Development of Decomposition Product Limits for Lab-Scale Tests of Burnthrough Compliant Insulation Systems

Louise C. Speitel

FAA, WJH Technical Center, Atlantic City, NJ USA

Materials Meeting, Niagara Falls, NY

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Outline

- Purpose
- Toxicity Measures for 5 minute Exposures
- Toxicity References
- Other Hazard Measurements
  - Lower Explosive Limit as Propane
  - Temperature
- Allowable 5 Minute Box Toxicity Limits
  - Evaluate Full-Scale Toxicity of Material Systems
  - Determine Gases to Measure
  - Obtain Scaling factor to convert Full Scale Tox Limit to Lab Scale Tox Limits
- Setting Lab Scale Gas Concentration Limits.
  - Determine Mutiplication factor for Box Test Yields
  - Determine Maximum Allowable Concentration Guidance for Selected Gases

Purpose

For insulation constructions and innovations meeting the new burnthrough test requirements:

To ensure survivability (*including ability to escape*) inside an intact fuselage when exposed to an external fuel fire.

Toxicity Measures for 5 Minute Exposures

Incapacitation

Incapacitation is the best measure of the ability to escape and survive exposure to the narcotic gases such as carbon monoxide (CO), carbon dioxide (CO2), hydrogen cyanide (HCN), and low oxygen. The incapacitation concentration is less than the LC50 for these gases. If a passenger were incapacitated, one can assume that subsequent death would occur by rapidly spreading fire or toxic gases. The FEDIs for each hazard are added to give the total FEDI as a function of time.

Lethality LC50s

An LC50 is the concentration for a given exposure duration which results in death or subsequent death of 50 percent of the animals. Exposure to high concentrations of these gases may not prevent escape but may result in subsequent death due to respiratory system damage. The LC50s are less than the incapacitation concentrations for these gases. Lethal concentration 50 percent is the concentration in which 50 percent of an exposed population is expected to die LC50s are the best measure of the ability to escape and survive for the irritant gases such as hydrogen fluoride (HF), hydrogen chloride (HCl), hydrogen bromide (HBr), nitrogen dioxide (NO2) and sulfur dioxide

Toxicity Measures for 5 Minute Exposures

FAA Combined Hazard Model

The FAA's Combined Hazard Survival Model was created using selected regression equations, obtained from animal modeling data, to be used as a predictive tool to gauge human survivability in full-scale aircraft cabin fire tests. This model uses incapacitation data to obtain fractional effective dose histories for incapacitation (FED_I) and lethality data to obtain fractional effective dose histories for lethality (FED_L). **The time when either FED reaches 1 determines the exposure time available to escape from an aircraft cabin fire and survive postexposure**

VCO2, The enhanced uptake of other gases due to the presence of CO2

The effect of CO2 on increasing the uptake of other gases should be factored into the concentration term in the FED equation for all gases with the exception of CO2 and oxygen. Higher respiratory minute volumes due to CO2 exposure has been found to be an important factor in predicting the time to incapacitation or death.

Toxicity Measures for 5 Minute Exposures

Emergency Response Planning Guidelines- Level 3 (ERPG 3)

Maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing life threatening health effects (Based on 1 hour exposures)

Immediately Dangerous to Life and Health (IDLH)

Maximum concentration from which a worker could escape without injury or without irreversible health effects in the event of respiratory equipment failure (e.g. contaminant breakthrough)

- *Based on 30 minute exposures*
- *IDLH is conservative: assumes repeated occupational exposure*

Toxicity References

Speitel Louise C. (1995) Toxicity assessment of combustion gases and development of a survival model, US Department of Transportation, Federal Aviation Administration, Washington D.C. Report DOT/FAA/AR-95/5.

Speitel, Louise C. (1996) Fractional effective dose model for post-crash aircraft survivability" Toxicology 115, 167-177.

