



MOLECULAR PROPERTY SPECTROMETER™ (MPS™) FLAMMABLE GAS SENSOR EVALUATION UNIT USER MANUAL

NNTS Proprietary Information

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Notices

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Contents

| | | |
|------|---|----|
| 1. | System Overview | 3 |
| 1.1. | Evaluation Kit Contents | 3 |
| 2. | Setup and Test | 4 |
| 2.1. | Proper use of laboratory gases | 4 |
| 2.2. | System Setup | 5 |
| 2.3. | System Operation..... | 8 |
| 2.4. | Conducting a Gas Test | 9 |
| 2.5. | System Shutdown | 10 |
| 3. | Data Collection and Analysis | 11 |
| 3.1. | Adding Test Notes | 12 |
| 3.2. | Saving Data..... | 13 |
| 4. | General Guidelines | 14 |
| 5. | Definitions | 14 |
| | Appendix A: Alternative Communication Configuration | 15 |

1. System Overview

The Molecular Property Spectrometer™ (MPS™) Flammable Gas Sensor Evaluation Unit is a user-friendly sensor system developed for assessing flammable gas detection performance. The evaluation system is shown in Figure 1. The sensor is 20.0 \varnothing x 16.6 mm with 1.52 mm diameter connector pins and connects to a provided evaluation PCB for communication with a PC (USB) or breakout to individual sensor signals (optional 5-wire harness). The sensor contains the MPS sensing element, environmental sensor, microprocessor, and supporting electronics. A quarter-turn plastic gas mask and housing is included to provide a sealed headspace above the sensor for test gas delivery.

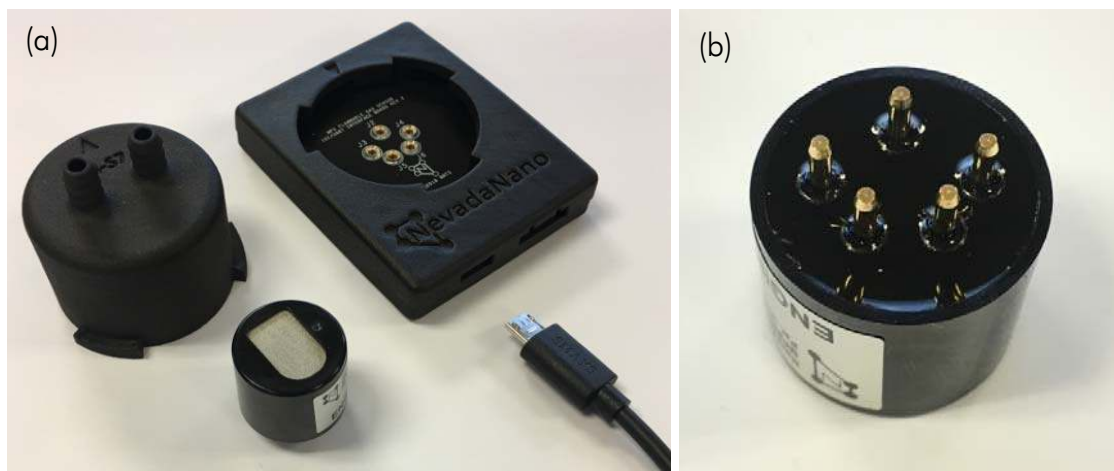


Figure 1 - (a) MPS™ S4 Flammable Gas Sensor, PCB with housing, gas-delivery mask, and USB A-to-micro-B cable. (b) Sensor bottom-side detail.

1.1. Evaluation Kit Contents

The complete MPS™ Flammable Gas Sensor Evaluation Unit kit consists of:

- MPS™ Sensor Interface Software and Drivers
- Evaluation PCB + housing
- Gas delivery mask with integrated barbs
- USB A-to-micro-B cable
- 1/4" Tygon tubing (McMaster: 6516T17)
- Micro USB plug (not shown--optional)
- MPS™ S4 Flammable Gas Sensor (sold separately)

2. Setup and Test

2.1. Proper use of laboratory gases

The MPS Flammable Gas Sensor is capable of sensing the composition of the air. During operation, all composition variations due to environmental factors (temperature, pressure, and humidity) are automatically compensated out in order to report accurate gas concentration readings. The sensor, however, cannot compensate out the effects of massive, instantaneous changes to the constituent fractions of, for example, nitrogen, oxygen, or argon in the air. Such changes are extremely unlikely, if not impossible, in the real world; they can however easily occur when switching between different compressed gas tanks.

