Federal Aviation Administration

International Aircraft Materials Fire Test Working Group

Update on Toxicity of Burnthrough-Compliant Insulation

Presented to: IAMFT WG, Atlantic City, NJ

By: Tim Marker, FAA Technical Center

Date: October 21, 2008

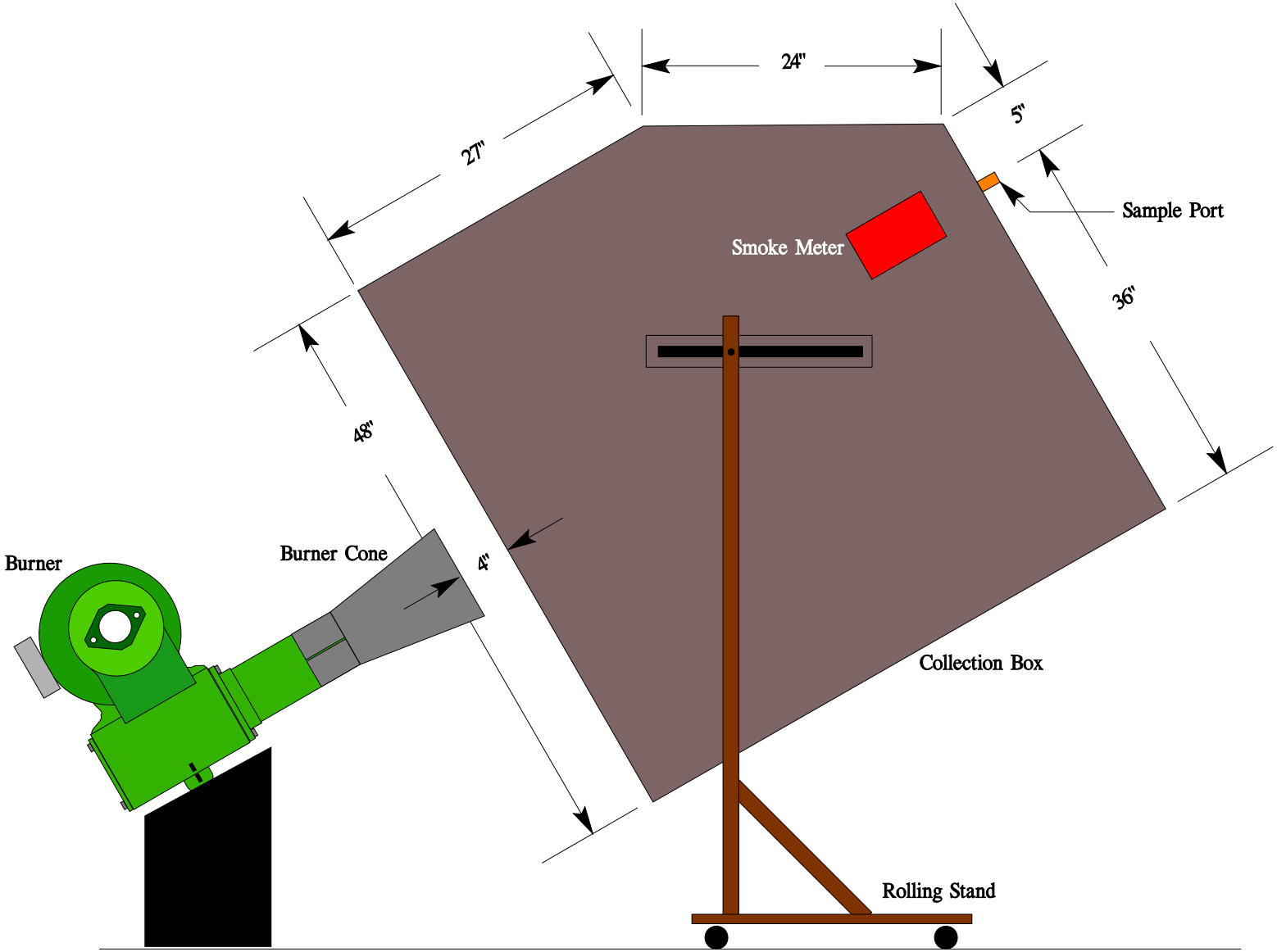
Development of Lab-Scale Test For Measuring Decomposition Products During a Postcrash Fire

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.

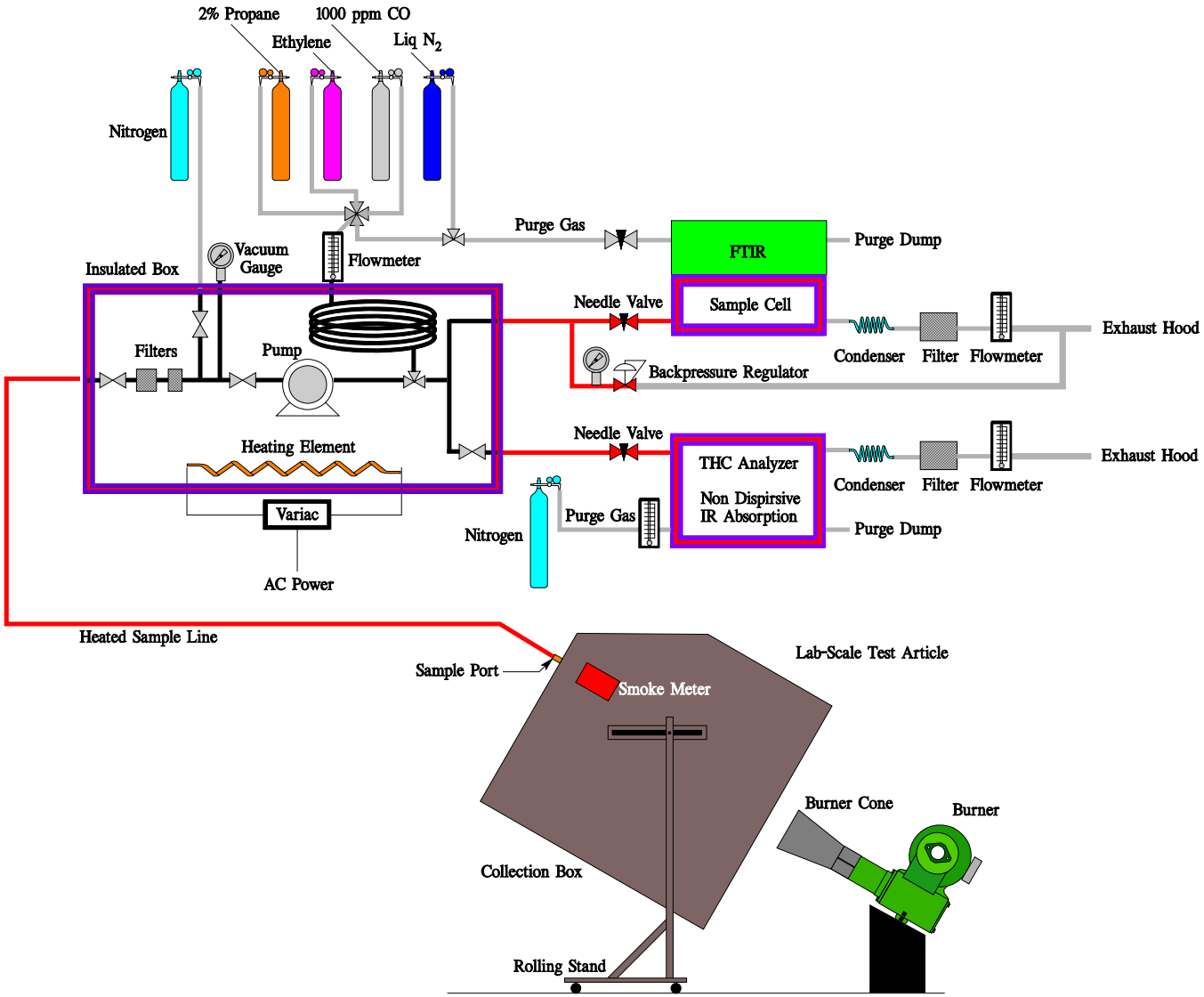
It is anticipated that this test method could be used to evaluate the potential toxicity of insulation constructions and innovations meeting the new burnthrough test requirements, in order to ensure that an *adverse* condition will not result inside an intact fuselage when exposed to an external fuel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

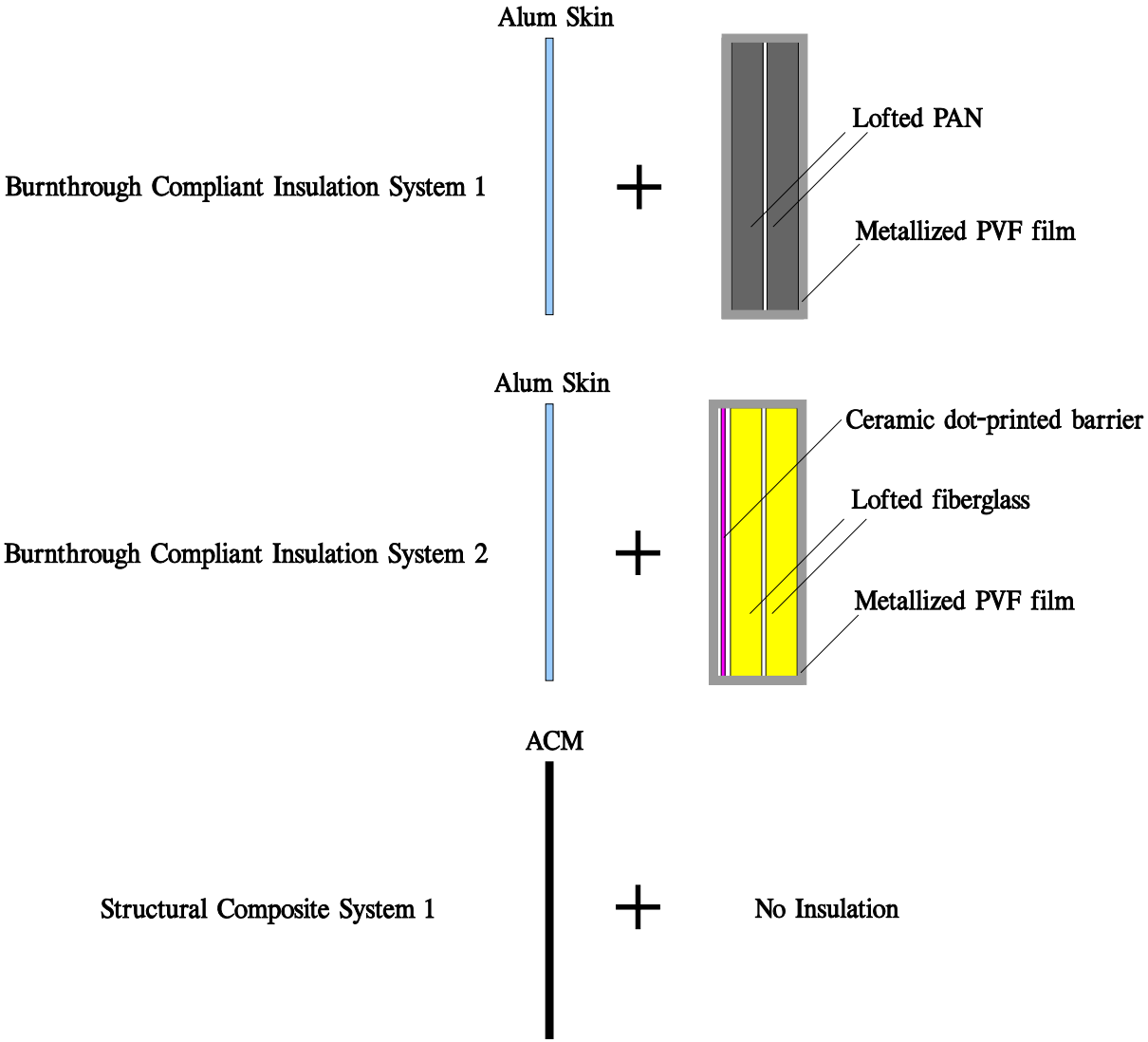
Apparatus for Evaluating Toxic Gas Decomposition Products



