Development of a Lab-Scale Test For Evaluating Decomposition Products of Burnthrough Compliant Insulation Systems

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Fuselage Burnthrough Chronology

Full-sale test article built at FAATC in mid 1990's for evaluating performance of burnthrough-resistant thermal acoustic insulation materials.

Testing indicated burnthrough-resistant insulation provided a much more survivable cabin atmosphere when compared to current insulation materials.

FAA issued NPRM, 2003 Final Rule issued, 2009 compliance.

Although burnthrough resistant materials provide a benefit, the ingress of toxic gases resulting from decomposition of the insulation needs to be quantified.

2005 FAATC began development of a lab-scale test for evaluating toxic gas decomposition products that could be generated inside fuselage during a postcrash fire.

Development of Lab-Scale Test For Measuring Decomposition Products During a Postcrash Fire

It is anticipated that this test method could be used to evaluate the potential toxicity of insulation constructions and innovations meeting the new burnthrough test requirements, in order to ensure that an *adverse* condition will not result inside an intact fuselage when exposed to an external fuel fire, despite the high burnthrough performance associated with a particular system.

This test method could also be used to evaluate the toxic contribution of the basic fuselage structure, whenever a nonmetallic material is used as the primary component.

Methodology

Conduct lab-scale burnthrough test on 2 types of burnthrough resistant insulation, and 1 type of structural composite material (without insulation). Measured the build-up of toxic and flammable gases within an enclosure simulating a fuselage

complete

Conduct subsequent full-scale tests with identical insulation materials to establish realistic baseline data using FTIR.

complete

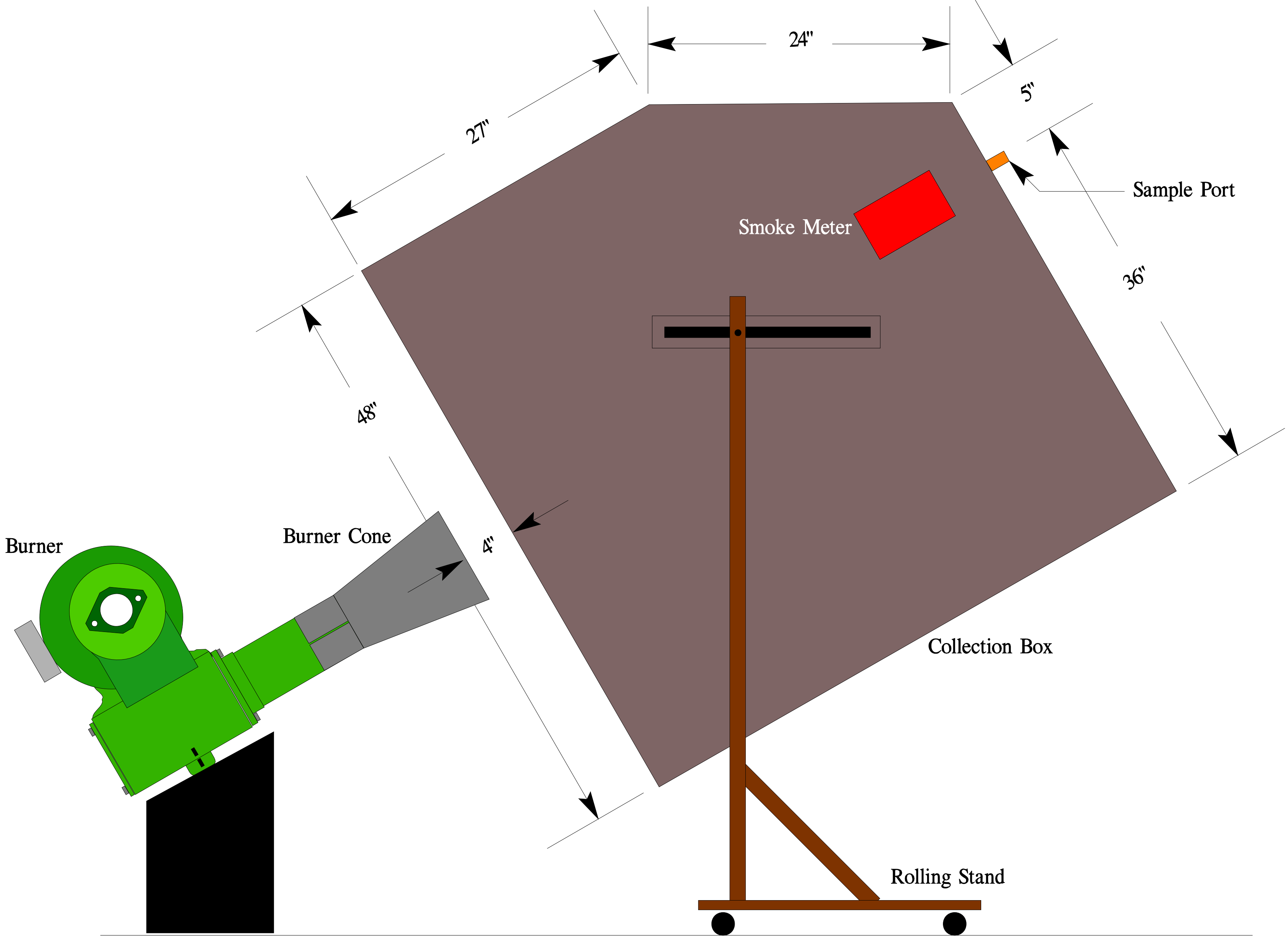
Determine concentration scaling factor between lab and full-scale tests in order to develop appropriate pass/fail criteria for lab-scale test.

complete

Produce Final Report and guidance on the acceptable level of decomposition products generated during lab-scale box test.

pending

Apparatus for Evaluating Toxic Gas Decomposition Products



Lab-Scale Apparatus for Evaluating Toxic Gas Decomposition Products

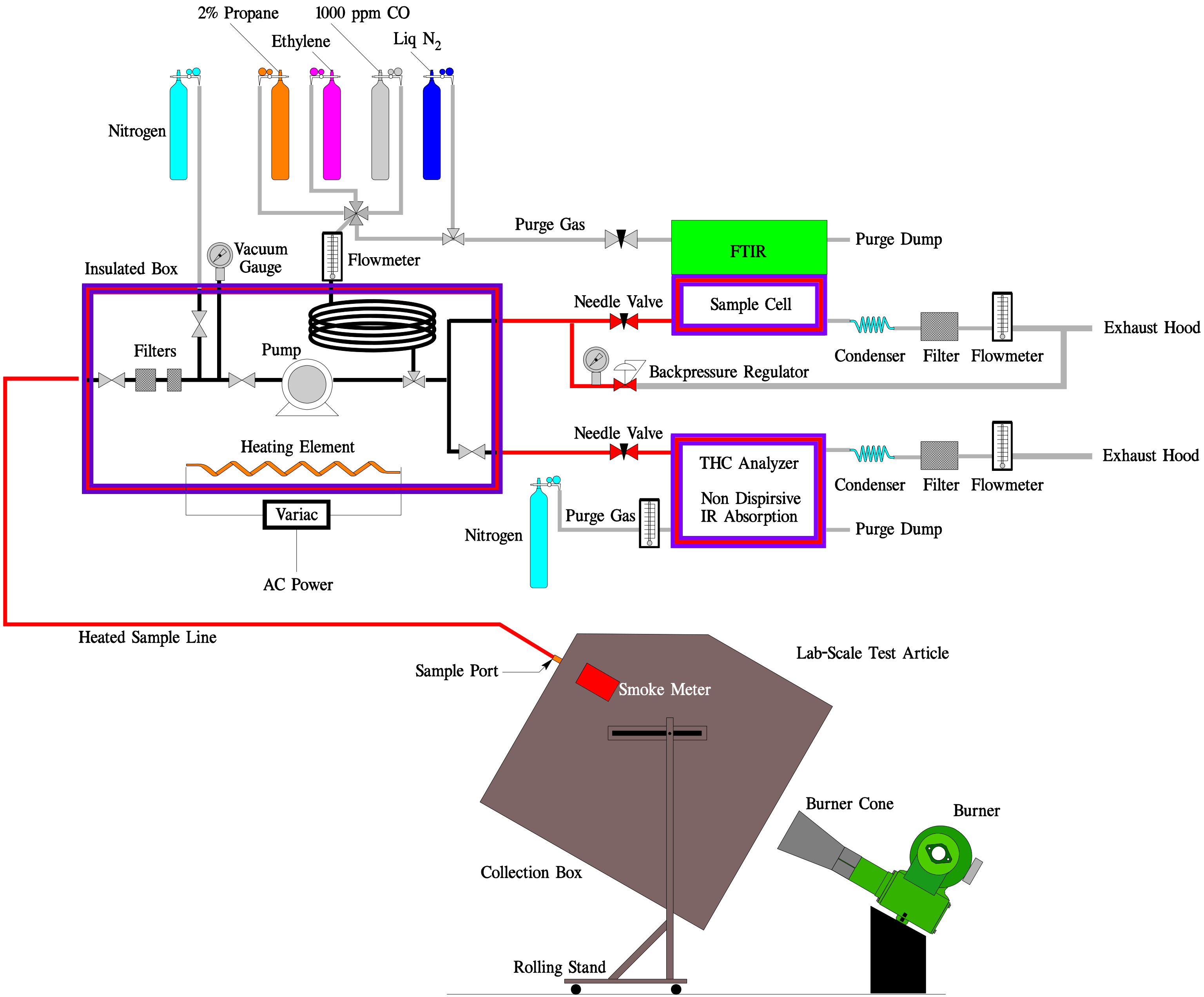
Burner configuration according to 25.856(b) Appendix F, Part VII.

Steel cube box simulates intact fuselage and serves as enclosure to collect emitted gases.

Fourier Transform Infrared (FTIR)/Total Hydrocarbon Gas analysis system used to collect and measure toxic and flammable gases yielded during tests.

Additional analyzers measured the concentration of carbon monoxide, carbon dioxide, oxygen, and total hydrocarbons (THC) as propane.

FTIR and THC Sampling System Used in Lab-Scale Testing



Gases Measured By FTIR

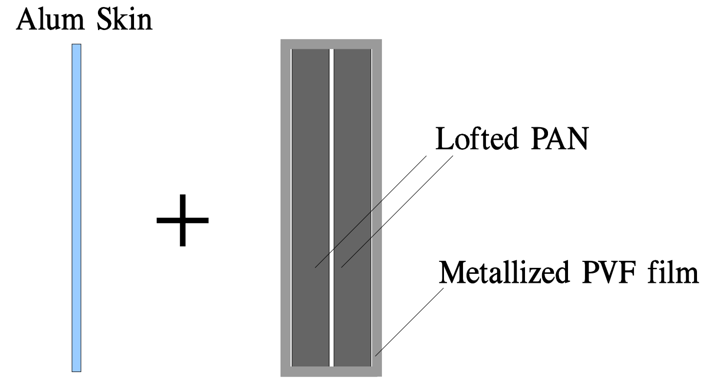
Toxic Gases	
$C_6H_5NH_2$	Aniline
C_6H_5OH	Phenol
C_6H_6	Benzene
CH_2CHCHO	Acrolein
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
$COCl_2$	Phosgene
COF_2	Carbonyl Fluoride
COS	Carbonyl Sulfide
HBr	Hydrogen Bromide
HCL	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrofluoric Acid
NH_3	Ammonia
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
SO_2	Sulfur Dioxide

Flammable Gases	
C_2H_2	Acetylene
C_2H_4	Ethylene
C_2H_6	Ethane
C_3H_8	Propane
$C_6H_5NH_2$	Aniline
C_6H_5OH	Phenol
C_6H_6	Benzene
CH_2CHCHO	Acrolein
CH_4	Methane

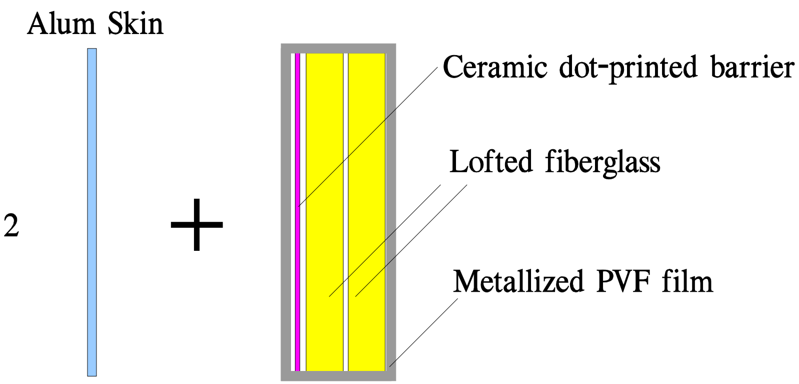
Other Gases	
CO_2	Carbon Dioxide
H_2O	Water
N_2O	Nitrous Oxide

Material Systems Tested in Lab-Scale Apparatus

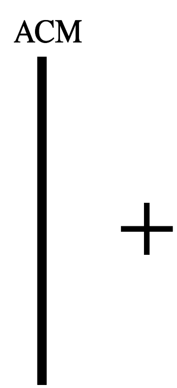
Burnthrough Compliant Insulation System 1



