Federal Aviation Administration

Engine Nacelle Halon Replacement

Presented to:	International Aircraft Systems Fire Protection Working Group
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Presentation Overview
Major Discussion Points

- **The “MPSe rev03 to rev04” Transition**
  - Overview & Status
- **Flow Visualization in a Small-Scale Wind Tunnel**
  - Work accomplished for qualitative purpose
  - Providing pictures of tube array & fuel pan lip wake regions
- **Gas Analysis in the Nacelle Fire Simulator**
  - Work accomplished for quantitative purpose
  - Outcomes show a certain MPSe modification is permissible
- **Thermal Characterization of the NFS Fires**
  - Test fixture modifications underway
  - Providing pictures & brief description

MPSe Rev 03 → 04, Overview

- **Issues driving the test process revision**
  - Terminating the use of halon 1301 in the test process
  - General characteristics for halon-replacing fire suppressants are becoming more unlike halon 1301
    - Fire suppressants are becoming more like “streaming” agents, as indicated by the trend of increasing normal boiling points
    - Liquid & solid aerosols appear to offer solutions
  - Must degrade confusing effects occurring during the assessment of an “equivalent” amount of a fire suppressant in a nacelle fire simulator (NFS)

MPSe Rev 03 → 04, Overview

Terminating Halon 1301 Usage

- **Modify the halon 1301 benchmark process**
  - A surrogate will replicate the flame extinction behavior of halon 1301 for certain test conditions
  - Surrogate = HFC-125
- **Thermally characterize fire threats**
  - Benchmark process may be dropped in the future
  - Energy release will be measured "globally" via a "control volume" while invoking symmetry logic
    - Air-sensing thermocouples
    - "Heat flux" plates

MPSe Rev 03 ➔ 04, Overview

Degrading the Negative Impacts on Assessment

- **Modify test process**
  - Change from an iterative search to a proof-test
  - Requires preliminary testing to produce an identified suppressant delivery for the 2 NFS ventilation conditions
- **Review suppressant measurement rationale**
  - Investigate with flow testing at small- & large-scale
  - Perhaps revise measurement concept when considering :
    - Trends for the characteristics of halon-replacing fire suppressants
      - MPSe rev03 → based solely on free-stream measurement
      - Wake region measurement provides a "total-flood" challenge
      - Rev04 → plan to incorporate some wake region measurements
    - Outcomes from flow observations

MPSe Rev 03 → 04, Status

- **Items Completed**
  - Small-scale flow visualizations
  - Large-scale flow observations
- **Remaining tasks are in-process**
  - HFC-125 surrogate validation; testing begins momentarily
  - Modify test fixture for thermal characterization; underway
  - Administrative considerations for MPSe rev04; underway
    - Altering test process flow
    - Define additional alterations based on flow observation outcomes
    - Define surrogate benchmark processes
    - Author the draft document
    - Attain an accepted final draft