Documentation of Threshold Limits and Biological Exposure Indices, Sixth Edition, Volumes 2 and 3 , 1993, American Conference of Government Industrial Hygienists.

http://www.aiha.org/Content/InsideAIHA/Volunteer%2BGroups/ERPcomm.htm American Industrial Hygiene Association Web Site for Emergency Response Planning Guidelines ERPGs

http://www.cdc.gov/niosh/idlh/idlh-1.html
National Institute for Occupational Safety and Health (NIOSH) web site containing documentation for Immediately Dangerous to Life and Health (IDLH) concentrations

Other Hazards

Lower Explosive Limit as Propane: LEL as Propane: 2.1% Propane

Heat: Measure Temperature and convert to FED_{Heat}

Development of Lab-Scale Decomposition Product Limits

- Evaluate the thermal decomposition products of existing burnthrough compliant insulation and structural systems in full-scale B-707 and box burnthrough tests.

- Assess the toxicity of the 3 material systems

  - Determine the maximum full-scale and box test yields for each gas for the three material systems tested.

  - Select appropriate toxic gas limit for each gas. Obtain toxic gas limit for lab-scale using the gas scaling factors.

  - Determine FEDs for each gas. Base FED on 5 minute observed concentration. Assume 5 minute exposure duration at that concentration.

  - FEDs should agree for full scale and lab scale.

  - Determine if the total FEDs are acceptable

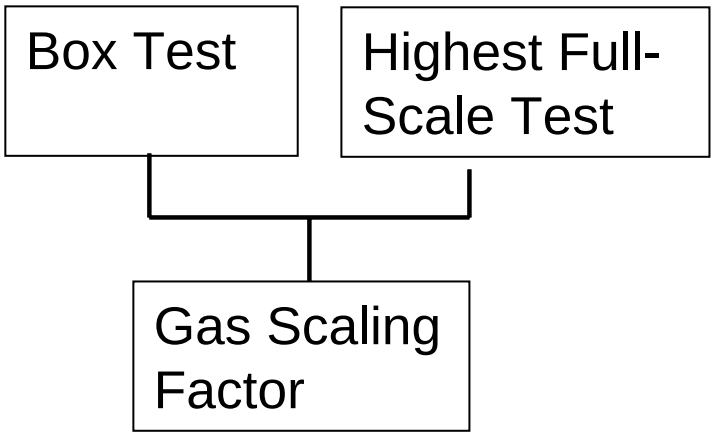
  - Select which gases should be measured for future lab tests

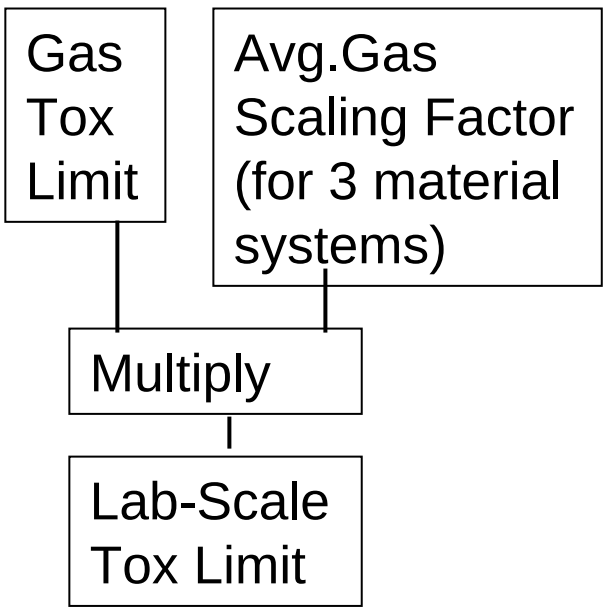
- Set pass criteria for small-scale tests

