NevadaNano
Digital Scent for the Internet of Things

MPS™ Flammable Gas Sensor

Performance in Canadian Standard Association (CSA) and International Electrotechnical Commission (IEC) Test Protocols

CSA specification: C22.2 No. 152-M1984 (Reaffirmed 2016)
IEC specification: 60079-29-1:2016
Testing conducted internally by NevadaNano
February 2019

NevadaNano

Molecular Property Spectrometer™
MPS™ Flammable Gas Sensor

Contents

Performance Test Standards

Canadian Standard Association Methane Performance Test

The Canadian Standard Association (CSA) methane performance test standards are an accepted method of testing and certifying the performance of a flammable gas detector system in North America. The purpose of CSA tests is to verify that a flammable gas detector, and the sensor mounted in the detector, accurately, reliably, and repeatedly measure methane concentrations in a wide variety of environmental, flow, and other conditions that simulate real-world implementation.

NevadaNano has performed the methane measurement tests from CSA Specifications C22.2 No. 152-M1984 (Reaffirmed 2016) to demonstrate that NevadaNano's MPS™ Flammable Gas Sensor is suitable for integration into flammable gas detection systems intended to be certified to the CSA Standard. The results of these tests are detailed in this report.

The MPS Flammable Gas Sensor has passed all relevant tests. We consider the MPS Flammable Gas Sensor to be "CSA Ready", and suitable for integration into any system intended for detection of flammable gases.

International Electrotechnical Commission Performance Test

International Electrotechnical Commission (IEC) performance test standards are an accepted method of testing and certifying the performance of a flammable gas detector system in Europe. The purpose of IEC tests is to verify that a flammable gas detector, and the sensor mounted in the detector, accurately, reliably, and repeatedly measure gas concentrations in a wide variety of environmental, flow, and other conditions that simulate real-world implementation.

NevadaNano has performed the measurement tests from IEC Specifications IEC 60079-29-1:2016 to demonstrate that NevadaNano's new MPS™ Flammable Gas Sensor is suitable for integration into flammable gas detection systems intended to be certified to the IEC Standard. The results of these tests are detailed in this report.

The MPS Flammable Gas Sensor has passed all relevant flammable gas measurement tests. We consider the MPS Flammable Gas Sensor to be "IECEx Ready", and suitable for integration into any system intended for detection of flammable gases.

CSA and IEC Test Definitions

CSA

Test Description	CSA Subclause	Tolerance	IEC Equivalent
Bounce (portable only)	6.6.2	±5 %LEL, no loss function/false alarm	IEC 5.4.13
Vibration(stationary/permanent)	6.6.3	±5 %LEL, no loss function/false alarm	IEC 5.4.12
Unpowered Storage	6.7	N/A	IEC 5.4.2
Step Change Response	6.9	t(50)<10sec, t(90)<30sec	IEC 5.4.14
Flooding	6.10	Report 60%FS<10sec	None
Supply Voltage Variation	6.11	±2 %LEL	IEC 5.4.18
Temperature Variation Part 1	6.12.1	±3 %LEL	IEC 5.4.6 (b)
Temperature Variation Part 2	6.12.2	±5 %LEL, ±10 %LEL @ -40C	IEC 5.4.6 (a & c)
Humidity Variation	6.13	±5 %LEL	IEC 5.4.8
Air Velocity Variation	6.14	+10/-5 %LEL	IEC 5.4.9
Accuracy Test	6.15	±3 %LEL for 10, 25, and 50 %LEL, ±5 %LEL for 75 and 100	IEC 5.4.3.2
Long Term Stability (stationary)	6.16.1	±5 %LEL for 24-hr exposures, ±10 %LEL final exposure	IEC 5.4.4.5 & 5.4.4.6
Long Term Stability (portable continuous duty)	6.16.2	±5 %LEL for 24-hr exposures, ±10 %LEL final exposure	IEC 5.4.4.5 & 5.4.4.6
Long Term Stability (portable intermittent duty)	6.16.3	±5 %LEL for 24-hr exposures, ±10 %LEL final exposure	IEC 5.4.4.5 & 5.4.4.6
Dielectric Strength	6.17		None

IEC

Test Description	IEC Subclause	Tolerance	CSA Equivalent
Unpowered Storage	5.4.2	N/A	CSA 6.7
Calibration Curve	5.4.3.2	±5 %LEL, or 10 % indication	CSA 6.15
Response to different gasses	5.4.3.3	±7 %LEL, or 15 % indication	None
Stability, short term	5.4.4.2	±3 %LEL, or 10 % indication	None
Stability, long term (fixed)	5.4.4.5	±7 %LEL, or 20 % indication	CSA 6.16.1
Stability, long term (portable)	5.4.4.6	±5 %LEL, or 10 % indication	CSA 6.16.1
Temperature (portable)	5.4.6 (a)	±5 %LEL, or 10 % indication from 20C	CSA 6.12.2
Temperature (non-portable equipment w/ restricted temperature range)	5.4.6 (b)	±3 %LEL, or 10 % indication from 20C	CSA 6.12.1
Temperature (all other non-portable equipment)	5.4.6 (c)	±3 %LEL, or 10 % indication from 20C	CSA 6.12.2
Pressure	5.4.7	±5 %LEL, or 30 % indication from 100kPa	None
Humidity of test gas	5.4.8	±10 %LEL, or 30 % indication from 40C	CSA 6.13
Air velocity (diffusion equipment)	5.4.9	±5 %LEL, or 10 % indication	CSA 6.14
Orientation (portable)	5.4.11.1	±5 %LEL, or 10 % indication	None
Orientation (fixed)	5.4.11.2	±5 %LEL, or 10 % indication	None
Vibration	5.4.12	±5 %LEL, or 10 % indication, and no loss of function/or false alarm	CSA 6.6.3
Drop test	5.4.13	±5 %LEL, or 10 % indication	CSA 6.6.2
Warm-up time	5.4.14	±5 %LEL, no false alarm	None
Time of response (increasing)	5.4.15	t(50)<20sec, t(90)<60sec	CSA 6.9
Time of response (decreasing)	5.4.15	t(50)<20sec, t(10)<60sec	None
High gas concentration operation	5.4.16	±7 %LEL, or +20 %/-10 % indication	None
Power supply variation	5.4.18	±5 %LEL, or 10 % indication	CSA 6.11
Electromagnetic compatibility	5.4.21	±5 %LEL, no spurious alarms or deactivation	None
Software function	5.4.23	N/A	None

Test Setup Descriptions

Four test setups were used to perform all the required testing and are described in this section. All test setups use two regulated gas cylinders: zero air (20.9 %volume oxygen in nitrogen), and 50 %LEL methane (or substitute analyte, ex. IEC 5.4.3.3) in a balance of zero air. During testing, the sensors were connected via USB to a data acquisition system.

