

# THE DOG THAT TROTS ABOUT FINDS A BONE: HOW TO CERTIFY THE MASS FLOW CONTROLLER OF THE THERMO 146I GAS DILUTION SYSTEM

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Des Moines Iowa



# Introduction

- ▣ EPA Requirement
- ▣ Guide to how a local gal found her trail
- ▣ Verification
  - Zero
  - Span
- ▣ Calibration
  - Zero
  - Span



# EPA Requirement

CO, NO<sub>x</sub> and SO<sub>2</sub> must have their Gas Dilution Systems evaluated once every 3 months with an accuracy of +/- 2%

EPA-454/B-08-003, December 2008.

Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Ambient Air Quality Monitoring Program. Appendix D Measurement Quality Objectives and Validation Templates.



# Complications

- ❑ Poor instruction manual
- ❑ Lack of guidance from EPA
- ❑ Up hill battle



# The Hesitation

- ▣ Pioneer
- ▣ As an operator, our motto is if it isn't broken don't try to fix it!



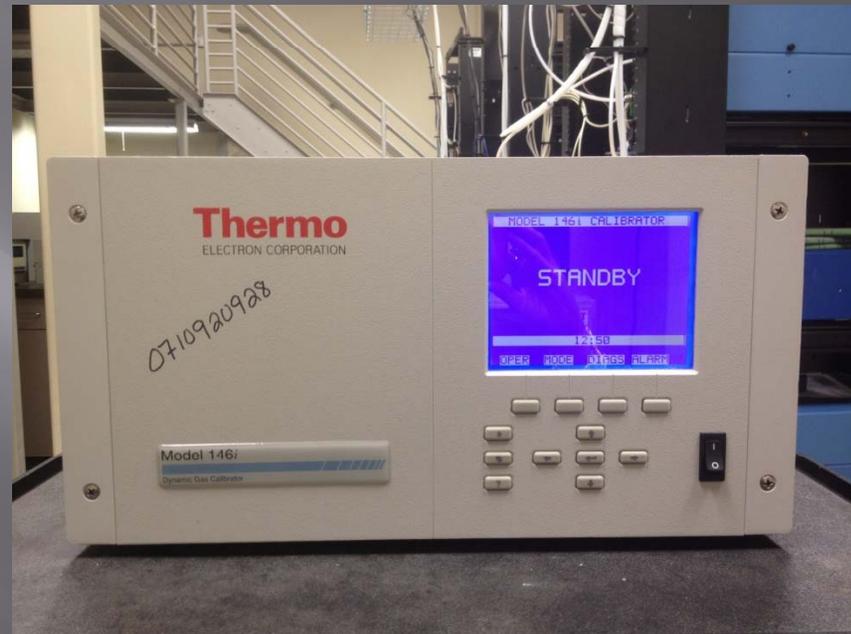
# Why Persist

- ▣ Operating at low levels.
- ▣ Proactive to insure accurate data.
- ▣ Requirement by EPA



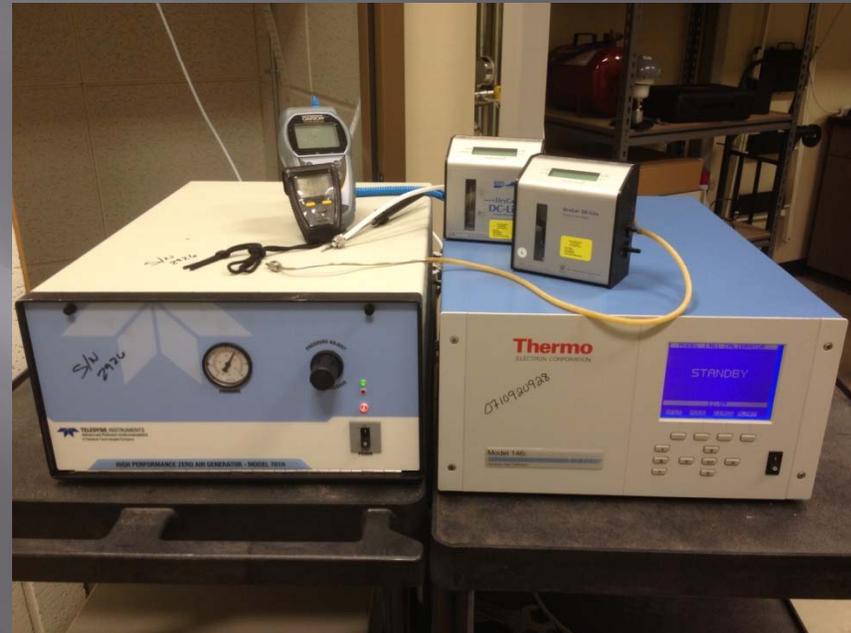
# When to Verify

- ▣ Measurement Quality Objectives (MQO's) require once every 3 months
- ▣ New – Out of the box
- ▣ Following a repair
- ▣ Following a calibration



# Components Needed

- ▣ NIST traceable flow meter
  - ▣ Zero Air MFC: DC-Lite 40K BIOS
  - ▣ Gas Air MFC: DC-Lite L BIOS
- ▣ Zero air generator: Teledyne API 701H
- ▣ Temperature gauge
- ▣ Pressure gauge
- ▣ 9/16" and 7/16" wrenches



