Halon Replacement

Federal Aviation
Administration

Halon Replacement in the Civil Transport Aircraft Engine Nacelle (2013)

Presented to: Seventh Triennial International Fire & Cabin Safety Research Conference

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Presentation Overview

- **Encompassing conditions**

  …who, how, why, the threat, threat mitigation, halon elimination

- **A test process**

  …a history, some existing outcomes, the future ?

- **Overview of the current test process**

- **Description of the FAA test article**

Encompassing Conditions

- **Who is involved, why, and how…**
  - Who?
    - Principally, large civil transport aircraft propulsion and auxiliary power system (APS) interests
    - Industry and government
  - How?
    - Task group[(1)] interaction within the FAA International Aircraft Systems Fire Protection Working Group[(2)]
  - Why?
    - Providing assistance to satisfy FAA regulations requiring adequate fire extinguishing systems for aircraft engine/APS fire zones without using halon

Encompassing Conditions

- **Circumstances in the real world...**
  - Circumstances in the turbine enclosure :
    - Spatial volume of complex structure with forced ventilation
    - Flowing flammable liquids normally contained in plumbing
    - Resident ignition sources; electrical arc, “hot” surfaces
    - Wide range of local conditions during operations
    - Failure can create conditions resulting with undesired fire
  - The mitigation of the fire threat
    - *Passive fire protection* - component “fire worthiness”
    - *Active fire protection* - ventilation, limited fuel/ignition source elimination, fire detection & extinguishment systems

Encompassing Conditions

- **Circumstances in the real world...**
  - Basis for the threat mitigation in the FAA regulations
    - The broad foundation : 14 CFR §25.1181 – §25.1207
    - The specific interest...
      - 14 CFR §25.1195 Fire Extinguishing Systems
      - Demonstrating acceptability for fire extinguishing systems
        - » FAA Advisory Circular (AC) 20-100[(3)]
        - » Acceptable performance at “worst”-case condition(s)

Encompassing Conditions

- **Circumstances in the real world...**
  - – State-of-the-art is roughly a 30 year evolution, where it's typically…
    - Based on a pressure vessel :
      - – mounted in the engine pylon, wing or fuselage
      - – connected to the fire zone with plumbing
      - – manually discharged from the flight deck
      - – containing halon 1301 and nitrogen (N_2)
      - – discharged through open-ended tubes and drilled holes
    - Shown acceptable with a Statham-derivative gas analyzer
  - – Halon 1301 is being eliminated
    - 1993, FAA halon replacement program officially announced[(4)]

A Test Process

- **Revisional history/engine halon replacement…**
  - 1993, revision 1, FAA halon replacement program began
    - Engine halon replacement to be handled by US Department of Defense (DoD) in a 3-phase program
    - Culminated with a design model for HFC-125[(5)]
    - Civil interests wanted additional choices in FAA format
  - 1996, revision 2, minimum performance standard, halon replacement, engine nacelle (MPSe)
    - Halon 1301 versus replacement candidate; extinguishant injection into forced flow against the “robust fire”
    - Much learned from this iteration plus that from the US DoD
    - 2002, discontinued, “robust fire” too unreliable

A Test Process

- **Revisional history/engine halon replacement…**
  - 2003, revision 3, MPSe
    - Empirical basis; halon 1301 versus replacement candidate; extinguishant injection into forced flow against forced reignition
    - Experience with halon 1301 and 5 replacement candidates
      - HFC-125, CF3I, 2-BTP, FK-5-1-12, and KSA[6]
      - successful outcomes
        - » design concentration must reside in fire zone for ½ second
        - » 17.6%v/v HFC-125, 7.1%v/v CF3I or 6.1%v/v FK-5-1-12
    - 2008, discontinued
      - replacement candidates tending less halon-like; empiricism failing
      - design concentrations shrinking to unreasonable values

A Test Process

- **Revisional history/engine halon replacement…**
  - 2010, revision 4, MPSe
    - Replacement candidate injection into forced flow against forced reignition; compared to historical halon 1301 performance
    - Currently active
    - Draft format is publically available[(7)]
    - Incorporates all learned to date
    - Likely accounts for what the future may offer
    - Experience with 1 candidate, KSA

A Test Process

- **Future**
  - Revision 3 outcomes remain viable; rework not planned
  - Currently drafting a report on MPSe activity & process
    - All MPSe development, 1996 – present (2014?)
    - Design criteria for HFC-125, CF3I & FK-5-1-12 from MPSe rev 3
    - MPSe rev 3 & 4 processes
    - MPSe revision 4 will editorially change
      - experiential information will disappear from procedural text
      - experience will reappear in report body
  - Subsequent reports to contain FK-5-1-12 & KSA testing
  - A revision 5 ? FAATC NFS #2 ? a post-FAATC NFS ?

