0	$\geq 1,5$				
RS53	1,8	$\geq 1,5$				
RS54	1,8	$\geq 1,5$				
RS55	1,9	$\geq 1,5$				
Motor circuit:						
RS61	1,7	$\geq 1,5$				

Separation distances between tracks and components [mm]. Requirements mm:

Battery/protect circuit:

- Between R4 and RT1: 2.0

Charger circuit:

- Between D2 and RS42: 1.6

Buzzer circuit:

- Between RS11 and R22: 2.1

Pump circuit:

- Between RS54 and RS55: 1.5

Main circuit:

- Between RS31 and RS34: 1.6
- Between RS42 and RS43: 1.5
- Between RS43 and R16: 1.6

B.2 Piezo-electric device (buzzer)

Equipment Tested:	BZ1
Date of Test (yyyy/mm/dd):	2022/02/03
Clause and Standards:	7.7 and 10.7 of IEC 60079-11: 2011

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

B.2.1 Test procedures

The piezoelectric device (BZ1) was isolated from the other components in the circuit (IC4 was removed). Wires were soldered to the + and - soldering pads on the pcb.

2 resistance to impact tests were performed on the surface of the enclosure. The impacts hit as close as possible to BZ1. Maximum voltage was measured by the use of a oscilloscope.

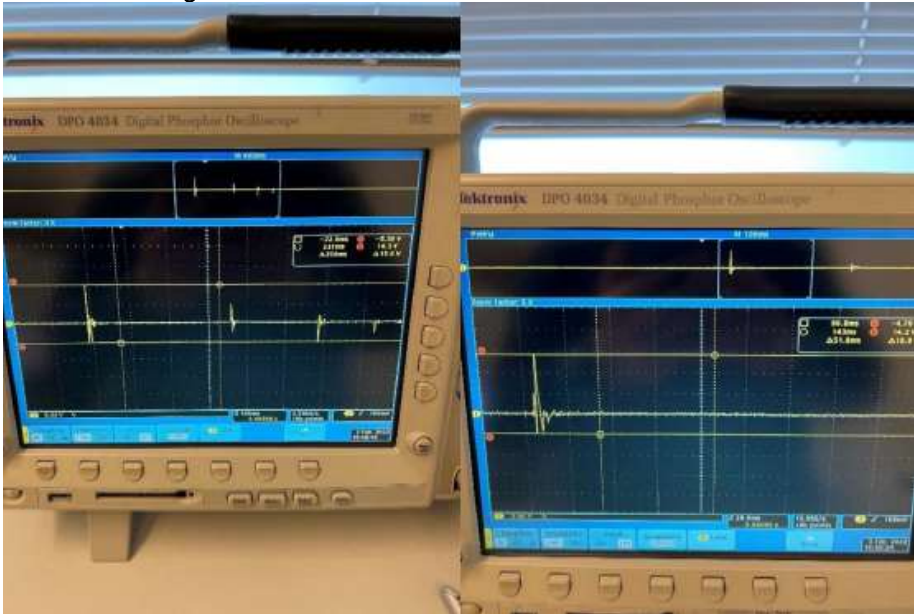
**B.2.2 Results**

Measured capacitance: 34.37 nF

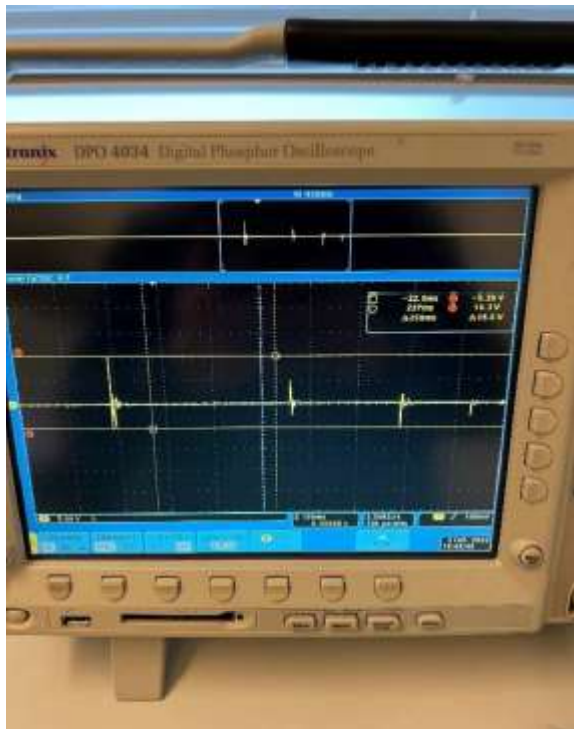
Claimed maximum capacitance in bom: 42.9 nF



Test 1:
Maximum voltage: 18.9 V



Test 2:
Maximum voltage: 15.6 V



Result:

$$E = 0.5 \times 42.9 \text{ nF} \times 18.9 \text{ V}^2 = 7.67 \text{ } \mu\text{J}$$

$7.67 \text{ } \mu\text{J} < 50 \text{ } \mu\text{J} \rightarrow \text{IIC}$

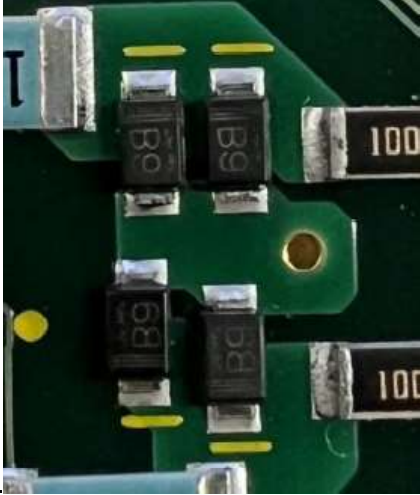
B.3 Measurement of infallible tracks

Equipment Tested:	Safety shunt assembly tracks, ZD1-ZD4
Date of Test (yyyy/mm/dd):	2022/06/21
Clause and Standards:	8.8 b2) of IEC 60079-11: 2011

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

B.3.1 Test procedures

Track is measured on the most narrow by the use of a microscope and



micrometer.

B.3.2 Results

Minimum = 2.2 mm
Requirement: ≥ 2 mm

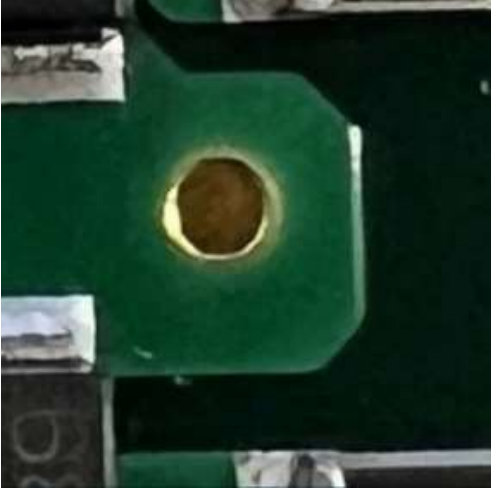
B.4 Measurement of infallible vias

Equipment Tested:	Safety shunt assembly vias, ZD1-ZD4 anodes to GND
Date of Test (yyyy/mm/dd):	2022/06/21
Clause and Standards:	8.8.b.3 of IEC 60079-11: 2011

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

B.4.1 Test procedures

Internal diameter is measured on the most narrow by the use of a microscope and micrometer.



B.4.2 Results

Internal diameter = 0.7 mm
 Circumference = $3.14 \times 0.7 \text{ mm} \approx 2.2 \text{ mm}$
 Requirement: $\geq 2 \text{ mm}$

B.5 Battery testing

Equipment Tested:	Panasonic NCR18650GA (single cell)
Date of Test (yyyy/mm/dd):	Date of issue for ExTR: 2020/03/30
Clause and Standards:	10.5 of IEC 60079-11: 2011

Note: This test was performed for NO/PRE/ExTR20.0043/00 and documented as part of NO/DNV/ExTR21.0088/00.

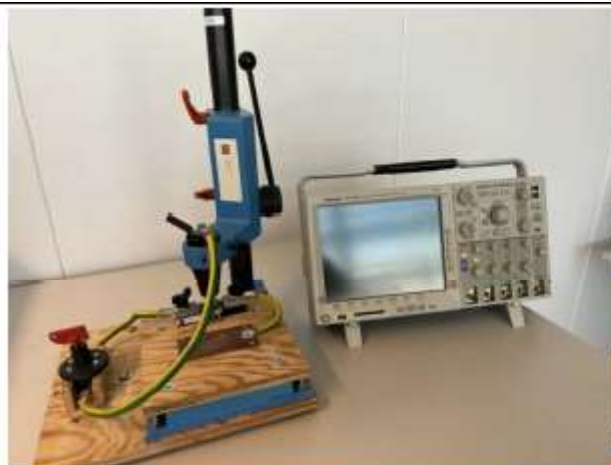
B.5.1 Test procedures

Tested according to 10.5.3.a and 10.5.3.b and 10.5.2. Test results are copied from IECEx TR NO/PRE/ExTR20.0043/00.

B.5.2 Results

Panasonic NCR18650GA:
 Spark ignition testing, clause 10.5.3. a:

No.	Open circuit voltage [V]	Resistance of short circuit link [mΩ]	Measured voltage over short circuit link [mV]	Short circuit current ($I = U / R$) [A]	Internal resistance ($R = U / I$) [mΩ]
1	4,139	2	300	150	28
2	4,127	2	324	162	25
3	4,127	2	320	160	26
4	4,128	2	334	167	25
5	4,139	2	328	164	25
6	4,137	2	340	170	24
7	4,138	2	320	160	26
8	4,126	2	324	162	25
9	4,143	2	322	161	26
10	4,132	2	324	162	25



Overview.



The cell is placed between the contact points.



Probe for oscilloscope measures voltage drop over shunt resistor. Short circuit current is then calculated ($I = U / R$).



Calibrated shunt resistor of 2mΩ.

Surface temperature testing, clause 10.5.3.b (single cell):

No.	Ambient temperature [°C]	Measured temperature [°C]	Delta temperature [K]	Max. ambient temperature [°C]	Temperature class
1	60	89	29	60	T5
2	60	103	43	60	T4
3	60	96	36	60	T5
4	60	89	29	60	T5
5	60	87	27	60	T5
6	60	91	31	60	T5
7	60	93	33	60	T5
8	60	90	30	60	T5
9	60	85	25	60	T5
10	60	89	29	60	T5

NOTE: the temperature tests are done without an enclosure upon customer request. Due to the large safety margin (32 K) T4 is accepted.

A thermal camera is used to find the hottest point on the cell, so the thermal couple can be placed at the correct area. The thermal couple is fixed to the cell and temperature rise is measured by temperature meter.



Note: the temperature rise is measured by thermal couple and not the thermal camera.

Electrolyte leakage testing, clause 10.5.2:

The ten test cells are placed over a piece of blotting paper.

Test duration ≥ 12 h.



Results:

Maximum short circuit current (if required): 170 A

Minimum internal resistance: 24 m Ω

Maximum temperature rise: 43 K

Visible sign of electrolyte on the blotting paper or on the external surfaces of the test samples: No

Comments:

Discharged with 2.5 A, and a cut off voltage of 2.5 V.

