Molecular Property Spectrometer™

MPS™ 6.0 Ultra Low Power (ULP) Flammable Gas Sensor

OVERVIEW

NevadaNano's MPS 6.0 Ultra Low Power (ULP) Flammable Gas Sensor builds upon its predecessor and boasts an average power that has been reduced by a factor of 20. As a smart sensor, it delivers industry-leading performance by quickly detecting, quantifying, and classifying myriad flammable gases and gas mixtures with unprecedented TrueLEL™ accuracy. It comes factory calibrated for its entire 15+ year life—no field calibrations are required—and has built-in environmental compensation and automatic self-testing for fail-safe operation. The sensor is robust, extremely poison resistant, and certified intrinsically safe. Sensor readings are output on a digital bus.

TrueLEL™ GAS DETECTION

Gas	Formula	Detection Range	Accuracy (0-50 %LEL)
butane	C_4H_{10}	0-100 %LEL	±5 %LEL
ethane	C_2H_6	0-100 %LEL	±5 %LEL
hydrogen	**H_2**	**0-100 %LEL**	**±5 %LEL**
isobutane	C_4H_{10}	0-100 %LEL	±5 %LEL
isobutylene	C_4H_8	0-100 %LEL	±6 %LEL
isopropanol	C_3H_8O	0-100 %LEL	±10 %LEL
methane	**CH_4**	**0-100 %LEL**	**±3 %LEL**
pentane	C_5H_{12}	0-100 %LEL	±7 %LEL
propane	C_3H_8	0-100 %LEL	±7 %LEL
propylene	C_3H_6	0-100 %LEL	±5 %LEL
toluene	C_7H_8	0-100 %LEL	±12 %LEL
xylene	C_8H_{10}	0-100 %LEL	±12 %LEL

Accuracy guaranteed for methane and hydrogen across full environmental range. Other gases will typically meet the published tolerances across the full environmental range, but are guaranteed only near standard conditions of 20 °C, 50 %RH. The sensor is capable of detecting most common flammable gases/vapors (see page 4).

PERFORMANCE

Resolution	0.1 %LEL
Response time (T90)	< 20 seconds
Calibration	Factory calibrated

ENVIRONMENTAL OPERATING RANGE

Temperature	−40 to 75 °C
Humidity	0 to 100 %RH
Pressure	80 to 120 kPa

FM C US APPROVED

IECEx

Ex ATEX UKEX

Series 4 ("S4")

KEY FEATURES

- Built-in environmental compensation
- Automatic multi-gas accuracy in real-time
- Can detect flammable gas at start-up
- Built-in self-test for fail-safe operation
- Supports 15+ year lifetimes
- No calibration required
- Extremely poison resistant
- Can be powered by 3V
- Low average power: 1.35 mW typical at 3V
- Intrinsically safe (IS) certified
- Compliant to IEC 60079-29-1 Edition 2.1 Annex A

OPERATING PRINCIPLE

The MPS transducer is a patented micro-machined membrane with an embedded Joule heater and resistance thermometer. The transducer is mounted on a PCB and packaged inside a rugged enclosure open to ambient air. Presence of a flammable gas causes changes in the thermodynamic properties of the air/gas mixture that are measured by the transducer. Sensor data are processed by patented algorithms to report an accurate concentration and classify the flammable gas.

SM-DS-0018-03

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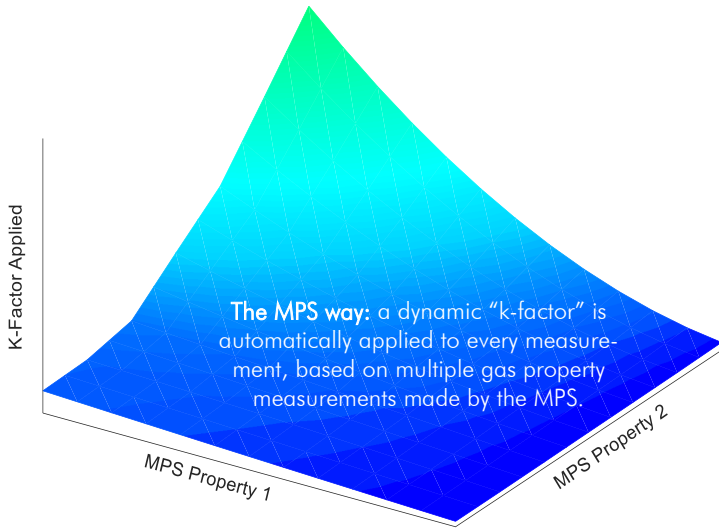
GAS CLASSIFICATION

The old way: Conventional sensing technologies (e.g. catalytic bead, NDIR) use a "k-factor" multiplier to convert raw sensor signals to gas concentrations in %LEL. These "k-factors" are based on known relative sensitivities of these sensors to different gases. A single "k-factor," corresponding to a particular gas, must be selected manually during system setup. When the sensor is later exposed to any gas other than the one selected, significant errors in reported concentration can occur.

