Development of a Lab-Scale Test For Evaluating Toxicity 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 Toxicity Test For 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

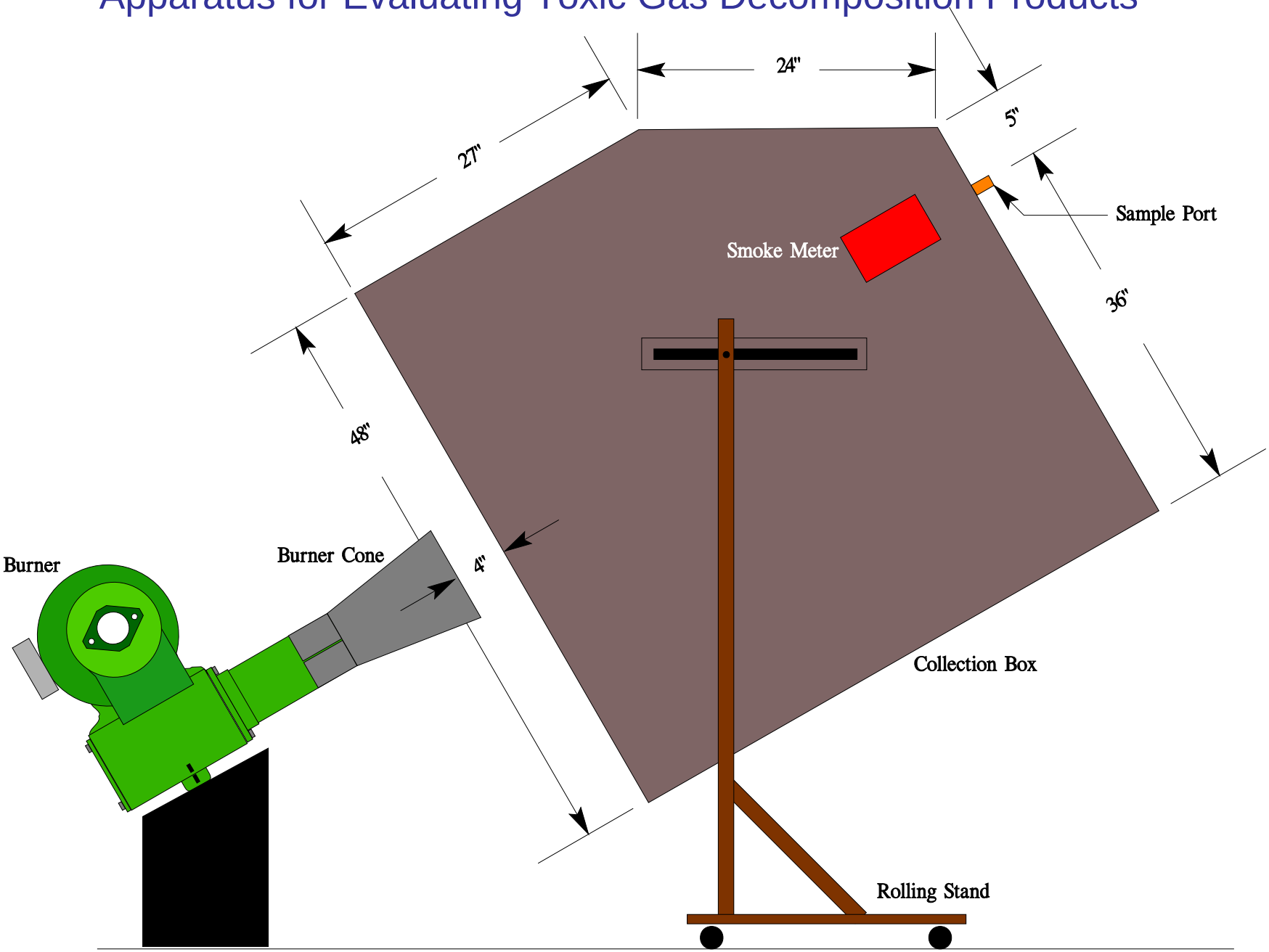
Conduct subsequent full-scale tests with identical insulation materials to establish realistic baseline data using FTIR.

complete

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

pending

Apparatus for Evaluating Toxic Gas Decomposition Products



Apparatus for Evaluating Toxic Gas Decomposition Products

Lab-Scale Apparatus for Evaluating Toxic Gas Decomposition Products

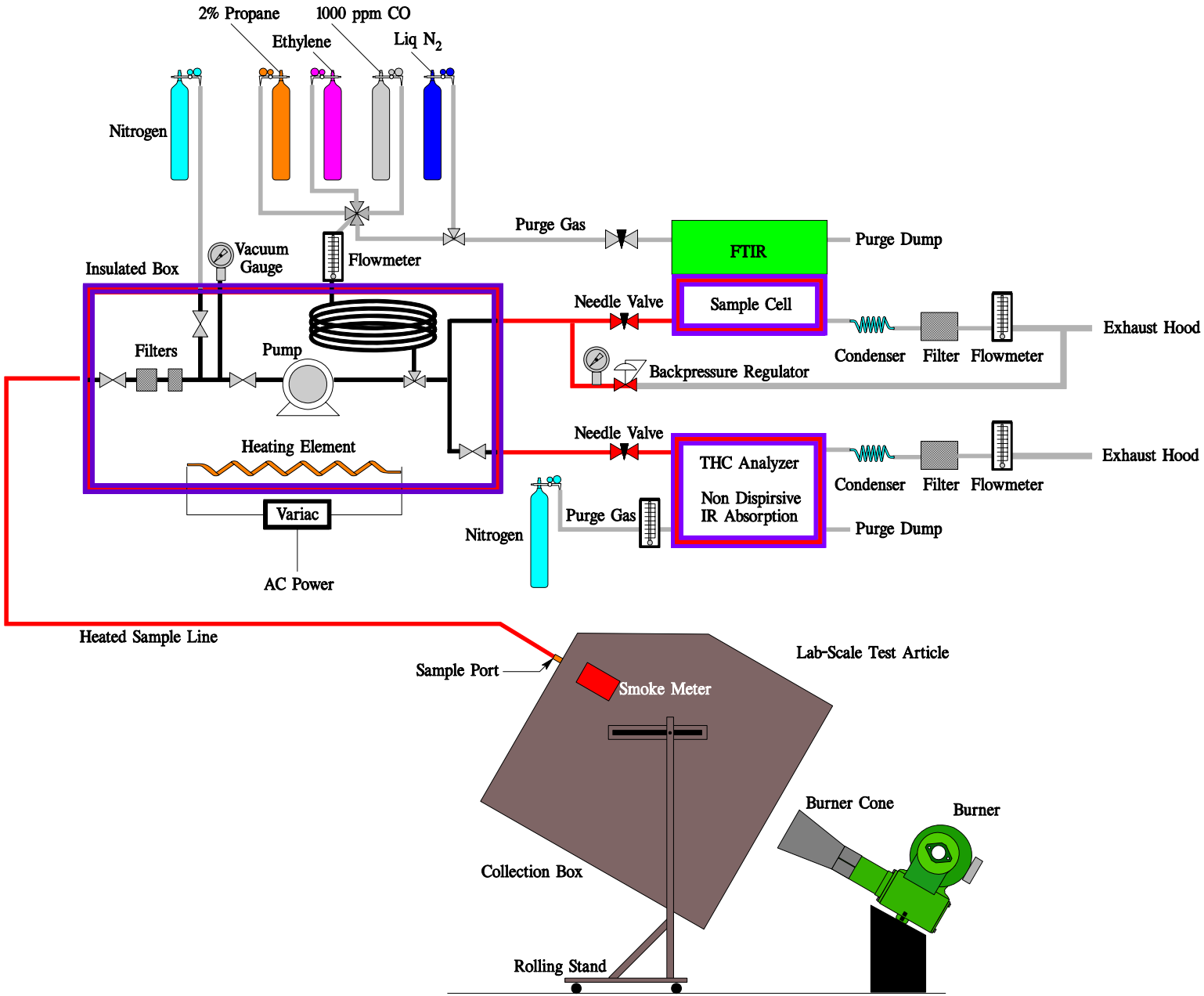
Burner configuration according to 25.856(b) Appendix F, Part VII.

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

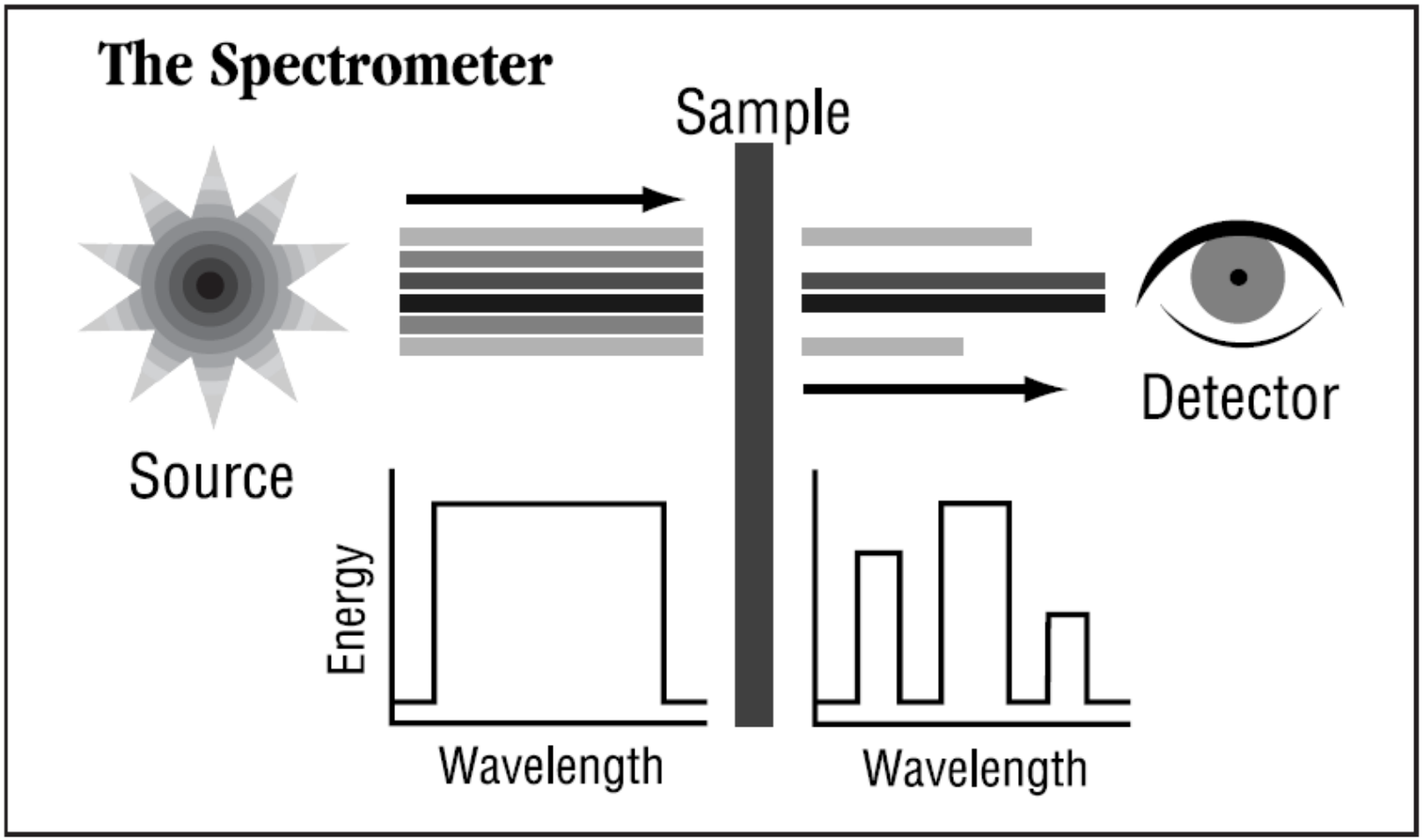
Fourier Transform Infrared (FTIR)/Total Hydrocarbon Gas analysis system used to collect and measure toxic and flammable gases yielded during tests.

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



What is FTIR Spectroscopy?



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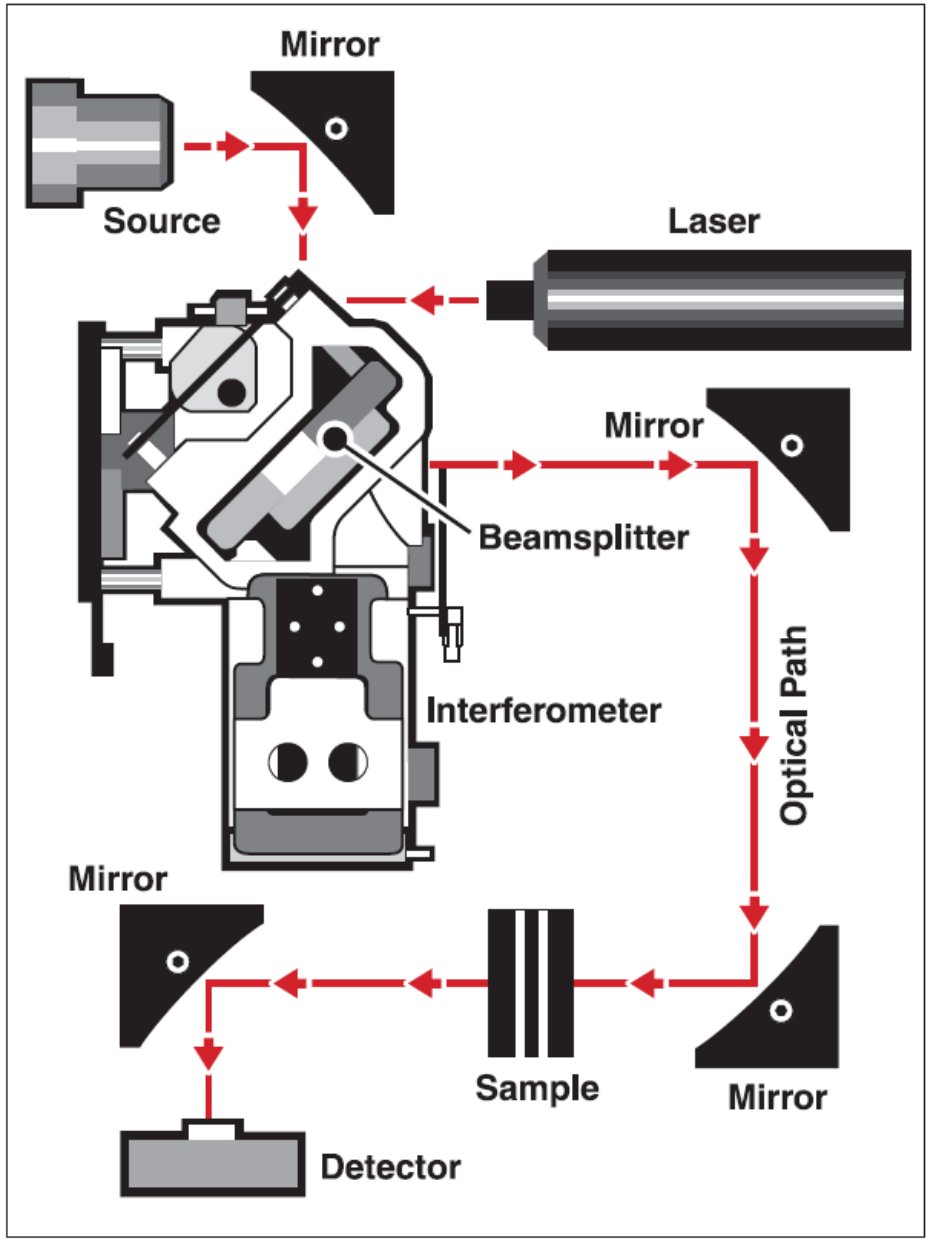

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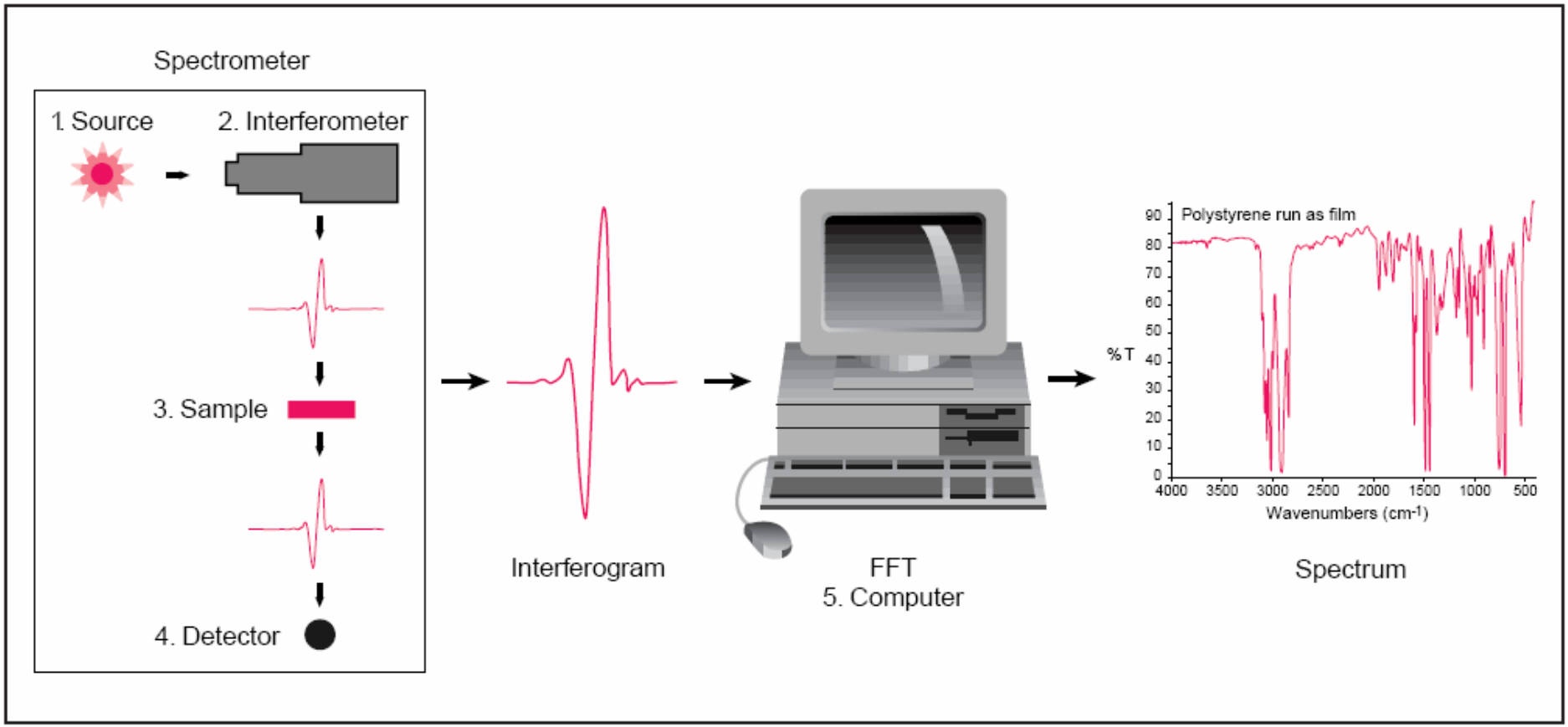
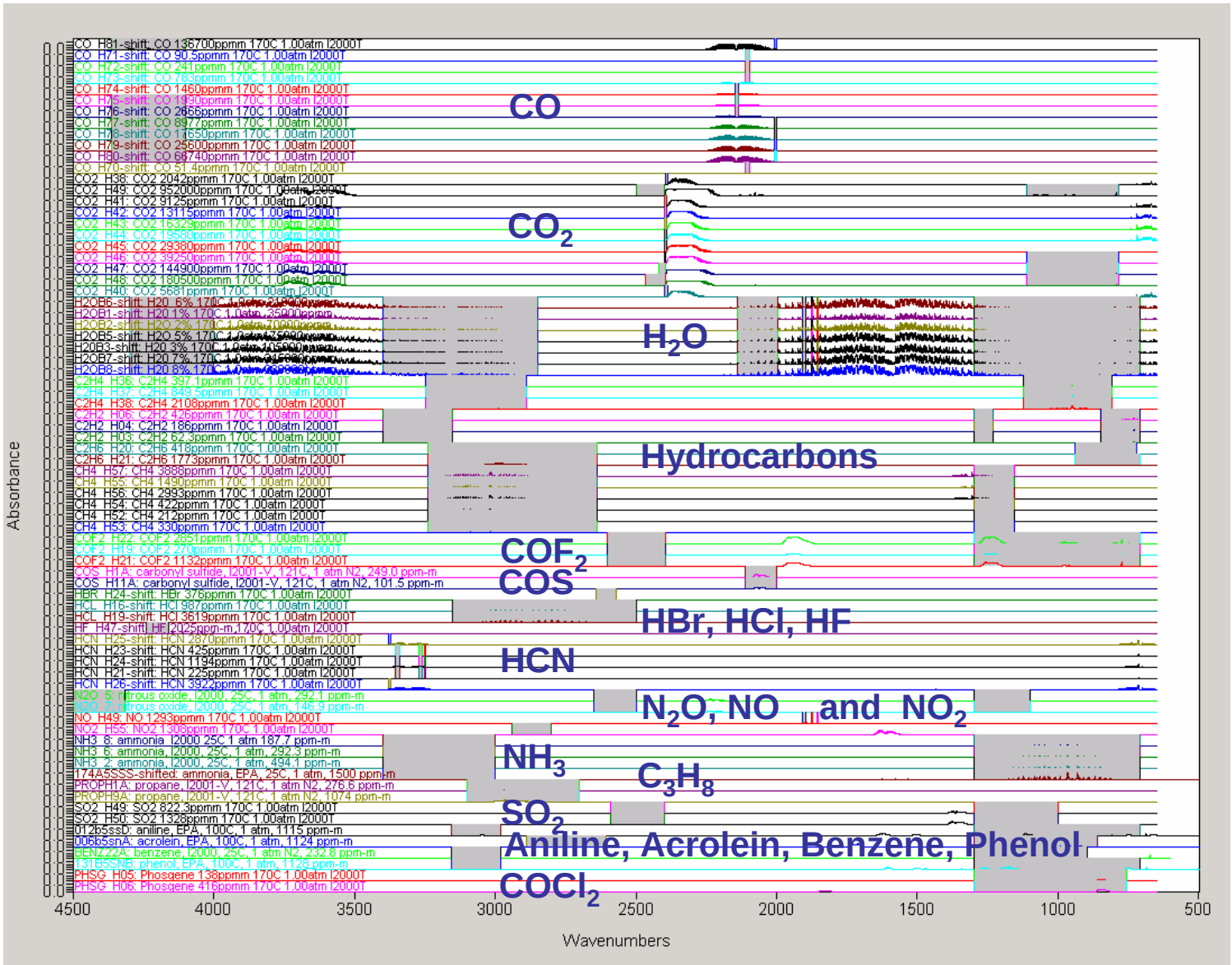