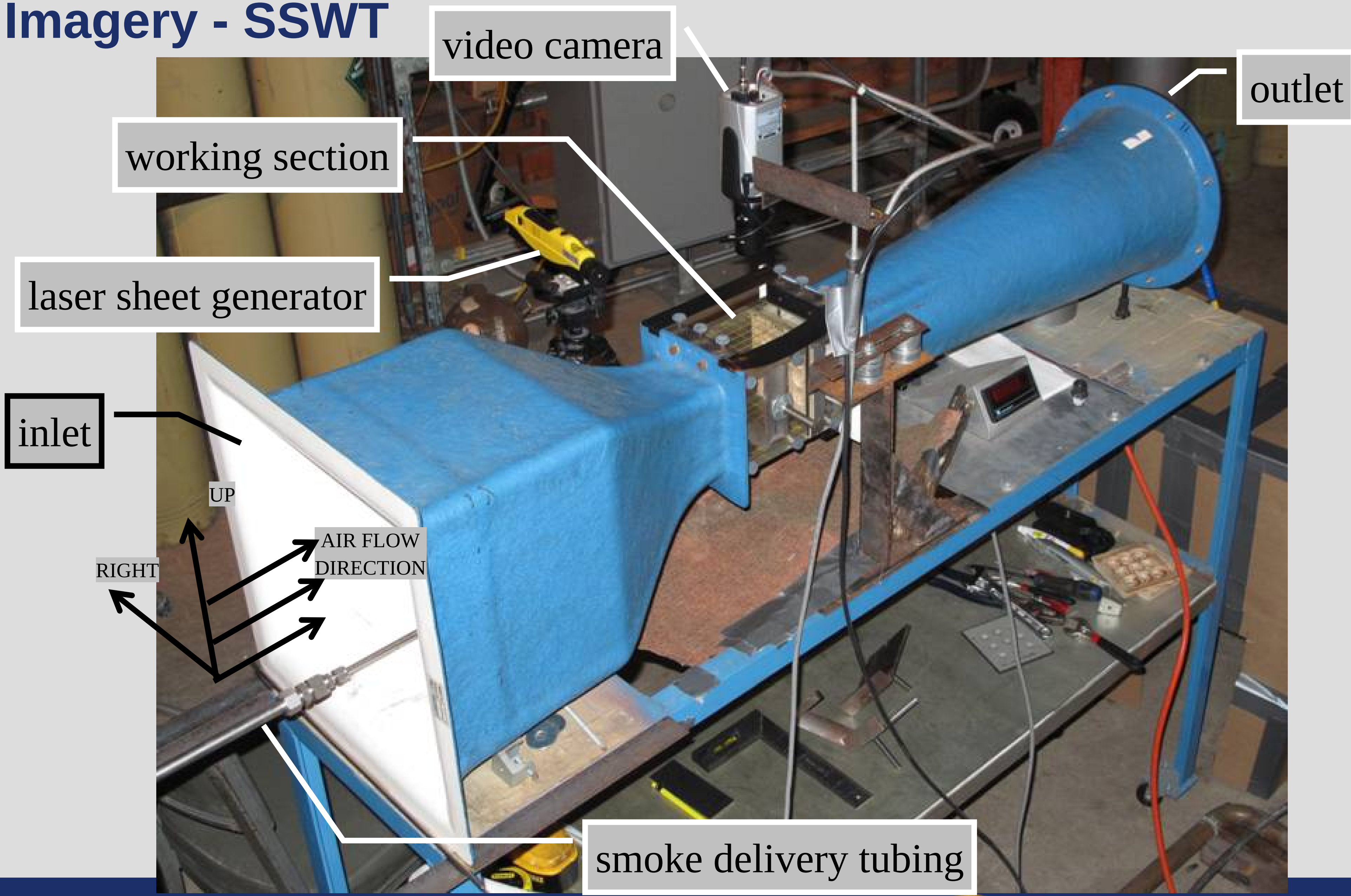
Flow visualization, Small-Scale Wind Tunnel

Overview

- **Utilizing a small-scale wind tunnel (SSWT) to visualize wake regions**
  - Wake regions challenge fire suppressant distribution & relate to flame behavior
  - Observations guide choice of NFS sample point locations
- **SSWT details**
  - Suction tunnel; speeds up to 50 ft/sec (15.2 m/sec)
  - Working section 4 x 4 x 7.5 inches (102 x 102 x 191 mm)
  - Used 2 aerodynamic models; tube array & fuel pan lip
  - Delivered smoke to visualize flow near models
  - Red laser sheet illuminates horizontal planes