The MPS way: The MPS sensor applies conversion factors automatically and in real-time, based on the "live" measured thermal properties of the ambient air/gas and the current environmental conditions. The %LEL values reported for the bulk, which may contain a mixture of gases, achieve the same high levels of accuracy as those achieved with single gases.



The sensor also automatically outputs the class of flammable gas present, in the following categories:

CLASS 1: Hydrogen

Molecular Weight: 2.0 [g/mol]
Density: 0.09 [kg/m^3]
Number of Carbons: 0

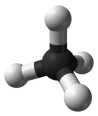
CLASS 2: Hydrogen Mixture

Avg. Mol. Weight: 1-14 [g/mol]
Avg. Density: 0.1-0.6 [kg/m^3]
Number of Carbons: varies

This classification is unique as it guarantees the presence of hydrogen and another flammable gas

CLASS 3: Methane/Natural Gas

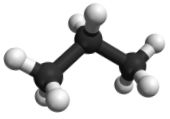
Avg. Mol. Weight: 16 to 19 [g/mol]
Avg. Density: 0.6-0.9 [kg/m^3]
Typical Number of Carbons: 0-2



Gases having molecular properties similar to that of methane may be classified as methane (e.g. ammonia, acetylene)

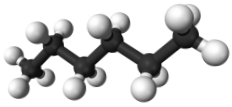
CLASS 4: Light Gas (or Light Gas Mixture)

Avg. Mol. Weight: 25 to 75 [g/mol]
Avg. Density: 1.2-2.5 [kg/m^3]
Typical Number of Carbons: 1-4
Example Gases: Ethane, Propane



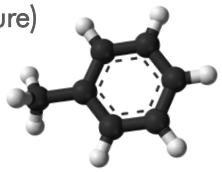
CLASS 5: Medium Gas (or Medium Gas Mixture)

Avg. Mol. Weight: 50 to 120 [g/mol]
Avg. Density: 1.5-4.0 [kg/m^3]
Typical Number of Carbons: 2-8
Example Gas: Pentane



CLASS 6: Heavy Gas (or Heavy Gas Mixture)

Avg. Mol. Weight: 80+ [g/mol]
Avg. Density: 3.5+ [kg/m^3]
Typical Number of Carbons: 6+
Example Gases: Octane, Toluene, Xylene



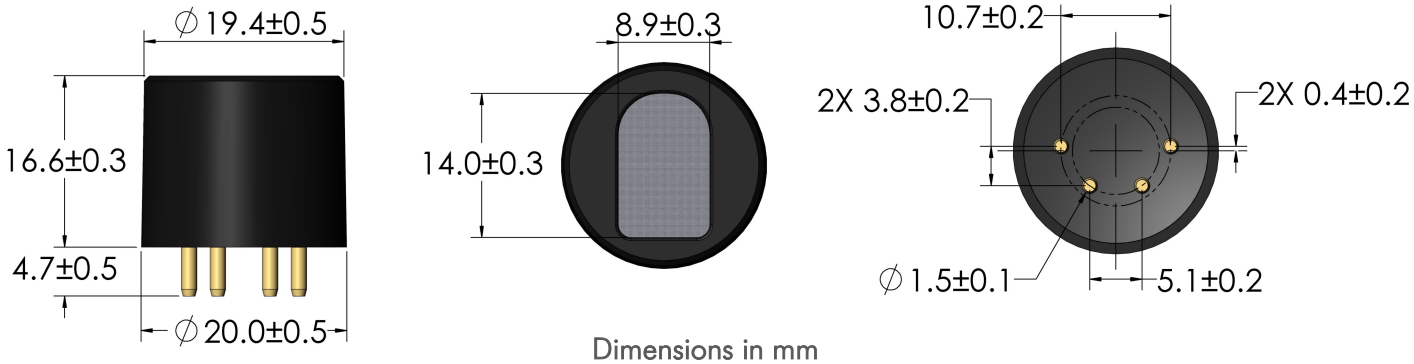
SELF-DIAGNOSTICS

The MPS 6.0 ULP automatically performs a comprehensive sequence of self-checks at power-up and every 4 seconds during operation to ensure fail-safe operation. The MPS alerts the user of any sensor failure or status alert. For additional information on how to interpret and handle detected faults, refer to the MPS 6.0 ULP User Manual at www.nevadanano.com/downloads

MECHANICAL AND ELECTRICAL INTEGRATION—S4

The intrinsically safe MPS 6.0 ULP has a standard "4 series" form factor. The sensor interface pins are compatible with industry-standard receptacles or socket assemblies.