Calibration Spectra and Selected Regions for FTIR Analysis

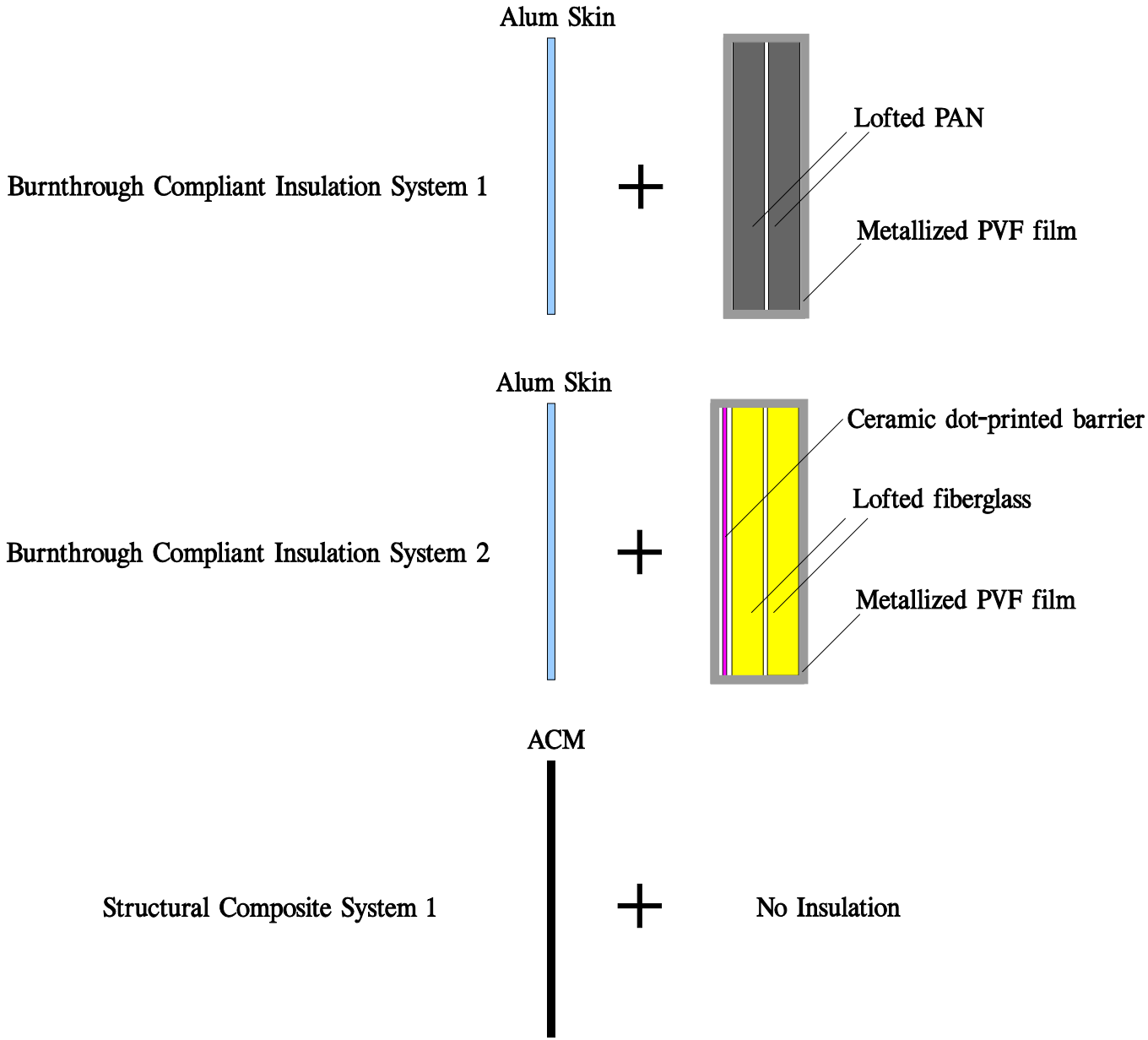


Gases Measured By FTIR

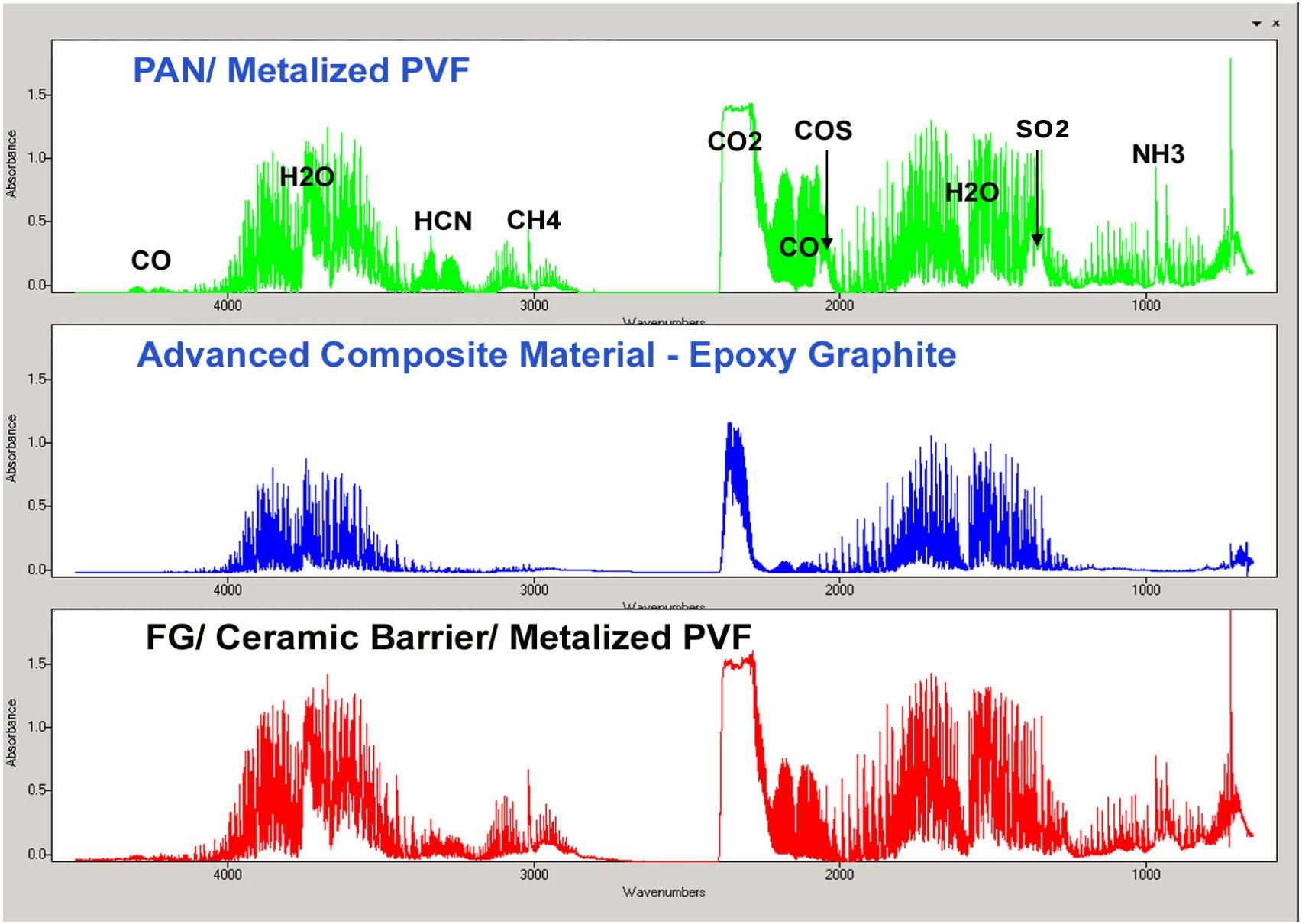
Toxic Gases	
$C_6H_5NH_2$	Aniline
C_6H_5OH	Phenol
C_6H_6	Benzene
CH_2CHCHO	Acrolein
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
$COCl_2$	Phosgene
COF_2	Carbonyl Fluoride
COS	Carbonyl Sulfide
HBr	Hydrogen Bromide
HCL	Hydrogen Chloride
HCN	Hydrogen Cyanide
HF	Hydrofluoric Acid
NH_3	Ammonia
NO	Nitrogen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

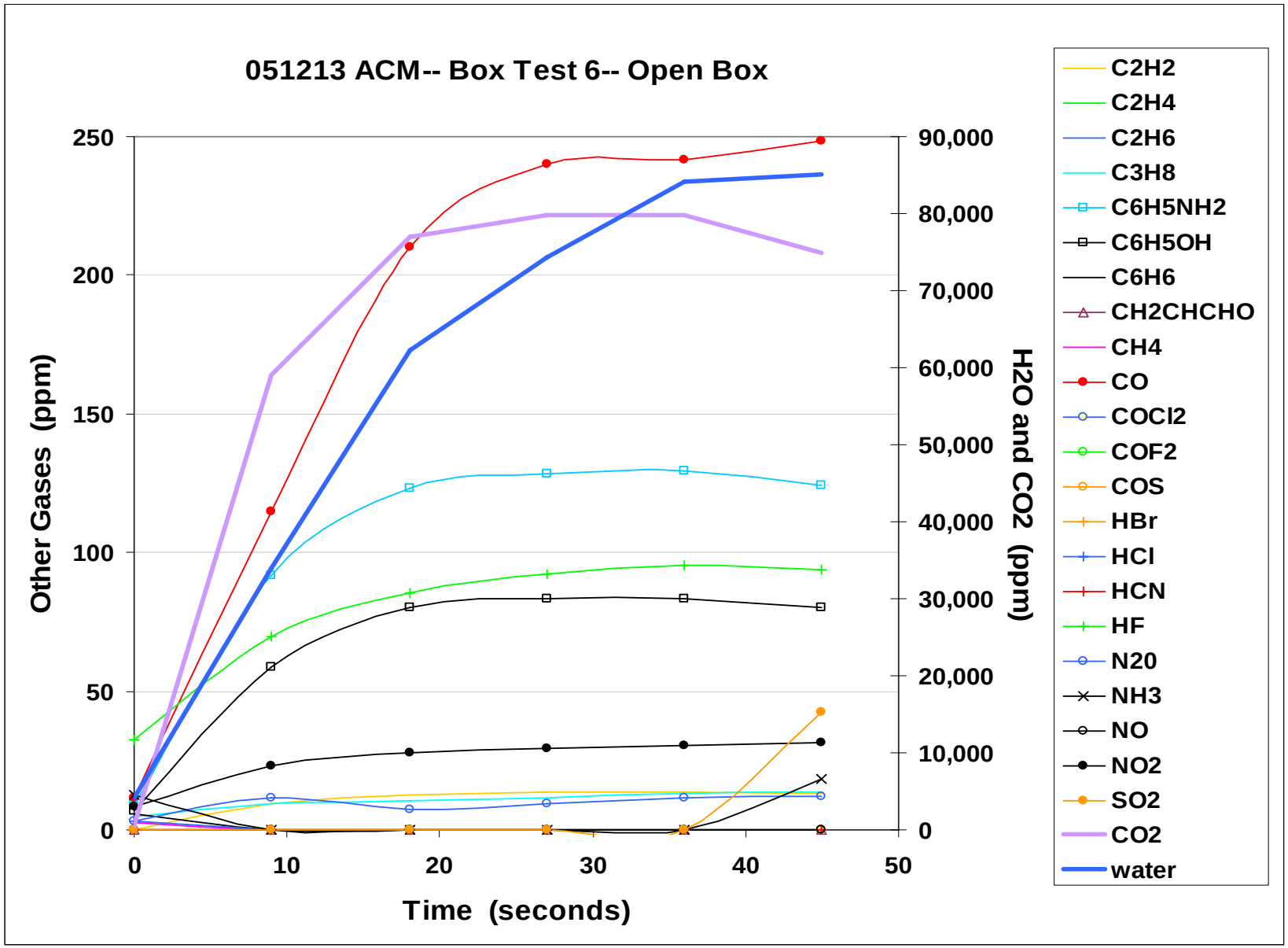
Material Systems Tested in Lab-Scale Apparatus



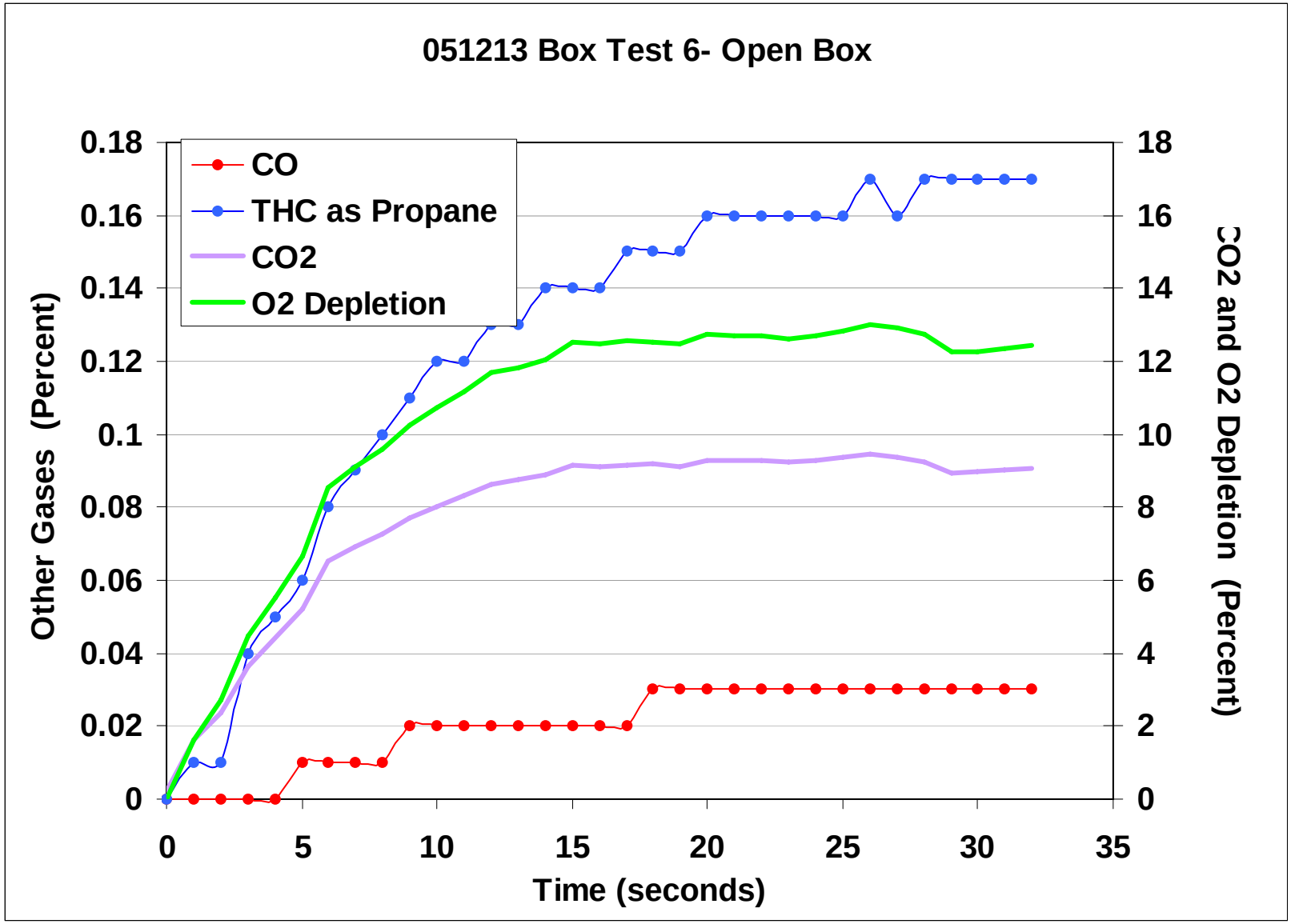
Spectra at 5 Minutes



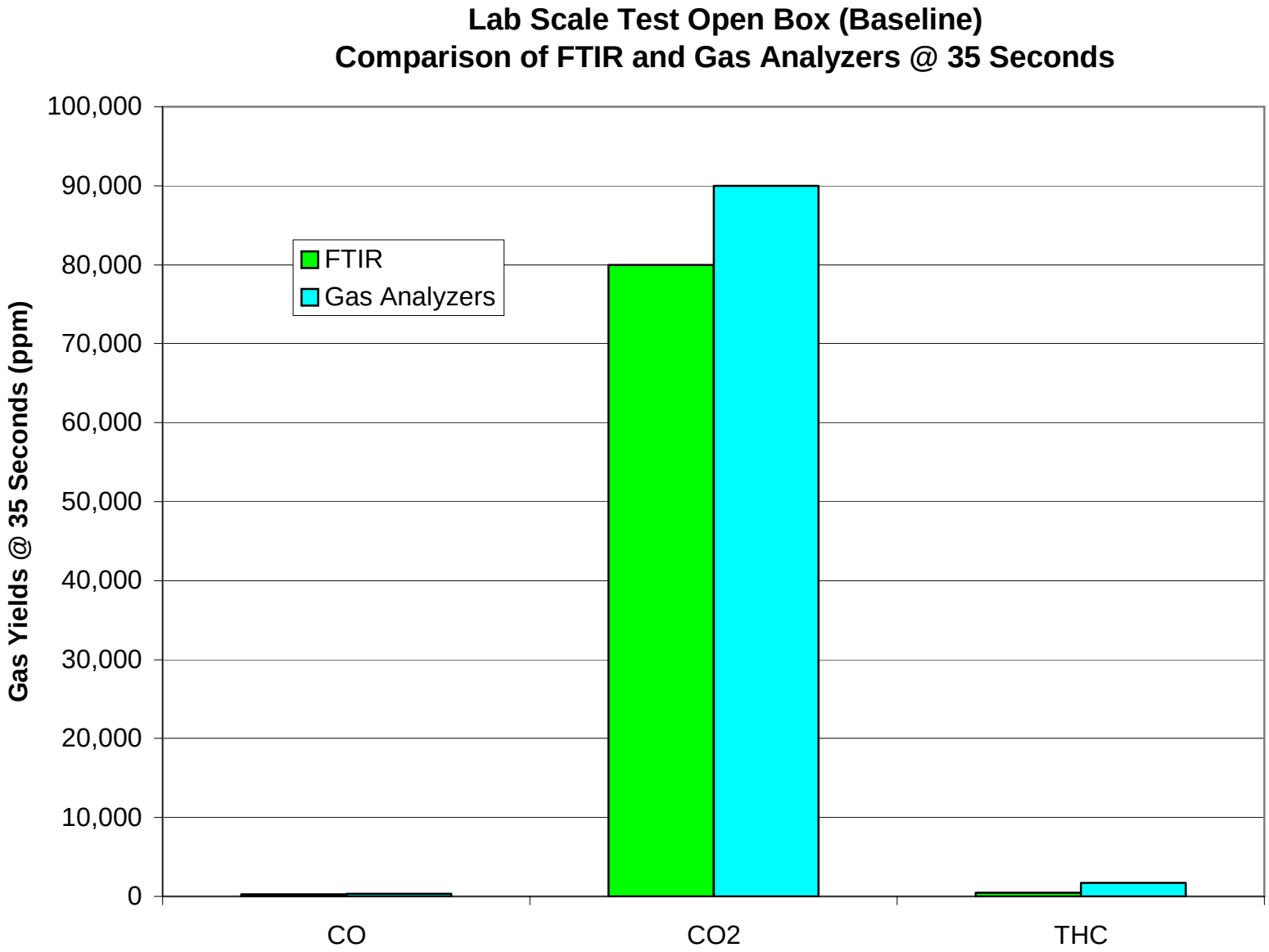
Open Box (Baseline) Test Using FTIR Analysis