# Zero Verification Procedure

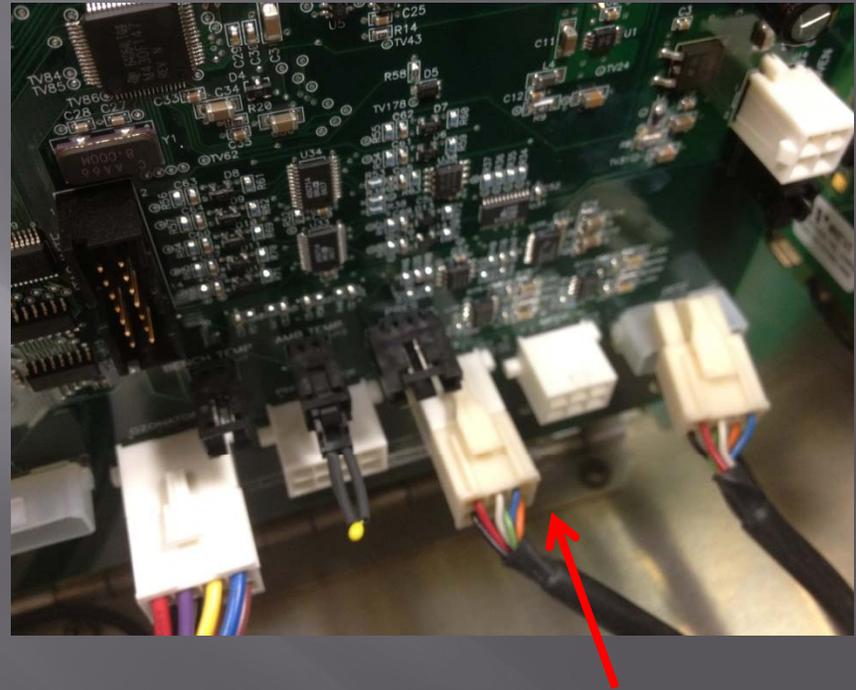
ZERO MFC (20L)



# Zero Verification Set-up

ZERO MFC (20L)

- ▣ Power off instrument.
- ▣ Disconnect MFC2 from the interface board.



# Zero Verification Set-up

ZERO MFC (20L)

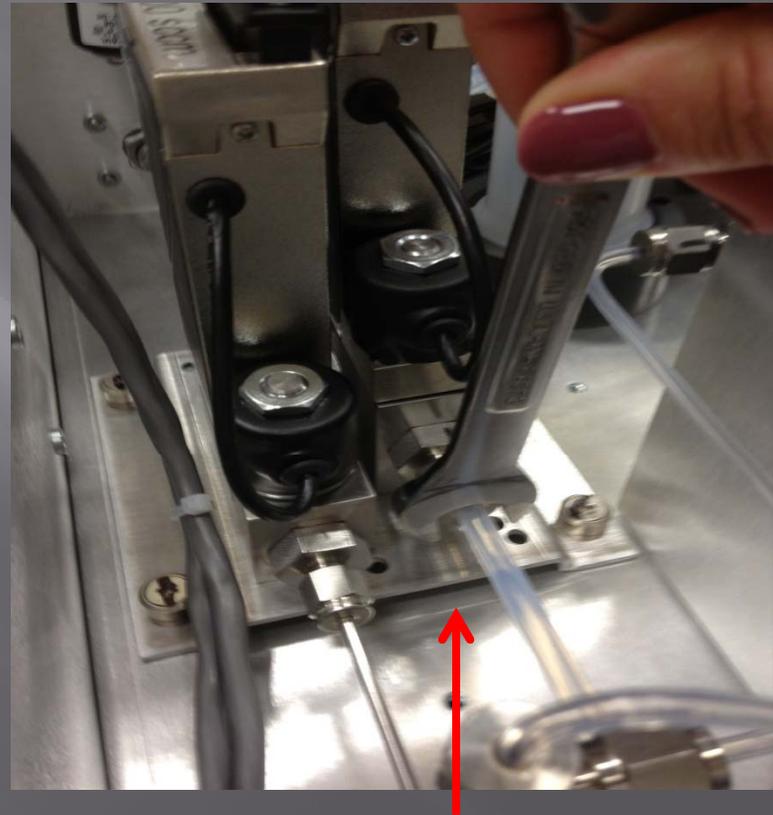
- Connect a source of clean, dry air to the zero air inlet on the back of the 146i.



# Zero Verification Set-up

ZERO MFC (20L)

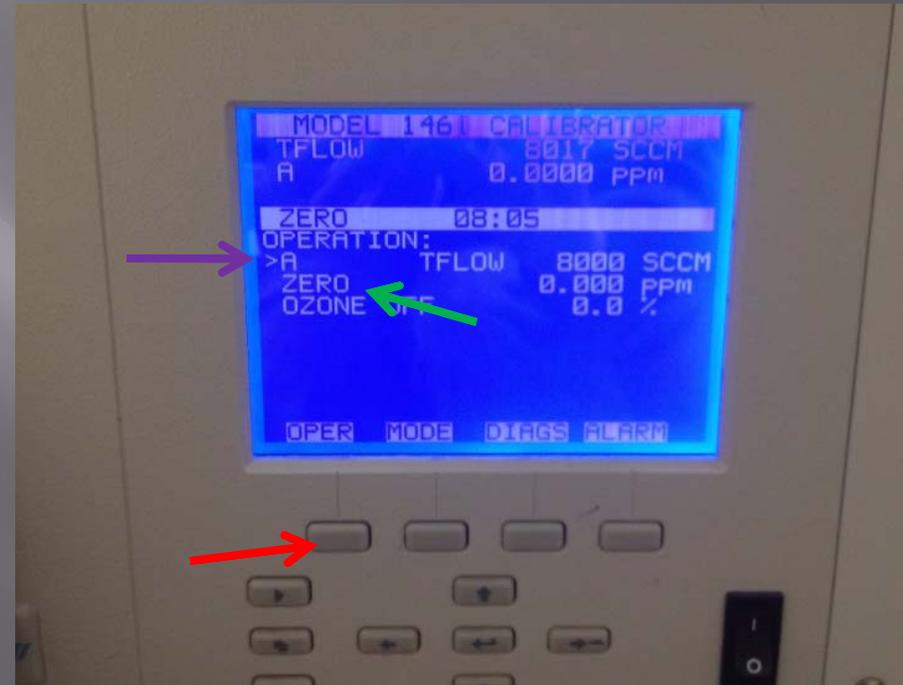
- ▣ Directly connect the NIST traceable flow meter (40K BIOS) to the Zero Air MFC (20 slpm) with a 9/16" wrench.