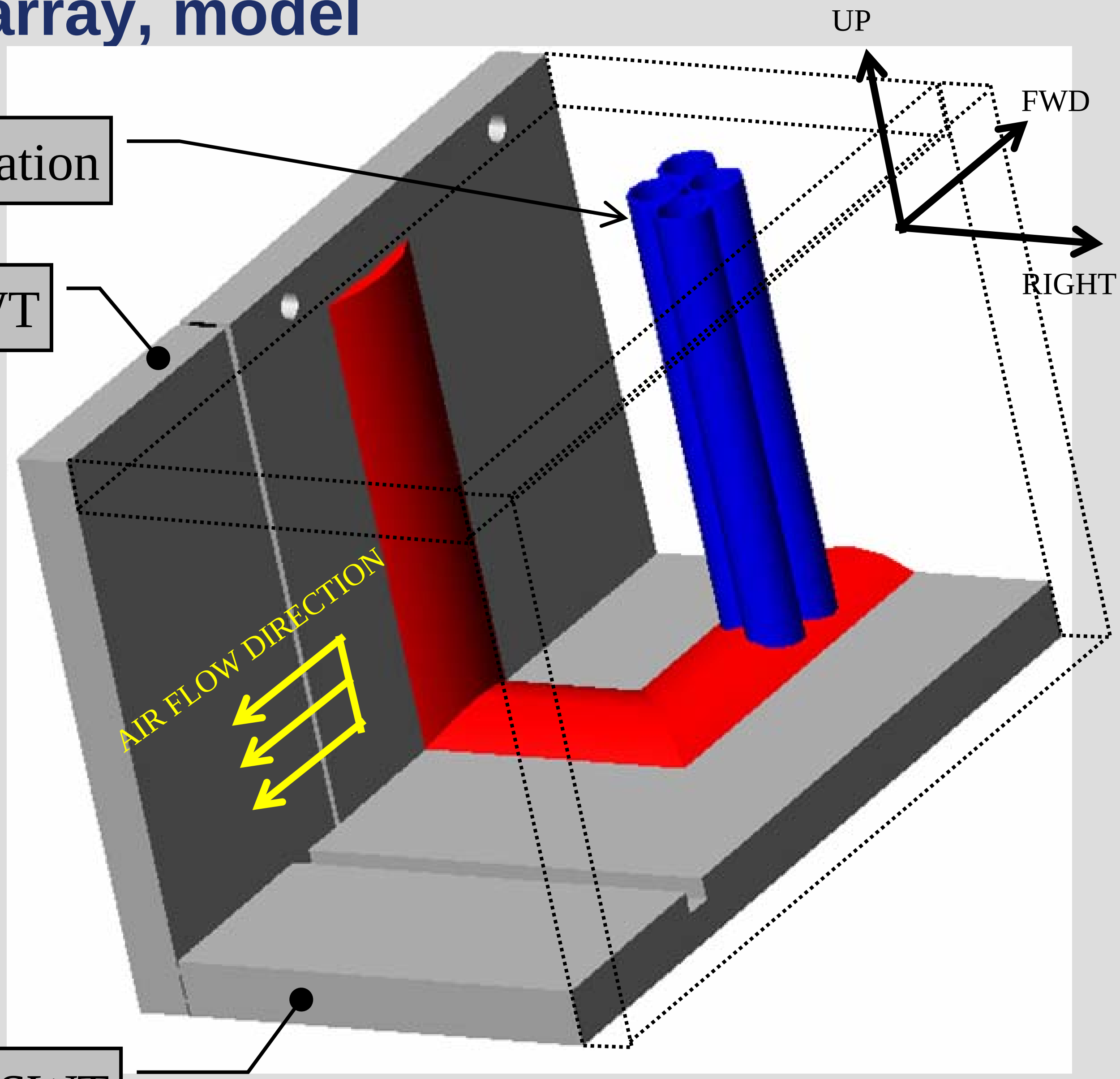
Flow visualization, Small-Scale Wind Tunnel