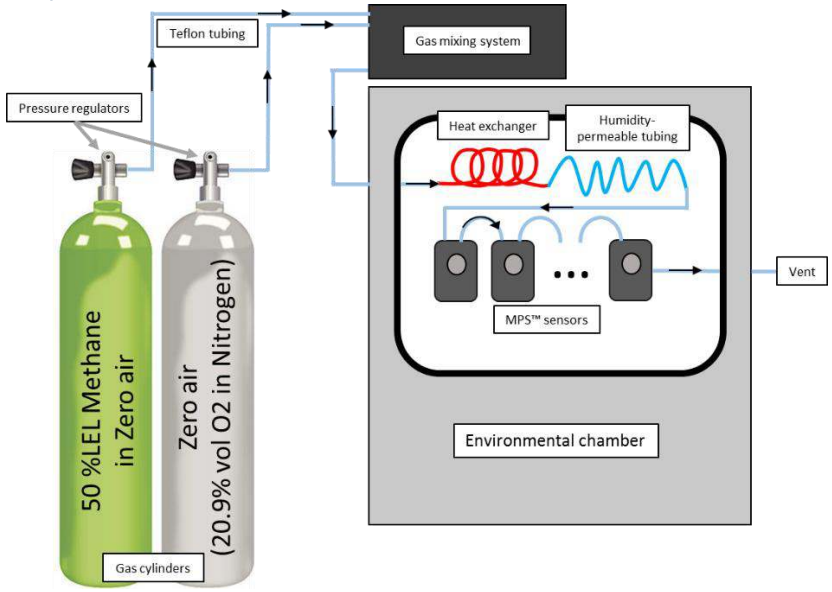
Setup #1: Environmental Chamber Test Setup

Applicable Tests

CSA: 6.7, 6.11, 6.12.1, 6.12.2, 6.13, 6.15

IEC: 5.4.2, 5.4.3.2, 5.4.3.3, 5.4.4.2, 5.4.6 (a, b, c), 5.4.8, 5.4.18, 5.4.21

Diagram of Setup



Description

Regulated gas cylinders are connected to a gas mixing system (e.g. Environics 4040) to control gas flow rates and concentrations. The gas travels through a heat exchanger and humidity-permeable tubing (e.g. Nafion™ TT-110[1]), allowing the gas to reach the chamber temperature and relative humidity. Gas then flows serially through each of the MPS sensors and out a vent exhaust-tube. The environmental chamber is programmed with the required temperature/humidity profiles for each test. Gas profiles are created in the gas mixing system software to deliver the analyte at the correct time. Flow rate is constant at 300 mL/min for both analyte and zero air throughout the tests.

[1] https://www.permapure.com/products/nafion-tubing/nafion-dryer-performance-and-selectivity/

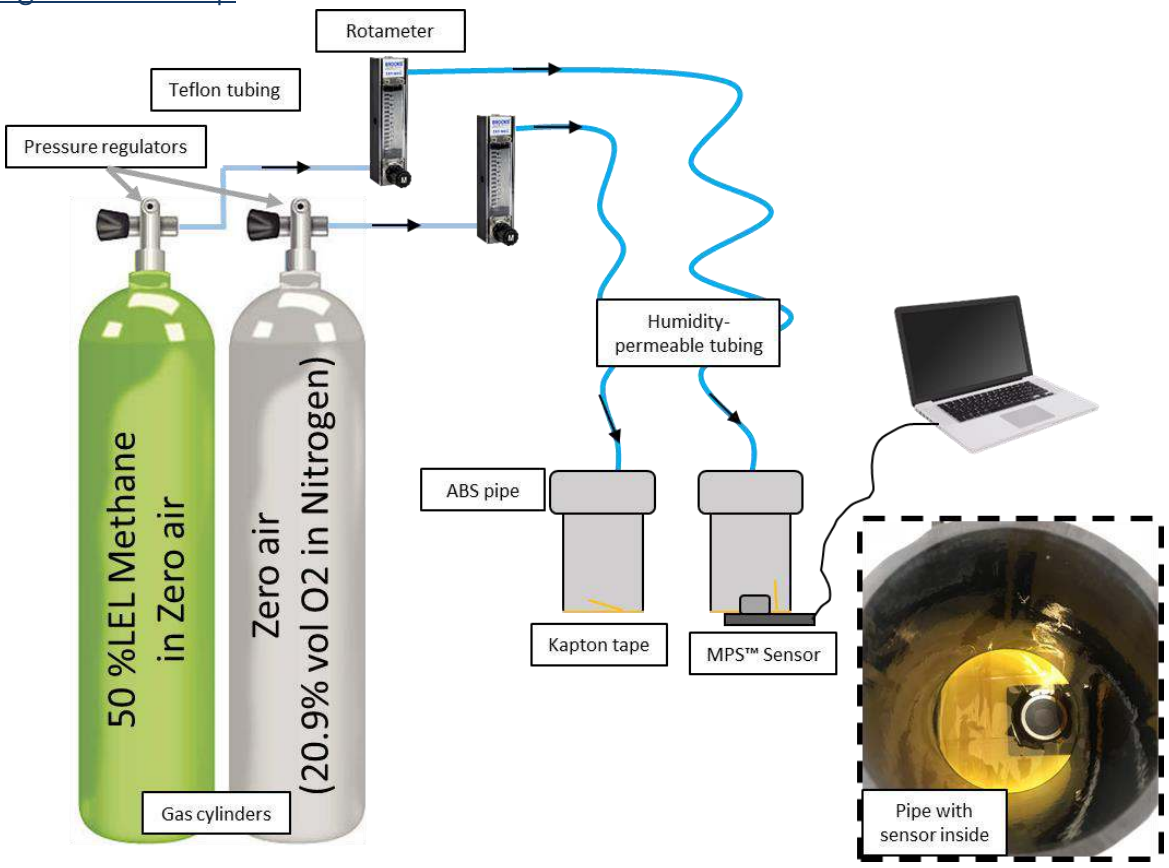
Setup #2: Step Change Response Test Setup

Applicable Tests

CSA: 6.9, 6.10

IEC: 5.4.15

Diagram of Setup



Description

Regulated gas cylinders are connected individually via rotameters and humidity-permeable tubing to sealed ABS pipe sections. The pipe sections are approximately 15-centimeters tall and 10-centimeters in diameter. The rotameters enable flow control, while the Nafion™ tubing humidifies the gas streams. The upper portion of the pipes are sealed with an ABS cap, while the bottoms are closed with Kapton tape. The tape has an opening with a circular flap the size of the sensor. Analyte gas leaks out via positive pressure through this flap, ensuring that the concentration in the tube remains a constant, homogenous 50 %LEL. The flow is regulated at 400 mL/min throughout the test to maintain near-constant gas concentration inside the tube. Then, when the sensor is pressed through the flap, it is exposed to a near step-function rise in concentration.