Rated capacity: 3300 mAh

B.6 Temperature test of 0603 component

Equipment Tested:	R73 (0603 - 33 Ω)
Date of Test (yyyy/mm/dd):	2022/03/09
Clause and Standards:	10.2 of IEC 60079-11: 2011

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

B.6.1 Test procedures

Component tested: R73 (33 Ω). The component was isolated so all current supplied to it will float through this specific component. Connection wires were attached to CN6 and CN8 on the opposite site. Tracks had to be cut to isolate the component.

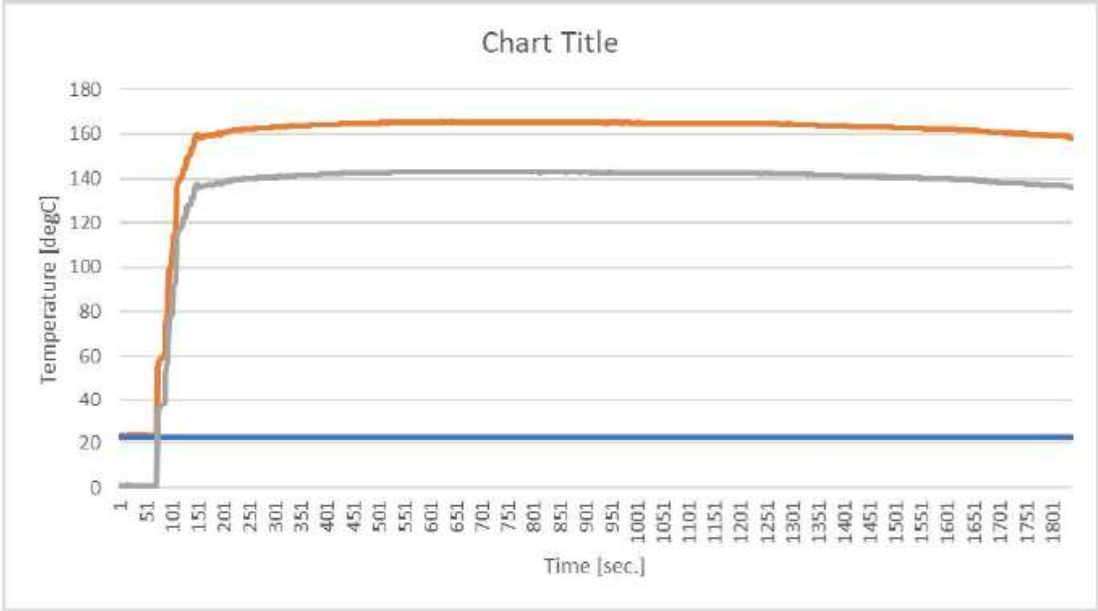
R73 was chosen to be tested as it has less cooling area connected to the soldering pads (very thin tracks).

Thermocouple attached to the component had a diameter of 0.08 mm.



B.6.2 Results

Power dissipated of R73, P = 825 mW
Ta: 22.3 °C
Tmeasured = 165.6 °C
ΔT = 143.3 K
143.3 K + 60 °C = 203.3 °C
203.3 °C < 275 °C → T4



B.7 Temperature test of L4 (part of IC16 / BLE module)

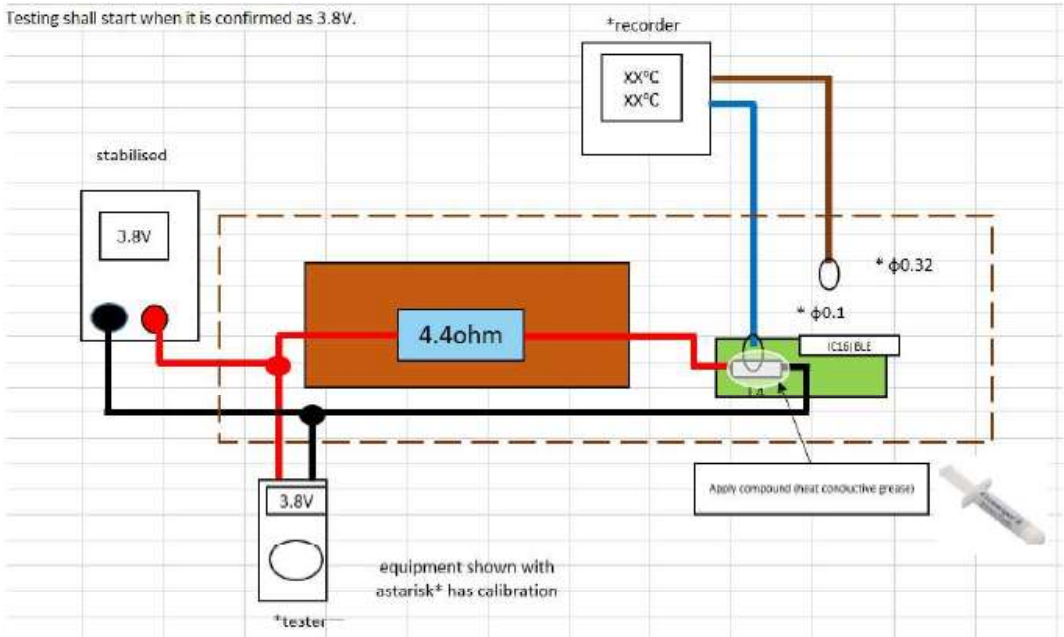
Equipment Tested:	L4 (inductor) as a part of the hybrid component IC16
Date of Test (yyyy/mm/dd):	2022/05/19
Clause and Standards:	10.2 of IEC 60079-11: 2011

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

B.7.1 Test procedures

According to clause 7.6.h of IEC 60079-11: 2011 the resistance of an inductor at failure shall be between nominal value (0.34 Ω) and 0.
The inductor L4 was isolated on the circuit board.

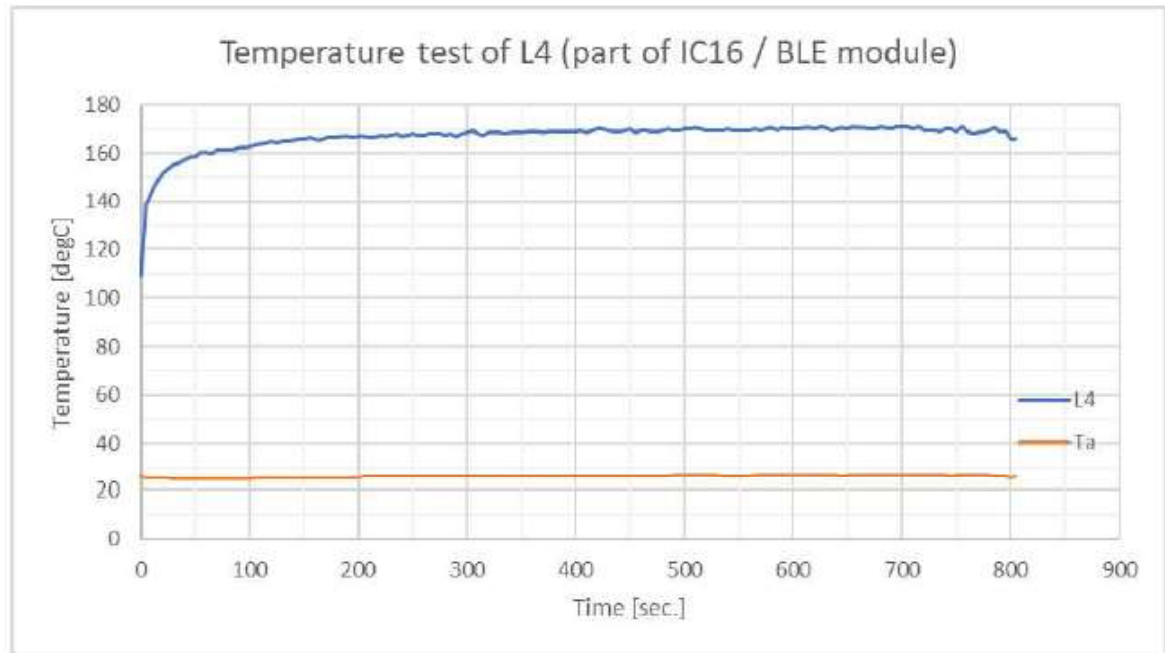
Testing shall start when it is confirmed as 3.8V.



$R = 4.37 \, \Omega$ $U = 3.8 \, V$

B.7.2 Results

$T_{\text{measured}} = 171 \, ^\circ\text{C}$ $T_{\text{a-max}} = 60 \, ^\circ\text{C}$ $T_{\text{a}} = 26 \, ^\circ\text{C}$ $\Delta T = 145 \, \text{K}$
 $T_{\text{max}} = 145 \, \text{K} + 60 \, ^\circ\text{C} = 205 \, ^\circ\text{C}$
 $205 \, ^\circ\text{C} < 275 \, ^\circ\text{C} \rightarrow T_4$





ATEX ASSESSMENT REPORT IECEX TEST REPORT of NATIONAL DIFFERENCES



ExTR Reference Number: See Report No. above.
 ATEX Assessment Report Number: See Report No. above.
 ExTR Free Reference Number: See report cover.
 Compiled by + signature (ExTL): A. Hadak
 Reviewed by + signature (ExTL).....: B.P.O. Meijer (Ex i part)
 H.J.G. de Wild (Ex d part)
 Date of issue (yyyy-mm-dd).....: 2024-04-15

A. Hadak

[Signature]
[Signature]

Ex Testing Laboratory (ExTL).....: DEKRA Certification B.V.
 Address: Meander 1051, 6825 MJ Arnhem, the Netherlands

Applicant's name.....: See report cover.
 Address: See report cover.

Country/Region.....: The European Union
 Directive.....: ATEX directive 2014/34/EU
 Standards: EN IEC 60079-0 : 2018
 EN 60079-1 : 2014
 EN 60079-11 : 2012

Related reports: NL/DEK/ExTR17.0047/01

Test procedure.....: IECEX System

Test Report Form Number.....: Form 255, based on IECEX form released 2018-03.

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Possible test case verdicts:


- test case does not apply to the test item.....: N/A
- test item does meet the requirement: Pass

General remarks:

The test results presented in this ExTR of National Differences relate only to the item or product tested. Only clauses and manufacturer's documents impacted by this document are detailed.

- "(see Attachment #)" refers to additional information appended to this document.
- "(see appended table)" refers to a table appended to this document.
- Throughout this document, a point is used as the decimal separator.

The technical content of this ExTR of National Differences shall not be reproduced except in full without the written approval of the Issuing ExCB and ExTL.

