Fires: Microgravity vs. Earth

- Non-convecting purely diffusive environment
- No bouyant flow---heated gases don’t rise
  - Example: Candle Experiment
  - $O_2$ supply dependent on STS/ISS ventilation fans
  - CO orders of magnitude higher---more toxic
  - Flammable material still present after fire is extinguished
  - Hemispherical flames
STS/ISS Detection Designs

- **CURRENT (STS)**
  - Ionization detection, Freon-1301 bottles, and hand-held Halon-1301 extinguishers
  - NASA requirements: Each payload must monitor SOH-- multiple sensors

- **FUTURE (STS/ISS)**
  - SECOND GENERATION HALON REPLACEMENTS: Flame-Ex & Halon 1211
  - FIRESCAPE: Images invisible flames of alcohol & hydrogen fires-- sees through smoke
  - SOLID-SOLID HYBRID GAS GENERATOR
Concluding Remarks

- Need more data on microgravity combustion
- Ground-based scientists will have to adopt new approaches to space combustion phenomena
- Each component will continuously need to be monitored for overheat conditions
- Combination of new technologies utilized
  - Portable extinguishers will continue to be used in manned area so 2nd generation Halon replacements are a given
  - Solid-solid hybrid gas generators likely since the pros far outweighed the cons
  - FIRESCAPE will possibly be an asset on the launch pad but not relevant to STS or ISS
References

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Fire Detection in Microgravity

ASEN 5519
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Overview

• Background
• NASA Requirements
• Current STS Fire Detection System
• Micro-gravity Fire Experiments
• Future Designs/ISS
• Conclusion
Fires: Microgravity vs. Earth

- No bouyant flow-- heated gases don’t rise
  - Example: Candle wax consumed 5 times more slowly

- Entire candles melt in 2 min due to increased downward heat conduction
- Surface tension of liquid wax prevents fire extinction
Fires in Microgravity

- Non-convecting, purely diffusive environment
  - \(O_2\) supply dependent on STS/ISS ventilation fans
  - CO orders of magnitude higher—more toxic
- Flammable material still present after fire is extinguished
- Hemispherical flames
Air Flow Dependency in Space

- Quiescent (no airflow) environment
  - Materials burn more slowly than on Earth
- Low-speed airflow (2-8 inches/sec)
  - Materials more flammable than on Earth
  - Flame front which propagates into wind stronger due to increased O₂ supply & no convection
- Lesson: Turn off ventilation to suppress fires
Fire Detection & Suppression Methods

- Detection Methods: IR, UV, ion, particle
- Detection Approach: centralized, distributed, or a combination
- Suppression Methods: CO₂, N₂, H₂O, halon
  - Water & foam not suitable for space habitats
- Suppression Approach: centralized, distributed, portable, or a combination
- Bottom Line: remove oxidizer or fuel or else remove heat req’d for combustion to occur
- Cleanup Options: sorption, conversion, vent to space
NASA Requirements

- All payloads shall output SOH data at 1 Hz continuously
- Must identify fire potential while reducing possibility of false alarms
- Multiple sensors of more than one type
  - 2 temperature and 2 current sensors
- Fire potential defined: 2 or more sensors of any type have out-of-tolerance conditions
Current STS Fire Detection/Suppression

- Ionization detection: sense levels of smoke concentrations and trigger alarms
- Avionics bays fire suppression
  - Freon 1301 (bromotrifluoromethane) extinguisher bottle
- Crew cabin fire suppression
  - Hand-held fire extinguishers with Halon-1301 (monobromotrifluoromethane)
Microgravity Combustion Experiments

- Droplet Combustion Experiment (STS-94)
  - Researches the dynamics of burning drop of fuel in space
  - Scientists compare the effects that a supporting fiber has on a droplet with a free-floating droplet
  - Following image shows ignition of vapor cloud around the droplet and the outline of the fiber
Droplet Combustion Experiment
• Comparative Soot Diagnostics Experiment
  – Designed to compare the effectiveness of an ionization detector vs. an infrared light-scattering detector in micro-gravity
  – Light-scattering detector more sensitive to smoke particulate samples than the ionization detector
Microgravity Combustion Experiments

- The Structure of Flameballs
  - Why fires keep burning and what makes them go out?

- The Laminar Soot Experiment
  - Soot re-radiates fire’s heat as visible light & infrared warmth--formed faster in space

- Candle Flames in Microgravity
  - Studies candle flame behavior in space
2.2 second droptower experiment. 2 cm/s wind blows from bottom to top. 30% oxygen concentration. Pictures are 0.25 s apart. Notice strong blue flame front propagating into the wind (upstream), while yellow sooty flame front (downstream) dies out.
Future Design Possibilities

• Solid-solid hybrid gas generator
  – Pros:
    • Replaces ozone depleting Halon 1301
    • Agents drastically cooler than conventional gas generators
    • Significantly smaller and lighter
    • Single storage vessel as a solid
    • Acceptable atmosperhic & toxicological properties
  – Cons:
    • Clean-up can be problem in space/contained environment
Future Design Possibilities

• Second-generation Halon replacements
  – Flame-Ex, trifluoriodomethane, Halon 1211, & perfluorohexane
  – Pros:
    • Increased application density for comparable agent amounts
    • More effective than most chemicals as total flooding agent
  – Cons:
    • Less effective than Halon 1301 as total flooding agent
    • Toxicity info and atmospheric impact studies incomplete
    • High manufacturing costs
    • Has not yet received EPA SNAP approval
Future Design Possibilities

- **FIRESCAPE**
  - Images invisible flames of alcohol & hydrogen fires
  - Sees through smoke & finds origin of visible fires

- **Pros:**
  - First affordable commercial product for fire imaging
  - Used like binoculars-- no moving parts/easy to operate
  - Firefighters can remain at safe distance while finding invisible fires
  - Low purchase cost-- $5,000 per unit

- **Cons:**
  - More useful on launch pad than on STS or ISS since most space fires are electrical, not gas-related
Concluding Remarks

• Need more data on micro-gravity combustion
  – Can’t fight/prevent space fires w/o understanding their characteristics

• Ground-based scientists will have to adopt new approaches to space combustion phenomena
  – Things burn differently in micro-gravity

• Each component will continuously need to be monitored for overheat conditions
  – Only way to isolate/determine source in forced air environment
Concluding Remarks

- Combination of new technologies most-likely incorporated
  - Portable extinguishers will continue to be used in manned area so 2nd generation Halon replacements are a given
  - Solid-solid hybrid gas generators likely since the pros far outweighed the cons
  - FIRESCAPE will possibly be an asset on the launch pad but not relevant to STS or ISS
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