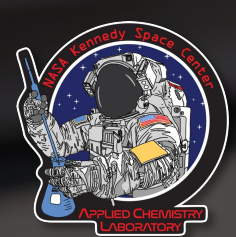




# **DEVELOPMENT OF THE VOLATILE MONITORING OXYGEN MEASUREMENT SYSTEM**

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# TEAM

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Resources)



# VOLATILE MONITORING OXYGEN MEASUREMENT SYSTEM

- Goal is to quantify oxygen and detect other volatiles
- Zirconium oxide oxygen sensor, Residual Gas Analyzer (RGA), and Gas Chromatography (GC)
- Best suited for technologies/research that requires gas detection or oxygen quantification
- Technology was developed at Kennedy Space Center by researchers in the Applied Chemistry (ACL) and Granular Mechanics Regolith Operation (GMRO) laboratories
- Tested on Molten Regolith Electrolysis (MRE) experiment (25 kg of regolith)

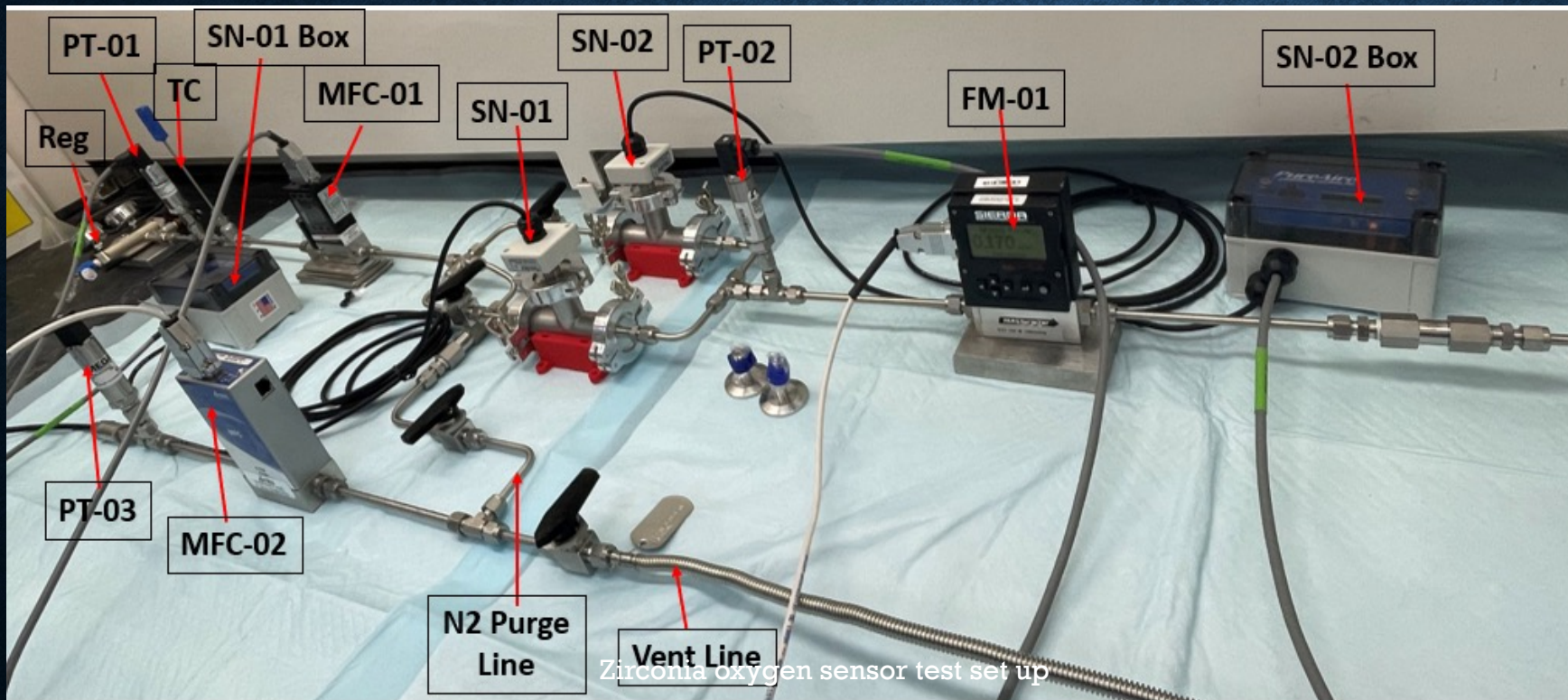




# OXYGEN SENSOR TEST

The Oxygen sensor experiment performed was to test two main aspects of VMOMS prior to the build

- Goal 1- verify oxygen quantification of the two range zirconium oxide sensors
- Goal 2 – verify the software user interface design for VMOMS



Abbreviations	Term
Reg	Regulator
PT	Pressure Transducer
TC	Thermocouple
SN	Sensor
MFC	Mass Flow Controller
FM	Flow Meter
N2	Nitrogen