FAATC = FAA Technical Center
NFS = nacelle fire simulator

Overview of the Current Process

- **The MPSe Test Process**
  - Prior to any MPSe activity, the applicant identifies :
    - The airframe & replacement candidate to the aviation authority
    - The justification for testing; i.e. satisfy preliminary requirements
  - MPSe sequencing
    - Satisfy preliminary requirements (before testing in any MPSe forced flow…)
      - safety : life, maintained flight safety during candidate use
      - usage compatibility : materials, shelf-life, operational envelope
      - identify established preliminary design criteria
    - Conduct generic simulator & *possibly* “high”-fidelity testing
    - Report observations/outcomes (i.e. includes the recommended criteria for certification)

** Successful MPSe outcome *does not* assure certification

Overview of the Current Process

- **MPSe Testing Sequence**
  - Generic simulator testing (always required)
    - Accomplished in an acceptable test fixture capable of…
      - 2 different forced ventilation flows
      - replacement candidate storage, conditioning, & delivery
      - several fire threats; spray & pool combustion for varied fuel types
    - Generic testing sequence
      - establish candidate design criteria in the 2 forced flows
      - challenge and acceptably defeat all fire threat conditions
        - » candidate assessed using forced reignition behavior (as it compares to historical performance in the FAATC NFS…)
        - » may require adjusting design criteria during testing progress
      - identify acceptable design criteria & recommend for certification

Overview of the Current Process

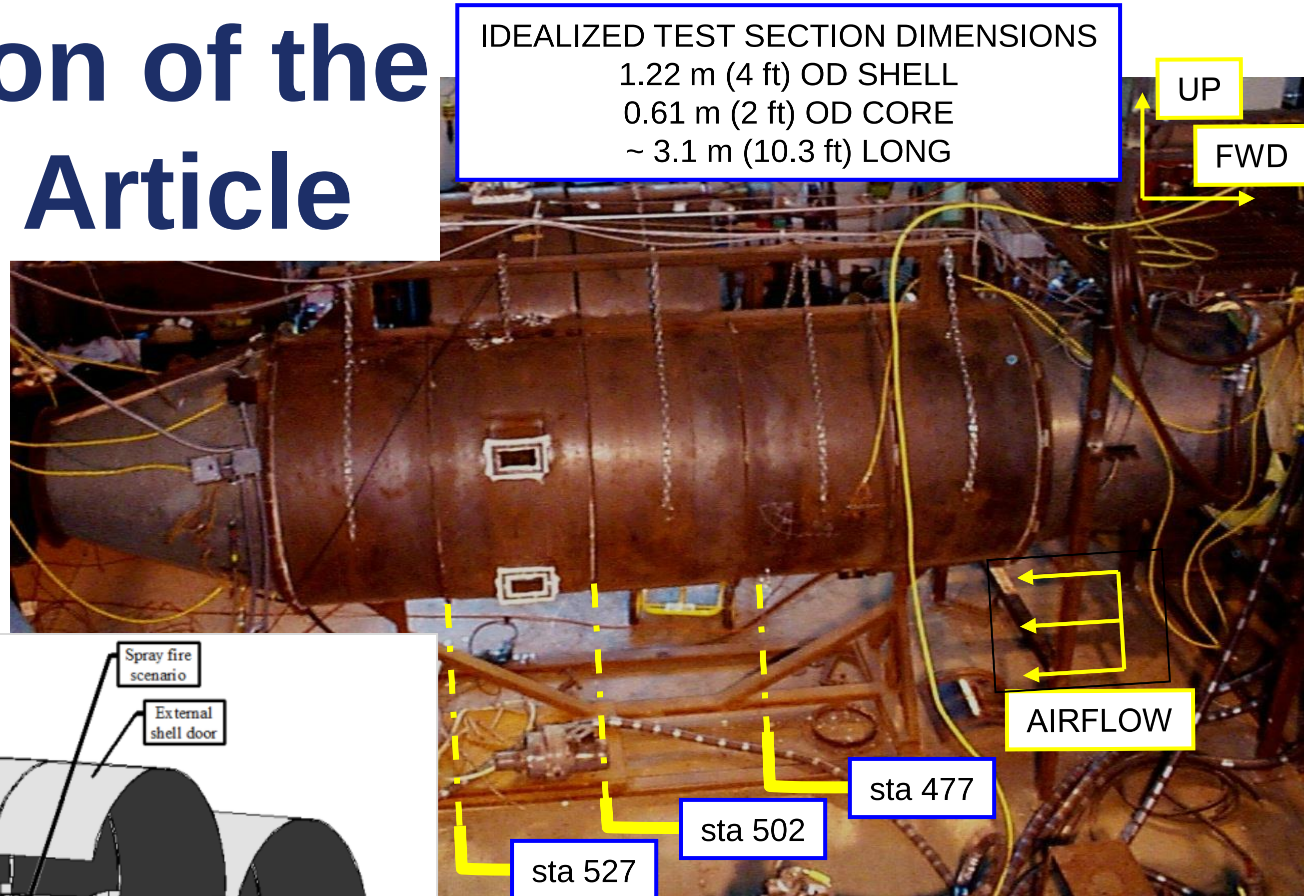
- **MPSe Testing Sequence**
  - "High"-fidelity testing (*not* always required)
    - Analogous to testing in the fire zone of an actual engine
    - Applicability
      - decision to perform lies with aviation authority
      - relates to the difference between the circumstances of the candidate and the state-of-the-art
    - A demonstration test
      - a "go/no-go" test of the design criteria recommended for certification; <u>not</u> a rework of the generic test phase…
      - conversation occurs between applicant and aviation authority
      - test conditions are defined as local circumstances dictate