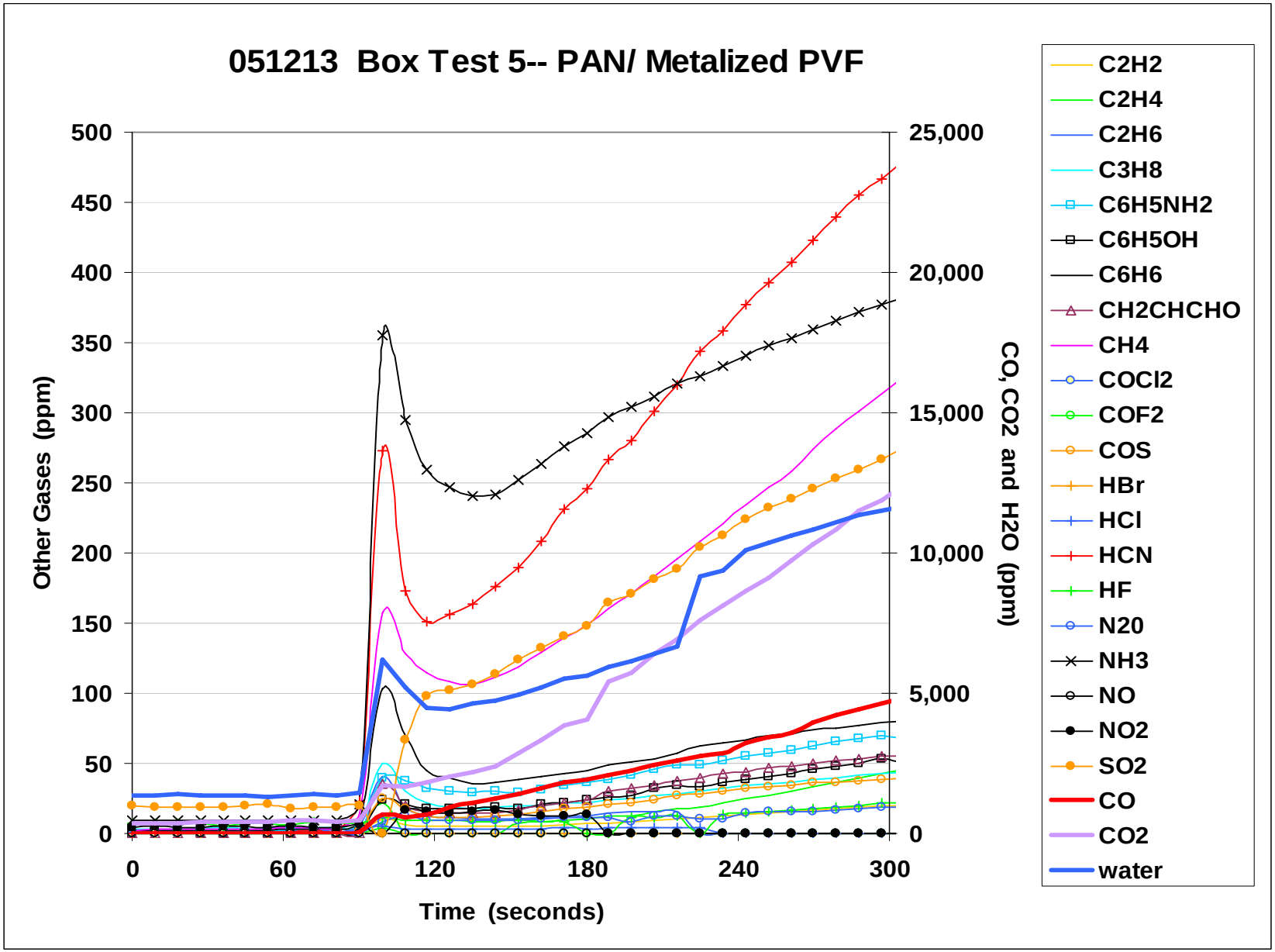
Open Box (Baseline) Test Using Gas Analyzers



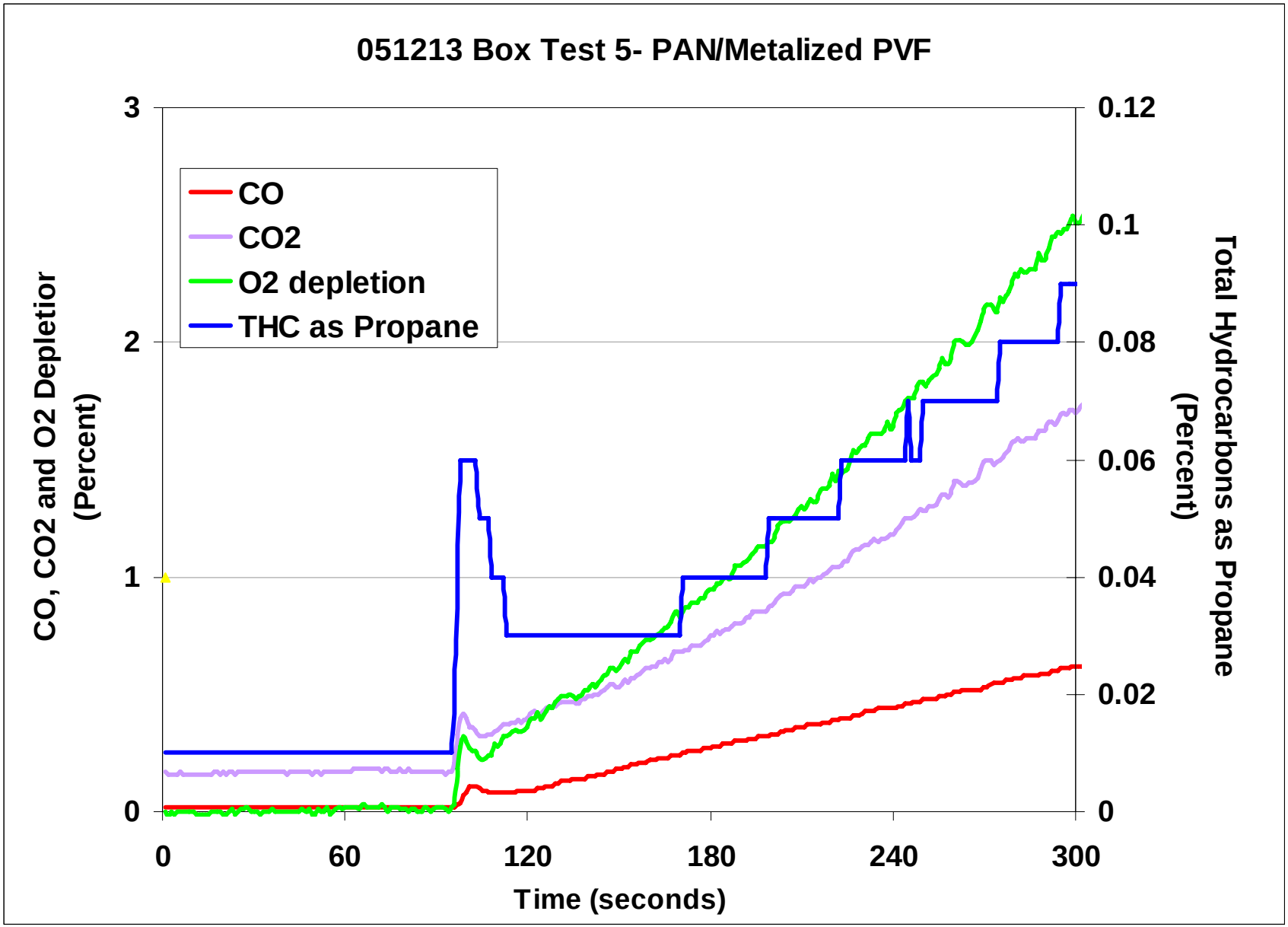
Comparison of FTIR and Gas Analyzers for Open Box (Baseline) Test



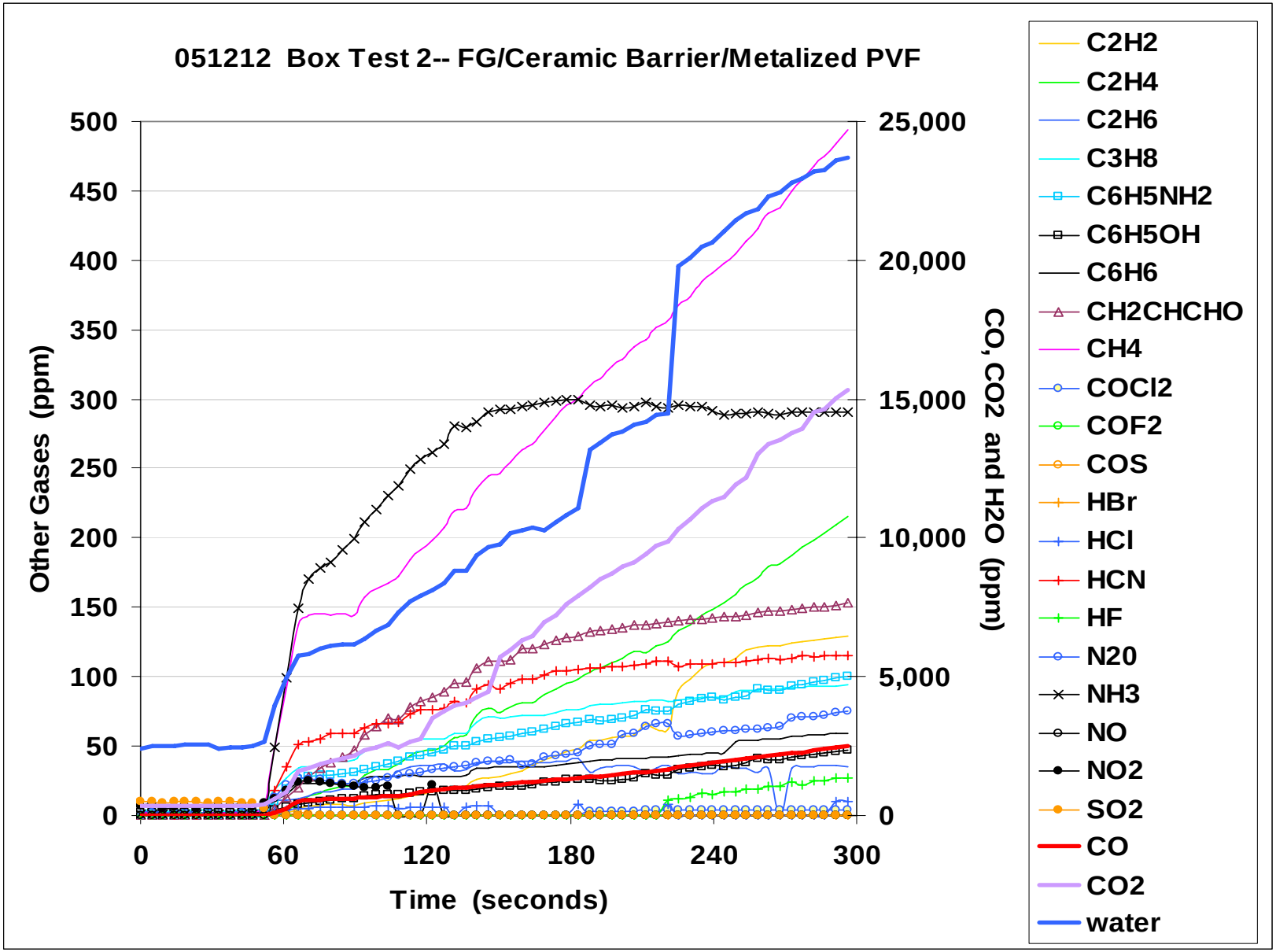
PAN Insulation Test Using FTIR Analysis



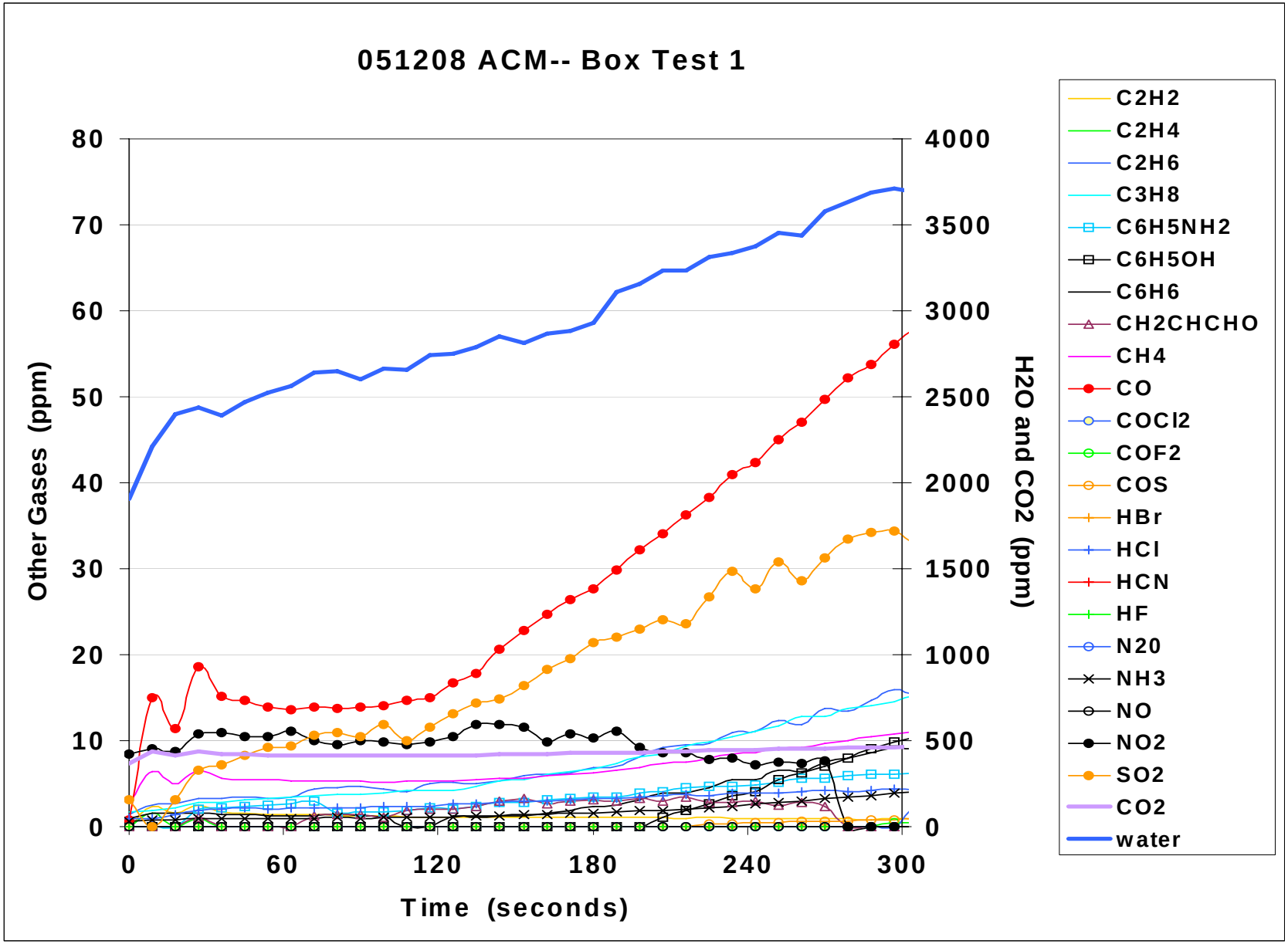
PAN Insulation Test Using Gas Analyzers



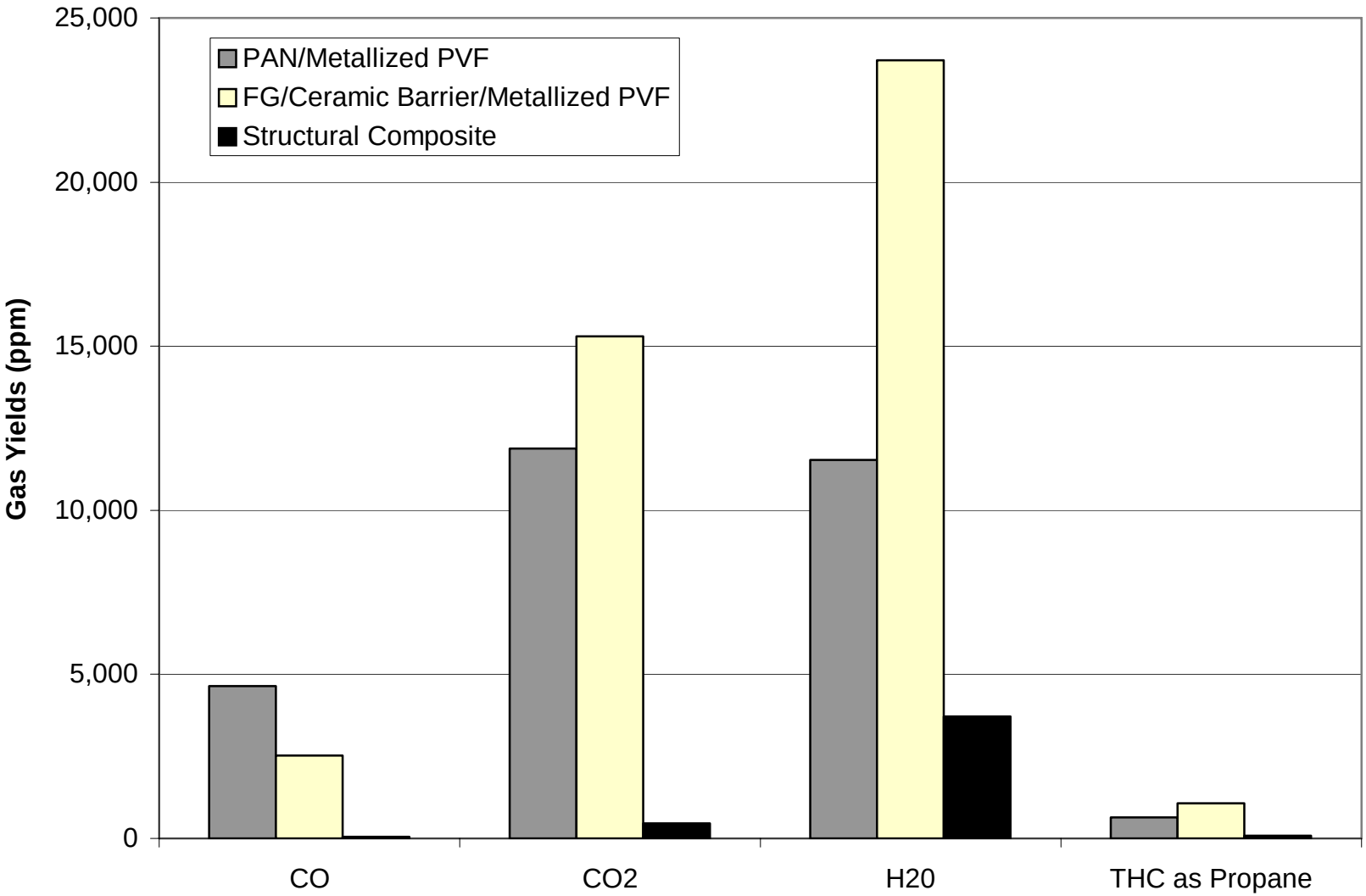
FG/Ceramic Barrier Insulation Test Using FTIR Analysis



Structural Composite Material Test Using FTIR Analysis



Comparison of Box Test Results at 5 Minutes



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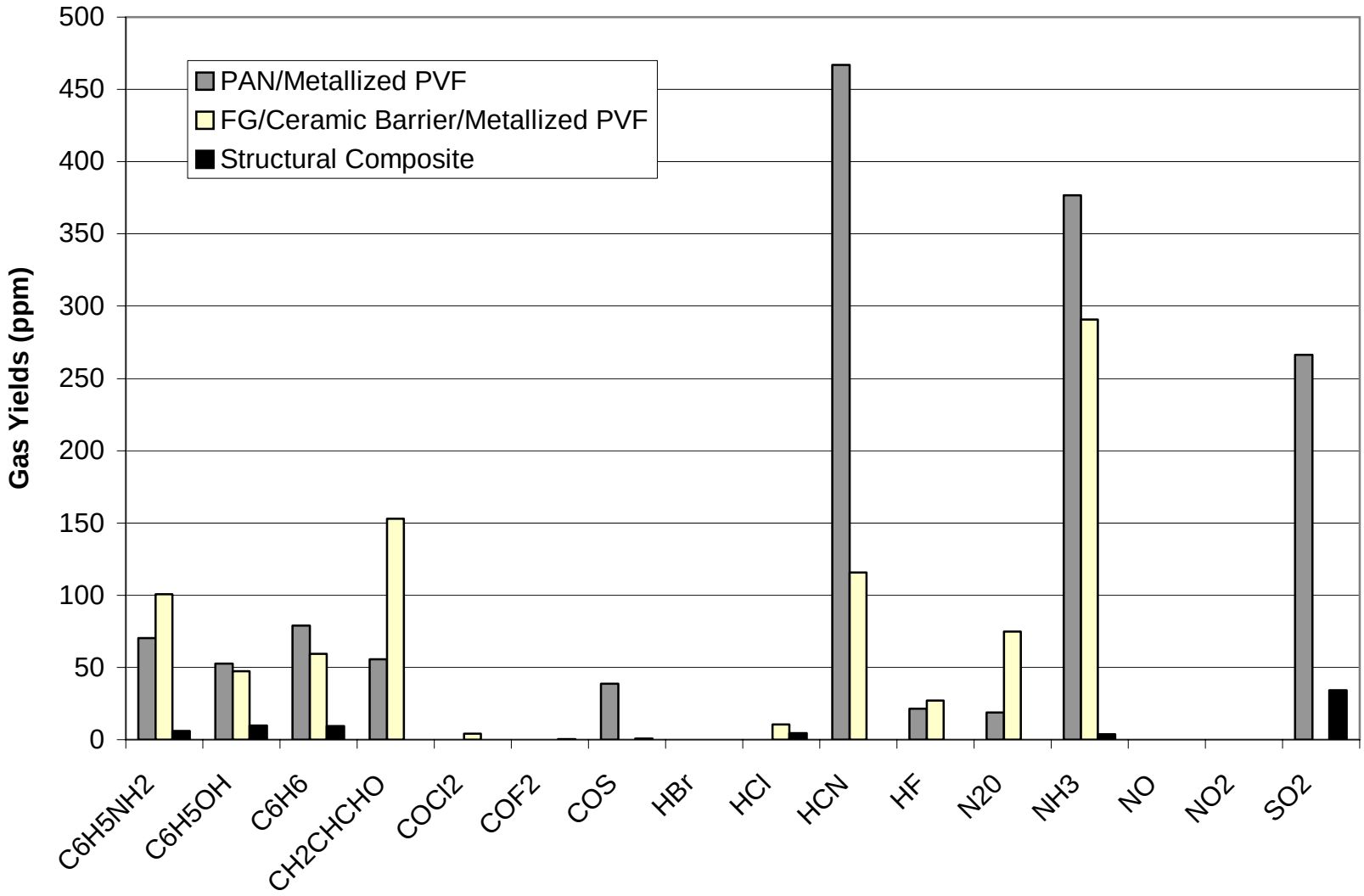