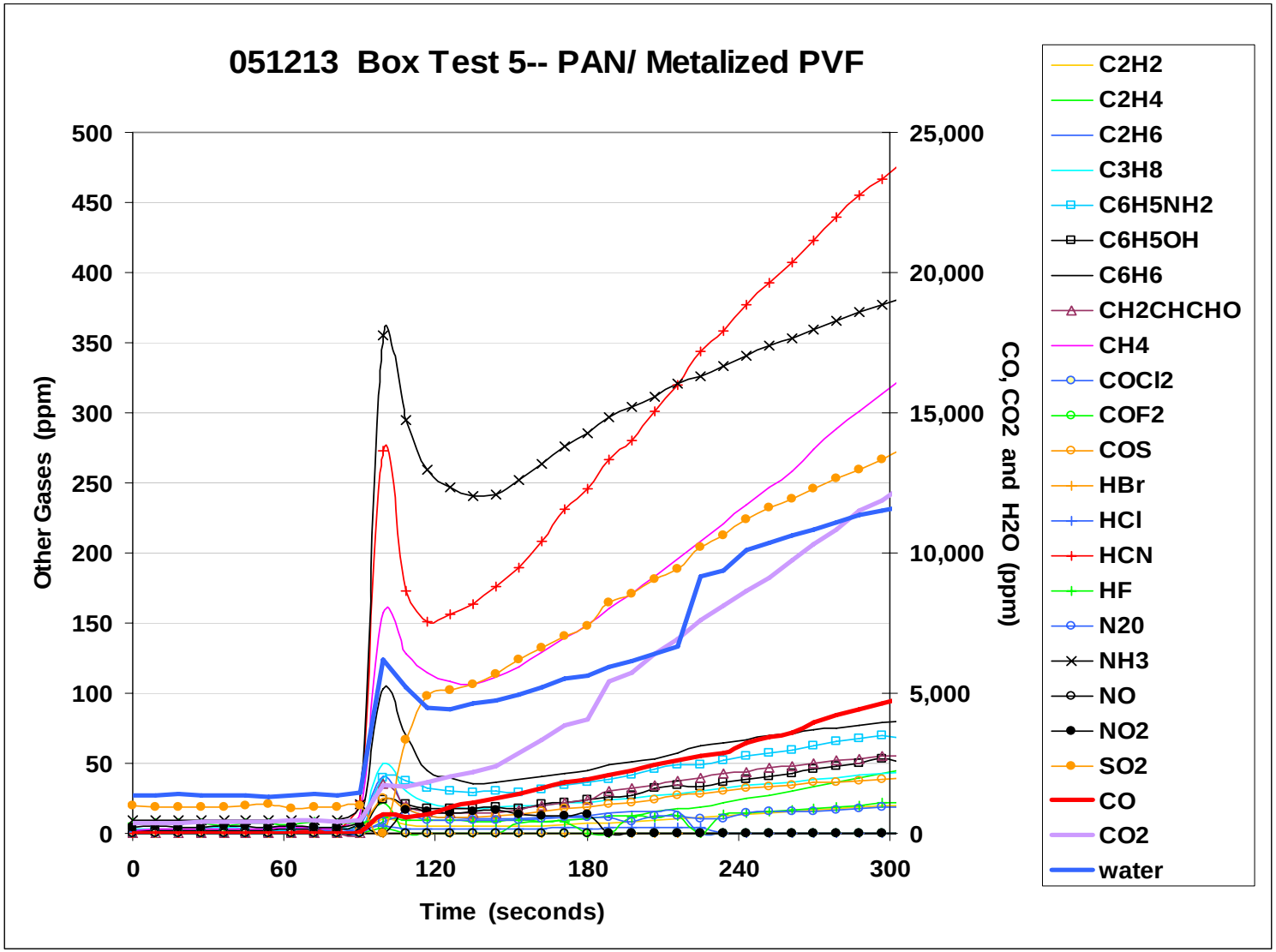
FTIR and THC Sampling System Used in Lab-Scale Testing



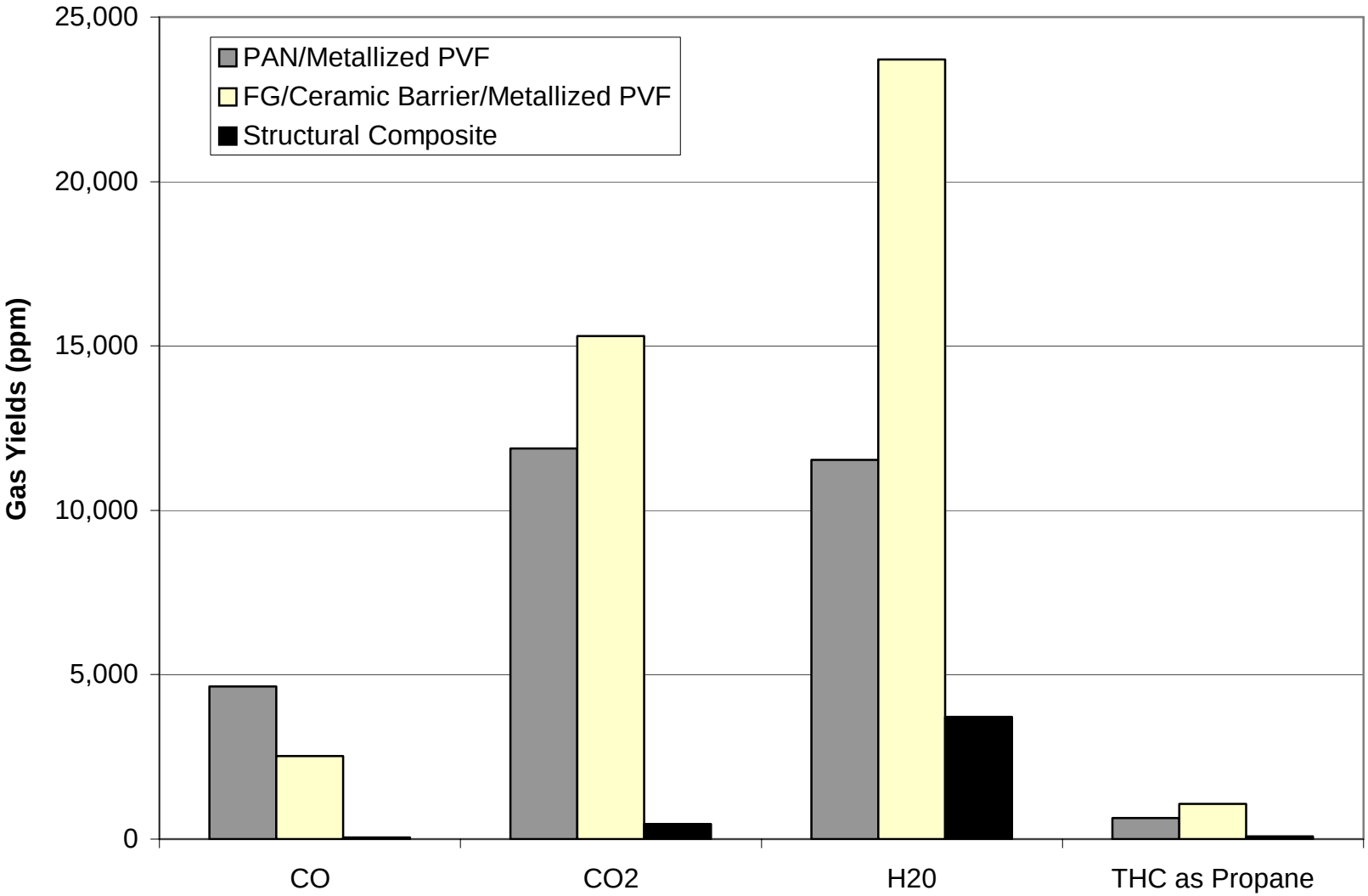
Material Systems Tested in Lab-Scale Apparatus