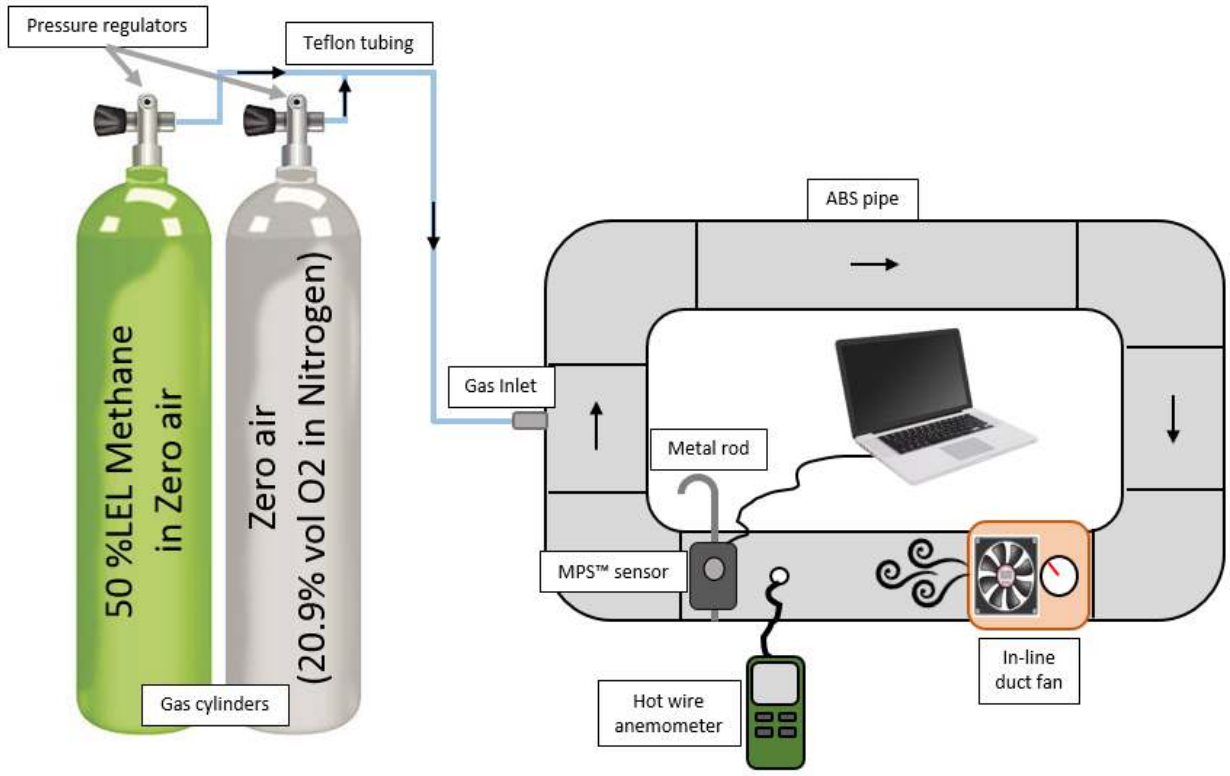
Setup #3: Air Velocity Test Setup

Applicable Tests

CSA: 6.14

IEC: 5.4.9

Diagram of Setup



Description

Regulated gas cylinders are plumbed to a sealed, 10-centimeter diameter ABS pipe loop. All of the sections are cemented together except for a single section that can be opened to access the MPS. The sensor is mounted to a metal rod which allows the sensor to be rotated a full 360° during testing. A hot wire anemometer is installed inside the pipe to measure air velocity, and an in-line duct fan with a speed controller provides flow as well as disperses methane evenly throughout the system.

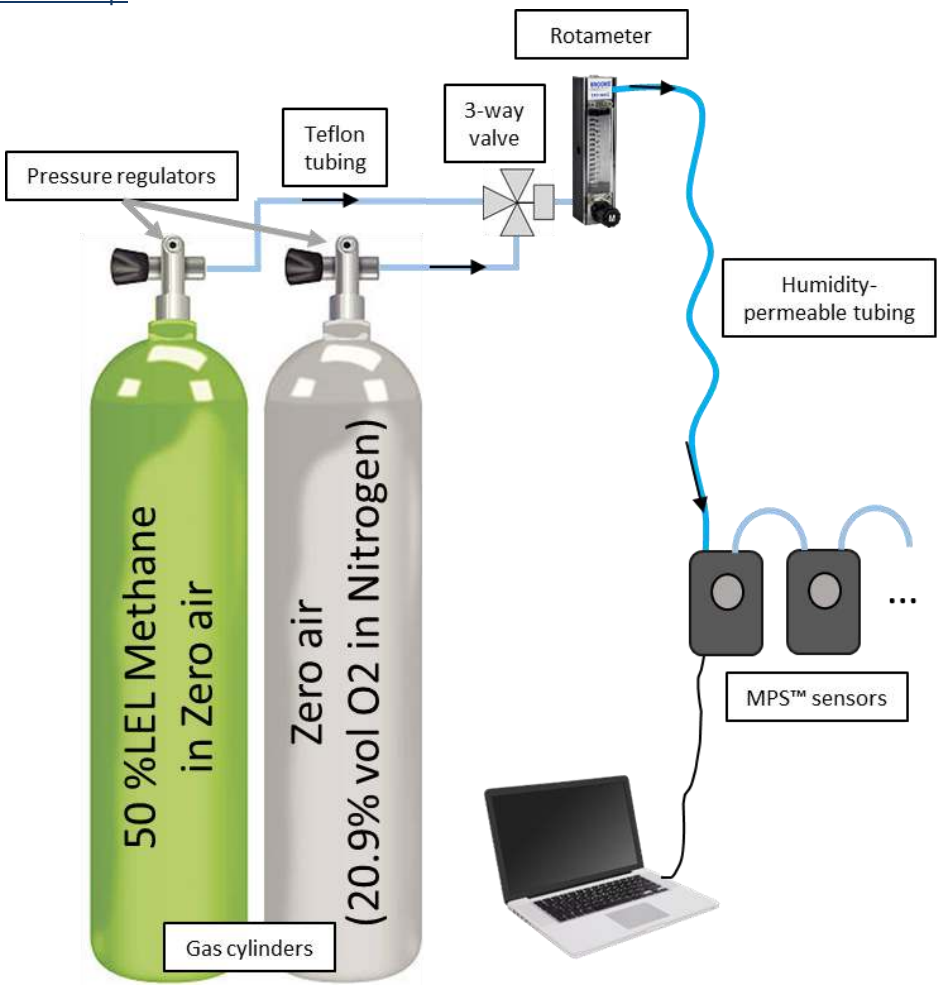
Setup #4: Benchtop Test Setup

Applicable Tests

CSA: 6.16.1, 6.16.2, 6.16.3

IEC: 5.4.4.5, 5.4.4.6, 5.4.11.1, 5.4.11.2, 5.4.14, 5.4.16

Diagram of Setup



Description

Regulated gas cylinders are connected together via a 3-way valve, a rotameter, and humidity-permeable tubing to the MPS sensors. The sensors are encased in a plastic box with a removable lid that seals against the face of the sensor. The lid contains an inlet and an outlet that allows for multiple MPS sensors to be connected in series. The 3-way valve allows gas switching, the rotameter enables flow control, and the Nafion™ tubing humidifies the gas stream. The flow is regulated at 300 mL/min throughout the test to maintain near-constant gas concentration throughout all sensors.