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Development of a Laboratory-Scale Test for Evaluating the Decomposition Products Generated Inside an Intact Fuselage During a Simulated Postcrash Fuel Fire

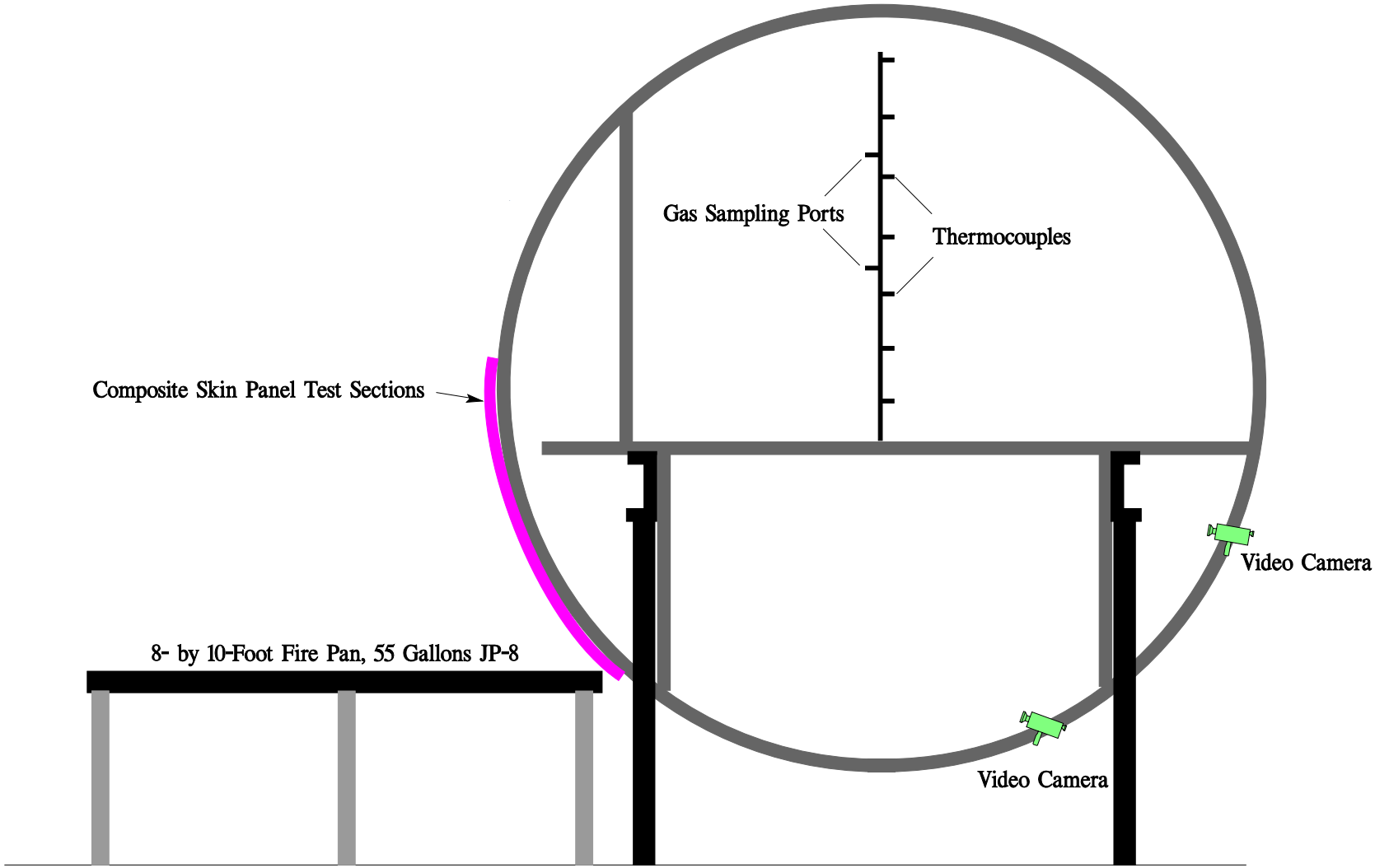
Timothy R. Marker
Louise C. Speitel

April 2007

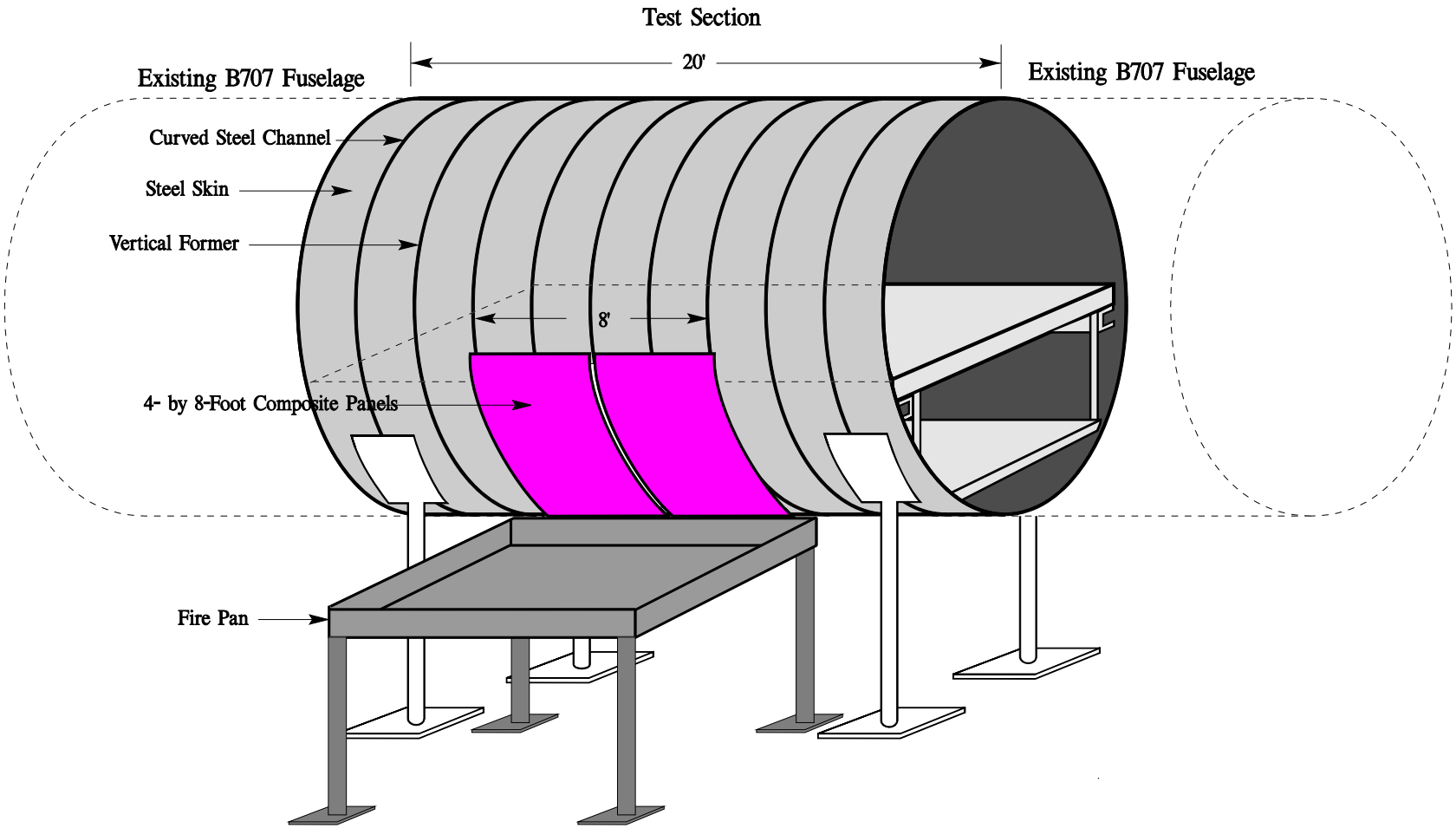
DOT/FAA/AR-TN07/15

U.S. Department of Transportation
Federal Aviation Administration

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



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



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

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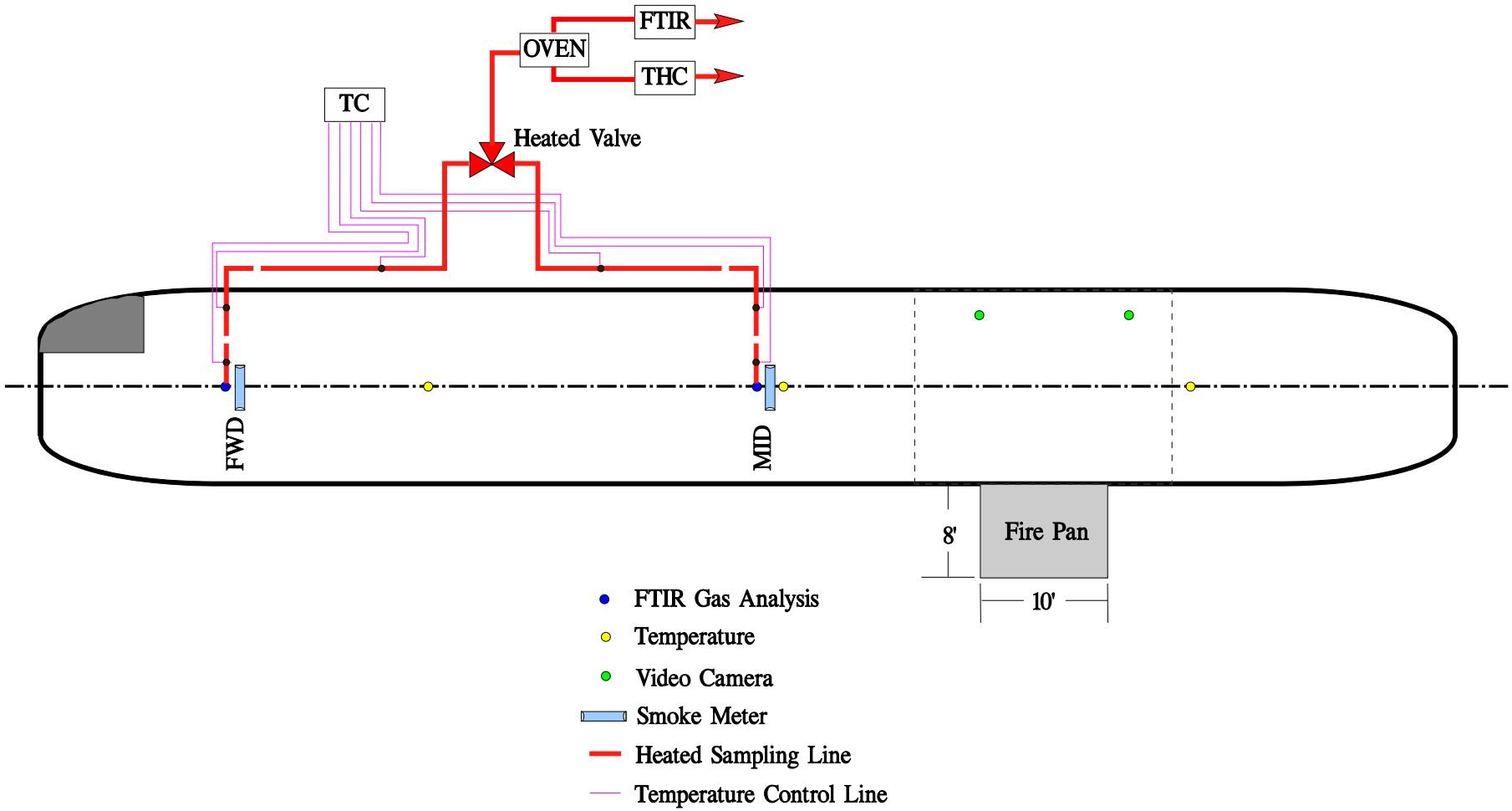
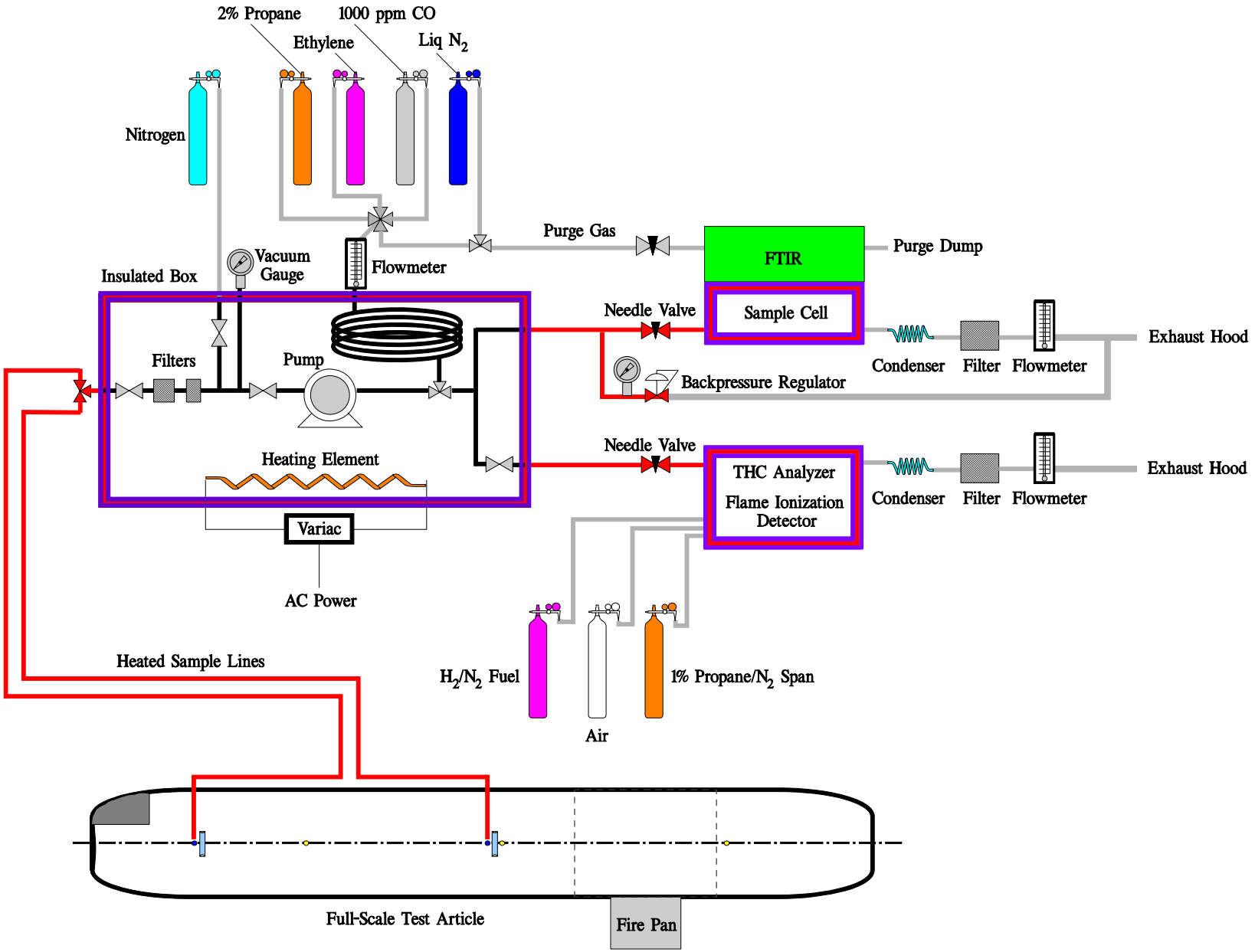


FTIR and THC Sampling System Used in Full-Scale Testing



Full-Scale Test Results
PAN Insulation System

Full-Scale Test Results, PAN Insulation System

Full-Scale Test Results, PAN Insulation System

Pre-test

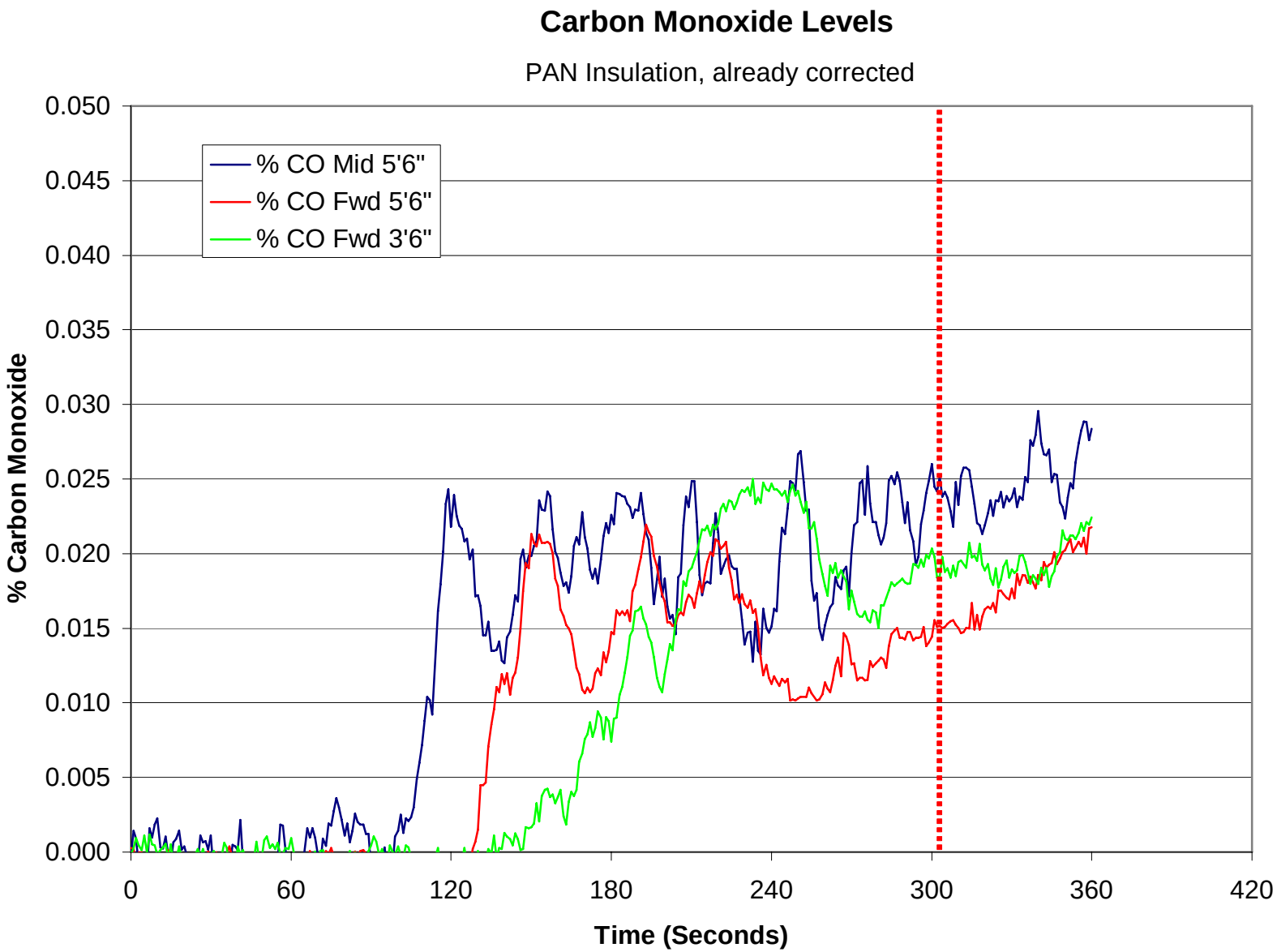
Full-Scale Test Results, PAN Insulation System