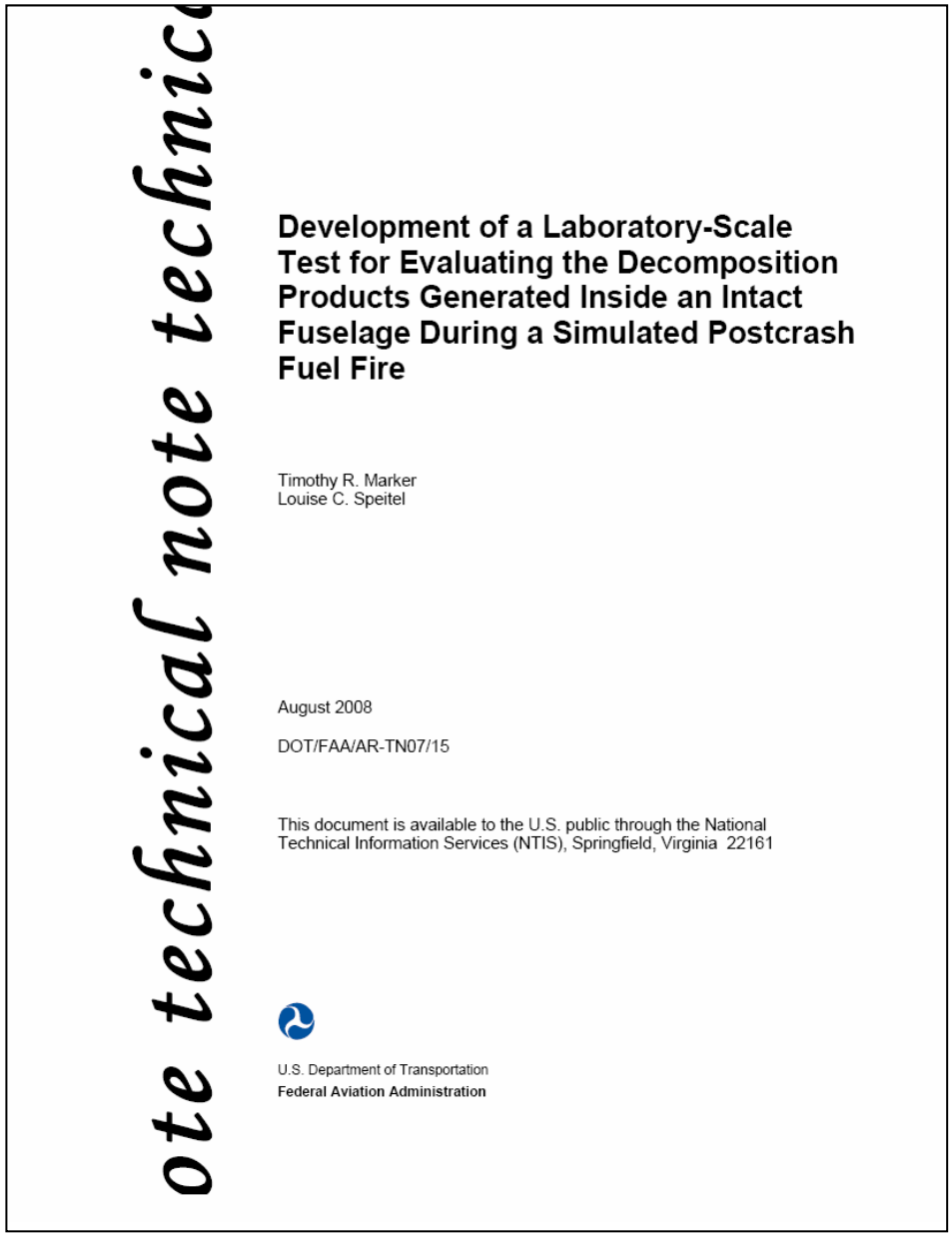


Typical Data Obtained Using FTIR Analysis During Lab-Scale Test



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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August 2008

DOT/FAA/AR-TN07/15

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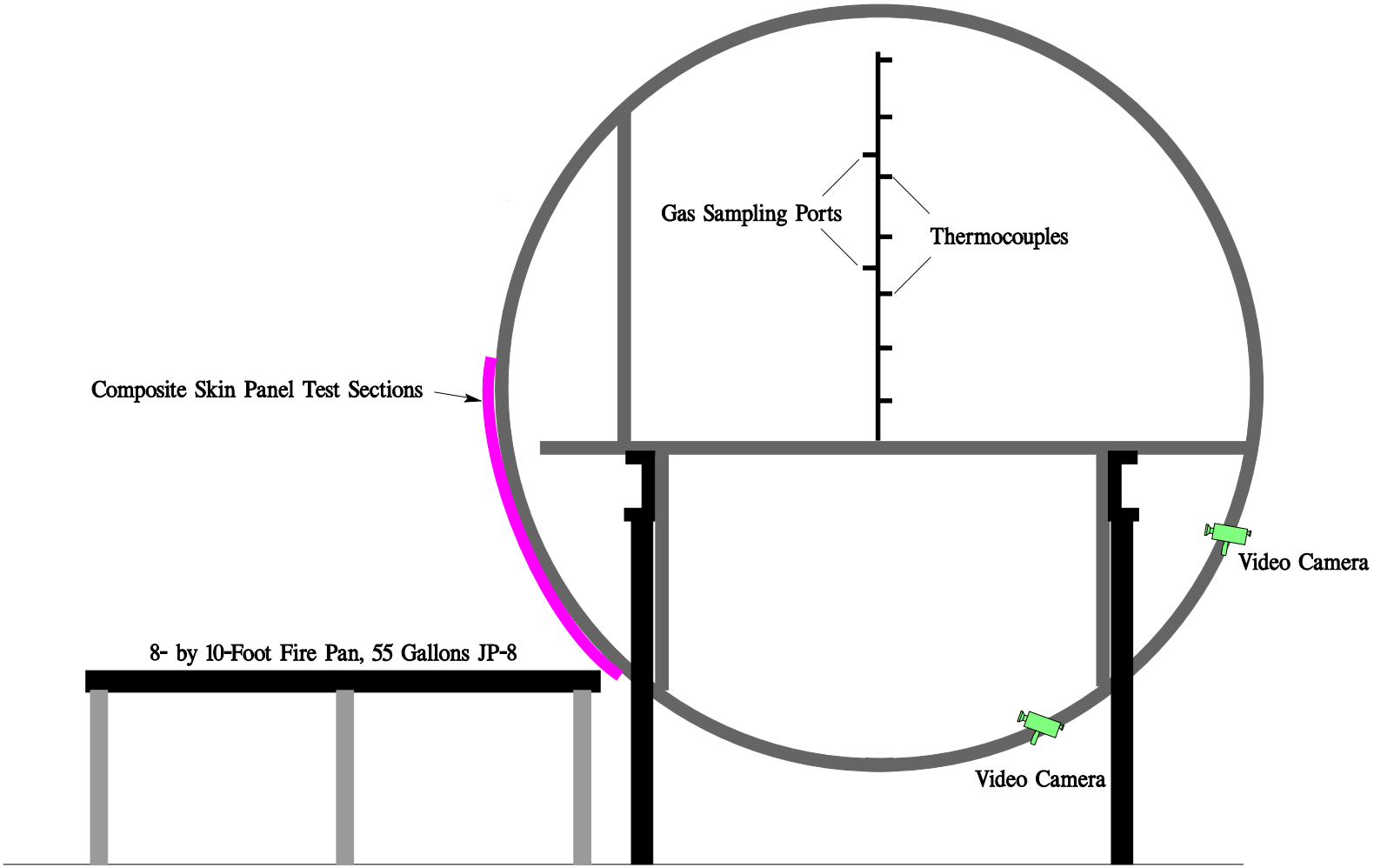
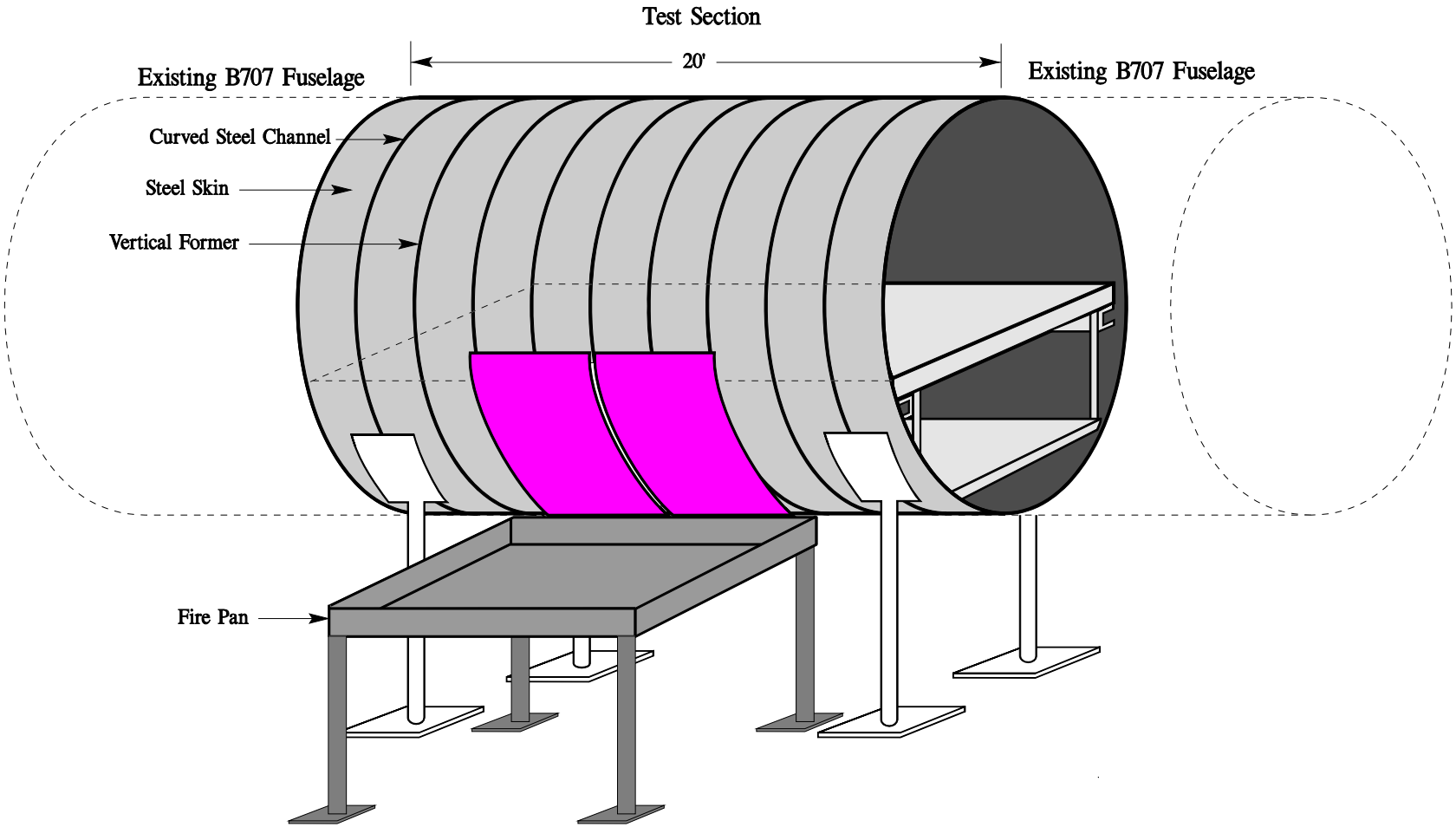
U.S. Department of Transportation
Federal Aviation Administration