Determine Toxicity of Lab-Scale Decomposition Products

Gas Conc. at 5 minutes

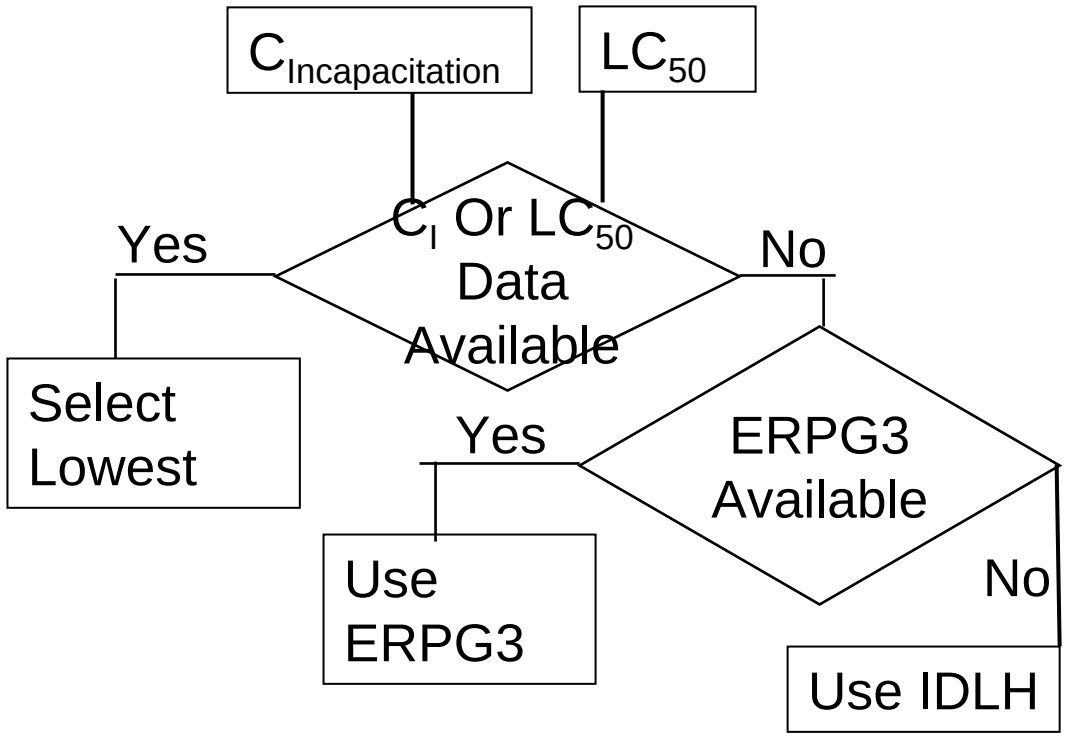
(for particular gas)





Tox Limit Selection:

(for 5 min exposure)