Post-test

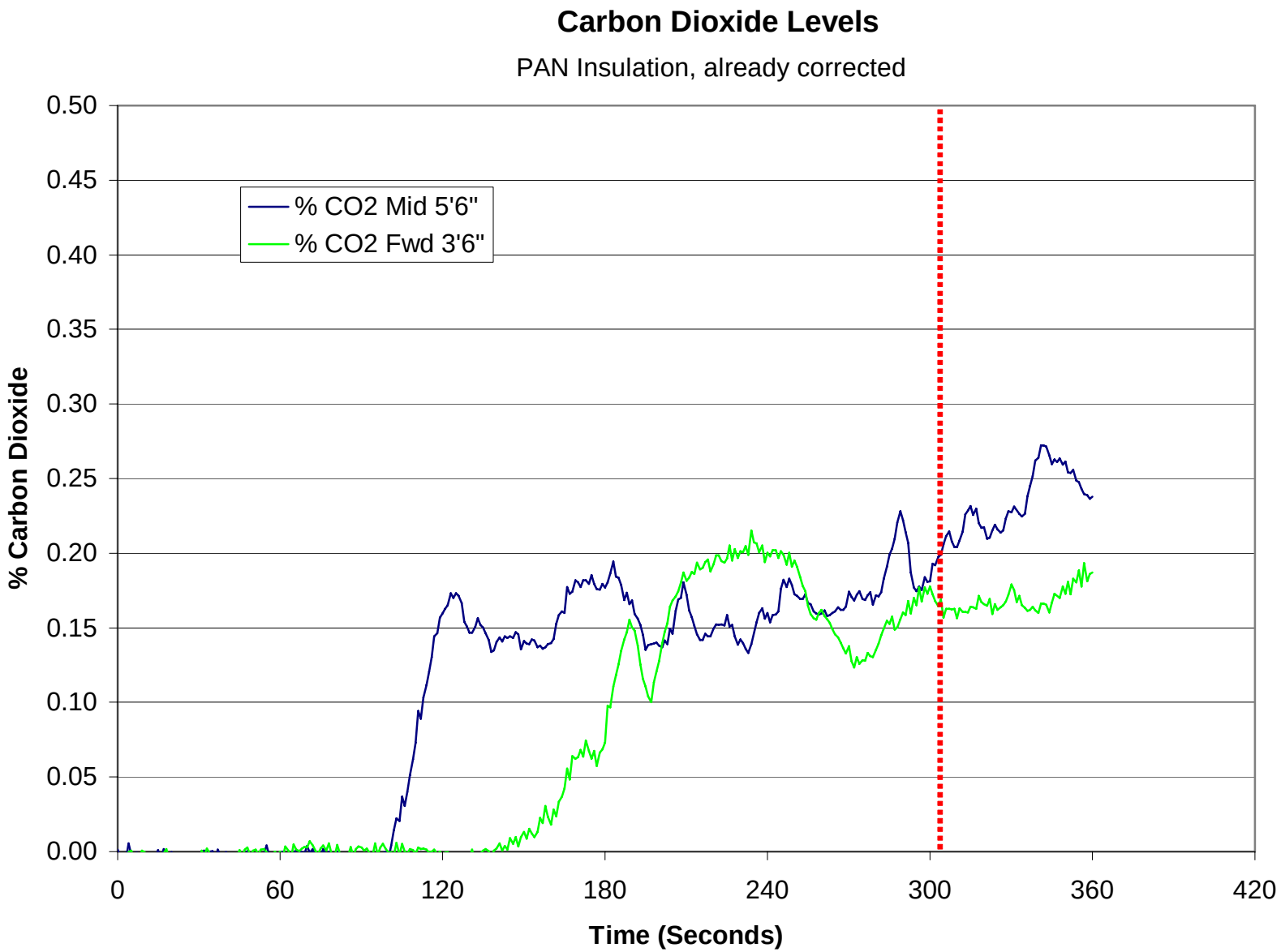
Full-Scale Test Results, PAN Insulation System

Post-test

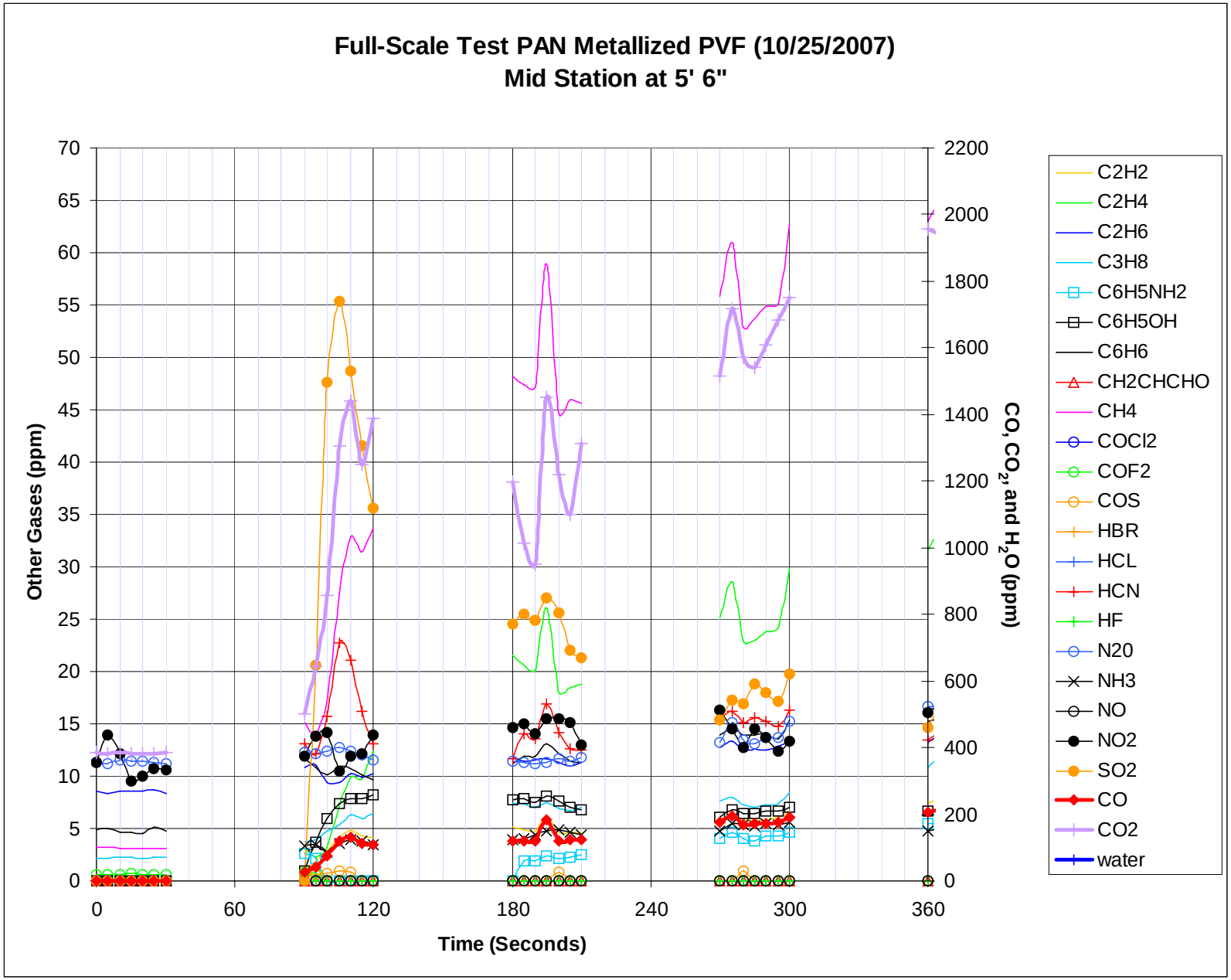
Full-Scale Results, PAN Insulation, Gas Analyzers



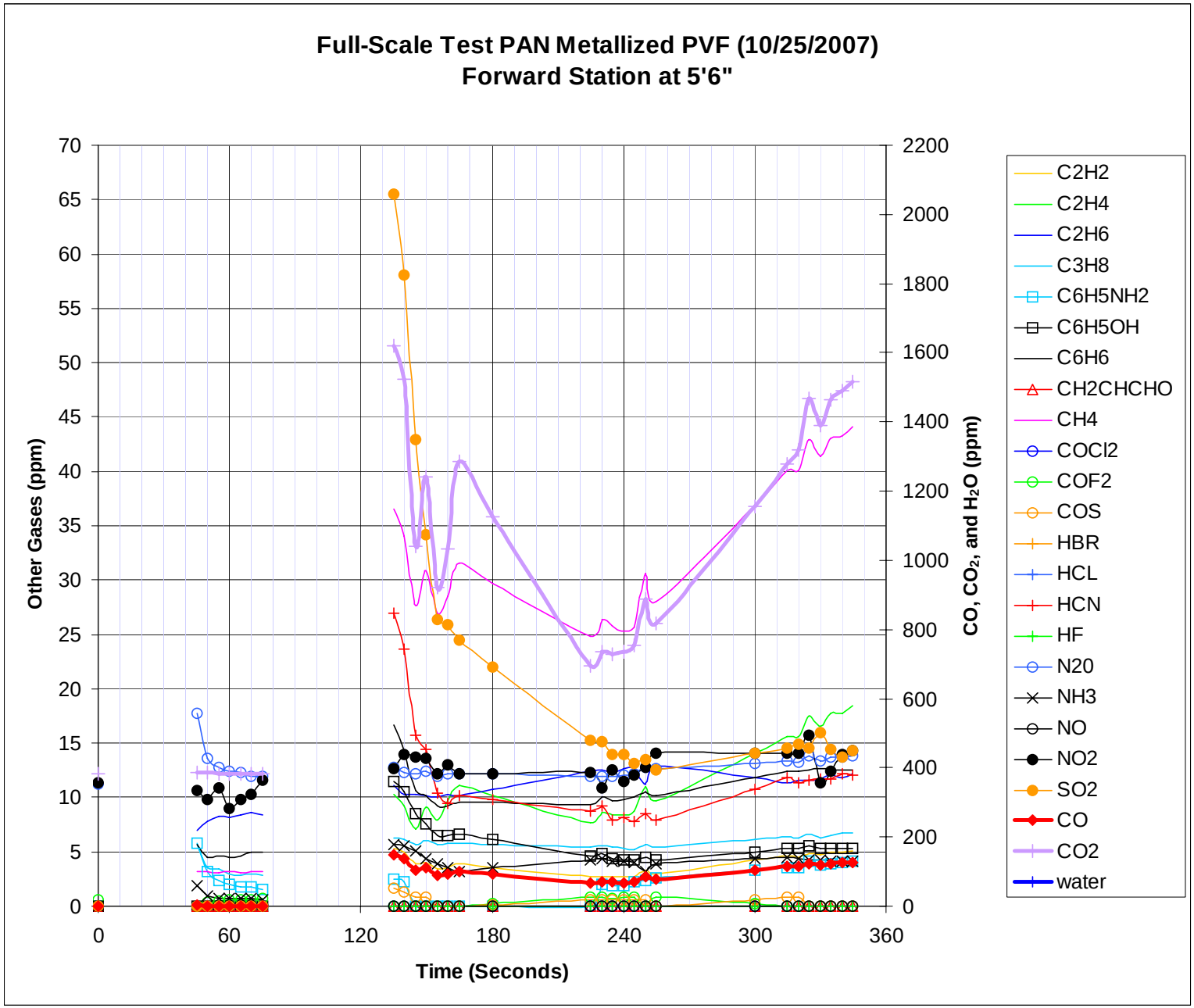
Full-Scale Results, PAN Insulation, Gas Analyzers



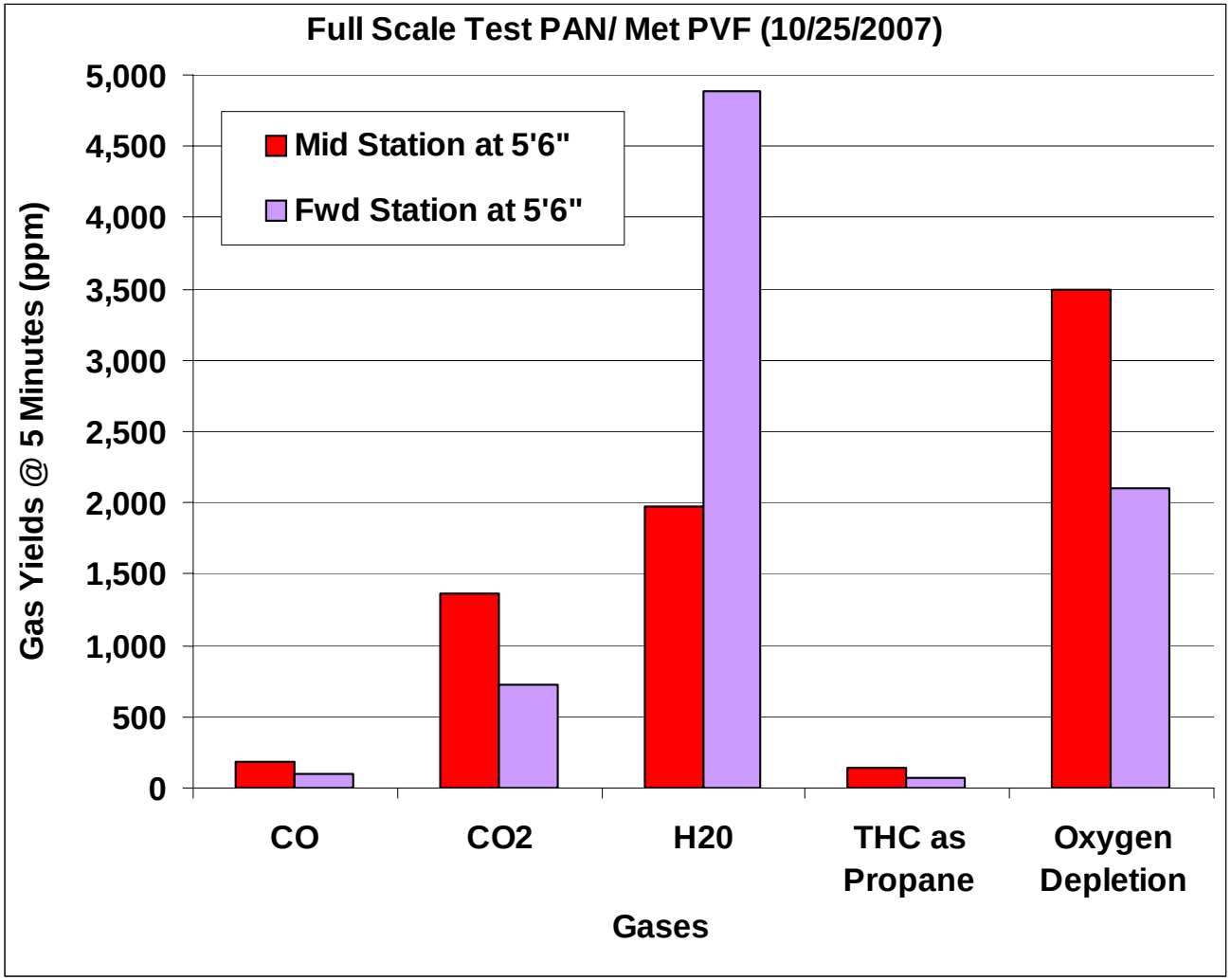
Full-Scale Results, PAN Insulation, FTIR



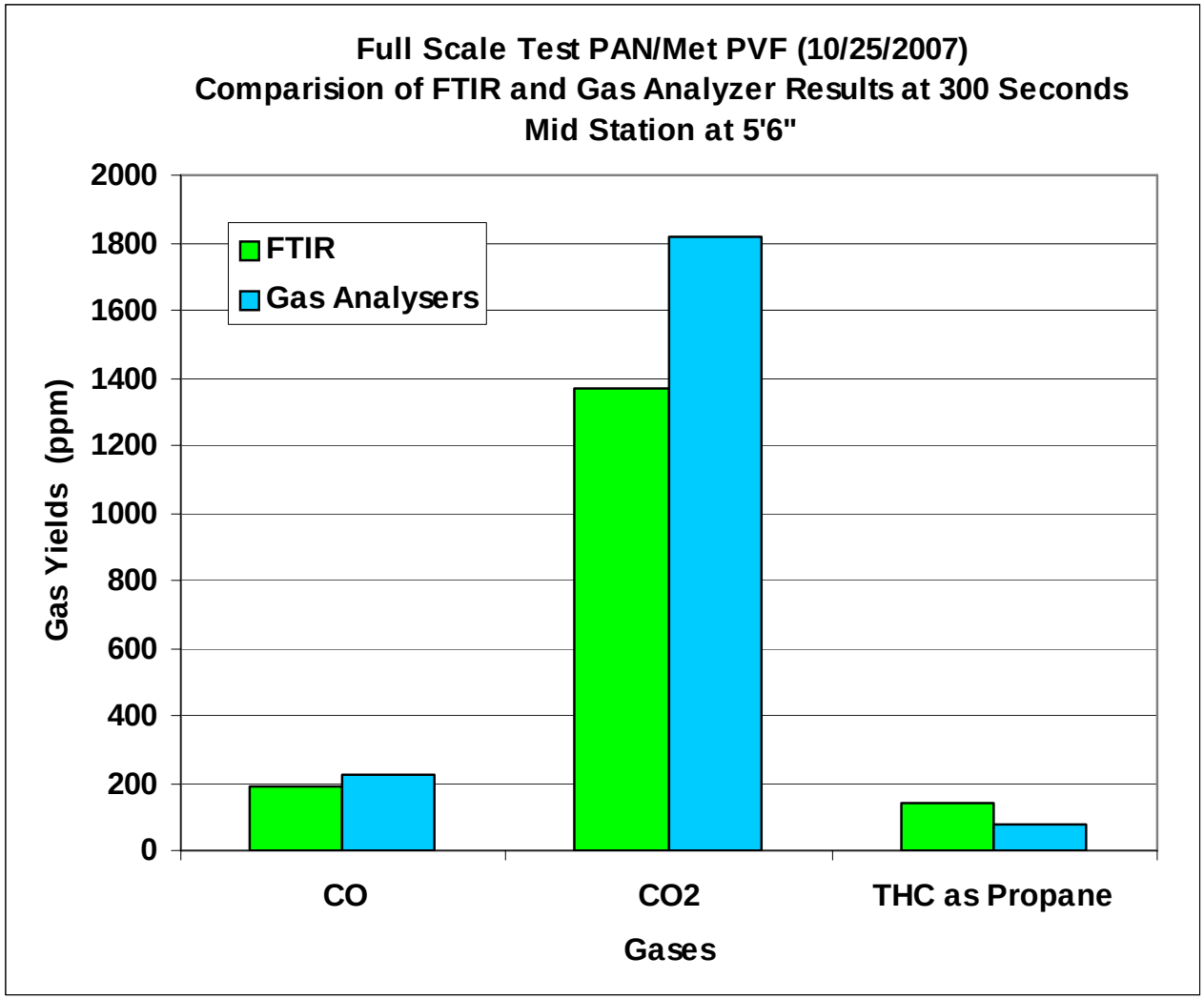
Full-Scale Results, PAN Insulation, FTIR



