NevadaNano

Digital Scent for the Internet of Things

MPS™ Flammable Gas Sensor

Performance in Canadian Standard Association (CSA) test protocols

CSA specification: C22.2 No. 152-M1984 (Reaffirmed 2016)

Testing conducted internally by NevadaNano

November 2018

NevadaNano

Molecular Property Spectrometer™
MPS™ Flammable Gas Sensor

Canadian Standard Association Methane Performance Test

Canadian Standard Association (CSA) methane performance test standards are a generally accepted method of testing and certifying the performance of a flammable gas detector system. The purpose of CSA tests is to insure that a flammable gas detector, and the sensor mounted in the detector, accurately, reliably, and repeatedly measures methane concentrations in a wide variety of environmental, flow, and other conditions.

In this report, NevadaNano has performed the methane measurement tests from CSA Specification C22.2 No. 152-M1984 (Reaffirmed 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 CSA Standard.

We are pleased to report that the MPS Flammable Gas Sensor passed all relevant methane measurement tests and we consider the MPS Flammable Gas Sensor to be "CSA Ready" or suitable for integration into any flammable gas detection system intended for reliable detection of methane and other flammable gases.

Test Setup Descriptions

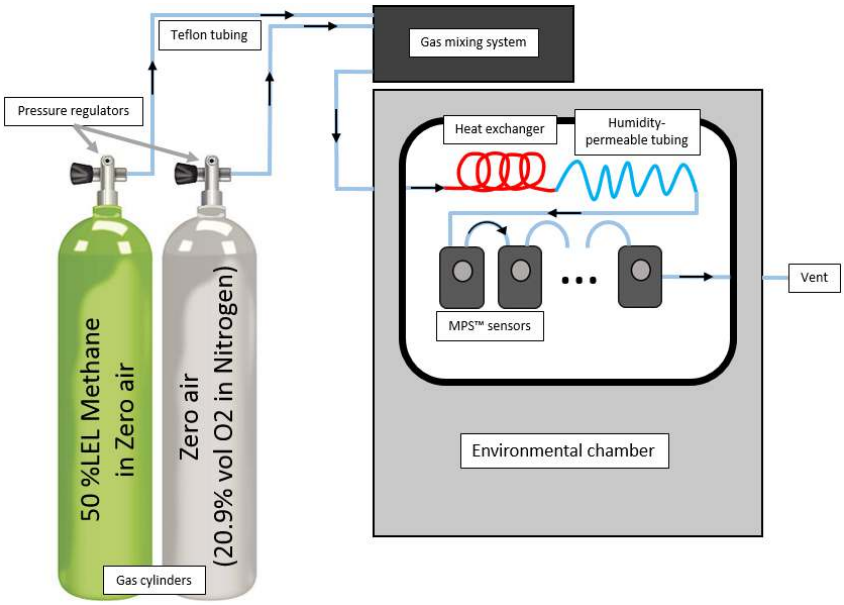
Three main test setups were used in order to perform all the required testing and are described in this section. All test setups use two regulated gas cylinders: zero air (20.9 %volume oxygen in nitrogen), and 50 %LEL methane in a balance of zero air. During testing, the sensors were connected via USB to a computer that performed all of the data collection.

Setup #1: Environmental Chamber Test Setup

Applicable CSA Tests

Temperature Variation: 6.12.1 & 6.12.2, Humidity Variation: 6.13.1, Accuracy Test: 6.15

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 temperature and relative humidity inside the chamber. Gas then flows serially through each of the MPS sensors and out an exhaust tube to vent. The environmental chamber is programmed with specific 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, flowing continuously throughout the tests.