Clause	Requirement – Test	Result – Remark	Verdict
ATEX directive 2014/34/EU			
1.0.5	Marking		
	Name, registered trade name, or registered trade mark and address of the manufacturer	Name and address of the manufacturer are on the marking.	Pass
	CE marking	CE mark applied.	Pass
	Identification number of the Notified body monitoring the production	Marked: XXXX. This is a placeholder for the identification number of the Notified Body. Marking of the applicable number is a manufacturers responsibility. Verification is not required at the product assessment.	Pass
	the year of construction	Year of construction is marked and explained in safety instructions.	Pass
	The ATEX certificate number	DEKRA 24ATEX0018X is marked	Pass
	 marking, followed by equipment group I or II and category M 1, M 2, 1, 2, or 3.	Ex marked, followed by: II 1.	Pass
	the letter “G” and/or “D”	Marked: G	Pass
1.0.6	Instructions		
	Instructions are written in one of the community languages	Instructions are in English.	Pass
EN IEC 60079-0 : 2018 based on IEC 60079-0 : 2017 (Ed. 7.0) + C1 : 2020 + IS1 : 2019			
ZY.2 30.1	Instructions	Requirements on the language are covered per ATEX directive 2014/34/EU as detailed above. The instructions include information for safety at installation and erection, other than the general requirements given in EN 60079-14 and EN 50628 (mines).	Pass
ZY.3	Marking	Requirements are covered per ATEX directive 2014/34/EU as detailed above.	
ZY.4 17.2.5	Fans	The product is no room ventilating fan.	N/A
EN 60079-1 : 2014 based on IEC 60079-1 : 2014 (Ed. 7.0) + C1 : 2018			
All		No National Differences.	
EN 60079-11 : 2012 + IS01 : 2014 based on IEC 60079-11 : 2011 (Ed. 6.0) + ISH1 : 2014 + ISH2 : 2016 + ISH3 : 2016 + ISH4 : 2019 + ISH5 : 2019 + ISH6 : 2019			
All		No National Differences.	
Measurement Section, including Additional Narrative Remarks (as deemed applicable)			N/A

	Report Appendix A Description of the test item	
Report Number.....:	See Report No. above.	
Free Reference Number	See report cover.	
Compiled by + signature (ExTL):	A. Hadak	 
Reviewed by + signature (ExTL) ...:	H.J.G. de Wild (Ex d part) B.P.O. Meijer (Ex i part)	
Date of issue (yyyy-mm-dd)	2024-04-15	
Ex Testing Laboratory (ExTL)	DEKRA Certification B.V.	
Address	Meander 1051, 6825 MJ Arnhem, The Netherlands	
Applicant's name	See report cover.	
Address	See report cover.	
Test item description	See report cover.	
Model/type reference	See report cover.	
Standards	See report cover.	
Test procedure	IECEX System	
Instructions for Intended Use of Report Appendix A: Appendix A describes (the assessment of) the test item.		
General remarks: The test results presented in this report Appendix A relate only to the item or product tested. - Throughout this document, a point is used as the decimal separator. The technical content of this report Appendix shall not be reproduced except in full without the written approval of the Issuing Body and Ex Testing Laboratory .		

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1 General product information:

GX-Force is a suction type portable gas monitor which can measure up to 4 gases using 3 sensors. GX-Force measure the combustible gases (LEL), oxygen (O₂), hydrogen sulfide (H₂S), and carbon monoxide (CO).

The sensors to be mounted are electrochemical type and catalytic type. The catalytic type sensor, combustible gas sensor NCR-6309, detects flammable gases. It uses catalyst, and therefore is designed in "Ex da" type of protection. For more details see drawing M3-4463-10-02K. Other parts of detector are designed in "Ex i" type of protection.

Gas sensor NCR-6309 was tested and results are reported in NL/DEK/ExTR17.0047/01 Appendix B. Those results are used for this project and report is listed in Cover ExTR Package Contents. Gas sensor was tested for use in GX-3R and GX-3R Pro (IECEx DEK 17.0050X). The differences between that detector and the GX-Force detector are:

- GX-3R and GX-3R Pro are used also for mining,
- GX-3R and GX-3R Pro have higher power dissipation.

2 General requirements

Marking and rating:

Ex da ia IIC T4 Ga, Tamb = -20°C to +60°C (Including flammable gas sensor.)

Ratings of the sensor: DC 1 V, 100 mA

Charging terminal, Um: 6.0 V

Supply is by an Ex ia circuit. Maximum dissipated power < 1.3 W

Temperatures:

The service temperatures of the Sensor are determined based on engineering judgment; see narrative remarks in ExTR part IEC 60079-0.

$$T_{\text{service max.}}: T_{\text{ambient}} + \Delta T_{\text{housing}} + \Delta T_{\text{sensor}} = 60 + 4.3 + 5 = 69.3 \text{ }^{\circ}\text{C}.$$

Schedule of Limitations from Report No. NL/DEK/ExTR17.0047/02 for Gas Sensor type NCR-6309 with conclusions of assessment:

- 1) The Sensor is tested with low risk of mechanical danger for use in a Group I environment.
- 2) The Sensor is assessed for use in a monitor unit with a max. temperature increase of 5 K.
- 3) The Sensor shall not be exposed to ultraviolet light or used in equipment in which it is not fully enclosed.
- 4) This product is an explosion-proof product and is not to be disassembled or modified with the exception of specified parts.
- 5) The equipment shall not be exposed to oil or hydraulic fluid.

Conclusions:

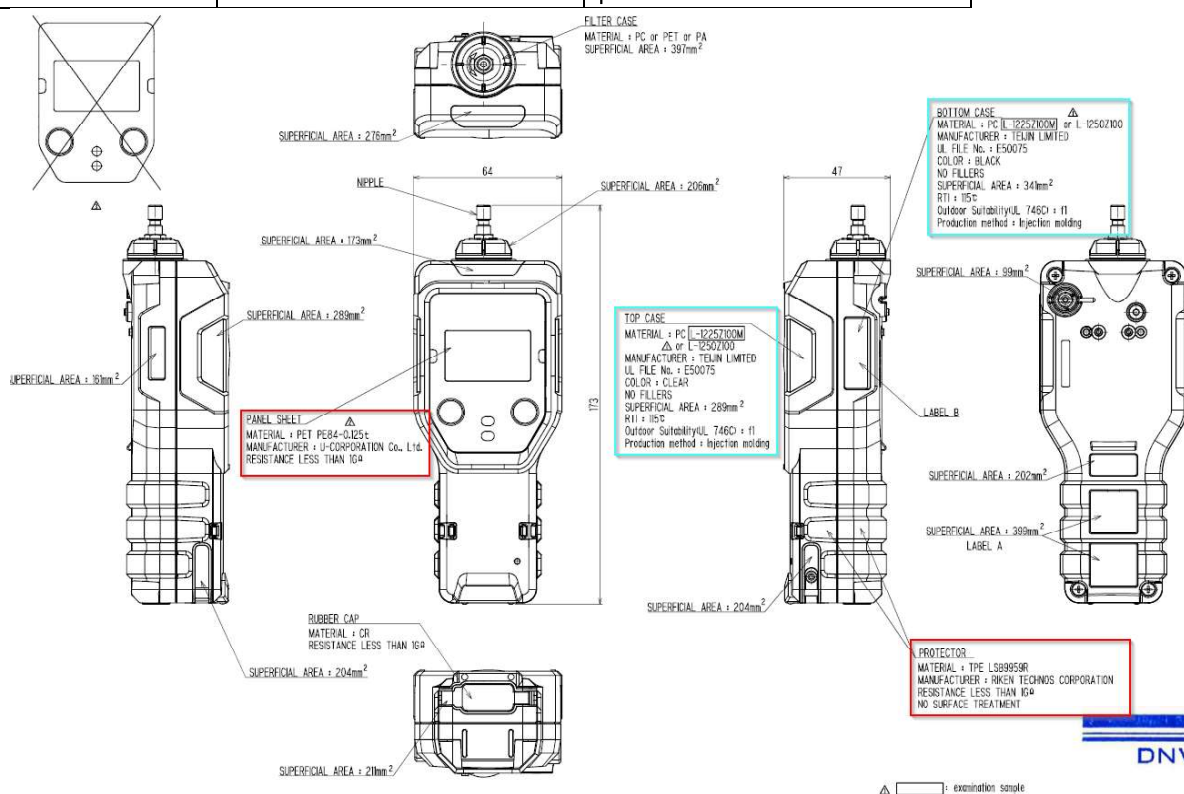
- 1) Group I not applied
- 2) Considered for surface temperature
- 3) Sensor is covered with enclosure of the detector
- 4) Stated in safety instructions for the detector
- 5) Group I not applied

Data for used plastic:

For sensor, see drawing: M3-4463-10-02K, RTI required > 79.6 °C

For overview of used plastic materials see picture below. Materials marked in red are part of detector enclosure surface which have resistance of < 1 GΩ (electrostatic charge, sign X in certificate).

Used at:	Sensor NCR-6309 enclosure	Detector enclosure: Top case (transparent), bottom case (black), marked in blue
Manufacturer name	DIC Corporation	Teijin Ltd.
Material identification	PPS FZ-1130-D5 Colour: natural, Glass fillers: 30%	L-1225Z100M Colour: clear/black, No fillers
Surface treatment	None	None
RTI	+130 °C, graphics show no loss of strength at -40 °C	+115 °C
Resistance to UV	Protected against UV by enclosure of the detector	f1
Relevant for:	Ex d protection	Enclosure is not relevant for Ex i protection, but only as UV protection for sensor



Picture 1: Overview of used plastic materials

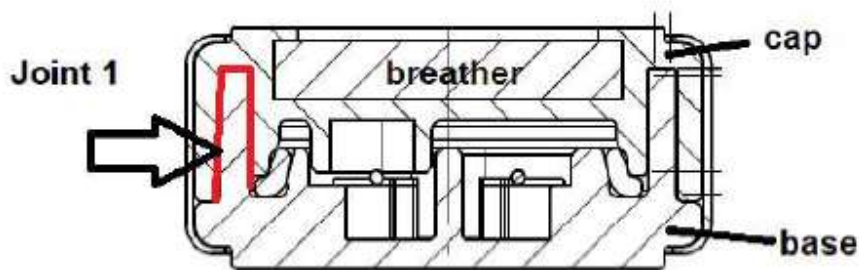
3 Type of protection flameproof:

3.1 General overview

The gas sensor, type NCR-6309, consists of two catalytic elements in a flameproof enclosure. It is used in the portable gas detectors GX force which are no part of this assessment (gas detectors are designed in Ex i protection). The gas sensor is fed by an Ex i signal from the gas detector.

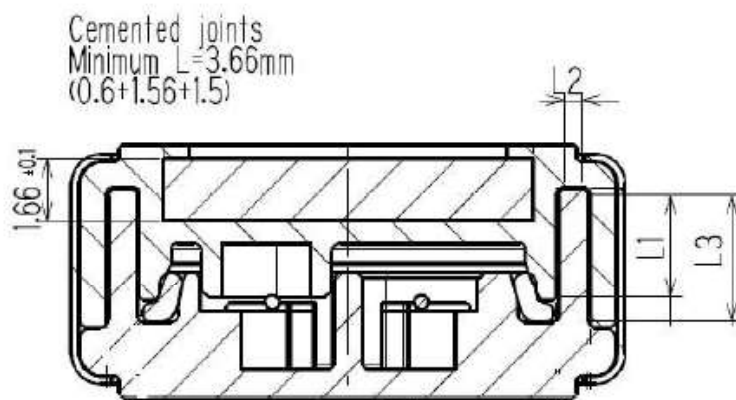
- Internal volume < 1 cm³

The gas sensor consists of two plastic enclosure halves (the Cap and the Base) permanently fixed together with metallic rim. A stainless steel breather element is enclosed in the cap by injection moulding.