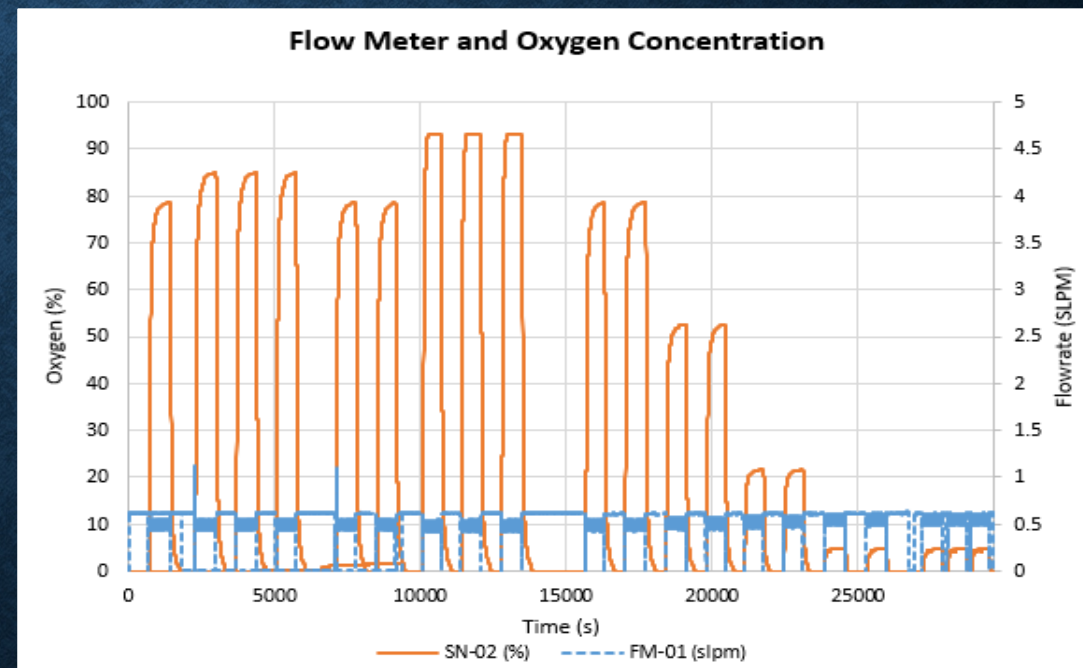
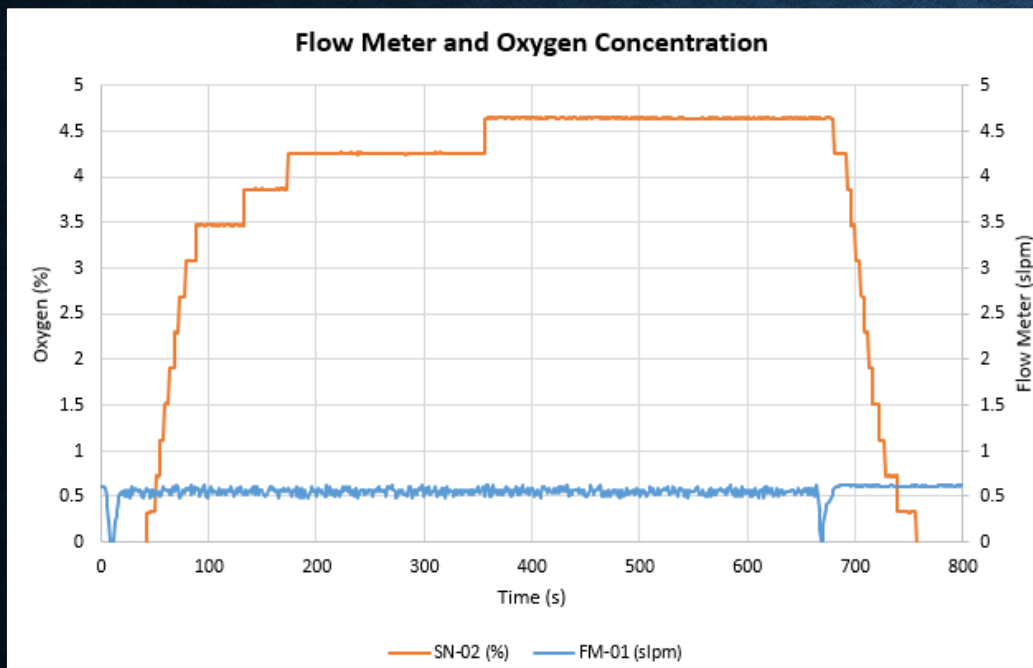
# OXYGEN SENSOR TEST

- 0 – 95 % O<sub>2</sub> sensor tested with
  - 1000 ppm O<sub>2</sub> (0.1%); 20.9% O<sub>2</sub>; 50% O<sub>2</sub>; 80% O<sub>2</sub>; and 99.999% O<sub>2</sub> with N<sub>2</sub> balance.
  - 5% O<sub>2</sub> / 5% CO<sub>2</sub> / 90% N<sub>2</sub>
  - 75% O<sub>2</sub> / 1% CO<sub>2</sub> / 24% N<sub>2</sub>
- 0 – 1000 ppm sensor tested with
  - 500 ppm O<sub>2</sub> with N<sub>2</sub> balance
  - 1000 ppm O<sub>2</sub> with N<sub>2</sub> balance
  - 20.9% O<sub>2</sub>/ 79.1% N<sub>2</sub>
- Bottles were run for 5 minutes and purged with N<sub>2</sub> for 5 minutes minimum each run at 0.5 SLPM