Test Results

Step Change Response, CSA 6.9, IEC 5.4.14

10/10 Sensors PASSED

Test Details

Test Setup: #2 Step Change Response

 # Sensors: 10

Temperature: Ambient ~20 °C

Humidity: Ambient ~20 %RH

Flow rate: 400 mL/min

MPS Sensor Performance

	t50	t90
Max Time [s]	8.3	18.8
Min Time [s]	6.6	17.3

Procedure

One MPS sensor was placed under the ABS pipe containing zero air for two minutes, ensuring homogenous gas concentration over the sensor. The sensor was then powered and allowed to stabilize for 50 seconds. The pipe containing zero air was removed, and the pipe containing 50 %LEL methane was placed over the sensor. Once stability was reached, the methane pipe was removed. This test was repeated with 10 MPS sensors.

Results

Figure 1 shows the concentrations reported by the MPS sensors. The green dotted lines represent 50 and 90% of the applied gas concentration. CSA 6.9 requires that t50 and t90 (the duration of time the sensor takes before reporting at least 50% and 90% of the applied concentration) must be ≤10 and ≤30 seconds, respectively, highlighted by the vertical magenta lines. The t50 and t90 of the MPS sensors were 6.6-8.3 and 17.3-18.8 seconds, respectively, nearly twice as fast as required.

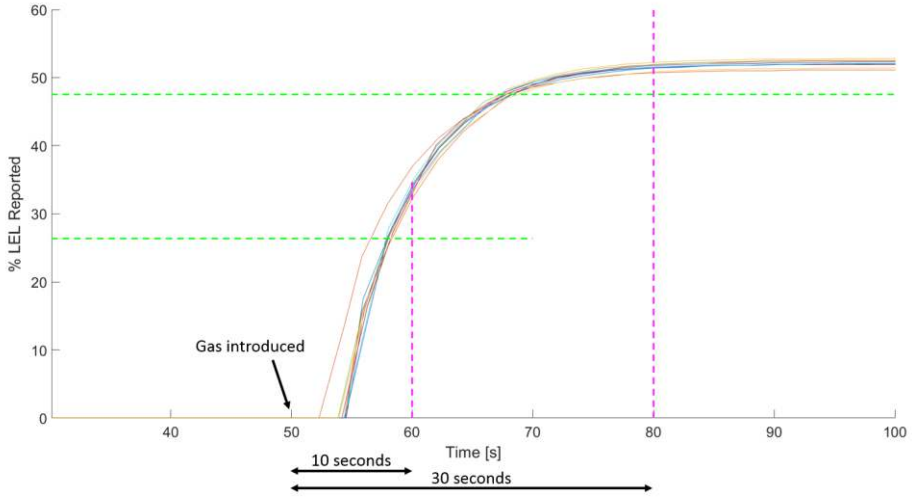


Figure 1: Concentration output of 10 MPS sensors during step change response test

Temperature Variation Part 1, CSA 6.12.1, IEC 5.4.6 (b)

10/10 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 10

Temperature: Various (see figure below)

Humidity: Constant 50 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Temperature [°C]	20	0	40	20
Max Reported [%LEL]	50.3	49.5	49.6	50.7
Min Reported [%LEL]	49.5	48.1	48.8	50.2

Procedure

Ten MPS sensors were attached in series configuration per test setup #1. Initially, the chamber was set to 20 °C, 50 %RH, with zero air flowing over the sensors. After an hour, the sensors were exposed to 50 %LEL methane in a balance of zero air for 5 minutes. The temperature was modulated from 20 °C to 0 °C, and then to 40 °C. After an hour at each of the temperatures, the sensors were exposed to 50 %LEL methane in a balance of zero air for 5 minutes.

Results

Figure 2a shows the concentrations reported by 10 MPS sensors during the testing with corresponding environmental data shown in Figure 2b. CSA 6.12.1 requires the reported concentration to be accurate within ±3 %LEL, as indicated by the green dashed lines, at all temperatures tested. All 10 of the MPS sensors report within the specification bounds.

a)

b)

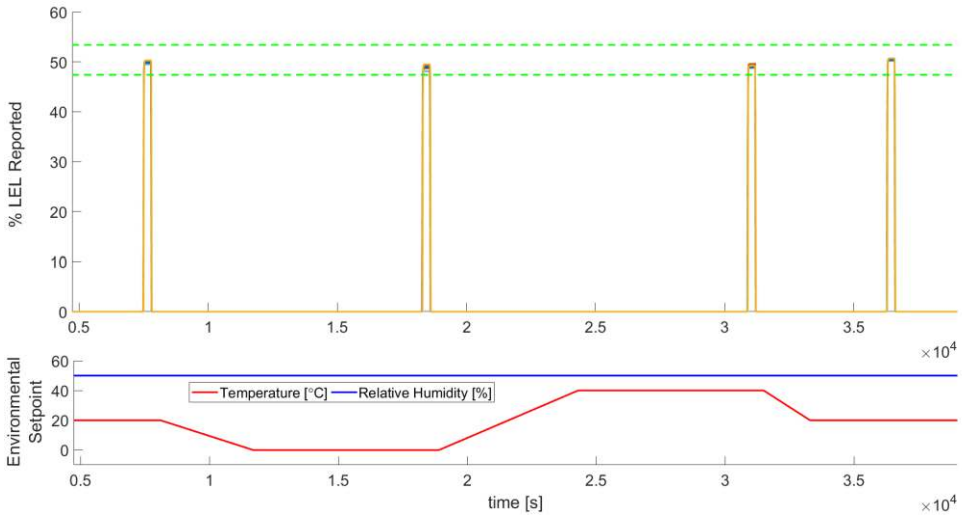


Figure 2: a) Concentration reported by 10 MPS sensors and b) environmental chamber settings during temperature variation part 1 test

Temperature Variation Part 2, CSA 6.12.2, IEC 5.4.6 (a & c)

10/10 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 10

Temperature: Various (see figure below)

Humidity: Constant 40 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Temperature [°C]	20	-40	-25	75	20
Max Reported [%LEL]	51.7	51.5	51.5	50.4	51.8
Min Reported [%LEL]	51.1	50.4	50.6	48.9	51.5

Procedure

Ten MPS sensors were attached in series configuration per test setup #1. The chamber was set to 20 °C, 50 %RH, with zero air flowing over the sensors at 300 mL/min. After an hour, the sensors were exposed to 50 %LEL methane in a balance of zero air for 5 minutes. With the relative humidity held constant at 40 %RH, the temperature was then modulated from 20 °C to -40 °C, to -20 °C, and then to 75 °C. After an hour at each temperature, the sensors were exposed to 50 %LEL methane in a balance of zero air for 5 minutes.