Picture 2. Flameproof enclosure of the gas sensor NCR-6309

The enclosure consists of one multi-step joint and two cemented joints. As shown on picture 3 below



Picture 3. Flameproof enclosure of the gas sensor NCR-6309

3.2 Multi-step joints

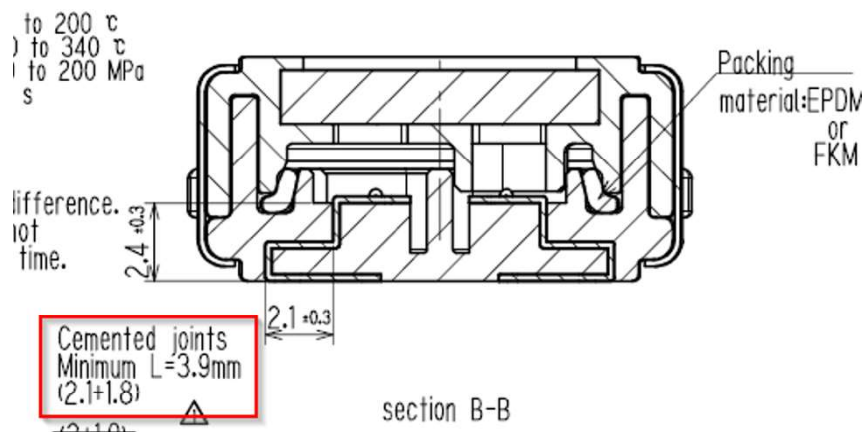
Table 1. Multi-step joint 1

Segment x	Lx min [mm] (specified drawing M3-4463-10-02K)	Gap max (ic) [mm] (specified drawing M3-4463-10-02K)
1	2.65	0.10
2	0.48	0.15
3	3.35	0.10
Total length:	6.48	-

3.3 Cemented joints

Table 2. Cemented joints 2 and 3

Cemented joints according to Clause 6.1.3	Requirement [mm]	Specification [mm]
Cemented joints 2 of electrical contacts	≥ 3	$3.9 = 2.1 + 1.8$
Cemented joints 3 of breather element	≥ 3	$3.66 = 0.6 + 1.56 + 1.5$



Picture 4. Flameproof enclosure of the gas sensor NCR-6309

4 Type of protection intrinsic safety:

See report part IEC 60079-11



IECEx TEST REPORT
Appendix B
Description of the tests



ExTR Reference Number.....:	See Report No. above	<i>A. Hadak</i>
ExTR Free Reference Number.....:	See report cover.	
Compiled by + signature (ExTL).....:	A. Hadak	
Reviewed by + signature (ExTL)	H.J.G. de Wild (Ex d part) B.P.O. Meijer (Ex i part)	<i>H.J.G. de Wild</i> <i>B.P.O. Meijer</i>
Date of issue (yyyy-mm-dd).....:	2024-04-15	
Ex Testing Laboratory (ExTL).....:	DEKRA Certification B.V.	
Address :	Meander 1051, 6825 MJ Arnhem, The Netherlands	
Applicant's name	See report cover.	
Address	See report cover.	
Test item description.....:	See report cover.	
Model/type reference.....:	See report cover.	
Standards.....:	See report cover.	
Test procedure.....:	IECEx System	
Instructions for Intended Use of ExTR Appendix B: Appendix B describes the tests performed.		
General remarks: The test results presented in this ExTR Appendix B relate only to the item or product tested. - Throughout this document, a point is used as the decimal separator. The technical content of this ExTR Appendix shall not be reproduced except in full without the written approval of the Issuing ExCB and ExTL.		

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1 Test Samples and test sequence

1.1 Overview of samples

no	Description
1	GX-Force (test sample 7)
2	GX-Force (test sample 8)
3	Gas Sensor NCR-6309, sample no. 3-1 (Sensors especially prepared for FNT)
4	Gas Sensor NCR-6309, sample no. 3-2 (Sensors especially prepared for FNT)
5	Gas Sensor NCR-6309, sample no. 3-3 (Sensors especially prepared for FNT)
6	Gas Sensor NCR-6309, sample no. 3-4 (Sensors especially prepared for FNT)
7	Gas Sensor NCR-6309, sample no. 3-5 (Sensors especially prepared for FNT)
8	Complete test sample / nipple

1.2 Test sequence

The test sequence is different for different set of samples and can be determined with dates of testing. The listed tests are performed and documented as part of IECEx report no. NO/DNV/ExTR21.0088/00.

Note: Temperature test performed and documented in NL/DEK/ExTR17.0047/01 is not listed below.

sample no			1	2	3	4	5	6	7	8
Standard	Test	Date								
IEC 60079-0	Thermal endurance to heat	2022-01-07 to 2022-02-04			X	X	X	X	X	
IEC 60079-0	Thermal endurance to cold	2022-02-07 to 2022-02-08			X	X	X	X	X	
IEC 60079-0	Drop test	2022-01-26	X	X						
IEC 60079-0	IP-test	2022-01-26	X							
IEC 60079-0	Measurement of capacitance	2022-01-25								X
IEC 60079-1	Overpressure test (static)	2022-03-16			X	X				
IEC 60079-1	Test for non-transmission of an internal ignition	2022-04-29 to 2022-05-17					X			

2 Tests of IEC 60079-0

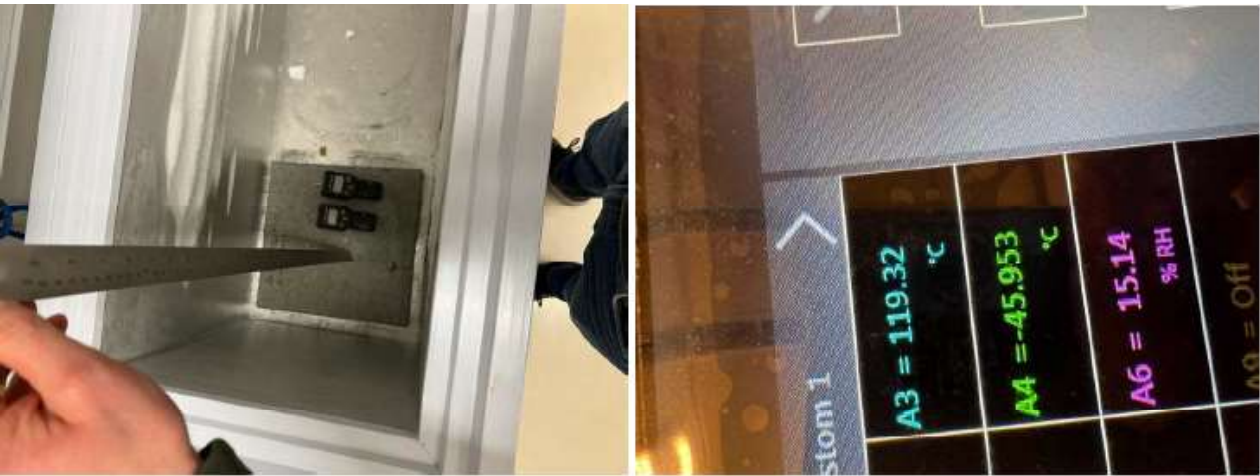
2.1 Drop test

Equipment Tested:	GX-Force (test sample 7 and 8)
Date of Test (yyyy-mm-dd):	2022-01-26
Standard and Clause:	IEC 60079-0 : 2017 (Ed. 7), clause 26.4.3

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description/Procedure:

4 drop tests on two different test samples are performed from a height of 1m onto a concrete surface. Ambient temperature: -45 °C for 24 hours prior to the tests. The actual tests were also performed in this temperature (inside freezer).



Picture: Temperature measured on channel A4

Results:

Only superficial scratches to the enclosure after drop tests. No damages to invalidate the protection, see photos below.



Conclusion

Pass, no damage affecting the type of protection.

2.2 IP-tests

Equipment Tested:	GX-Force (test sample 7)
Date of Test (yyyy-mm-dd):	2022-01-26
Standard and Clause:	IEC 60079-0 : 2017 (Ed.7), clause 26.4.5

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description/Procedure:

Test probe for IP20 was used to determine the ingress protection, after the test sample was drop tested.

Result/conclusion :

The test probe could not enter the enclosure in any place. Ingress protection is IP20 or better.

2.3 Temperature measurement

Equipment Tested:	Sample Gas Sensor NCR-6309 in detector GX-3R and GX-3R Pro
Date of Test (yyyy-mm-dd):	2018-02-19 to 2018-02-21
Standard and Clause:	IEC 60079-0 : 2017 (Ed. 7), clause 26.5.1

Note: This test was performed and documented as part of NL/DEK/ExTR17.0047/01.

The service temperature has been measured and then calculated to +69.3 °C ($\Delta T=9.3$ K) on the external (plastic) surface of the gas sensor at the highest ambient temperature of +60 °C.

The highest surface temperature has been measured and then calculated to +79.4 °C ($\Delta T=19.4$ K) on the pressed metal wire of the (breather element) of the gas sensor at the highest ambient temperature of +60 °C.

2.4 Thermal endurance to heat

Equipment Tested:	Sample no. Gas Sensor NCR-6309 3-1, 3-2, 3-3, 3-4 and 3-5 (Sensors especially prepared for FNT)
Date of Test (yyyy-mm-dd):	2022-01-07 to 2022-02-04
Standard and Clause:	IEC 60079-0 : 2017 (Ed. 7), clause 26.8

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description/Procedure:

The samples were submitted to continuous storage for:
4 weeks in an ambience of 90 % relative humidity and at a temperature of 90 °C

Result

No any visible damage or changes on samples was observed.

Conclusion

After the following tests

2.5 Thermal endurance to cold

Equipment Tested:	Sample no. Gas Sensor NCR-6309 3-1, 3-2, 3-3, 3-4 and 3-5 (Sensors especially prepared for FNT)
Date of Test (yyyy-mm-dd):	2022-02-07 to 2022-02-08
Standard and Clause:	IEC 60079-0 : 2017 (Ed. 7), clause 26.9

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description/Procedure:

Samples were submitted to continuous storage for 24 hours in an ambience of a temperature of -46 °C

Result

No any visible damage or changes on samples was observed.

Conclusion

After the overpressure tests.

2.6 Measurement of capacitance

Equipment Tested:	Complete test sample / nipple
Date of Test (yyyy-mm-dd):	2022-01-25
Standard and Clause:	IEC 60079-0 : 2017 (Ed. 7), clause 26.14

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description/procedure:

The test sample was conditioned for 1.5 hours in 25 °C and 50 % RH.

Results:

Test 1:

Stray capacitance 3-5 mm above nipple and unearthed metal plate: 6.8 pF

Measured capacitance between nipple and un-earthed metal plate: 7.8 pF
capacitance: 1 pF

Test 2:

Stray capacitance 3-5 mm above nipple and unearthed metal plate: 6.7 pF

Measured capacitance between nipple and un-earthed metal plate: 8.3 pF
capacitance: 1.6 pF

Test 3:

Stray capacitance 3-5 mm above nipple and unearthed metal plate: 6.5 pF

Measured capacitance between nipple and un-earthed metal plate: 8.0 pF
capacitance: 1.5 pF

Average capacitance = $(1 \text{ pF} + 1.6 \text{ pF} + 1.5 \text{ pF}) / 3 = 1.4 \text{ pF}$, $1.4 \text{ pF} < 3 \text{ pF}$

Conclusion

Pass, the measured capacitance is below the maximum allowed capacitance

3 Tests of IEC 60079-1

3.1 Overpressure test (static)

Equipment Tested:	Sample no. 3-1, 3-2 (Sensors especially prepared for FNT, flame non-transmission).
Date of Test (yyyy-mm-dd):	2022-03-16
Standard and Clause:	IEC 60079-1 : 2014 (Ed. 7), clause 15.2.3

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description/procedure

Test performed on normal ambient temperature. Sensor head tested empty, the wire mesh was covered with thin membrane from the inner side. Test performed in four test rounds.