# OXYGEN SENSOR TEST RESULT

- 0 – 95% sensor passed the oxygen mixed gas test with (+/- 5% accuracy)
- 0 to 1000 ppm sensor was out of calibration (recalibration)
- LabVIEW was able to log data. “Take Notes” column was update



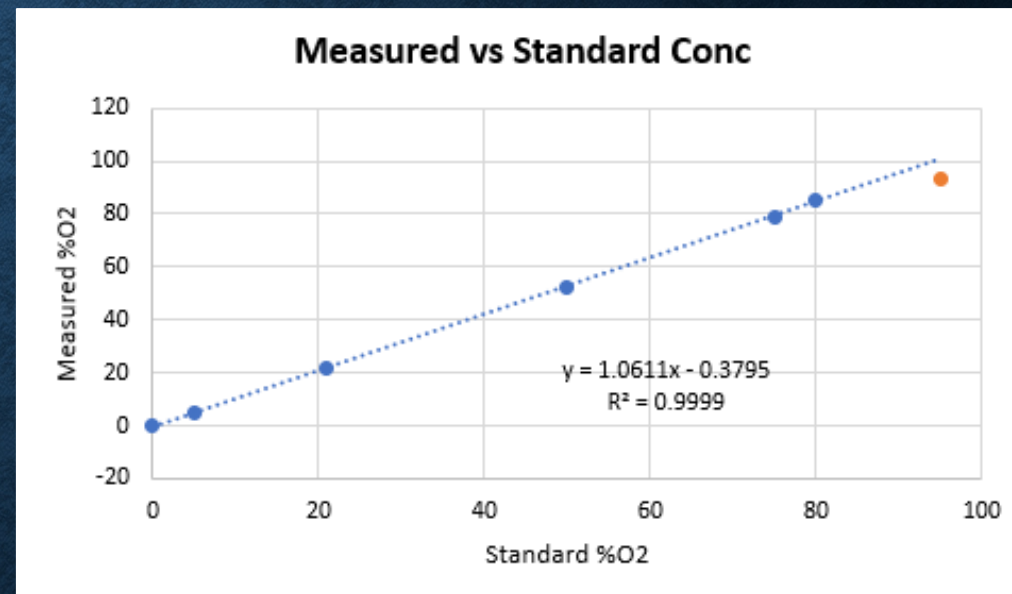


# OXYGEN SENSOR TEST RESULT

- Lessons learned from the test was incorporated in VMOMS full scale software (5 minutes sensor warm up, high range sensor does not detect between 0 – 0.2%, total of moles software caluclations)
- LabVIEW user interface was upgraded (changes in time stamp and front panel view)