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

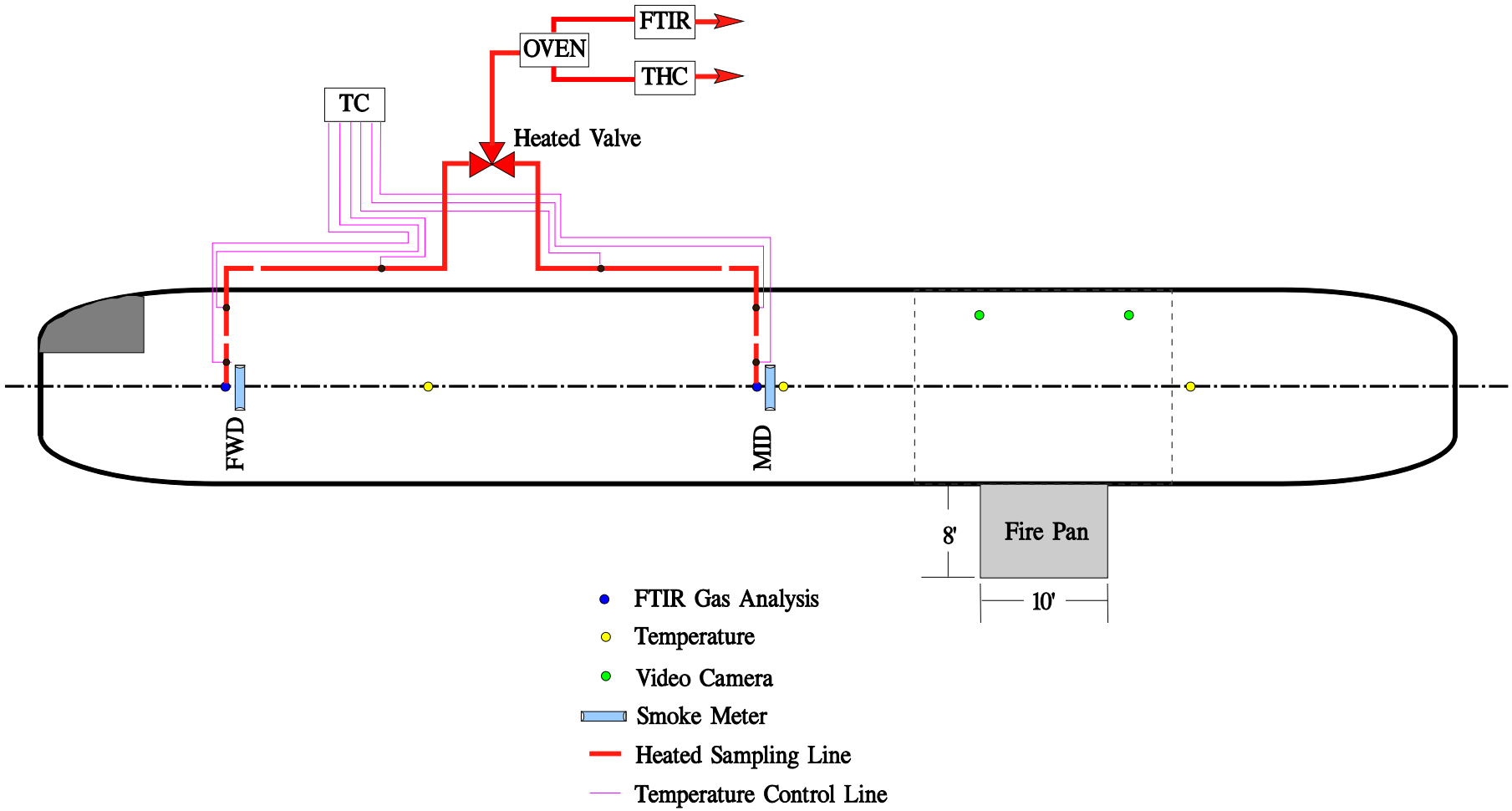


Full-Scale Test Article for Evaluating Decomposition Products of Burnthrough Compliant Insulation Systems and Non-Metallic Fuselage Structure

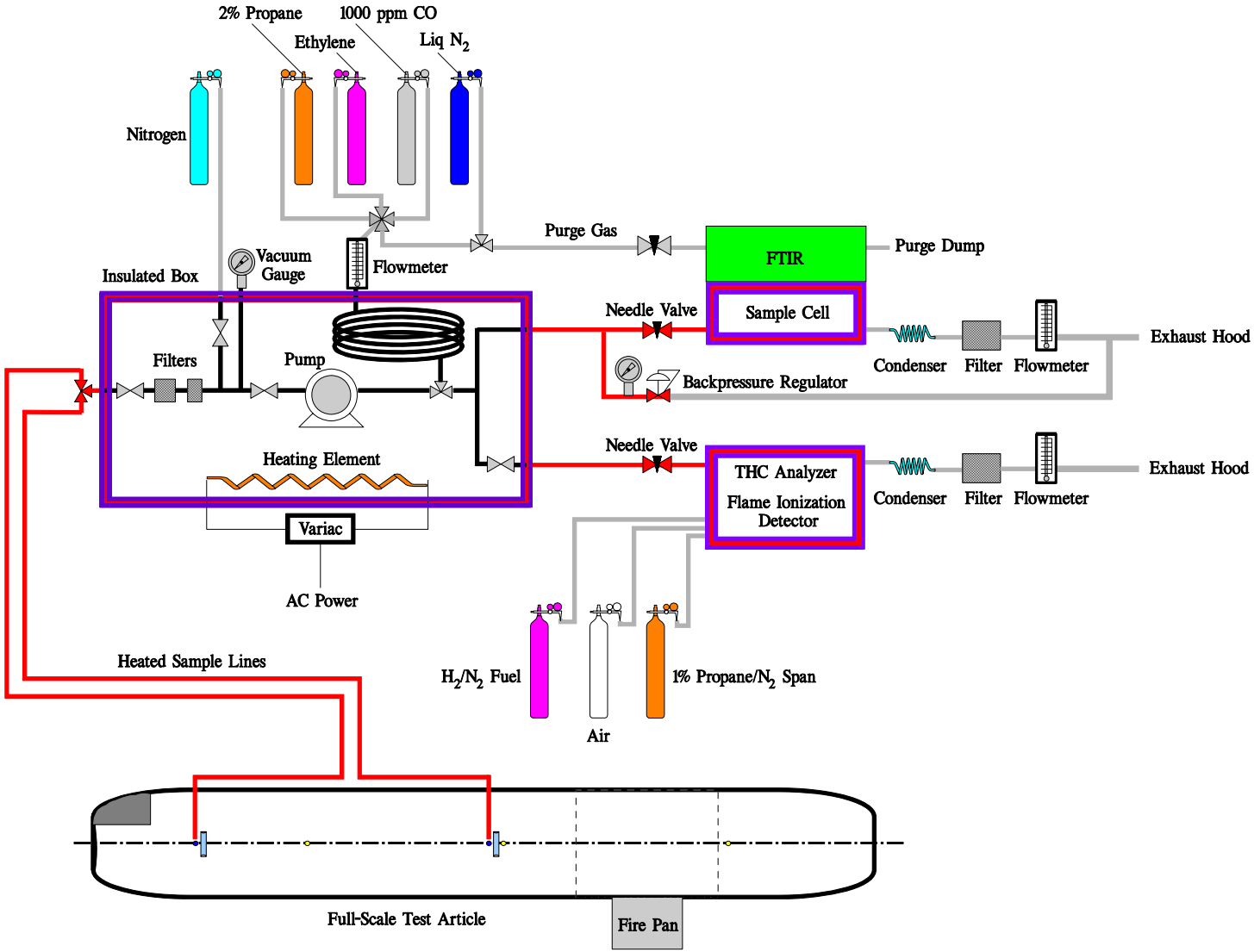


Full-Scale Test Article for Evaluating Decomposition Products of Burnthrough Compliant Insulation Systems and Non-Metallic Fuselage Structure

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



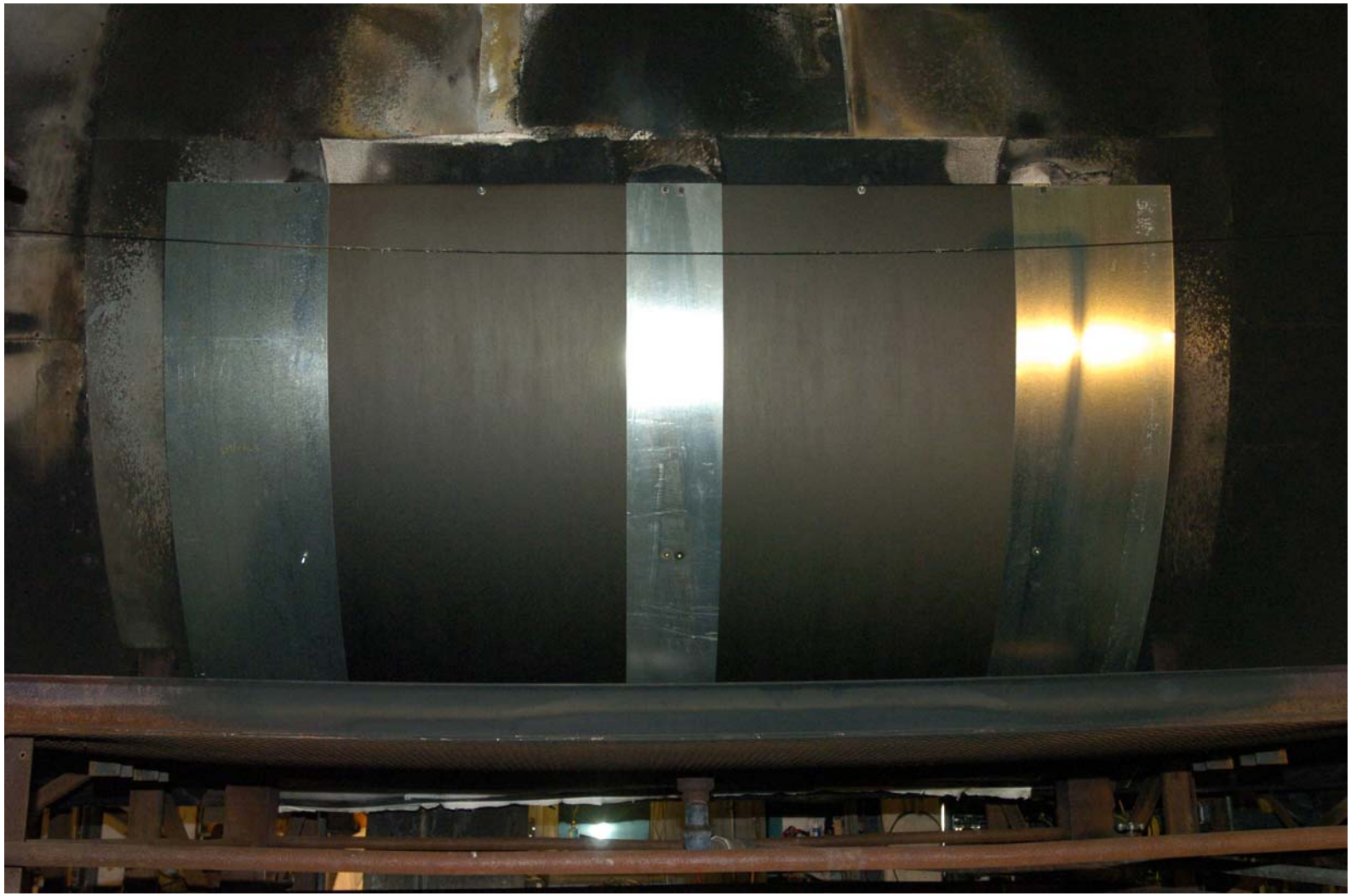
FTIR and THC Sampling System Used in Full-Scale Testing