Burnthrough Compliant Insulation System 2

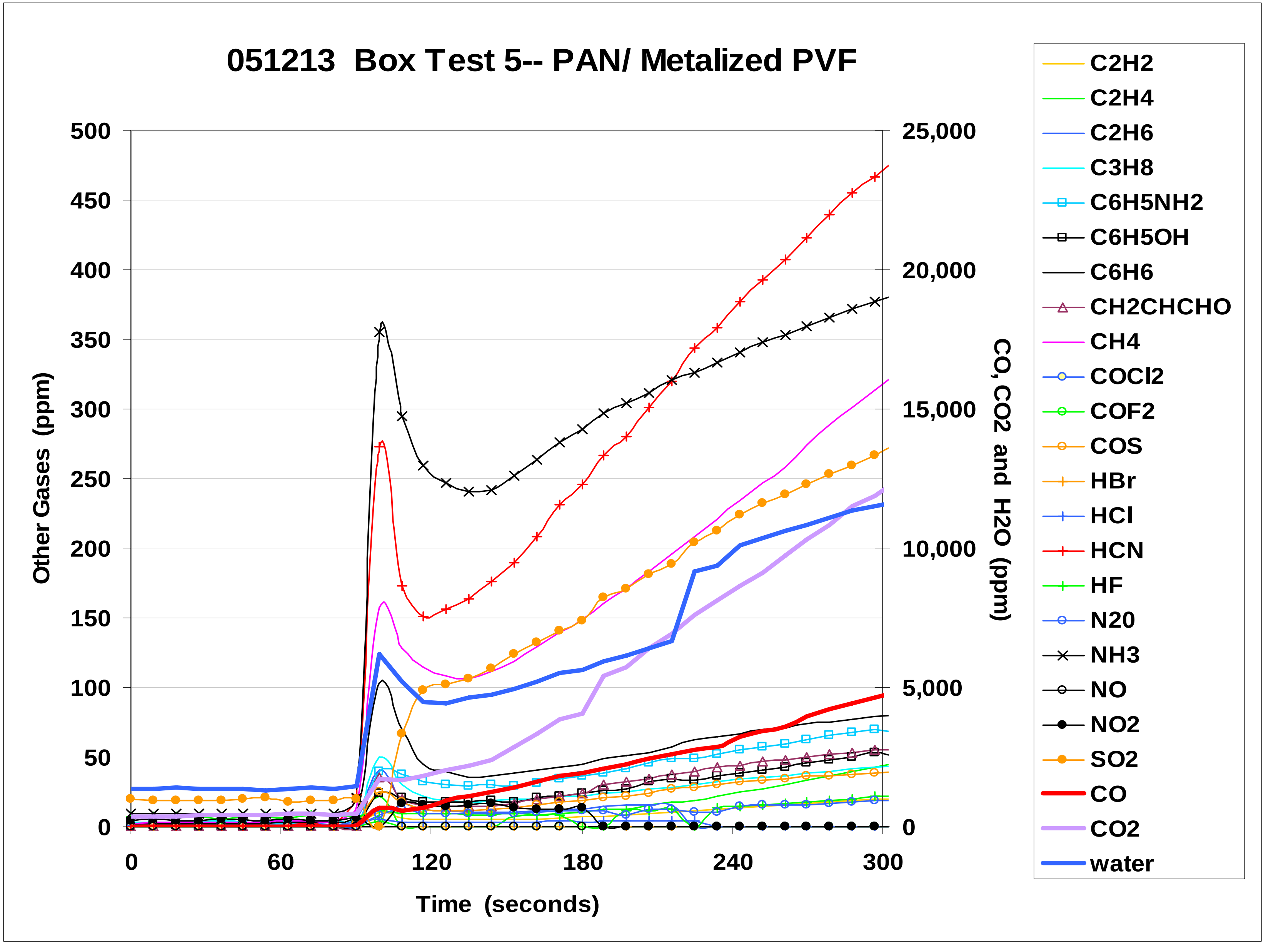


Structural Composite System 1

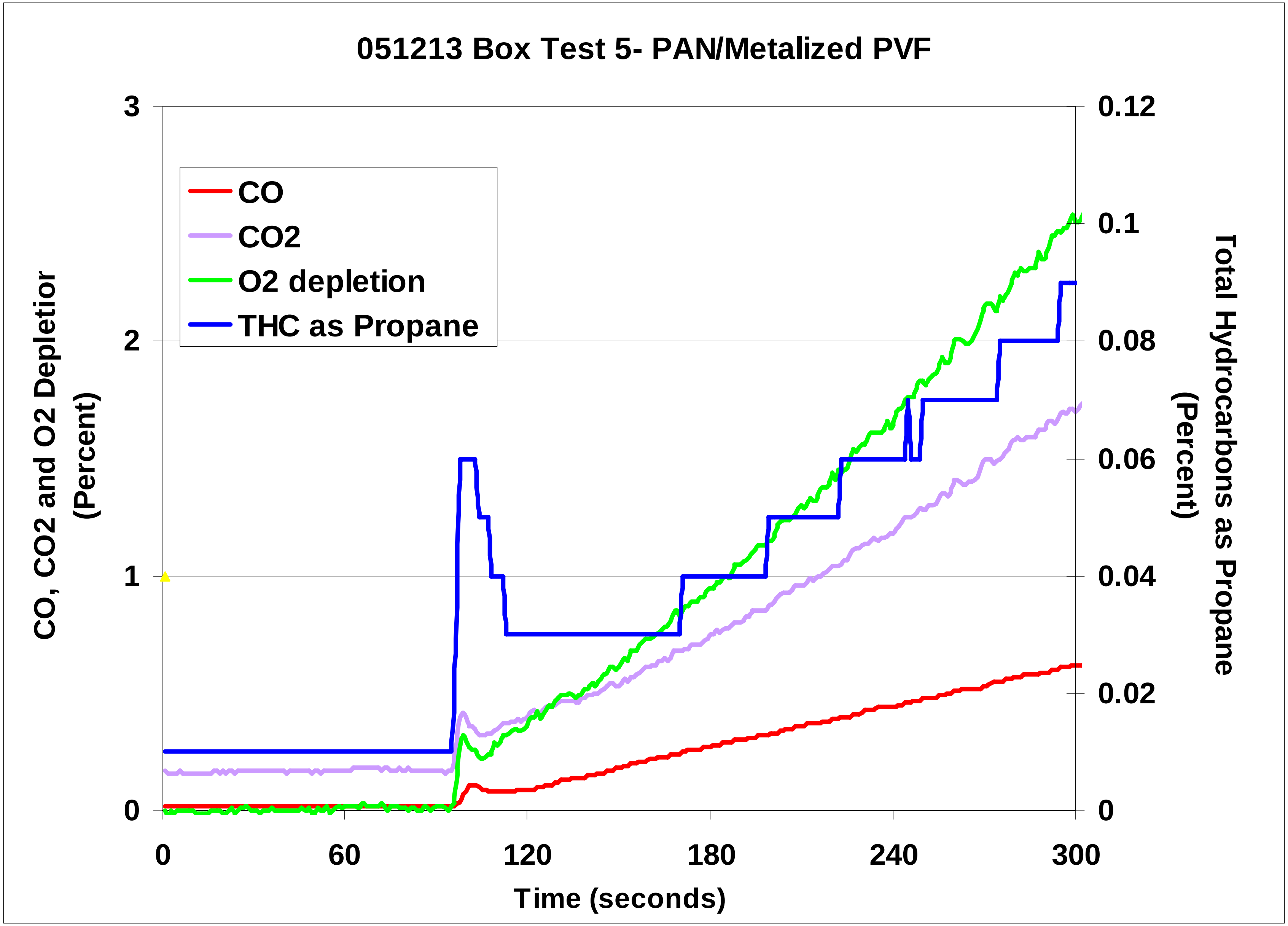


No Insulation

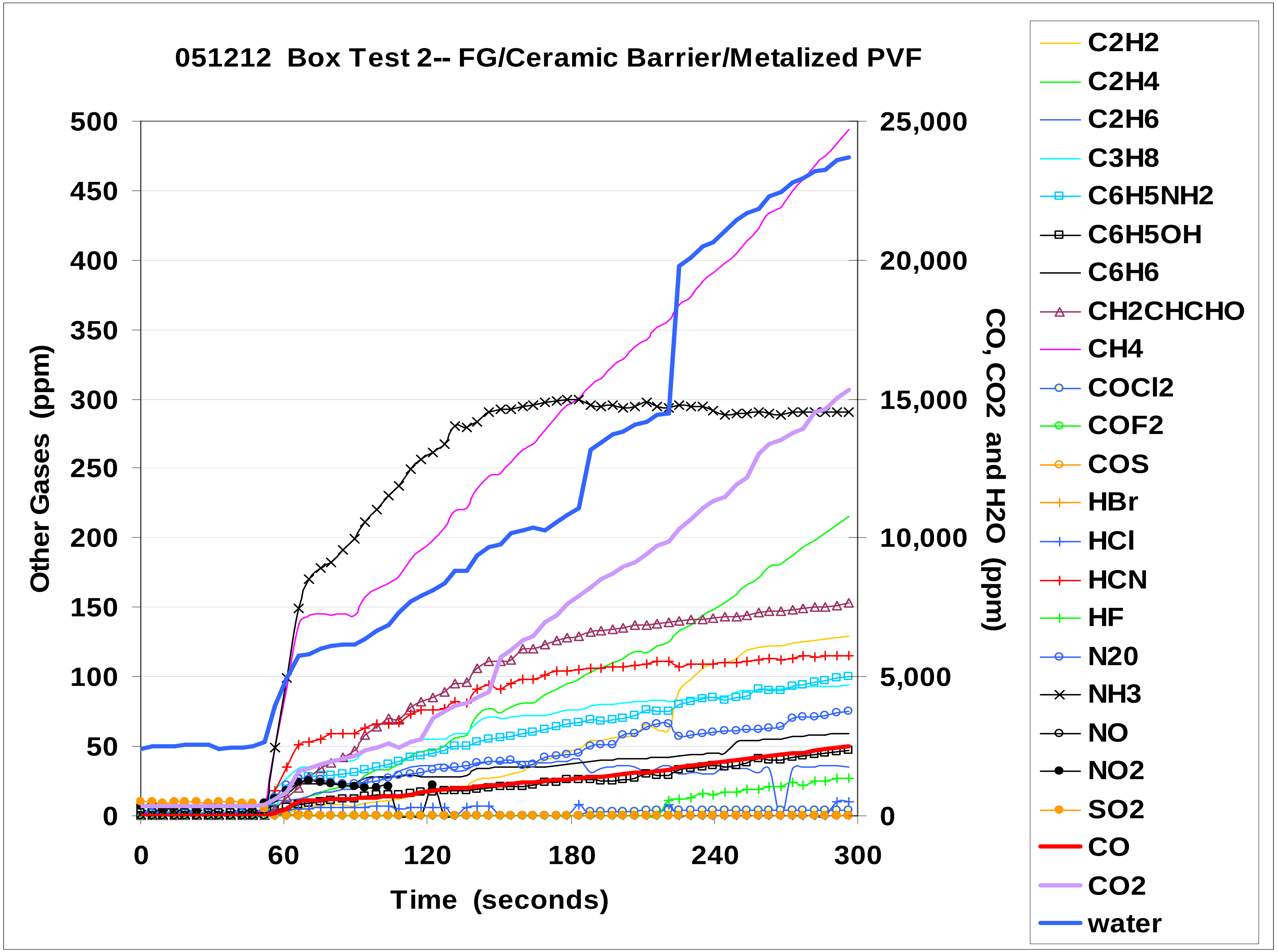
PAN Insulation Test Using FTIR Analysis



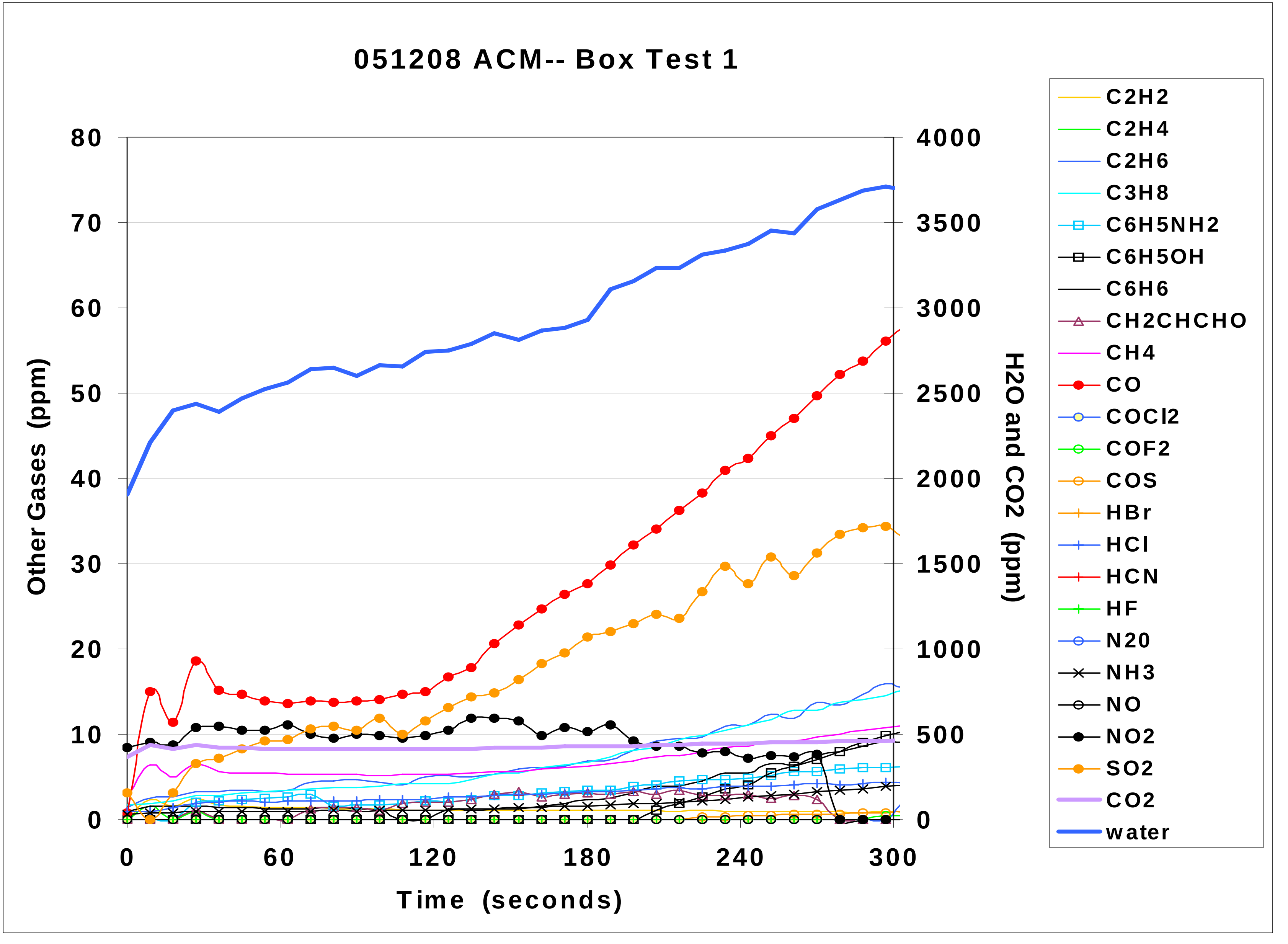
PAN Insulation Test Using Gas Analyzers



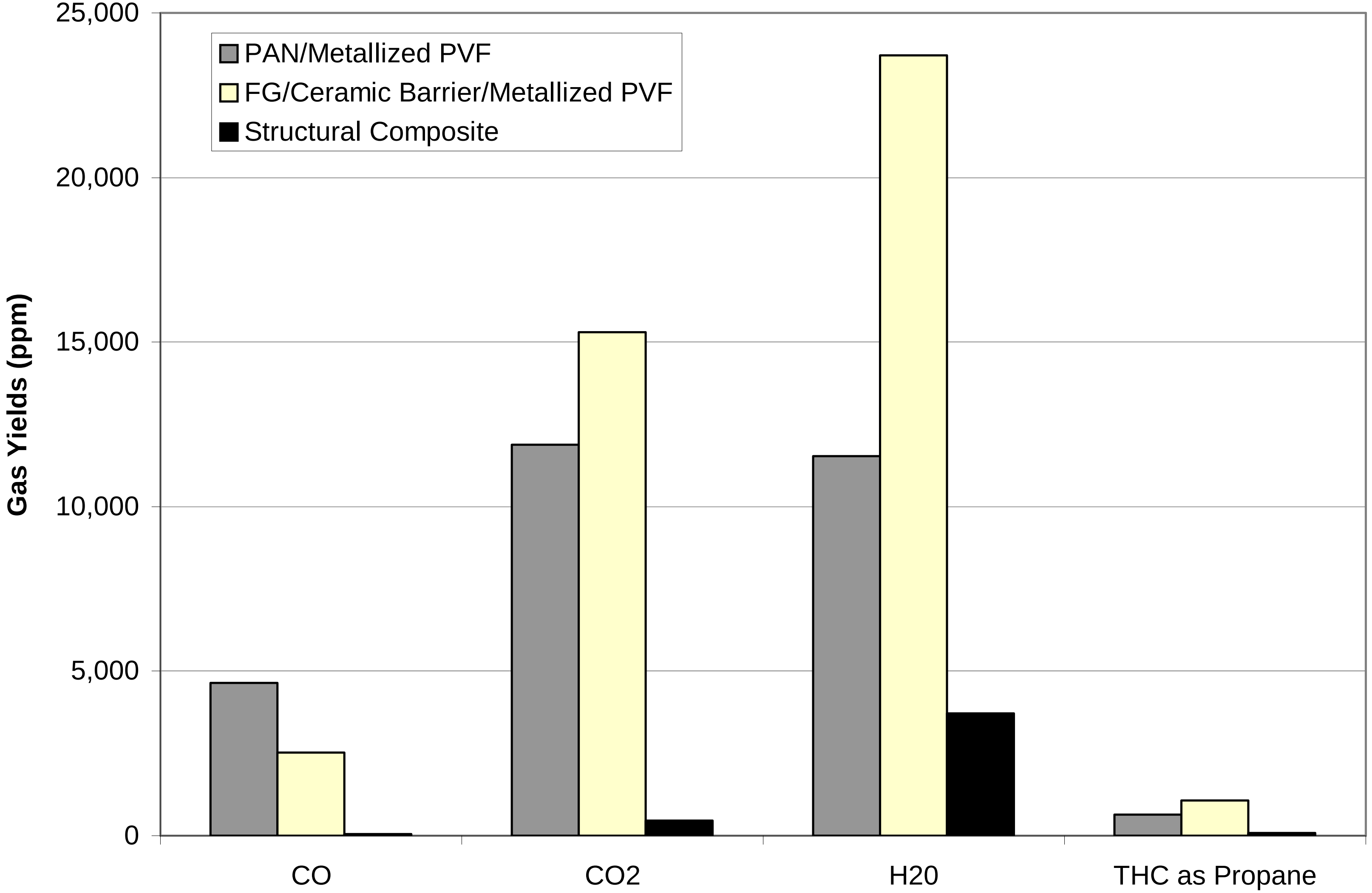
FG/Ceramic Barrier Insulation Test Using FTIR Analysis



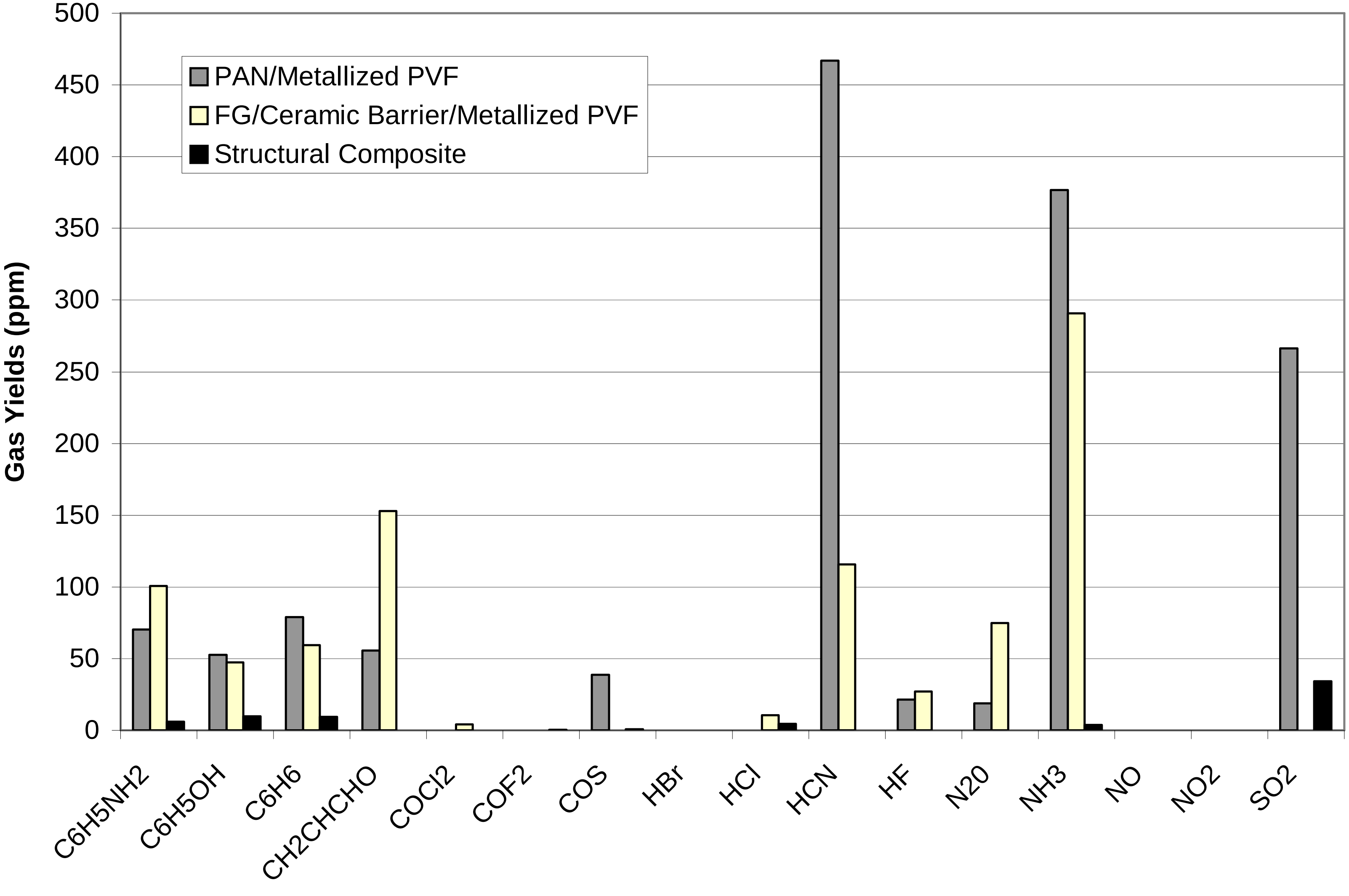
Structural Composite Material Test Using FTIR Analysis



Comparison of Box Test Results at 5 Minutes



Comparison of Box Test Results at 5 Minutes



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Development of a Laboratory-Scale Test for Evaluating the Decomposition Products Generated Inside an Intact Fuselage During a Simulated Postcrash Fuel Fire