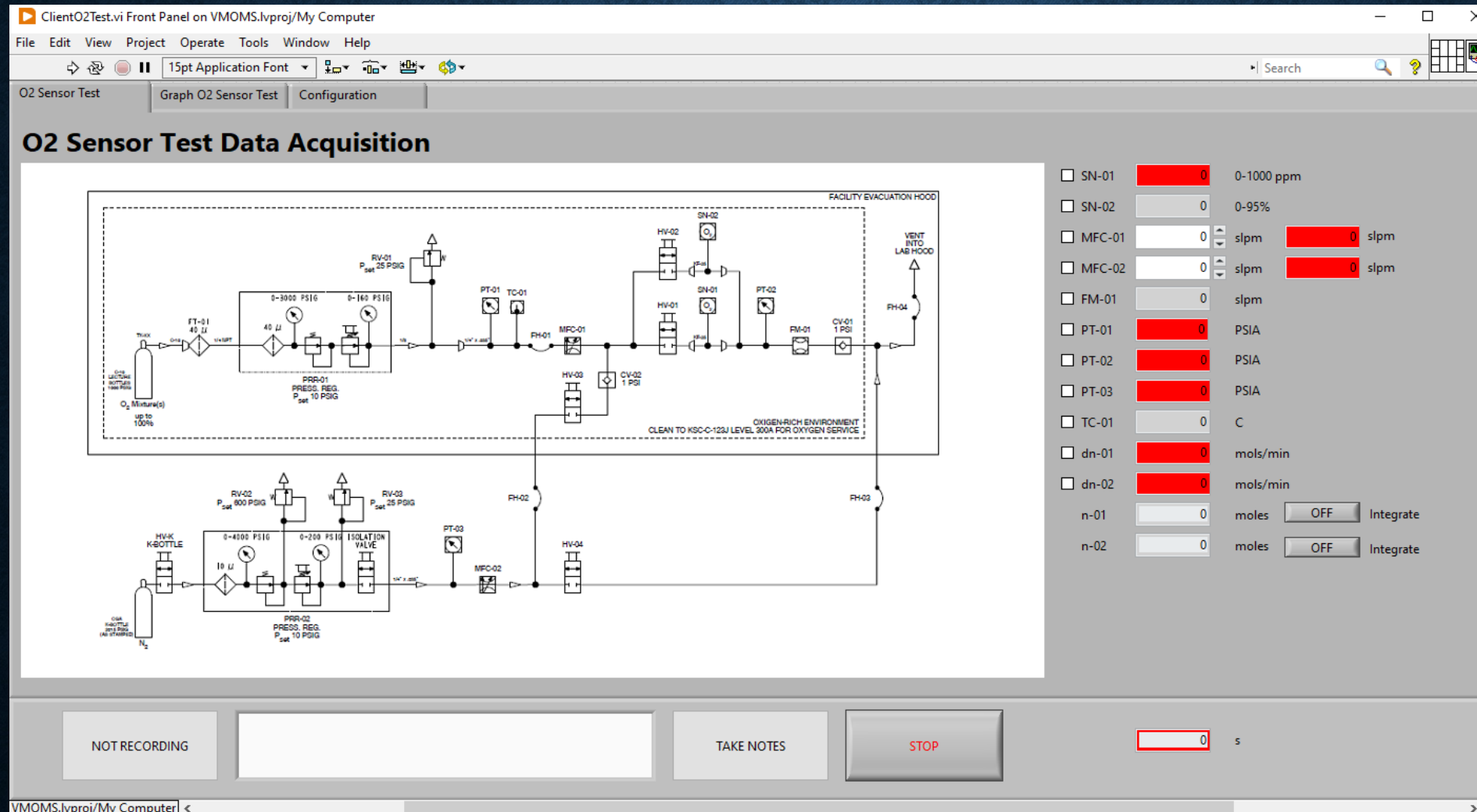
## Data Average Calculation

	0% O2	5% O2	20.9% O2	50% O2	75% O2	80% O2	95% O2
1		4.642648	21.78706	52.63104	78.80762	85.02966	93.24153
2		4.637728	21.78832	52.63208	78.80093	84.75965	93.24258
3		4.641153			78.79846	85.03192	93.24334
Avg	-0.06103	4.640509	21.78769	52.63156	78.80234	84.94041	93.24248





# OXYGEN SENSOR LABVIEW USER INTERFACE



Oxygen Sensor software user interface – front panel

# OXYGEN SENSOR SOFTWARE – LIMITS

Vmoms Values
Configuration

TELEMETRY IDS			MAX	MIN		ID	MAX	MIN		
TIME	1					PT-05	12	50	14	PSIA
SN-01	2	1000	0	0-1000 ppm	PT-06	13	0	0	atm	TIME RST
SN-02	3	95	0	0-95%	TC-01	14	40	0	C	TARE N-01
MFC-01	4	5	0	slpm	TC-02	15	40	0	C	TARE N-02
MFC-02	5	5	0	slpm	dn-01	16	0	0	mols/min	MFC-01
FM-01	6	7	0	slpm	dn-02	17	40	0	mols/min	MFC-02
FM-02	7	0	0	slpm	n-01	18				SN-01
PT-01	8	0	0	atm	n-02	19				SN-02
PT-02	9	0	0	atm						
PT-03	10	50	14	PSIA						
PT-04	11	50	14	PSIA						