To adequately simulate the real-world application (Figure 2a) in a laboratory test environment, the same type of “air” must be used as the carrier for both the “air-only” condition and the “air + flammable gas” condition. This methodology must be maintained throughout the test. An example of a proper protocol is shown in Figure 2b. Examples of incorrect (non-“real-world”) gas delivery protocols are shown in Figure 2c and Figure 2d. In these cases, the analyte carrier gas is not the same as the baseline gas. Using a variation of the “incorrect” procedure will introduce a bias or offset into the MPS’ measurements of analytes (just as, for example, testing a catalytic-bead type sensor using nitrogen as the carrier “air” would—since, in that case, the catalyst requires oxygen to work.)

The *best practice for performance testing* in a laboratory is to use a humidified, zero-air background, followed by a switch to a humidified analyte stream with the same zero-air composition serving as the balance gas, then a switch back to humidified zero-air to clear the test chamber. This best mimics real-world scenarios.

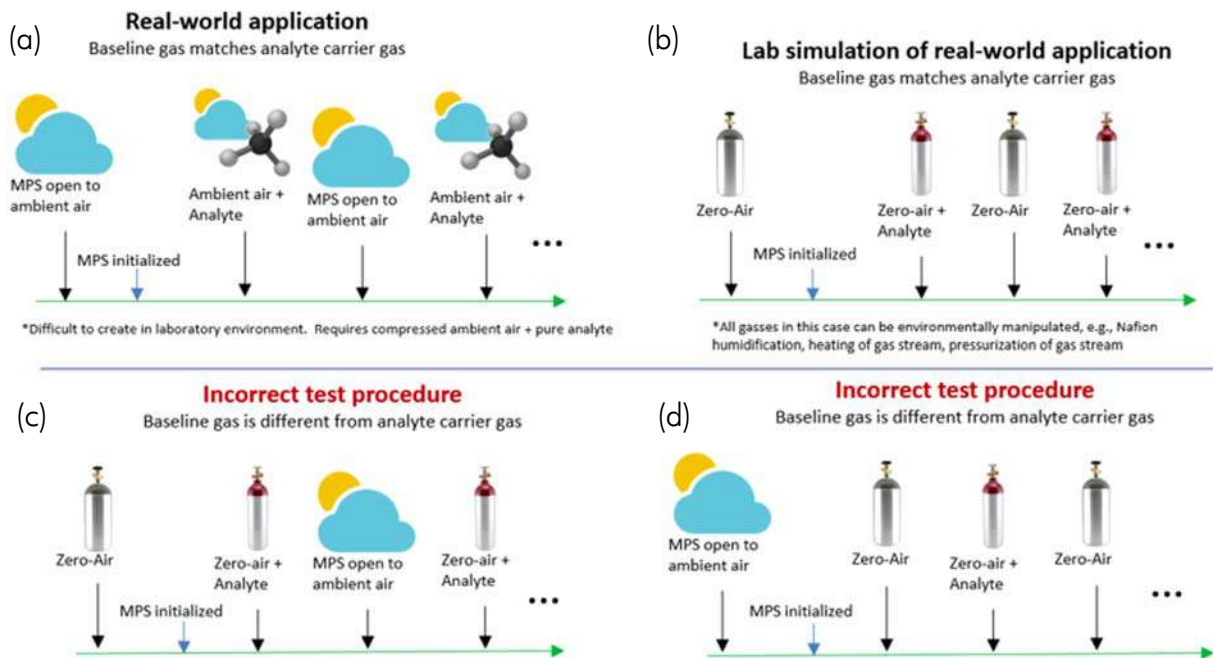


Figure 2 – (a) The real-world flammable gas leak scenario. (b) The method for simulating the real-world scenario in a laboratory. Incorrect test procedures are shown in (c) and (d); in these cases, the carrier-only condition does not use the same “air” as the carrier + flammable gas condition, causing inaccurate results.

2.2. System Setup

The MPS™ Flammable Gas Sensor Evaluation Unit receives power and interfaces either with a PC via USB (default configuration for evaluation) or by using the UART protocol through a 5-wire harness (see Appendix A for more details regarding UART operation and setup). The user interacts with the sensor while using the MPS™ Sensor Interface Software. With this application, the user can:

- establish communication with the sensor to start, pause, and end evaluation tests
- examine data in real-time
- record test notes
- save data to .csv file

The MPS™ Sensor Interface, accompanying drivers, and Firmware Upgrade Instructions are available at: <https://nevadanano.com/downloads/>

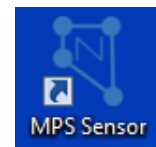
The user should first install the FTDI Driver, followed by a system restart, and then install the MPS™ Sensor Interface Software. The setup procedure follows:

1. It is recommended that the computer used to operate the MPS sensor be powered on prior to plugging the sensor in, since the MPS receives its power from the computer. Interruption in power to the sensor will result in a sensor fault.
2. Connect the micro-USB cable to the MPS, then connect the opposite end of the USB cable to a USB port on the computer. The MPS will automatically receive power from the computer.
3. Using the supplied ¼ -in tubing, connect the test gas system to one of the integrated barbed connectors on the MPS gas mask.
 - Test gas should be supplied to the sensor at rates no greater than 300 mL/min.
 - The use of Nafion¹ tubing is recommended to humidify the test gas stream.
4. Attach the gas mask to the housing by aligning the arrow on the gas mask at the 10 o'clock position and inserting the three tabs into the housing. Turn the mask clockwise until the arrows on the housing and mask align and the mask “clicks” into place. The barbs will be aligned across the horizontal axis of the housing.



Figure 3 – Proper gas mask attachment is achieved when the arrow points align and the barbs are in the horizontal position.

5. Open the MPS Sensor Interface application from the desktop icon:



¹ For more information on Nafion, including its permeability for various gases, refer to:
<http://www.permapure.com/products/nafion-tubing/>

- Click the “Find MPS Devices” button and select the MPS Flammable Gas Sensor connected to the computer (Figure 4). The sensor name is found on the sensor serial number in the form: Bxxxxxxx.

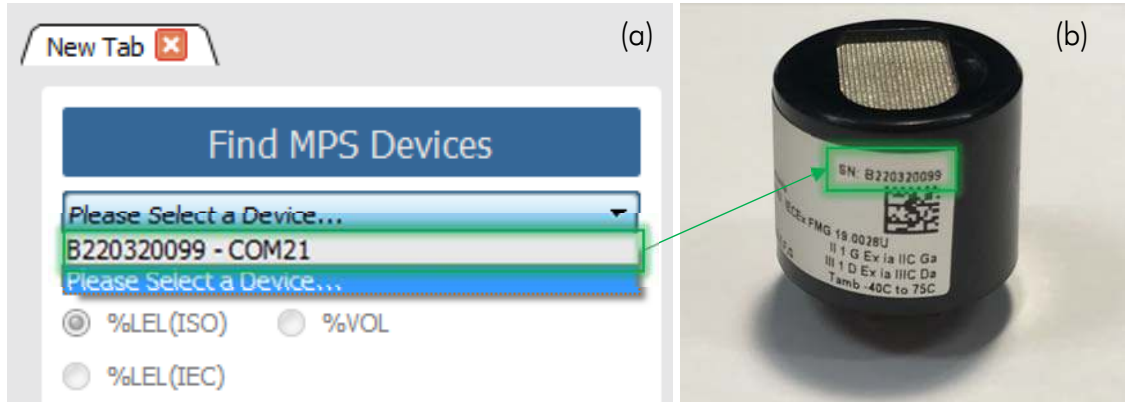


Figure 4 – (a) Selecting the active MPS™ Flammable Gas Sensor. (b) Device serial number

- The MPS sensor is now ready for testing. Proceed to System Operation, and read thoroughly before continuing.

2.3. System Operation

A typical benchtop test setup is shown in Figure 5. A calibrated gas cylinder (e.g., zero-air, 50 %LEL methane in air) supplies gas from a 300-mL/min regulator via Nafion tubing to the gas mask. An example of a suitable regulator is a 70-series fixed-flow regulator, which is compatible with 34, 58, 74, 103 and 116-Liter aluminum cylinders as well as 103-Liter steel cylinders. Flow can be stopped by removing the regulator or closing the black knob. The Nafion tubing humidifies the analyte gas stream to ambient humidity levels without appreciable loss of analyte. The experimental test area should have adequate ventilation to avoid exposure of gases to the user. An additional zero-air gas cylinder should be applied to the sensor when analyte gas is not flowed.