Determine Toxicity of Lab-Scale Decomposition Products

Gas	Full-Scale Gas Yields at 5 minutes into test (ppm)						Allowable Exposure from Various References						FED Effect *Full Scale*	Lab-Scale Gas Yields at 5 min (ppm)			Lab-Scale Tox Limit= 5 Min Exp Limit x Scaling Factor (ppm)	Lab-Scale Tox Limit (ppm)	FED Effect *Lab Scale Using Scaling Factor*	Gas	Scaling Factor Mid Station at 5'6"			Gases to Measure FED > 0.02	Max Allowed Conc. (ppm) = Max Box Test Conc x 1.4
	PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260 Sec)		Structural Composite		5 Minute Exposure				60 Minute Exposure	30 Minute Exposure													
	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)	IDLH (1995)		PAN/Met PVF	FG/Ceramic Barrier/Met PVF	Structural Composite					PAN/Met PVF	FG/Ceramic Barrier/Met PVF (260 Sec)	Structural Composite		
C6H5NH2	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		
C6H5OH	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		4.1	1.0		
C6H6	**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		
CH2CHCHO	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		
COCl2	0	0	0	0	0	0	?	**102** c	12	12	1	2	**0.000**	0.00	**3.9**	0	102 x 4 (LC50)	408	**0.010**	COCl2	ND	#DIV/0!	ND		
COF2	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!		
COS	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 20	10,000	**0.004**	COS	>40	ND	1.6		
HBr	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		
HCl	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		
HCN	**16.4**	10.75	0	0	0	0	**176**	560	300	300	25	50	**0.093**	**467.00**	111.74	0	176 x 28.5 (Incap)	5,016	**0.093**	HCN	28.5	#DIV/0!	ND		
HCN (peak)	22.7	**26.9**					**176**	560	300	300	25	50	**0.153**	**467.00**	111.74	0	176 x 17.4 (Incap)	2,992	**0.156**	HCN	17.4			**Yes**	**654**
HF	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		
N20	3.95	**9.94**	7.81	3.72	2.99	1	?	?			?	?		18.75	**62.56**	0		No Limit		N20	4.7	8.0	ND		
NH3	**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		
NO	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		
NO2	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		
SO2	**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		
SO2 (peak)	55.4	**65.5**					?	**2115**	180	600	15	100	**0.031**	**246.57**	0	31.17	2115 x 3.8	8,037	**0.031**	SO2	3.8			**Yes**	**345**
CO	**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	6850 x 22.8 (ERPG3)	156,180	**0.030**	CO	24.3	21.3	7.2	**Yes**	**6,504**
CO2	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		**17,720**
H2O	1973.9	**4885**	3160.63	1684	627	276								10164.77	**19430**	1808.29	No Limit		**N/A**	H2O	5.1	6.1	2.9		**27,202**
THC as Propane	**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		
Oxygen Depletion	3500	2100	**6470**	2920	150	0	**136000**							3000.00		1120	Remove			Oxygen Depletion	0.9		7.5		

					FED						**FED**	
					Total =	**0.238**	0.24	0.08	0.01		**Total =**	**0.252**
					x 1.4 =	**0.333**	0.33	0.11	0.00941		**x 1.4 =**	**0.353**

a. NO is 1/5 as potent as NO2: See Documentation of TLV and BEI indicies, Sixth Edition, Vol 2, American Conference of Governmental Industrial Hygienists, Inc, 1993.

b. See Documentation of The Threshold Limits and Biological Exposure Indices, Sixth Edition Vol 2 , pp. 1245-1247

c. extrapolated from 1 min LC50= approx 500ppm COCl2

FED CO, HCN, SO2 = 0.242 x 1.4= 0.339 90%

Measure CO, CO2, HCN, SO2, Water

FED CO, HCN, SO2= 0.238 x 1.4= 0.334 87%

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.
The ERPG-2 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 irreversible or other serious health effects or symptoms that could impair their abilit
The ERPG-1 is the maximum airborne concentration below which it is believed nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined objectionable odour.
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 (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