# Zero Verification Set-up

ZERO MFC (20L)

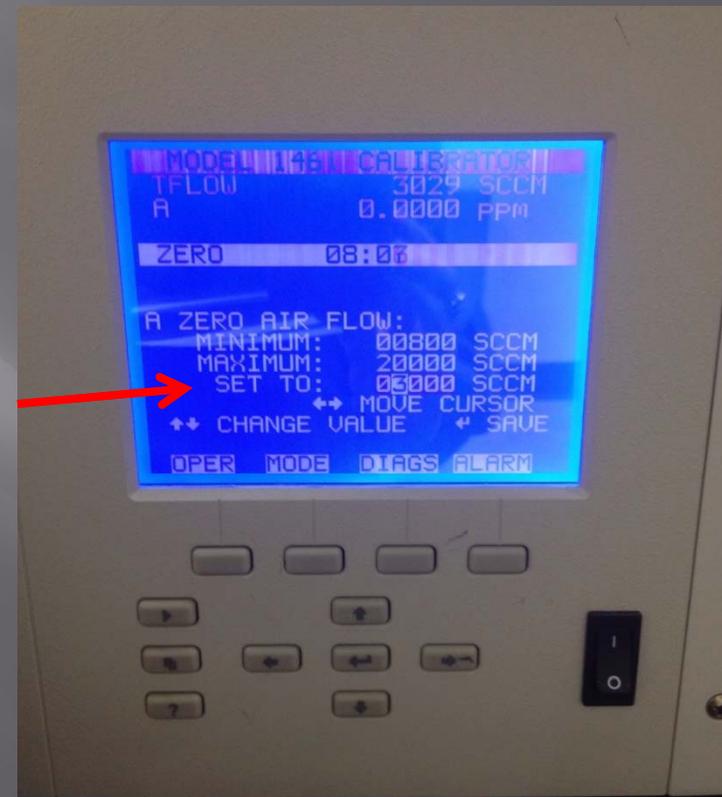
- With the power back on, press the **OPER** key.
- Select **GAS A**.
- Select **ZERO** gas dilution mode.



# Zero Verification

ZERO MFC (20L)

- ▣ Manually adjust **GAS**  
A flow to verification  
levels of: 90%, 60%,  
30%, and 15%.
- ▣ For a 20 L Calibrator:  
18,000 12,000 6,000  
and 3,000 sccm  
respectively.



# Verification Field Sheet

ZERO MFC (20L)

- Turn the NIST traceable flow meter on. Wait until it stabilizes.
- Record readings from the flow meter and 146i on the Mass Flow Controller Verification Form.
- Note: the calibrator is reading the flow in sccm. Divide by 1000 to convert all units to L.

146i MASS FLOW CONTROLLER VERIFICATION FIELD SHEET				
Date	3/28/2012			
Time	9:40			
Technician Name	JP			
Analyzer s/n	710920928			
Std Temp	24.2			
Std Pressure	29.21			
Reference	Manufacturer/Model	Serial Number		
Temperature Standard	Oakton Temp 10 T	451032		
Pressure Standard	Cole Palmer Hand Held Barometer	212		
Zero Air Standard	API 701 H	2926		
Gas Flow Standard	BIOS H	1899		
Gas Flow Standard	BIOS L	105653		
Zero Air Calibration 20L				
Percent	SCCM	Bios L/min	Calibrator SCCM	Convert Calibrator SCCM to L
15%	3000	3.101	2988	2.988
30%	6000	6.178	5988	5.988
60%	12000	12.36	12004	12.004
90%	18000	18.25	18004	18.004
Gas Calibration 100 CC				
Percent	SCCM	Bios L/min	Calibrator SCCM	
15%	15.00	15.57	14.99	
30%	30.00	31.34	30.01	
60%	60.00	62.22	60.02	
90%	90.00	93.00	90.05	

# Linear Regression

- Once all 4 points are completed, enter the results into the Mass Flow Controller Verification Linear Regression.



146I MASS FLOW CONTROLLER COMPARISSON TO NIST TRACEABLE FLOW STANDARD										
VERIFICATION LINEAR REGRESSION SPREADSHEET										
Analyzer:		Thermo 146i								
Serial #:		710520926								
Zero Air Source		API 701 H								
Serial #:		2928								
Flow Device:		BIOS H				BIOS L				
Serial #:		1899				105653				
Date:		3/28/2012								
Temperature:		24.2								
Pressure:		741.934								
Operator:		rp								
ZERO AIR VERIFICATION (20L)										
PERCENT	SCCM	BIOS-ACTUAL	BIOS-CONIV	CALIBRATOR	RPD	slope	intercept	rsq	logical	Pass/Fail
15%	3000	3.101	3.035	2.988	-2%	1.011153216	-0.124275279	0.999871054	TRUE	PASS
30%	6000	6.178	6.047	5.988	-1%					
60%	12000	12.36	12.099	12.004	-1%					
90%	18000	18.25	17.864	18.004	1%					
GAS FLOW VERIFICATION (100 cc)										
SCCM	PERCENT	BIOS-ACTUAL	BIOS-CONIV	SAMPLER	RPD	slope	intercept	rsq	logical	Pass/Fail
15.00	15%	15.570	15.24	14.99	-2%	0.991165212	-0.259574127	0.999983982	TRUE	PASS
30.00	30%	31.340	30.68	30.01	-2%					
60.00	60%	62.220	60.90	60.02	-1%					
90.00	90%	93.000	91.03	90.05	-1%					
logical = acceptance criteria for multipoint curve										
Acceptance Criteria: 0.9<=slope<=1.1 10>=intercept>=-10 rsq>=0.995										

# Zero Verification Shut Down

ZERO MFC (20L)

- ▣ Return **GAS A** zero air flow back to its previous setting by selecting the **OPERATION** button and turning Gas and Zero mode to off.
- ▣ Turn off instrument and plug the MFC2 back into the interface board.
- ▣ Disconnect Flow device and reconnect the fitting to the Zero MFC.
- ▣ Turn instrument back on.