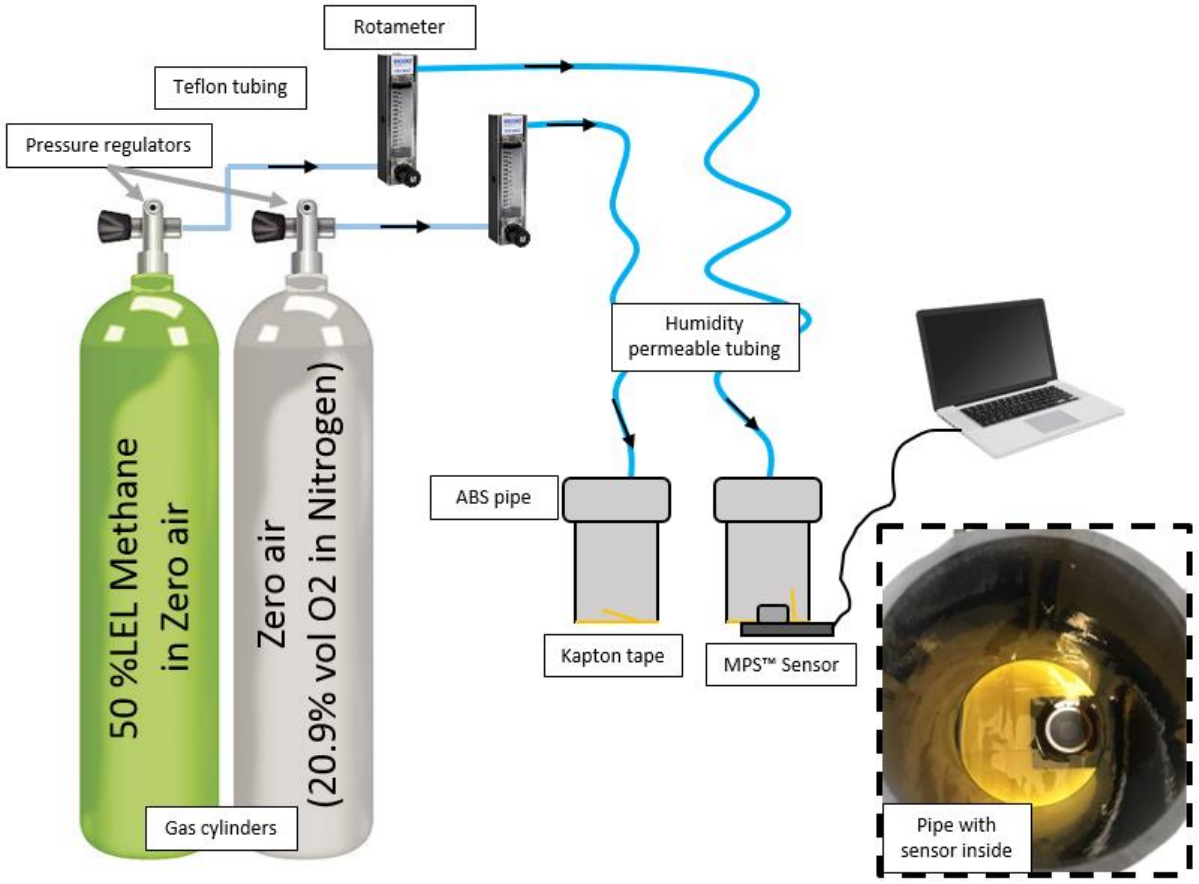
[1] https://www.permapure.com/products/nafion-tubing/nafion-dryer-performance-and-selectivity/