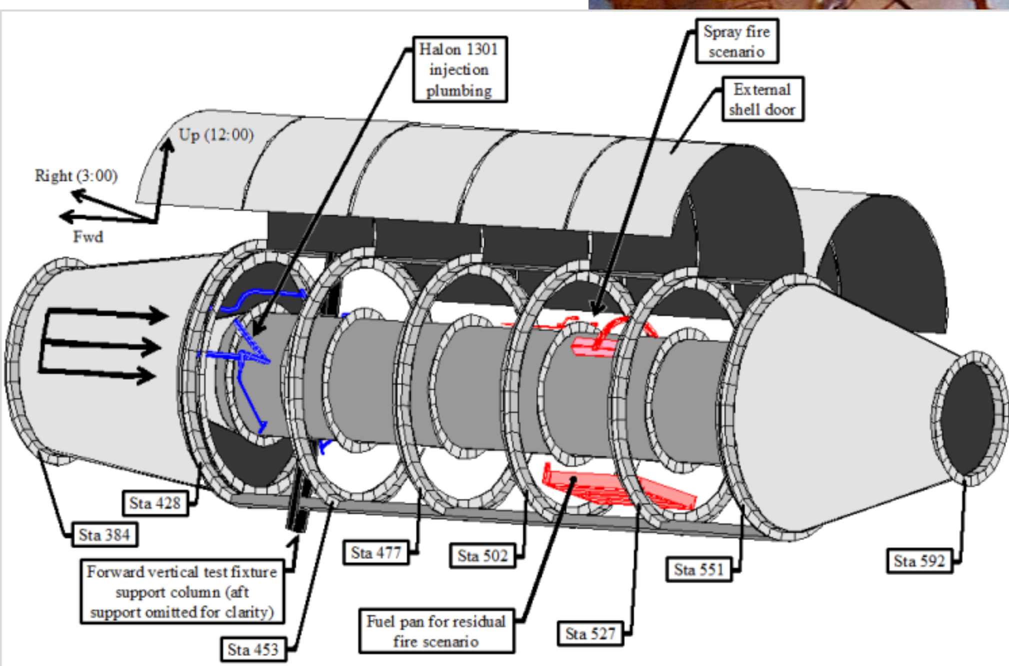
Description of the FAA Test Article

- **Multiple components**
  - Ventilation supply equipment; blower, 2 heat sources
  - Test section
    - Receives ventilation flow & firex system injection
    - Contains spray and pool fire threats
    - Internal environment constantly monitored
  - Fire extinguishing (firex) system
  - Exhaust ducting
  - Telemetry; visual and numerical data collection
- **Controlled during test from adjacent space**

