ALTERNATE FIRE SUPPRESSION RESEARCH FOR AIRCRAFT ENGINE NACELLES AND DRY BAYS

NEXT GENERATION FIRE SUPPRESSION TECHNOLOGY PROGRAM [NGP]

www.bfrl.nist.gov/866/NGP

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THE NGP

- Halon 1301 has been out of production since January 1, 1994
- There is uncertainty about the sufficiency and longevity of the supply
- Fire suppression is essential to the readiness and effectiveness of nearly all weapons systems
- The NGP is in place because the cost of environmental stewardship (*i.e.,* retrofitting or designing with current alternatives) is huge

GOAL

Develop and demonstrate technology for economically feasible, environmentally acceptable and user-safe processes, techniques, and fluids that meet the operational requirements currently satisfied by halon 1301 systems in aircraft

- Pertains to both current and planned platforms
- Results will likely be of benefit to other applications

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NGP RESEARCH AREAS

- New Flame Suppression Chemistry
- Suppressant Screening Tests
- New and Improved Aerosol Suppressants
- Better Suppressant Delivery
- Viability of New Suppression Technologies
- Fuel Tank Inertion

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- New Flame Suppression Chemicals
- Improved Suppressant Storage and Delivery

NGP DELIVERABLES

- A suite of screening tools and guidance for their use [2000]
- Identification of the best places to look for alternative chemicals and a first set of “best looks” [2000]
- A method for determining and comparing the total life-cycle costs of new fire suppression technologies [2001]
- Specific chemicals as in the goal statement [2002-2005]
- Verified precepts for improved suppressant delivery [2002-2005]
- Validated modeling to guide the selection of optimal dispensing and distribution conditions for the variety of nacelle and dry bay configurations [2002-2005]
- Limited toxicity testing and real-scale experiments [2002-2005]

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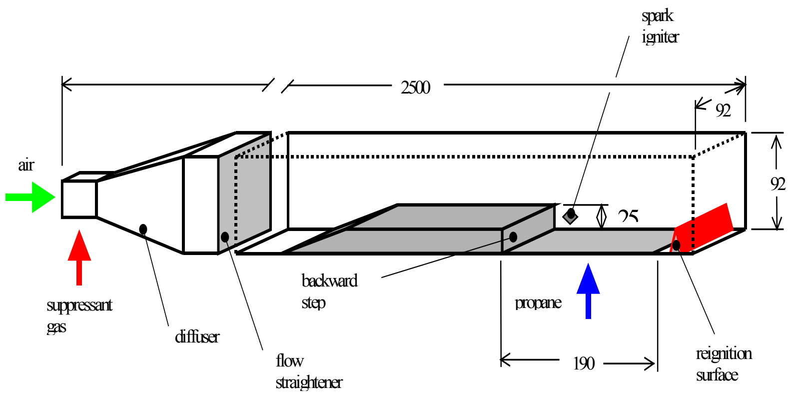
SUPPRESSANT SCREENING TESTS



- Completed last screen: Transient Application, Recirculating Pool Fire (TARPF) agent effectiveness screen
- For the first time, compressed and solid-propellant-generated gases compared side by side
- Modeled for extrapolation
- Held workshop with SPGG manufacturers
- Aerosol suppressants deferred until the demand arises

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NEW FLAME SUPPRESSION CHEMISTRY

- Comprehensive view of fire suppression
  - Chemically active agents reduce flame radicals toward equilibrium levels
  - Adding heat capacity reduces the flame temperature and thus the flame reaction rates below the level needed to sustain combustion
  - Non-linear synergism
  - Suppression concentration limit may be at ~1 % (mole)
- Search attributes
  - Fire suppression efficiency at least comparable to halon 1301
  - Short atmospheric lifetime ($\leq$1 month)
  - Low toxicity relative to the concentration needed for suppression
  - High volatility (low BP) to achieve an extinguishing concentration quickly

NEW CONCERN

- Effectiveness of some types of chemicals varies significantly in different laboratory tests (where there is no “right” answer yet)
  - Inert, thermal agents and halocarbons are consistent across burners
  - Metal- and phosphorus-containing compounds are highly effective in opposed flow diffusion flames, not effective in co-flow flames or SPGG experiments
- Reasons being examined in FY2001