Full-Scale Results, PAN Insulation, FTIR



Full-Scale Results, PAN Insulation, Comparison



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

Full-Scale Test Results, Ceramic Barrier Insulation System I

Pre-test

Full-Scale Test Results, Ceramic Barrier Insulation System I

Post-test

Full-Scale Test Results, Ceramic Barrier Insulation System I

Post-test

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

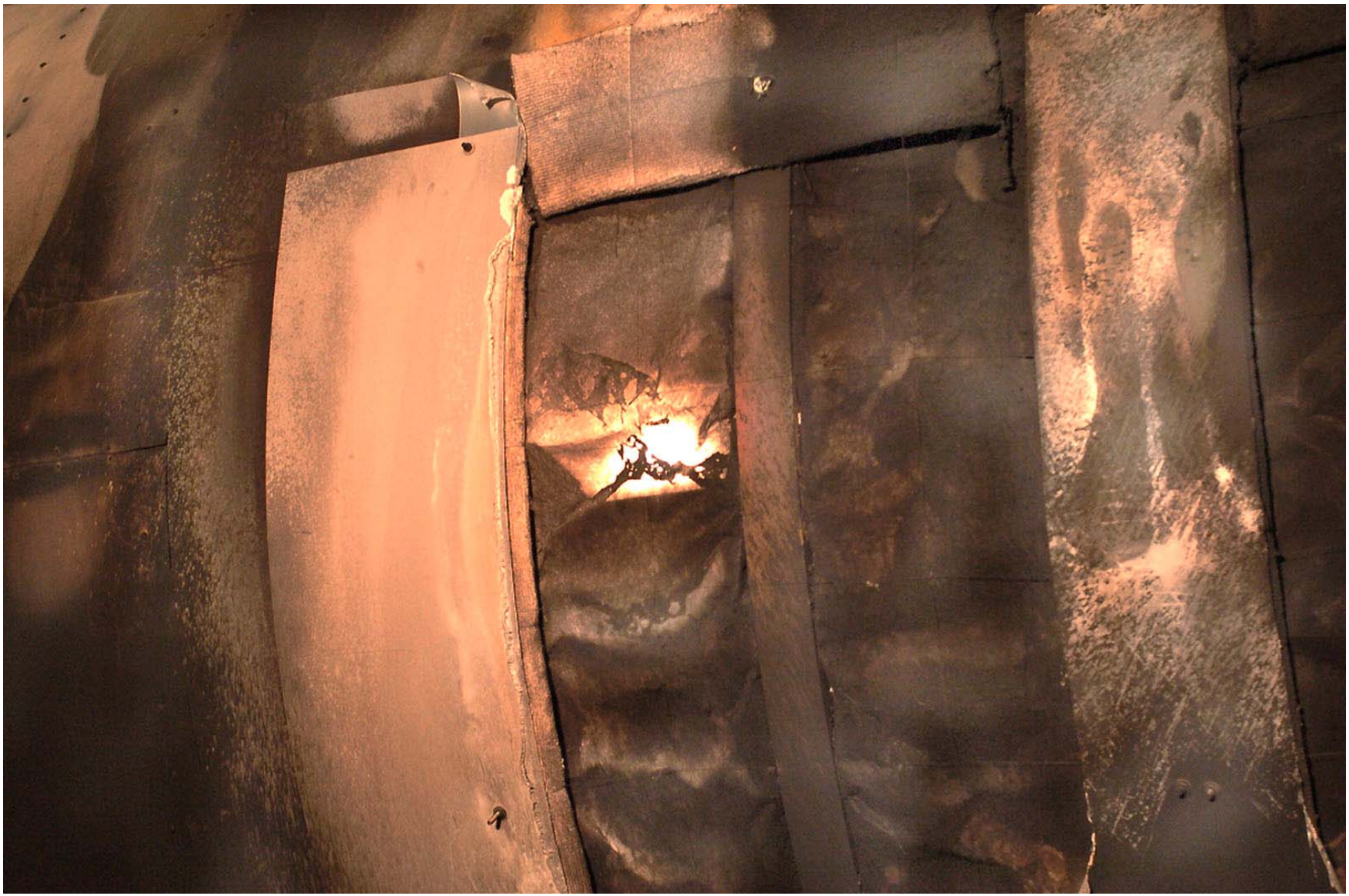
Post-test

Full-Scale Test Results, Ceramic Barrier Insulation System II

Post-test

Full-Scale Test Results, Ceramic Barrier Insulation System II

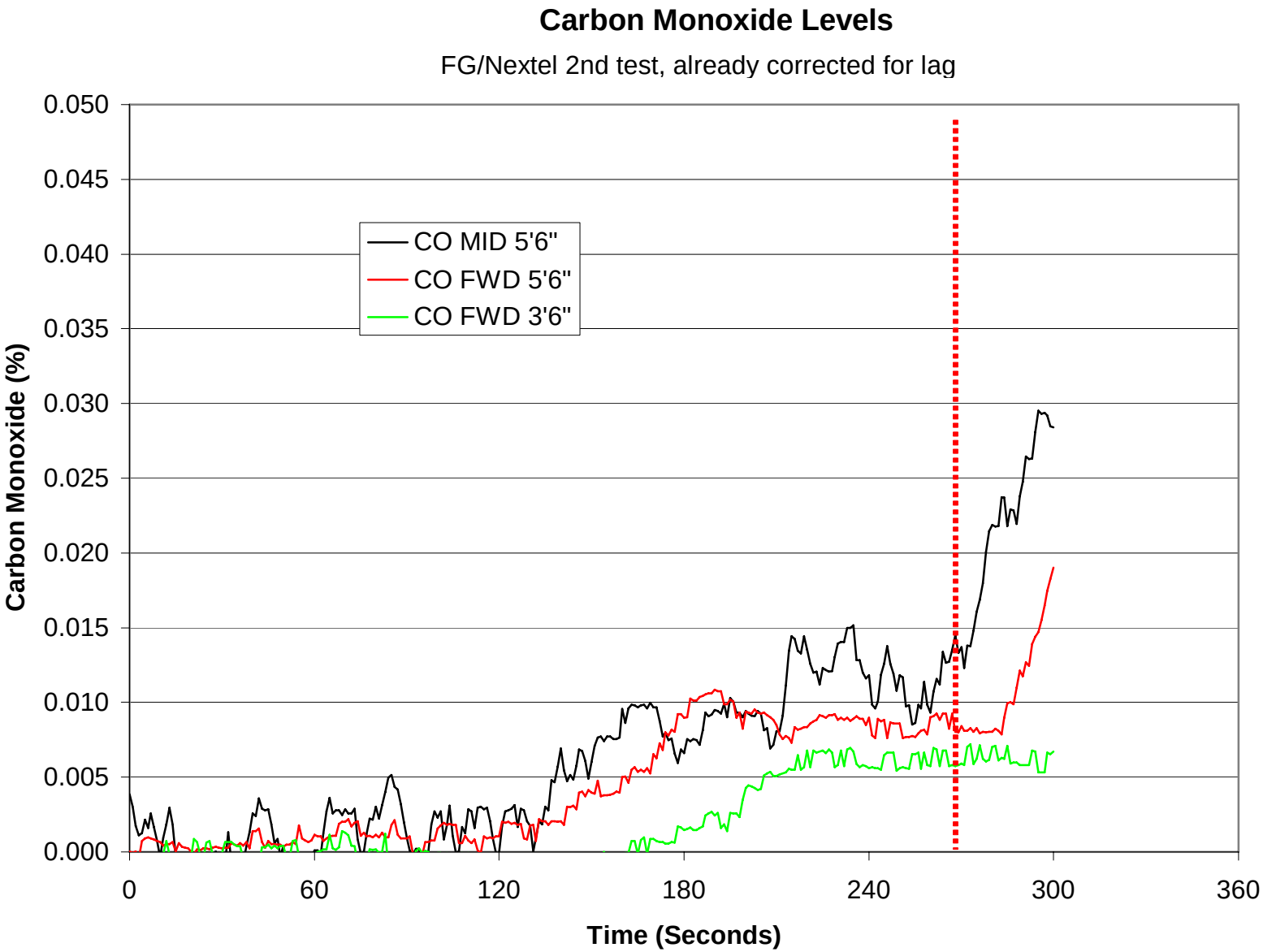
Post-test



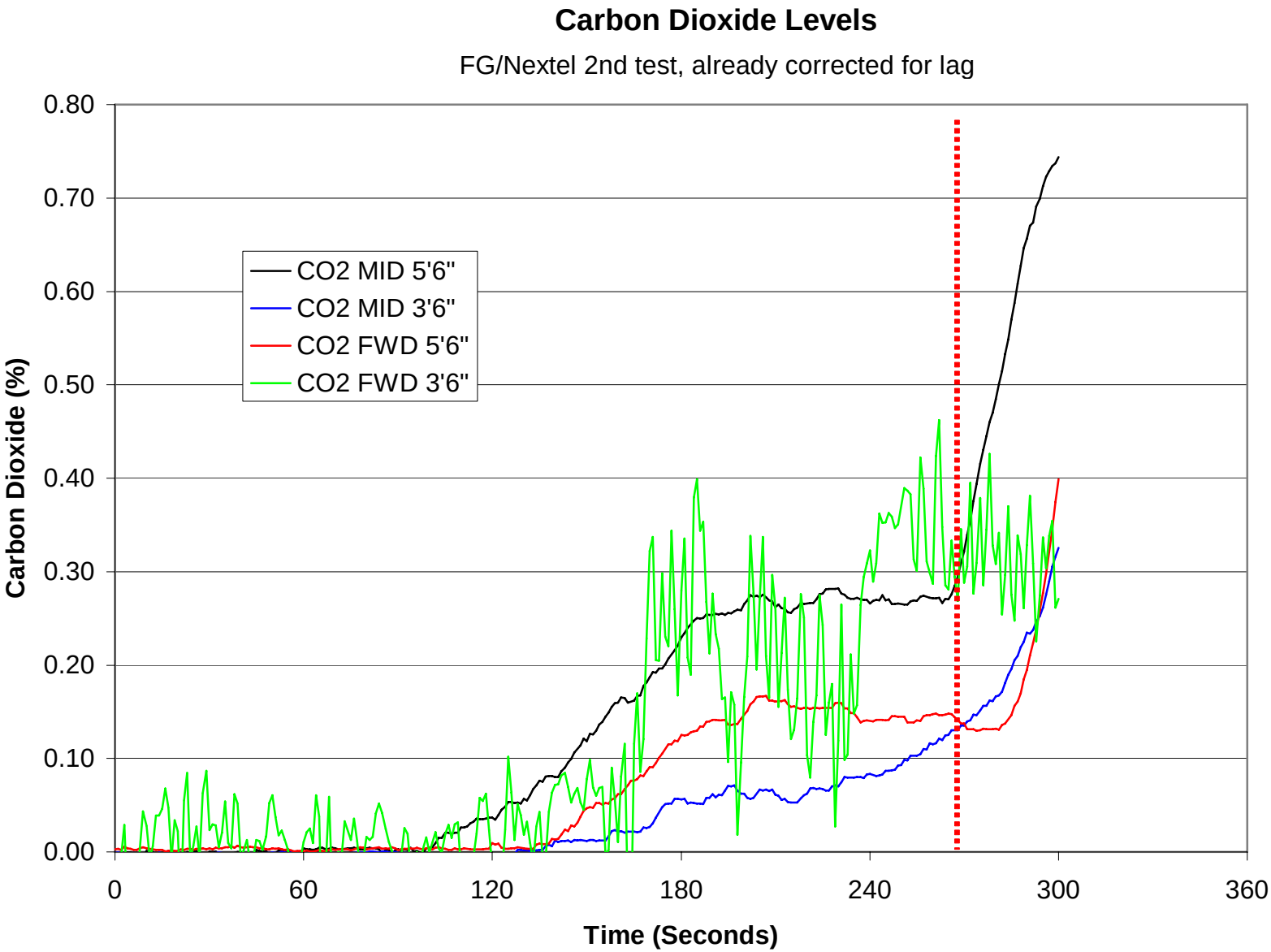
Full-Scale Test Results, Ceramic Barrier Insulation System II

Post-test

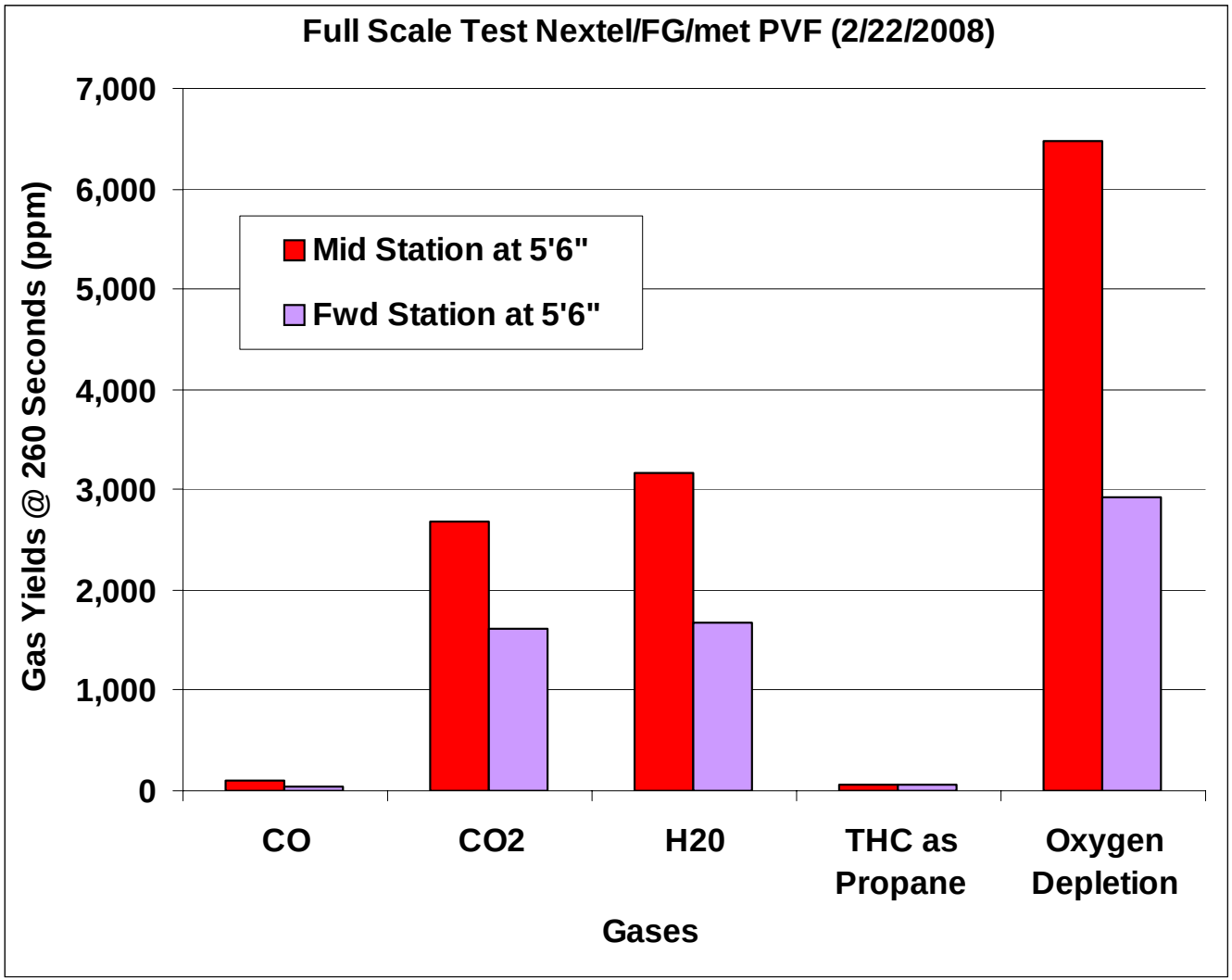
Full-Scale Results, Ceramic Barrier Insulation II, Gas Analyzer



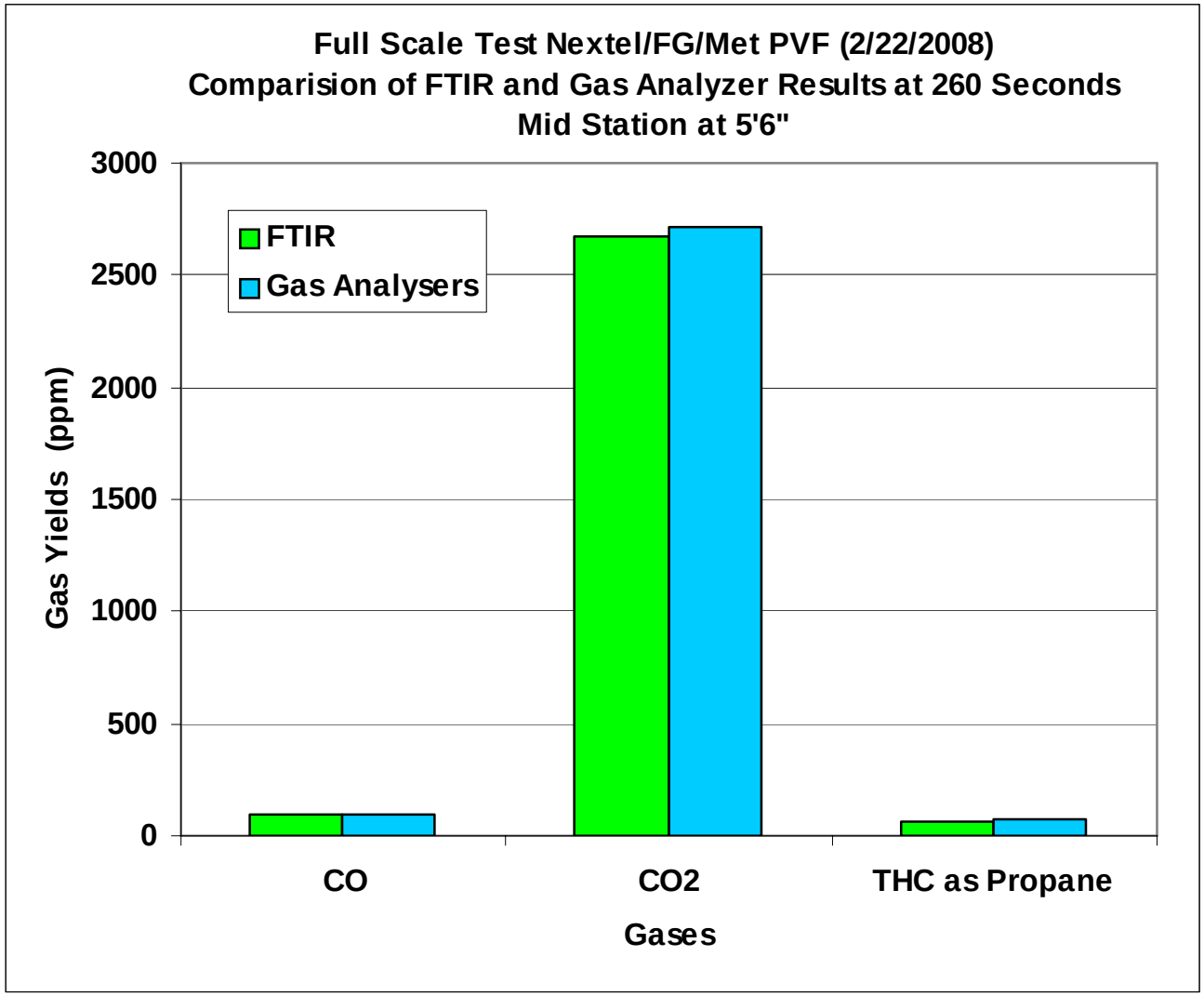
Full-Scale Results, Ceramic Barrier Insulation II, Gas Analyzer



Full-Scale Results, Ceramic Barrier Insulation II, FTIR



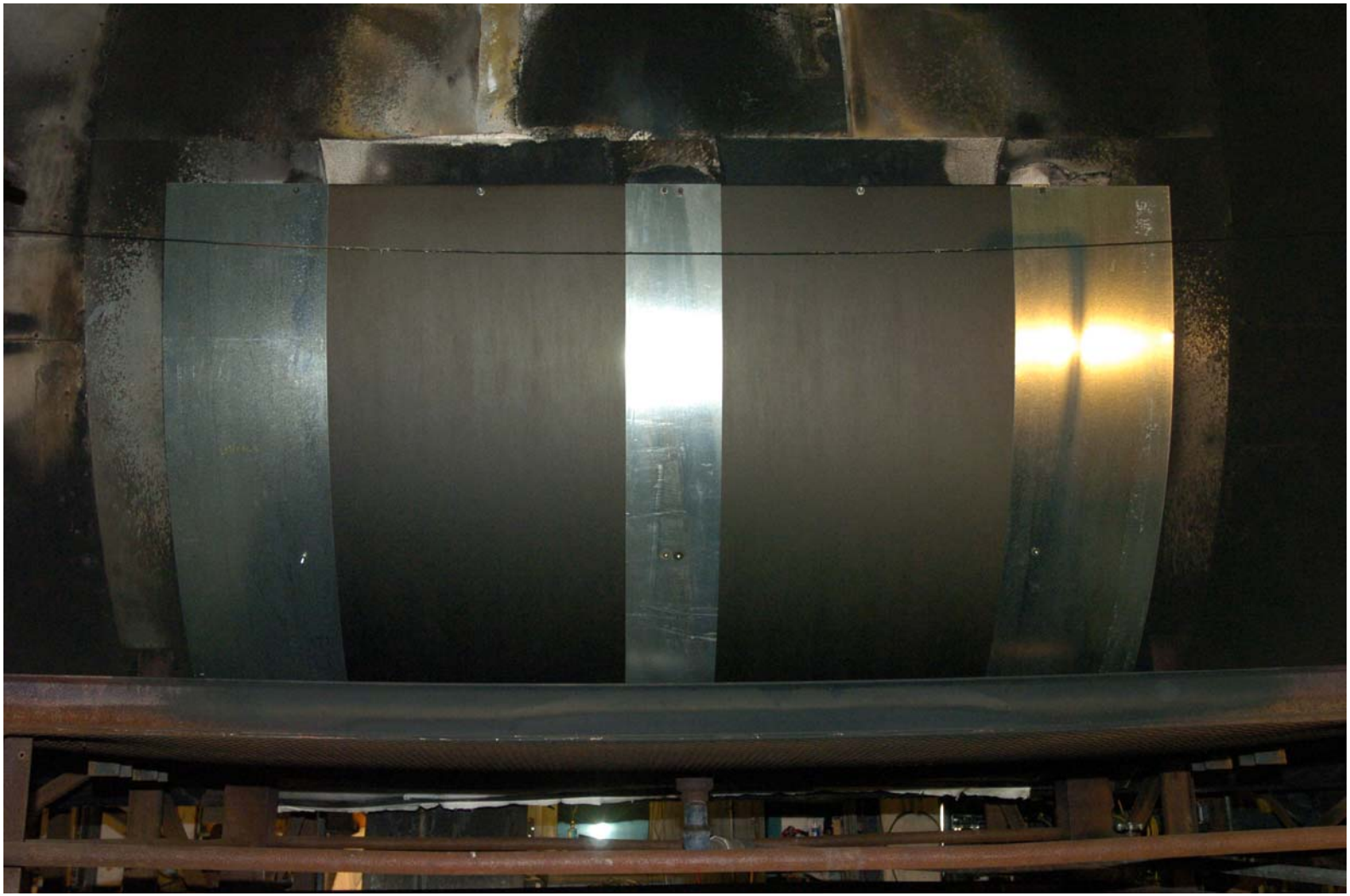
Full-Scale Results, Ceramic Barrier Insulation II, Comparison