MECHANICAL



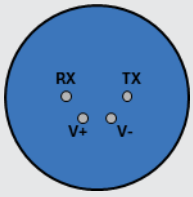
Dimensions in mm

Dimensions	16.6 mm (H) x 20.0 mm (D)
Mass	7.6 ± 0.5 grams
Body material	Ultem PEI

ELECTRICAL

Operating voltage	3.0 - 5.0 ±5% VDC		
Current consumption (typical)	Range 0.4-22 mA	Start-up (~30 sec) 21.1 mA, 3.3V supply 22.0 mA, 5.0V supply	Average 0.45 mA

4-pin
Digital Input/Output



Bottom View

Communication: UART
Logic signaling standard: 3.0 V
Baud rate: 38,400. 8 data, 1 stop bits. No parity.
RX Data Input : Do not exceed 3.6 V
Input High Voltage (V_{IH}) = 2.0 V minimum
Input Low Voltage (V_{IL}) = 0.85 V maximum
TX Data Output : Source / Sink 4 mA maximum
Output High Voltage (V_{OH}) = 2.45 V minimum
Output Low Voltage (V_{OL}) = 0.45 V maximum

FLAMMABLE GASES DETECTED

The volume percentage (%VOL) corresponding to 100 %LEL for a given gas varies across regions and standards due to differences in criteria, including the methods used for ignition and for the determination of an explosion. The MPS 6.0 ULP is factory calibrated to achieve the accuracy levels shown below without any further recalibration or adjustment. The sensor can be queried via UART to report %LEL concentrations predominately aligned with either (a) ISO 10156:1996 or (b) IEC60079-20-1 and companion specification EN61779. (Note, the IEC output is the ISO output multiplied by 1.136).

The MPS as configured is confirmed to detect a variety of other gases not shown in the table below. These include: 1-butene, acetylene, ammonia, cyclohexane, decane, diesel, dimethyl carbonate, ethanol, gasoline vapors, hexane, and methanol. The sensor does not provide TrueLEL accuracy to these gases and will systematically over- or under-report, depending on the gas, and special precautions should be taken when using the MPS to detect these gases. Contact NevadaNano for more information.

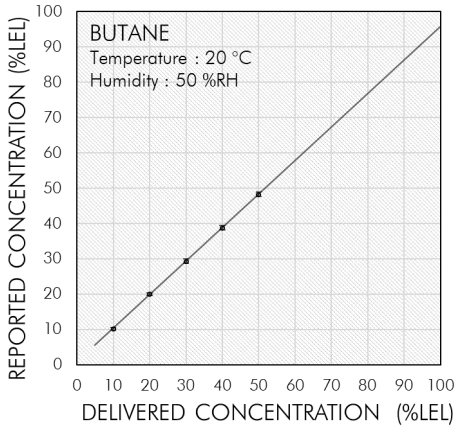
Gas	Formula	Class[4]	Detection Range [%LEL]	% Volume of gas at 100 %LEL (ISO 10156)	MPS Accuracy 0 to 50 %LEL (ISO 10156)	% Volume of gas at 100 %LEL (IEC60079-20-1)	MPS Accuracy 0 to 50 %LEL (IEC60079-20-1)
butane	C_4H_{10}	4	0-100	1.8 %VOL	±5 %LEL	1.4 %VOL	±9 %LEL
ethane	C_2H_6	4	0-100	3.0 %VOL	±5 %LEL	2.4 %VOL	±5 %LEL
hydrogen	H_2	1	0-100	4.0 %VOL	±5 %LEL	4.0 %VOL	±9 %LEL
isobutane	C_4H_{10}	4	0-100	1.8 %VOL	±5 %LEL	1.3 %VOL	−11 %LEL
isobutylene	C_4H_8	4	0-100	1.8 %VOL	±6 %LEL	1.8 %VOL	±5 %LEL
isopropanol	C_3H_8O	4-5	0-100	2.0 %VOL	±10 %LEL	2.0 %VOL	+18 %LEL
methane	CH_4	3	0-100	5.0 %VOL	±3 %LEL	4.4 %VOL	±3 %LEL
pentane	C_5H_{12}	5	0-100	1.5 %VOL	±7 %LEL	1.1 %VOL	±10 %LEL
propane	C_3H_8	4	0-100	2.1 %VOL	±7 %LEL	1.7 %VOL	±10 %LEL
propylene	C_3H_6	4	0-100	2.4 %VOL	±5 %LEL	2.0 %VOL	±5 %LEL
acetone	C_3H_6O	5	0-100	2.5 %VOL	±20 %LEL	2.5 %VOL	±20 %LEL
ethylene	C_2H_4	4	0-100	2.7 %VOL	−12 %LEL	2.3 %VOL	−14 %LEL
heptane	C_7H_{16}	5	0-100	1.1 %VOL	±20 %LEL	0.85 %VOL	−14 %LEL
MEK	C_4H_8O	5-6	0-100	1.4 %VOL	±18 %LEL	1.5 %VOL	−12 %LEL
octane	C_8H_{18}	6	0-100	1.0 %VOL	±16 %LEL	0.8 %VOL	−18 %LEL
styrene	C_8H_8	6	0-100	1.1 %VOL	−20 %LEL	1.0 %VOL	−17 %LEL
toluene	C_7H_8	6	0-100	1.2 %VOL	±12 %LEL	1.0 %VOL	±15 %LEL
xylene	C_8H_{10}	6	0-100	1.1 %VOL	±12 %LEL	1.0 %VOL	±13 %LEL