Results

Figure 3a shows the concentrations reported by 10 MPS sensors during the testing with corresponding environmental data shown in Figure 3b. Acceptable sensor variations in CSA 6.12.2 are indicated by the green (±5 %LEL) and magenta (±10 %LEL @ -40 °C) lines. All 10 sensors pass the ±5 %LEL specification and remain within ±3 %LEL for all exposures.

a)

b)

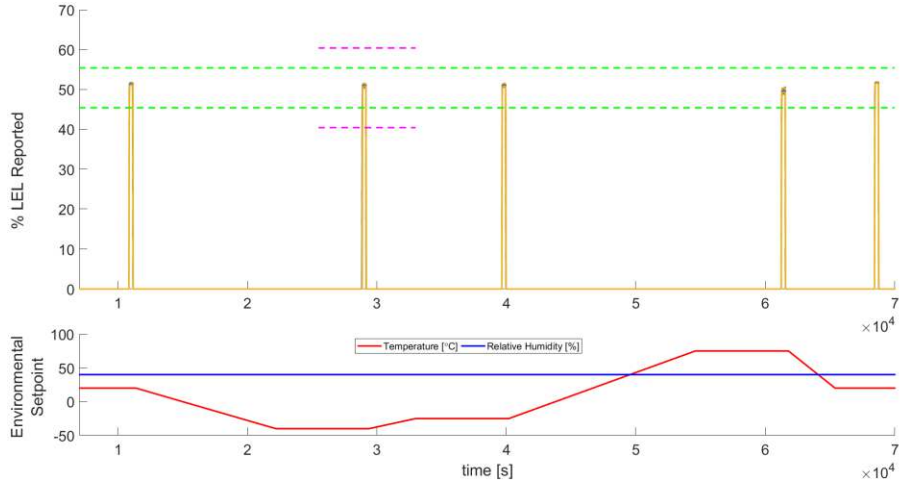


Figure 3: a) Concentration reported by 10 MPS sensors and b) environmental chamber settings during temperature variation part 2 test

Humidity Variation, CSA 6.13, IEC 5.4.8

10/10 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 10

Temperature: Constant 20 °C

Humidity: Various (see figure below)

Flow rate: 300 mL/min

MPS Sensor Performance

Humidity [%RH]	50	90	10	50
Max Reported [%LEL]	50.3	49.0	54.0	50.8
Min Reported [%LEL]	49.1	48.2	52.4	50.0

Procedure

Ten MPS sensors were attached in series per test setup #1. Initially, the chamber was set to 20 °C, 50 %RH, with zero air flowing over the sensors. After an hour, the sensors were exposed to 50 %LEL methane in a balance of zero air for 5 minutes. The humidity was then modulated from 50 %RH up to 90 %RH, then down to 10 %RH. After an hour at each humidity, the sensors were exposed to 50 %LEL methane in a balance of zero air for 5 minutes.

Results

Figure 4a shows the concentrations reported by 10 MPS sensors during the testing with corresponding environmental data shown in Figure 4b. CSA 6.13.1 requires the reported concentration be accurate within ±5 %LEL, a threshold indicated by green dashed lines, for all exposures. All 10 MPS sensors report within the specification bounds.

a)

b)

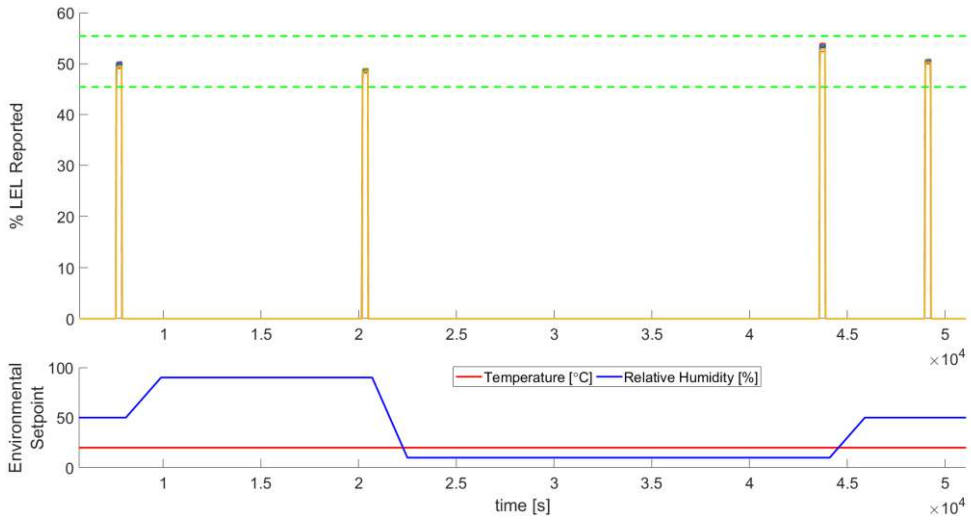


Figure 4: a) Concentration reported by 10 MPS sensors and b) environmental chamber settings during humidity variation test

Air Velocity Test, CSA 6.14, IEC 5.4.9

2/2 Sensors PASSED

Test Details

Test Setup: #3 Air Velocity

 # Sensors: 2

Temperature: Ambient ~20 °C

Humidity: Dry ~10 %RH

Flow rate: Varies

Procedure

One MPS sensor was set up per test setup #3. Zero air was used to fill the system, with the sensor inside, while the fan was on. When stable, 50 %LEL methane in a balance of zero air was introduced. Once stable, methane flow was stopped and the fan was turned off, creating a stagnant headspace. After 5 minutes, the fan was turned back on and the sensor was re-orientated by 180° in both directions, changing the direction that flow impinged on the sensor. An anemometer was used to measure air velocity. After rotation through the various orientations, the pipe was opened.

Results

Figure 5 shows the concentrations reported by two MPS sensors. CSA 6.14 requires the reported concentration to vary less than ±3 %LEL, a threshold indicated by green dashed lines, from no flow to flow and in all orientations. The test was performed at 377 m/min, greater than the requirement of 305 m/min. The two sensors vary less than 1 %LEL due to air velocity or orientation.

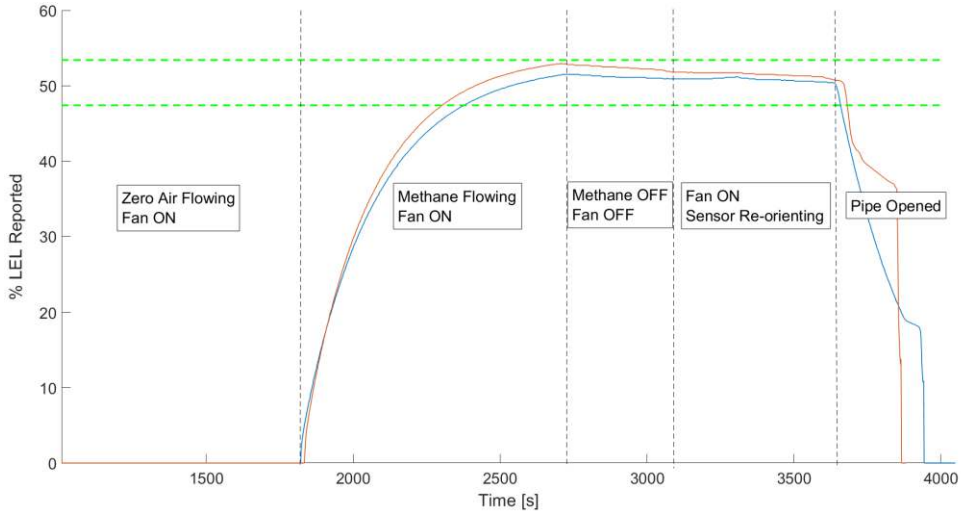


Figure 5: Concentration output of two MPS sensors during air velocity test

Accuracy Test, CSA 6.15, IEC 5.4.3.2

8/8 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 8

Temperature: Constant 20 °C

Humidity: Constant 50 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Concentration Delivered [%LEL]	100	75	50	25	10
Max Reported [%LEL]	100.0	76.4	50.1	25.9	10.8
Min Reported [%LEL]	99.1	75.6	49.5	25.5	10.6