Setup #2: Step Change Response Test Setup

Applicable CSA Tests

Step Change Response: 6.9

Diagram of Setup



Description

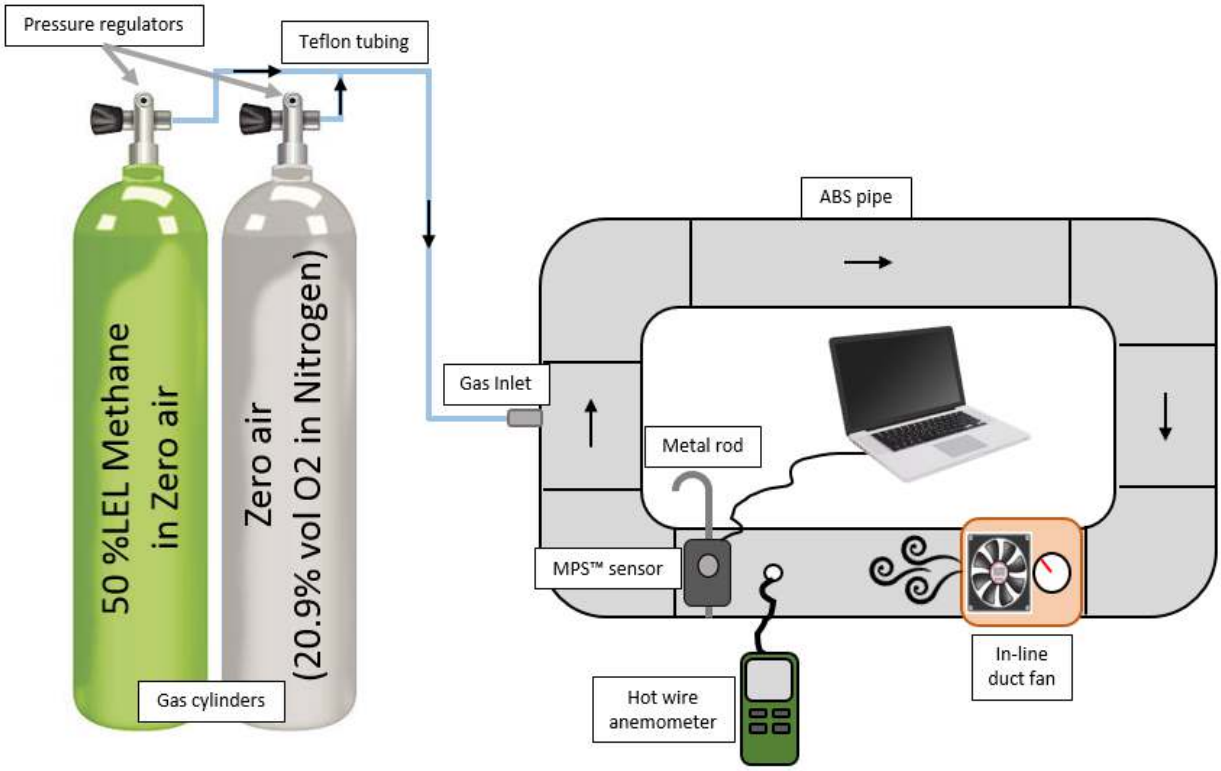
Regulated gas cylinders are connected individually via rotameters and humidity-permeable tubing to sealed ABS pipe sections. The pipe sections are approximately 6-inches tall and 4-inches in diameter. The rotameters enable flow control, while the Nafion™ tubing humidifies the gas streams. The upper portion 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 CSA Tests

Air Velocity: 6.14

Diagram of Setup



Description

Regulated gas cylinders are plumbed to a sealed, 4-inch 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.

Test Results

Step Change Response, CSA 6.9

10/10 Sensors PASSED

Test Details

Test Setup: #2 Step Change Response

 # Sensors: 10

Temperature: Ambient (~25 °C)

Humidity: Ambient (~15 %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.

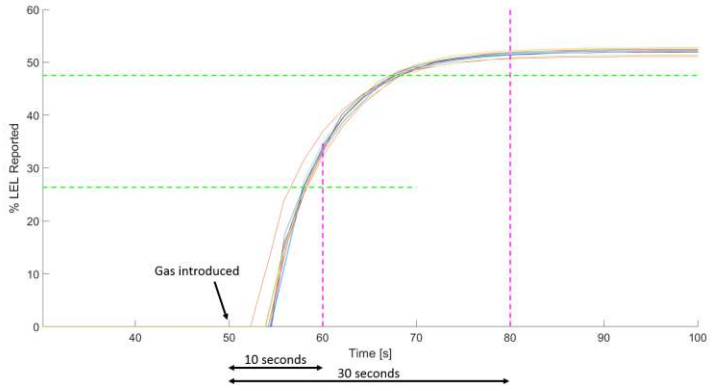


Figure 1: Concentration output of 10 MPS sensors during step change response test

Molecular Property Spectrometer™
MPS™ Flammable Gas Sensor

Temperature Variation Part 1, CSA 6.12.1

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

10 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 spec bounds.

a)

b)