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NEW FLAME SUPPRESSION CHEMICALS

- 4 Tropodegradable Bromocarbons being worked with AAWG
  - 1-bromo-3,3,3-trifluoropropene — $CF_3CH=CHBr$
  - 2-bromo-3,3,3-trifluoropropene — $CF_3CBr=CH_2$
  - 4-bromo-3,3,4,4-tetrafluorobutene — $CF_2BrCF_2CH=CH_2$
  - 2-bromo-3,3,4,4,4-pentafluorobutene — $CF_3CF_2CBr=CH_2$
- Cup burner values < 4 mole percent (≈ halon 1301)
- No effect on rats - 5 % for 30 minutes; negative Ames test, etc.
- Cardiotoxicity LOAEL of second propene: ≤1 %
- Atmospheric lifetimes of several days
- Boiling points: 34 ºC - 56 ºC
- Searching for others with lower boiling points

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SURVEY OF CHEMICAL FAMILIES

- Comprehensive review of the world of chemistry
- Most promising families:
  - N compounds: amines nitriles
  - P Compounds: *acids* *esters* nitriles halides
  - S Compounds: sulfides mercaptans sulfoxides
  - Metal Compounds: *manganese* *tin*
  - Halogenated Organics: alkenes (I) *fluoroethers (Br,*I*)*
- Substantial fluorination likely needed for low boiling points
- Screening started in FY2001

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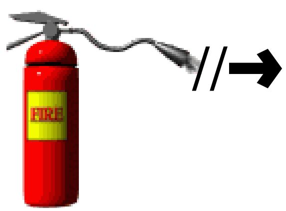
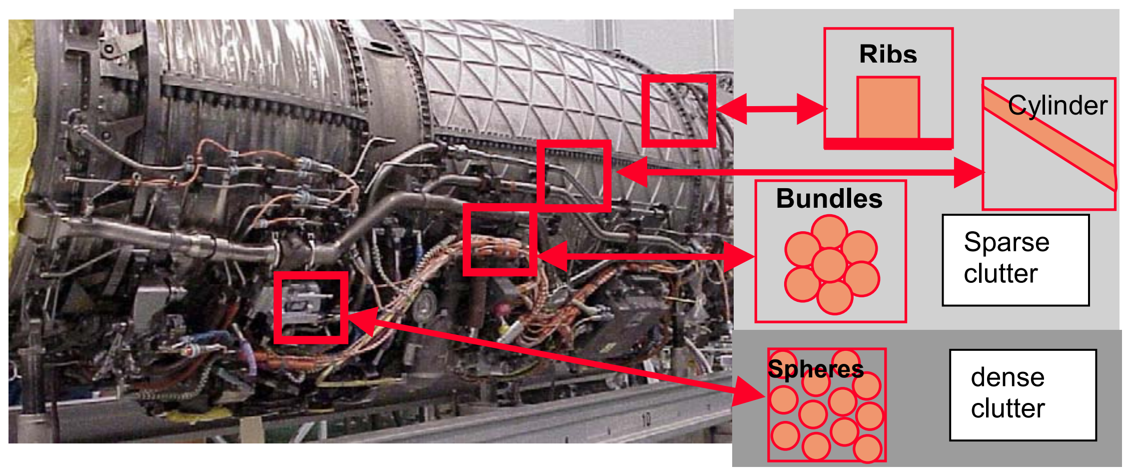
COMPLEXITY OF ENGINE NACELLE FIRE SUPPRESSION