Description of the FAA Test Article

- **Test section**

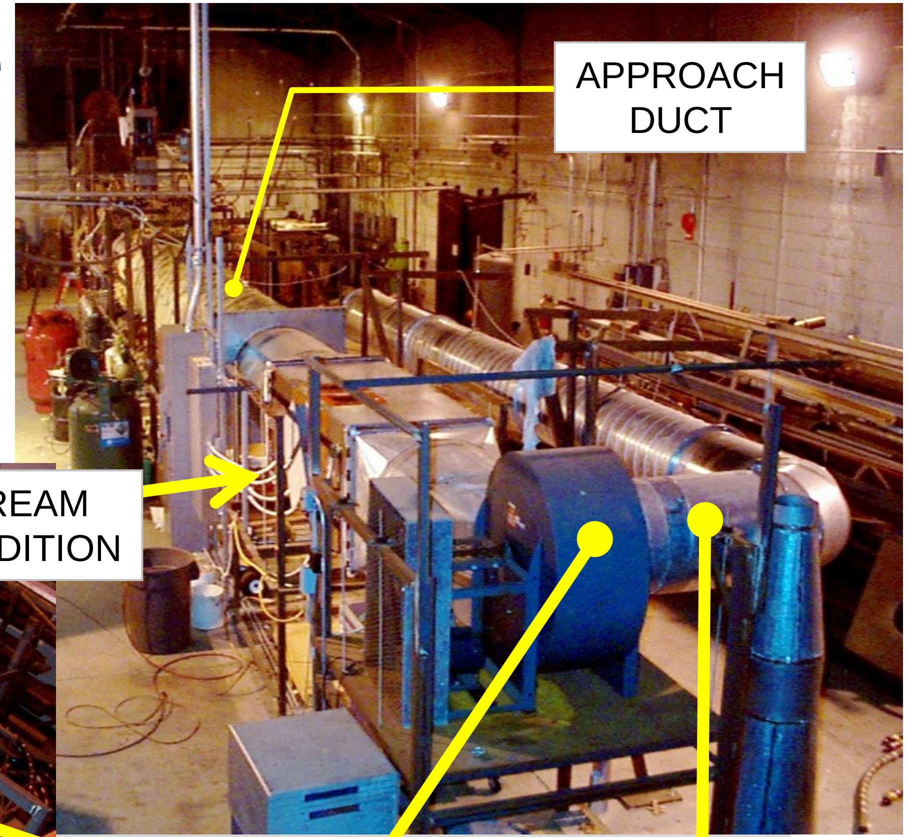


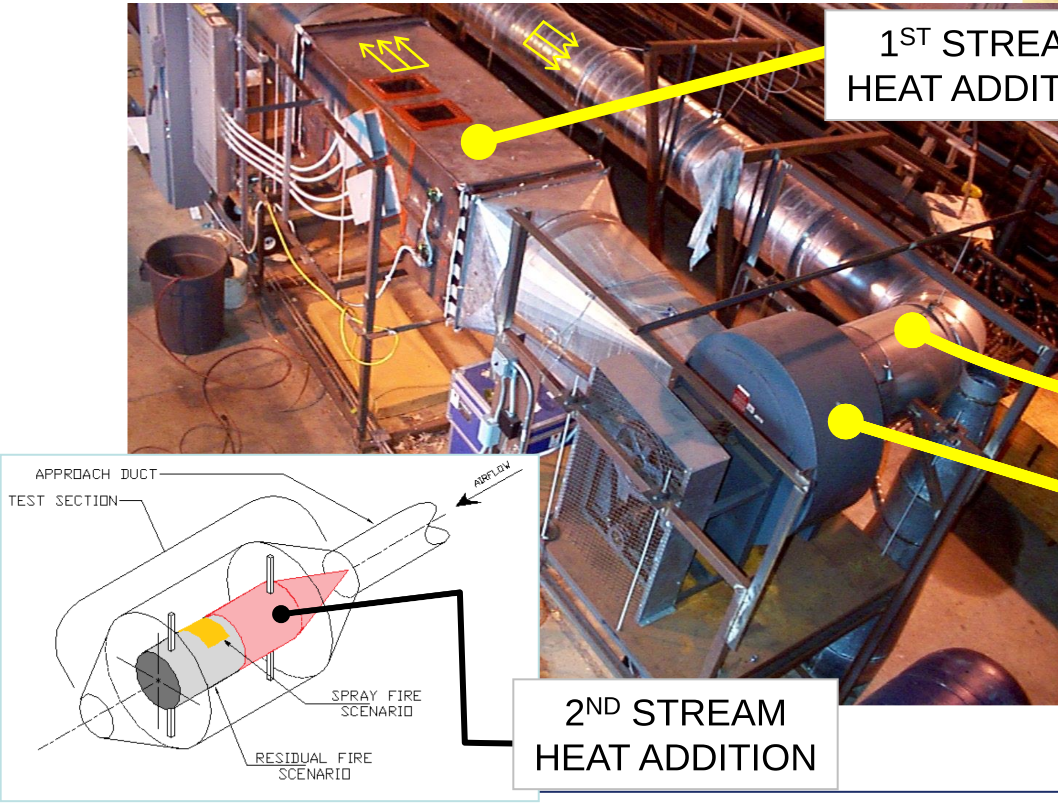


OD = outside diameter

Description of the FAA Test Article

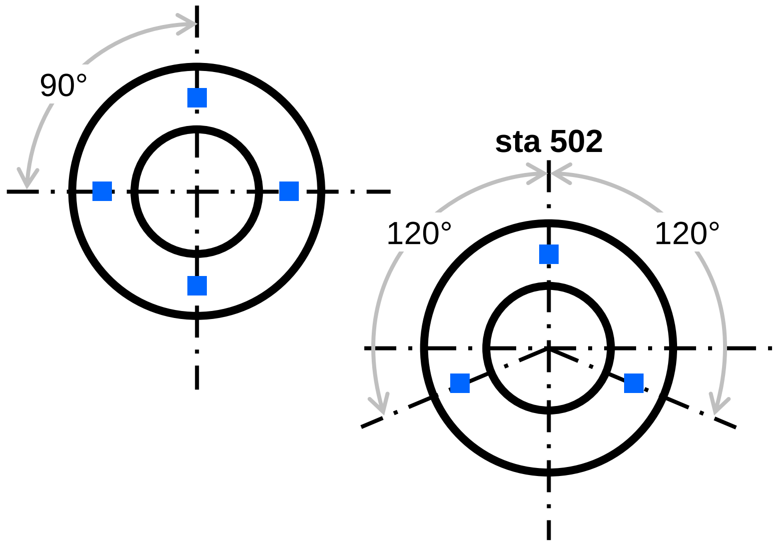
- **Ventilation supply**

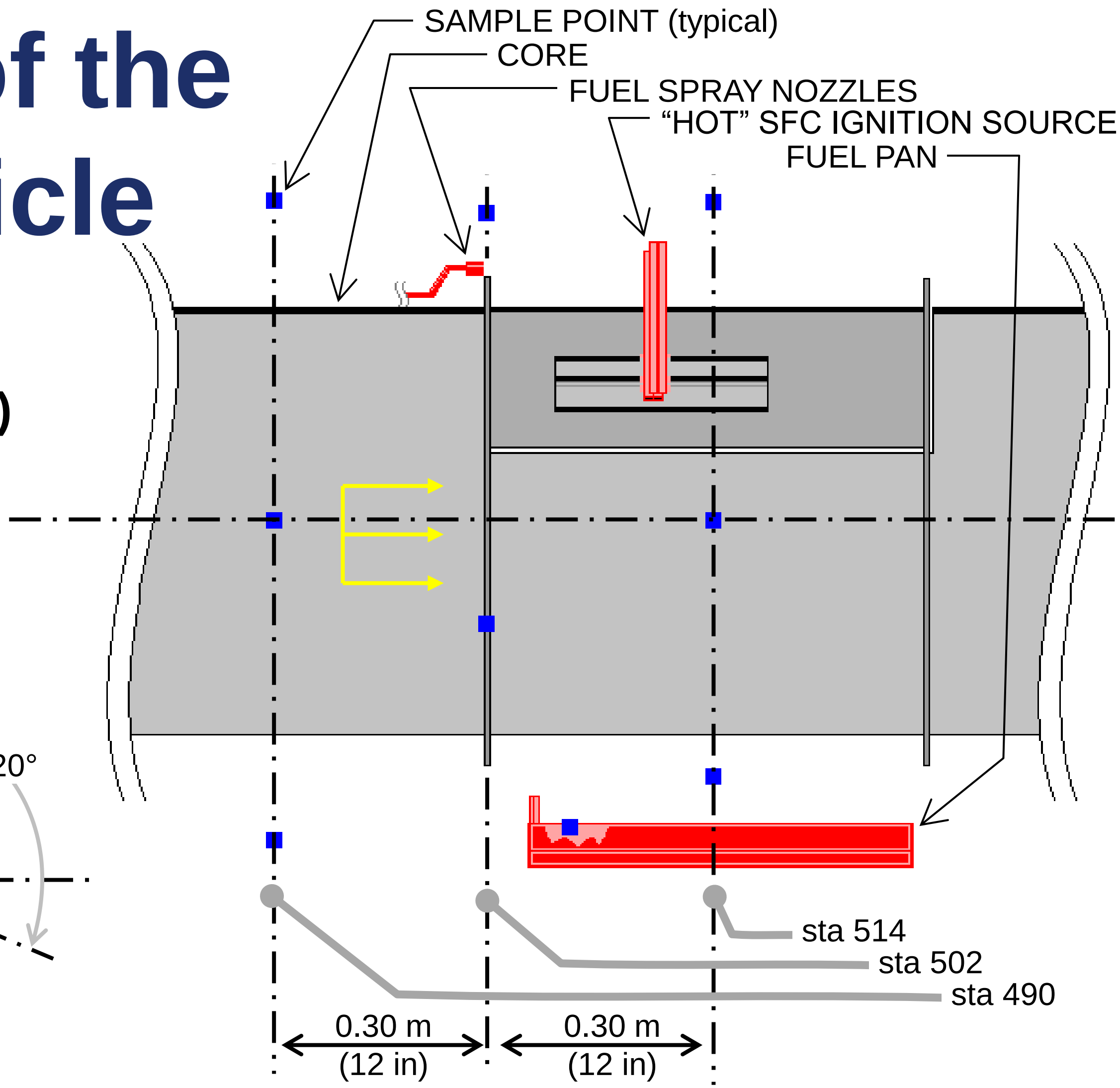




Description of the FAA Test Article

- **Firex system**
  (concentration sampling)





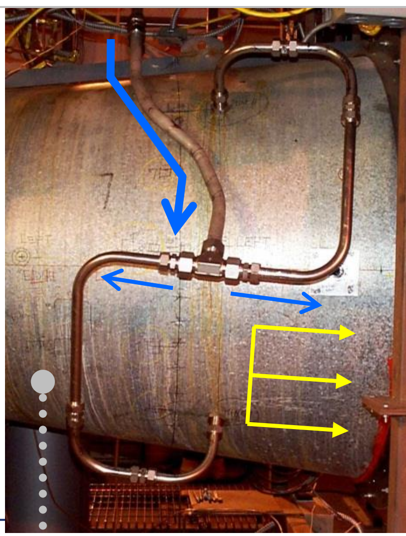
- CONCENTRIC CORE & SHELL, 0.61 m (2 ft) OD CORE, 1.2 m (4 ft) OD SHELL