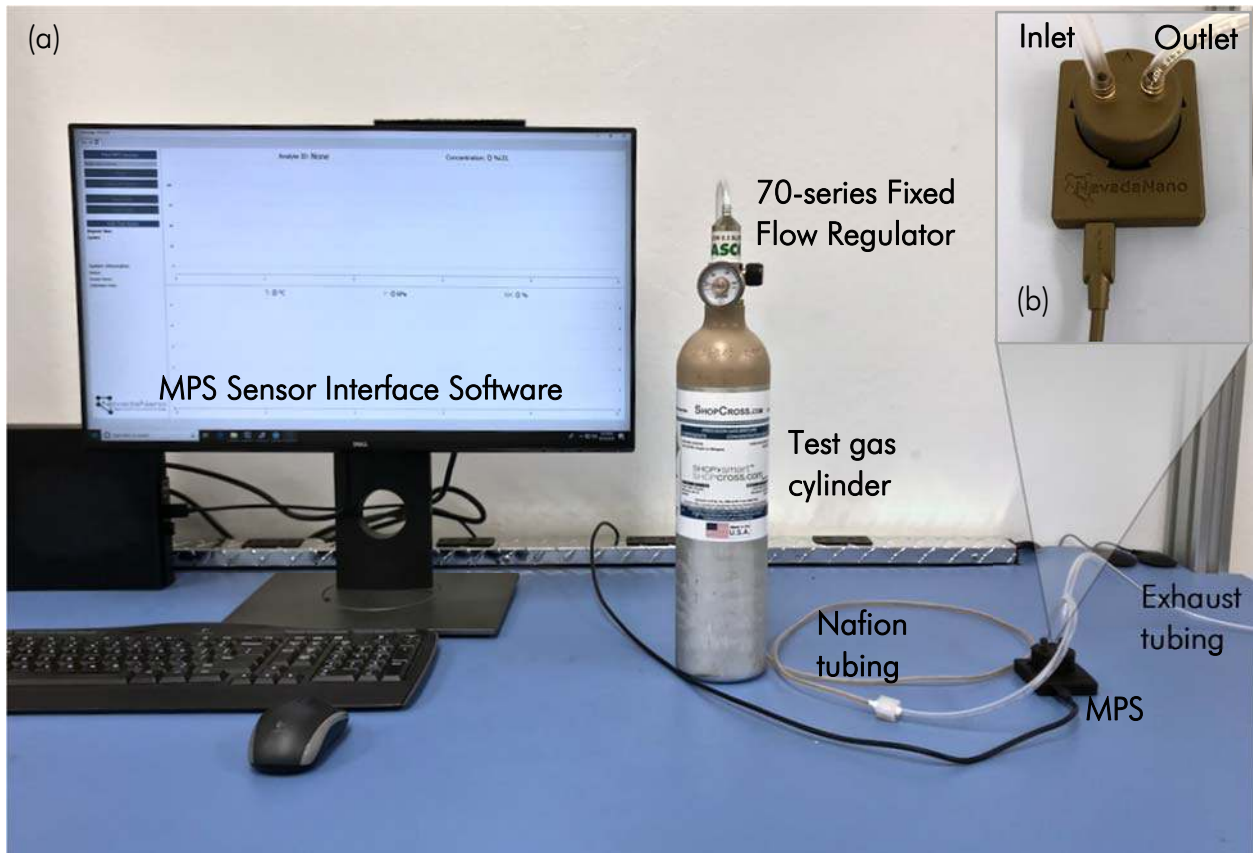


Figure 5 – (a) Typical benchtop test setup. (b) Detail gas and PC connections.

2.4. Conducting a Gas Test

1. After performing system setup, the concentration unit selector and start button will be enabled (highlighted in green in Figure 6). **IMPORTANT:** Start the flow of zero-air baseline gas over the MPS Flammable Gas Sensor and wait ~1 minute for baseline gas to replace ambient air before proceeding. Select the desired concentration unit (%LEL(ISO), %LEL(IEC)², or %VOL) and click Start to begin data acquisition. Once the test starts, the concentration unit cannot be changed until the test finishes.