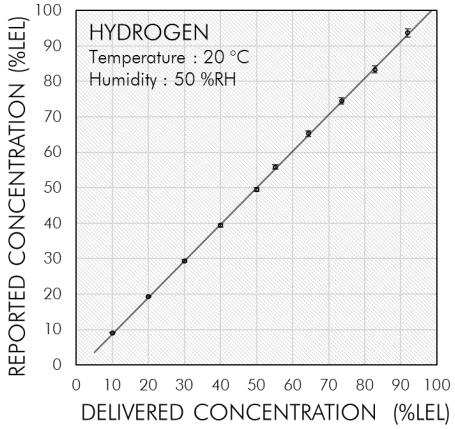
Notes:
1) Accuracy guaranteed for methane and hydrogen across full environmental range.
2) Other gases will typically meet published tolerances across the full environmental range, but guaranteed only near standard conditions of 20°C, 50%RH.
3) Accuracy (+) %LEL corresponds to a higher-than-delivered reading and Accuracy (–) %LEL corresponds to a lower-than-delivered reading.
4) Refer to Gas Classification section on page 2 for value descriptions. Class values shown in table will typically be accurate across the full environmental range, but were determined near standard conditions of 20 °C, 50 %RH.

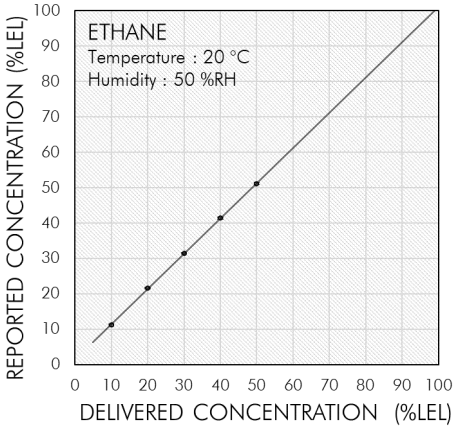
TYPICAL GAS PERFORMANCE CHARACTERISTICS

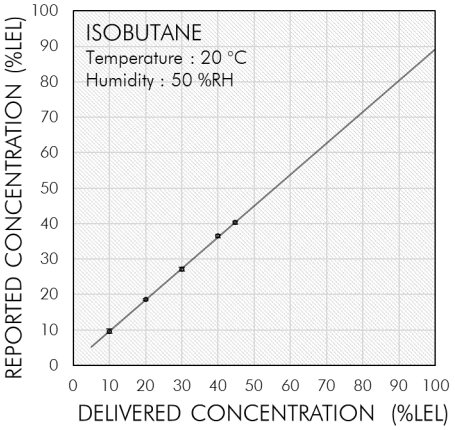
Accuracy to Representative Gases

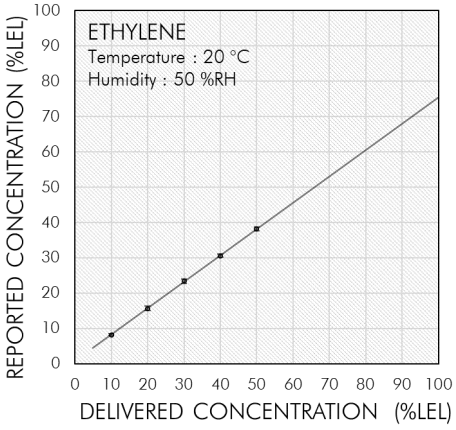
Data points are averages of tested sensors. Error bars indicate the standard deviations of the average readings. Note: all performance data provided was collected using standard, factory-calibrated MPS sensors. No recalibration for specific gases is necessary to achieve these results. The variability measured with isopropanol is caused by the test fixture for the liquid injection of very small volumes of analyte.