CO2 (%)	VCO2
1	1.27
1.5	1.44
2	1.63
2.5	1.85
3	2.10
3.5	2.38
4	2.69
4.5	3.05
5	3.45

21,000 ppm = LEL propane

IDLH occupational - most conservative- repeated occupational exposures

ERPG release into the environment

Gas	Full-Scale Yields at 5 min (ppm)						Allowable Exposure References (ppm)						FED Effect
	PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260		Structural Composite		5 Minute Exposure				60 Min Exposure	30 Min Exposure	
	Mid at 5'6"	Fwd at 5'6"	Mid at 5'6"	Fwd at 5'6"	Mid at 5'6"	Fwd at 5'6"	Incap Conc	LC50	From 60 min ERPG3	From 30 min IDLH	ERPG 3 (2007)	IDLH (1995)	*Full Scale*
C6H5NH2	4.63	3.27	**5.5**	3.27	1.73	0.29	Avail			**600**	?	100	**0.009**
C6H5OH	7.02	4.59	**9.57**	5.01	9.4	4	Avail		**2400**	1500	200	250	**0.004**
C6H6	**10.5**	10.4	8.05	4.56	7.21	3.21	?	?	**12,000**	3000	1000	500	**0.001**
CH2CHCHO	0	0	0	0	0	0	10928	**7783**	18	12	1.5	2	**0.000**
COCl2	0	0	0	0	0	0	?	**102** c	12	12	1	2	**0.000**
COF2	0	**0.21**	0	0	0	0	?	?	**300**		25 (est)	?	**0.001**
COS	0	**0.61**	0	0	0.53	0.34	**500*** (500 for 15min-	(1000 for 15 minutes)	1200 (H2S)		100 (H2S)	?	**0.001**
HBr	0	0	0	0	0	0	16830	**15900**	1800	180	150 (est)	30	**0.000**
HCl	0	0	0	0	**0.49**	0.29	16830	**15900**	1800	300	150	50	**0.000**
HCN	**16.4**	10.8	0	0	0	0	**176**	560	300	300	25	50	**0.093**
HCN (peak)	22.7	**26.9**					**176**	560	300	300	25	50	**0.153**
HF	0	0	0	0	0	0	7663	**7227**	600	180	50	30	**0.000**
N20	3.95	**9.94**	7.81	3.72	2.99	1	?	?			?	?	
NH3	**5.55**	4.32	4.5	1.82	1.36	1	?	?	**9000**	1800	750	300	**0.003**
NO	0	0	0	0	0	0	12850	**4260**	1800	600	150	100	**0.000**
NO2	2.02	1.19	13.13	**6.19**	0	0	2570	**852**	360	120	30	20	**0.007**
SO2	**19.8**	2.06	2.04	1.33	2.82	2.56	?	**2115**	180	600	15	100	**0.009**
SO2 (peak)	55.4	**65.5**					?	**2115**	180	600	15	100	**0.031**
CO	**190.9**	104.8	99.18	44.49	7.7	4.2	**6850**	16600	6000	7200	500	1200	**0.028**
CO2	6	730.3	**2675**	1608	42	30	**88000**					40000	***0.030***
H2O	1973.	**4885**	3161	1684	627	276							
THC as C3H6	**97.9**	72.2	68.17	55.21	22	20.8							**0.005**
O2 Depletion	3500	2100	**6470**	2920	150	0	**136000**						

Next * Obtain Scaling Factors for each Gas and Check resultant Box Test FEDs

FED Total =	0.238
x 1.4 =	0.333

Lab-Scale Decomposition Product Limits for Material Systems Similar To The 3 Systems Tested

For each gas (CO, HCN, and SO2) at 5 minutes:

Highest Box Test Concentration *(for 3 material systems)*	X 0.4 =	Box Test Concentration Limit