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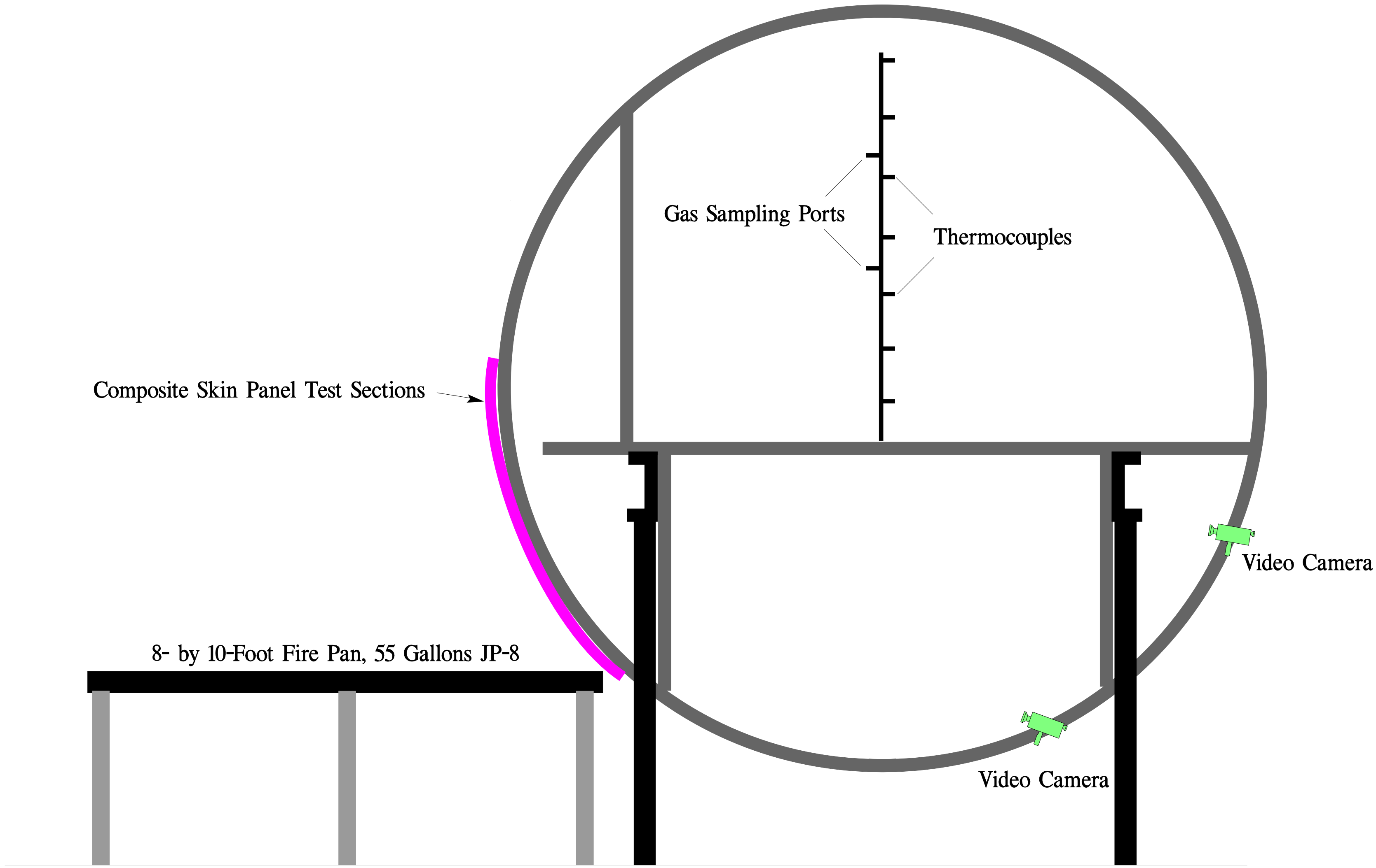
Louise C. Speitel

April 2007

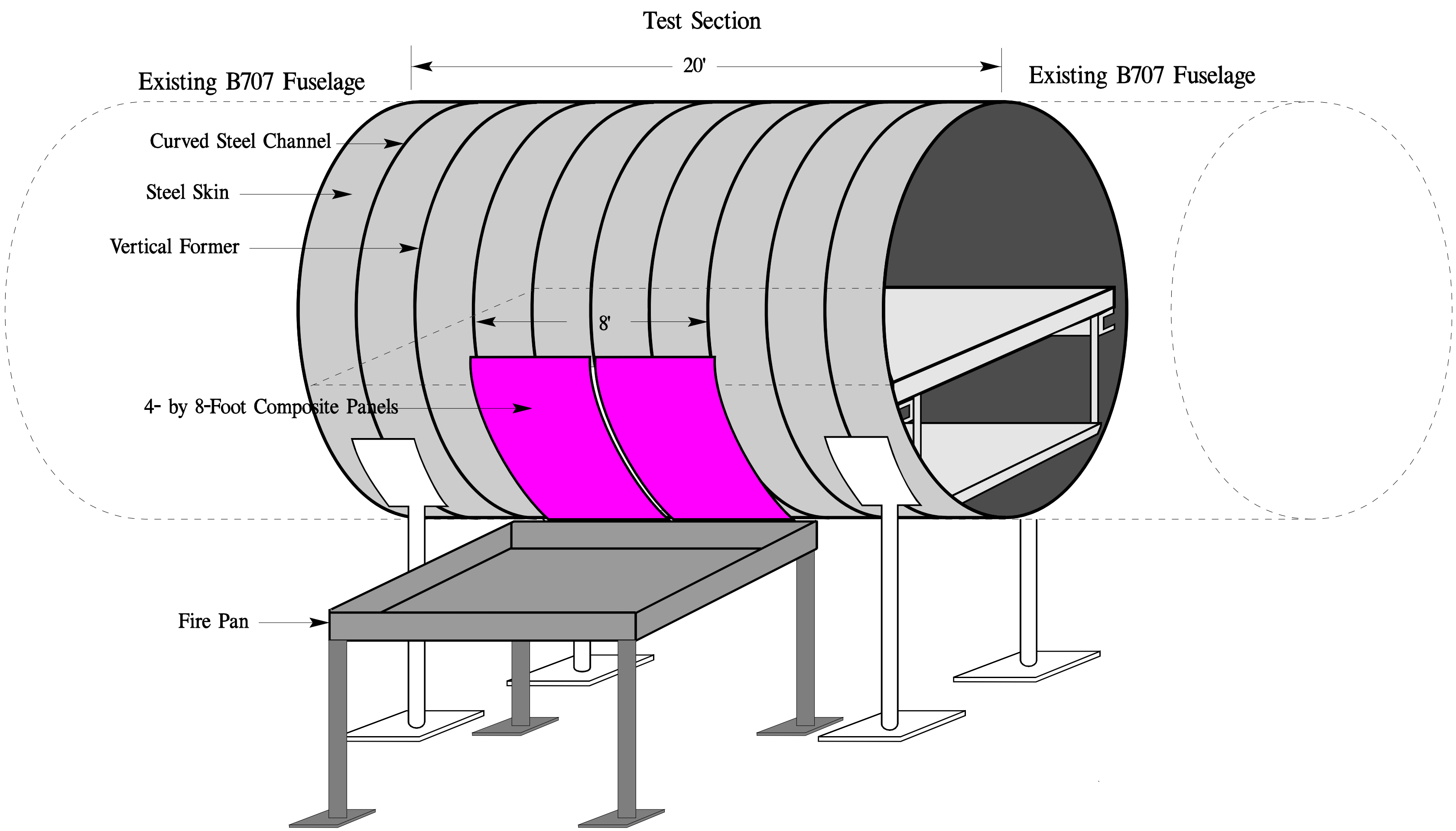
DOT/FAA/AR-TN07/15

U.S. Department of Transportation
Federal Aviation Administration

Full-Scale Test Article for Evaluating Decomposition Products of Burnthrough Compliant Insulation Systems and Non-Metallic Fuselage Structure



Full-Scale Test Article for Evaluating Decomposition Products of Burnthrough Compliant Insulation Systems and Non-Metallic Fuselage Structure



Full-Scale Test Article for Evaluating Decomposition Products of Burnthrough Compliant Insulation Systems and Non-Metallic Fuselage Structure

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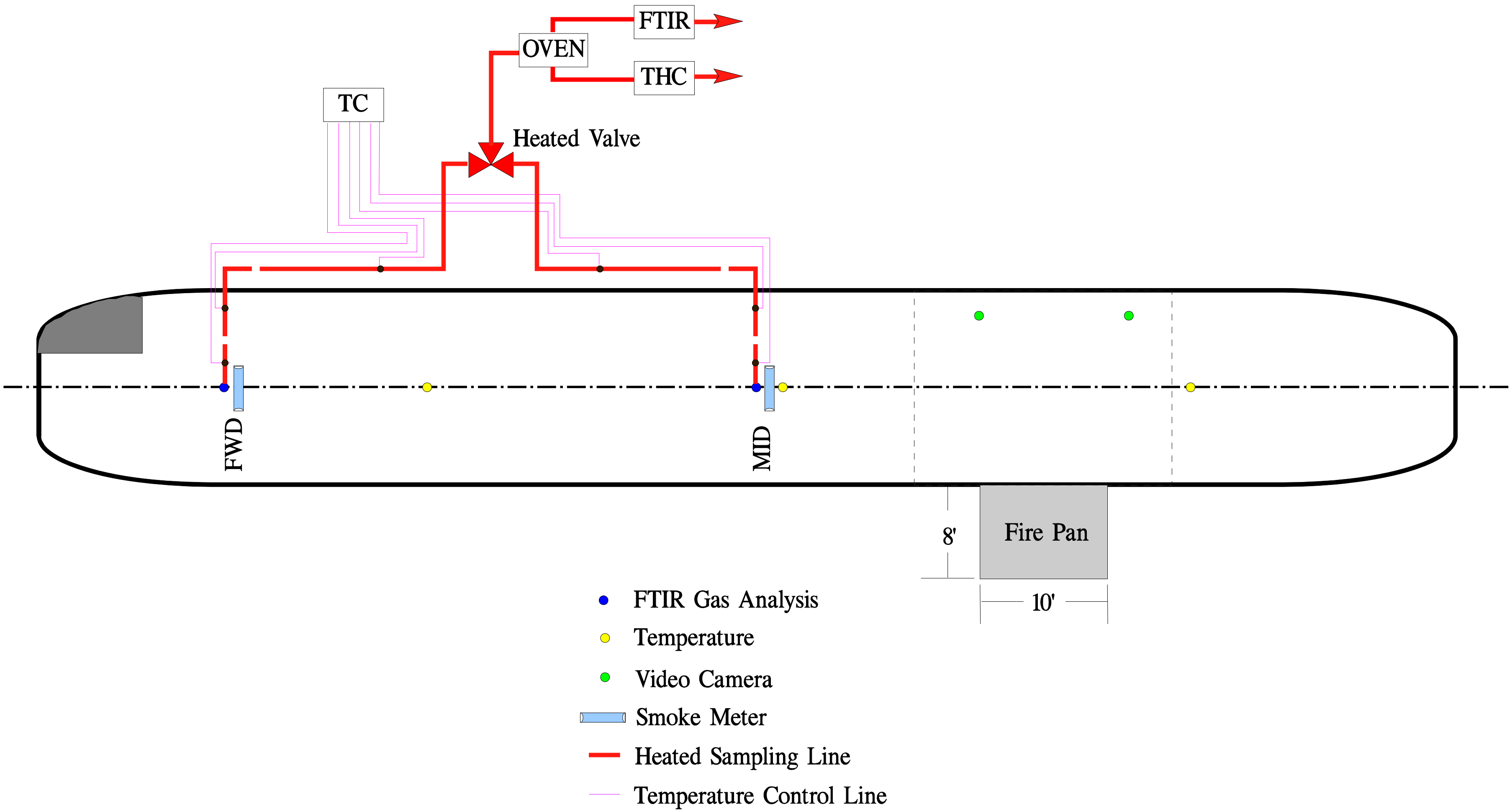
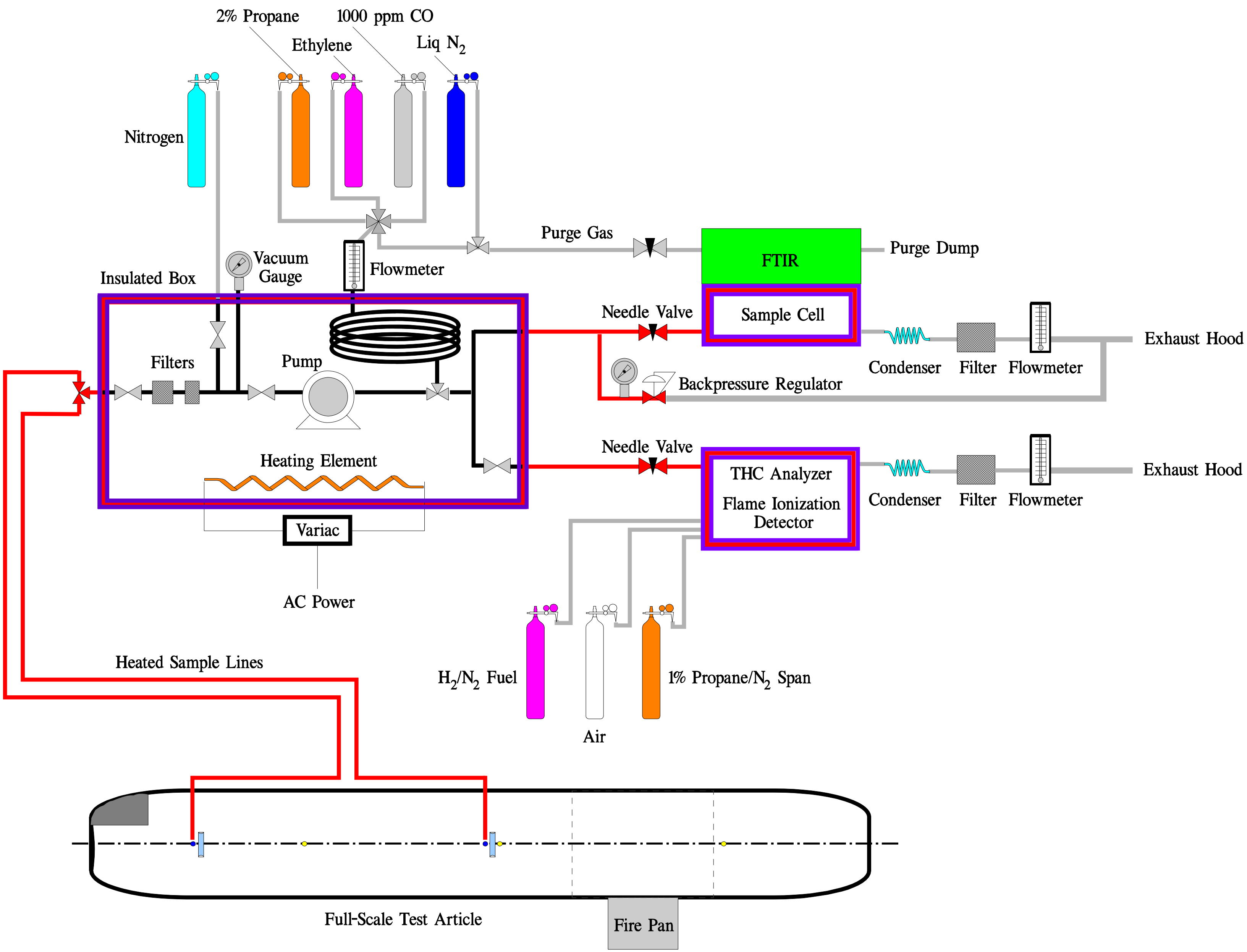


FTIR and THC Sampling System Used in Full-Scale Testing



Full-Scale Test Results
PAN Insulation System

Full-Scale Test Results, PAN Insulation System

Full-Scale Test Results, PAN Insulation System

Pre-test

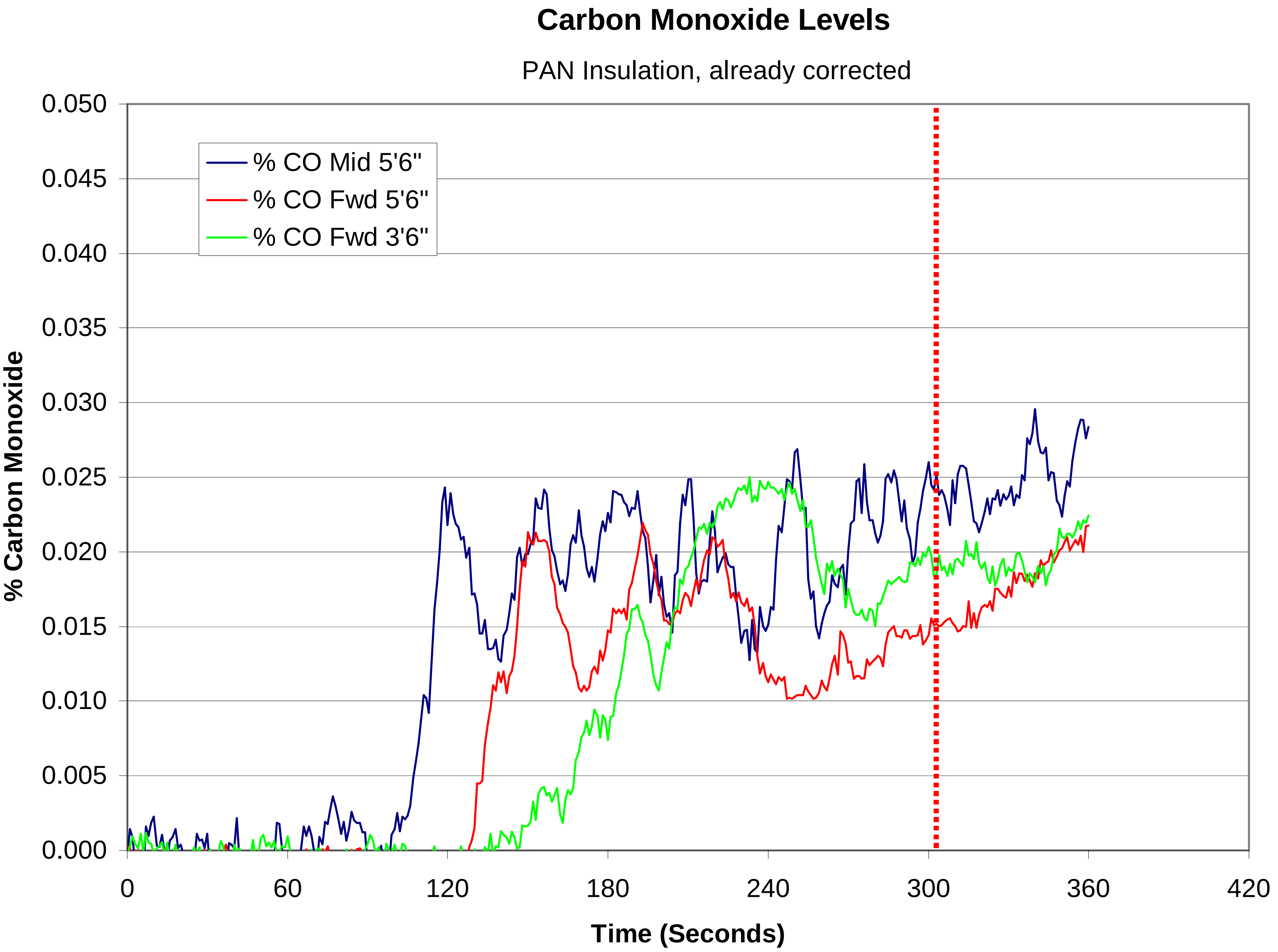
Full-Scale Test Results, PAN Insulation System