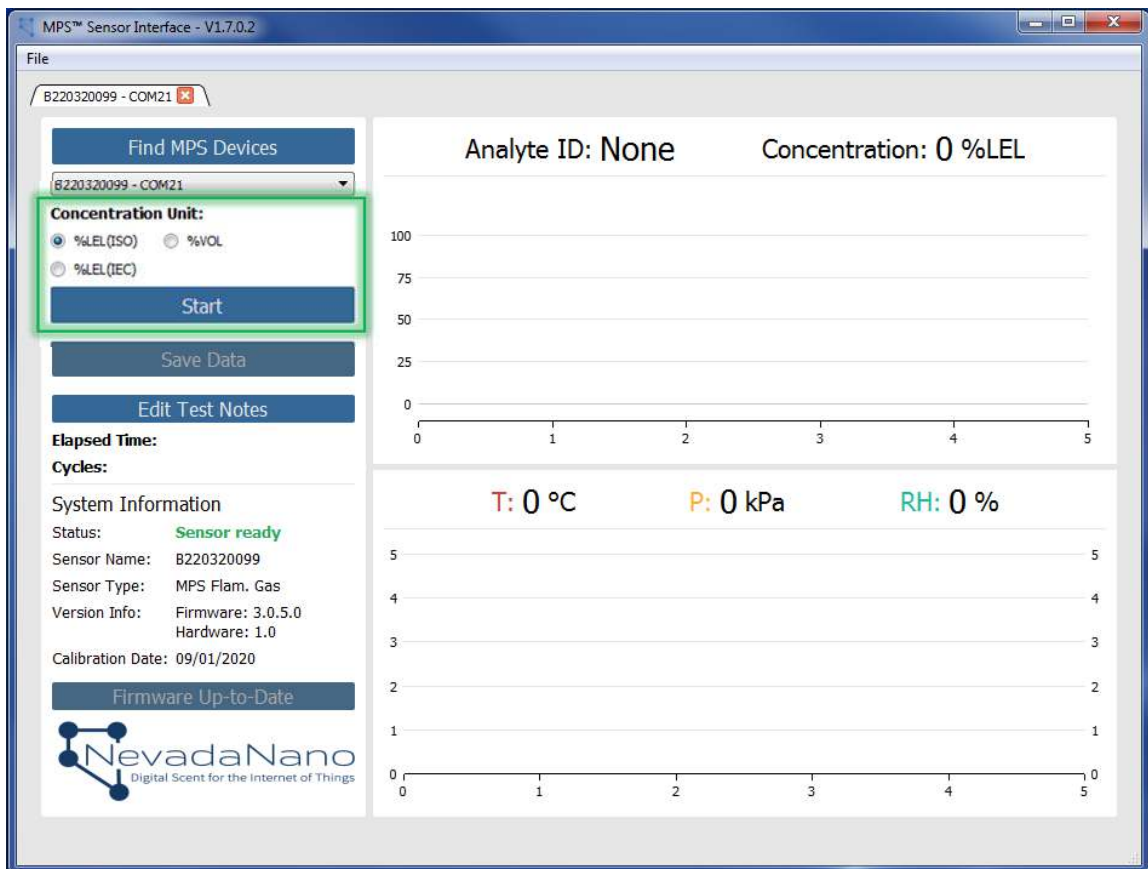


Figure 6 – MPS™ Flammable Gas Sensor Evaluation Software ready for testing. Sensor name is populated and start button is enabled.

2. The unit will acquire 10 baseline readings (Figure 7, highlighted in green). After this stabilization period, the sensor is ready for testing.