# EPA Acceptance Criteria

- ▣ If readings are  $\leq 2\%$ , the verification is complete.
- ▣ If readings are off by  $\geq 2\%$ , a calibration must be done on the Zero Air MFC.



# Thermo Acceptance Criteria

Part 1 - target values versus the measured flow

- ▣ Zero Mass Flow Controller (20 lpm) is verified at 3000, 6000, 12000, & 18000. The allowable difference is  $\pm 200$  sccm.



# Thermo Acceptance Criteria

## Part 2

- ▣ Set flow 90% full-scale
- ▣ Push the Menu button and select DIAGNOSTICS and then FLOWS to view the Zero Actual Readings
- ▣ **Actual flow** must be no more than  $\pm 2\%$  **Target Flow**



# Gas Verification Procedure

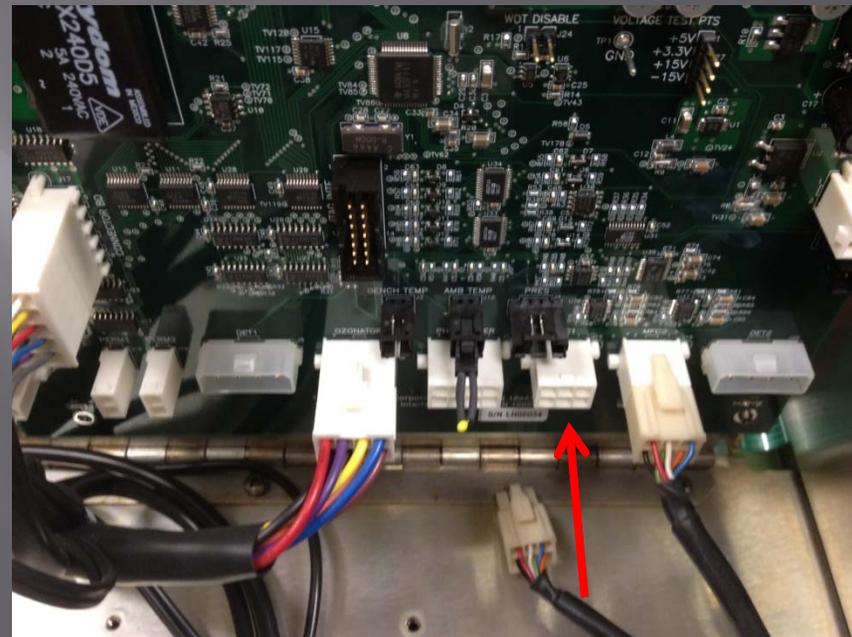
GAS MFC (100CCM)



# Gas Verification Set-up

GAS MFC (100CCM)

- Turn Off Instrument.
- Disconnect MFC1 from the interface board.



# Gas Verification Set-up

GAS MFC (100CCM)

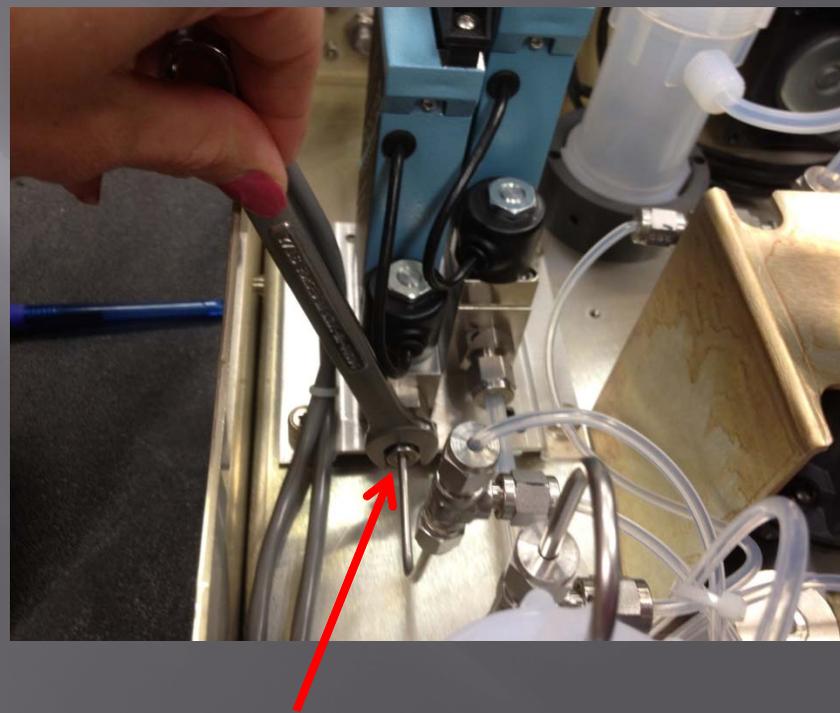
- ▣ Connect a source of clean, dry air to the GAS A inlet on the back of the 146i.



# Gas Verification Set-up

GAS MFC (100CCM)