- 11 SAMPLE POINTS IN "FREE" STREAM (roughly 0.15 m off core sfc)
- 12TH SAMPLE POINT IS IN THE FWD WAKE REGION OF THE FUEL PAN
- "PROTECTED" VOLUME ≈ 0.61 m LONG x 0.61 m ID x 1.2 m OD

SFC = surface
FWD = forward
ID = inside diameter

Description of the FAA Test Article

- **Firex system**
  (unit given to the FAA by the USAF)

ONE EXAMPLE, "GENERIC" INJECTION PLUMBING



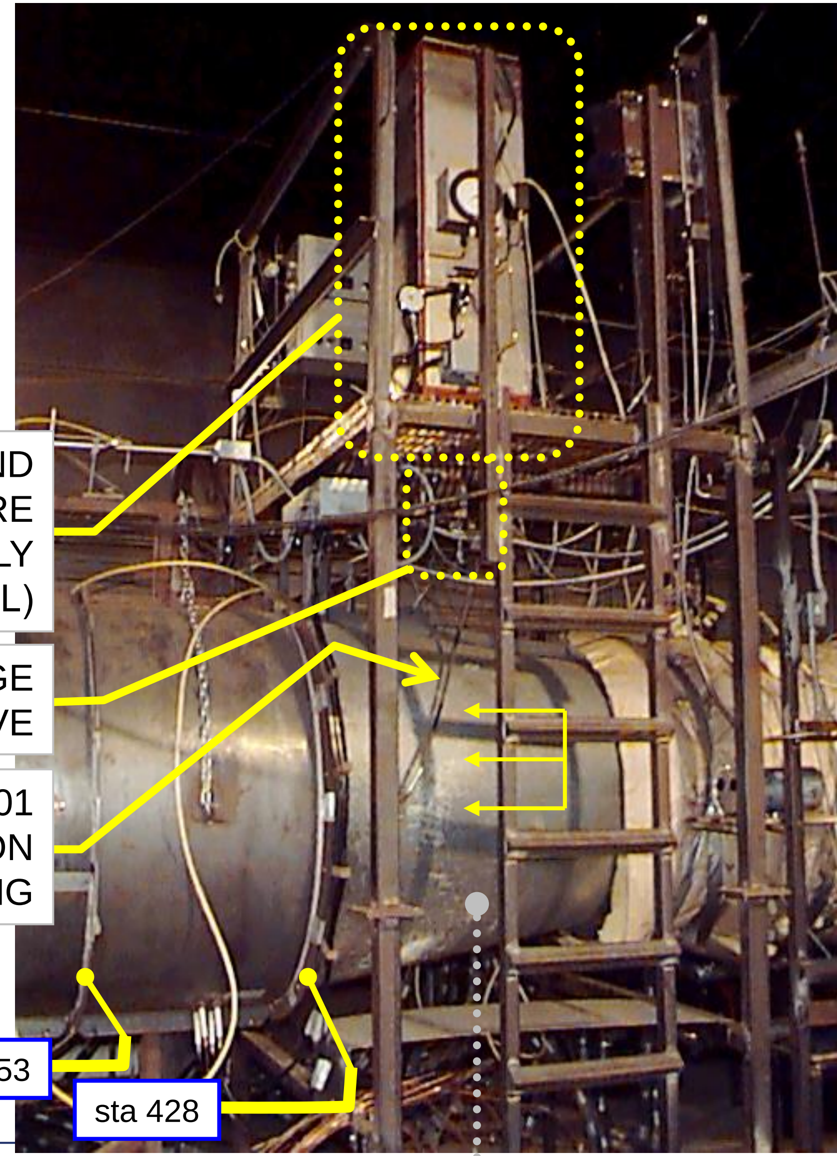
STORAGE AND CONDITIONING PRESSURE VESSEL ASSEMBLY (maximum volume ≈ 18 L)