The overpressure test was made at 14.5 bar. This pressure was held for 60 s. The ambient temperature during test was +20 °C.

Conclusion:

Pass, no leakage through the cemented joints, deformation or damage affecting the type of protection.

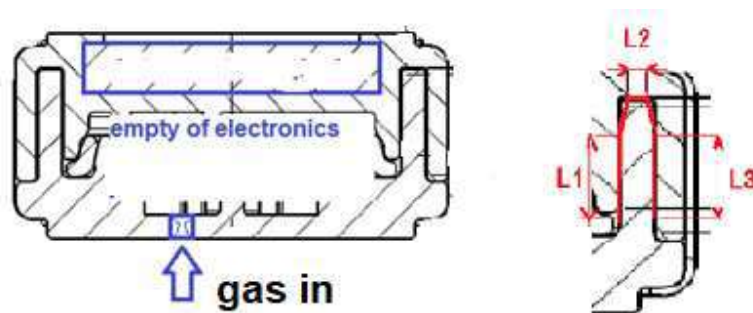
3.2 Test for non-transmission of an internal ignition

Equipment Tested:	Sample no. 3-3 (Sensors especially prepared for FNT)
Date of Test (yyyy-mm-dd):	2022-04-29 to 2022-05-17
Standard and Clause:	IEC 60079-1 : 2014 (Ed. 7), clause 15.3

Note: This test was performed and documented as part of NO/DNV/ExTR21.0088/00.

Description

Subject of this test was Joint 1 (multi-step joint) as shown on picture below. Test gap provided a follows.



Picture 3. Especially prepared sample of the gas sensor NCR-6309 enclosure for flame non-transmission test

Verification of the specially prepared sample for Flame Non-transmission test.

Multistep joint (declared and verified measures)

Segment	Lc max	Le (reduced)	Gap (ie)	Comment
1	1.95	74%	0.10	100%
2	0.35	73%	0.15	100%
3	2.5	75%	0.10	100%

For test arrangement see picture above. Ignition point was located on gas inlet.

The gas mixture was measured at the gas outlet from the both sample and external chamber prior to each internal ignition. The internal mixture was ignited by spark plug. The test was made at pre-compression pressure (1500-1530 mbar) and normal ambient temperature of 20 °C, 50 times with each gas mixture, for Acetylene within the range by (7.4 to 7.9)% volumetric ratio to air and with Hydrogen by (27.0 to 27.5)% volumetric ratio to air.

Mixture in external enclosure verified the same as in the test sample before each ignition.

Gas A: acetylene

Lab temp and pressure: +21C, 1012-1015 mbar.

Gas B: hydrogen

Lab temp and pressure: +21C, 1004-1007 mbar.

Ignition no	O ₂ %	Pressure	Result	Ignition no	O ₂ %	Pressure	Result
1	19.40	1520	Pass	1	15.29	1500	Pass
2	19.38	1520	Pass	2	15.28	1500	Pass
3	19.37	1520	Pass	3	15.27	1500	Pass
4	19.37	1530	Pass	4	15.25	1500	Pass
5	19.37	1530	Pass	5	15.25	1500	Pass
6	19.37	1520	Pass	6	15.24	1500	Pass
7	19.36	1530	Pass	7	15.24	1500	Pass
8	19.36	1520	Pass	8	15.24	1500	Pass
9	19.36	1520	Pass	9	15.24	1500	Pass
10	19.36	1520	Pass	10	15.24	1510	Pass
11	19.36	1520	Pass	11	15.24	1510	Pass
12	19.35	1520	Pass	12	15.24	1510	Pass
13	19.35	1530	Pass	13	15.23	1510	Pass
14	19.35	1530	Pass	14	15.23	1500	Pass
15	19.35	1520	Pass	15	15.23	1500	Pass
16	19.35	1520	Pass	16	15.23	1500	Pass
17	19.34	1530	Pass	17	15.23	1510	Pass
18	19.34	1520	Pass	18	15.23	1510	Pass
19	19.34	1530	Pass	19	15.23	1510	Pass
20	19.34	1530	Pass	20	15.23	1510	Pass
21	19.34	1530	Pass	21	15.22	1500	Pass
22	19.34	1530	Pass	22	15.22	1500	Pass
23	19.34	1530	Pass	23	15.22	1510	Pass
24	19.33	1520	Pass	24	15.22	1500	Pass
25	19.33	1530	Pass	25	15.22	1500	Pass
26	19.33	1520	Pass	26	15.22	1500	Pass
27	19.33	1520	Pass	27	15.22	1510	Pass
28	19.33	1520	Pass	28	15.22	1510	Pass
29	19.33	1520	Pass	29	15.22	1510	Pass



30	19.33	1520	Pass	30	15.21	1510	Pass
31	19.33	1520	Pass	31	15.21	1510	Pass
32	19.32	1520	Pass	32	15.21	1510	Pass
33	19.32	1520	Pass	33	15.21	1510	Pass
34	19.32	1530	Pass	34	15.21	1510	Pass
35	19.32	1520	Pass	35	15.21	1510	Pass
36	19.32	1520	Pass	36	15.21	1510	Pass
37	19.32	1520	Pass	37	15.21	1510	Pass
38	19.32	1520	Pass	38	15.21	1510	Pass
39	19.32	1520	Pass	39	15.20	1510	Pass
40	19.31	1530	Pass	40	15.20	1510	Pass
41	19.31	1520	Pass	41	15.20	1510	Pass
42	19.31	1520	Pass	42	15.20	1510	Pass
43	19.31	1520	Pass	43	15.20	1510	Pass
44	19.31	1530	Pass	44	15.20	1510	Pass
45	19.31	1520	Pass	45	15.20	1510	Pass
46	19.31	1520	Pass	46	15.20	1510	Pass
47	19.31	1520	Pass	47	15.20	1510	Pass
48	19.30	1520	Pass	48	15.20	1510	Pass
49	19.30	1520	Pass	49	15.19	1510	Pass
50	19.30	1520	Pass	50	15.19	1510	Pass

Conclusion:

Pass, no transmission to the surrounding atmosphere



IECEX TEST REPORT APPENDIX B DESCRIPTION OF THE TESTS

ExTR Reference Number	NL/DEK/ExTR17.0047/01	
ExTR Free Reference Number	222988000	
Compiled by + signature (ExTL)	A. Hamaker	
Reviewed by + signature (ExCB)...	K.R. Sekhri	
Date of issue.....	2018-11-16	
Ex Testing Laboratory (ExTL)	DEKRA Certification B.V.	
Address :	Meander 1051, 6825 MJ Arnhem, The Netherlands	
Applicant's name.....	Riken Keiki Co.,Ltd	
Address.....	2-7-6, Azusawa, Itabashi-ku, Tokyo 174-8744, Japan	
Test item description.....	Gas Sensor	
Model/type reference.....	NCR-6309	
Standards	See cover sheet	
Test procedure	IECEX System	
Test Report Form Number	N/A	
Instructions for Intended Use of ExTR Appendix B: Appendix B describes the tests performed.		
General remarks: The test results presented in this ExTR Appendix B relate only to the item or product tested. <ul style="list-style-type: none">- Throughout this document, a point is used as the decimal separator.- When a series of sample is intended this is noted with an '-' e.g. no.'s 34 up to and including 41 is noted as: 34-41 or 34 – 41. The technical content of this ExTR Appendix shall not be reproduced except in full without the written approval of the Issuing ExCB and ExTL.		

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Applicant's name: Riken Keiki
Test item: Gas Sensor

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1 Test Samples and test sequence

1.1 Overview of samples

Sample No	Description	Quantity,
1	Part: Sensor <ul style="list-style-type: none"> Without caulking cap Internal rims removed Holes: suitable for support jig T1 	1 for thermal test breather
2, 3, 4, 5, 6, 7, 8 and 9	Part: Sensor <ul style="list-style-type: none"> Caulking Cap, not caulked Breather blocked from the inside E.g. with silicon kit Internal rims removed With M3 (female) hole in Base Suitable for flame-propagation test 	4 for aging + overpressure Rest: spare.
10 and 11	Part: Sensor <ul style="list-style-type: none"> Breather blocked from the inside E.g. with silicon kit With M3 (female) hole in Base 	2 for overpressure test before aging.
Worst of: 2, 3, 4, 5, 6, 7, 8 or 9 after testing	Part: Sensor housing with breather <ul style="list-style-type: none"> Without Caulking Cap Gap between 90 and 100% of max. design. Joint width < 115% of min. of 6 mm Flat parts gap: > 1 mm Pore size > 85% of 139.3 µm 	1 for flame propagation
12, 13 and 14	Part: Breather <ul style="list-style-type: none"> Breather complete with Cap. 	3 for bubble test.
15 m (multiple)	Part: Breather <ul style="list-style-type: none"> Bare breather without any other material than the pressed metal wire. Breather composition as designed. 	≥ 3, at least > 5 gram in total For density measurement
18, 19, 20, 21, 22, 23, 24 and 25	Part: Sensor <ul style="list-style-type: none"> Caulking Cap (Caulked) Breather blocked from the inside E.g. with silicon kit Internal rims removed With M3 (female) hole in Base 	4 for aging + overpressure 4 spare
26, 27, 28, 29, 30, 31, 32 and 33	Part: Equipment enclosure <ul style="list-style-type: none"> Empty GX-3R enclosure Empty GX-3R Pro enclosure 	4 Samples GX-3R 4 Samples GX-3R Pro To be aged and used for impact testing.

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Sample No	Description	Quantity,
34, 35, 36, 37, 38, 39, 40 and 41	Part: Equipment enclosure <ul style="list-style-type: none"> • Empty GX-3R enclosure • Empty GX-3R Pro enclosure 	4 Samples GX-3R 4 Samples GX-3R Pro To be aged and used for impact testing.
48 thru 52	Part: Sensor <ul style="list-style-type: none"> • With caulking cap • With blind plate instead of breather • Hole in blind plate: M3 	4 in total for overpressure tests before and after aging to test changed electrical contact preparation. 1 for spare.
1 T 72347-1	Part: <ul style="list-style-type: none"> • Complete gas monitor GX-3R • Including sensors 	1 for service temperature measurement
2 T 72347-2	Part: <ul style="list-style-type: none"> • Complete gas monitor GX-3R Pro • Including sensors 	1 for service temperature measurement
Support parts	Part: <ul style="list-style-type: none"> • Charger • Dry cell batteries 	2 for overpressure before aging
Additional samples for NL/DEK/ExTR17.0047/01		
no	Description	
1 - 4 73804 1-4	Part: Equipment enclosure <ul style="list-style-type: none"> • Empty GX-3R enclosure 4 off: • Sensor cap: PC B-4110R • Sensor cover: PC B-4110R 	
5 - 8. 73804 5-8	Part: Equipment enclosure <ul style="list-style-type: none"> • Empty GX-3R Pro enclosure 4 off: • Sensor cap: PC B-4110R • Sensor cover: PC B-4110R 	
9 - 16 73804	Part: <ul style="list-style-type: none"> • NCR 6309 sensor 	
17 - 20 73804 9-12	Part: Equipment enclosure <ul style="list-style-type: none"> • Empty GX-3R enclosure 4 off: • Sensor cap: PC B-4110R • Sensor cover: Teijin Panlite L-1225Z100M 	
21 - 24. 73804 13-16	Part: Equipment enclosure <ul style="list-style-type: none"> • Empty GX-3R Pro enclosure 4 off: • Sensor cap: PC B-4110R • Sensor cover: Teijin Panlite L-1225Z100 	
25 - 32 73804	Part: <ul style="list-style-type: none"> • NCR 6309 sensor 	

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1.2 Test sequence

The test sequence is top down according the table below.