Full-Scale Test Results
Structural Composite System

Full-Scale Test Results, Structural Composite System

Pre-test



Full-Scale Test Results, Structural Composite System

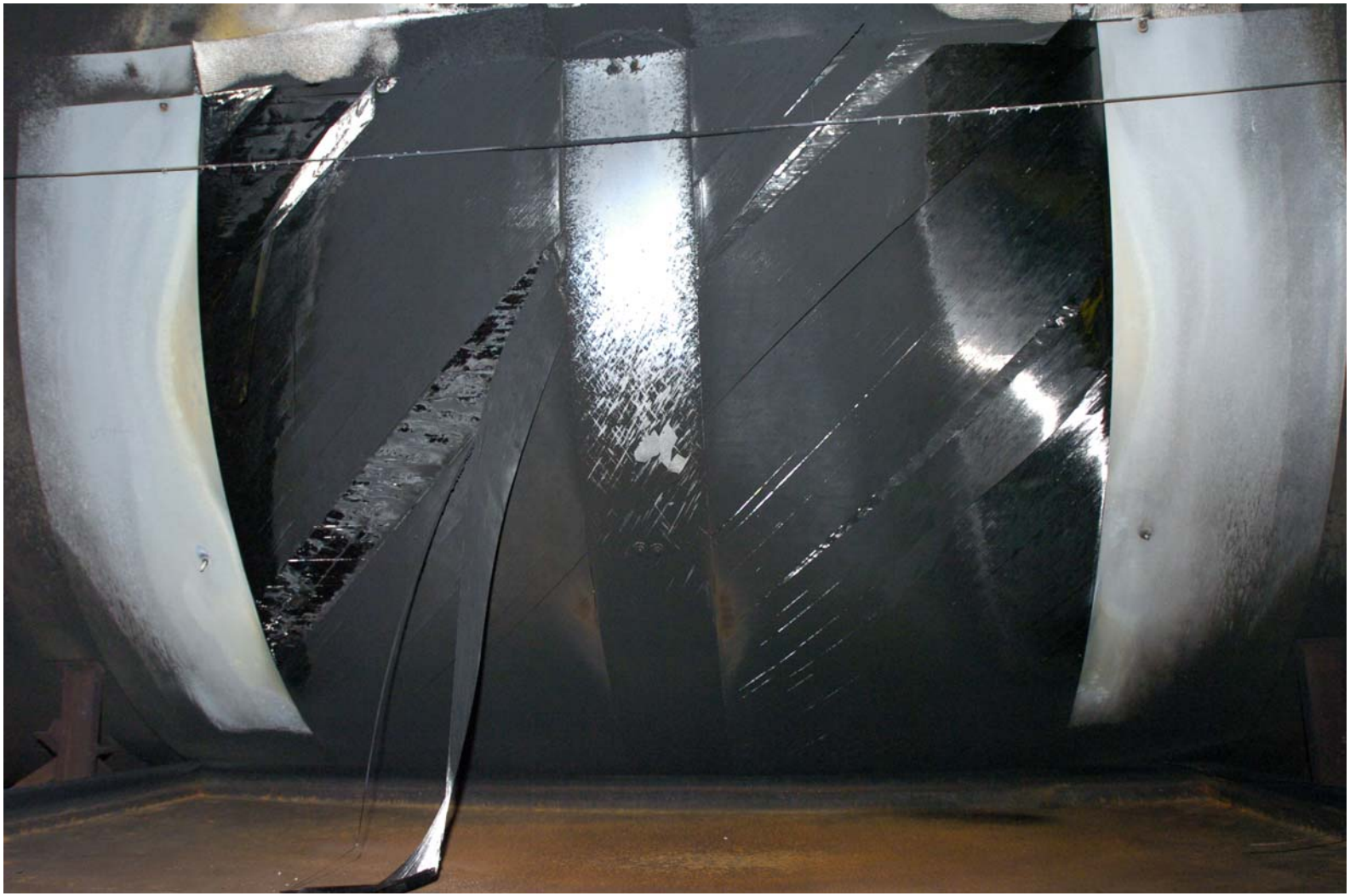
Full-Scale Test Results, Structural Composite System

Full-Scale Test Results, Structural Composite System

Post-test

Full-Scale Test Results, Structural Composite System

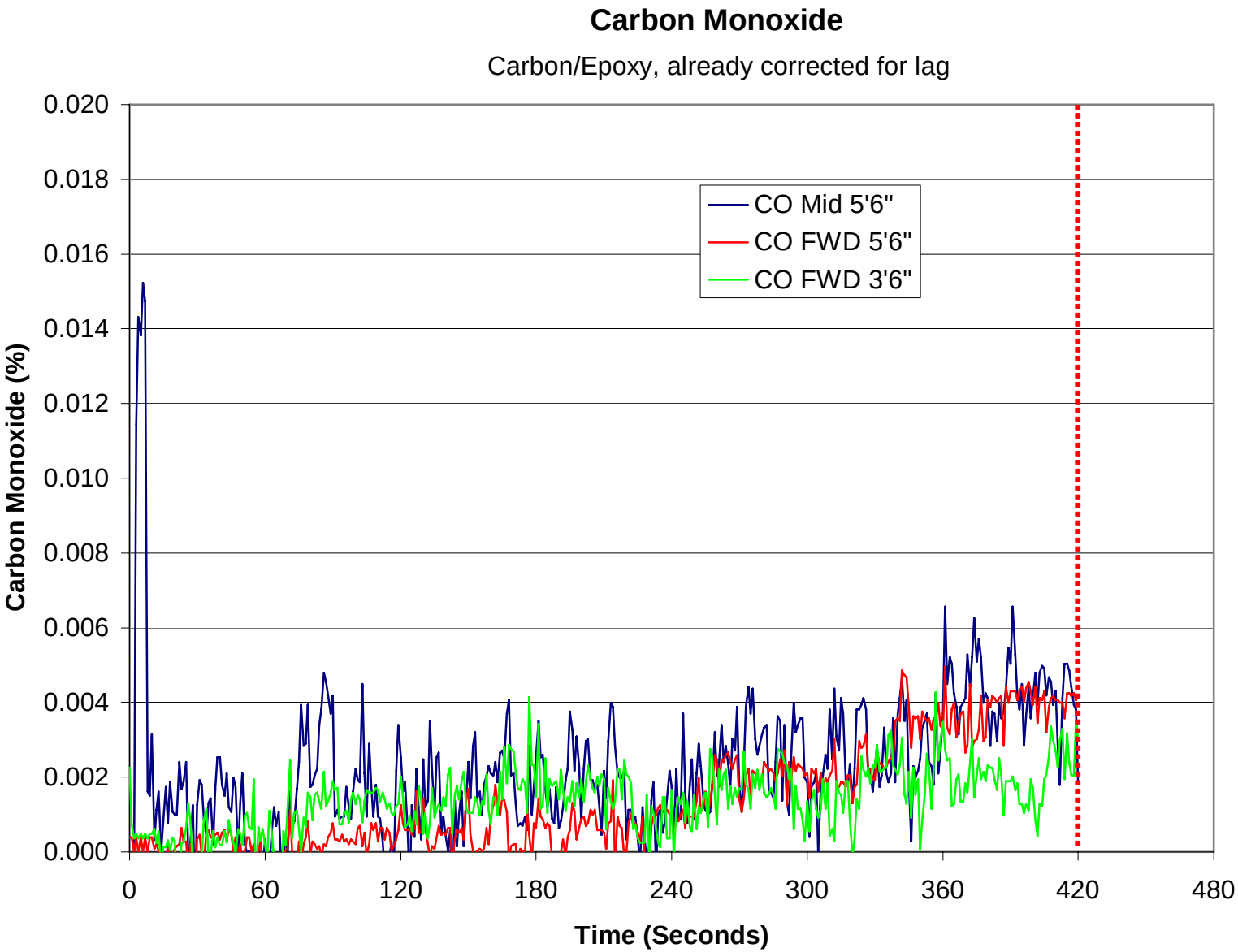
Post-test



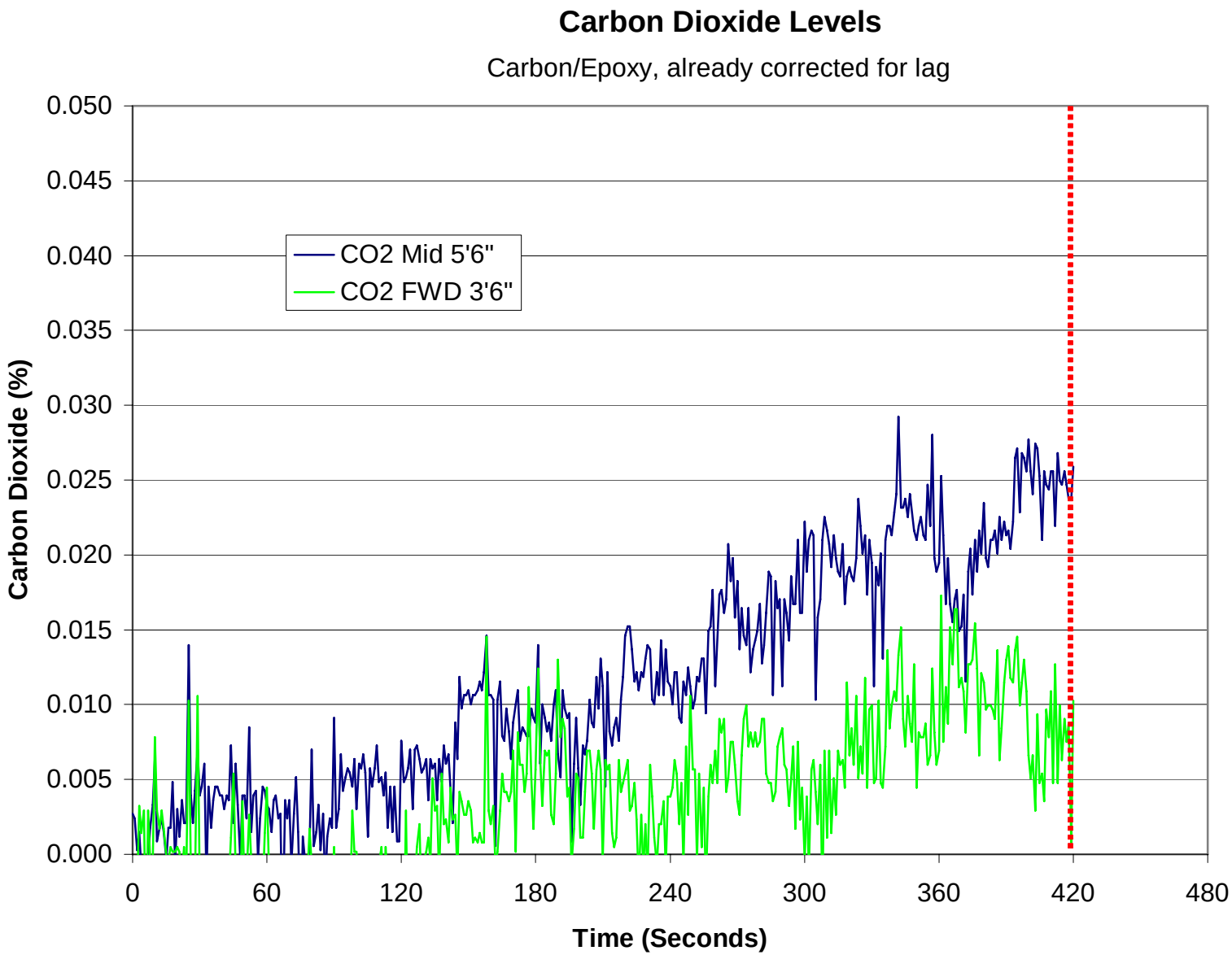
Full-Scale Test Results, Structural Composite System

Post-test

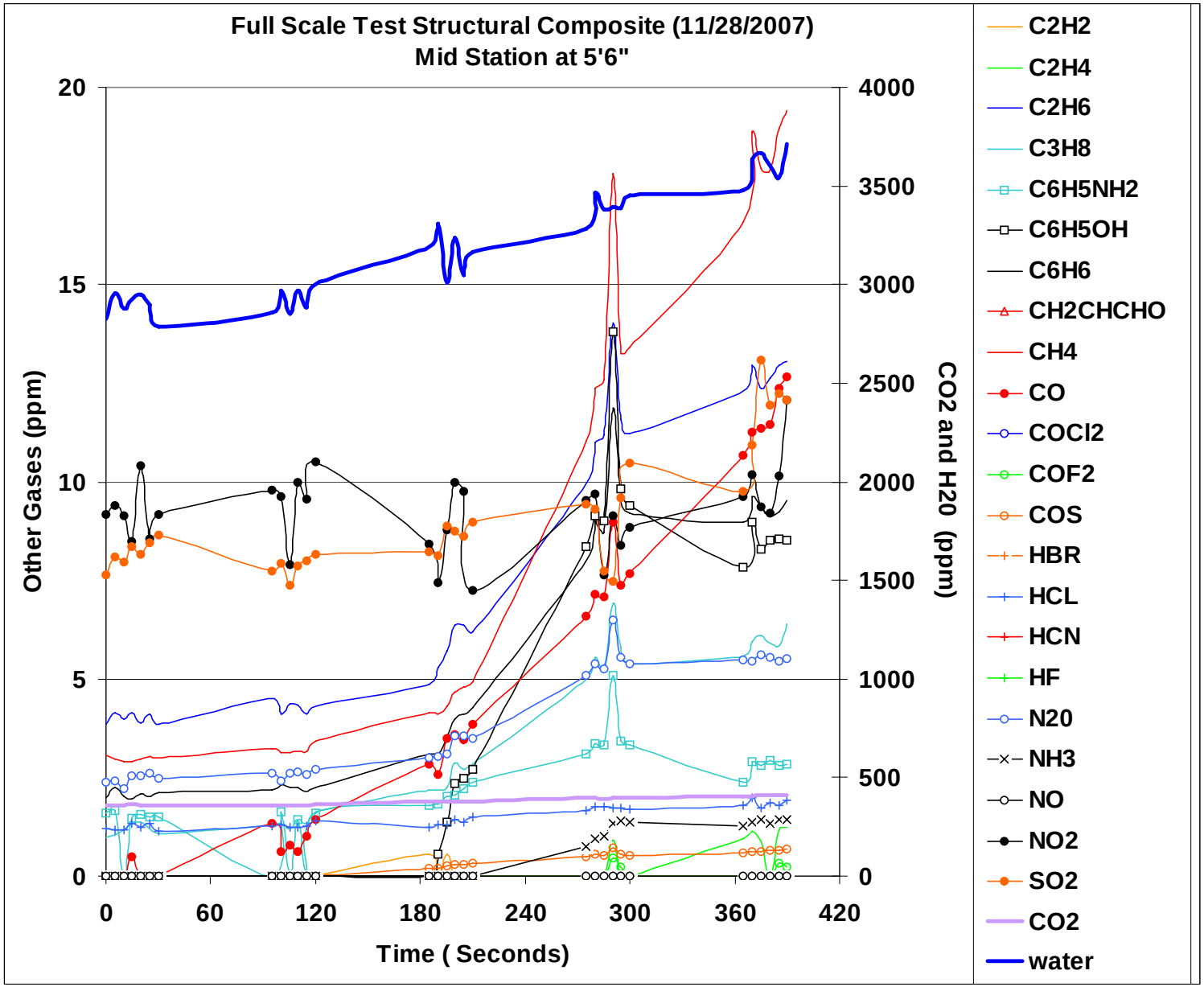
Full-Scale Results, Structural Composite, Gas Analyzer



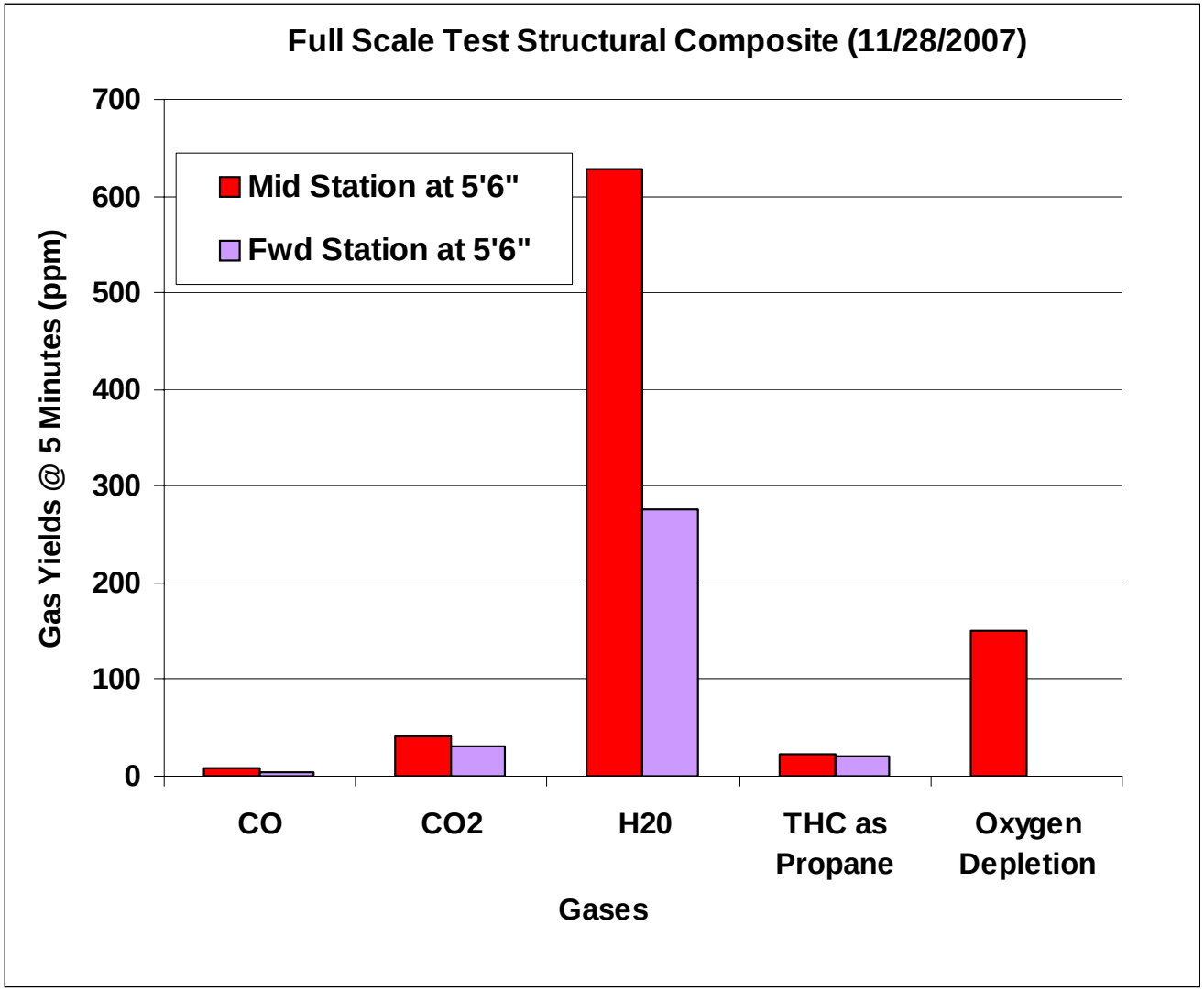
Full-Scale Results, Structural Composite, Gas Analyzer



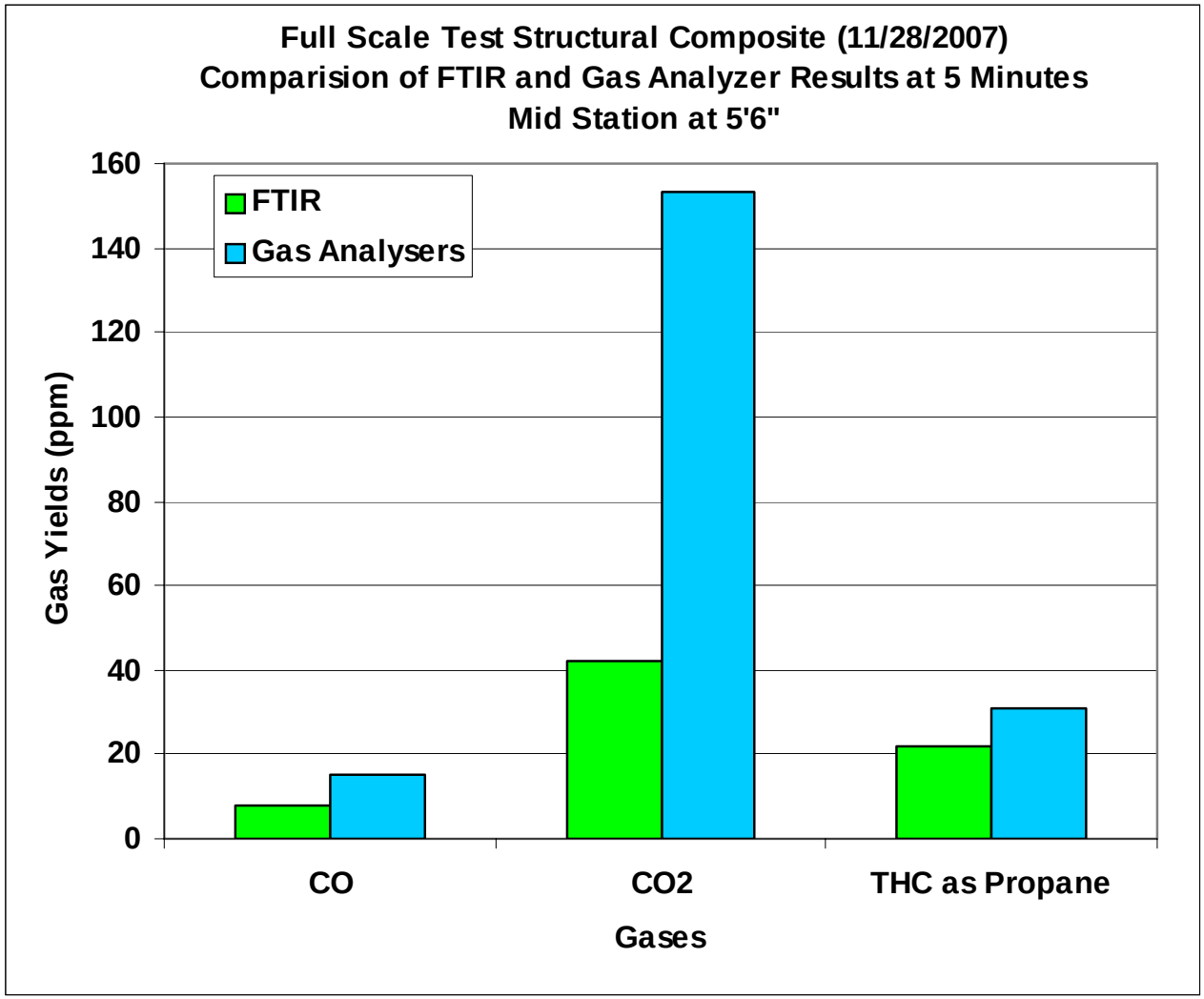
Full-Scale Results, Structural Composite, FTIR