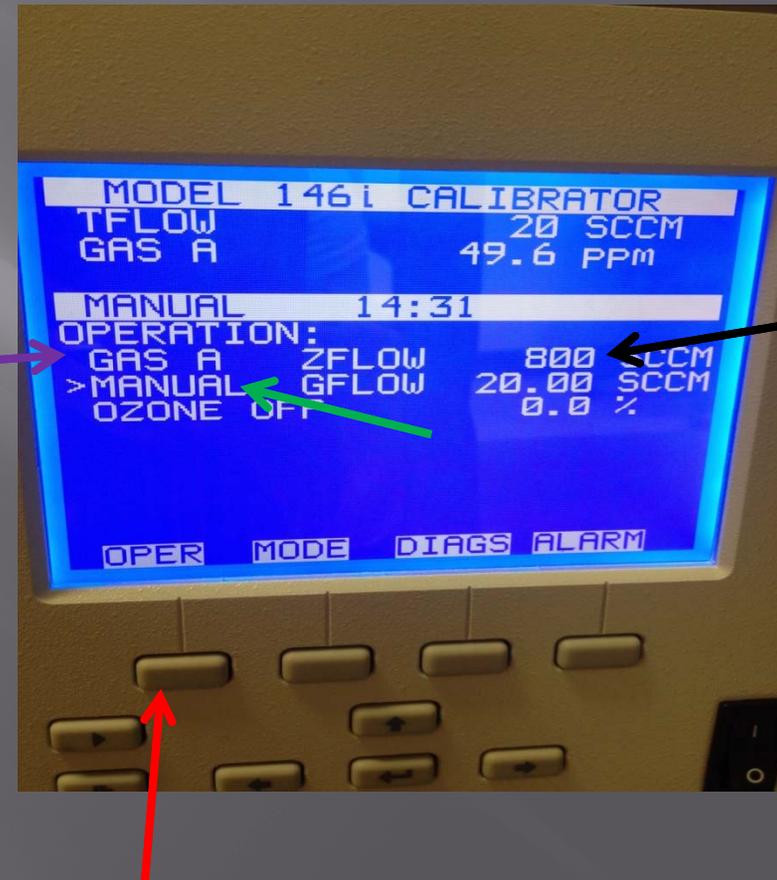
- ▣ Directly connect the NIST traceable flow meter to the Gas MFC (100 sccm) inside the instrument with a 7/16" wrench.



# Gas Verification Set-up

GAS MFC (100CCM)

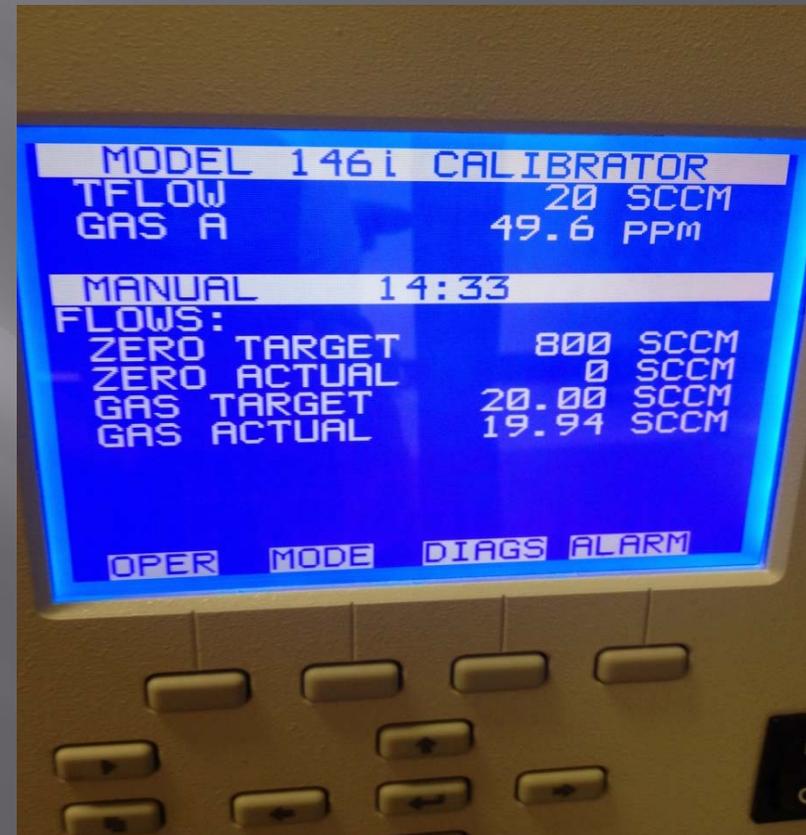
- ▣ Push the **OPER** button. Select **GAS A**. Scroll to **MANUAL** and press **ENTER**.
- ▣ Select **ENTER** again and set **GAS A Z FLOW** to 90% (18,000 sccm) and press **ENTER**.



# Gas Verification

GAS MFC (100CCM)

- Turn on the NIST traceable flow meter and allow it to stabilize .
- Push the menu button and select **DIAGNOSTICS** and then **FLOWS** to view the Gas Actual reading.
- Record readings on the Gas Mass Flow Controller Verification Form.



# GAS VERIFICATION

GAS MFC (100 SCCM)

- ▣ Select the **OPER** button again. Toggling back and forth from the **OPER** button to the **MENU** button will allow the user to view both actual readings and set readings.
- ▣ Continue for gas flow settings of 60%, 30%, and 15% of full-scale (12000, 6000 and 3000 respectively).
- ▣ Once all 4 points are complete, enter the results into the Mass Flow Controller Linear Regression.

# Gas Verification Shut Down

GAS MFC (T00CCM)

- ▣ Turn the GAS off in the OPERATION menu.  
Put back in STANDBY mode.
- ▣ Turn instrument off and plug the MFC1 back into the interface board.
- ▣ Disconnect the dry air source.
- ▣ Disconnect flow device and reattach fitting to the gas MFC.



# EPA Acceptance Criteria

- ▣ If readings are  $\leq 2\%$ , the verification is complete.
- ▣ If readings are off by  $\geq 2\%$ , a calibration must be done on the Gas MFC.



# Thermo Acceptance Criteria

Target values versus the measured flow

- ▣ Gas Side (100 sccm) Verify at 15%, 30% 60%, 90% full scale  $\pm 1.0$  sccm
- ▣ If readings are off by  $\pm 1.0$  sccm a calibration must be done on the Gas MFC.