DISCHARGE VALVE

HALON 1301 INJECTION PLUMBING

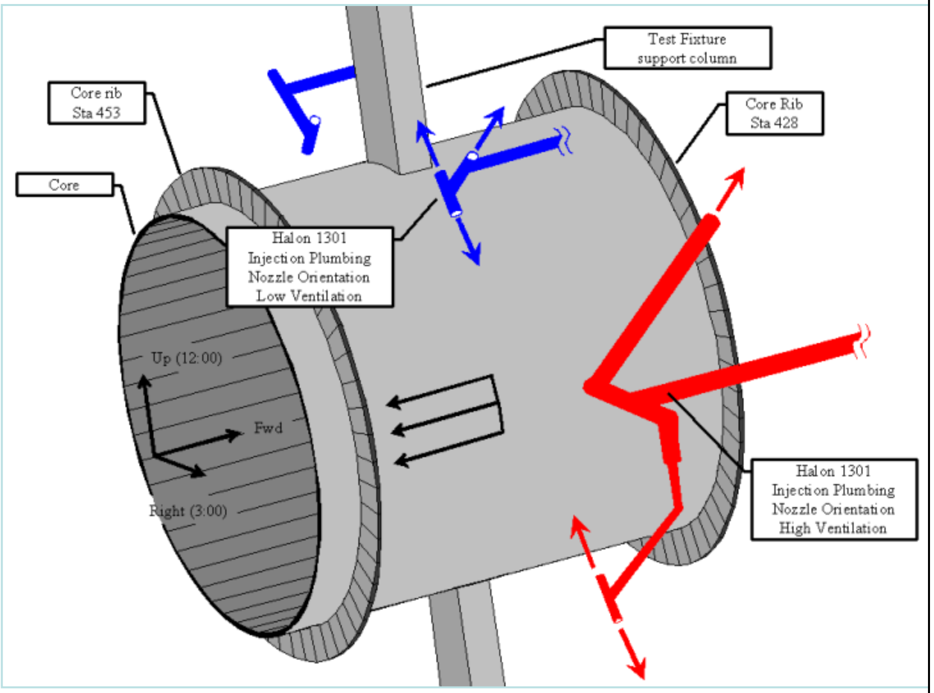
sta 453

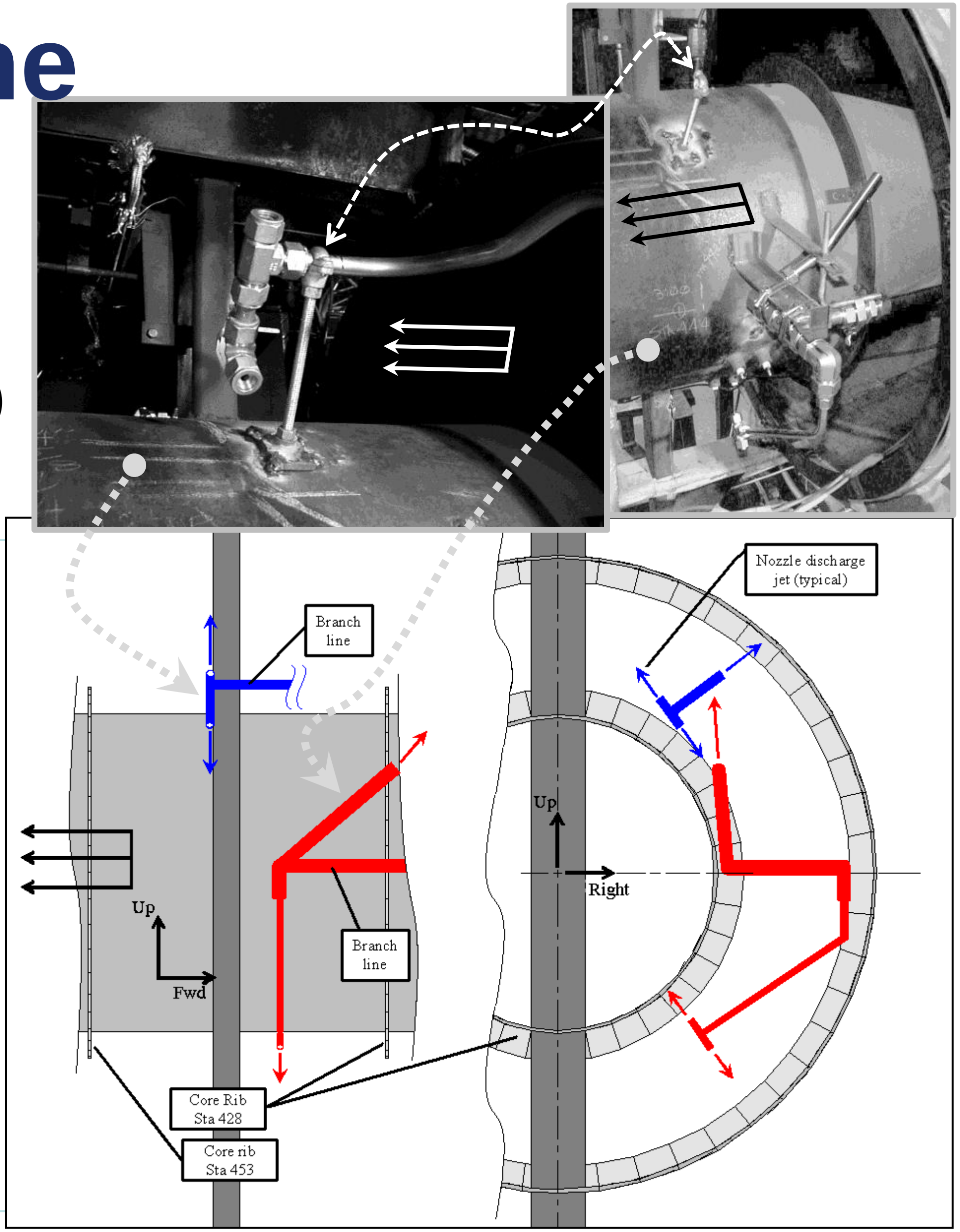