Test	sample no	1	2-5	10, 11	12-14	15 m	18-21	22-25	34-41	1T	2T	18, 49	50, 51
Sequence 1													
60079-1													
B.2.3 pore size				X									
10.8 impact test	X			X 13									
15.4.3.1 thermal test breather	X			X 13									
15.2.3.2 Overpressure test before aging			X										
B.2.4 Density determination					X								
60079-0													
26.8 Endurance to heat		X					X						
26.9 Endurance to cold		X					X						
60079-1													
15.2.3.2 Overpressure test		X					X	X					
15.3.3.4 Dimension check		X											
15.3.3.4 Non-transmission		X 5											
60079-0													
26.8 Endurance to heat									X				
26.9 Endurance to cold									X				
26.4.2 Impact test		X							X				
Sequence 2													
60079-0													
26.5.1.2 Temperature measurement										X	X		
Sequence 4													
60079-1													
15.2.3.2 Overpressure test												X	
60079-0													
26.8 Endurance to heat													X
26.9 Endurance to cold													X
60079-1													
15.2.3.2 Overpressure test													X

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Sequence 5 for NL/DEK/ExTR17.0047/01

sample no	1-4	5-8	9-16	17-20	21-24	25-32
Test						
60079-0						
Thermal endurance to heat	X	X	X	X	X	X
Thermal endurance to cold	X	X	X	X	X	X
Resistance to impact	X	X	X			

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2 Tests of IEC 60079-0

2.1 Resistance to impact before thermal test

Sample(s) Tested:	Sample no. 1, 13
Date of Test (dd/mm/yyyy):	04/12/2017
Standard and Clause:	IEC 60079-0:2011, clause 26.4.2

Description:

The samples were submitted to the effect of a test mass of 1 kg falling vertically from a height (h).

Procedure:

The mass is fitted with an impact head in hardened steel in the form of a hemisphere of 25 mm diameter.

Before each test, the surface of the impact head is checked for good condition.

The points of impact are the places considered to be the weakest.

The samples were placed on a steel base, having a mass of at least 20 kg, so that the direction of the impact was normal to the surface being tested at the point of impact.

Result:

Sample no.	Height h [m]	Temperature of the sample [°C]	Location of impact	Result
1	0.7	20	On breather cell	Slight flattening of breather
1	0.7	20	On breather cell	Slight flattening of breather

Remarks:

The sensor was hit directly on the breather, no protection or guards mounted.

For support the sensor was placed in an empty enclosure.

Result; no damage affecting the type of protection.

Picture:



Sensor after impact.

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2.2 Resistance to impact general

Sample(s) Tested:	Sample no. 34 – 41 using 18 – 21
Date of Test (dd/mm/yyyy):	28/02/2018 and 09/03/2018
Standard and Clause:	IEC 60079-0:2011, clause 26.4.2

Description:

The samples were submitted to the effect of a test mass of 1 kg falling vertically from a height (*h*).

Procedure:

The mass is fitted with an impact head in hardened steel in the form of a hemisphere of 25 mm diameter.

Before each test, the surface of the impact head is checked for good condition.

The points of impact are the places considered to be the weakest.

The samples were placed on a steel base, having a mass of at least 20 kg, so that the direction of the impact was normal to the surface being tested at the point of impact.

The sensors 18 – 21 were placed in the enclosures before testing and inspected afterward for damage

Result:

Sample no.	Height <i>h</i> [m]	Temperature of the sample [°C]	Location of impact	Result
36, 18	0.7	+73	Top of sensor cap	Dent and cracks in enclosure Sensor not affected
36, 18	0.7	+73	Side of sensor cap	Dent in enclosure Sensor not affected
37, 19	0.7	+73	Top of sensor cap	Dent and cracks in enclosure Sensor not affected
37, 19	0.7	+73	Side of sensor cap	Dent and cracks in enclosure Sensor not affected
40, 20	0.7	+73	Top of sensor cap	Dent and small crack in enclosure Sensor not affected
40, 20	0.7	+73	Side of sensor cap	Dent in enclosure Sensor not affected
41, 21	0.7	+73	Top of sensor cap	Dent and cracks in enclosure Sensor not affected
41, 21	0.7	+73	Side of sensor cap	Dent and cracks in enclosure Sensor not affected
34, 18	0.7	-47	Top of sensor cap	Cracks in enclosure Sensor not affected
34, 18	0.7	-47	Side of sensor cap	Cracks in enclosure, cap broke Sensor not affected
35, 19	0.7	-47	Top of sensor cap	Cracks in enclosure Sensor not affected
35, 19	0.7	-47	Side of sensor cap	Dent in enclosure Sensor not affected
38, 20	0.7	-47	Top of sensor cap	Dent and cracks in enclosure Sensor not affected

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38, 20	0.7	-47	Side of sensor cap	Dent and cracks in enclosure Sensor not affected
39, 21	0.7	-47	Top of sensor cap	Small cracks in enclosure Sensor not affected
39, 21	0.7	-47	Side of sensor cap	Dent in enclosure Sensor not affected

Result: the protective enclosure is damaged, but the sensor did not suffer damage affecting the type of protection.

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2.3 Resistance to impact for max. ambient temperature: +60 °C

Sample(s) Tested:	Sample no.'s: 1 up and till 16
Date of Test (dd/mm/yyyy):	09/10/2018 and 11/10/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.4.2 and 26.4.4

Description:

The samples were submitted to the effect of a test mass of 1 kg falling vertically from a height (*h*).

Procedure:

The mass is fitted with an impact head in hardened steel in the form of a hemisphere of 25 mm diameter.

Before each test, the surface of the impact head is checked for good condition.

The points of impact are the places considered to be the weakest.

The samples were placed on a steel base, having a mass of at least 20 kg, so that the direction of the impact was normal to the surface being tested at the point of impact.

See overview on the next page.

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Results:

Sample no.	Height h [m]	Temperature of the sample [°C]	Location of impact	Result
1	0.7	+82	On top of sensor cover	Guard broke / cracked, Sensor not affected.
1	0.7	+82	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.
2	0.7	+82	On top of sensor cover	Guard broke / cracked, Sensor not affected.
2	0.7	+82	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.
3	0.7	-47	On top of sensor cover	Guard broke / cracked, Sensor: superficial damage.
3	0.7	-47	At side of sensor cover near joint	Guard broke / cracked, Sensor: superficial damage.
4	0.7	-47	On top of sensor cover	Guard broke / cracked, Sensor not affected.
4	0.7	-47	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.
5	0.7	+82	On top of sensor cover	Guard broke / cracked, Sensor not affected.
5	0.7	+82	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.
6	0.7	+82	On top of sensor cover	Guard broke / cracked, Sensor not affected.
6	0.7	+82	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.
7	0.7	-47	On top of sensor cover	Guard broke / cracked, Sensor not affected.
7	0.7	-47	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.
8	0.7	-47	On top of sensor cover	Guard broke / cracked, Sensor not affected.
8	0.7	-47	At side of sensor cover near joint	Guard broke / cracked, Sensor not affected.

Conclusion:
Pass, no damage affecting the type of protection.

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2.4 Temperature measurement GX-3R

Equipment Tested:	Sample no. 1 T
Date of Test (dd/mm/yyyy):	19/02/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.5.1

This test is performed to determine the service temperature of the Gas Monitor when operating, since it is used as protection of the Sensor.

Description

- Sample mounted in different normally used positions, in drought free room ambient.
- The final temperature is considered to be reached when the rate of rise of temperature does not exceed 1 K/h.
- The measuring devices (thermocouples, thermometers, etc.) and the connecting cables are selected and arranged so that they do not significantly affect the thermal behavior of the sample.

Conditions of loading/output/operation:

Where the sample rating is a range, test is performed at the highest or lowest rating value in the range, whichever gave the highest temperature rise.

Test condition and result sample 1 T (GX-3R):

Sample number:	U _{rated} [Vdc]	I _{rated} [mA]	Power [mW]	U _{test} : [Vdc]	I _{test} : [mA]	Power [mW]	ambient: [°C]	Test position:
1 T	3.7	64.1	237	4.2	57.3	241	21.5	Vertical position (sensors upward)
Dekra reporter ID: 42381								
Report annex: 1								
Method of measurement was performed with: *) TC(J) = Thermocouple J-type, TC(K) = Thermocouple K-type, RR = Rise-of-Resistance method, TM = Thermometer								
*) used method is applicable for all channels								
Channel number	Location of measurement (component / surface / part)		Maximum absolute [°C]		Maximum DeltaT [K]			
1	Housing, inside center		24.7		3.2			
2	Housing, inside near sensors		24.7		3.2			
3	Housing, inside opposite sensors		24.3		2.8			
4	Housing, inside close to center sensor		23.1		1.6			
5	Housing, inside close to outer sensor		23.5		2.0			
6	Inside outer cap		23.3		1.8			
7	Lab ambient (inside cabinet)		21.5		0.0			

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Sample number:	U _{rated} [Vdc]	I _{rated} [mA]	Power [mW]	U _{test} : [Vdc]	I _{test} : [mA]	Power [mW]	ambient: [°C]	Test position:
1	3.7	64.1	237	4.2	57.3	241	20.5	horizontal position (batteries downward)
Dekra reporter ID: 42390 Report annex: 2								
Method of measurement was performed with: *) TC(J) = Thermocouple J-type, TC(K) = Thermocouple K-type, RR = Rise-of-Resistance method, TM = Thermometer *) used method is applicable for all channels								
Channel number	Location of measurement (component / surface / part)					Maximum absolute [°C]	Maximum DeltaT [K]	
1	Housing, inside center					23.7	3.4	
2	Housing, inside near sensors					23.6	3.3	
3	Housing, inside opposite sensors					23.4	3.1	
4	Housing, inside close to center sensor					22.0	1.7	
5	Housing, inside close to outer sensor					22.4	2.1	
6	Inside outer cap					22.0	2.2	
7	Lab ambient (inside cabinet)					20.5	0.0	

Remarks:

Maximum power dissipation according to customer at 114% of rated voltage, with fully charged batteries.
Prior to the test, batteries were fully loaded with customer's charger.
Alarm mode was activated as per customer's instructions.
Test was performed in a sound proof cabinet.