² %LEL(IEC) is available starting with version 3.0.5.0

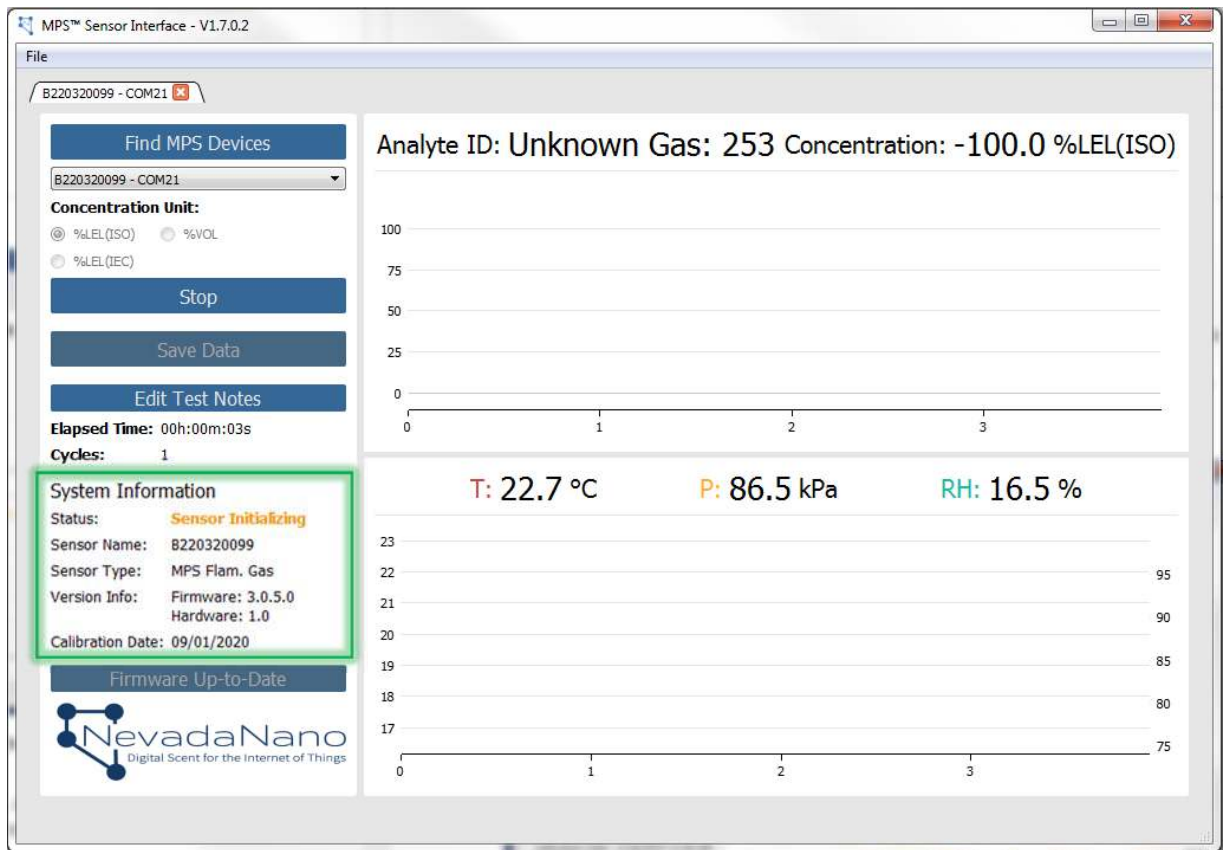


Figure 7 – Acquiring sensor environmental baselines at the beginning of a test.

3. Next, apply a test gas cylinder and note the results. A stable gas reading should be displayed within 30 seconds of applying a test cylinder as the supplied gas mask equilibrates with the tank concentration.
4. After removing the test gas cylinder, reconnect to a zero air cylinder to purge the test gas and continue to maintain a stable environment.
5. Repeat steps 3, 4 as needed to test various gasses and concentrations. When analyte is not tested, it is important to keep the baseline/zero-gas flowing as the MPS smart-algorithms will periodically record baselines.

2.5. System Shutdown

The MPS™ Flammable Gas Sensor must be in an idle state before shutdown. Pause the current test and wait for the system status dialogue to display "Idle", then save or clear the data. The USB cable can now be disconnected.

3. Data Collection and Analysis

During a test, the system generates a new data point every 2 seconds. Data can be visualized on the MPS™ Sensor Interface Software in real time throughout a test. Graphs can be resized and zoomed in and out while data are being collected. An example screenshot is shown in Figure 8. Graphs can be reset to auto-scale by double clicking on the desired axis.