Storage Bottle

Agent Discharge

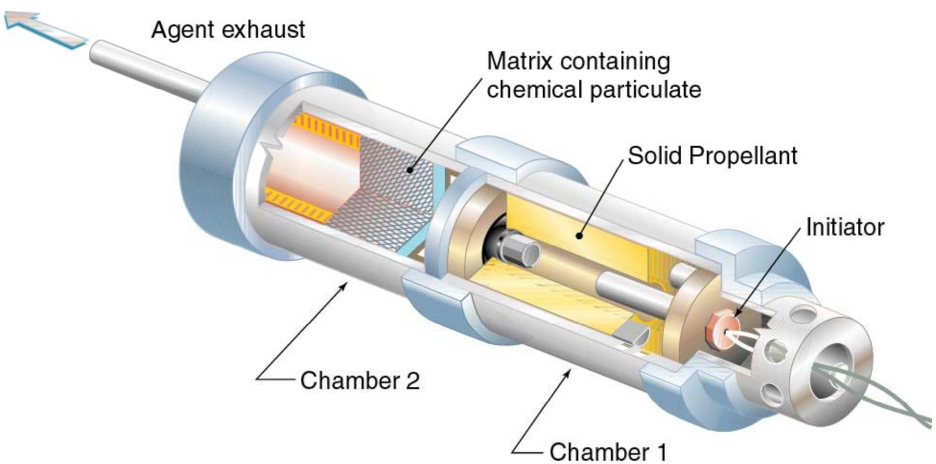


(Cold) Air Flow

DISPERSION OF MID-BOILING SUPPRESSANTS AT LOW TEMPERATURE

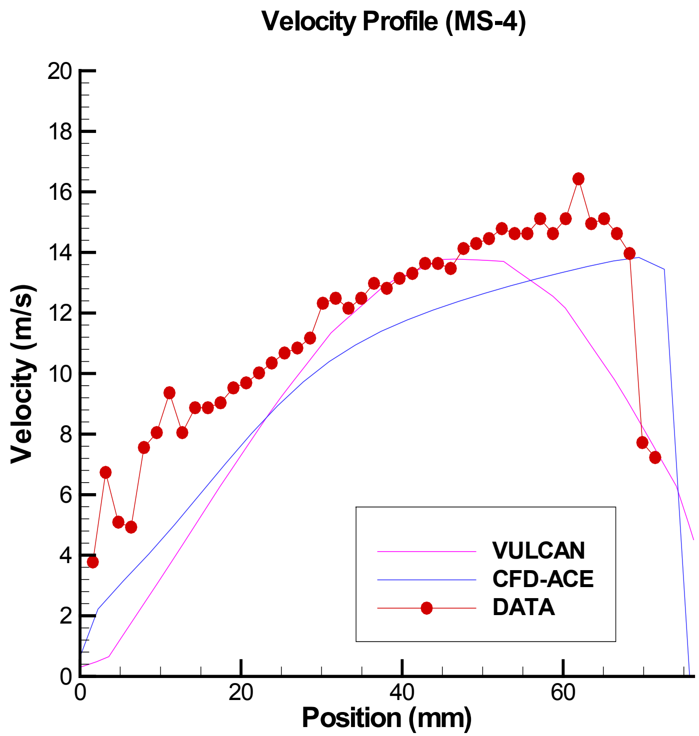
- CF_3I has a flame suppression efficiency similar to halon 1301
- Halon 1301 (B.P -58 °C) flash vaporizes and distributes well, even at the lowest temperatures (*ca*. -40 °C) in in-flight aircraft
- CF_3I B.P. is -22 °C, and earlier research had indicated that its dispersion at low temperature might be problematic
- Aircraft engine nacelle simulator has been built to examine this and other higher boiling chemicals
- Initial results indicate heating will be needed

SOLID PROPELLANT GAS GENERATORS



- Novel high-N fuels achieved 20 % reduction in effluent gas temperatures
- Less or different oxidizer will reduce combustion temperatures further
- Additional fuel formulations under development
- Odd results with chemically active agents (KI, KBr, K_2CO_3, Fe_2O_3, iron oxalate, decabromodiphenyl ether, ferrocene) added downstream
- Quantifying the agent mass reaching the flame and modifying the SPGG design to improve the agent delivery

FIRE SUPPRESSANT DYNAMICS IN ENGINE NACELLES



- Objective: validated computational fluid dynamic (CFD) model of suppressant flow, a fire, and fire extinguishment in cluttered environments
- Provide basis for optimizing the distribution of suppressants
- Baseline: CFD predictions compared with detailed measurements in a quarter-scale, smooth nacelle fixture under well-controlled conditions
- Experiments in cluttered nacelle mock-up to begin soon
- Movement of aerosol agents and effects on flame to be added