# Zero Calibration Procedure

ZERO MFC (20L)



# Zero Calibration Set-up

ZERO MFC (20L)



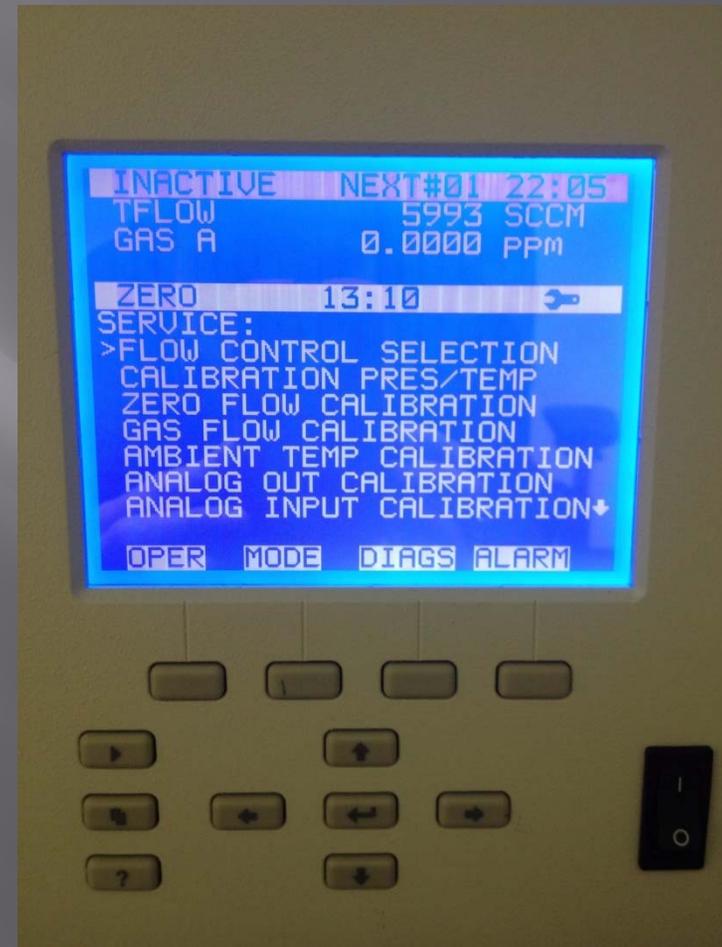
Same as Verification:

- 1) Power off the instrument and disconnect MFC2 from the interface board.
- 2) Connect a source of clean, dry air to the zero air inlet on the back of the 146i.
- 3) Directly connect the NIST traceable flow meter to the zero MFC (20 slpm) inside the instrument.

# Service Menu

ZERO MFC (20L)

- ▣ Put 146i in Service Mode.
- ▣ Once in Service Mode, the Service Menu becomes available.



# Calibrate

## Pressure/Temperature

ZERO MFC (20L)

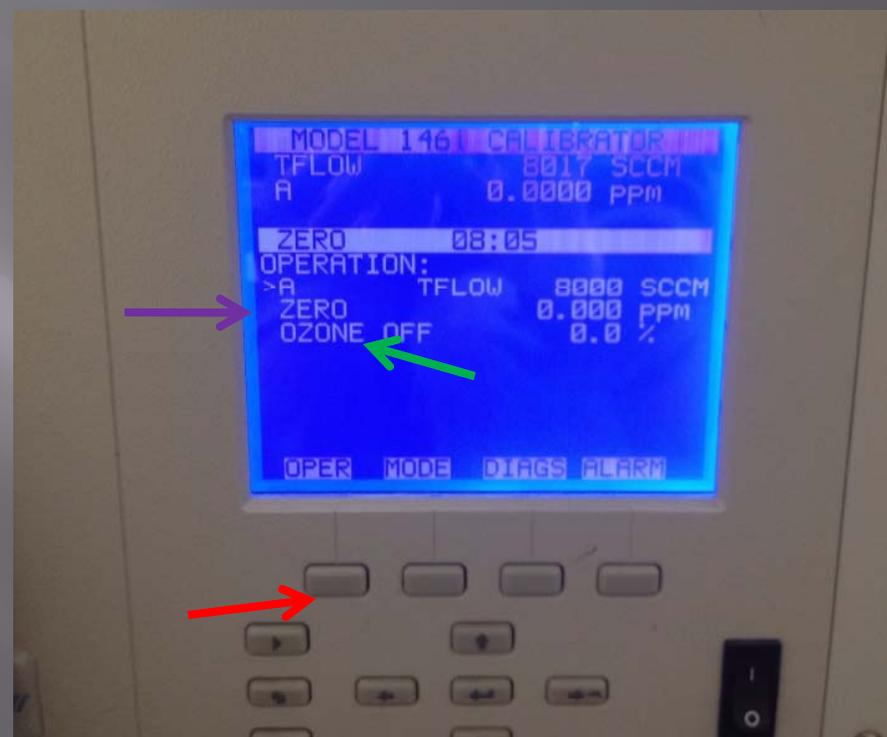
- ▣ Scroll to **CALIBRATION PRESS/TEMP** and press **ENTER**.
- ▣ Enter the transfer standard barometric pressure and temperature readings.



# Zero Calibration Set-up

ZERO MFC (20L)