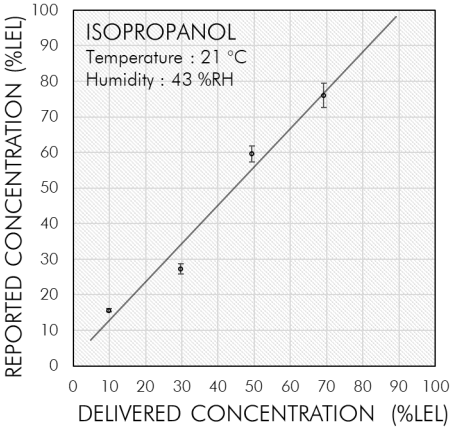








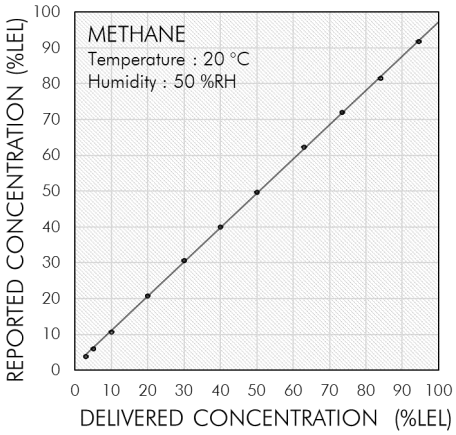


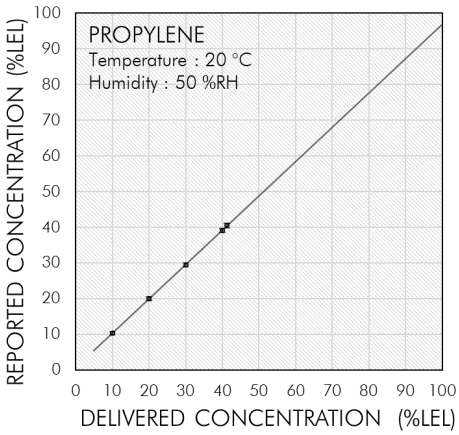


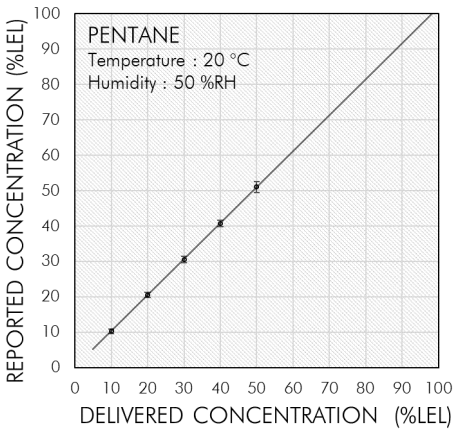
TYPICAL GAS PERFORMANCE CHARACTERISTICS

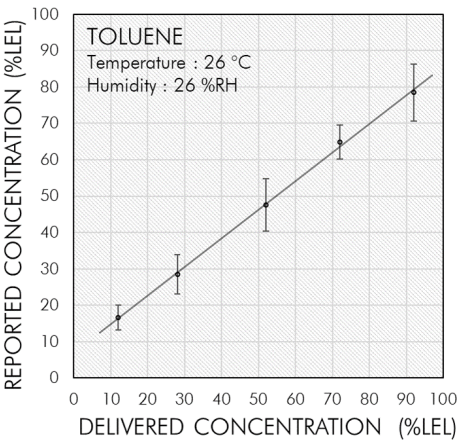
Accuracy to Representative Gases - Continued

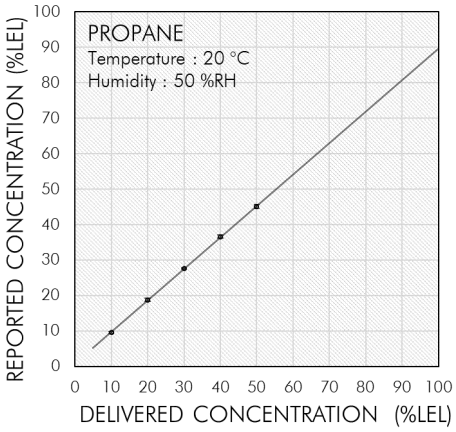
Data points are averages of tested sensors. Error bars indicate the standard deviations of the average readings. Note: all performance data provided was collected using standard, factory-calibrated MPS sensors. No recalibration for specific gases is necessary to achieve these results. The variability measured with toluene and xylene is caused by the test fixture for the liquid injection of very small volumes of analyte.