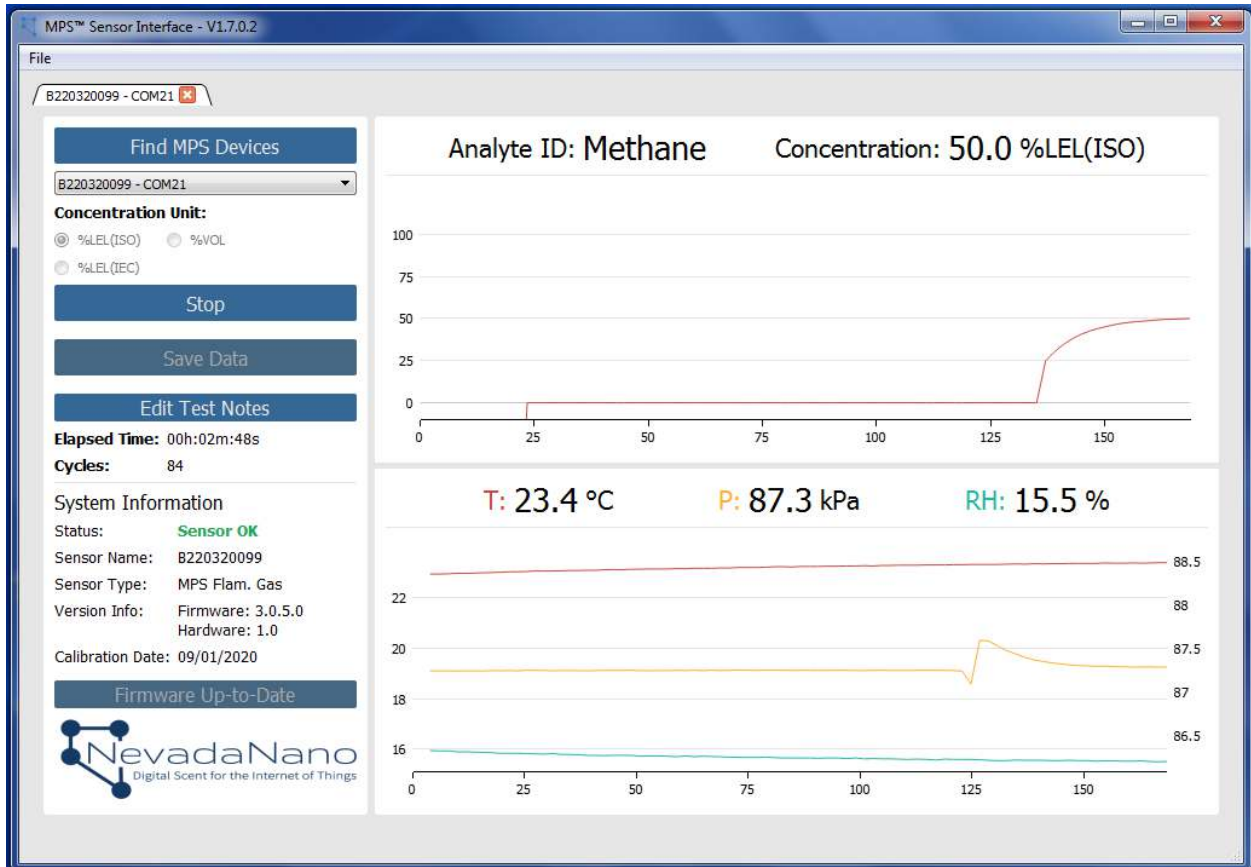


Figure 8 – MPS™ Flammable Gas Sensor Evaluation Unit during testing.

3.1. Adding Test Notes

The user must enter test notes by clicking the “Edit Test Notes” button highlighted in green in Figure 9 any time prior to saving data. A set of example test notes is shown below.

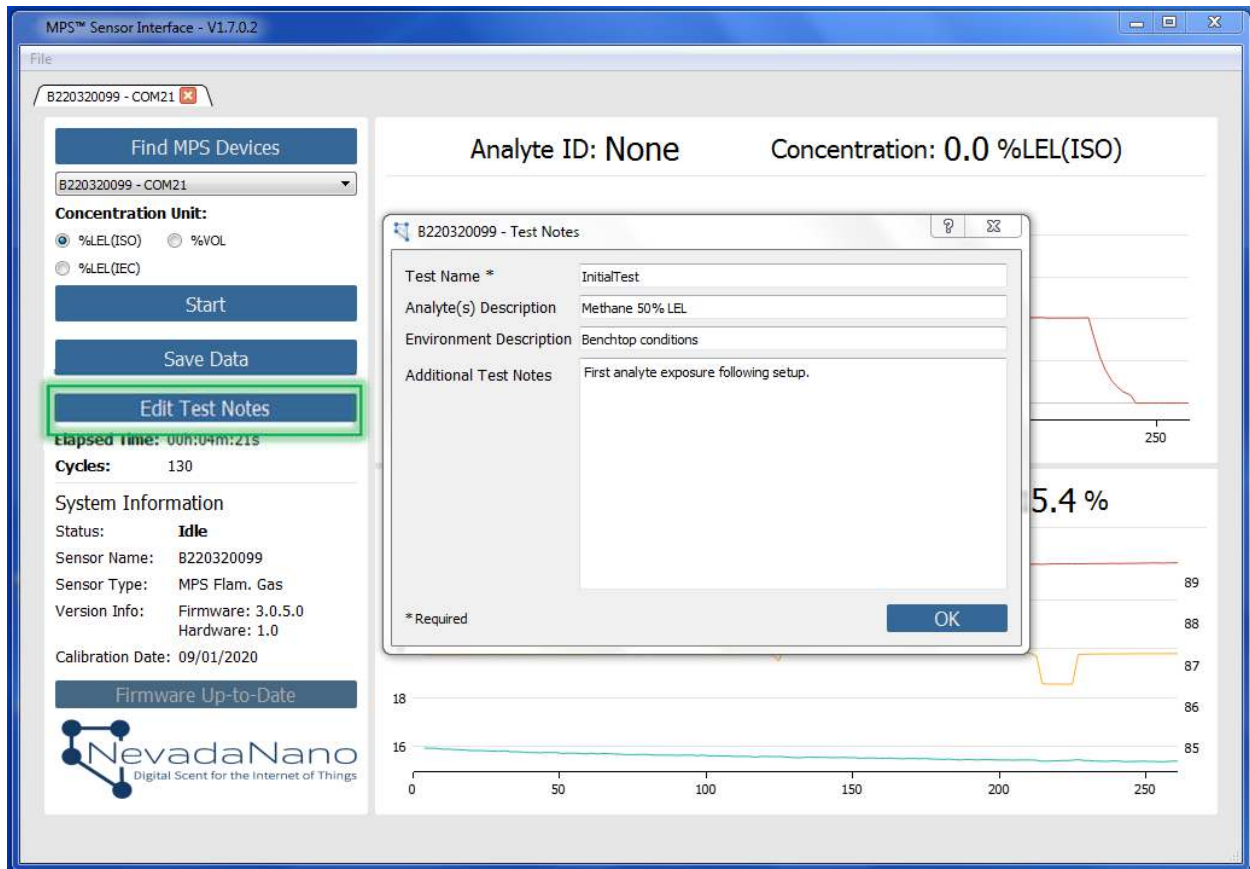


Figure 9 – Example test notes dialogue box.