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2.5 Temperature measurement GX-3R Pro

Equipment Tested:	Sample no. 2 T
Date of Test (dd/mm/yyyy):	20-21/02/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.5.1

This test is performed to determine the service temperature of the Gas Monitor when operating, since it is used as protection of the Sensor.

Description

- Sample mounted in different normally used positions, in drought free room ambient.
- The final temperature is considered to be reached when the rate of rise of temperature does not exceed 1 K/h.
- The measuring devices (thermocouples, thermometers, etc.) and the connecting cables are selected and arranged so that they do not significantly affect the thermal behavior of the sample.

Conditions of loading/output/operation:

Where the sample rating is a range, test is performed at the highest or lowest rating value in the range, whichever gave the highest temperature rise.

Test condition and result sample 1 T (GX-3R Pro):

Sample number:	U _{rated} [Vdc]	I _{rated} [mA]	Power [mW]	U _{test} : [Vdc]	I _{test} : [mA]	Power [mW]	ambient: [°C]	Test position:
2	3.0	100.0	300	2.7	119.2	322	21.1	Vertical position (sensors upward)
Dekra reporter ID: 42397								
Report annex: 1								
Method of measurement was performed with: *) TC(J) = Thermocouple J-type, TC(K) = Thermocouple K-type, RR = Rise-of-Resistance method, TM = Thermometer								
*) used method is applicable for all channels								
Channel number	Location of measurement (component / surface / part)		Maximum absolute [°C]		Maximum DeltaT [K]			
1	Housing, inside center		24.3		3.3			
2	Housing, inside near sensors		25.1		4.0			
3	Housing, inside opposite sensors		25.4		4.3			
4	Housing, inside close to center sensor		24.2		3.1			
5	Housing, inside close to outer sensor		23.8		2.7			
6	Inside outer cap		23.5		2.5			
7	Lab ambient (inside cabinet)		21.1		0.0			

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Sample number:	U _{rated} [Vdc]	I _{rated} [mA]	Power [mW]	U _{test} : [Vdc]	I _{test} : [mA]	Power [mW]	ambient: [°C]	Test position:
2	3.0	100.0	300	2.7	119.2	322	21.3	Horizontal position (batteries downward)
Dekra reporter ID: 42402 Report annex: 1								
Method of measurement was performed with: *) TC(J) = Thermocouple J-type, TC(K) = Thermocouple K-type, RR = Rise-of-Resistance method, TM = Thermometer *) used method is applicable for all channels								
Channel number	Location of measurement (component / surface / part)		Maximum absolute [°C]		Maximum DeltaT [K]			
1	Housing, inside center		24.2		3.0			
2	Housing, inside near sensors		25.1		3.9			
3	Housing, inside opposite sensors		25.5		4.2			
4	Housing, inside close to center sensor		24.0		2.8			
5	Housing, inside close to outer sensor		23.5		2.3			
6	Inside outer cap		23.3		2.1			
7	Lab ambient (inside cabinet)		21.3		0.0			

Remarks:

Maximum power dissipation according to customer at 90% of rated voltage, with battery charge of 1/3.
Alarm mode was activated as per customer's instructions.
Test was performed in a sound proof cabinet.

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2.6 Thermal endurance to heat of sensors

Equipment Tested:	Sample no. 2 – 5, 18 – 21
Date of Test (dd/mm/yyyy):	20/12/2018 – 17/01/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.8

Description:

The samples were submitted to continuous storage for:
336 h in an ambience of 90 % relative humidity and at a temperature of +95 °C,
followed by a period of 336 h at a temperature of +103 °C.

Result:

The samples showed discolouration of the material.

Conclusion:

Depending on other tests.

2.7 Thermal endurance to cold of sensors

Equipment Tested:	Sample no. 2 – 5, 18 – 21
Date of Test (dd/mm/yyyy):	18-19/01/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.9

Description:

Samples were submitted to continuous storage for 24 hours in an ambience of a temperature of -47 °C

Result:

The samples showed no visual effect at all.

Conclusion:

Depending on other tests.

2.8 Thermal endurance to heat of enclosures

Equipment Tested:	Sample no. 34 – 41
Date of Test (dd/mm/yyyy):	26/01-23/02/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.8

Description:

The samples were submitted to continuous storage for:
672 h in an ambience of 90 % relative humidity and at a temperature of +80 °C

Result:

The samples showed no visual effect at all.

Conclusion:

Depending on other tests.

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2.9 Thermal endurance to cold of enclosures

Equipment Tested:	Sample no. 34 – 41
Date of Test (dd/mm/yyyy):	26-27/02/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.9

Description:

Samples were submitted to continuous storage for 24 hours in an ambience of a temperature of -47 °C

Result:

The samples showed no visual effect at all.

Conclusion:

Depending on other tests.

2.10 Thermal endurance to heat of sensors seq. 4

Equipment Tested:	Sample no. 50, 51
Date of Test (dd/mm/yyyy):	16/04/2018 – 15/05/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.8

Description/Procedure:

The samples were submitted to continuous storage for:

336 h in an ambience of 90 % relative humidity and at a temperature of 95 °C, followed by a period of 336 h at a temperature of 103 °C.

Result:

The samples showed discolouration of the material.

Conclusion:

After the following tests

2.11 Thermal endurance to cold of sensors seq. 4

Equipment Tested:	Sample no. 50, 51
Date of Test (dd/mm/yyyy):	15-16/05/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.9

Description/Procedure:

Samples were submitted to continuous storage for 24 hours in an ambience of a temperature of -47 °C

Result:

The samples showed no visual effect at all.

Conclusion:

After the following tests

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2.12 Thermal endurance to heat for seq. 5

Equipment Tested:	Sample no.'s: 1 up and till 32
Date of Test (dd/mm/yyyy):	07/09/2018 – 05/10/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.8

Description/Procedure:

The samples were submitted to continuous storage for:
672 hours in an ambience of 90 % relative humidity and at a temperature of +90 °C.

Result:

The samples showed no visual effect at all.

Remark:

Covers are not opened and re-closed, since there are no covers that can be opened at the Sensor.

Conclusion: After the following tests.

2.13 Thermal endurance to cold for seq. 5

Equipment Tested:	Sample no.'s: 1 up and till 32
Date of Test (dd/mm/yyyy):	08/10/2018 to 09/10/2018
Standard and Clause:	IEC 60079-0:2011 clause 26.9

Description/Procedure:

Samples were submitted to continuous storage for 24 hours in an ambience of a temperature of -47 °C

Result

The samples showed no visual effect at all.

Remark:

Covers are not opened and re-closed, since there are no covers that can be opened at the Sensor.

Conclusion: After the following tests.

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3 Tests of IEC 60079-1

3.1 Overpressure test (static) before aging

Equipment Tested:	Sample no. 48, 49
Date of Test (dd/mm/yyyy):	28/03/2018
Standard and Clause:	IEC 60079-1:2014 clause 15.2.3

Description.

The overpressure test was carried out at room temperature.

First method (static).

At the following pressures, since reference pressure determination has been impracticable:

Test applied	Volume (cm ³)	Group	Pressure [kPa] ^a
YES	≤ 10	I, IIA, IIB, IIC	1000
NO	> 10	I	1000
NO	> 10	IIA, IIB	1500
NO	> 10	IIC	2000

a) For equipment intended for use at an ambient temperature below –20 °C, the above pressures shall be increased by the appropriate test factors noted in Table 7.

Increased to 1450 kPa for –40 °C ambient low.

The period of application of the pressure was at least 10 s but shall exceed 60 s.

The test is made once on each sample.

Result: no leakage, deformation or damage affecting the type of protection

Pictures:



No leakage at contacts of sample 48



No leakage at contacts of sample 49

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3.2 Overpressure test (static) after aging

Equipment Tested:	Sample no. 50 – 51
Date of Test (dd/mm/yyyy):	18/05/2018
Standard and Clause:	IEC 60079-1:2014 clause 15.2.3

Description.

The overpressure test was carried out at room temperature.

First method (static).

At the following pressures, since reference pressure determination has been impracticable:

Test applied	Volume (cm ³)	Group	Pressure [kPa] ^a
YES	≤ 10	I, IIA, IIB, IIC	1000
NO	> 10	I	1000
NO	> 10	IIA, IIB	1500
NO	> 10	IIC	2000

a) For equipment intended for use at an ambient temperature below –20 °C, the above pressures shall be increased by the appropriate test factors noted in Table 7.

Increased to 1450 kPa for –40 °C ambient low.

The period of application of the pressure was at least 10 s but shall exceed 60 s.

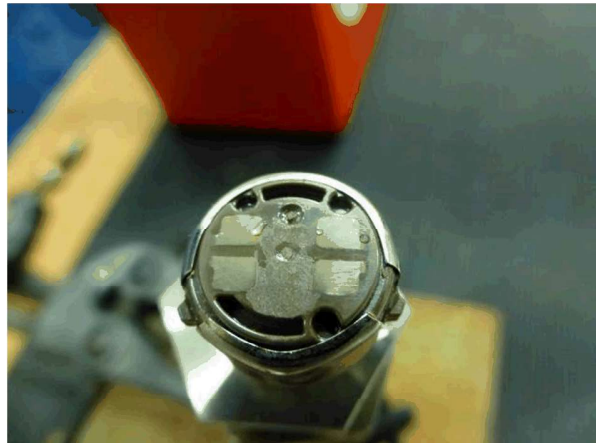
The test is made once on each sample.

Result: no leakage up to 1200 kPa. Above 1200 kPa droplet leakage.

Pictures:



Leakage at contacts of sample 50 > 1200 kPa



Leakage at contacts of sample 51 > 1200 kPa

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3.3 Test for non-transmission of an internal ignition

Equipment Tested:	Sample no. 5 using tool 1
Date of Test (dd/mm/yyyy):	12-15/03/2018
Standard and Clause:	IEC 60079-1:2014 clause 15.3.3.4 / 15.4.4.3.3

Description

The non-transmission tests were carried out on a sample of the enclosure under the following conditions:

- Enclosure tested empty, because of the small size of the equipment a tool is used to hold the equipment. The tool, with an internal volume as small as possible, is to make the required connections possible.
- Ambient/sample temperature: room temperature.
- No overpressure applied.
- Tested with oxygen enrichment.