Gas	Full-Scale Yields at 5 min (ppm)						Lab-Scale Yields at 5 min (ppm)			Scaling Factor		
	PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260 Sec)		Structural Composite							
	Mid at 5'6"	Fwd at 5'6"	Mid at 5'6"	Fwd at 5'6"	Mid at 5'6"	Fwd at 5'6"	PAN/Met PVF	FG/Ceramic Barrier/ Met PVF	Structural Composite	PAN/Met PVF	FG/ Ceramic Barrier/Met PVF (260 Sec)	Structural Composite
C6H5NH2	4.63	3.27	**5.5**	3.27	1.73	0.29	68.73	**91.14**	6.14	14.8	16.6	3.5
C6H5OH	7.02	4.59	**9.57**	5.01	9.4	4	**52.22**	38.95	9.78		4.1	1.0
C6H6	**10.46**	10.41	8.05	4.56	7.21	3.21	**76.60**	52.5	8.33	7.3	6.5	1.2
CH2CHCHO	0	0	0	0	0	0	55.50	**146.04**	0	#DIV/0!	#DIV/0!	ND
COCl2	0	0	0	0	0	0	0.00	**3.9**	0	ND	#DIV/0!	ND
COF2	0	**0.21**	0	0	0	0	0.00	0	**0.43**	ND	ND	#DIV/0!
COS	0	**0.61**	0	0	0.53	0.34	**38.66**	0	0.84	>40	ND	1.6
HBr	0	0	0	0	0	0	0.00	0	0	ND	ND	ND
HCl	0	0	0	0	**0.49**	0.29	0.00	0	3.43	ND	ND	7.0
HCN	**16.4**	10.75	0	0	0	0	**467.00**	111.74	0	28.5	#DIV/0!	ND
HCN (peak)	22.7	**26.9**					**467.00**	111.74	0	17.4		
HF	0	0	0	0	0	0	14.46	**19.3**	0	#DIV/0!	#DIV/0!	ND
NH3	**5.55**	4.32	4.5	1.82	1.36	1	**367.20**	289.19	3.3	66.2	64.3	2.4
NO	0	0	0	0	0	0	0.00	0	0	ND	ND	ND
NO2	2.02	1.19	13.13	**6.19**	0	0	0.00	0	0	ND	ND	ND
SO2	**19.81**	2.06	2.04	1.33	2.82	2.56	**246.57**	0	31.17	12.4	ND	11.1
SO2 (peak)	55.4	**65.5**					**246.57**	0	31.17	3.8		
CO	**190.9**	104.8	99.18	44.49	7.7	4.2	**4645.76**	2116.23	55.32	24.3	21.3	7.2
CO2	1367.6	730.3	**2674.66**	1608	42	30	11506.60	**12657**	96.7	8.4	4.7	2.3
THC as C3H6	**97.9**	72.2	68.17	55.21	22	20.8	629.71	**903.5**	22.0	6.4	13.3	1.0
Oxygen Deplet	3500	2100	**6470**	2920	150	0	3000.00		1120	0.9		7.5

Set Decomposition Product Limits for Lab-Scale Tests

Gas	FED Effect *Full Scale*	Lab-Scale Tox Limit= 5 Min Exp Limit x Scaling Factor (ppm)	Lab-Scale Tox Limit (ppm)	FED Effect *Lab Scale Using Scaling Factor*	Gases to Measure FED > 0.02	Max Allowed Conc. (ppm)= Max Box Test Conc x 1.4
C6H5NH2	0.009	600 x 15.7 (IDLH)	9,420	0.010		
C6H5OH	0.004	2400 x 4.2 (ERPG)	10,080	0.005		
C6H6	0.001	12,000 x 5.0 (ERPG)	60,000	0.001		
CH2CHCHO	0.000	7783 x 4 (LC50)	31,132	0.005		
COCl2	0.000	102 x 4 (LC50)	408	0.010		
COF2	0.001	300 x 4 (ERPG3)	1,200	0.000		
COS	0.001	500 x 20	10,000	0.004		
HBr	0.000	15900 x 4 (LC50)	63,600	0.000		
HCl	0.000	15900 x 4 (LC50)	63,600	0.000		
HCN	0.093	176 x 28.5 (Incap)	5,016	0.093		
HCN (peak)	0.153	176 x 17.4 (Incap)	2,992	0.156	Yes	654
HF	0.000	7227 x 4 (LC50)	28,908	0.001		
N20			No Limit			
NH3	0.003	9000 x 65.3 (ERPG)	587,700	0.001		
NO	0.000	4260 x 4 (LC50)	17,040	0.000		
NO2	0.007	852 x 4	3,408	0.000		
SO2	0.009	2115 x 11.8	24,957	0.010		
SO2 (peak)	0.031	2115 x 3.8	8,037	0.031	Yes	345
CO	0.028	6850 x 22.8 (ERPG3)	156,180	0.030	Yes	6,504
CO2	*0.030*	88,000 x 6.6	580,800	*0.022*		17,720
H2O		No Limit		N/A		27,202
THC as Propane	0.005	21,000 x 6.9	144,900	0.006		
Oxygen Depletion		Remove				