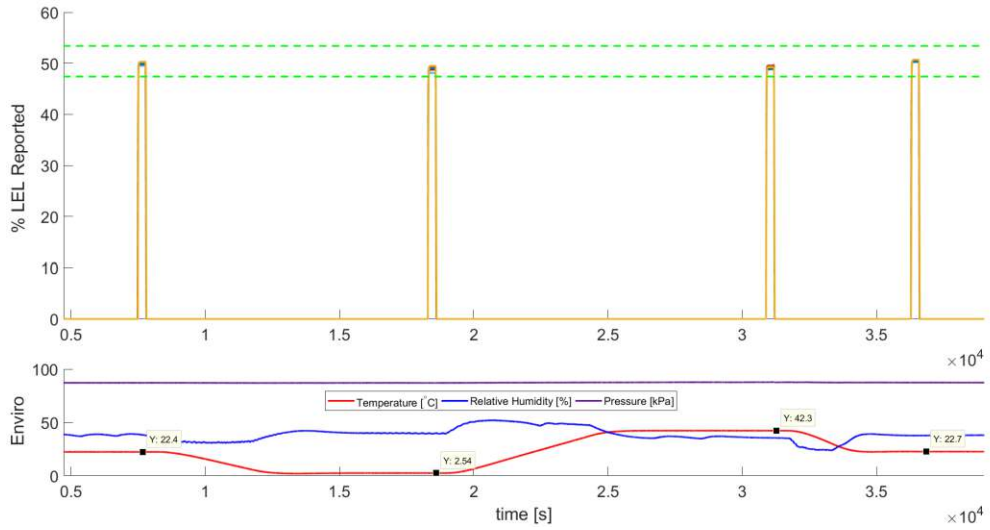


Figure 2: a) Concentration reported by 10 MPS sensors and b) environmental measurements during temperature variation part 1 test

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Molecular Property Spectrometer™ MPS™ Flammable Gas Sensor

Temperature Variation Part 2, CSA 6.12.2

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

10 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 control held constant at 50 %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 spec and remain within ±3 %LEL for all exposures.

a)

b)

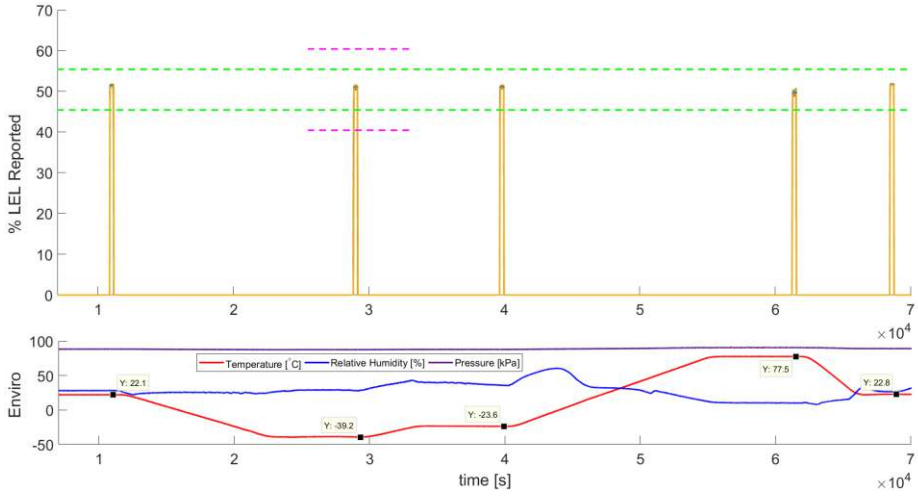

Figure 3: a) Concentration reported by 10 MPS sensors and b) environmental measurements during temperature variation part 2 test

Humidity Variation, CSA 6.13.1

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

10 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 spec bounds.

a)

b)