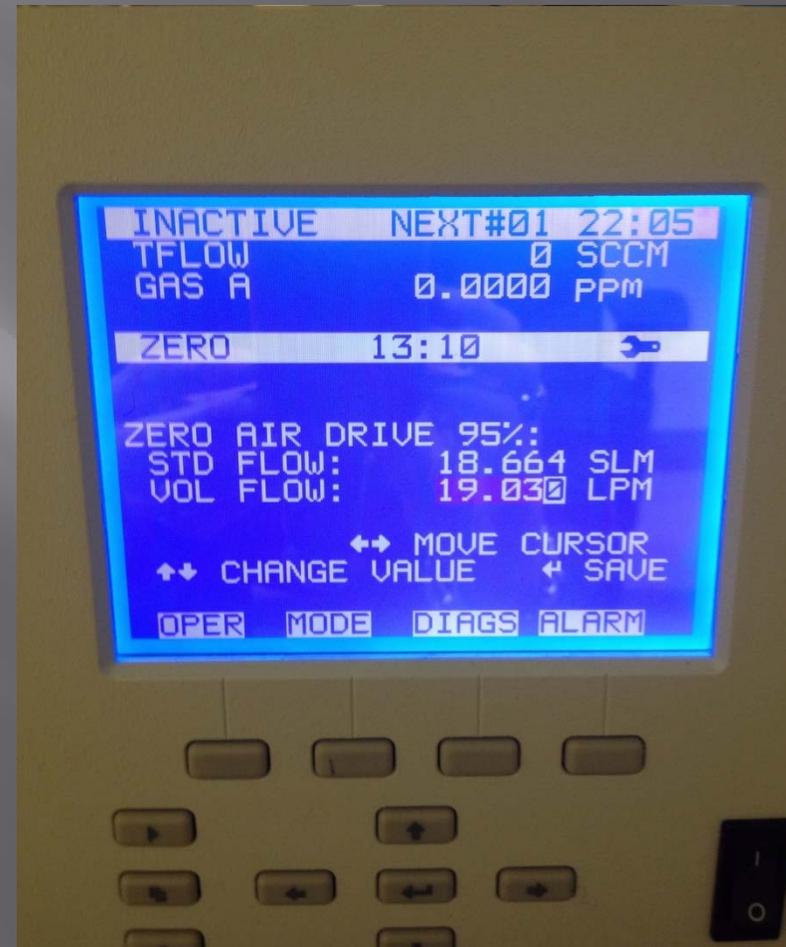
- ▣ Press the **OPER** key.
- ▣ Select **GAS A**.
- ▣ Select **ZERO** gas dilution mode.



# Zero Calibration Set-up

ZERO MFC (20L)

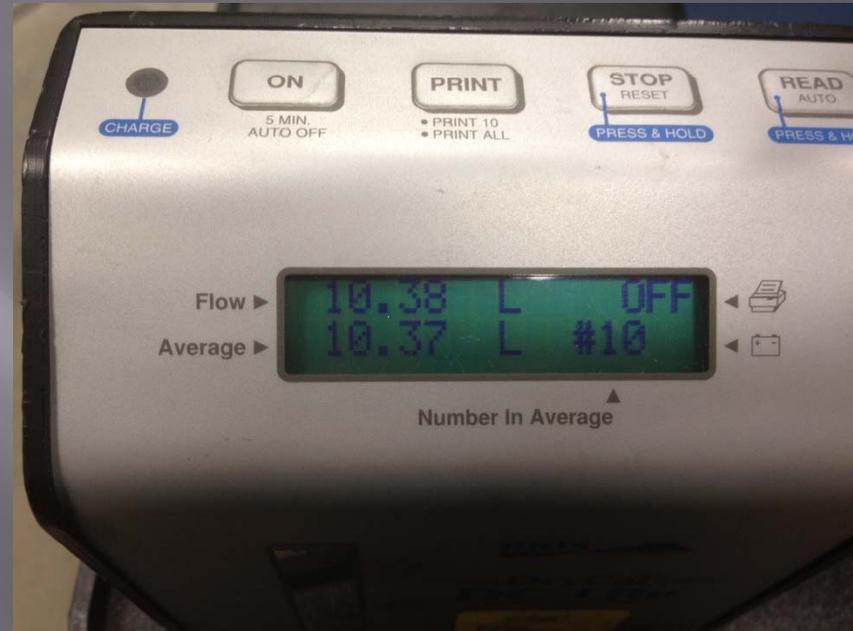
- ▣ From the Service Menu, scroll to **ZERO FLOW CALIBRATION** and press **ENTER**.
- ▣ Select **95%** and press **ENTER**.



# NIST Traceable Flow Meter

ZERO MFC (20L)

- Enter the NIST traceable flow reading into the VOL FLOW on the 146i.
- Continue for Zero Air settings of 80%, 65%, 50%, 35%, 20% and 5% of full-scale.



# Calibration Field Sheet

- Record readings from flow meter and new standard flow readings from 146i on the Mass Flow Controller Calibration Field Sheet

**146i MASS FLOW CONTROLLER CALIBRATION FIELD SHEET**

<b>Date</b>				
<b>Time</b>				
<b>Technician Name</b>				
<b>Analyzer s/n</b>				
<b>Std Temp</b>				
<b>Std Pressure</b>				

Reference	Manufacturer/Model	Serial Number
Temperature Standard	Oakton Temp 10 T	451032
Pressure Standard	Cole Parmer Hand Held Barometer	212
Zero Air Standard	API 701 H	2926
Gas Flow Standard	BIOS H	1899
Gas Flow Standard	BIOS L	105653

Zero Air Calibration 20 L				Gas Calibration 100CC			
Percent	scm	Bios L/min	Calibrator SCCM	Percent	SCCM	Bios L/min	Calibrator SCCM
5%	1000			5%	5.00		
20%	4000			20%	20.00		
35%	7000			35%	35.00		
50%	10000			50%	50.00		
65%	13000			65%	65.00		
80%	16000			80%	80.00		
95%	19000			95%	95.00		

# Linear Regression

- Once all points are completed, enter the results into the Mass Flow Controller Calibration Linear Regression.

146I MASS FLOW CONTROLLER COMPARISSON TO NIST TRACEABLE FLOW STANDARD										
CALIBRATION LINEAR REGRESSION SPREADSHEET										
Analyzer:		Thermo 146I								
Serial #:		710920928								
Zero Air Source		API 701 H								
Serial #:		2926								
Flow Device:		BIOS H				BIOS L				
Serial #:		1899				105653				
Date:		3/7/2012								
Temperature:		24.1								
Pressure:		732.79								
Operator:		RP								
ZERO AIR CALIBRATION (20L)										
PERCENT	SCCM	BIOS.ACTUAL	BIOS.CONV	CALIBRATOR	RPD	slope	intercept	rsq	logical	Pass/Fail
5%	1000	1.035	1.001	1.011	1%	1.005037322	-0.013106022	0.999894317	TRUE	PASS
20%	4000	4.087	3.953	3.996	1%					
35%	7000	7.194	6.957	6.999	1%					
50%	10000	10.390	10.048	10.003	0%					
65%	13000	13.420	12.979	13.001	0%					
80%	16000	16.550	16.006	16.003	0%					
95%	19000	19.450	18.810	19.001	1%					
GAS FLOW CALIBRATION (100 cc)										
CCM	PERCENT	BIOS.ACTUAL	BIOS.CONV	SAMPLER	RPD	slope	intercept	rsq	logical	Pass/Fail
5.00	5%	5.220	5.05	5.00	-1%	0.999926335	0.227961903	0.999807441	TRUE	PASS
20.00	20%	20.440	19.77	20.00	1%					
35.00	35%	35.670	34.50	34.97	1%					
50.00	50%	51.060	49.38	49.97	1%					
65.00	65%	66.770	64.57	64.97	1%					
80.00	80%	83.350	80.61	79.95	-1%					
95.00	95%	97.570	94.36	94.95	1%					
logical = acceptance criteria for multipoint curve										
Acceptance Criteria:						0.9<=slope<=1.1 10>=intercept>=-10 rsq>=0.995				