Procedure

Eight MPS sensors were attached in series per test setup #1. Initially, the environmental chamber was controlled to 20 °C, 50 %RH, with zero air flowing over the sensors. The sensors were exposed to 100, 75, 50, 25, and 10 %LEL methane in a balance of zero air, for 10 minutes each, with 10 minutes of zero air between. (Note: This order is the reverse of the CSA testing specification due to limitations of the gas mixing system.)

Results

Figure 6 shows the concentration reported by eight MPS sensors. CSA 6.15 requires the concentration reported to 100 and 75 %LEL exposures to be accurate within ±5 %LEL; 50, 25, and 10 %LEL exposures are required to be accurate within ±3 %LEL. These allowable errors are indicated by dashed green lines. All eight MPS sensors report within the CSA specification limits. (Note: The concentration spikes and slow purge at the end of the 75 and 10 %LEL exposures are caused by residual 100 %volume methane within the gas mixing system and are an artifact of the testing system.)

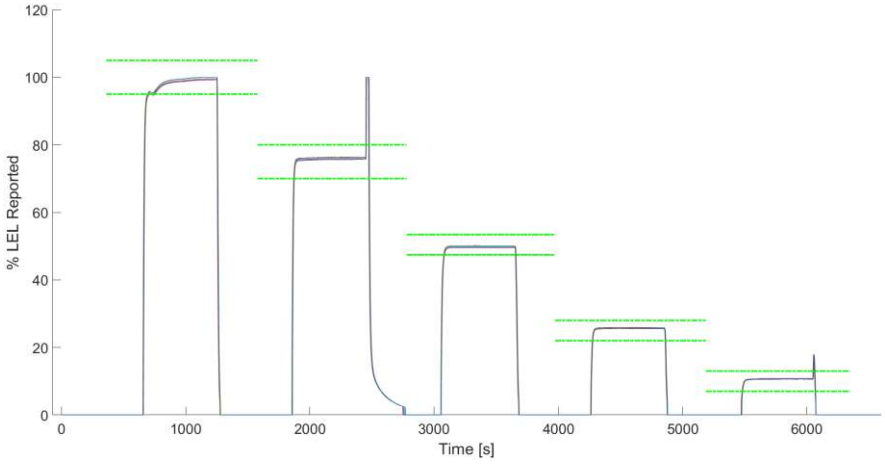


Figure 6: Concentration output of eight MPS sensors during accuracy test

Long Term Stability, CSA 6.16.1, IEC 5.4.4.5 & 5.4.4.6

2/2 Sensors PASSED

Test Details

Test Setup: #4 Benchtop

 # Sensors: 2

Temperature: Ambient ~20 °C

Humidity: Ambient ~20 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Exposure #	1	2	3	4	5
Max Reported [%LEL]	53.3	53.3	53.1	52.7	53.4
Min Reported [%LEL]	52.9	52.7	52.1	52.0	52.7

Procedure

Two MPS sensors were attached in series per test setup #4. Initially, the sensors had zero air flowing over them for six days. On the seventh day, the sensors were exposed to 50 %LEL methane in a balance of zero air for 24 hours. This procedure was repeated four times. On the 29th day, the sensors were exposed to zero air for 24 hours, followed by eight hours of 100 %volume methane. After one final 24 hours of zero air, 50 %LEL methane was exposed to the sensors for 5 minutes.

Results

Figure 7 shows the concentration reported by two MPS sensors. CSA 6.16 requires the concentration reported on the 14th and 28th day to be accurate within ±5 %LEL, and the final methane exposure to be accurate within ±10 %LEL. These allowable errors are indicated by dashed green lines. Both MPS sensors report within the CSA specification limits. (Note: The third methane exposure was left on for too long and lasted five days instead of the required one day.)

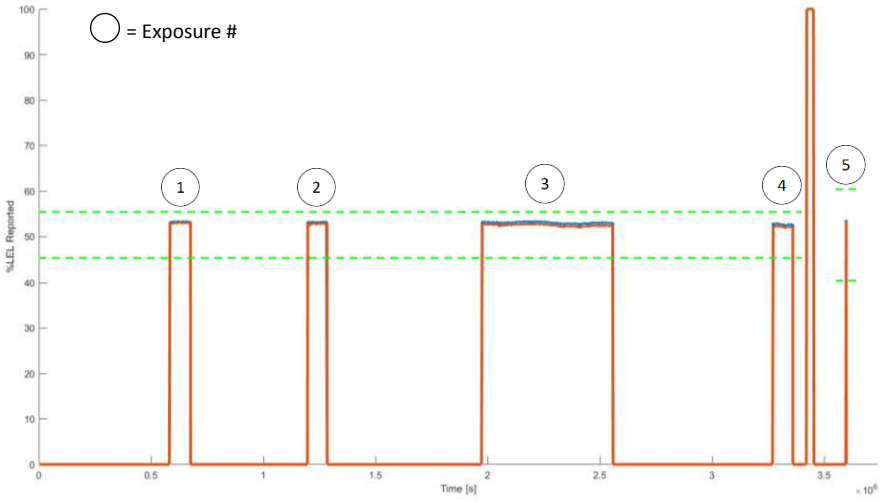


Figure 7: Concentration output of two MPS sensors during long term stability test

Response to Different Gases, IEC 5.4.3.3

6/6 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 6

Temperature: Constant 20 °C

Humidity: Constant 50 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Concentration Delivered [%LEL]	40	25	10	40	25	10	40	25	10
Max Reported [%LEL]	41.2	26.2	10.9	38.5	24.6	10.1	40.1	25.2	10.0
Min Reported [%LEL]	40.4	25.7	10.4	35.5	21.9	7.8	35.7	20.7	6.9

Procedure

Six MPS sensors were attached in series per test setup #1. Initially, the environmental chamber was controlled to 20 °C, 50 %RH, with zero air flowing over the sensors. The sensors were exposed to 10, 30, and 50 %LEL methane in a balance of zero air for three minutes with three minutes of zero air between, then to 50 %LEL methane for one hour. This procedure was repeated with propane, then pentane.