Post-test

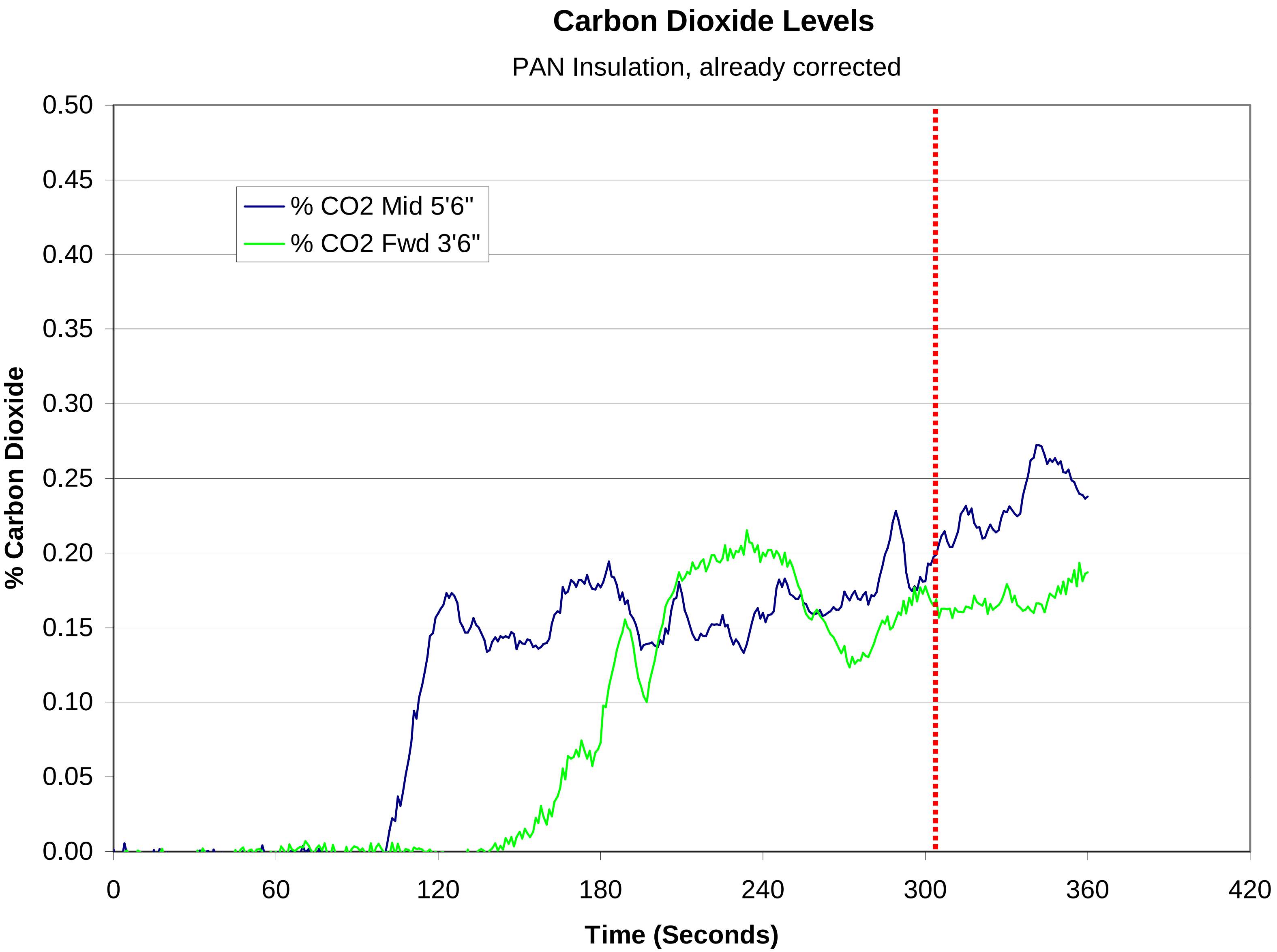
Full-Scale Test Results, PAN Insulation System

Post-test

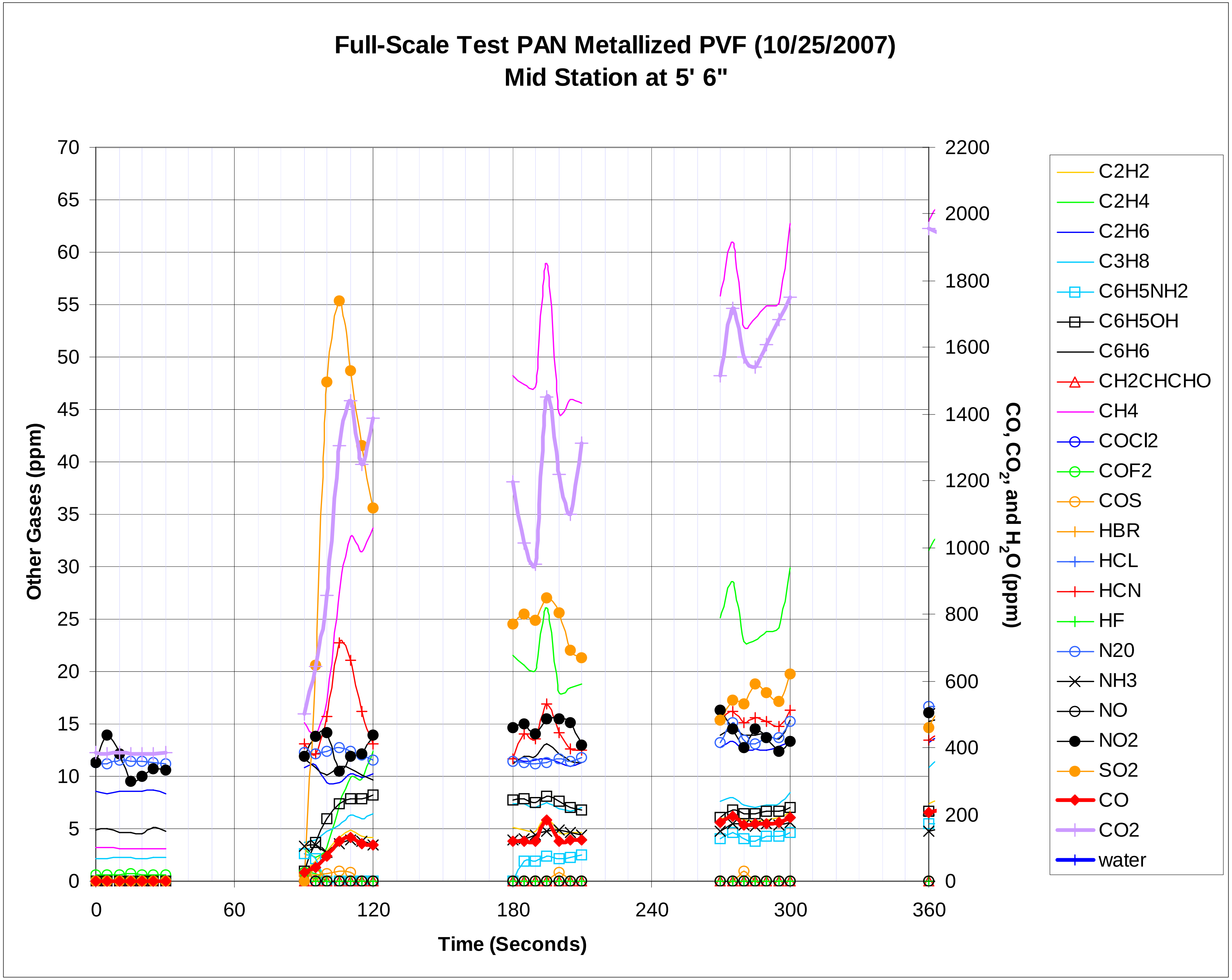
Full-Scale Results, PAN Insulation, Gas Analyzers



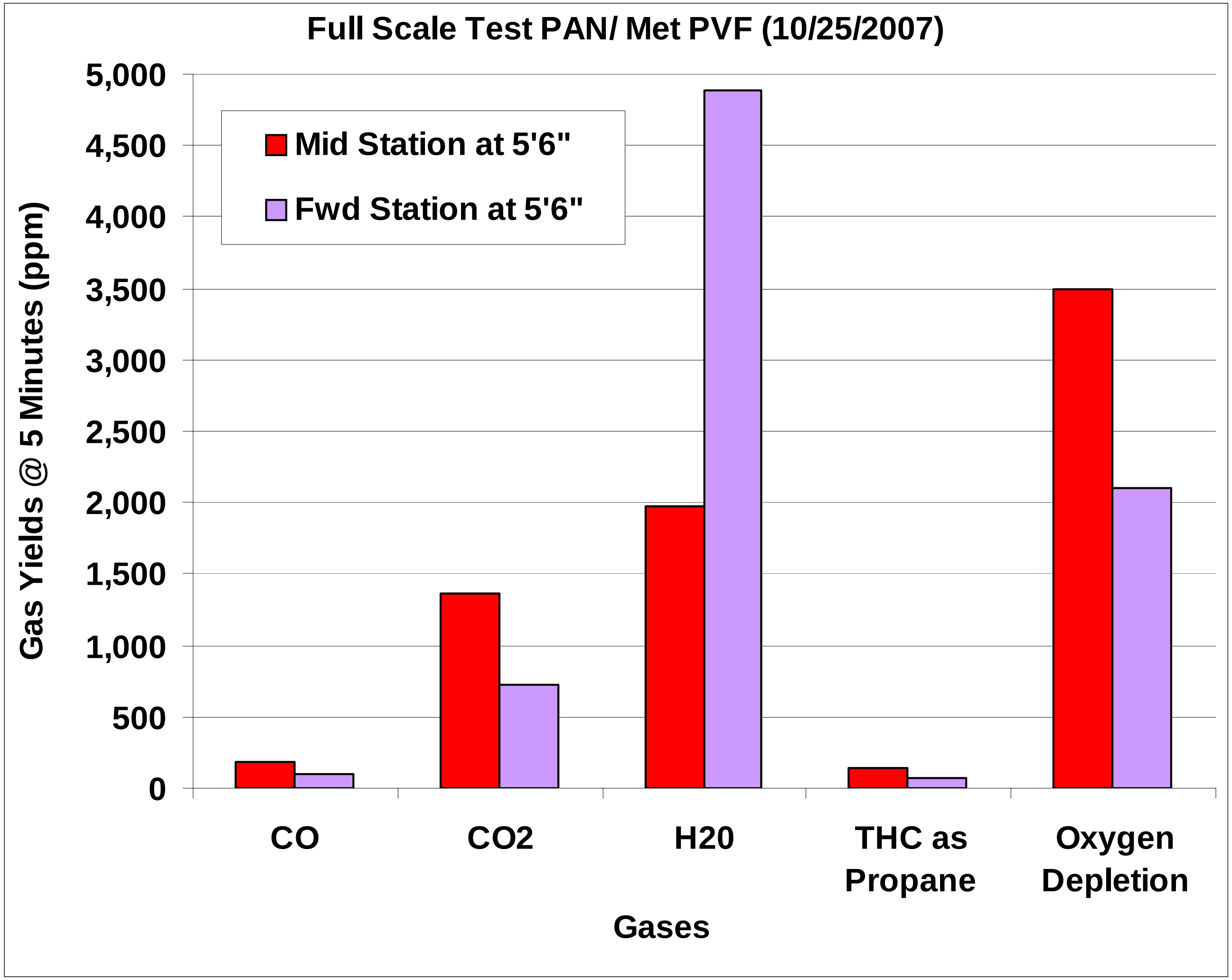
Full-Scale Results, PAN Insulation, Gas Analyzers



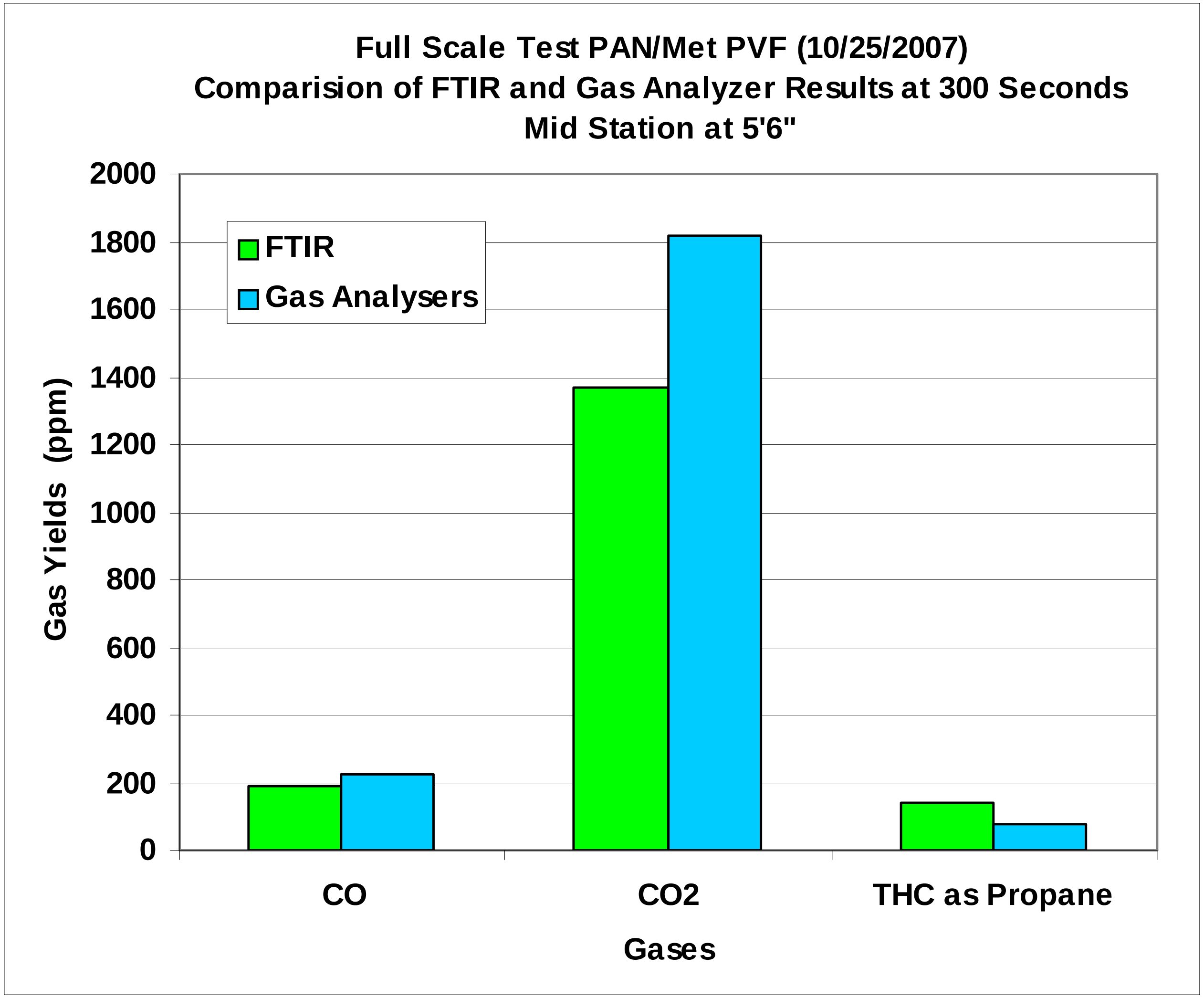
Full-Scale Results, PAN Insulation, FTIR



Full-Scale Results, PAN Insulation, FTIR



Full-Scale Results, PAN Insulation, Comparison



Full-Scale Test Results
Ceramic Barrier Insulation System
(Modified Configuration)

Full-Scale Test Results, Ceramic Barrier Insulation System II

Pre-test

Full-Scale Test Results, Ceramic Barrier Insulation System II

Full-Scale Test Results, Ceramic Barrier Insulation System II

Post-test

Full-Scale Test Results, Ceramic Barrier Insulation System II

Post-test

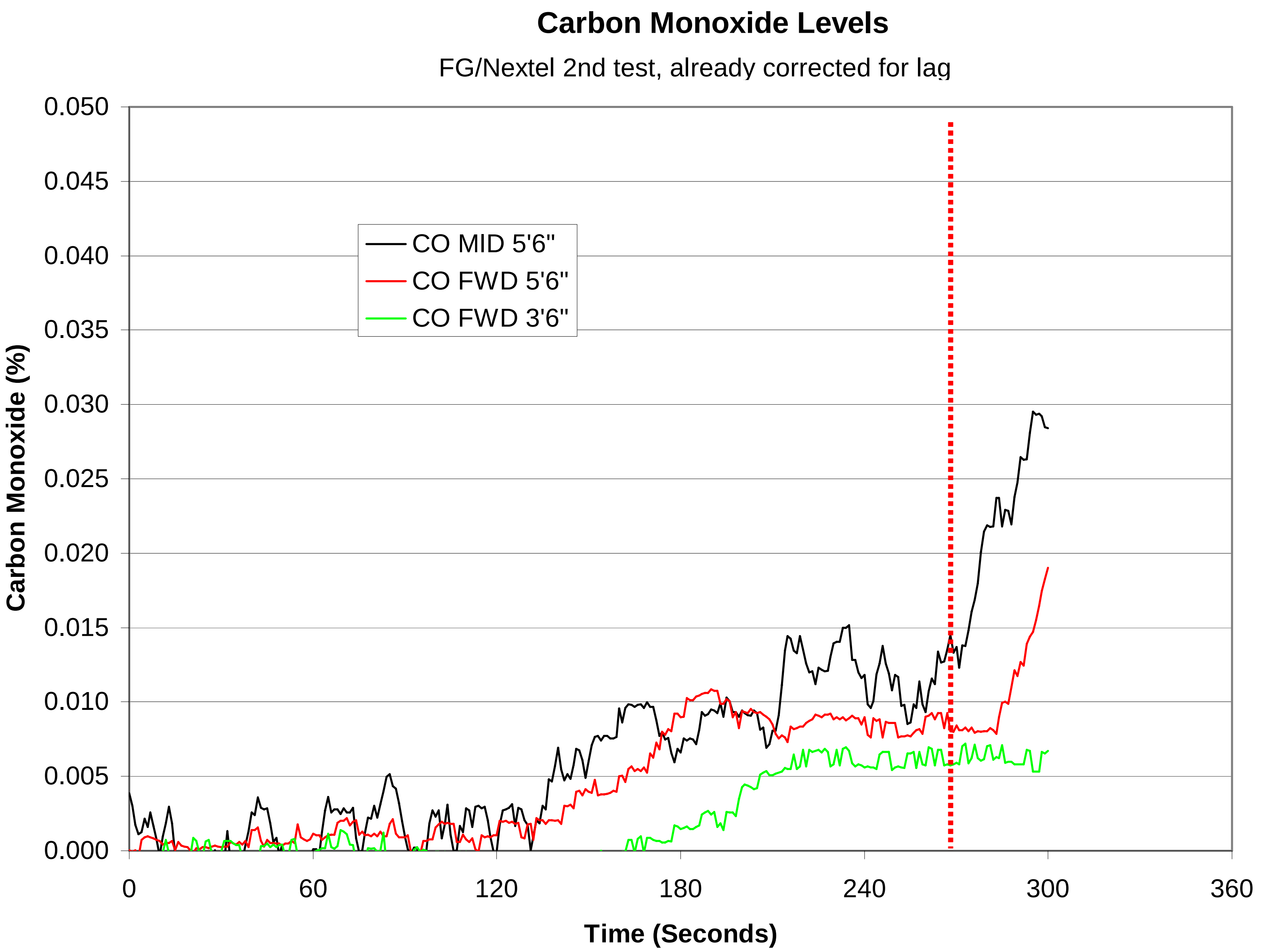
Full-Scale Test Results, Ceramic Barrier Insulation System II