sta 428



Description of the FAA Test Article

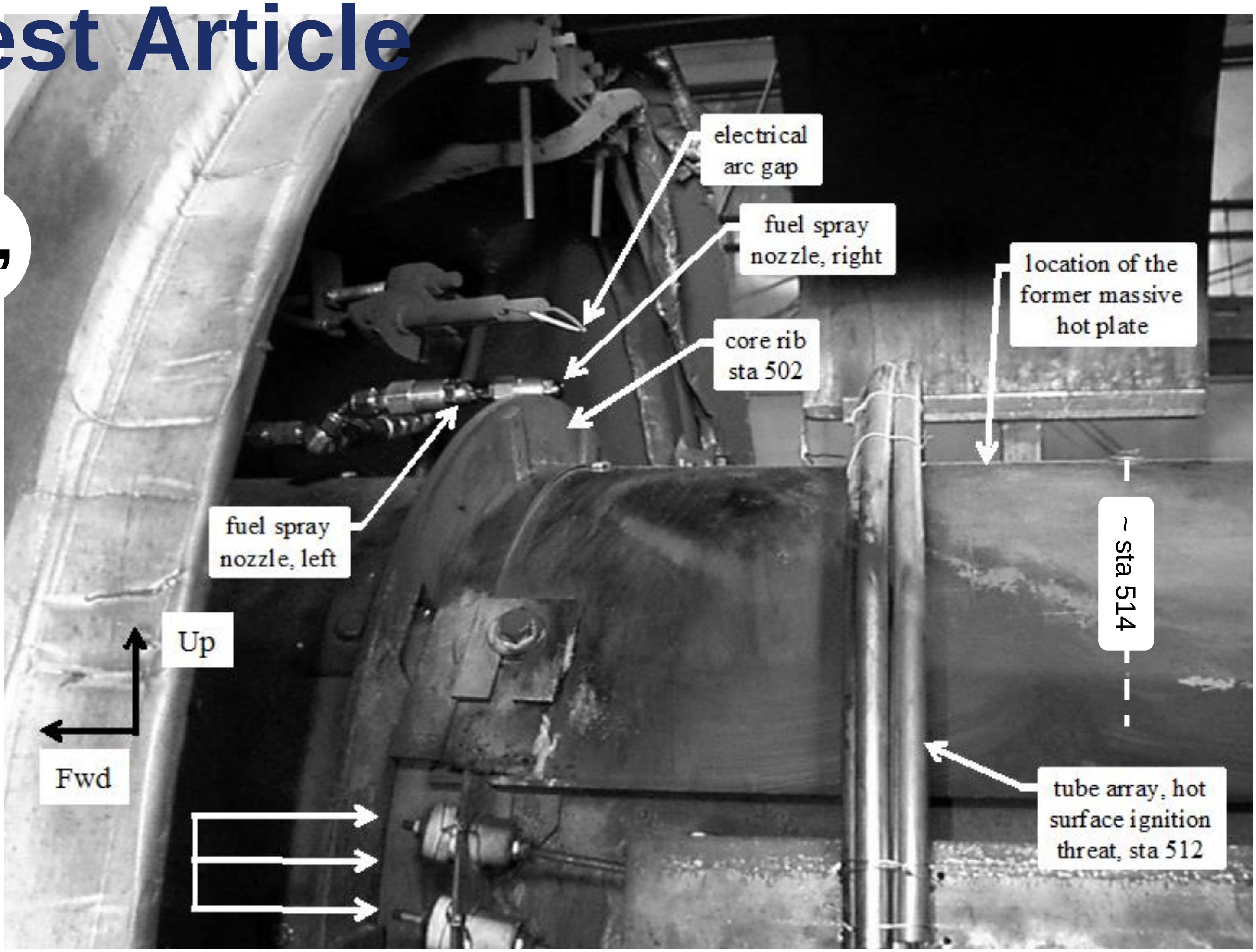
- **Firex system**
  (halon 1301 injection plumbing)