Results

Figure 8 shows the concentration reported by six MPS sensors. IEC 5.4.3.3 requires the concentration reported to be accurate within ±7 %LEL for all exposures. These allowable errors are indicated by dashed green lines. All MPS sensors report within the IEC specification limits. This is a challenging test for both NDIR and catalyst-type sensors due to their inability to accurately quantify gases other than which they are calibrated for. The MPS sensor uses a single calibration to methane, and is accurate for all gases without recalibration or "K-factors".

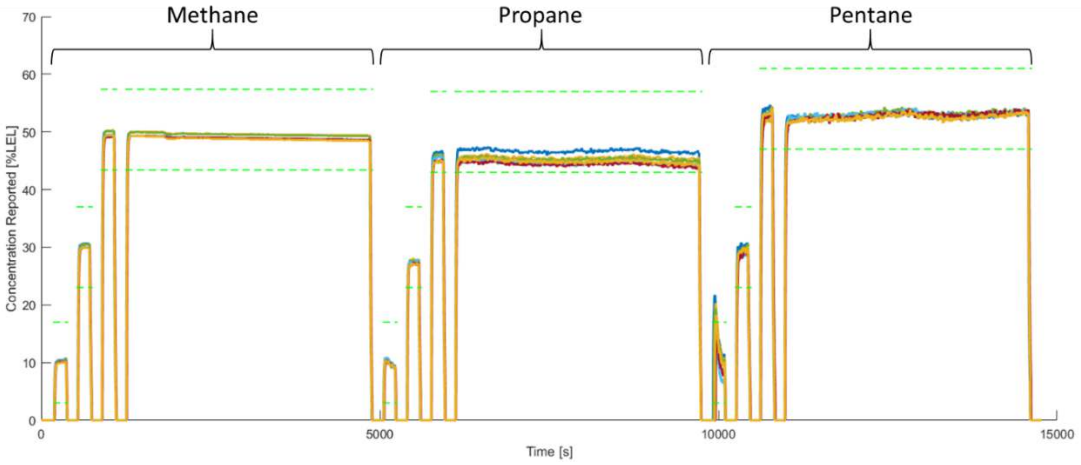


Figure 8: Concentration output of six MPS sensors during response to different gases test

Stability, Short Term, IEC 5.4.4.2

10/10 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 10

Temperature: Constant 20 °C

Humidity: Constant 50 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Exposure #	1	2	3	4	5	6
Max Reported [%LEL]	51.1	51.2	51.4	51.0	51.1	51.2
Min Reported [%LEL]	48.9	49.0	49.1	49.0	49.1	49.2

Procedure

Ten MPS sensors were attached in series per test setup #1. Initially, the environmental chamber was set to 20 °C, 50 %RH, with zero air flowing over the sensors. The sensors were exposed to 50 %LEL methane in a balance of zero air for three minutes with seven minutes of zero air between. This procedure was repeated for a total of six exposures.

Results

Figure 9 shows the concentration reported by 10 MPS sensors. IEC 5.4.4.2 requires the concentration reported to be accurate within ±5 %LEL for all exposures. These allowable errors are indicated by dashed green lines. All MPS sensors report within the IEC specification limits.

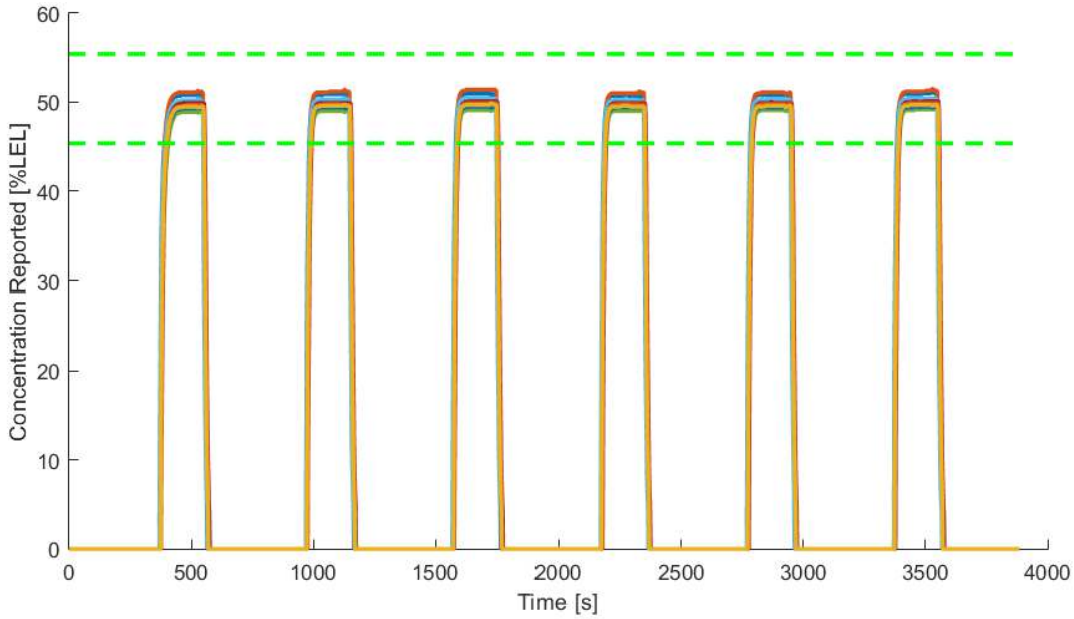


Figure 9: Concentration output of 10 MPS sensors during short term stability test

Orientation, IEC 5.4.11

1/1 Sensor PASSED

Test Details

Test Setup: #4 Benchtop

 # Sensors: 1

Temperature: Ambient ~20 °C

Humidity: Ambient ~20 %RH

Flow rate: 300 mL/min

MPS Sensor Performance

Orientation #	1	2	3	4	5	6
Max Reported [%LEL]	50.5	50.5	50.5	50.5	50.5	50.4
Min Reported [%LEL]	50.5	50.4	50.4	50.4	50.4	50.4

Procedure

One MPS sensor was attached to test setup #4. Initially, zero air was flowing over the sensor, with the sensor facing up from the table. The sensor was exposed to 50 %LEL methane in a balance of zero air for 30 minutes. During this exposure, the sensor was rotated 90 degrees every 4 minutes, in both the x and y-axis, until all 6 independent orientations were achieved.

Results

Figure 10 shows the concentration reported by one MPS sensor. IEC 5.4.11 requires the concentration reported to be accurate within ±5 %LEL for all orientations. These allowable errors are indicated by dashed green lines. The MPS sensor reports within the IEC specification limits and is virtually unaffected by orientation.