The sample was prepared as follows:

- All o-rings removed.
- So called 'caulking cap' removed.
- The cylindrical joint checked to be $\geq 90\%$ of constructional gap.
- Gap length checked to be $\leq 115\%$ of min. length.
- The flat part of the flamepath is enlarged to 0.3 mm

Location of gas connections, pressure transducers and ignition source:

Spark plug 1: At side wall of test enclosure (Tool T1)
P.T. (1): At side wall of test enclosure (Tool T1)
P.T. (2): At manifold of test vessel
Gas in: At side wall of test enclosure (Tool T1)
Gas out: At side wall of test enclosure (Tool T1)

Tests performed:



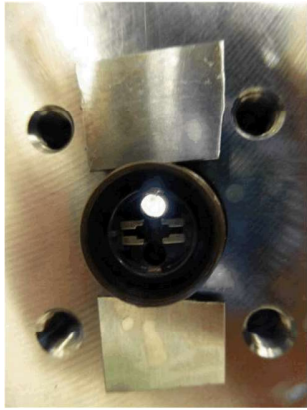
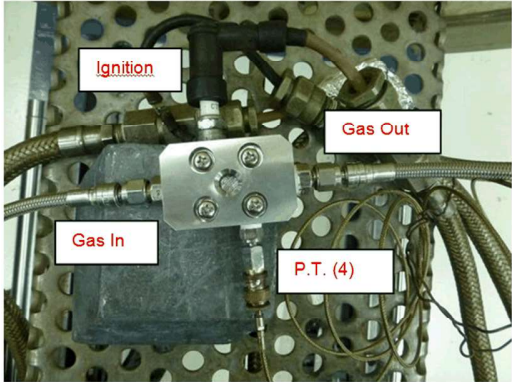


Fifty (50) tests with $(40 \pm 1)\%$ hydrogen, $(20 \pm 1)\%$ oxygen and the rest nitrogen and
Fifty (50) tests with $(10 \pm 1)\%$ acetylene, $(24 \pm 1)\%$ oxygen and the rest nitrogen.

At all tests the internal volume ignited without propagation to the surrounding atmosphere.

Result: no transmission to the surrounding atmosphere.

Pictures of set-up on next page:

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 <p>Flat part of joint enlarged with 0.3 mm shim</p>	 <p>gas inlet open (checked with a light source)</p>	 <p>gas outlet open (checked with a light source)</p>
 <p>Test enclosure in test vessel with connections</p>	 <p>Bottom part after 100 ignitions</p>	 <p>Top part after 100 ignitions</p>

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3.4 Tests of flameproof enclosures with breathing and draining devices

General.

Tests of ability of the enclosure to withstand pressure.

The tests are in accordance with 15.1 with the following additions and modifications:

Determination of the explosion pressure not performed because of the very small internal volume.

For the overpressure test in accordance with 15.2.3 a thin flexible membrane (silicon kit) was laid over the inner surfaces of the breathing device.

Result:

After the overpressure test, the device did not show permanent deformation or damage, affecting the type of protection.

3.5 Thermal tests

Equipment Tested:	Sample no. 5 and breather 13
Date of Test (dd/mm/yyyy):	08/12/2017
Standard and Clause:	IEC 60079-1:2014 clause 15.4.3.1

Description.

The enclosure with the device(s) fitted was tested in accordance with the method 15.4.3.1 but with the ignition source only in one position as provided by tool 1.

The temperature of the external surface of the device(s) was monitored during the test.

The test was made five times with (4.2 ± 0.1) % propane in volumetric ratio with air and at atmospheric pressure and five times with (7.5 ± 1) % acetylene in volumetric ratio with air and at atmospheric pressure.

In an enclosure where there is the possibility of a forced or induced flow of a potentially dangerous gas, the enclosure is arranged during the tests so that the gas can flow through the device(s) and the enclosure. After each of the tests the external explosive mixture was maintained for a sufficient time to allow any continuous burning of the face of the device to become evident (e.g. for at least 10 min so as to increase the temperature of the external surface of the device or to make heat transfer to the outer face possible).

Ign	Gas mixture 4.2 ± 0.1 % propane (C ₃ H ₈)				
	Measured Temperature [°C]	Ambient [°C]	ΔT [K]	Safety factor 1,2	Max. external Surface [°C] <i>calculated</i>
1	22.0	20.7	1.3	-	26.4
2	21.8	20.5	1.3	-	26.2
3	22.0	20.5	1.5	-	26.4
4	22.1	20.4	1.7	-	26.5
5	21.8	20.6	1.2	-	26.7
Ign	Gas mixture 7.5 ± 1.0 % acetylene (C ₂ H ₂)				
	Measured Temperature [°C]	Ambient [°C]	ΔT [K]	Safety factor 1,2	Max. external Surface [°C] <i>calculated</i>
1	26.5	20.1	6.4	-	31.8
2	26.8	20.3	6.5	-	32.1

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3	26.9	20.4	6.5	-	32.3
4	28.8	20.4	8.4	-	34.6
5	24.3	20.4	3.9	-	29.2

Results

No continuous burning was observed. No flame transmission did occur. The measured external surface temperature rise of the device being 8.4 K was multiplied by a safety factor of 1.2 for the determination of the temperature class of the electrical apparatus, resulting in a maximum external surface temperature increase of 10.0 K.

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3.6 Bubble test pore size

Equipment Tested:	Sample no. 12 – 14
Date of Test (dd/mm/yyyy):	06/12/2018
Standard and Clause:	IEC 60079-1:2014 clause B.2.3

Procedure:

The test piece was clean, dry and free from extraneous material and any trace of grease or similar substances likely to hinder the perfect and uniform wetting action of the test liquid.

The used liquid is reported and the density and surface tension of the liquid obtained from the table under clause 5.6 in the standard.

The test piece is completely impregnated with the test liquid, inserted in the bubble test apparatus and maintained fixed, immersed consistent under the smallest depth of test liquid with the convenient observation of the appearance of the bubbles.

This depth h (see the figure in the standard) and the temperature of the liquid are measured and registered.

From an effective gas pressure of zero, the pressure is increased regularly at a rate of between 20 and 100 Pa/s (according to the estimated pore size), while the surface of the test piece was under constant observation.

Test conditions:

Used test liquid: Methanol

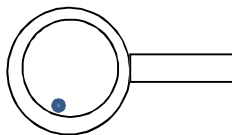
Density of test liquid (ρ_l): 790 kg/m³

Surface tension of test liquid (γ): 0.0225 N/m

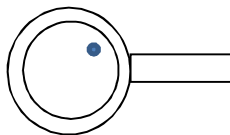
Temperature of test liquid: 18.8 °C

Test results:

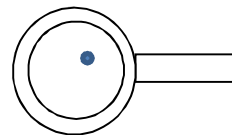
Position of the first bubble:



Sample 1



Sample 2



Sample 3

h sample 1: 0.03 m

h sample 2: 0.03 m

h sample 3: 0.03 m

First bubble pressure P_{g1} : 980 Pa

First bubble pressure P_{g2} : 910 Pa

First bubble pressure P_{g3} : 860 Pa

$$P_l = 9,81 \times \rho_l \times h$$

$$P_l = 9,81 \times \rho_l \times h$$

$$P_l = 9,81 \times \rho_l \times h$$

$$P_{l1} = 9,81 \times 790 \times 0.03 = 232.497 \text{ Pa}$$

$$P_{l2} = 9,81 \times 790 \times 0.03 = 232.497 \text{ Pa}$$

$$P_{l3} = 9,81 \times 790 \times 0.03 = 232.497 \text{ Pa}$$

$$\Delta p = p_g - p_l$$

$$\Delta p = p_g - p_l$$

$$\Delta p = p_g - p_l$$

$$\Delta p_1 = p_{g1} - p_{l1} = 980 - 232.497 = 747.50 \text{ Pa}$$

$$\Delta p_2 = p_{g2} - p_{l2} = 910 - 232.497 = 677.50 \text{ Pa}$$

$$\Delta p_3 = p_{g3} - p_{l3} = 860 - 232.497 = 627.50 \text{ Pa}$$

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Capillary diameter corresponding to the bubble pore size test, in meters:

$$d = \frac{4 \gamma}{\Delta p} \quad d_1 = \frac{4 \gamma}{\Delta p_1} = \frac{4 \times 0.0225}{747.50} = 120 \mu\text{m}$$

$$d = \frac{4 \gamma}{\Delta p} \quad d_2 = \frac{4 \gamma}{\Delta p_1} = \frac{4 \times 0.0225}{677.50} = 133 \mu\text{m}$$

$$d = \frac{4 \gamma}{\Delta p} \quad d_3 = \frac{4 \gamma}{\Delta p_1} = \frac{4 \times 0.0225}{627.50} = 143 \mu\text{m}$$

Arithmetical mean of the three determinations (in 2 decimals): 132 μm

Result:

Required: $\geq 118.4 \mu\text{m}$ (= 85% of 139.3 μm) okay.

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3.7 Density determination

Equipment Tested:	Sample no. 15 m (8 pieces used being > 5 g in weight)
Date of Test (dd/mm/yyyy):	06/12/2018
Standard and Clause:	IEC 60079-1:2014 clause B.2.4

Procedure:

Determination of the initial mass of the test piece

Weigh the test piece in the condition in which it was received, to obtain m_1 .

Removal of oil from the test piece by solvent extraction

Approximately 3 h of soaking and about ten solvent changes are required to remove the oil from test pieces of average density and small wall thickness. For thick walls and high density, up to 24 h are sometimes required. Weigh the test piece after solvent extraction and drying to obtain m_2 .

m_1 .

Sample 1: 0.627 g
 Sample 2: 0.630 g
 Sample 3: 0.631 g
 Sample 4: 0.628 g
 Sample 5: 0.629 g
 Sample 6: 0.633 g
 Sample 7: 0.628 g
 Sample 8: 0.635 g

m_2 .

Sample 1: 0.628 g
 Sample 2: 0.631 g
 Sample 3: 0.631 g
 Sample 4: 0.627 g
 Sample 5: 0.628 g
 Sample 6: 0.633 g
 Sample 7: 0.628 g
 Sample 8: 0.634 g

total mass: 5.041 g

Partial impregnation (suitable for determination of the volume)

The requirements of the oil are the same as stated in 8.4.1. Submerge the test piece in hot oil (70 °C ±10 °C) until no further air bubbles appear. Cool the test piece to room temperature whilst still submerged in oil by removing it from the hot oil and quickly transferring it to cold oil. Remove the cooled test piece from the cold oil, allow to drain, and remove the surplus surface oil as described in 7.4. (oil Referenz fluessigket IRM 902)

Determination of the volume of the test piece

Determine the volume V of the test piece by weighing in air to obtain m_a , and then submerge in water or other liquid of known density ρ_w (see table 4) to obtain m_w . The volume V in cm³ is given by the equation:

Temperature water: 21.9 °C

ρ_w : 0.9978 g/cm³

$$V = \frac{m_a - m_w}{\rho_w}$$

m_a .

Sample 1: 0.663 g
 Sample 2: 0.666 g
 Sample 3: 0.678 g
 Sample 4: 0.677 g
 Sample 5: 0.668 g
 Sample 6: 0.675 g
 Sample 7: 0.674 g
 Sample 8: 0.673 g

m_w .

Sample 1: 0.541 g → V: 0.1222
 Sample 2: 0.521 g → V: 0.1453
 Sample 3: 0.581 g → V: 0.1062
 Sample 4: 0.557 g → V: 0.1202
 Sample 5: 0.549 g → V: 0.1192
 Sample 6: 0.550 g → V: 0.1252
 Sample 7: 0.552 g → V: 0.1222
 Sample 8: 0.523 g → V: 0.1503

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Density

$$\text{Density} = \frac{m_2}{V}$$

Sample 1: 5.139 g/cm³
Sample 2: 4.342 g/cm³
Sample 3: 5.941 g/cm³
Sample 4: 5.216 g/cm³
Sample 5: 5.268 g/cm³
Sample 6: 5.055 g/cm³
Sample 7: 5.139 g/cm³
Sample 8: 4.218 g/cm³

Result: density between 4.218 – 5.941 g/cm³
median: 5.139 g/cm³