Loop Counters

DAQ Input
2

TCP IP
2
2
2

TCP State
Initialize

Connections
0

DAQ Rate
2
Samples/Sec

DAQ Samples
2
Samples

Recieved Messages
0

Message ID
0

Message Data
0

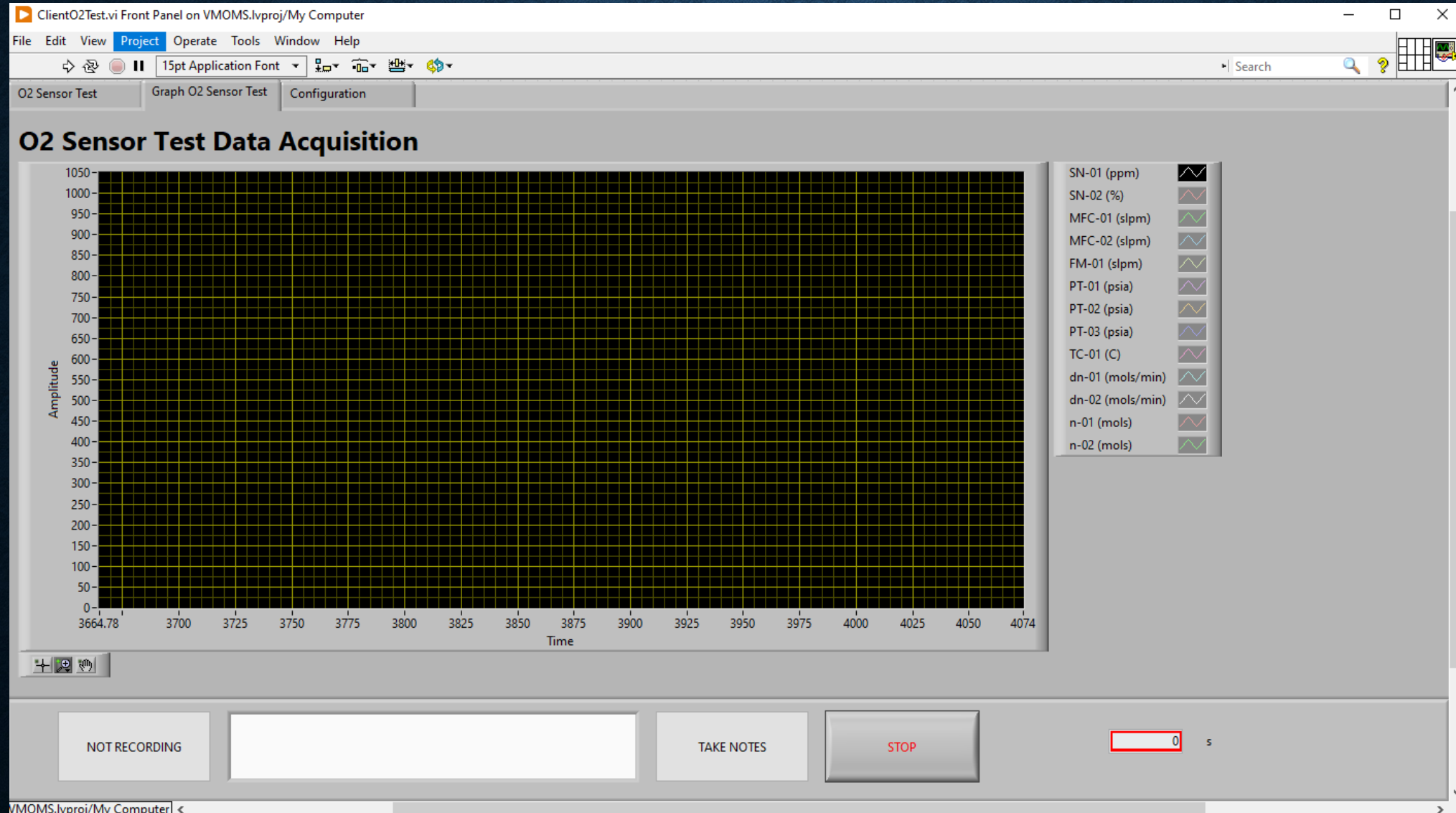
Sent Messages
0

Message ID
0

Message Data
0

10

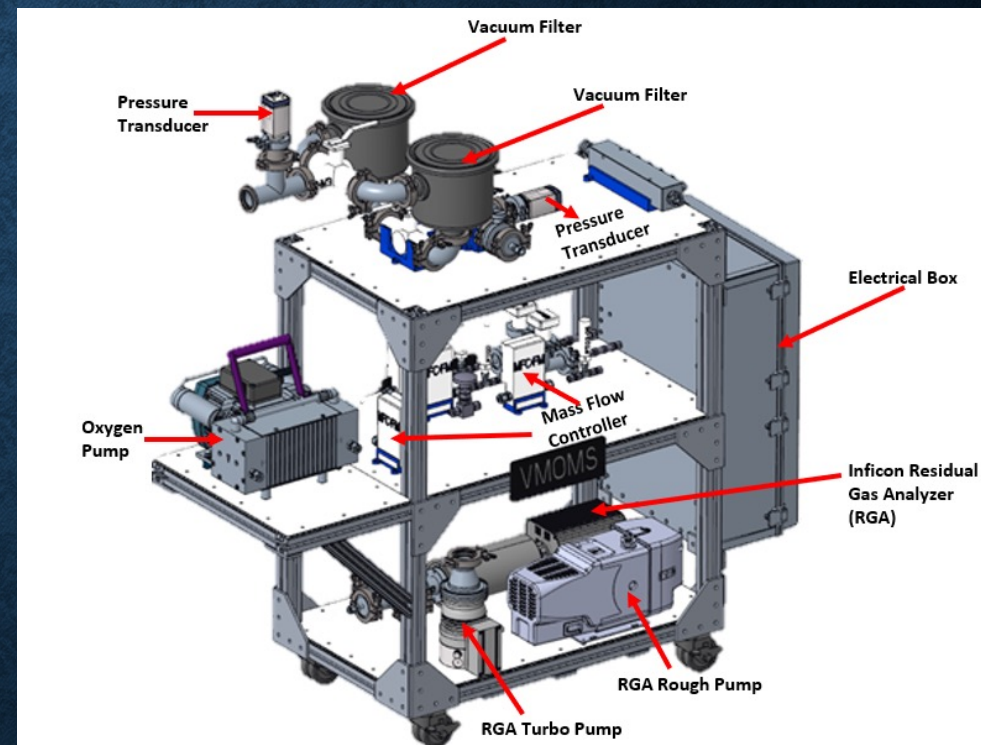
# OXYGEN SENSOR LABVIEW GRAPH



Oxygen Sensor software LabVIEW graph panel of different sensors

# DEVELOPMENT VOLATILE MONITORING OXYGEN MEASUREMENT SYSTEM

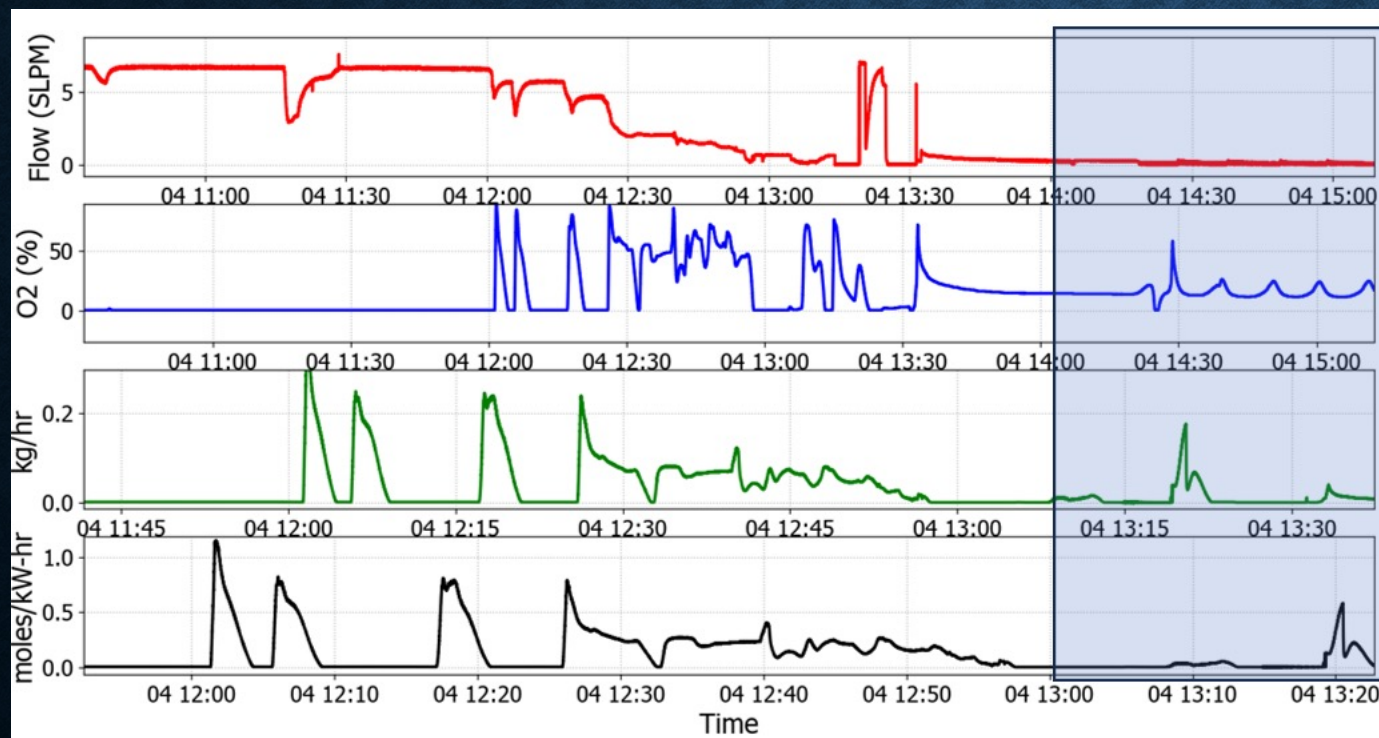
- In addition to quantification of oxygen the technology needed
  - Volatile detection sensors (RGA and GC)
  - Gas Chromatography was placed on a separate table
  - Pressure transducers (atmospheric and vacuum)
  - Thermocouple (temperature limit of vacuum pump)