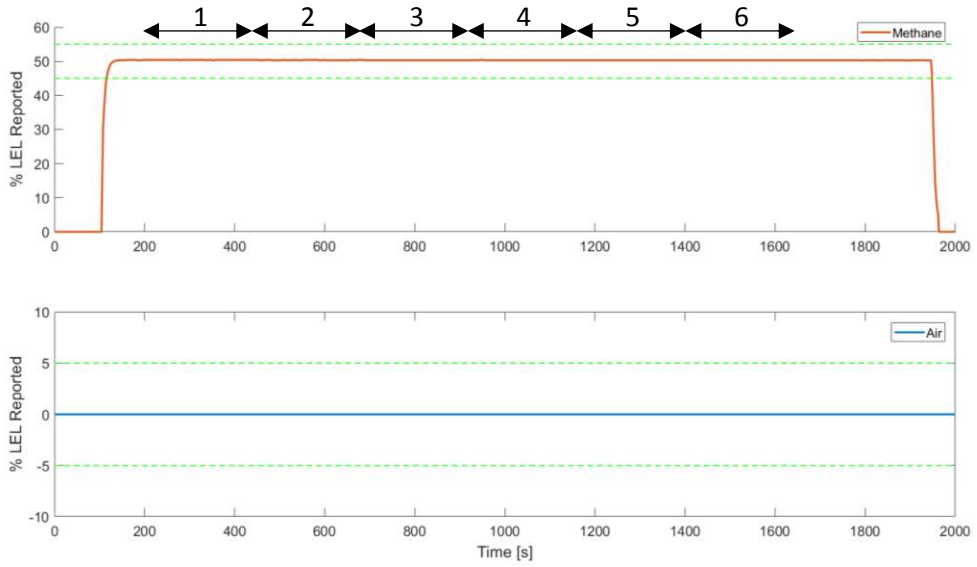


Figure 10: Concentration output of one MPS sensor during orientation test

Time of Response (Decreasing), IEC 5.4.15

10/10 Sensors PASSED

Test Details

Test Setup: #2 Step Change Response

 # Sensors: 10

Temperature: Ambient ~20 °C

Humidity: Ambient ~20 %RH

Flow rate: 400 mL/min

MPS Sensor Performance

	t50	t10
Max Time [s]	7.7	16.5
Min Time [s]	5.8	15.6

Procedure

One MPS sensor was placed under an ABS pipe containing zero air for two minutes, ensuring homogenous gas concentration over the sensor. The sensor was then powered and allowed to stabilize for 50 seconds. The pipe containing zero air was removed, and the pipe containing 50 %LEL methane was placed over the sensor. Once stability was reached, the methane pipe was removed. This test was repeated with 10 MPS sensors.

Results

Figure 11 shows the concentrations reported by the MPS sensors once the pipe was removed. (Note: the test was conducted ten times with ten different sensors, and the results overlaid in the graph.) The green dotted lines represent 50 and 10% of the applied gas concentration. IEC 5.4.15 requires that t50 and t10 (the duration of time the sensor takes before reporting at least 50 and 10% of the applied concentration) must be 10 and 30 seconds, respectively, as highlighted by the vertical magenta lines. The t50 and t10 of the MPS sensors were 5.8-7.7 and 15.6-16.5 seconds, respectively, nearly twice as fast as required.

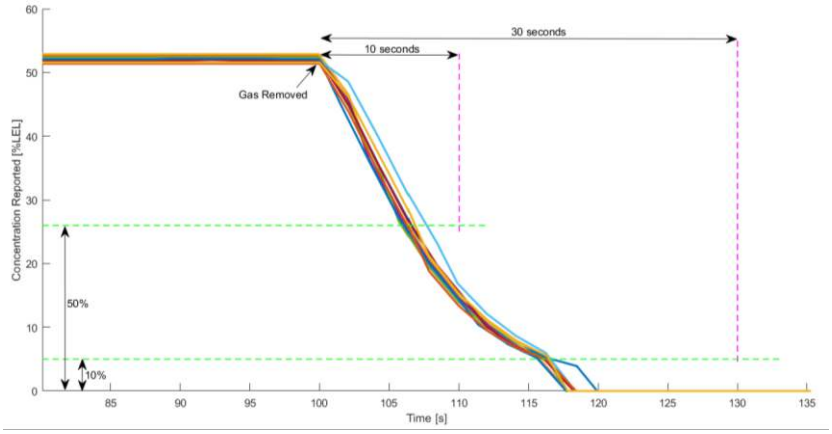


Figure 11: Concentration output of 10 MPS sensors during time of response test

High Gas Concentration, IEC 5.4.16

2/2 Sensor PASSED

Test Details

Test Setup: #4 Benchtop

 # Sensors: 2

Temperature: Ambient ~20 °C

Humidity: Ambient ~20 %RH

Flow rate: 300 mL/min

Procedure

Two MPS sensors were attached to the gas cylinders per test setup #4, with zero air flowing over them. The sensors were exposed to 100 %volume methane for 8 hours. After the eight hours, zero air was flowed over the sensors for 20 minutes.

Results

Figure 12 shows the concentration reported by two MPS sensors. IEC 5.4.16 requires the sensor to report full scale (100 %LEL) during the exposure, and report within ±7 %LEL following the exposure, when test gas is removed. The allowable baseline error is indicated by the dashed green line. The MPS sensors report within the IEC specification limits for both of these requirements and do not report an offset in reading after exposure to 100 %v/v methane.

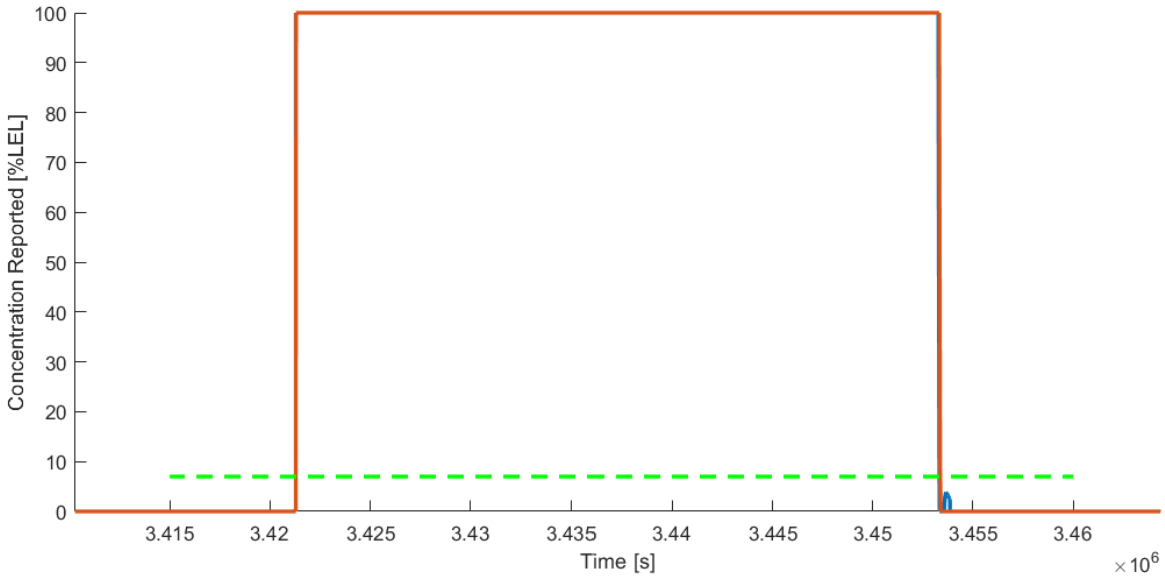


Figure 12: Concentration output of two MPS sensors during high gas concentration test