Full-Scale Test Configuration, Aluminum Skin + Insulation System

Full-Scale Test Configuration, Aluminum Skin + Insulation System

Full-Scale Test Configuration, Structural Composite, no Insulation

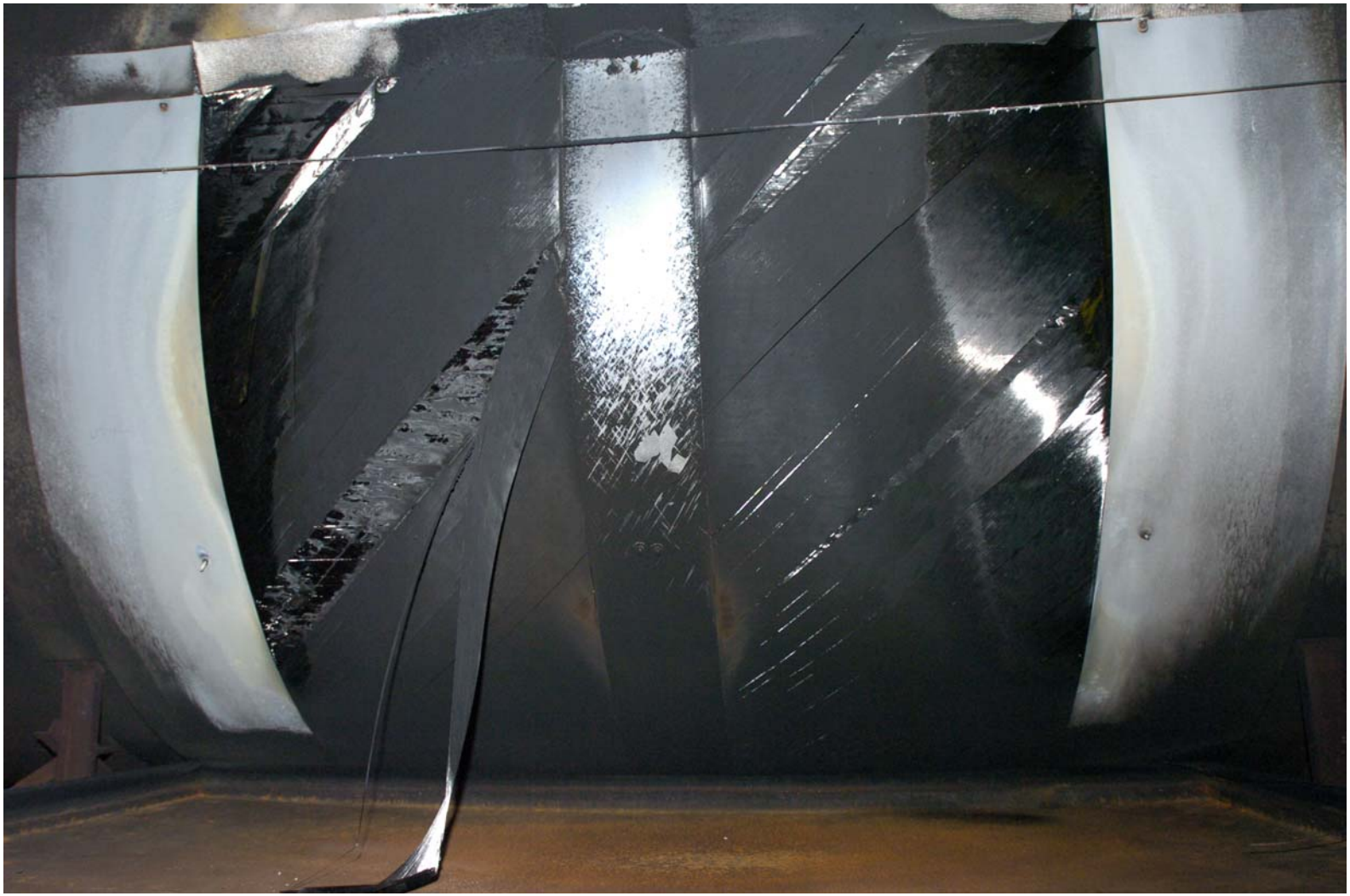


Full-Scale Test Results, Structural Composite System

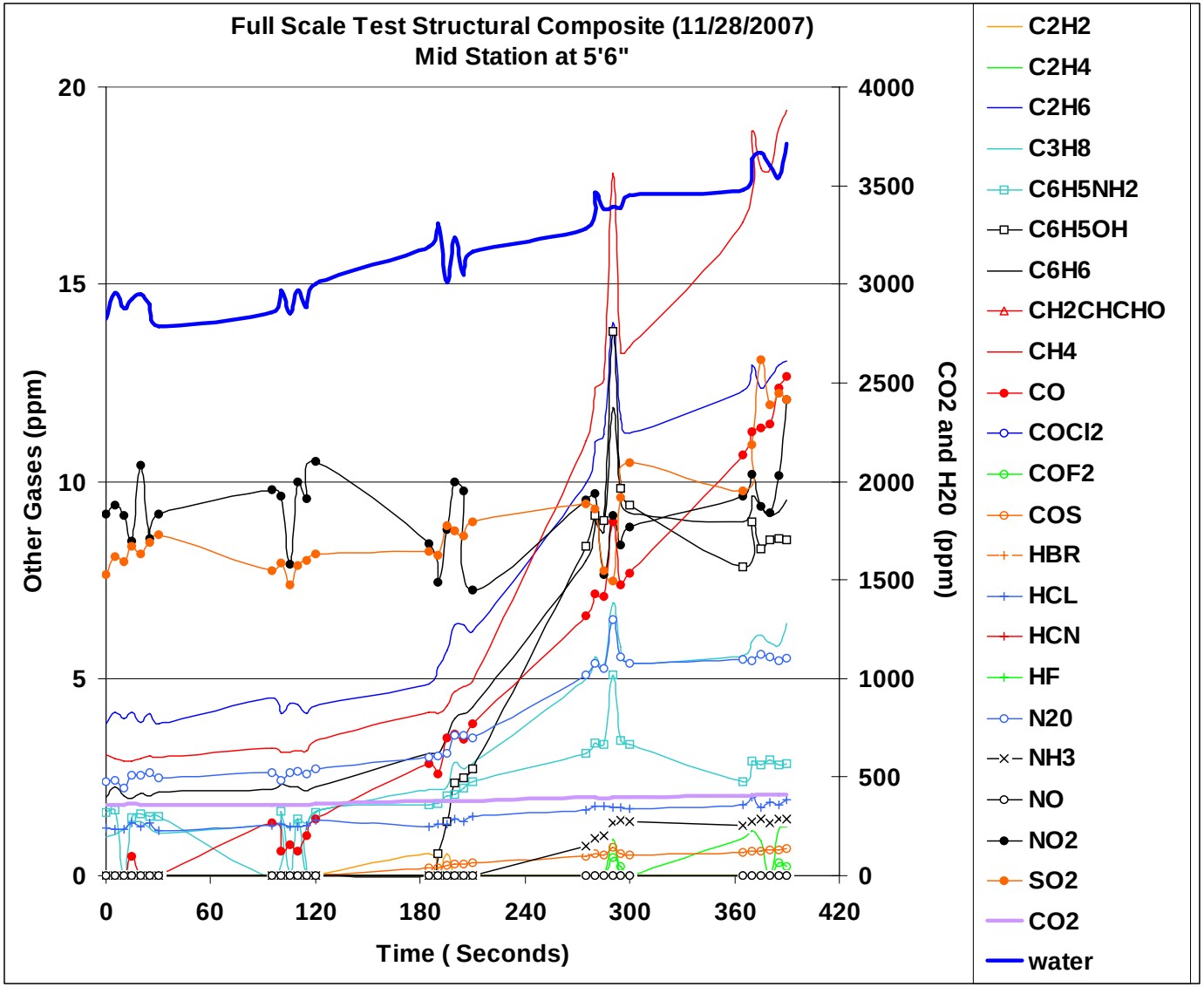
Post-test

Full-Scale Test Results, Structural Composite System

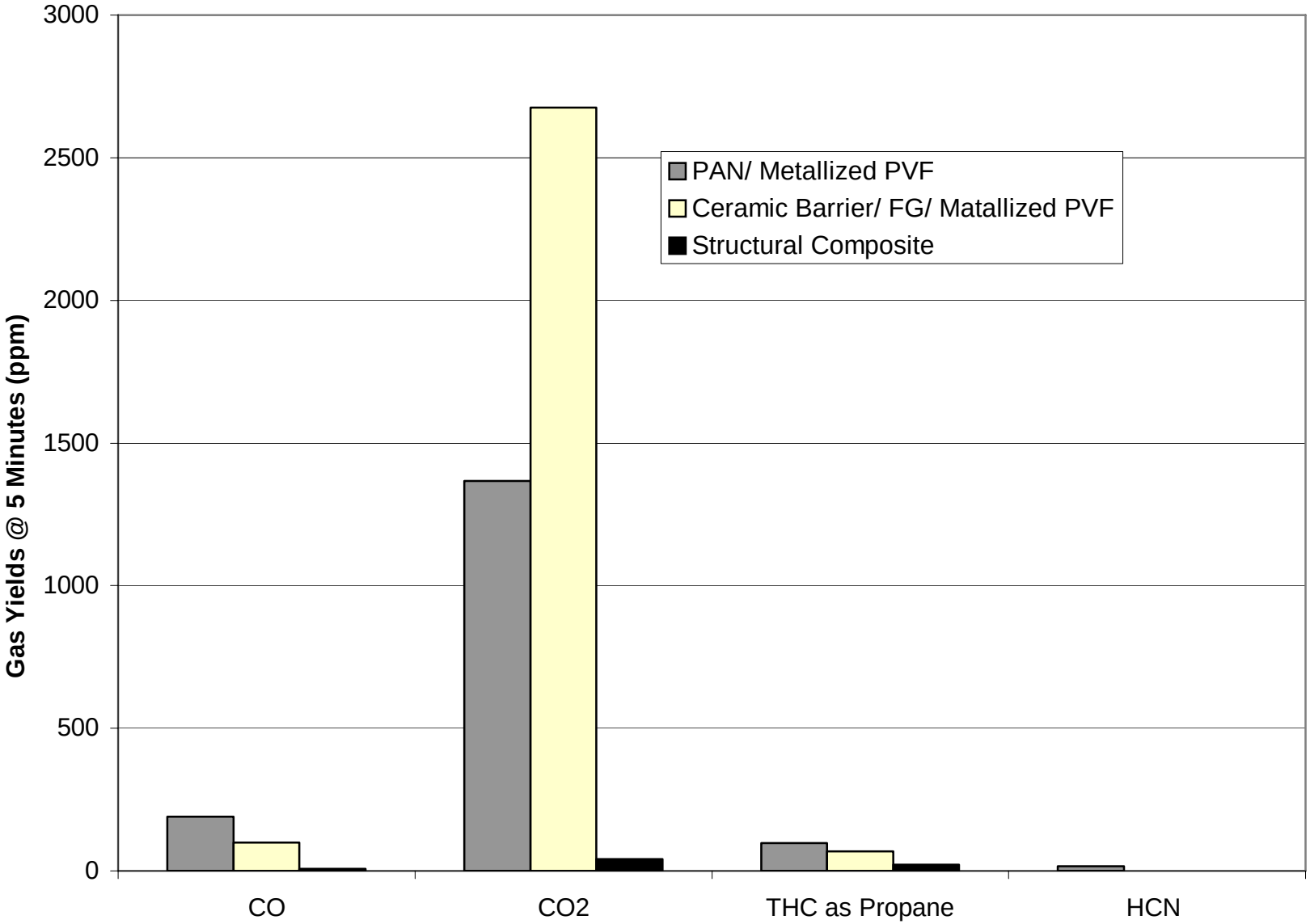
Post-test



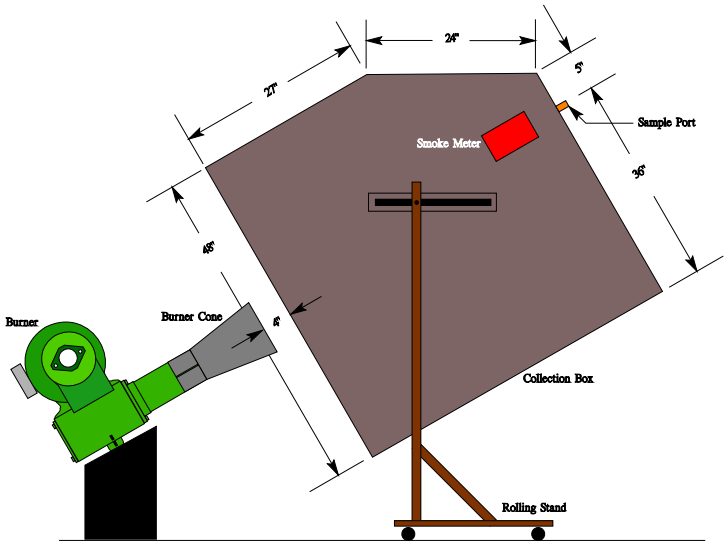
Full-Scale Results, Structural Composite, FTIR