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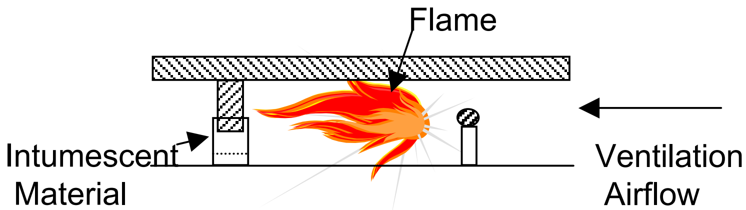
USE OF AN INTUMESCENT COATING TO REDUCE ENGINE NACELLE AIR FLOW



- Coating on inside of nacelle responds to the impingement of fire heat by swelling (> x10), reducing the open area of the nacelle and thus air flow
  - weaken the fire due to oxygen starvation
  - reduce the mass of suppressant needed
  - lead to extinguishment by itself
- No effect in the absence of a fire
- Survey shows a wide range of candidate materials

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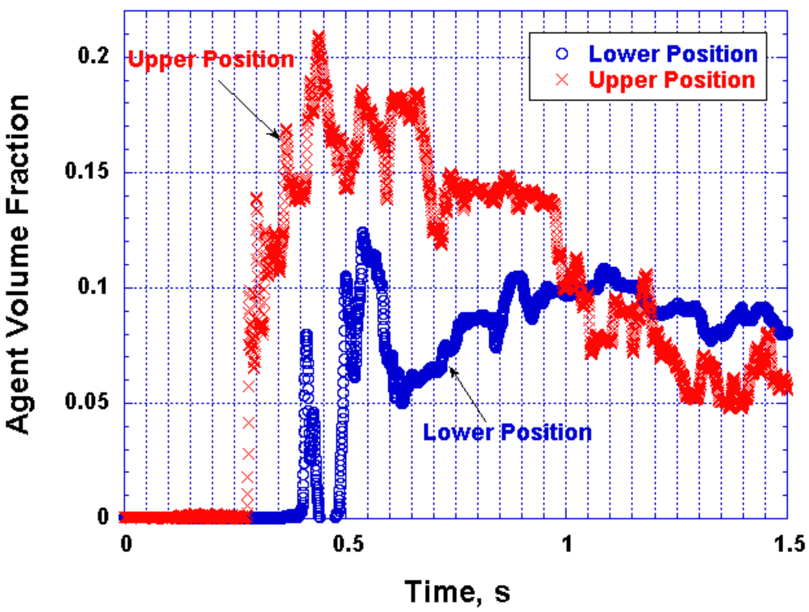
CONCENTRATION MEASUREMENT FOR REAL-SCALE TESTS



- Fabricated portable version of Differential Infrared Agent Concentration Sensor (DIRRACS2): *ca*. 22 cm x 31 cm x 18 cm
- HFC-125 discharge tests carried out in a Bradley armored personnel carrier
- Concentration monitored near head height or waist height for an occupant of the vehicle
- Time resolution acceptable
- “Noise” dominated by turbulence of mixing

BENEFIT ASSESSMENT OF FIRE PROTECTION SYSTEM CHANGES

- Total cost of the system minus the cost savings provided by the system (extinguishant effectiveness and aircraft saved)
- Example: C-17 aircraft - halon 1301 *vs.* equal performance HFC-125
  - Results have sizable uncertainties
  - Fleet-wide (20-year) cost of ownership of the halon 1301 systems: ≈ $37 M
  - Equivalent cost of ownership for a proposed HFC-125 system: ≈ $43 M
  - Each is ≈ 0.1 % of the total life cycle cost of the aircraft
  - Benefits greatly outweigh cost; difference in total cost of the two systems is modest compared to the total cost of owning and operating the aircraft
- Next: extend methodology to nacelles in the F/A-18 E/F and a rotary wing platform and one dry bay application

FY2002 PROGRAM

- Continuing evaluation of chemical families
  - RFP for new ideas likely in winter, 2001
- Continuing development of dispersion model
- Complete work on powder panels (dry bay application)
- Planning for limited real-scale fire experiments

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