Imagery - SSWT



Flow visualization, Small-Scale Wind Tunnel

Imagery - SSWT, tube array, model

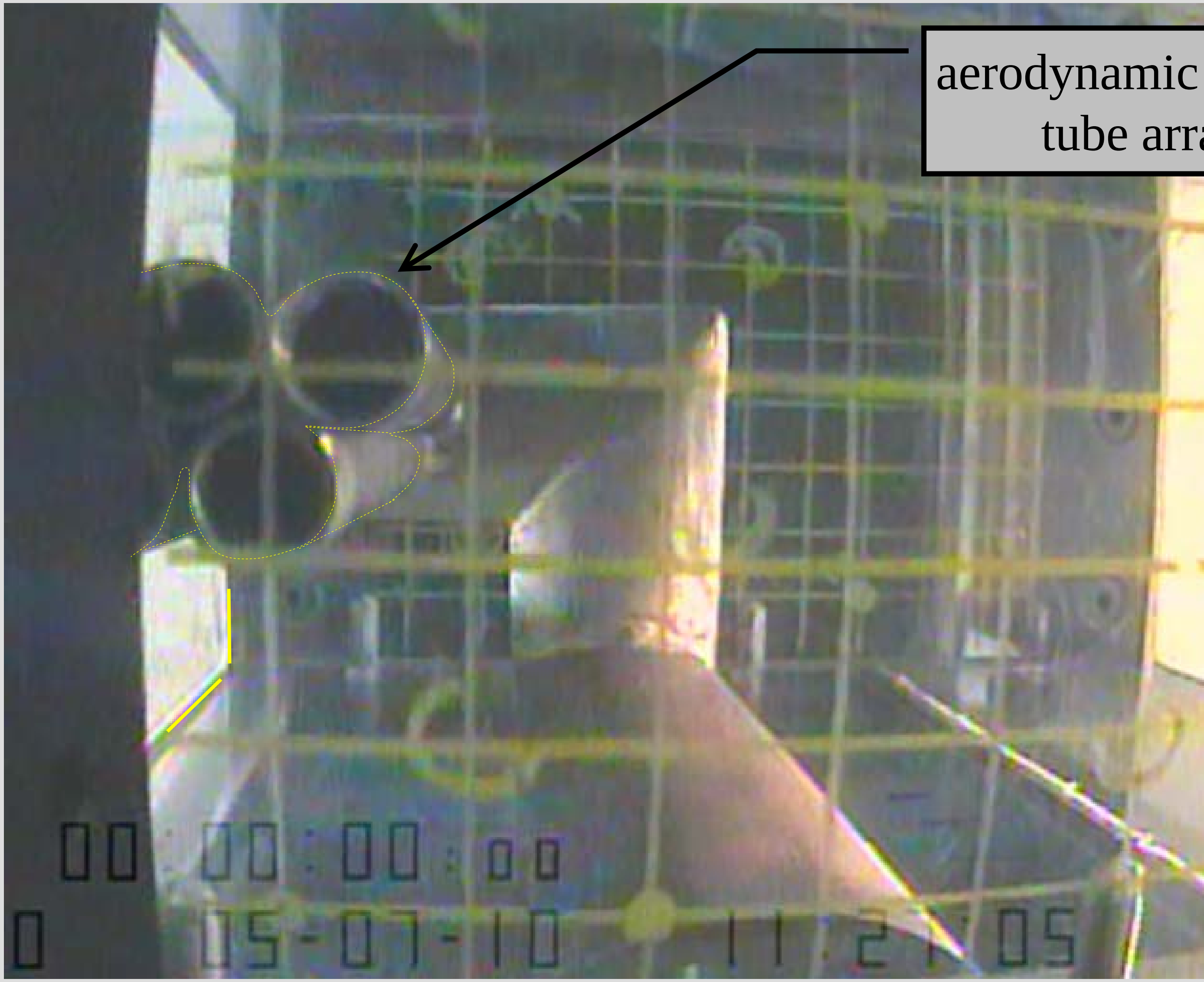


Flow visualization, Small-Scale Wind Tunnel

Imagery - SSWT, tube array, orientation

RIGHT

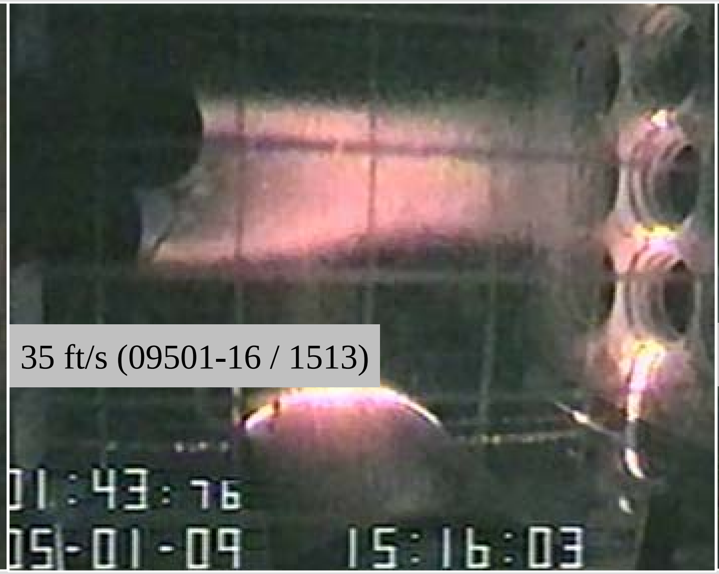
FWD



Flow visualization/t, Small-Scale Wind Tunnel

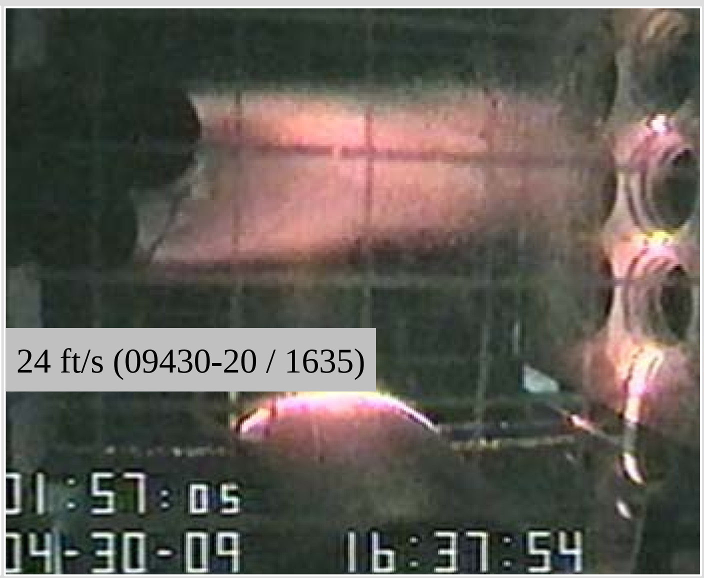
Imagery - SSWT, tube array, smoke visualizations