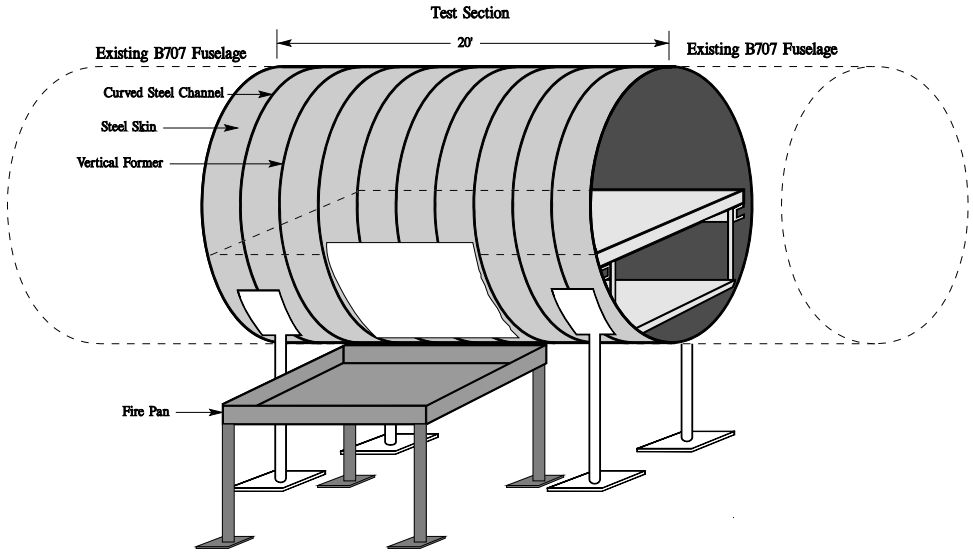


Full-Scale Results, Comparison of 3 Insulation Systems

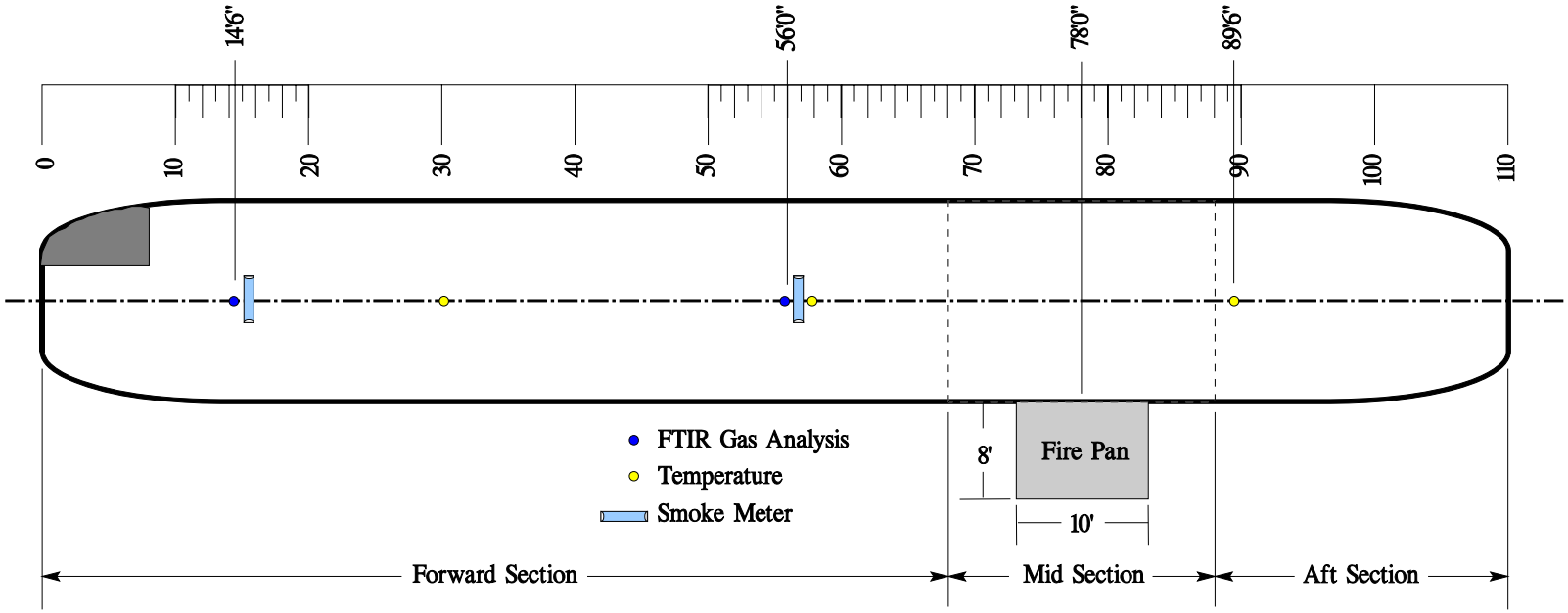


How do the test results compare?





Determination of Full Scale Test Article Volume



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

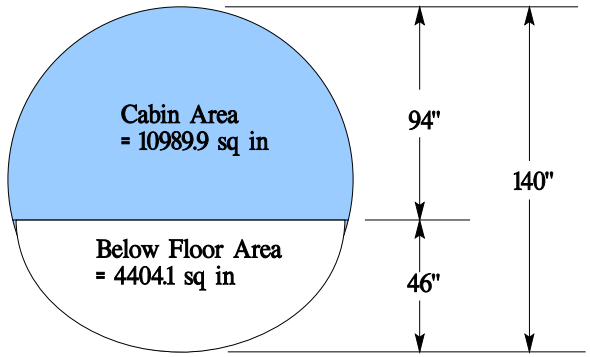
Mid Volume = Total Cabin Area x Mid Length = (17203/144) x 20 = 2389.4 cu ft

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

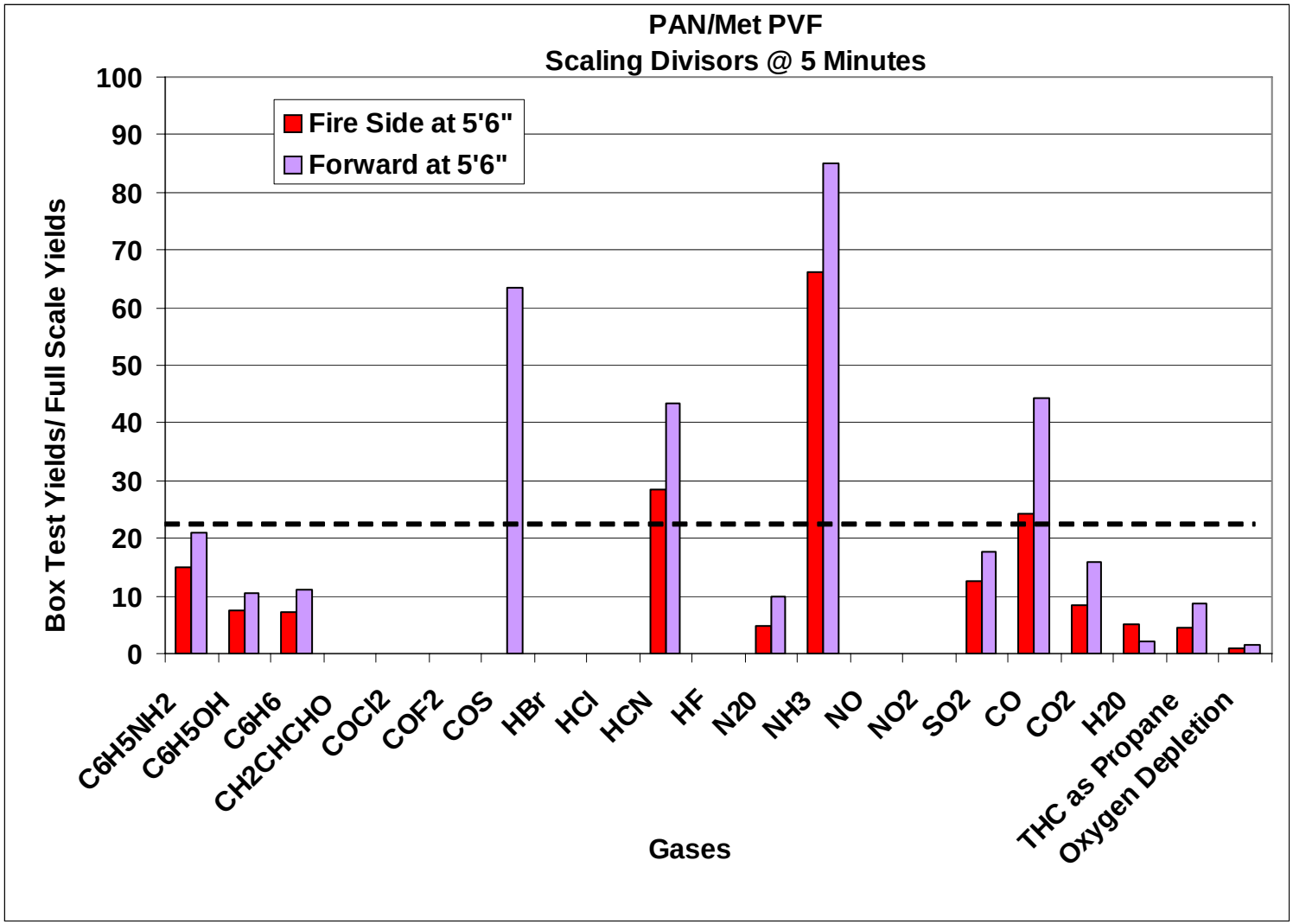
Ratio of $Volume_{FSTest}$ to Burn $Area_{FSTest}$ = 9258.1 ft^3 / 64 ft^2 = 144.7