Post-test

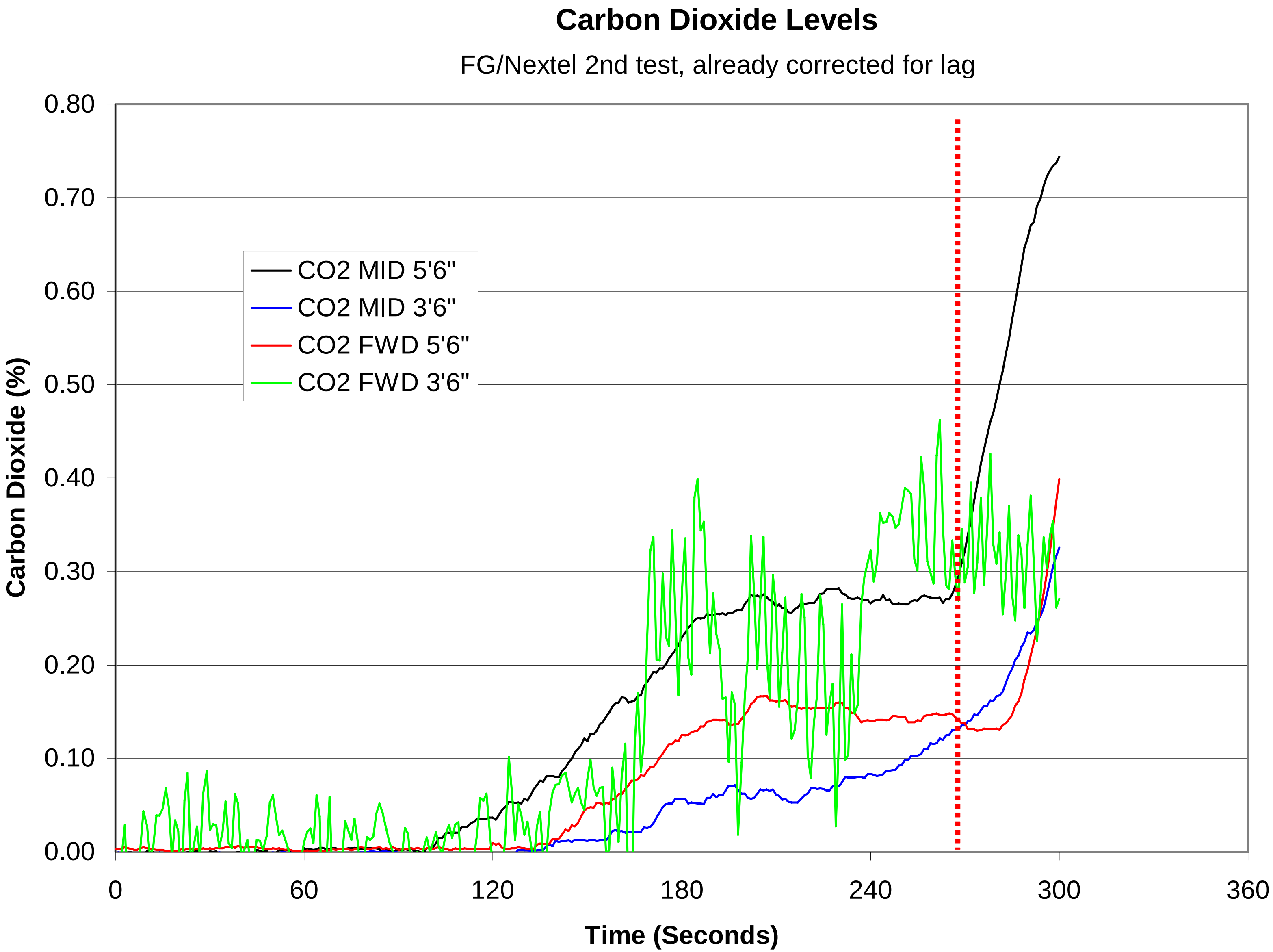
Full-Scale Test Results, Ceramic Barrier Insulation System II

Post-test

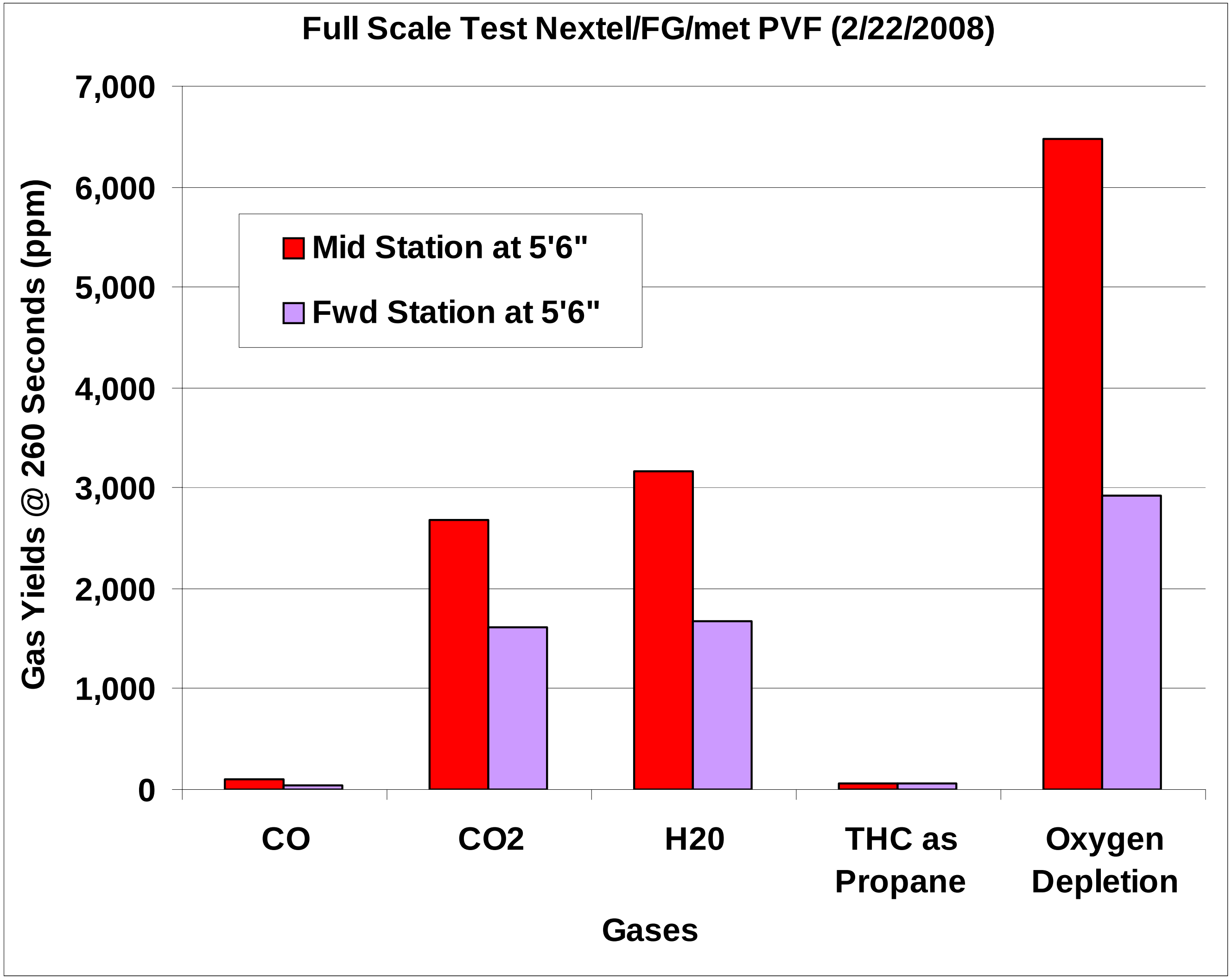
Full-Scale Results, Ceramic Barrier Insulation II, Gas Analyzer



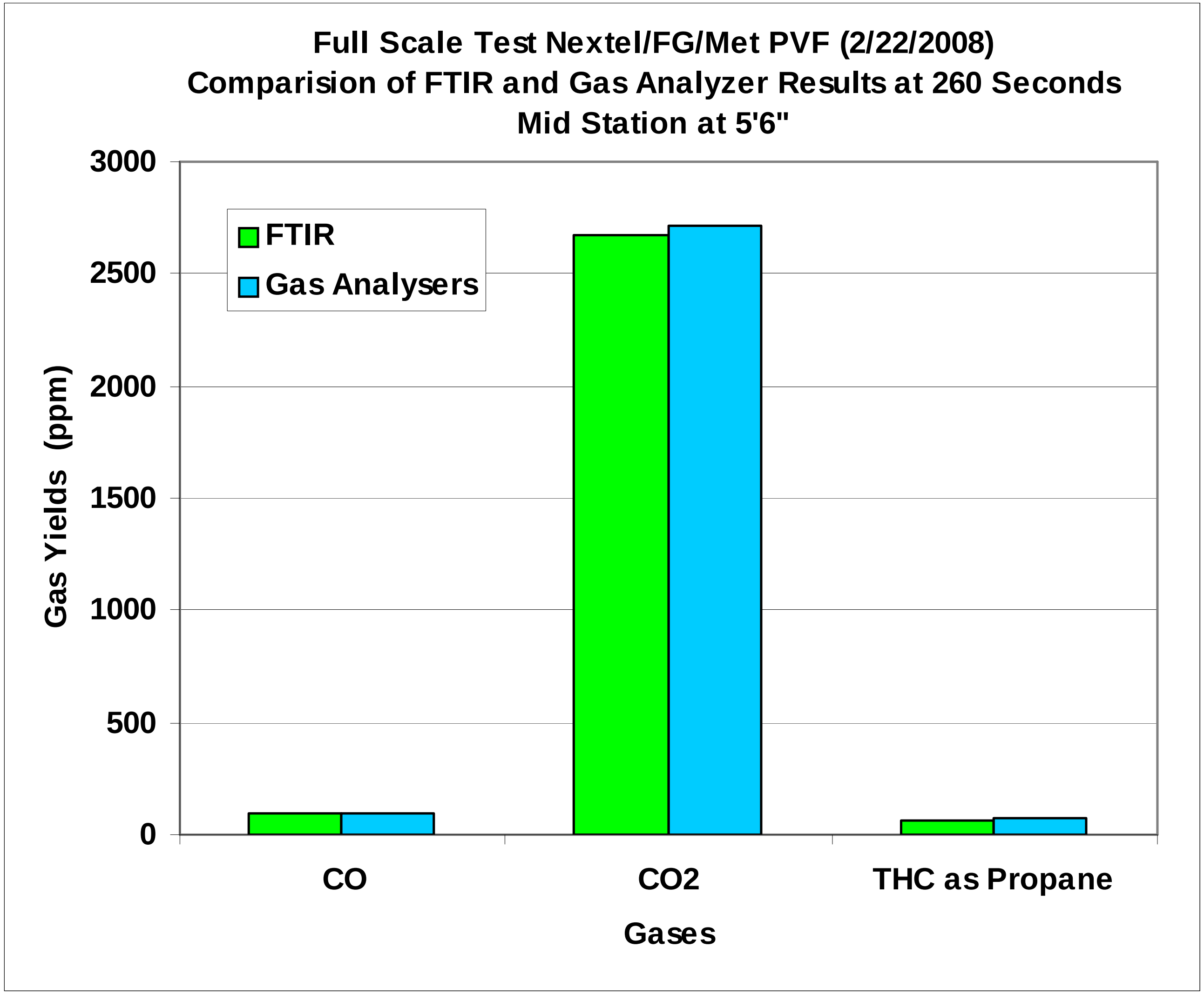
Full-Scale Results, Ceramic Barrier Insulation II, Gas Analyzer



Full-Scale Results, Ceramic Barrier Insulation II, FTIR



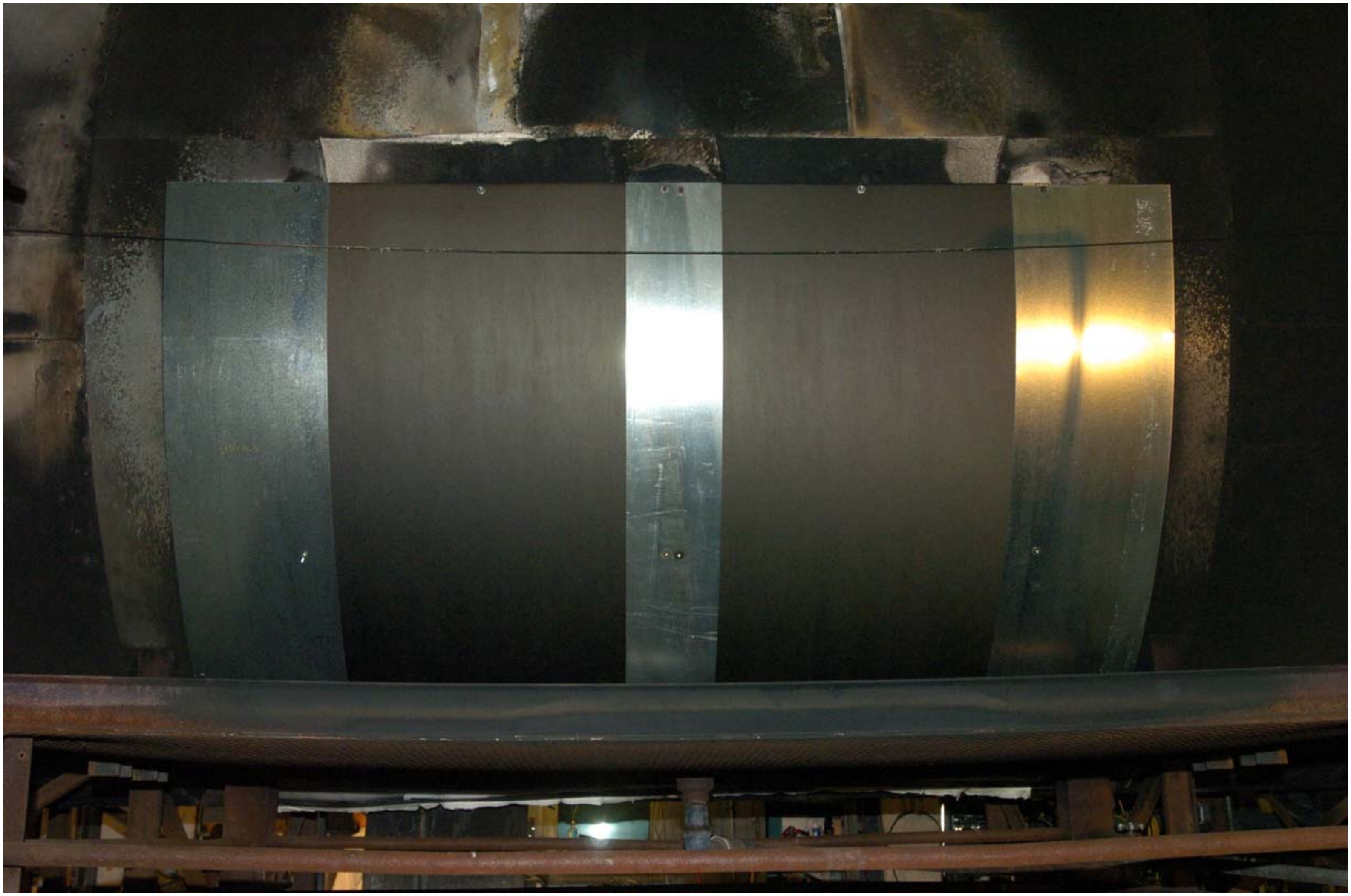
Full-Scale Results, Ceramic Barrier Insulation II, Comparison



Full-Scale Test Results
Structural Composite System

Full-Scale Test Results, Structural Composite System

Pre-test



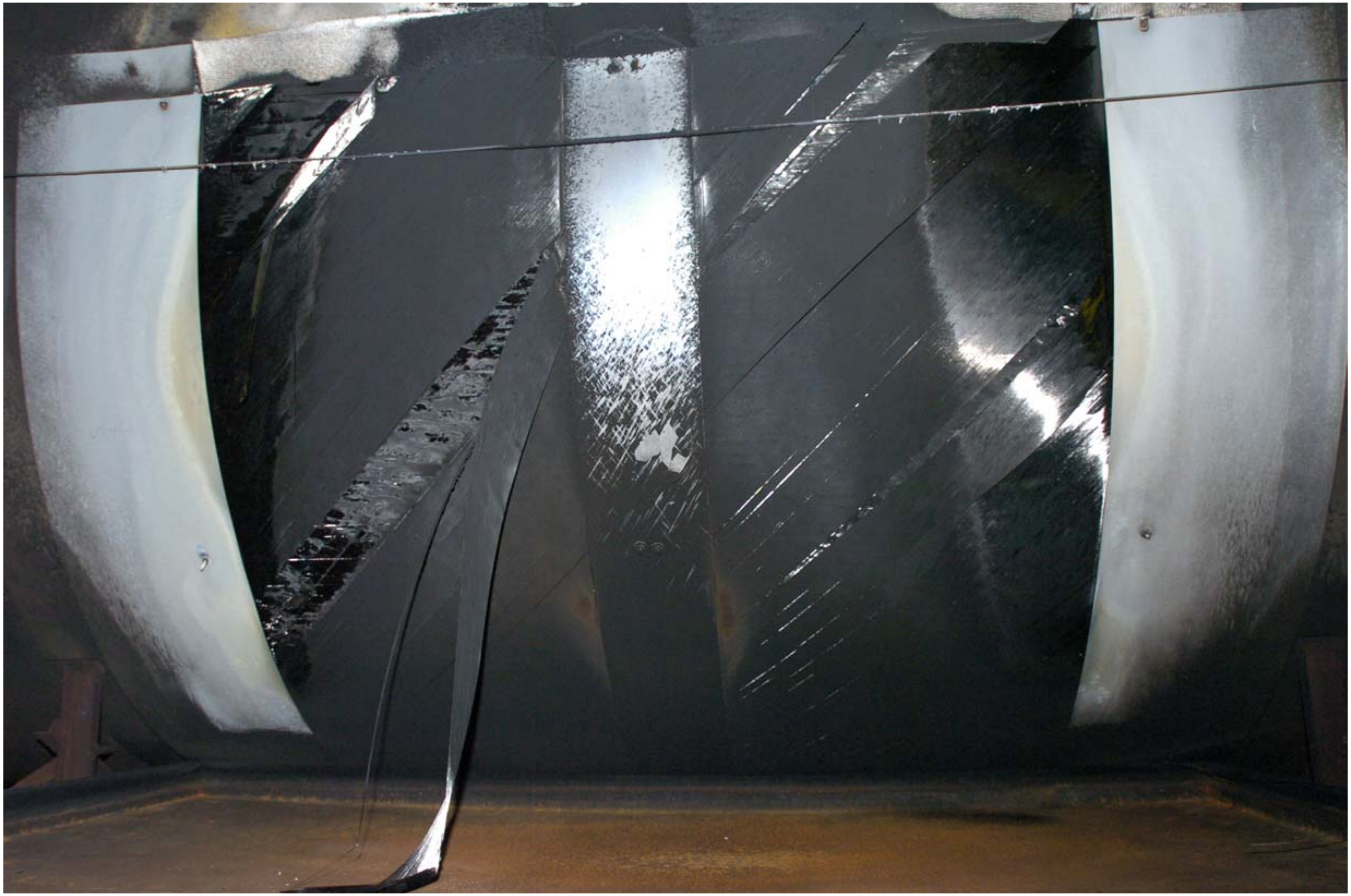
Full-Scale Test Results, Structural Composite System