  - Filters (particulate filter)
  - Mass Flow controllers
  - Mass flow meters
  - Oxygen rated pumps
- System had to be “oxygen cleaned”
- System modification (oxygen rated pump failure two weeks to MRE test)
  - Two argon bottles for dilution
  - Change in software calculation to include argon dilution
  - Tested 25 kg of CSM-LHT-1G in Lunar Resource reactor



CAD Image of VMOMS System

# VMOMS MRE TEST RESULT

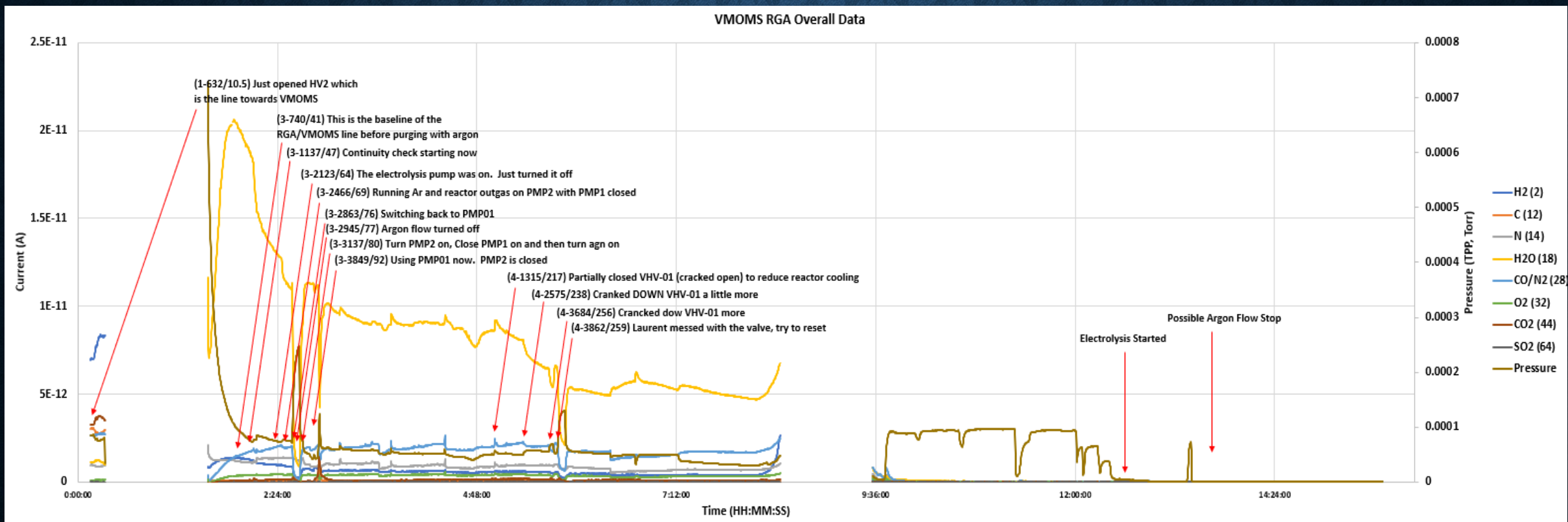
- VMOMS LabVIEW logged data during the four-day testing (which included evacuation, heating, and electrolysis phases of the test)
- Up to **80%** of oxygen was detected
- VMOMS collected and identified oxygen production concentrations.
  - The time unit (x-axis) recorded on LabVIEW was in DD:HH:MM