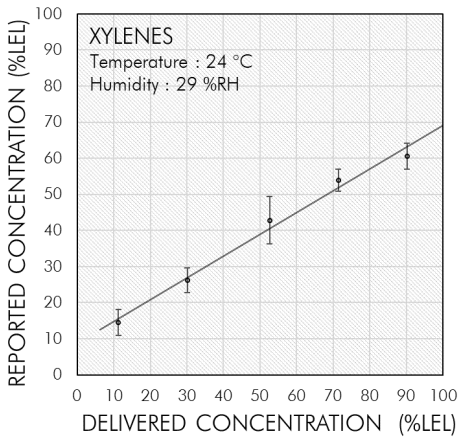












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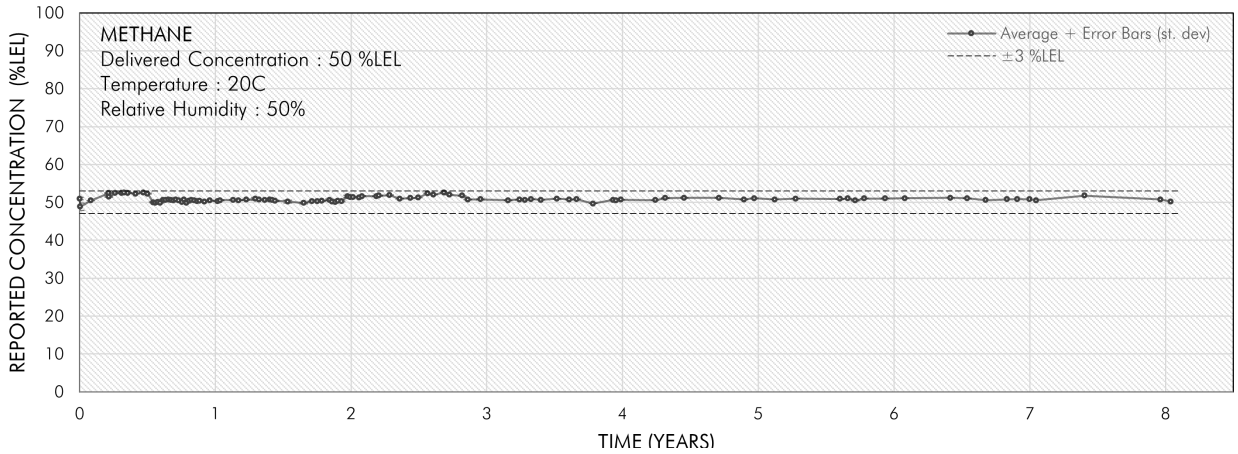
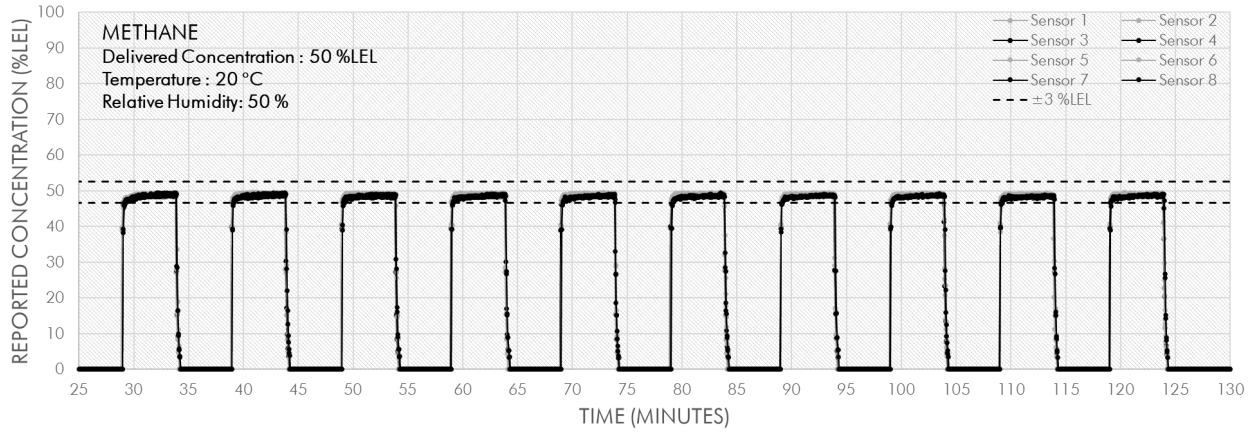
TYPICAL GAS PERFORMANCE CHARACTERISTICS

Long-Term Accuracy/Stability



Average concentration reported by representative MPS sensors to repeated exposures of 50 %LEL methane vs. time. Between exposures, all sensors operated continuously in clean air. During exposures, all sensors were placed in an environmental chamber set at standard conditions (20 °C, 50 %RH) where gas was delivered from a cylinder. Accuracy has remained within ±3 %LEL to date. The test is ongoing.

Repeatability



Sensor #	Average [%LEL]	Standard Deviation [%LEL]
Sensor 1	49.1	0.07
Sensor 2	49.1	0.14
Sensor 3	48.5	0.14
Sensor 4	48.7	0.08
Sensor 5	49.0	0.11
Sensor 6	48.9	0.12
Sensor 7	48.9	0.21
Sensor 8	48.6	0.17

Top: methane concentration reported to 10 exposures over 100 minutes by 8 sensors. Bottom: table shows the averages and standard deviations of the concentrations reported during this test, by sensor. Standard deviation over 10 exposures is less than 0.25 %LEL.

FLAMMABLE GASES NOT DETECTED

The MPS 6.0 ULP, as currently configured, does not detect:

- **Carbon Monoxide (CO):** CO is a toxic gas, immediately dangerous to life and health (IDLH) at 1,200 ppm; the lower explosive limit is 109,000 ppm. The sensor is immune to poisoning by CO.
- **Hydrogen Sulfide (H_2S):** H_2S is a toxic gas, immediately dangerous to life and health (IDLH) at 100 ppm; the lower explosive limit is 40,000 ppm. The sensor is immune to poisoning by H_2S.