Full-Scale Test Results, Structural Composite System

Post-test

Full-Scale Test Results, Structural Composite System

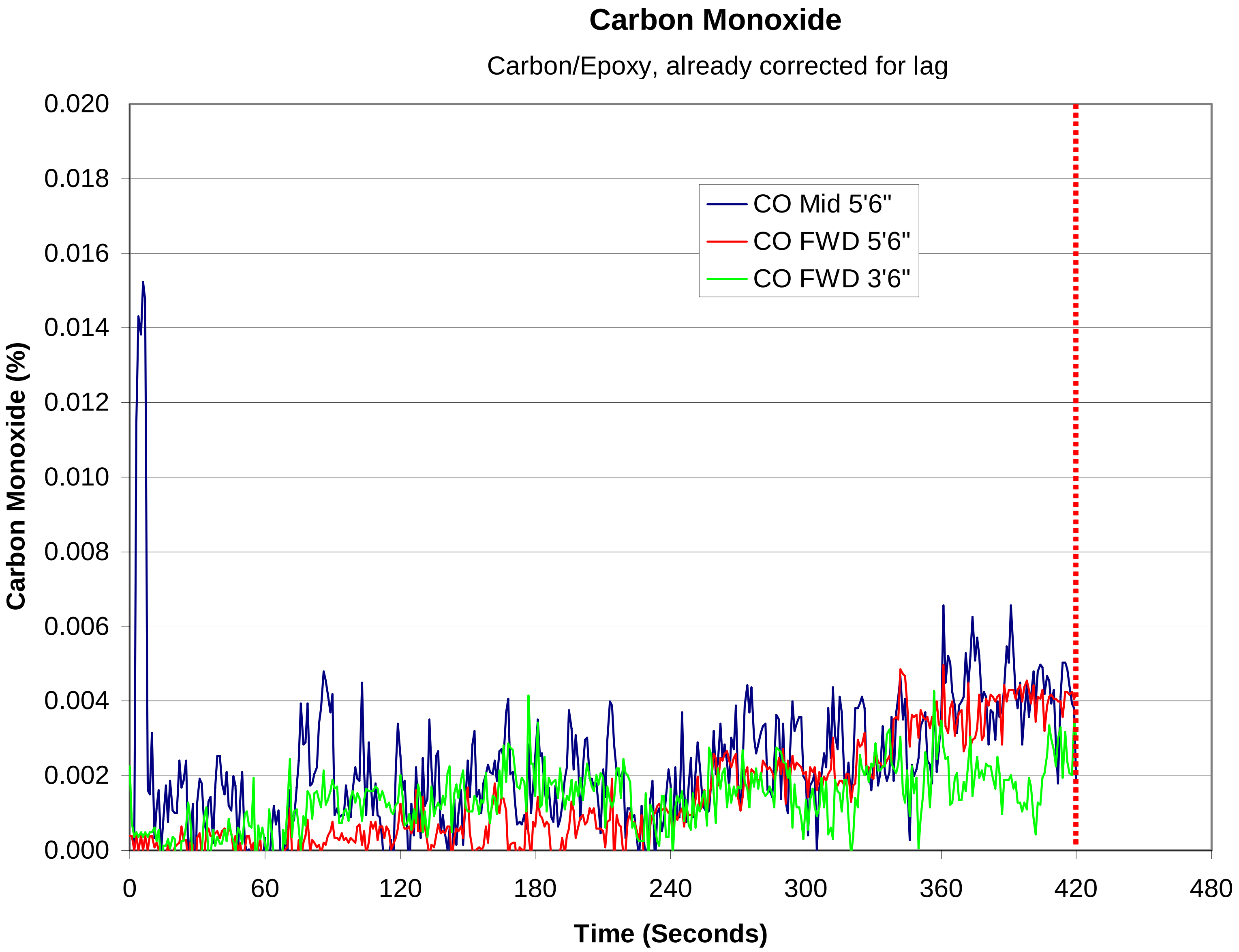
Post-test



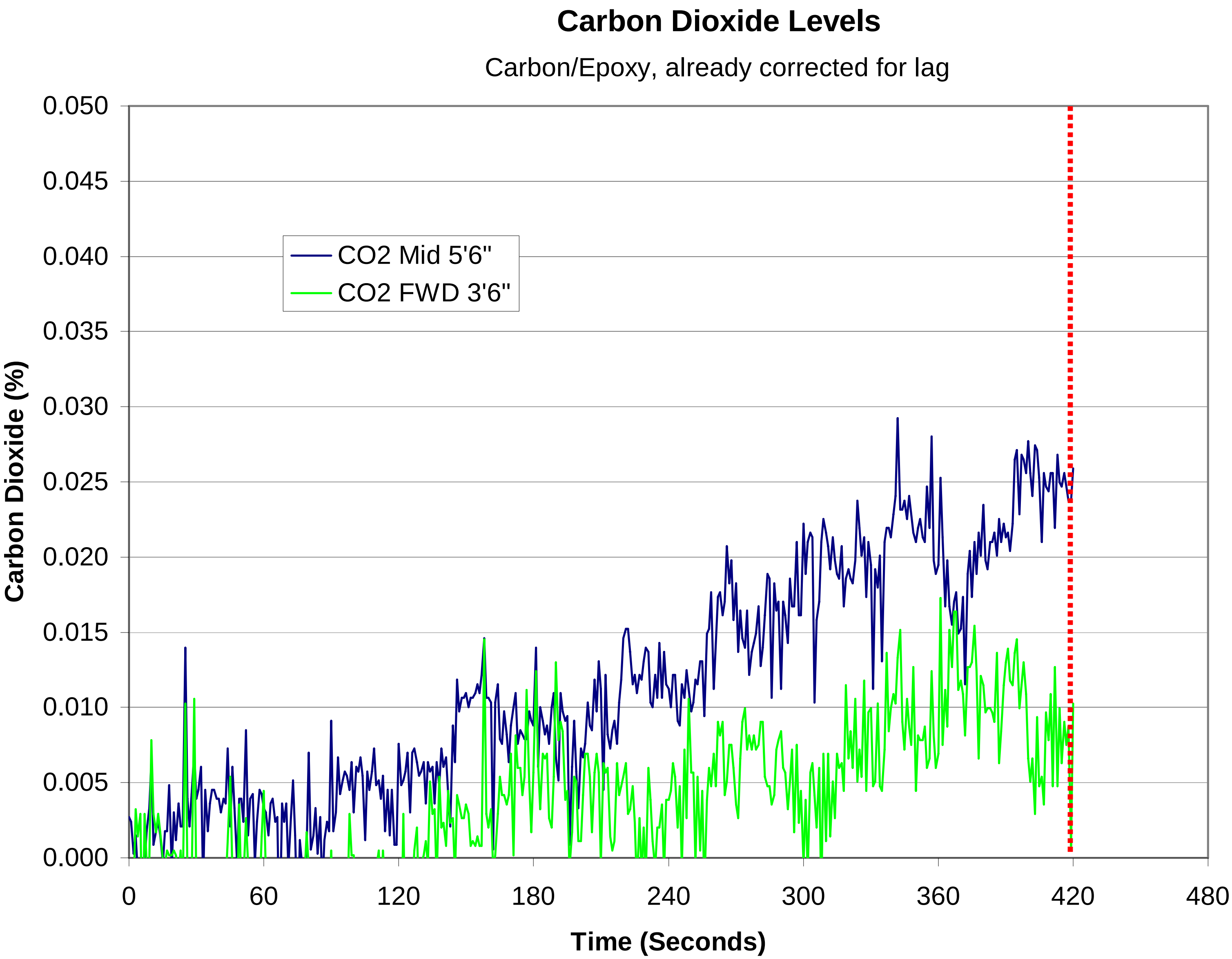
Full-Scale Test Results, Structural Composite System

Post-test

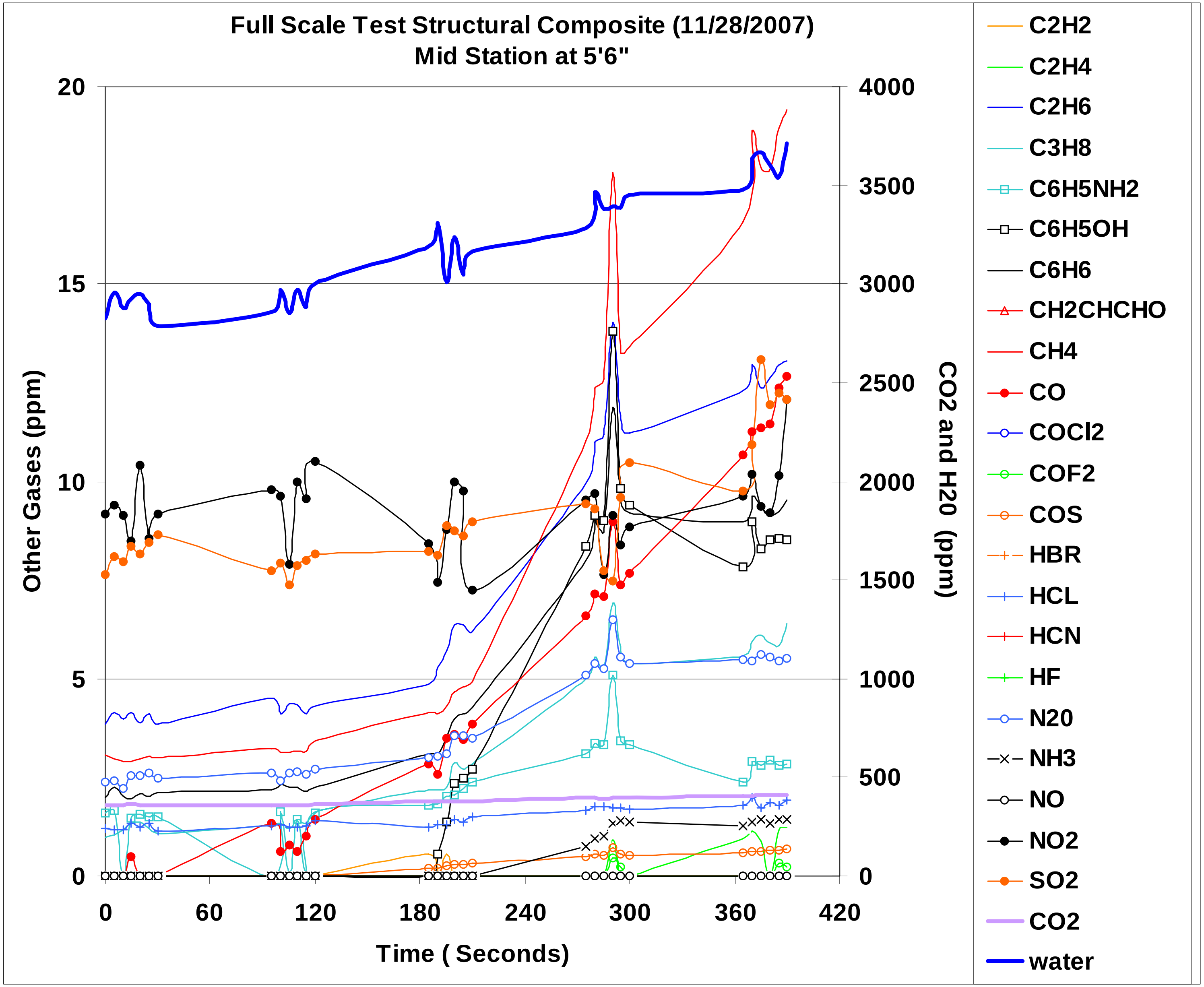
Full-Scale Results, Structural Composite, Gas Analyzer



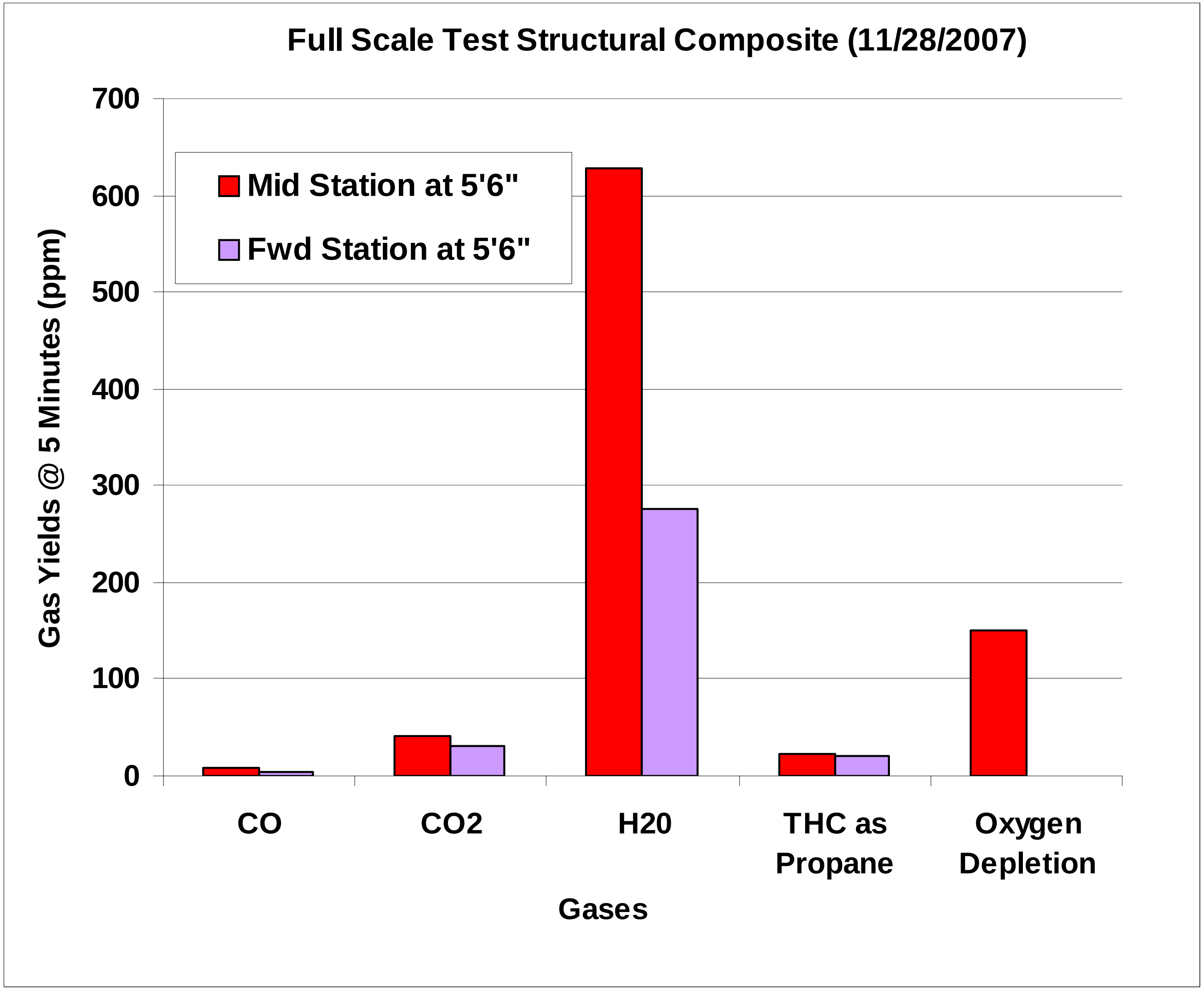
Full-Scale Results, Structural Composite, Gas Analyzer



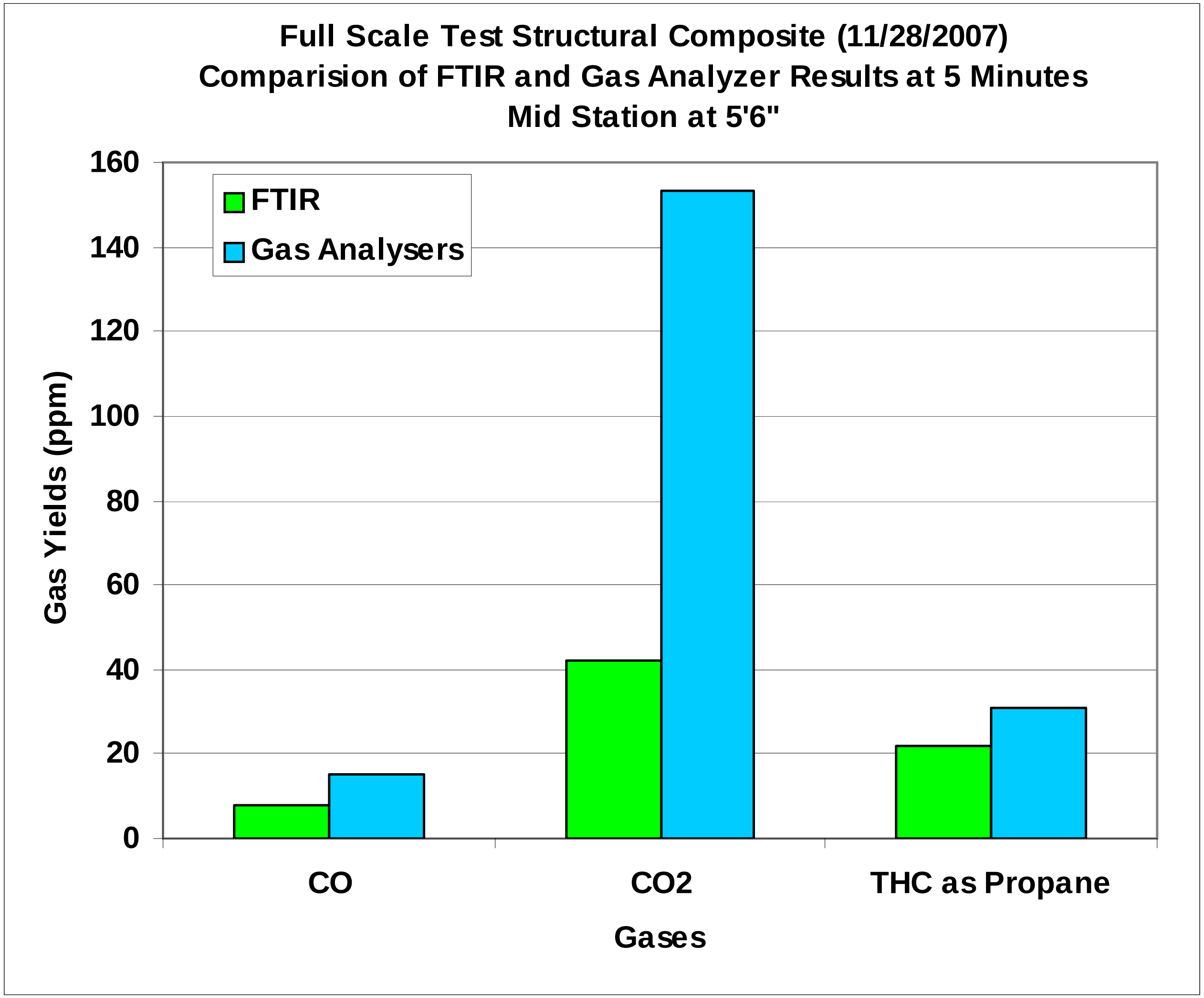
Full-Scale Results, Structural Composite, FTIR