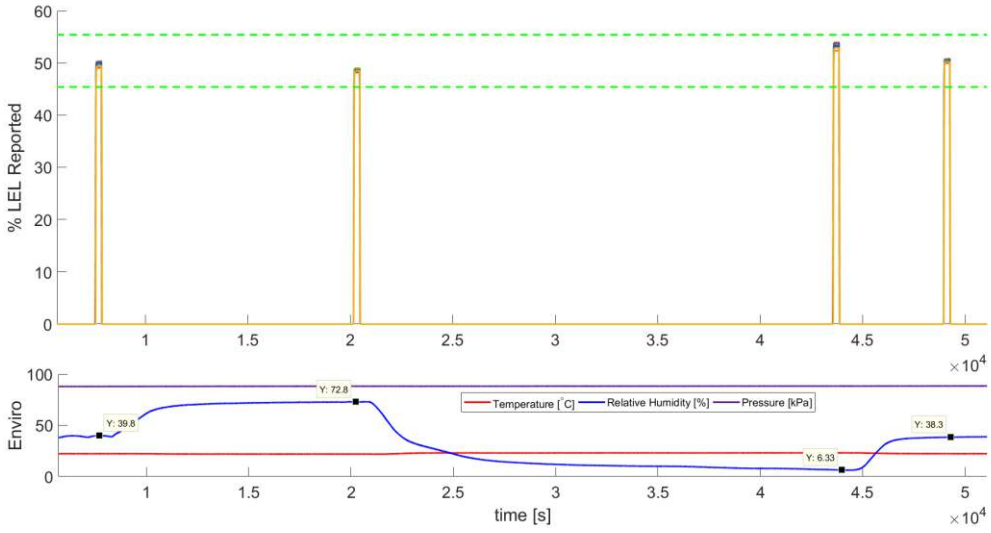

Figure 4: a) Concentration reported by 10 MPS sensors and b) environmental measurements during humidity variation test

Air Velocity Test, CSA 6.14

2/2 Sensors PASSED

Test Details

Test Setup: #3 Air Velocity

 # Sensors: 2

Temperature: Ambient (~25 °C)

Humidity: Dry (~5 %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 5a shows the concentrations reported by two MPS sensors during the testing, with corresponding environmental data shown in Figure 5b. 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.

a)

b)

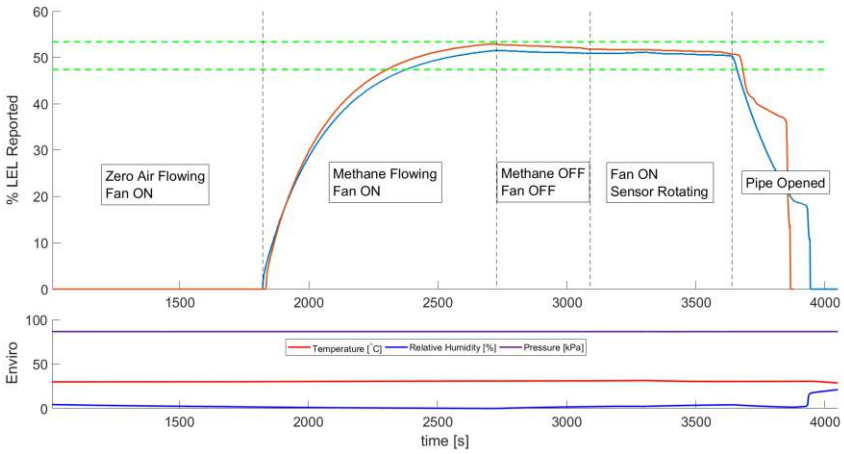

Figure 5: a) Concentration reported by two MPS sensors and b) environmental measurements during air velocity test

Accuracy Test, CSA 6.15

8/8 Sensors PASSED

Test Details

Test Setup: #1 Environmental Chamber

 # Sensors: 8

Temperature: Constant 20 °C

Humidity: Various (see figure below)

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 set 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 reverse from 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.)

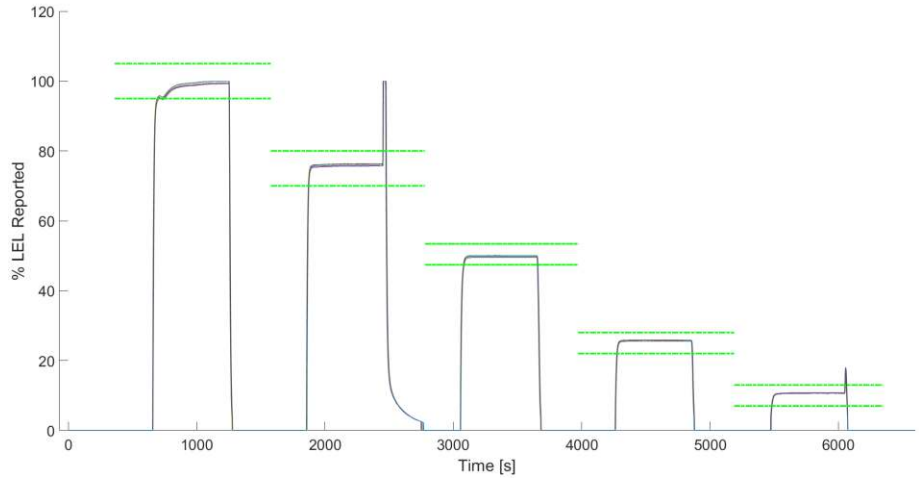

Figure 6: Concentration output of eight MPS sensors during accuracy test