There may be other gases the sensor does not detect that have not yet been assessed or tested. For additional information about a particular flammable gas, please contact NevadaNano.

RESPONSE TO NON-FLAMMABLE GASES

Because the MPS performs an analysis of the molecular properties of a given "air" sample, large-scale fluctuations in the relative concentrations of the components in the air can affect accuracy. False readings can occur at non-flammable gas concentration variations (from normal air) greater than about 1 %VOL (~10,000 ppm), as discussed below; accuracy of the %LEL readings can be impacted at concentration variations (from normal air) greater than about 0.1 %VOL (~1,000 ppm).

- **Oxygen (O_2):** Normal air has an O_2 concentration of 20.95% by volume. Higher ambient O_2 concentrations up to ~21.8 %VOL have little to no effect on the sensor. Concentrations exceeding this can be reported as a flammable gas at %LEL levels. The cross sensitivity is approximately 1.07 %LEL per 1 %vol O_2 (e.g., oxygen at 30 %vol in air, a 9.1 %vol enrichment, would read approximately 9.7 %LEL and be identified as Class 2 - Hydrogen Mixture). The sensor is immune to poisoning by O_2.
    - Note: if O_2 concentrations *decrease*, the sensor response will depend on what gas is displacing the oxygen. Flammable gases displace oxygen. Methane at 100 %LEL (5 %VOL methane) will reduce oxygen's relative concentration by 1.05 %VOL in ambient air, meaning the O_2 concentration decreases from 20.9 to 19.85 %VOL. Such flammable-gas-caused O_2 depletions are already taken into account by the sensor calibration and therefore cause no unwanted effects on sensor output.
    - NevadaNano has conducted testing to demonstrate the effect of extreme oxygen depletion. A gas stream containing 2.5 %VOL methane in balance zero air was diluted using a stream containing pure nitrogen to achieve 15, 10, and 5 %VOL O_2 levels. Note that the concentration of methane decreases as pure nitrogen is introduced into the gas stream. Calculated concentrations and the %LEL reported by the MPS are shown below.

	Nitrogen [%VOL]	Oxygen [%VOL]	Methane [%VOL]	Calculated [%LEL]	MPS error [%LEL]
50 %LEL Methane in Zero Air	77.1	20.4	2.5	50.0	+1.0
Diluting with N_2 to 15 %O_2	83.2	15.0	1.8	36.0	-6.0
Diluting with N_2 to 10 %O_2	88.8	10.0	1.2	24.0	-7.0
Diluting with N_2 to 5 %O_2	94.4	5.0	0.6	12.0	-12.0

*Calculated %LEL assumes normal "air" as the background. Actual %LEL is dictated by limiting oxygen concentration.

- **Carbon Dioxide (CO_2):** CO_2 is present at concentrations near 400 ppm in normal air. This ambient level of CO_2 is already taken into account by sensor calibrations. The sensor is unaffected by elevated CO_2 concentrations up to approximately 5,000 ppm. Concentrations above this can be misinterpreted by the sensor as flammable gas. The cross sensitivity is approximately 1.74 %LEL per 1,000 ppm CO_2 (e.g., CO_2 at 10,000 ppm would read approximately 17.4 %LEL). The sensor is immune to poisoning by CO_2.
    - Note: Exhaled human breath contains CO_2 at concentrations of approximately 4-5 %VOL (40,000-50,000 ppm). (During respiration, the CO_2 replaces oxygen, reducing its concentration from 20.95% by volume in normal air to 13.6-16% in exhaled air.) **As such, breathing directly onto the sensor can cause it to falsely report flammable gas for a brief period.**

INTRINSIC SAFETY (IS) CERTIFICATION

Certification Body	IECEx	ATEX NB 2809 / UKEX AB 1725	FM C US APPROVED	
Certificate	IECEx FMG 19.0028U	FM19ATEX0184U FM21UKEX0159U	FM19US0145U	FM19CA0077U
Protection Categories	Ex ia IIC Ga Ex ia IIIC Da Ta = −40 °C to 75 °C	Ex II 1 G Ex ia IIC Ga Ex II 1 D Ex ia IIIC Da Ta = −40 °C to 75 °C	Class I, Division 1, Group A,B,C,D Class II and III, Division 1, Group E,F,G Class I, Zone 0 AEx ia IIC Ga Zone 20 AEx ia IIIC Da Ta = −40 °C to 75 °C	Class I, Division 1, Group A,B,C,D Class II and III, Division 1, Group E,F,G Class I, Zone 0 Ex ia IIC Ga Zone 20 Ex ia IIIC Da Ta = −40 °C to 75 °C