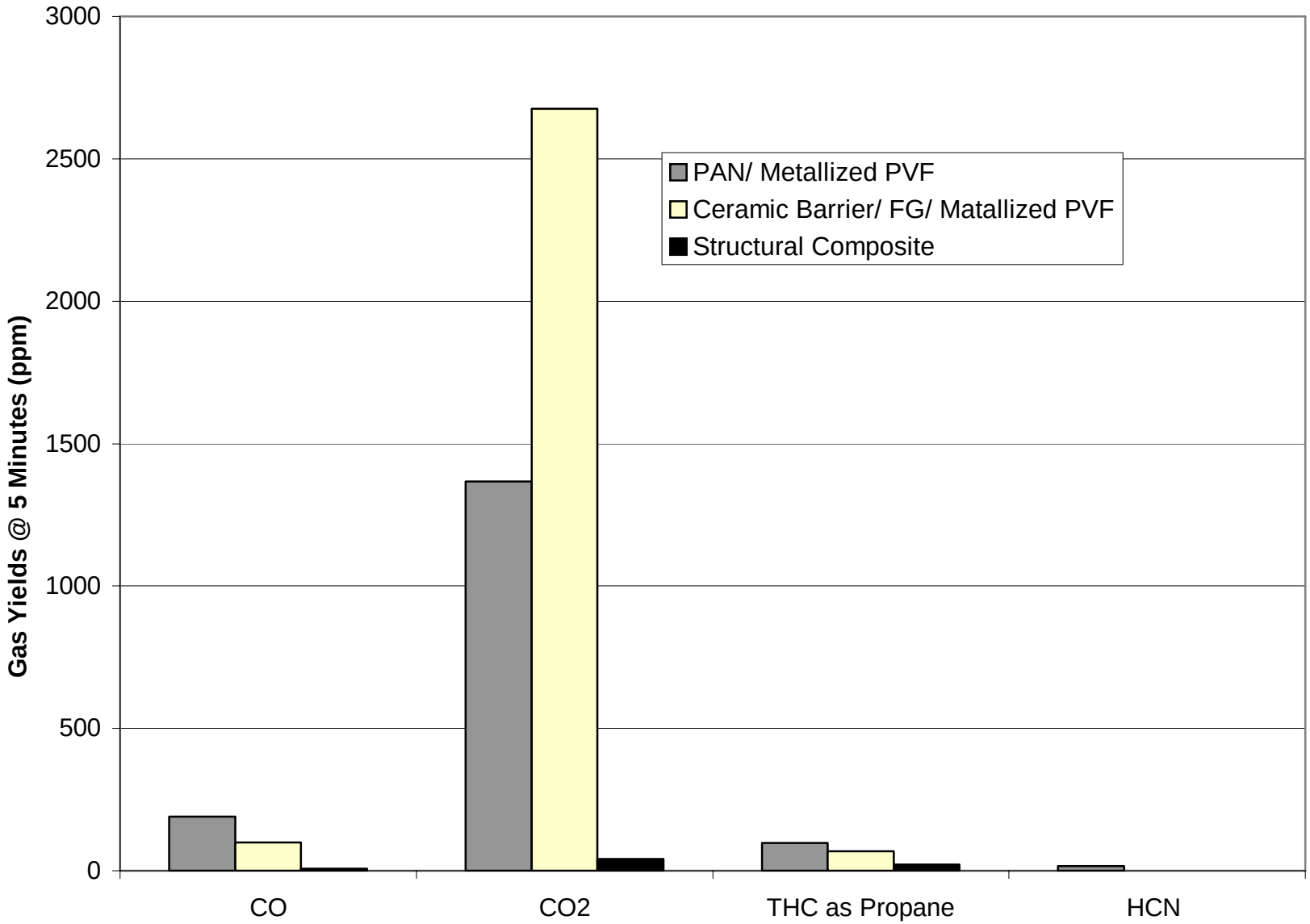
Full-Scale Results, Structural Composite, FTIR



Full-Scale Results, Structural Composite, Comparison



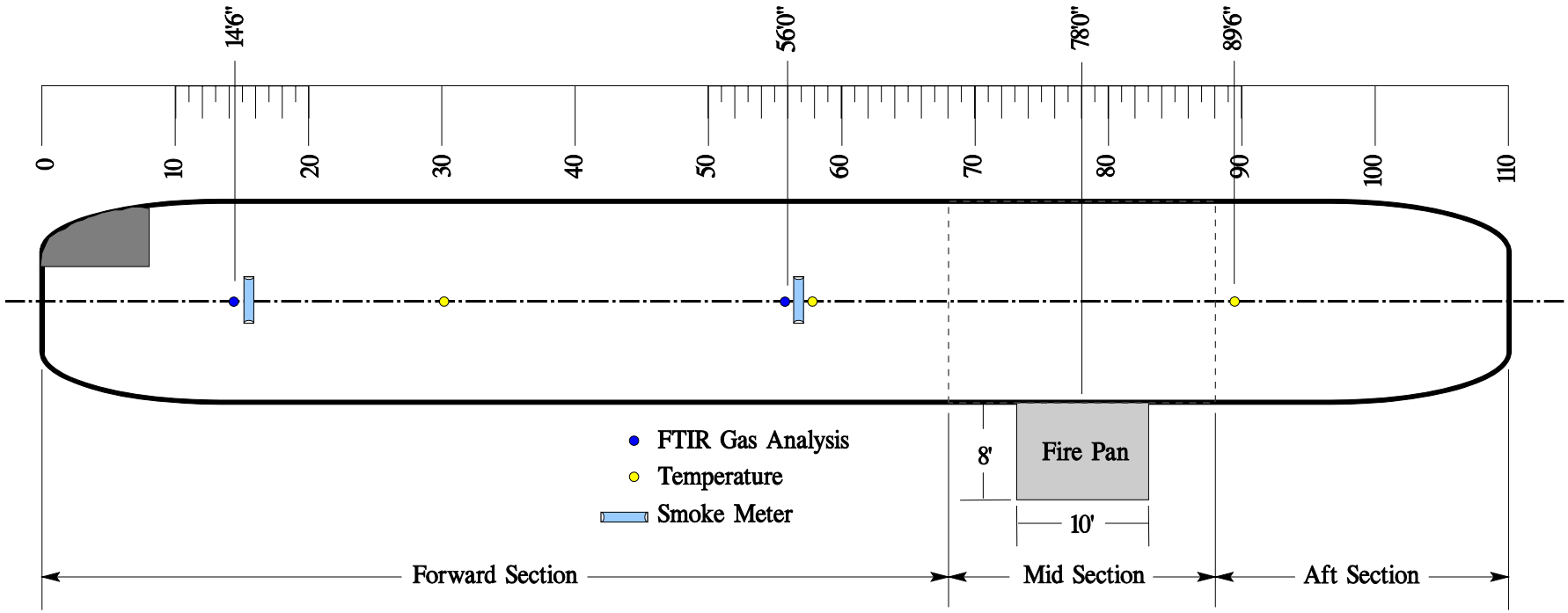
Full-Scale Results, Comparison of 3 Insulation Systems



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

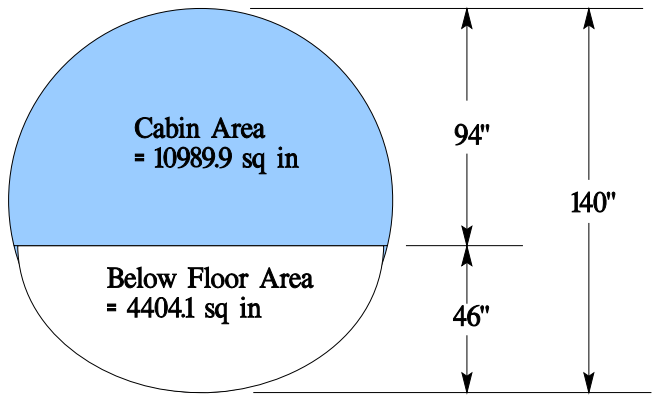
Mid Volume = Total Cabin Area x Mid Length = (17203/144) x 20 = 2389.4 cu ft

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 $Volume_{Box}$ to Burn $Area_{Box}$ = 60.33 ft^3 / 9.25 ft^2 = 6.52

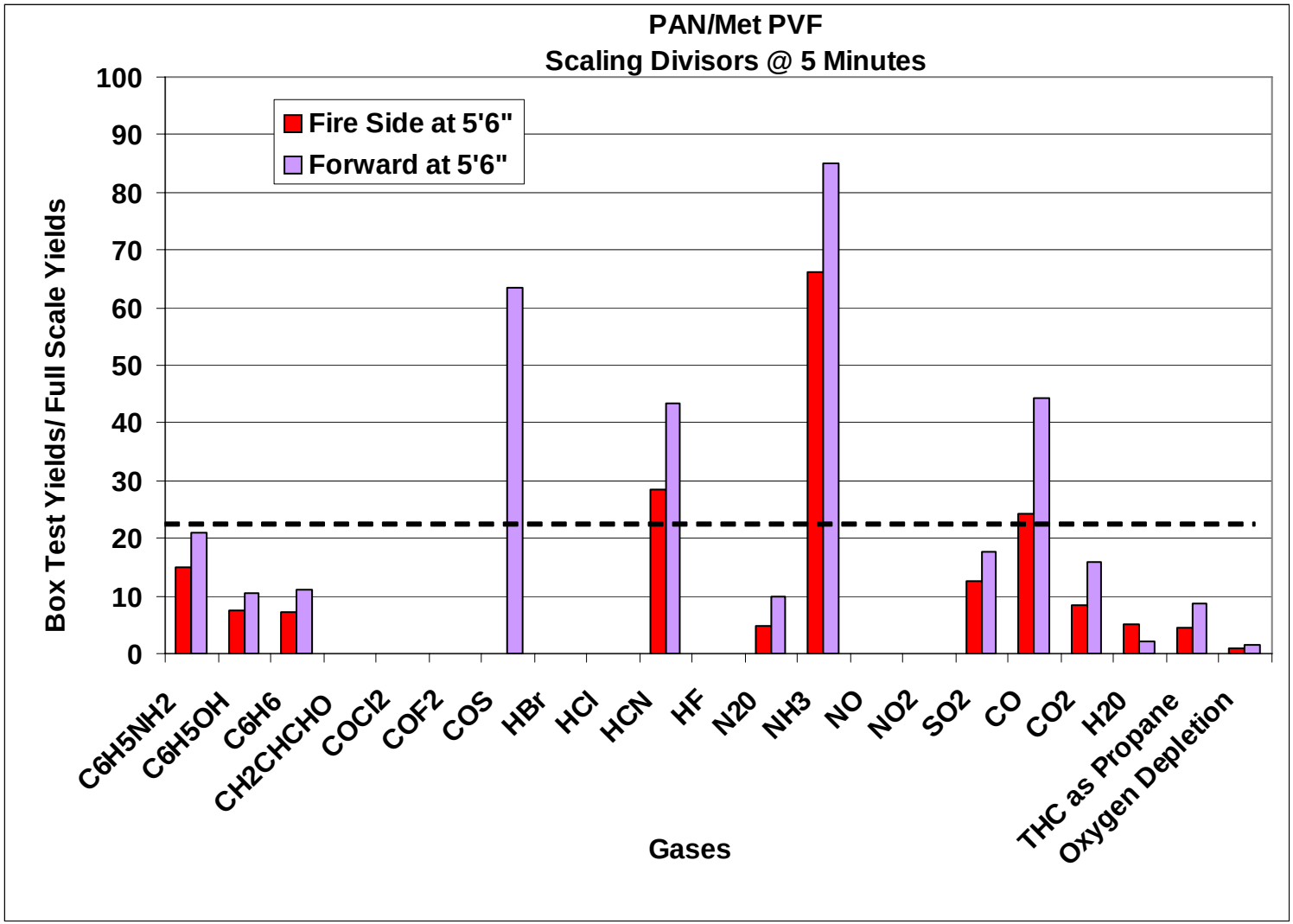
Ratio of $Volume_{FSTest}$ to Burn $Area_{FSTest}$ = 9258.1 ft^3 / 64 ft^2 = 144.7

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

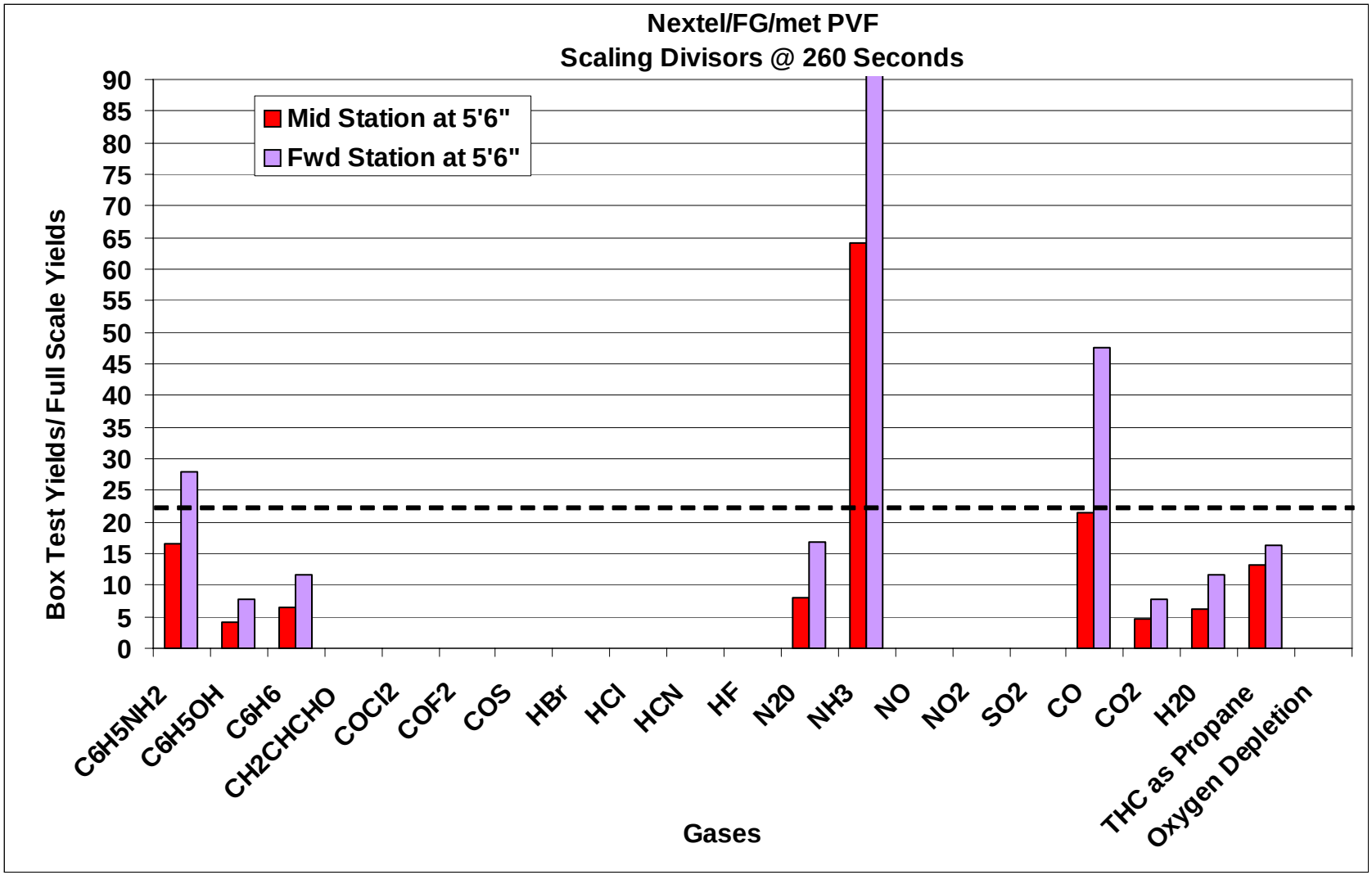
Full-Scale Test Article has 22.2 Times More Volume per Burn Area than Lab Scale Box

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

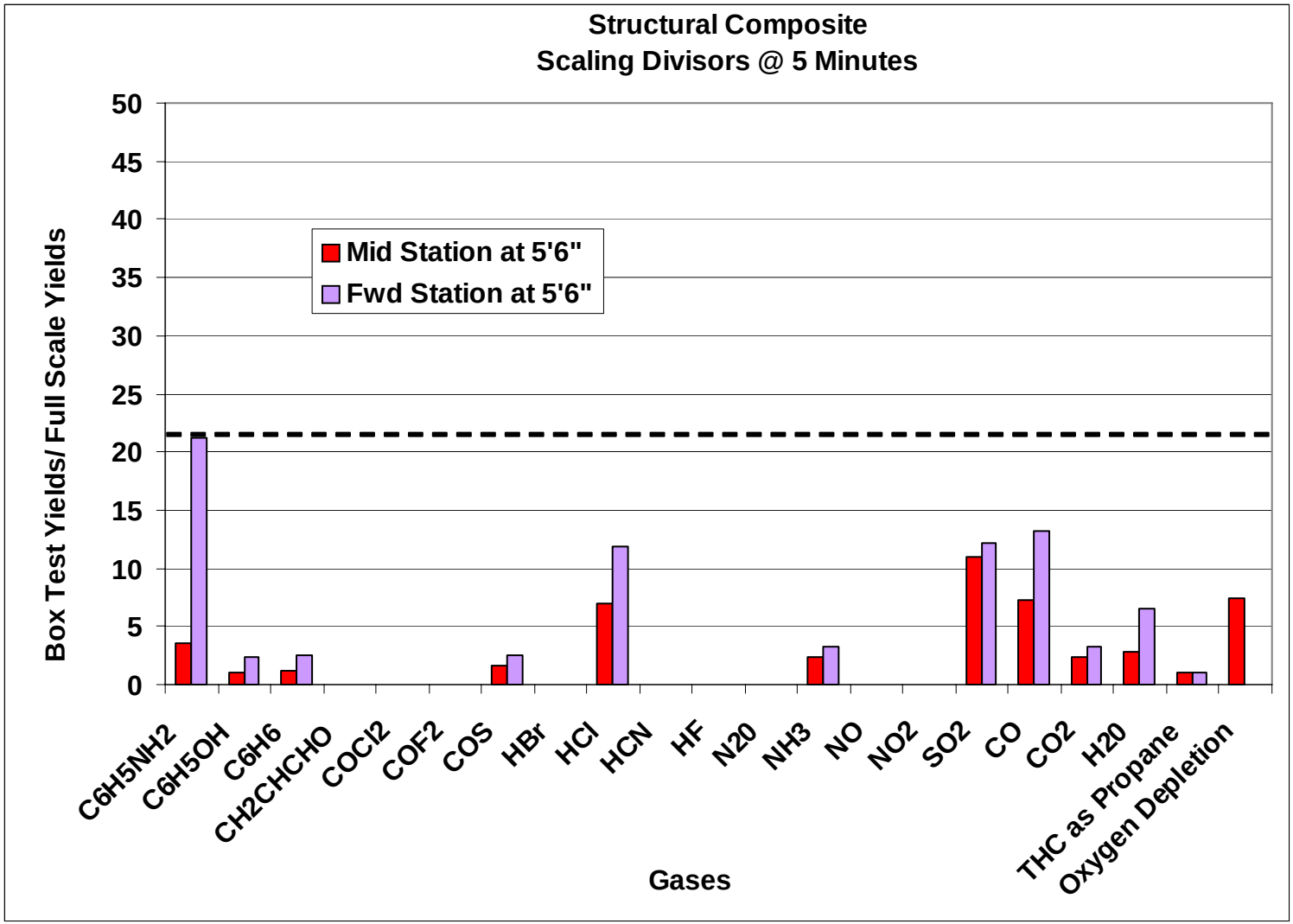
Gas Concentration Scaling, PAN Insulation System



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