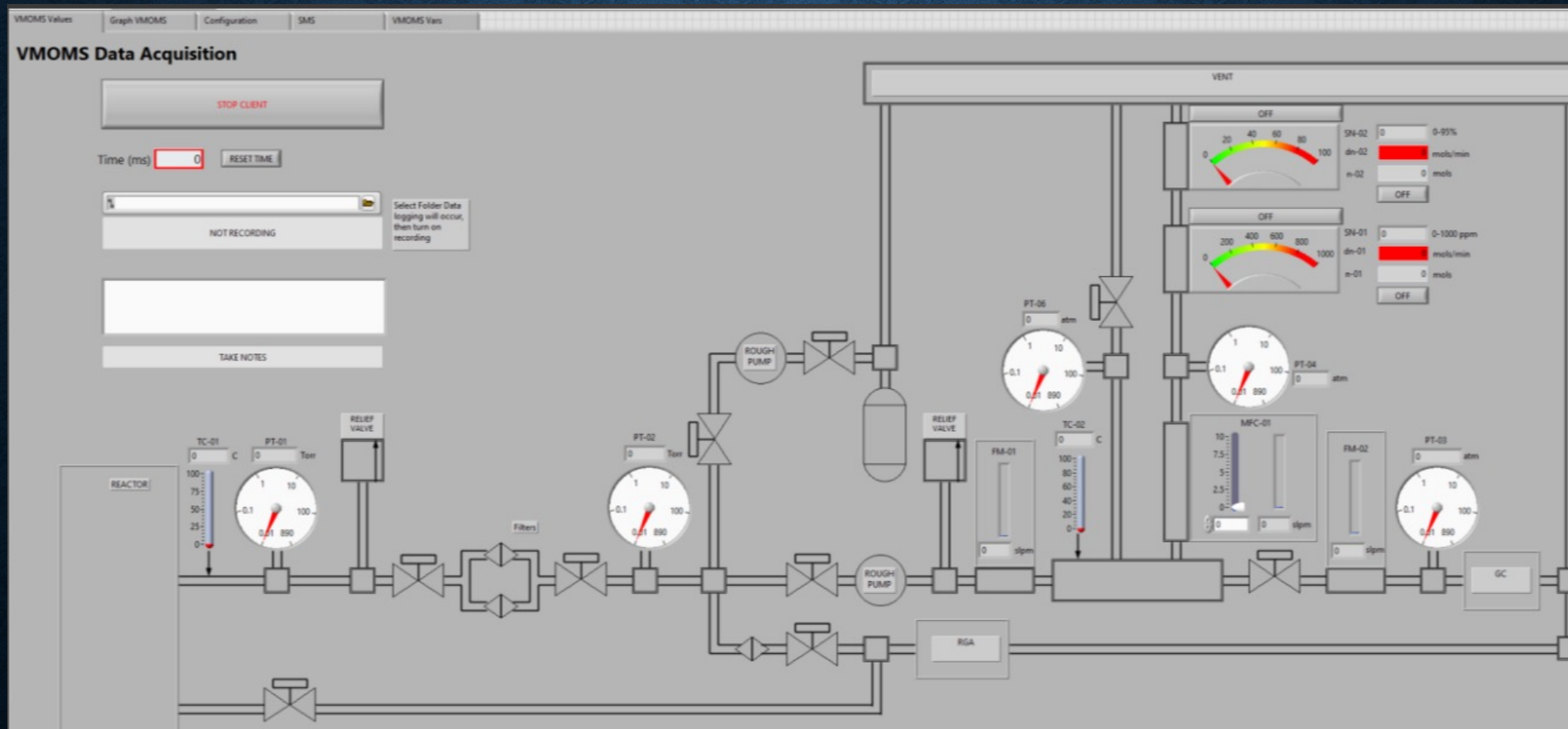


# VMOMS MRE TEST RESULT

- Argon dilution at high pressure created an unintended purge during the electrolysis phase
- RGA showed high level of water during heating phase