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

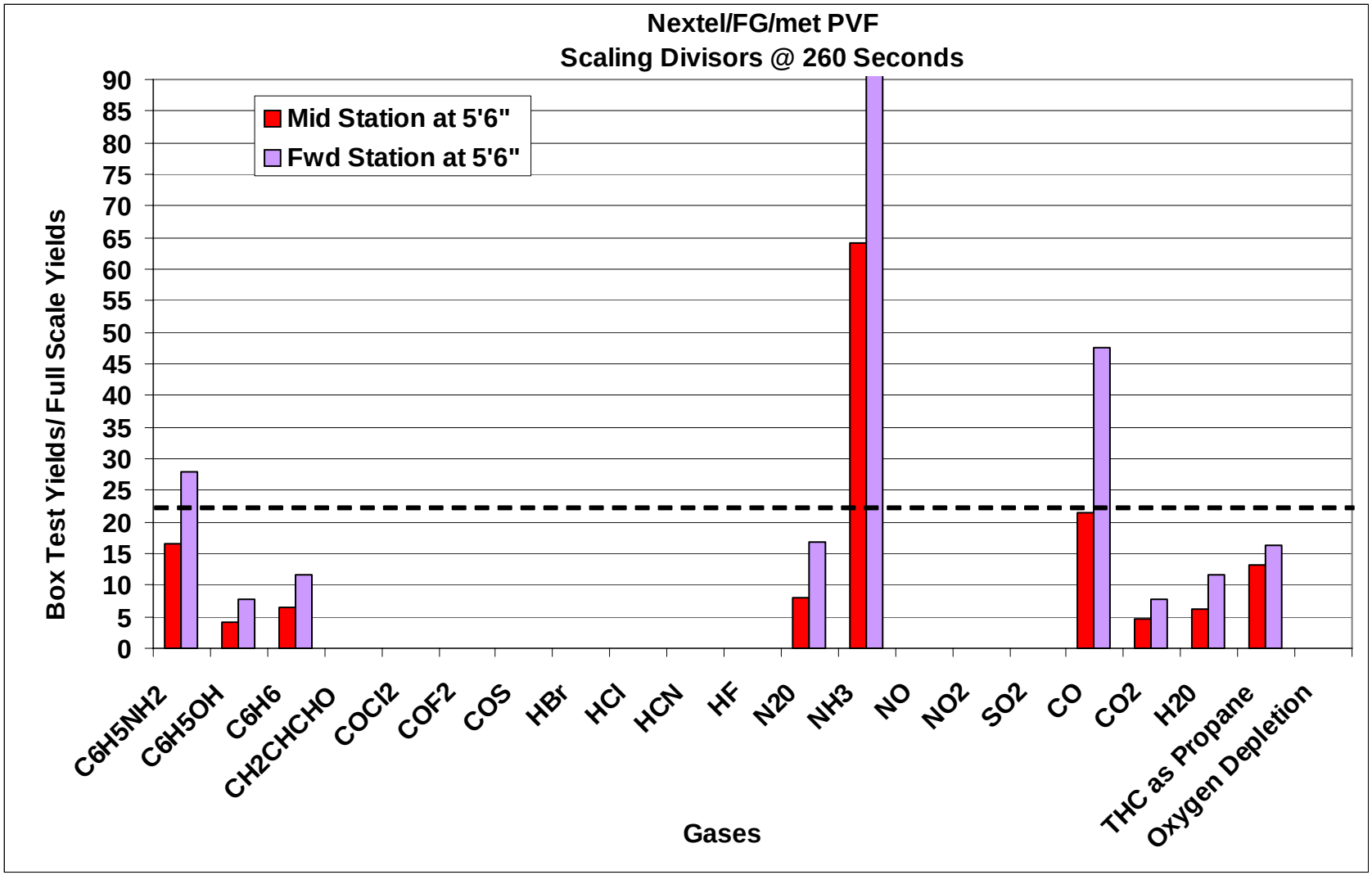
Full-Scale Test Article has 22.2 Times More Volume per Burn Area than Lab Scale Box

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

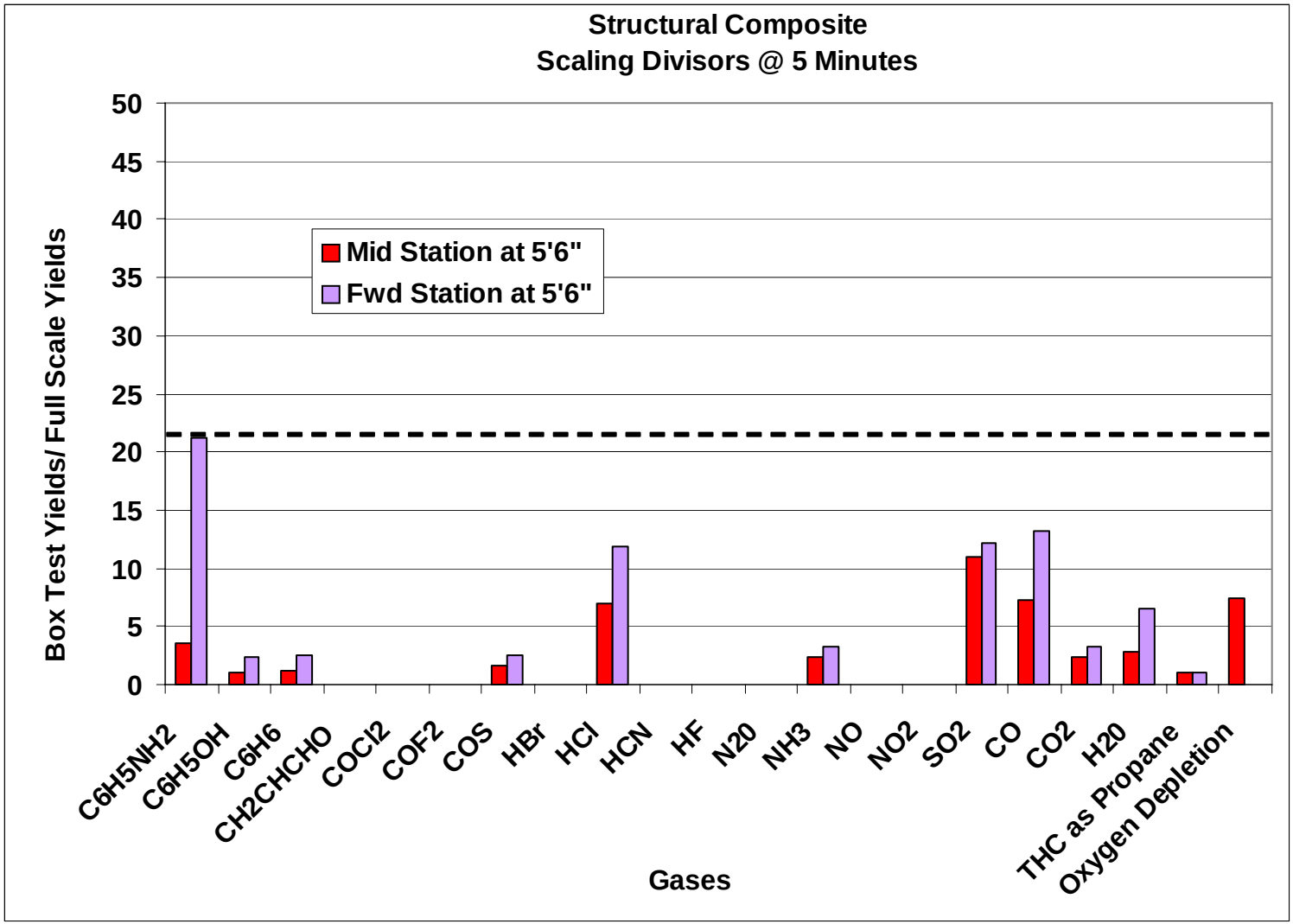
Gas Concentration Scaling, PAN Insulation System



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.

Spreadsheet Data Used to Compare Tests

	Full-Scale Test Data						Allowable Exposure from Various References						Lab-Scale Data			Scaling Factor				
	PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260 Sec)		Structural Composite		5 Minute Exposure				60 Minute Exposure	30 Minute Exposure								
Gas Yields at 5 minutes into test	Mid Station at 5'6"	Fwd Station at 5'6"	Mid Station at 5'6"	Fwd Station at 5'6"	Mid Station at 5'6"	Fwd Station at 5'6"	Incap Conc	LC50	Derived from 60 min ERPG3	Derived from 30 min IDLH	ERPG 3 (2007) [d]	IDLH (1995) [e]	PAN/Met PVF	FG/Ceramic Barrier/Met PVF	Structural Composite	PAN/Met PVF	FG/ Ceramic Barrier/Met PVF (260 Sec)	Structural Composite	Acceptable Lab-Scale Tox Limit= 5 Min Exp Limit x Scaling Factor (ppm)	Acceptable Lab-Scale Tox Limit (ppm)
C6H5NH2	4.63	3.27	5.5	3.27	1.73	0.29	Not Avail			600	?	100	68.73	91.14	6.14	14.8	16.6	3.5	600 x 15.7 (IDLH)	9,420
C6H5OH	7.02	4.59	9.57	5.01	9.4	4	Not Avail		2400	1500	200	250	52.22	38.95	9.78	7.4	4.1	1.0	2400 x 4.2 (ERPG)	10,080
C6H6	10.46	10.41	8.05	4.56	7.21	3.21	Not Avail	Not Avail	12,000	3000	1000	500	76.60	52.5	8.33	7.3	6.5	1.2	12,000 x 5.0 (ERPG)	60,000
CH2CHCHO	0	0	0	0	0	0	10928	7783	18	12	1.5	2	55.50	146.04	0	ND	ND	0.0	7783 x 4 (LC50)	31,132
COCl2	0	0	0	0	0	0	Not Avail	102 [c]	12	12	1	2	0.00	3.9	0	ND	ND	0.0	102 x 4 (LC50)	408
COF2	0	0.21	0	0	0	0	Not Avail	Not Avail	300		25 (est)	?	0.00	0	0.43	0.0	0.0	ND	300 x 4 (ERPG3)	1,200
COS	0	0.61	0	0	0.53	0.34	500* (500 for 15min-brain damage)	(1000 for 15 minutes)	1200 (H2S)		100 (H_2S)	?	38.66	0	0.84	63.4	0.0	1.6	500 x 4	2,000
HBr	0	0	0	0	0	0	16830	15900	1800	180	150 (est)	30	0.00	0	0	ND	0.0	0.0	15900 x 4 (LC50)	63,600
HCl	0	0	0	0	0.49	0.29	16830	15900	1800	300	150	50	0.00	0	3.43	ND	0.0	7.0	15900 x 4 (LC50)	63,600
HCN	16.4	10.75	0	0	0	0	176	560	300	300	25	50	467.00	111.74	0	28.5	ND	0.0	176 x 20 (Incap)	3,520
HCN (peak)	22.7	26.9					176	560	300	300	25	50	467.00	111.74	0	17.4	ND	ND	176 x 20 (Incap)	3,520
HF	0	0	0	0	0	0	7663	7227	600	180	50	30	14.46	19.3	0	ND	ND	0.0	7227 x 4 (LC50)	28,908
N20	3.95	9.94	7.81	3.72	2.99	1	Not Avail	Not Avail			?	?	18.75	62.56	0	1.9	8.0	0.0		No Limit
NH3	5.55	4.32	4.5	1.82	1.36	1	Not Avail	Not Avail	9000	1800	750	300	367.20	289.19	3.3	66.2	64.3	2.4	9000 x 65.3 (ERPG)	587,700
NO [a]	0	0	0	0	0	0	12850	4260	1800	600	150	100	0.00	0	0	ND	0.0	0.0	4260 x 4 (LC50)	17,040
NO2 [a]	2.02	1.19	13.13	6.19	0	0	2570	852	360	120	30	20	0.00	0	0	ND	0.0	0.0	852 x 4	3,408
SO2	19.81	2.06	2.04	1.33	2.82	2.56	Not Avail	2115	180	600	15	100	246.57	0	31.17	12.4	0.0	11.1	2115 x 11.8	24,957
SO2 (peak)	55.4	65.5					Not Avail	2115	180	600	15	100	246.57	0	31.17	3.8	0.0	ND	2115 x 4.5	9,518
CO	190.9	104.8	99.18	44.49	7.7	4.2	6850	16600	6000	7200	500	1200	4645.76	2116.23	55.32	24.3	21.3	7.2	16600 x 17.6 (ERPG3)	292,160
CO2	1367.6	730.3	2674.66	1608	42	30	88000					40000	11506.60	12657	96.7	8.4	4.7	2.3	88,000 x 6.6 [b]	580,800
H2O	1973.9	4885	3160.63	1684	627	276							10164.77	19430	1808.29	2.1	6.1	2.9	No Limit	
THC as Propane	97.9	72.2	68.17	55.21	22	20.8							629.71	903.5	22.0	6.4	13.3	1.0	21,000 x 6.9	144,900
Oxygen Depletion	3500	2100	6470	2920	150	0	136000						3000.00		1120	0.9	0.0	7.5	Remove	