Certificates of Compliance	Specification	Test Lab/Certification Body	Certificate/Report Number
IECEx Quality Assessment Report	IEC 80079-34:2018	FM Approvals LLC	GB/FME/QAR19.0020/00
ATEX Quality Assurance Notification	2014/34/EU	FM Approvals LLC	FM19ATEXQ0200
UK Quality Assurance Notification	UKSI 2016:1107 (as amended)	FM Approvals LLC	FM21UKQAN0168

For additional information on certifications, refer to the MPS Hazardous Locations User Guide here: www.nevadanano.com/downloads

CERTIFICATION

Certificates of Compliance	Specification	Test Lab/Certification Body	Certificate/Report Number
Certificate of Registration of Quality Management System	ISO 9001:2015	National Standards Authority of Ireland (NSAI)	19.8213
RoHS (2 & 3) Compliant	2011/65/EU & 2015/863; includes China RoHS—SJ/T 11363 & 11364	Claigan Environmental & Supplier Declarations	CETR-NNT002.3
REACH Compliant	EC 1907/2006 (33 & 67)	Claigan Environmental & Supplier Declarations	CETR-NNT002.3

Certificates of compliance are available at www.nevadanano.com/downloads or by contacting NevadaNano.

ADDITIONAL TEST STANDARDS

Test	Specification	Summary of Test Conditions
Low Temperature Operating*	IEC 60068-2-1:2007	500 Hours @ −50°C *[in test]*
High Temperature Operating	IEC 60068-2-2:2007	1000 Hours @ 85°C *[in test]*
Mean Time to Failure (MTTF)	IEC 60068-2-2:2007	116 years at 60 % confidence or 35 years at 99 % confidence
Mechanical Vibration*	IEC 60068-2-6:2008	31Hz – 150 Hz (2G acceleration), 1 hour per axis, 3 axes
Mechanical Shock*	IEC 60068-2-27:2008	50G peak/11ms half sine pulse, 3 axes (positive and negative pulses)
Drop—Free Fall*	IEC 60068-2-31:2008	Procedure I: 1 meter drop onto concrete
Damp heat - steady state	IEC 60068-2-78:2012	500 hours @ 40°C/93% RH *[in test]*
Temperature cycling	JESD22-A104E	Test Condition N, -40°C to 85°C for 200 cycles *[in test]*
Sand/Dust Ingress Protection*	MIL-STD-810G	Method 510.5 Sand: 150-850 μm SiO_2 particle size, 23 m/s nom. velocity, 1.5 hrs @ 70°C per axis, 3 axes. Dust: Red China Clay, 1.5 m/s nom. velocity, 6 hrs @ 20°C, 6 hrs @ 70°C
Poisoning and Interference	IEC 60335-2-40 ed.7	In this test the MPS was exposed to each of these gases and concentrations in turn. During each exposure, the sensor did not falsely report flammable gas. Following these exposures, the sensor reported within accuracy specification to 50 %LEL methane. • 1,000 ppm-hours methane • 600 ppm-hours n-butane • 1,394 ppm-hours n-heptane • 417 ppm-hours ethyl acetate • 409 ppm-hours isopropyl alcohol • 10,000 ppm-hours carbon dioxide • 202 ppm-hours ammonia • 420 ppm-hours ethanol • 208 ppm-hours toluene • 675 ppm-hours acetone • 231 ppm-hours hexamethyldisiloxane
Electrostatic Discharge Immunity	JEDEC JS001-2017	Human Body Model, passed at 2 kV
EMC: Radio Frequency Electromagnetic Field Immunity	EN 61326-1:2020	Test Method EN 61000-4-3:2013 *[in test]* 80 MHz to 6 GHz at 10 V/m, horizontal & vertical polarities. Class A.
EMC: Power Frequency Magnetic Field Immunity	EN 61326-1:2020	Test Method EN 61000-4-8:2010 *[in test]* 30 A/m, 3 axes, 50 Hz and 60 Hz
EMC: Radio Frequency Disturbance Characteristics	EN 61326-1:2020	Test Method EN 55011:2010 *[in test]* 30 MHz to 1 GHz. Class A.

*An asterisk in the table above indicates the MPS 6.0 ULP is qualified by similarity to the MPS Flammable Gas Sensor 5.0 and/or MPS Flammable Gas Sensor 4.0, which were subjected to the standardized tests and test conditions shown and which passed by demonstrating performance within their respective specifications both before and after each test.

PART NUMBER ORDERING GUIDE

Please refer to the following table below when ordering the MPS 6.0 ULP. When ordering a MPS Evaluation Kit, please specify the MPS 6.0 ULP part number to be evaluated.

SKU	Description
MPSF03-S43401-EX	MPS 6.0 ULP, S4, 4-Pin

SKU	Description
MPS999-S40000-99	MPS S4 Evaluation Kit (S4 sensor not included)

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