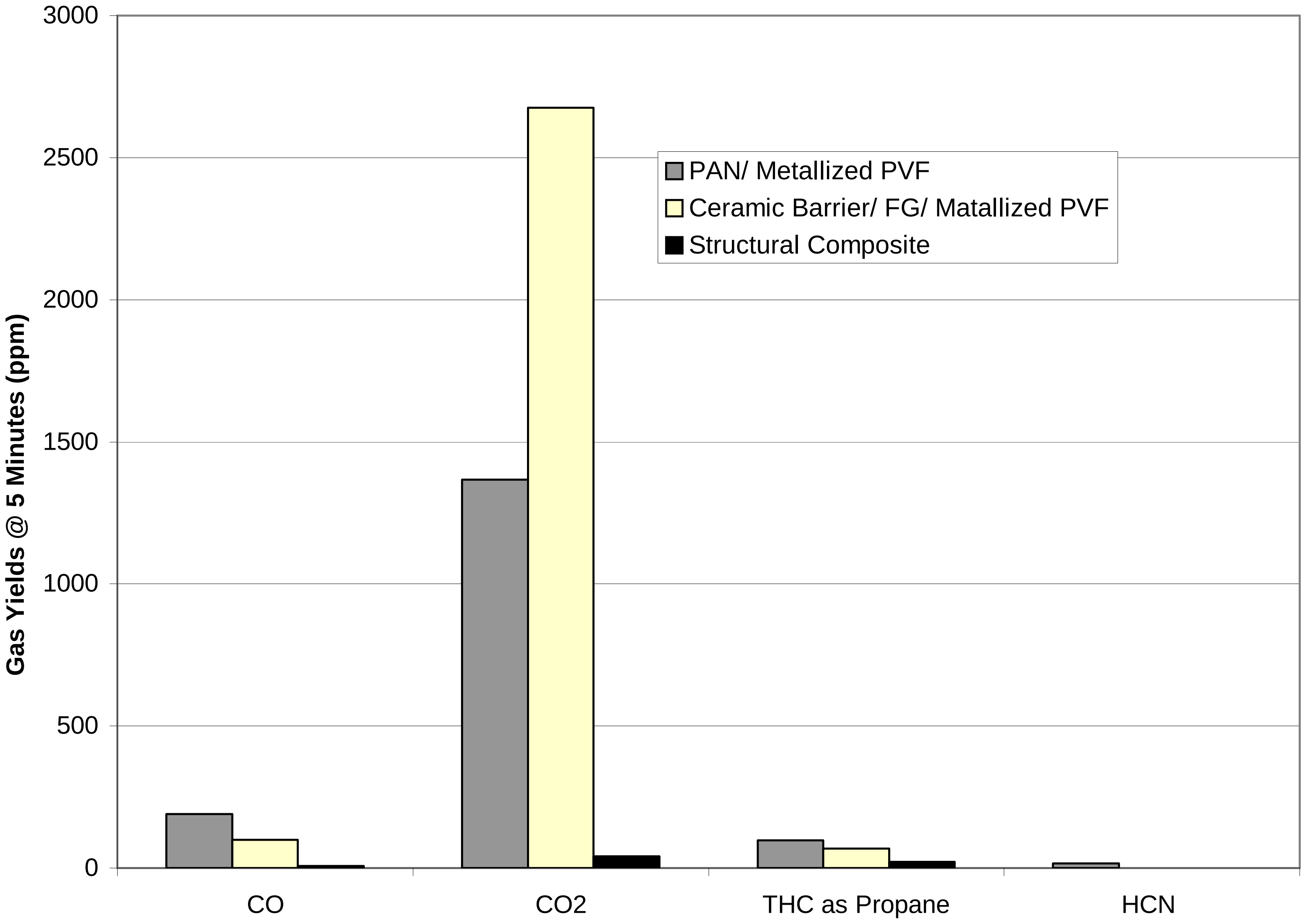
Full-Scale Results, Structural Composite, FTIR

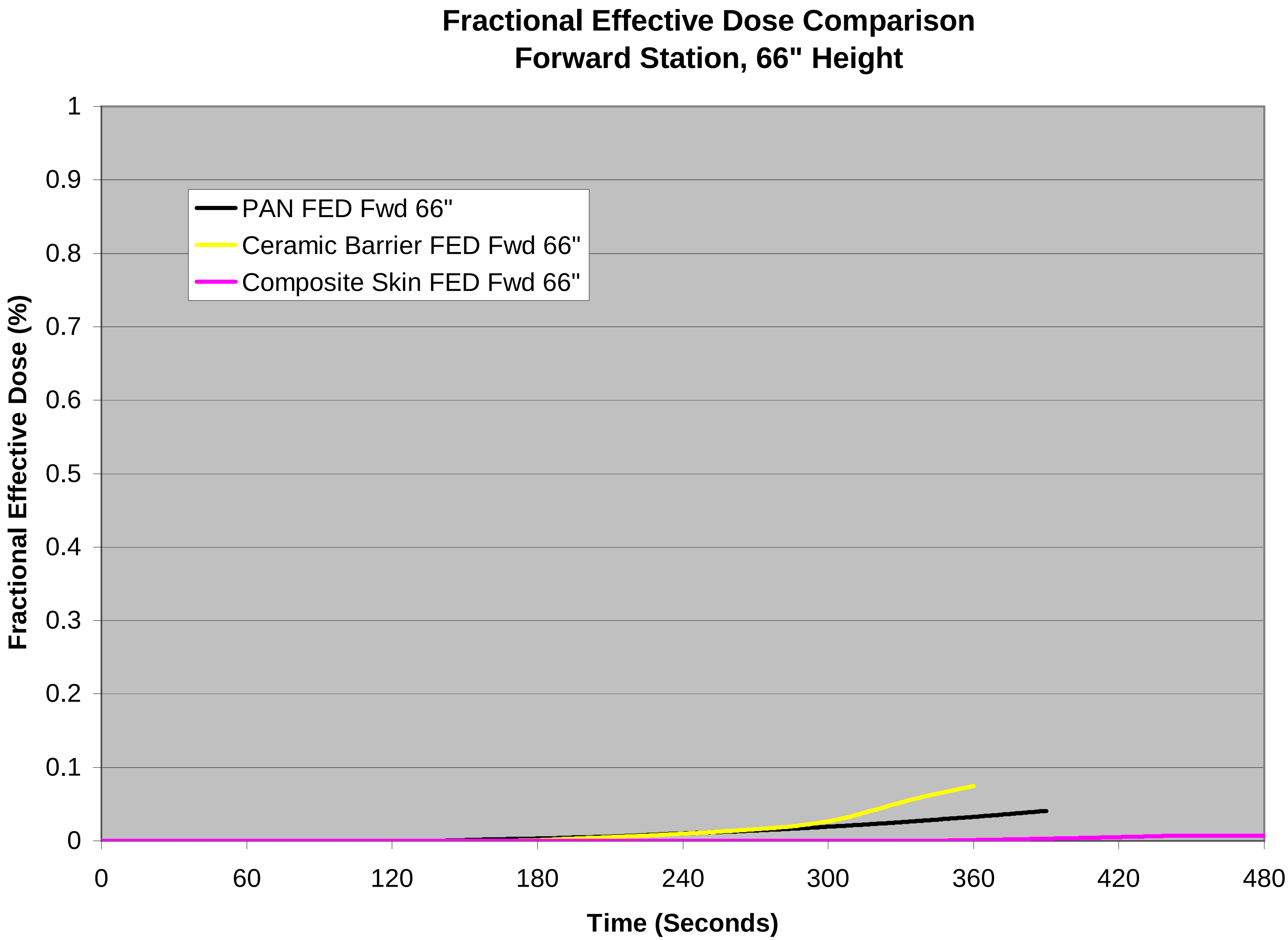


Full-Scale Results, Structural Composite, Comparison

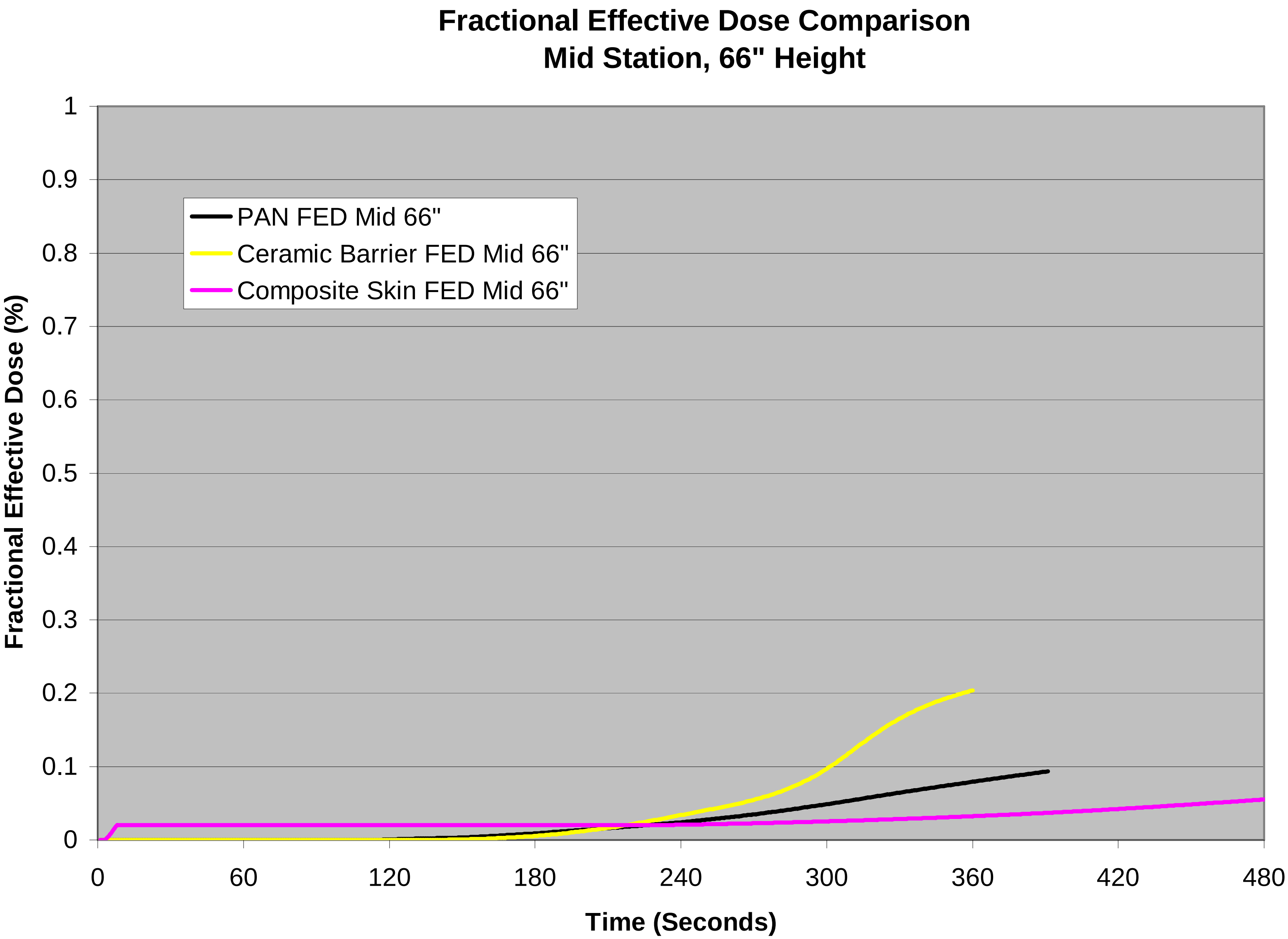


Full-Scale Results, Comparison of 3 Insulation Systems





Fractional Effective Dose Comparison
Forward Station, 66" Height
Fractional Effective Dose (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
PAN FED Fwd 66"
Ceramic Barrier FED Fwd 66"
Composite Skin FED Fwd 66"
0
60
120
180
240
300
360
420
480
Time (Seconds)

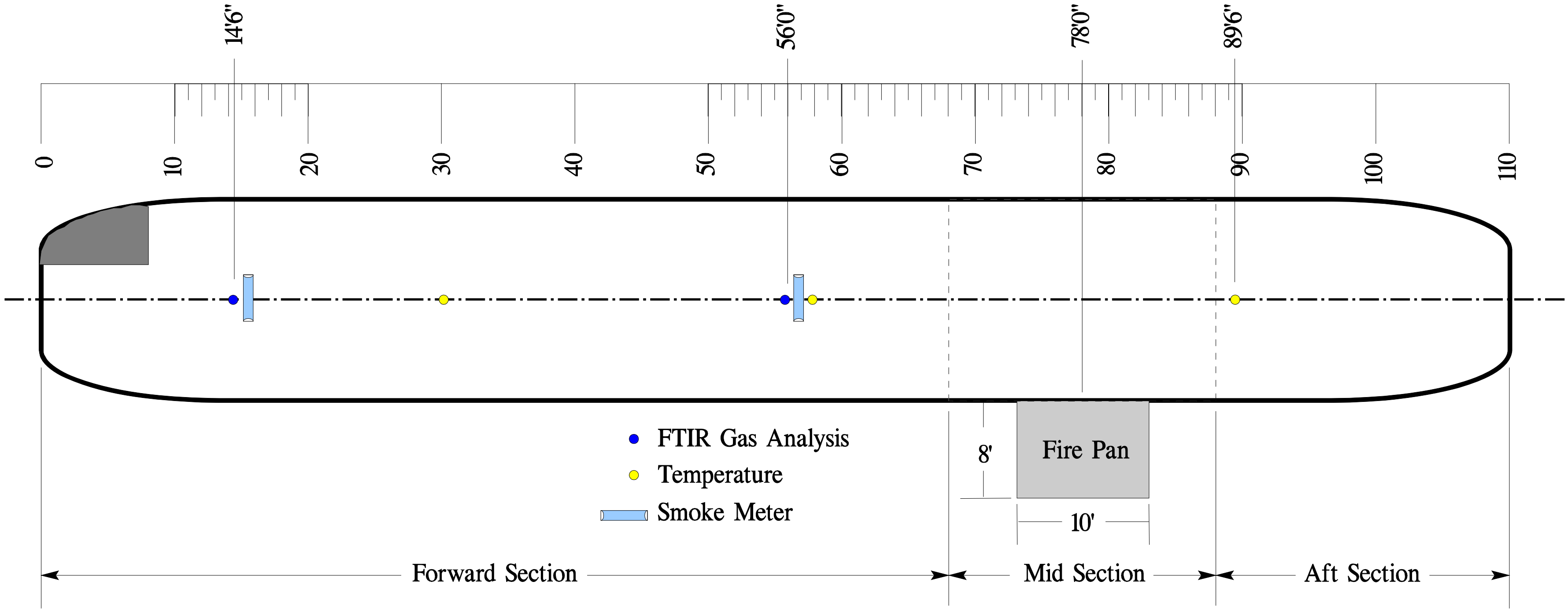


Fractional Effective Dose Comparison
Mid Station, 66" Height
Fractional Effective Dose (%)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
PAN FED Mid 66"
Ceramic Barrier FED Mid 66"
Composite Skin FED Mid 66"
0
60
120
180
240
300
360
420
480
Time (Seconds)

What do we do with all this data?

How does data compare to small scale results?