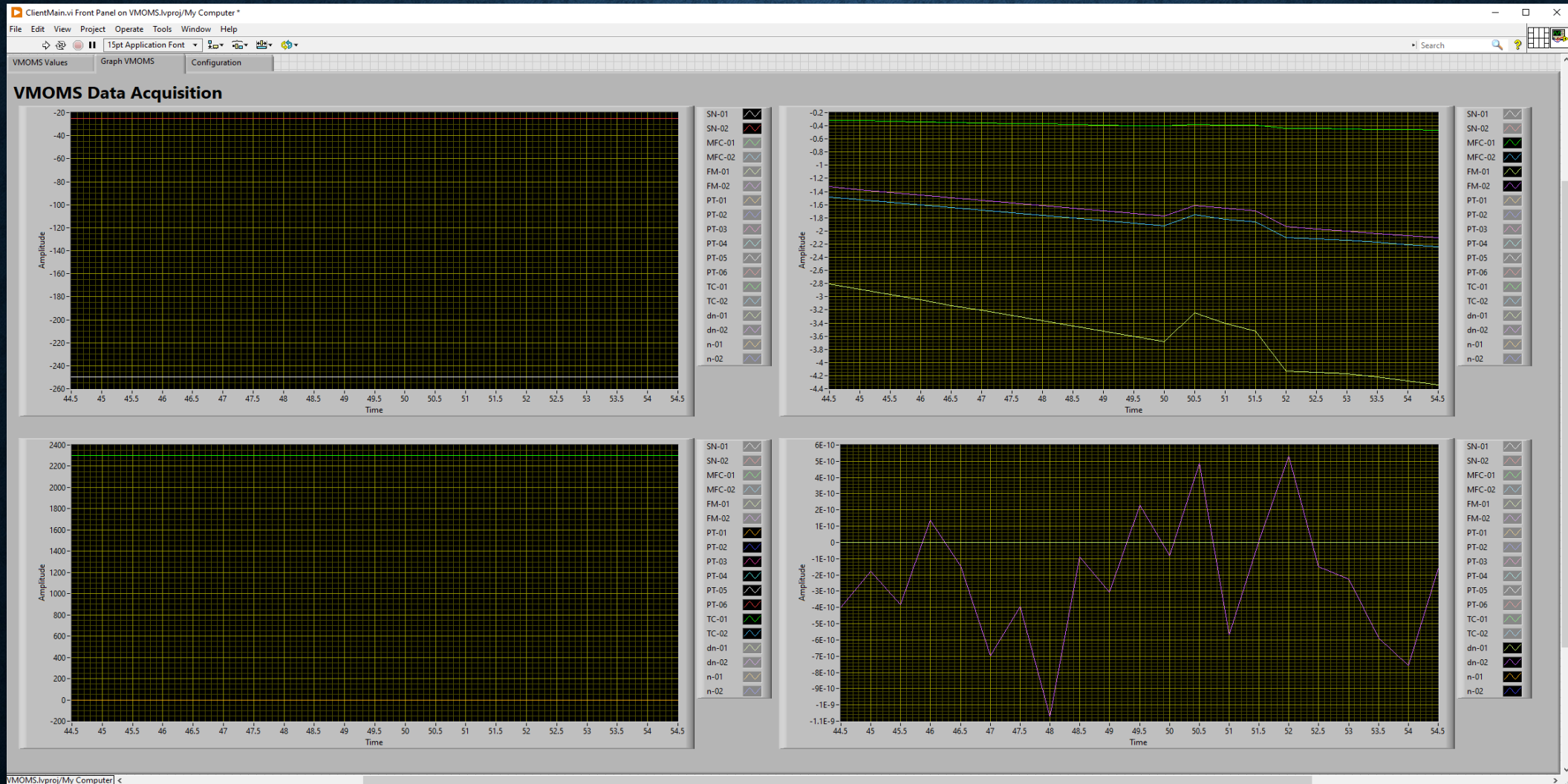
# VMOMS LABVIEW FRONT PANEL



VMOMS LabVIEW front panel



# VMOMS USER INTERFACE



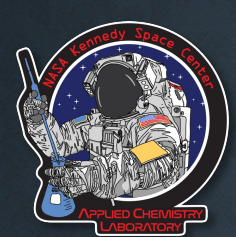
VMOMS LabVIEW of graphs for different sensors on same panel



# LESSONS LEARNED AND FUTURE

- Oxygen sensor test
- Sensors must be recalibrated every 6 months
- Sensors needs 4 minutes to warm up
- Exposing lower range sensors to higher percent oxygen for a long period of time throws off the sensor's calibration
- VMOMS MRE test
- Changes in VMOMS to address challenges (evolved water from reactor, filter, corrosion)
- Redesign for flight





**QUESTIONS?**  
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**BACK UP**



# HOW ZIRCONIA SENSOR WORKS

- Uses  $\text{ZrO}_2$  solid electrolyte
- Based on limiting current method and oxygen ion conductivity at high temperature (450 deg C)
  - Sample is diffused to electrode and heated
  - Oxygen becomes oxygen ions and quantified based on sensing voltage
  - Voltage differential created by  $\text{O}_2$  ions migration between higher and lower electrode
  - Voltage magnitude is measured which is related to difference in oxygen partial pressure between both electrodes
  - The Nernst equation is used to calculate oxygen concentration
- Oxygen ion is turned back to oxygen