FED Total =	0.238
x 1.4 =	0.333

FED Total =	0.252
x 1.4 =	0.353

Determine Toxicity of Lab-Scale Decomposition Products

Gas	Full-Scale Gas Yields at 5 minutes into test (ppm)						Allowable Exposure from Various References						FED Effect *Full Scale*	Lab-Scale Gas Yields at 5 min (ppm)			Lab-Scale Tox Limit= 5 Min Exp Limit x Scaling Factor (ppm)	Lab-Scale Tox Limit (ppm)	FED Effect *Lab Scale Using Scaling Factor*	Gas	Scaling Factor Mid Station at 5'6"			Gases to Measure FED > 0.02	Max Allowed Conc. (ppm) = Max Box Test Conc x 1.4
	PAN/Met PVF		FG/Ceramic Barrier/Met PVF (260 Sec)		Structural Composite		5 Minute Exposure				60 Minute Exposure	30 Minute Exposure													
	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)	IDLH (1995)		PAN/Met PVF	FG/Ceramic Barrier/Met PVF	Structural Composite					PAN/Met PVF	FG/ Ceramic Barrier/Met PVF (260 Sec)	Structural Composite		
C6H5NH2	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		
C6H5OH	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		4.1	1.0		
C6H6	**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		
CH2CHCHO	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		
COCl2	0	0	0	0	0	0	?	**102** c	12	12	1	2	**0.000**	0.00	**3.9**	0	102 x 4 (LC50)	408	**0.010**	COCl2	ND	#DIV/0!	ND		
COF2	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!		
COS	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 20	10,000	**0.004**	COS	>40	ND	1.6		
HBr	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		
HCl	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		
HCN	**16.4**	10.75	0	0	0	0	**176**	560	300	300	25	50	**0.093**	**467.00**	111.74	0	176 x 28.5 (Incap)	5,016	**0.093**	HCN	28.5	#DIV/0!	ND		
HCN (peak)	22.7	**26.9**					**176**	560	300	300	25	50	**0.153**	**467.00**	111.74	0	176 x 17.4 (Incap)	2,992	**0.156**	HCN	17.4			Yes	654
HF	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		
N20	3.95	**9.94**	7.81	3.72	2.99	1	?	?			?	?		18.75	**62.56**	0		No Limit		N20	4.7	8.0	ND		
NH3	**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		
NO	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		
NO2	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		
SO2	**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		
SO2 (peak)	55.4	**65.5**					?	**2115**	180	600	15	100	**0.031**	**246.57**	0	31.17	2115 x 3.8	8,037	**0.031**	SO2	3.8			Yes	345
CO	**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	6850 x 22.8 (ERPG3)	156,180	**0.030**	CO	24.3	21.3	7.2	Yes	6,504
CO2	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		17,720
H2O	1973.9	**4885**	3160.63	1684	627	276								10164.77	**19430**	1808.29	No Limit		**N/A**	H2O	5.1	6.1	2.9		27,202
THC as Propane	**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		
Oxygen Depletion	3500	2100	**6470**	2920	150	0	**136000**							3000.00		1120	Remove			Oxygen Depletion	0.9		7.5		

FED				
Total =	**0.238**	0.24	0.08	0.01
x 1.4 =	**0.333**	0.33	0.11	0.00941

FED	
Total =	**0.252**
x 1.4 =	**0.353**

a. NO is 1/5 as potent as NO2: See Documentation of TLV and BEI indicies, Sixth Edition, Vol 2, American Conference of Governmental Industrial Hygienists, Inc, 1993.