Determination of Full Scale Test Article Volume



Forward Volume = Cabin Area x Fwd Length = (10989.9/144) x 68 = 5189.7 cu ft

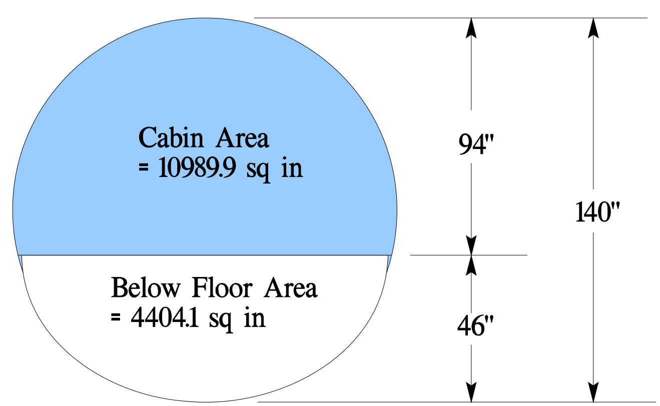
Mid Volume = Total Cabin Area x Mid Length = (17203/144) x 20 = 2389.4 cu ft

Aft Volume = Cabin Area x Aft Length = (10989.9/144) x 22 = 1679 cu ft

Total Volume = Forward Volume + Mid Volume + Aft Volume

Total Volume = 5189.7 + 2389.4 + 1679

Total Volume = 9258.1 cu ft



Determination of Gas Concentration Scaling Factor

Ratio of $\text{Volume}_{\text{Box}}$ to Burn Area_{Box} = 60.33 ft^3 / 9.25 ft^2 = 6.52

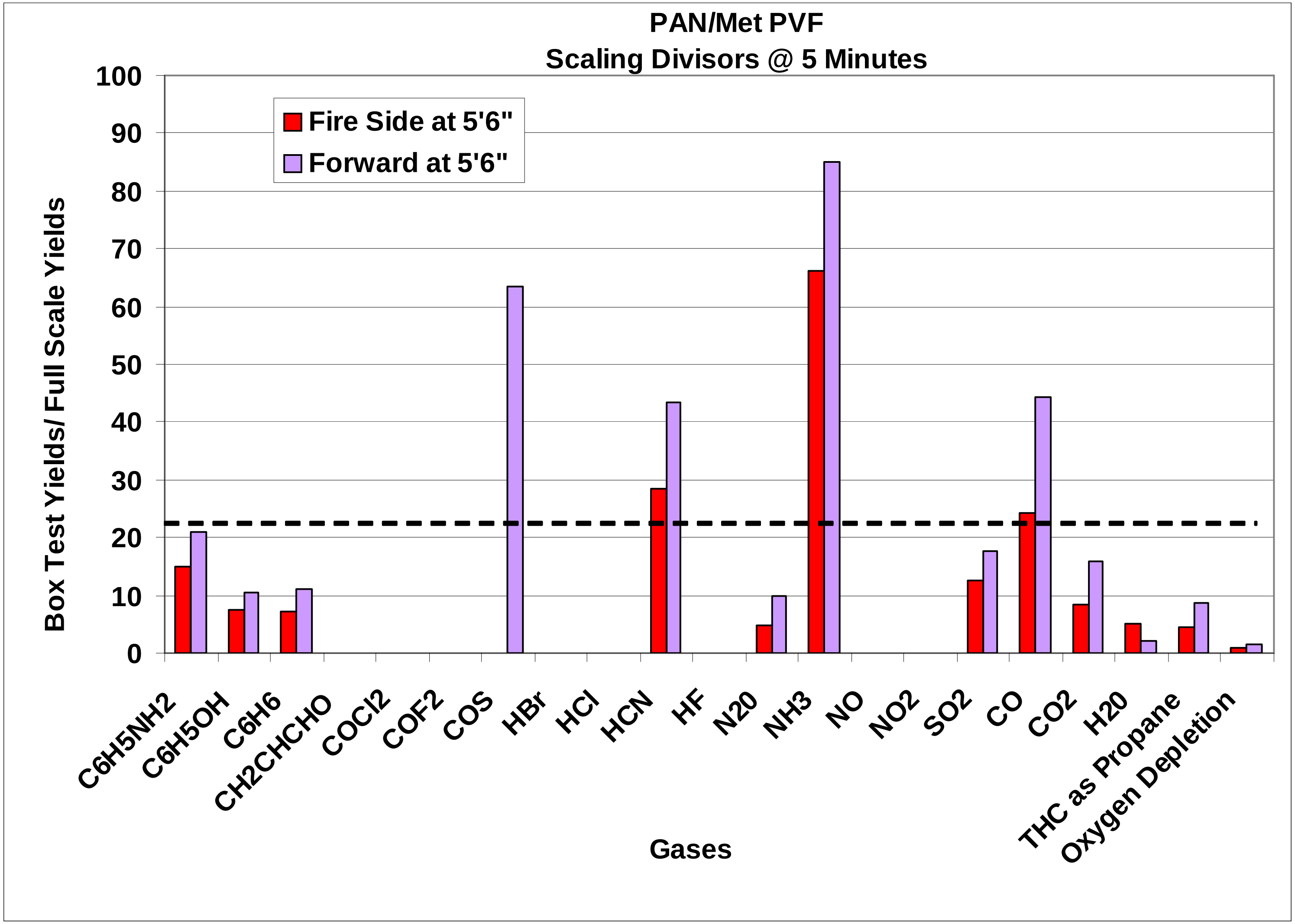
Ratio of $\text{Volume}_{\text{FSTest}}$ to Burn $\text{Area}_{\text{FSTest}}$ = 9258.1 ft^3 / 64 ft^2 = 144.7

Ratio of Full Scale to Lab Scale = 144.7 / 6.52 = **22.2**

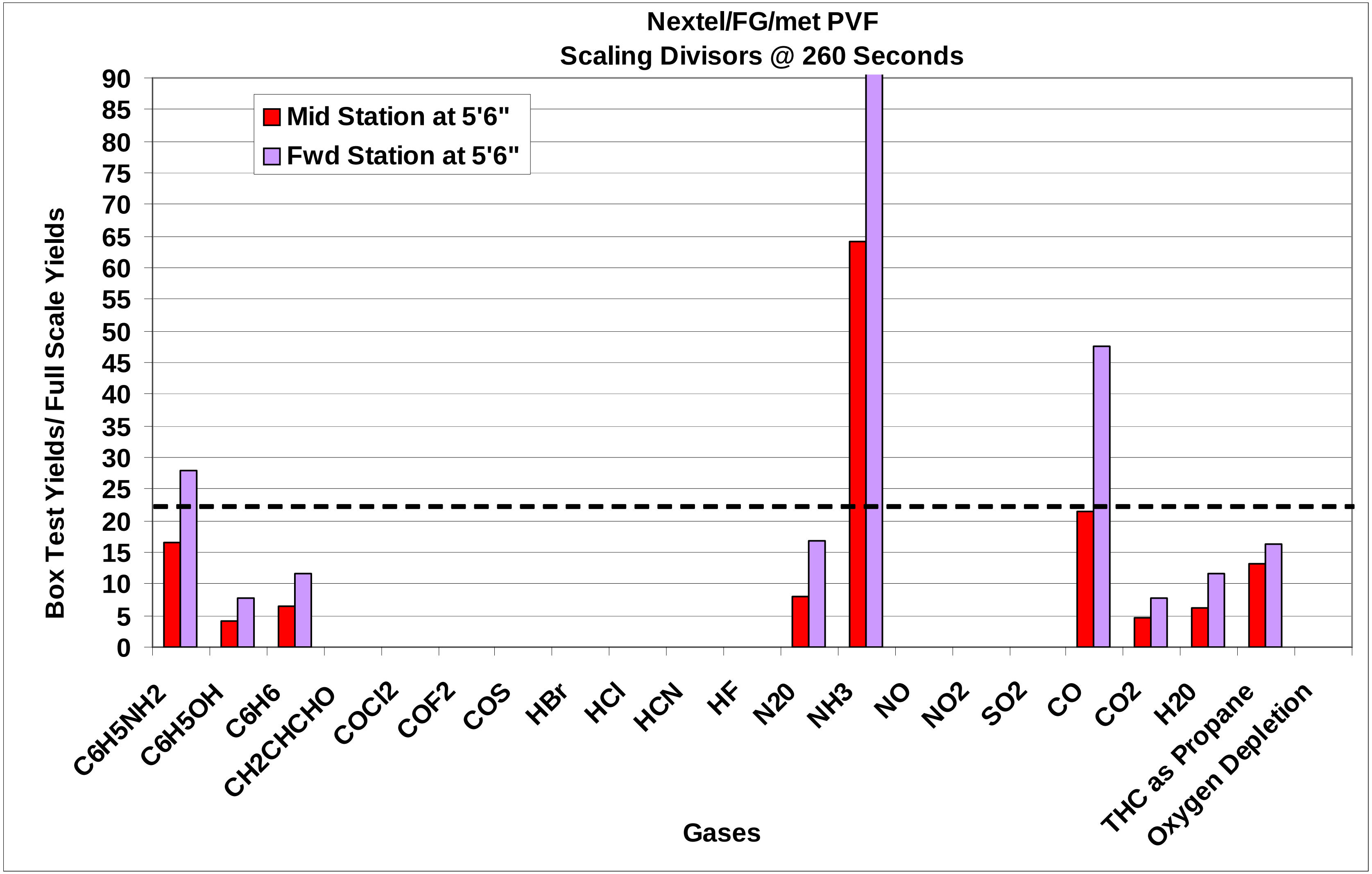
Full-Scale Test Article has 22.2 Times More Volume per Burn Area than Lab Scale Box

Theoretical Lab Scale Box Concentration is 22.2 Times Greater than Full Scale Concentration

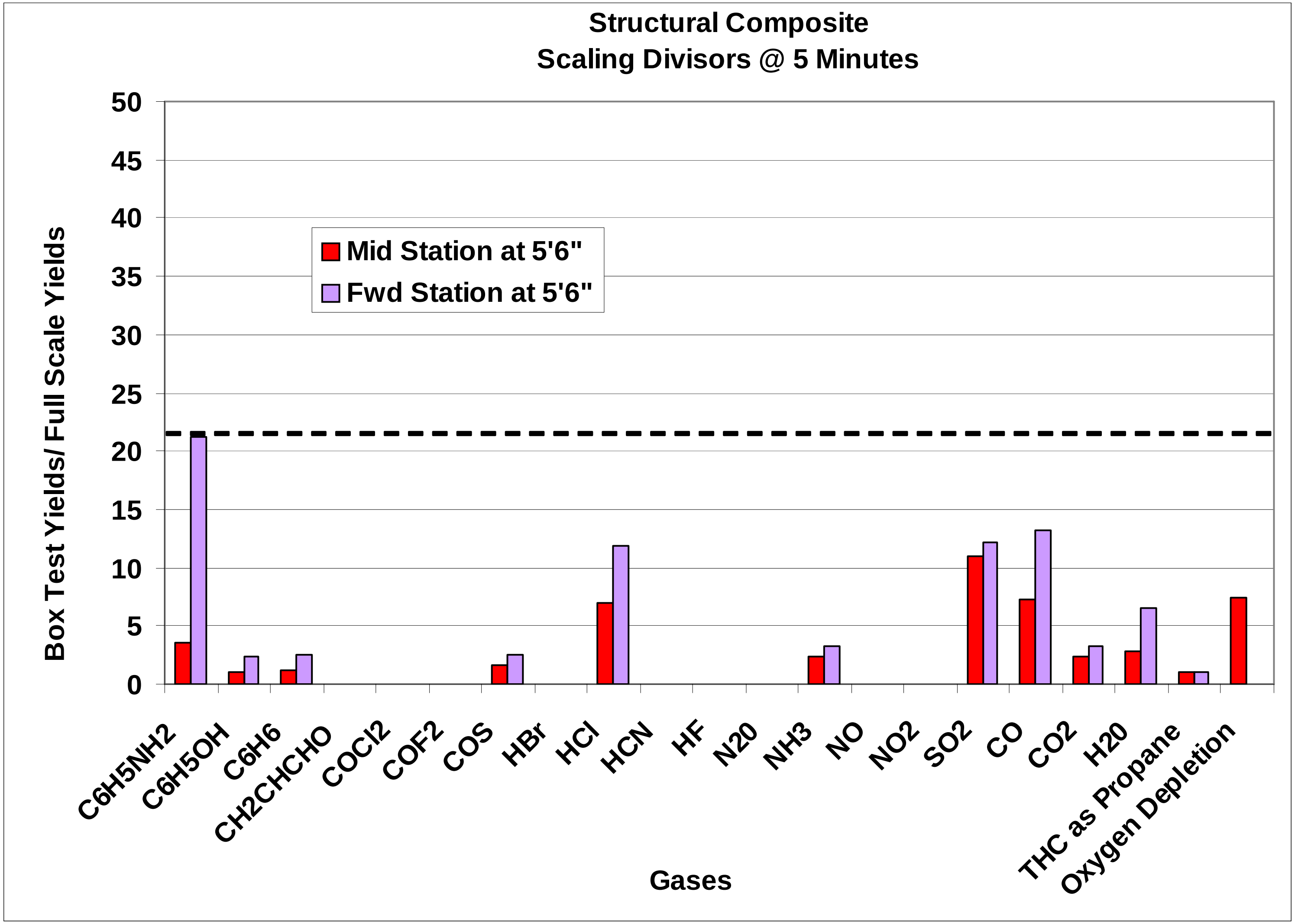
Gas Concentration Scaling, PAN Insulation System



Gas Concentration Scaling, Ceramic Barrier Insulation System



Gas Concentration Scaling, Structural Composite System



Gas Concentration Scaling, Findings

Analysis only considers volumetric aspects

Analysis assumes perfect mixing

Analysis does not consider surface area effects

Not all of gases scale similarly (example: COS)

Primary intoxicants (CO, HCN) scaled similarly

Development of Decomposition Products Limits for Burnthrough Compliant Insulation Systems

Difficult to use volumetric scaling as basis for setting limits in lab-scale test.

Since full-scale tests did not result in adverse conditions inside fuselage,

Take maximum (peak) values obtained in box test for each gas,

Add reasonable safety factor,

Establish acceptable decomposition limits in box test

Development of Decomposition Products Limits for Burnthrough Compliant Insulation Systems

Example: HCN

During full-scale tests, HCN did not reach toxic levels for any of three materials

During lab-scale tests, HCN reached the following levels:

PAN material 470 ppm

FG/ceramic barrier 120 ppm

Composite skin 0 ppm

HCN acceptable limit would be set at 500 ppm in box test.

If a burnthrough compliant material produced greater than 500 ppm HCN during a box test, then a full-scale test would be necessary.

ields 5 utes test	Full-Scale Test Data: PAN/Met PVF Mid Station at 5'6"	PAN/Met PVF Fwd Station at 5'6"	FG/Ceramic Barrier/Met PVF (260 Sec) Mid Station at 5'6"	FG/Ceramic Barrier/Met PVF (260 Sec) Fwd Station at 5'6"	Structural Composite Mid Station at 5'6"	Structural Composite Fwd Station at 5'6"	Allowable Exposure from Various References: 5 Minute Exposure Incap Conc	5 Minute Exposure LC50	5 Minute Exposure Derived from 60 min ERPG3	5 Minute Exposure Derived from 30 min IDLH	60 Minute Exposure ERPG 3 (2007)	30 Minute Exposure IDLH (1995)	FED Effect	Lab-Scale Data: PAN/Met PVF	FG/Ceramic Barrier/Met PVF	Structural Composite	Acceptable Lab-Scale Tox Limit= 5 Min Exp Limit x Scaling Factor (ppm)	Acceptable Lab-Scale Tox Limit (ppm)	FED Effect		Scaling Factor Mid Station at 5'6": PAN/Met PVF	FG/ Ceramic Barrier/Met PVF (260 Sec)	Structural Composite	Gases to Measure FED > .02	Max Allowe Conc. (ppm) Max Be Test Conc x 1.4
IH2	4.63	3.27	**5.5**	3.27	1.73	0.29	Not Avail			**600**	?	100	0.009	68.73	**91.14**	6.14	600 x 15.7 (IDLH)	9,420	0.010	C6H5NH2	14.8	16.6	3.5		
OH	7.02	4.59	**9.57**	5.01	9.4	4	Not Avail		**2400**	1500	200	250	0.004	**52.22**	38.95	9.78	2400 x 4.2 (ERPG)	10,080	0.005	C6H5OH	7.4	4.1	1.0		
	10.46	10.41	8.05	4.56	7.21	3.21	?	?	**12,000**	3000	1000	500	0.001	**76.60**	52.5	8.33	12,000 x 5.0 (ERPG)	60,000	0.001	C6H6	7.3	6.5	1.2		
HCHO	0	0	0	0	0	0	10928	**7783**	18	12	1.5	2	0.000	55.50	**146.04**	0	7783 x 4 (LC50)	31,132	0.005	CH2CHCHO	#DIV/0!	#DIV/0!	ND		
	0	0	0	0	0	0	?	**102** d	12	12	1	2	0.000	0.00	**3.9**	0	102 x 4 (LC50)	408	0.010	COCl2	ND	#DIV/0!	ND		
	0	**0.21**	0	0	0	0	?	?	**300**		25 (est)	?	0.001	0.00	0	**0.43**	300 x 4 (ERPG3)	1,200	0.000	COF2	ND	ND	#DIV/0!		
	0	**0.61**	0	0	0.53	0.34	**500*** (500 for 15min-brain damage)	(1000 for 15 minutes)	1200 (H2S)		100 (H2S)	?	0.001	**38.66**	0	0.84	500 x 4	2,000	0.019	COS	>40	ND	1.6	Yes	5
	0	0	0	0	0	0	16830	**15900**	1800	180	150 (est)	30	0.000	0.00	0	0	15900 x 4 (LC50)	63,600	0.000	HBr	ND	ND	ND		
	0	0	0	0	**0.49**	0.29	16830	**15900**	1800	300	150	50	0.000	0.00	0	3.43	15900 x 4 (LC50)	63,600	0.000	HCl	ND	ND	7.0		
	16.4	10.75	0	0	0	0	**176**	560	300	300	25	50	0.093	**467.00**	111.74	0	176 x 20 (Incap)	3,520	0.133	HCN	28.5	#DIV/0!	ND	Yes	
peak)	22.7	**26.9**					**176**	560	300	300	25	50	0.153	**467.00**	111.74	0	176 x 20 (Incap)	3,520	0.133	HCN	20.6			Yes	
	0	0	0	0	0	0	7663	**7227**	600	180	50	30	0.000	14.46	**19.3**	0	7227 x 4 (LC50)	28,908	0.001	HF	#DIV/0!	#DIV/0!	ND		
	3.95	**9.94**	7.81	3.72	2.99	1	?	?			?	?		18.75	**62.56**	0		No Limit		N20	4.7	8.0	ND		
	5.55	4.32	4.5	1.82	1.36	1	?	?	**9000**	1800	750	300	0.003	**367.20**	289.19	3.3	9000 x 65.3 (ERPG)	587,700	0.001	NH3	66.2	64.3	2.4		
	0	0	0	0	0	0	12850	**4260**	1800	600	150	100	0.000	0.00	0	0	4260 x 4 (LC50)	17,040	0.000	NO	ND	ND	ND		
	2.02	1.19	13.13	**6.19**	0	0	2570	**852**	360	120	30	20	0.007	0.00	0	0	852 x 4	3,408	0.000	NO2	ND	ND	ND		
	19.81	2.06	2.04	1.33	2.82	2.56	?	**2115**	180	600	15	100	0.009	**246.57**	0	31.17	2115 x 11.8	24,957	0.010	SO2	12.4	ND	11.1		
peak)	55.4	**65.5**					?	**2115**	180	600	15	100	0.031	**246.57**	0	31.17	2115 x 4.5	9,518	0.026	SO2	4.5			Yes	
	190.9	104.8	99.18	44.49	7.7	4.2	**6850**	16600	6000	7200	500	1200	0.028	**4645.76**	2116.23	55.32	16600 x 17.6 (ERPG3)	292,160	0.016	CO	24.3	21.3	7.2	Yes	6,
	1367.6	730.3	**2674.66**	1608	42	30	**88000**					40000	0.030	11506.60	**12657**	96.7	88,000 x 6.6	580,800	0.022	CO2	8.4	4.7	2.3	Yes c	17,
	1973.9	**4885**	3160.63	1684	627	276								10164.77	**19430**	1808.29	No Limit		N/A	H2O	5.1	6.1	2.9		
s ne	**97.9**	72.2	68.17	55.21	22	20.8							0.005	629.71	**903.5**	22.0	21,000 x 6.9	144,900	0.006	THC as Propane	6.4	13.3	1.0		
n ion	3500	2100	**6470**	2920	150	0	**136000**							3000.00		1120	Remove			Oxygen Depletion	0.9		7.5		