Development of Decomposition Products Limits for Burnthrough Compliant Insulation Systems

Example: HCN

Determine what the acceptable HCN limit should be in the lab-scale apparatus, based on the data obtained in both the lab- and full-scale tests.

Step 1: Determine if the full-scale concentration is less than the allowable 5-minute limits

	Full-Scale Test Data					
	PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260 Sec)		Structural Composite	
Gas Yields at 5 minutes into test	Mid Station at 5'6"	Fwd Station at 5'6"	Mid Station at 5'6"	Fwd Station at 5'6"	Mid Station at 5'6"	Fwd Station at 5'6"
C6H5NH2	4.63	3.27	5.5	3.27	1.73	0.29
C6H5OH	7.02	4.59	9.57	5.01	9.4	4
C6H6	10.46	10.41	8.05	4.56	7.21	3.21
CH2CHCHO	0	0	0	0	0	0
COCl2	0	0	0	0	0	0
COF2	0	0.21	0	0	0	0
COS	0	0.61	0	0	0.53	0.34
HBr	0	0	0	0	0	0
HCl	0	0	0	0	0.49	0.29
HCN	16.4	10.75	0	0	0	0
HCN (peak)	22.7	26.9	0	0	0	0
HF	0	0	0	0	0	0
N20	3.95	9.94	7.81	3.72	2.99	1
NH3	5.55	4.32	4.5	1.82	1.36	1
NO [a]	0	0	0	0	0	0
NO2 [a]	2.02	1.19	13.13	6.19	0	0
SO2	19.81	2.06	2.04	1.33	2.82	2.56
SO2 (peak)	55.4	65.5				
CO	190.9	104.8	99.18	44.49	7.7	4.2
CO2	1367.6	730.3	2674.66	1608	42	30
H2O	1973.9	4885	3160.63	1684	627	276
THC as Propane	97.9	72.2	68.17	55.21	22	20.8
Oxygen Depletion	3500	2100	6470	2920	150	0

Step 1: Determine if the full-scale concentration is less than the allowable 5-minute exposure limits.

is 26.9 less than 176?

Allowable Exposure from Various References					
5 Minute Exposure				60 Minute Exposure	30 Minute Exposure
Incap Conc	LC50	Derived from 60 min ERPG3	Derived from 30 min IDLH	ERPG 3 (2007) [d]	IDLH (1995) [e]
Not Avail			600	?	100
Not Avail		2400	1500	200	250
Not Avail	Not Avail	12,000	3000	1000	500
10928	7783	18	12	1.5	2
Not Avail	102 [c]	12	12	1	2
Not Avail	Not Avail	300		25 (est)	?
500* (500 for 15min-brain damage)	(1000 for 15 minutes)	1200 (H2S)		100 (H_2S)	?
16830	15900	1800	180	150 (est)	30
16830	15900	1800	300	150	50
176	560	300	300	25	50
176	560	300	300	25	50
7663	7227	600	180	50	30
Not Avail	Not Avail			?	?
Not Avail	Not Avail	9000	1800	750	300
12850	4260	1800	600	150	100
2570	852	360	120	30	20
Not Avail	2115	180	600	15	100
Not Avail	2115	180	600	15	100
6850	16600	6000	7200	500	1200
88000					40000
136000					

If yes, proceed to step 2

If no, toxicity levels exceed allowable limits for this material.

Step 2: Divide the lab-scale concentration by the full-scale concentration to obtain a scaling factor for each of the three material systems tested.

Lab-Scale Data			Full-Scale Test Data						Scaling Factor		
			PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260 Sec)		Structural Composite				
PAN/Met PVF	FG/Ceramic Barrier/Met PVF	Structural Composite	Mid Station at 5'6"	Fwd Station at 5'6"	Mid Station at 5'6"	Fwd Station at 5'6"	Mid Station at 5'6"	Fwd Station at 5'6"	PAN/Met PVF	FG/ Ceramic Barrier/Met PVF (260 Sec)	Structural Composite
68.73	91.14	6.14	4.63	3.27	5.5	3.27	1.73	0.29	14.8	16.6	3.5
52.22	38.95	9.78	7.02	4.59	9.57	5.01	9.4	4	7.4	4.1	1.0
76.60	52.5	8.33	10.46	10.41	8.05	4.56	7.21	3.21	7.3	6.5	1.2
55.50	146.04	0	0	0	0	0	0	0	ND	ND	0.0
0.00	3.9	0	0	0	0	0	0	0	ND	ND	0.0
0.00	0	0.43	0	0.21	0	0	0	0	0.0	0.0	ND
38.66	0	0.84	0	0.61	0	0	0.53	0.34	63.4	0.0	1.6
0.00	0	0	0	0	0	0	0	0	ND	0.0	0.0
0.00	0	3.43	0	0	0	0	0.49	0.29	ND	0.0	7.0
467.00	111.74	0	16.4	10.75	0	0	0	0	28.5	ND	0.0
467.00	111.74	0	22.7	26.9	0	0	0	0	17.4	ND	ND
14.46	19.3	0	0	0	0	0	0	0	ND	ND	0.0
18.75	62.56	0	3.95	9.94	7.81	3.72	2.99	1	1.9	8.0	0.0
367.20	289.19	3.3	5.55	4.32	4.5	1.82	1.36	1	66.2	64.3	2.4
0.00	0	0	0	0	0	0	0	0	ND	0.0	0.0
0.00	0	0	2.02	1.19	13.13	6.19	0	0	ND	0.0	0.0
246.57	0	31.17	19.81	2.06	2.04	1.33	2.82	2.56	12.4	0.0	11.1
246.57	0	31.17	55.4	65.5					3.8	0.0	ND
4645.76	2116.23	55.32	190.9	104.8	99.18	44.49	7.7	4.2	24.3	21.3	7.2
11506.60	12657	96.7	1367.6	730.3	2674.66	1608	42	30	8.4	4.7	2.3
10164.77	19430	1808.29	1973.9	4885	3160.63	1684	627	276	2.1	6.1	2.9
629.71	903.5	22.0	97.9	72.2	68.17	55.21	22	20.8	6.4	13.3	1.0
3000.00		1120	3500	2100	6470	2920	150	0	0.9	0.0	7.5

Step 3: Determine the average scaling factor for each gas measured. Do not average zero values.

Scaling Factor		
PAN/Met PVF	FG/ Ceramic Barrier/Met PVF (260 Sec)	Structural Composite
14.8	16.6	3.5
7.4	4.1	1.0
7.3	6.5	1.2
ND	ND	0.0
ND	ND	0.0
0.0	0.0	ND
63.4	0.0	1.6
ND	0.0	0.0
ND	0.0	7.0
28.5	ND	0.0
17.4	ND	ND
ND	ND	0.0
1.9	8.0	0.0
66.2	64.3	2.4
ND	0.0	0.0
ND	0.0	0.0
12.4	0.0	11.1
3.8	0.0	ND
24.3	21.3	7.2
8.4	4.7	2.3
2.1	6.1	2.9
6.4	13.3	1.0
0.9	0.0	7.5

Step 4: Multiply the 5-minute allowable exposure limit by the average scaling factor (times a safety factor?) for each gas. This will yield an acceptable limit In the lab-scale apparatus.

Acceptable Lab-Scale Tox Limit= 5 Min Exp Limit x Scaling Factor (ppm)	Acceptable Lab-Scale Tox Limit (ppm)
600 x 15.7 (IDLH)	9,420
2400 x 4.2 (ERPG)	10,080
12,000 x 5.0 (ERPG)	60,000
7783 x 4 (LC50)	31,132
102 x 4 (LC50)	408
300 x 4 (ERPG3)	1,200
500 x 4	2,000
15900 x 4 (LC50)	63,600
15900 x 4 (LC50)	63,600
176 x 20 (Incap)	3,520
176 x 20 (Incap)	3,520
7227 x 4 (LC50)	28,908
	No Limit
9000 x 65.3 (ERPG)	587,700
4260 x 4 (LC50)	17,040
852 x 4	3,408
2115 x 11.8	24,957
2115 x 4.5	9,518
16600 x 17.6 (ERPG3)	292,160
88,000 x 6.6 [b]	580,800
No Limit	
21,000 x 6.9	144,900
Remove	

Development of Decomposition Products Limits for Burnthrough Compliant Insulation Systems

Note on exposure limits: use incapacitation concentration for calculations when available.

If no incapacitation data exists, use LC50 data

If no LC50 data exists, use ERPG3 (5 min) data

If no ERPG3 (5 min) data exists, use IDLH (5 min) data

If incapacitation data and LC50 data available, use lower of two values

Development of Decomposition Products Limits for Burnthrough Compliant Insulation Systems

The ERPG-3 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

ERPGs are published by The American Industrial Hygiene Association
http://www.aiha.org/Content/InsideAIHA/Volunteer%2BGroups/ERPcomm.htm

The purpose for establishing this IDLH (Immediately Dangerous to Life and Health, NIOSH) was to determine a concentration from which a worker could escape without injury or without irreversible health effects in the event of respiratory protection equipment failure (e.g., contaminant breakthrough).