b. See Documentation of The Threshold Limits and Biological Exposure Indices, Sixth Edition Vol 2 , pp. 1245-1247

c. extrapolated from 1 min LC50= approx 500ppm COCl2

FED CO, HCN, SO2 = 0.242 x 1.4= 0.339 90%

Measure CO, CO2, HCN, SO2, Water

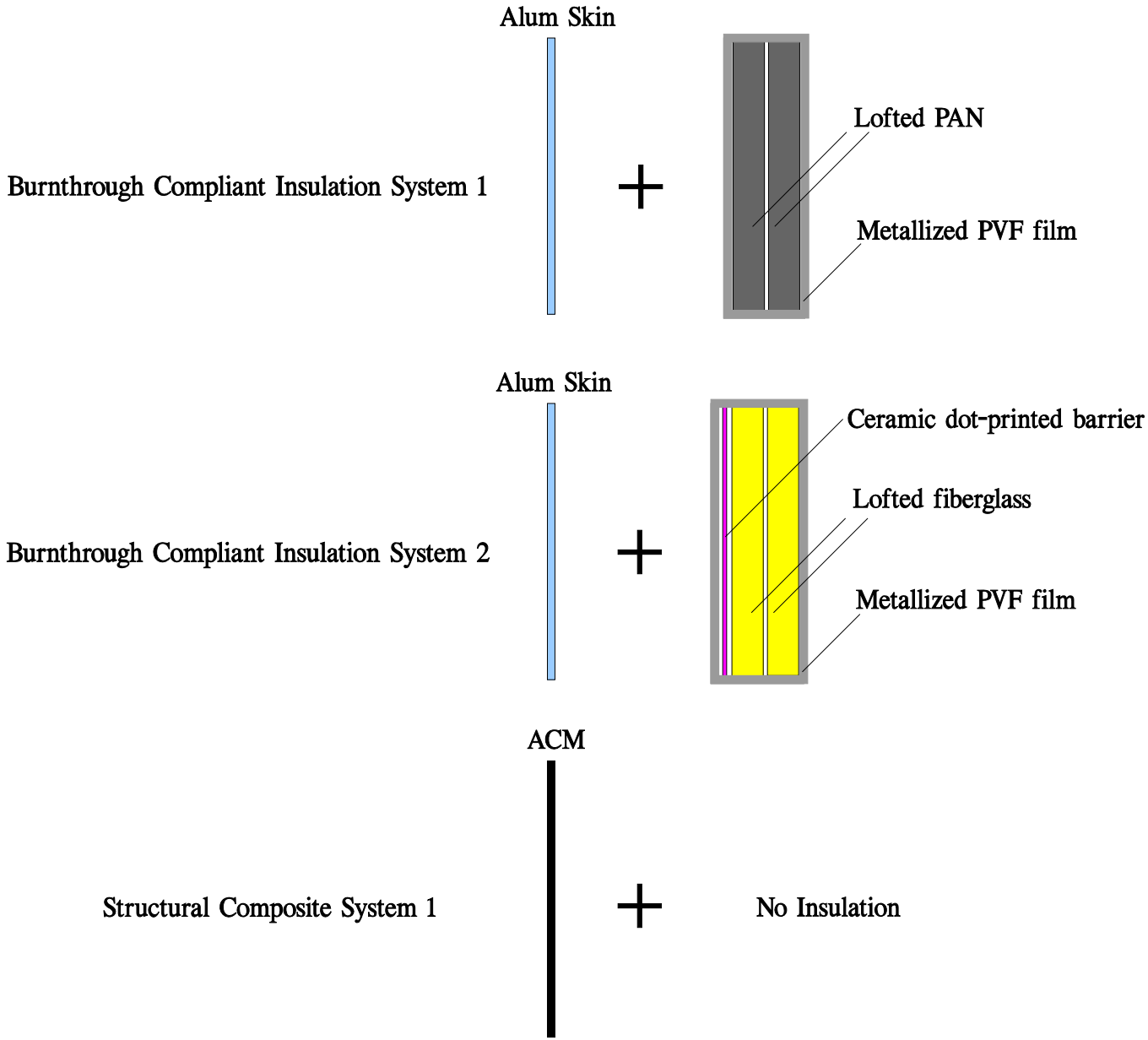
FED CO, HCN, SO2= 0.238 x 1.4= 0.334 87%

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



Spectra at 5 Minutes