# Zero Flow Calibration Shut Down

ZERO MFC (20L)

Same as Verification:

- ▣ Return **GAS A** zero air flow back to its previous setting by selecting the **OPERATION** button and turning Gas and Zero mode to off.
- ▣ Turn off instrument and plug the MFC2 back into the interface board.
- ▣ Disconnect Flow device and reconnect the fitting to the Zero MFC.
- ▣ Turn instrument back on.

# EPA Acceptance Criteria

ZERO MFC (20L)

- ▣ If readings are  $\leq 2\%$ , the calibration is complete.
- ▣ If readings are  $\geq 2\%$ , repeat procedure. If unable to meet technical support.  
(Thermo: 866-282-0430)



# Gas Calibration Procedure

GAS MFC (100CCM)



# Gas Calibration Set-Up

GAS MFC (100CCM)

Same as Verification:

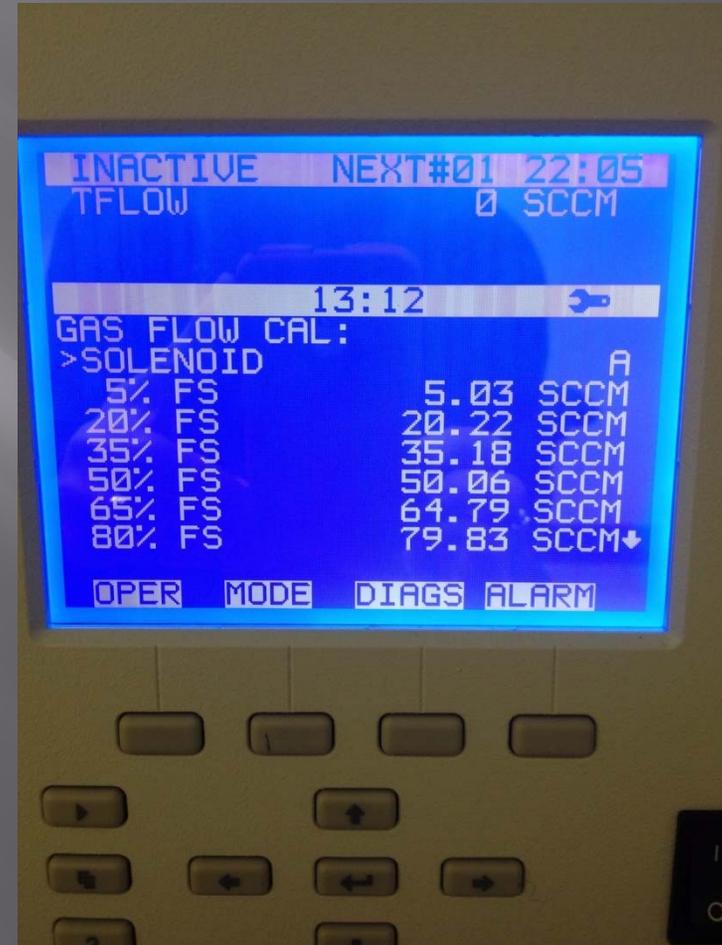
- 1) Power instrument off and disconnect the MFC1 from the interface board.
- 2) Connect a source of clean, dry air to the Gas A inlet on the back of the 146i.
- 3) Directly connect the NIST traceable flow meter to the gas MFC (100 sccm) inside the instrument .



# Gas Flow Calibration Set-up

GAS MFC (100CCM)

- ▣ Press the **OPER** key, select **Gas A** and **MANUAL** Mode.
- ▣ From the Service Menu, Scroll to **GAS FLOW CALIBRATION** and press **ENTER**.
- ▣ Select Solenoid A.



# Gas Flow Calibration

GAS MFC (100CCM)

- ❑ Select 95% and press **ENTER**.
- ❑ Enter the NIST traceable flow reading into the VOL FLOW on the 146i.
- ❑ Continue for gas flow settings of 80%, 65%, 50%, 35%, 20% and 5% of full-scale.
- ❑ Once all points are complete, enter results in the MFC Calibration Linear Regression



# EPA Acceptance Criteria

GAS MFC (100CCM)

- ▣ If readings are  $\leq 2\%$ , the calibration is complete.
- ▣ If readings are  $\geq 2\%$ , repeat procedure. If unable to meet, call technical support.  
(Thermo: 866-282-0430)



# Gas Calibration Shut Down

GAS MFC (100CCM)

Same as Verification:

- ▣ Turn the GAS off in the OPERATION menu. Put in STANDBY mode.
- ▣ Turn instrument off and plug the MFC1 back into the interface board.
- ▣ Disconnect the dry air source.
- ▣ Disconnect flow device and reattach fitting to the gas MFC.

Unique to Calibration:

- ▣ Take out of SERVICE mode.

# Conclusion

- ▣ Hasn't been an easy task – Black Diamond Run!
- ▣ Think we are there to the best of my knowledge.
- ▣ Remember to verify after a calibration.
- ▣ After instrument passes initial Thermo Criteria from factory stick to EPA Criteria.

# Contact Information

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AND THAT IS HOW IT IS DONE

