Selected topics on spacecraft fire safety

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Agenda

- Observations on materials combustion in space systems
- Correlation of size of transition zone from self-extinguishment to sustained combustion with extinguishment limits in threshold flammability tests
- Potential issues on applicability of laboratory test data for space systems safety

Observations on materials combustion in space systems

Observations on materials combustion in space systems

- For spacecraft fire risk assessment, it would be useful to evaluate the amounts of material which would burn before extinguishment due to oxygen depletion

- Relationships among heat release and oxygen consumption (Parker 1982*) in corroboration with known MOC values for materials could be used for this purpose

*Parker, W.J., Calculations of the Heat Release Rate by Oxygen Consumption for various Applications, NBSIR 81-2427, National Bureau of Standards, 1982

Estimated amounts of material consumed during combustion in a typical ISS rack before the O_2 concentration falls below noted values

Post-combustion oxygen concentration, % by volume (assumed 20.9 % @ 14.7 psia initially)	Estimated amount of material consumed (g)		
	For most common materials (heat of combustion HC approximately 6 kcal/g)	For materials with HC at the high end (approximately 11 kcal/g)	For materials with HC at the low end (approximately 3 kcal/g)
19	19.8	10.8	39.6
18	30.2	16.5	60.5
17	40.7	22.2	81.3
16	51.1	27.9	102.2

Estimated amounts of material consumed during combustion in a 8500 L ISS module before the O_2 partial pressure falls below noted values

Post-combustion oxygen partial pressure , torr (assumed 20.9 % @ 14.7 psia initially)	Estimated amount of material consumed (g)		
	For most common materials (heat of combustion HC approximately 6 kcal/g)	For materials with HC at the high end (approximately 11 kcal/g)	For materials with HC at the low end (approximately 3 kcal/g)
148 (OSHA and NIOSH limits)	82.6	45.1	165.2
135 (ACGIH limit)	182.9	99.8	365.8
100 (IDLH)	454.4	247.9	908.8

Estimated amounts of material consumed during combustion in an abandoned and sealed 8500-L ISS module before the O_2 concentration falls below noted values

Post-combustion oxygen concentration, % by volume (assumed 20.9 % @ 14.7 psia initially)	Estimated amount of material consumed (g)		
	For most common materials (heat of combustion HC approximately 6 kcal/g)	For materials with HC at the high end (approximately 11 kcal/g)	For materials with HC at the low end (approximately 3 kcal/g)
19	112.1	61.1	224.2
18	171.1	93.4	342.2
17	230.4	125.7	460.8
16	289.2	157.9	578.4

Estimated amounts of material consumed in the Orion Avionics Bay (assumed 1 m^3) before the O_2 concentration falls below noted values

Post-combustion oxygen concentration, % by volume (assumed 20.9 % @ 14.7 psia initially)	**Estimated amount of material consumed (g)**		
	For most common materials (heat of combustion HC approximately 6 kcal/g)	For materials with HC at the high end (approximately 11 kcal/g)	For materials with HC at the low end (approximately 3 kcal/g)
19	13.2	7.2	26.4
18	20.1	11	40.3
17	27.1	14.8	54.2
16	34.1	18.6	60.1

Estimated amounts of material consumed in the Orion (assumed 15 m^3) before the O_2 concentration falls below noted values

Post-combustion oxygen concentration, % by volume (assumed 20.9 % @ 14.7 psia initially)	**Estimated amount of material consumed (g)**		
	For most common materials (heat of combustion HC approximately 6 kcal/g)	For materials with HC at the high end (approximately 11 kcal/g)	For materials with HC at the low end (approximately 3 kcal/g)
19	198.0	108.0	396.0
18	301.5	165.0	604.5
17	406.5	222.0	813.0
16	511.5	279.0	901.5

Practical applications of data

- Direct applicability to spacecraft fire risk assessments

- The oxygen depletion estimates for various amounts of materials consumed could provide a relative perspective on the size of a potential spacecraft fire involving polymers when no fresh oxygen is supplied.

- Estimation of the approximate amount of material burned which would deplete the oxygen concentration below the hypoxia limits will allow to evaluate when the astronauts should abandon fighting a fire in an ISS module.

Practical applications of data (cont'd)

- If the module abandoned is sealed, the amount of material which could burn before the oxygen concentration falls below the oxygen concentration flammability threshold could be estimated.