After entering the experimental test notes, click “Save Data”. A dialogue box will appear to prompt the user to select a directory for saved test data. After saving, the user can now clear the data and begin another test by clicking ‘x’ on the tab and going to File->New.

3.2. Saving Data

Throughout a test, data are continuously updated and stored in a temporary directory. Once a test is complete, data can be saved to a drive location specified by the user. The folder created in this step is named using the following format:

Year_Month_Day-Time **SensorName**_testName

Here is an example:

2019_07_24-173313 **B220320099**_InitialTest

Avoid using hyphen and special characters (- , \ , / , % , &) when saving data.

The data folder will contain:

1. **timelog.txt** – This file provides the start, pause, re-start, and end times of a test. Here is an example:
 2019_07_24 - 17_22_10: Started
 2019_07_24 - 17_28_00: Stopped
 2019_07_24 - 17_33_13: Data saved
2. **mpsData.csv** – This is a comma-separated-value formatted file that contains all the data from the test, organized in columns:

| Time [s] | Cycle | T [C] | P [kPa] | RH [%] | Gas ID | Conc [%LEL] |
|----------|-------|-------|---------|--------|--------|-------------|
| | | | | | | |

3. **testNotes.txt** – This file provides a record of the test notes entered in the user dialogue box before saving.

4. General Guidelines

1. Follow all applicable lab safety procedures.
2. Using gas source concentrations below 100 %LEL (50 %LEL is common) will ensure that flammable conditions are not created in the test setup.
3. Lecture bottles with gas concentrations near 50 %LEL are commonly used for calibration of gas detection instruments in the field, and do not create unsafe (flammable) or unhealthy (toxic) gas conditions because the gases dilute quickly to safe concentrations when released into ambient air at 300 mL/min. Nonetheless, it's a good idea to ventilate the workspace, especially for prolonged tests. Implement a dilution/evacuation system to avoid exceeding the PEL.
4. Operate the unit within its specification ranges (temperature, pressure, concentration range, etc.).
5. The Nafion tubing is fragile. Avoid kinking or stressing the tubing to maintain adequate flow to the sensor.

5. Definitions

| Term | Definition |
|--------------------------------------|---|
| %LEL (Percent Lower Explosive Limit) | The percentage of the concentration at which a gas or vapor in air becomes capable of burning or exploding in the presence of an ignition source (e.g., arc, heat, flame). For example, 10 %LEL methane means ten percent of the concentration at which methane becomes flammable. (Methane becomes flammable at 5% by volume in air, so a sample measuring 10 %LEL would be 0.5% methane by volume, or 5,000 ppm methane). |
| PEL (Permissible Exposure Limit) | A legal limit on the amount or concentration of a substance in the air to which a person can be exposed. |
| %LEL (ISO) | The concentrations in accordance to the ISO 10156 standard. |
| %LEL (IEC) | The concentrations in accordance to IEC60079-20-1 and companion specification EN61779 |

Refer to the MPS Flammable Gas Sensor datasheet for more details and information at:
<https://nevadanano.com/downloads/>

Appendix A: Alternative Communication Configuration

An evaluation that requires direct communication to the MPS™ Flammable Gas Sensor via UART or I²C is shown in Figure 10. This configuration requires that the optional micro USB plug be inserted into the unused USB port when actively interfacing with the sensor via the 5-pin header located on the sensor PCB. The recommended 5-Pin mating connector has a Molex P/N: 0050579205. Please consult with NevadaNano regarding communication or system integration issues.



Figure 10 – Alternative communication configuration. The micro USB plug (a) is inserted prior to interfacing with the sensor via the 5-pin header (b)

Given the custom nature of this configuration, the following should be considered:

- Reversing the polarity of the input power will result in a damaged sensor
- Improper installation of the micro USB plug could result in interference on the communication line, corrupt or missing data, etc.
- The analog output of the sensor is available in all configuration scenarios

Table 1 details the pinout of the 5-pin header located on the MPS™ Flammable Gas Sensor evaluation PCB.

Table 1: 5-pin header pinout

| Pin Number | Function |
|------------|--------------------|
| 1 | GND |
| 2 | V+ (5.25V to 3.0V) |
| 3 | Sensor TX/SCL |
| 4 | Sensor RX/SDA |
| 5 | Analog Out |