Description of the FAA Test Article

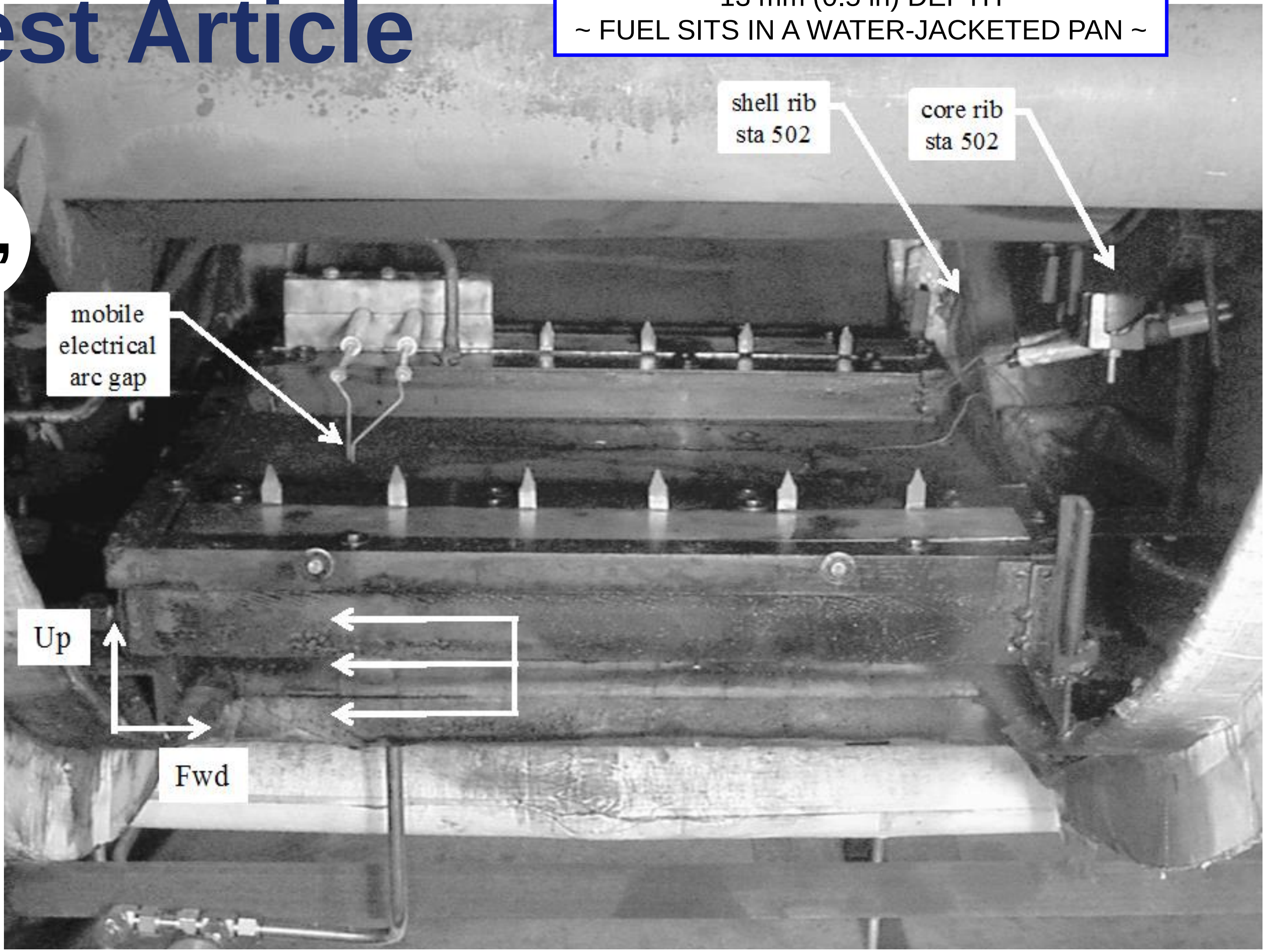
- **Test section, spray fire threat**



Description of the FAA Test Article

- **Test section, pool fire threat**

IDEALIZED FUEL PUDDLE DIMENSIONS
27.4 cm (10.8 in) WIDTH
52.8 cm (20.8 in) LENGTH
13 mm (0.5 in) DEPTH
~ FUEL SITS IN A WATER-JACKETED PAN ~



Referable Information

1. http://www.fire.tc.faa.gov/systems/engine/engine.stm
2. http://www.fire.tc.faa.gov/systems.asp
3. http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/22046
4. FAA program, "Halon Replacement Performance Testing", Federal Register, June 17, 1993, pp. 33477-33481.
5. Bennett, J.M., Bennett, M.V., 1999, "Aircraft Engine/APU Fire Extinguishing System Design Model (HFC-125)," Report No. AFRL-VA-WP-TR-1999-3068, Air Force Research Laboratory and Booz, Allen, and Hamilton, Incorporated, Wright Patterson Air Force Base, OH; available from http://www.fire.tc.faa.gov/pdf/systems/designguide.pdf
6. Further identifying the replacement candidates worked with
   name in presentation : a chemical name, chemical formula, molecular weight, example of a product name
   HFC-125 : pentafluoroethane, C_2HF_5, 120.02 g/mol, DuPont FE-25
   CF3I : iodotrifluoromethane, CF_3I, 195.91 g/mol, not known
   2-BTP : 2-bromotrifluoropropene, $C_3H_2BrF_3$, 174.95 g/mol, not known
   FK-5-1-12 : dodecafluoro-2-methylpentan-3-one, $C_6F_{12}O$, 316.04 g/mol, 3M Novec 1230
   KSA : sodium bicarbonate, $NaHCO_3$, 84.007 g/mol, Kidde Aerospace KSA
7. http://www.fire.tc.faa.gov/pdf/systems/MPSErev04_MPSeRev04doc-02submtd.pdf