- Module pressure effects could be evaluated

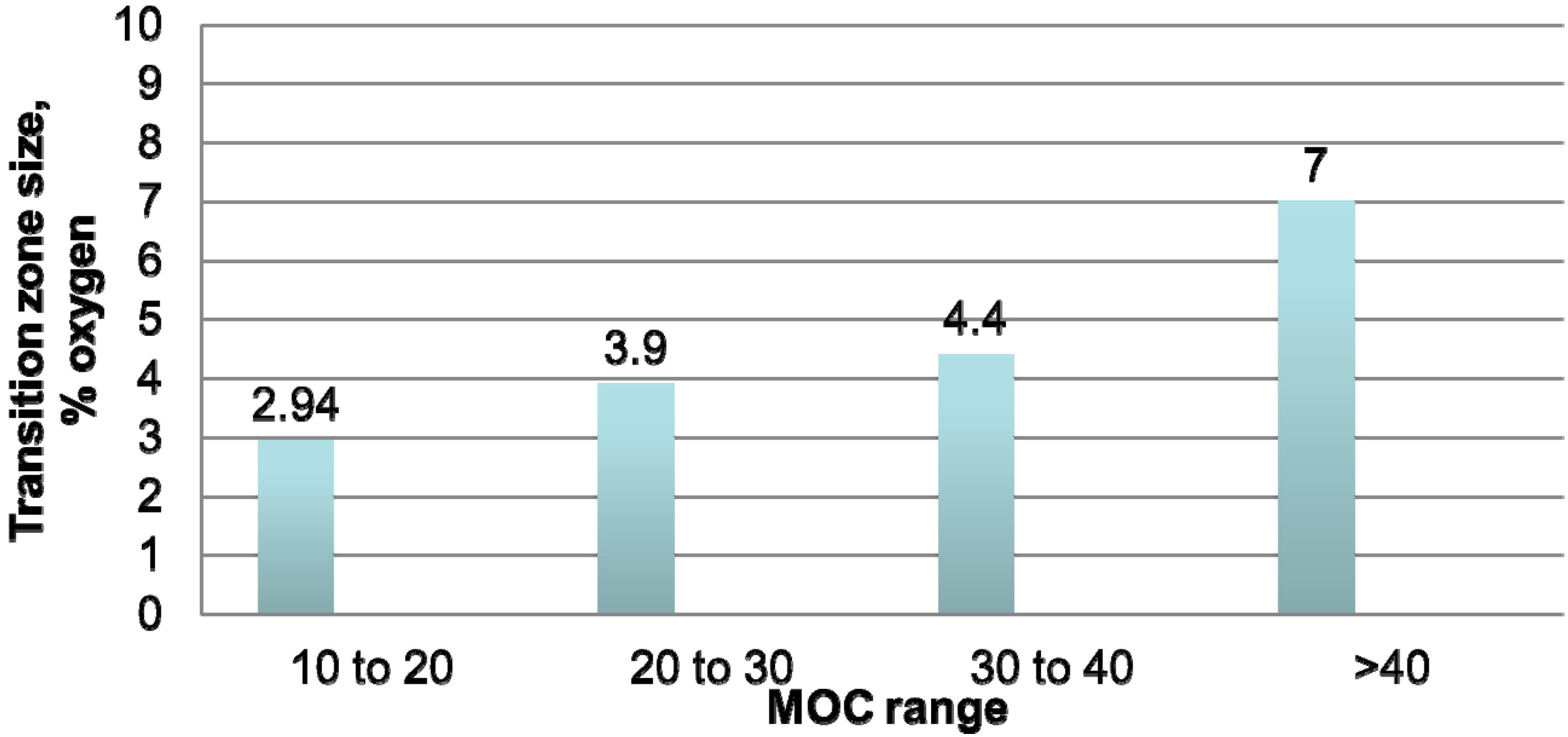
- Address post-fire module restoration issues

Practical applications of data (cont'd)

- Oxygen depletion due to combustion in the ISS racks, Orion Avionics Bay and other enclosures could be evaluated to determine the appropriate response in case of an incidental fire. There may be instances where fire extinguishment measures may not be necessary if the amount of material consumed is considered small enough before the combustion subsides due to oxygen depletion

Correlation of size of transition zone from self-extinguishment to sustained combustion with extinguishment limits in threshold flammability tests

Dependency of size of transition zone from consistent extinguishment to consistent burning on MOC



Potential issues on applicability of laboratory test data for space systems safety

Potential issues on applicability of laboratory test data for space systems safety*

- Perception of reality through experimentation and analysis

- Review a few cases of laboratory test data applicability issues: Statistical and epistemic uncertainties as sources of bias on perceiving reality

- Examples

Review a few cases of laboratory test data applicability issues

- Transient phenomena: the importance of what we measure with

- Statistical uncertainty: do we have enough data?

- Epistemic uncertainty: the importance of looking beyond laboratory test data

Epistemic uncertainty

- Epistemic uncertainty could cause bias in perceiving reality correctly due to a lack of in-depth knowledge of some sort, such as:
  - Test equipment constrains
  - Test method constrains
  - Overlooking the real-life applicability of laboratory test data

Discussion

- Laboratory test data for space systems and operations safety should be analyzed and used with real-life applicability in mind

- Potential limitations should be noted within the body of test method standards