3 ft/s (09430-15 / 1435)


35 ft/s (09501-16 / 1513)


35 ft/s (09506-14 / 1332)

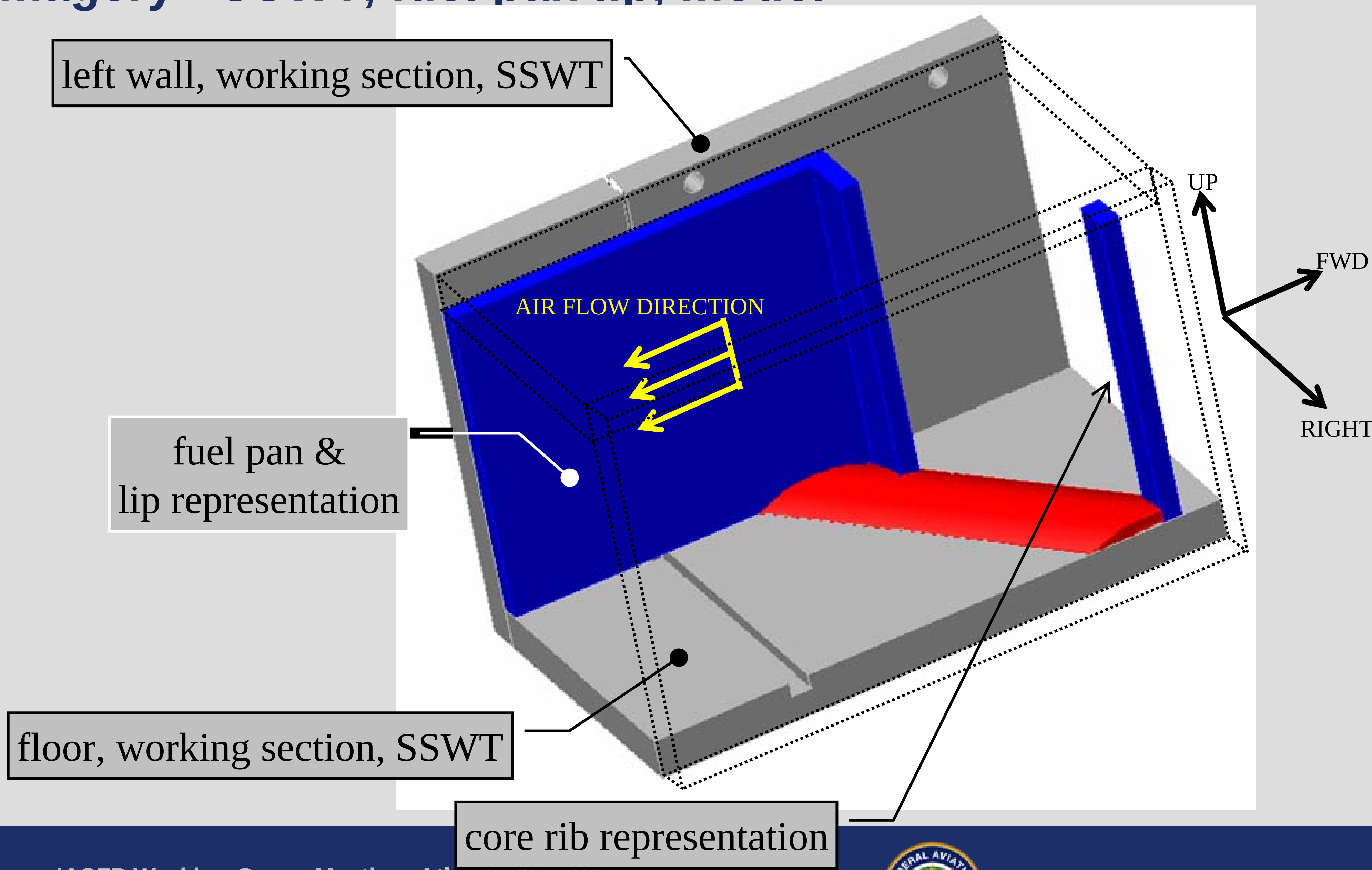

7 ft/s (09501-17 / 1533)


24 ft/s (09430-20 / 1635)


47 ft/s (09506-18 / 1517)

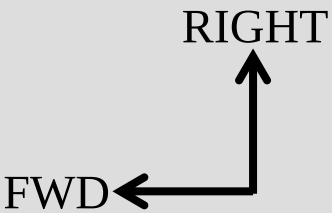
Flow visualization, Small-Scale Wind Tunnel

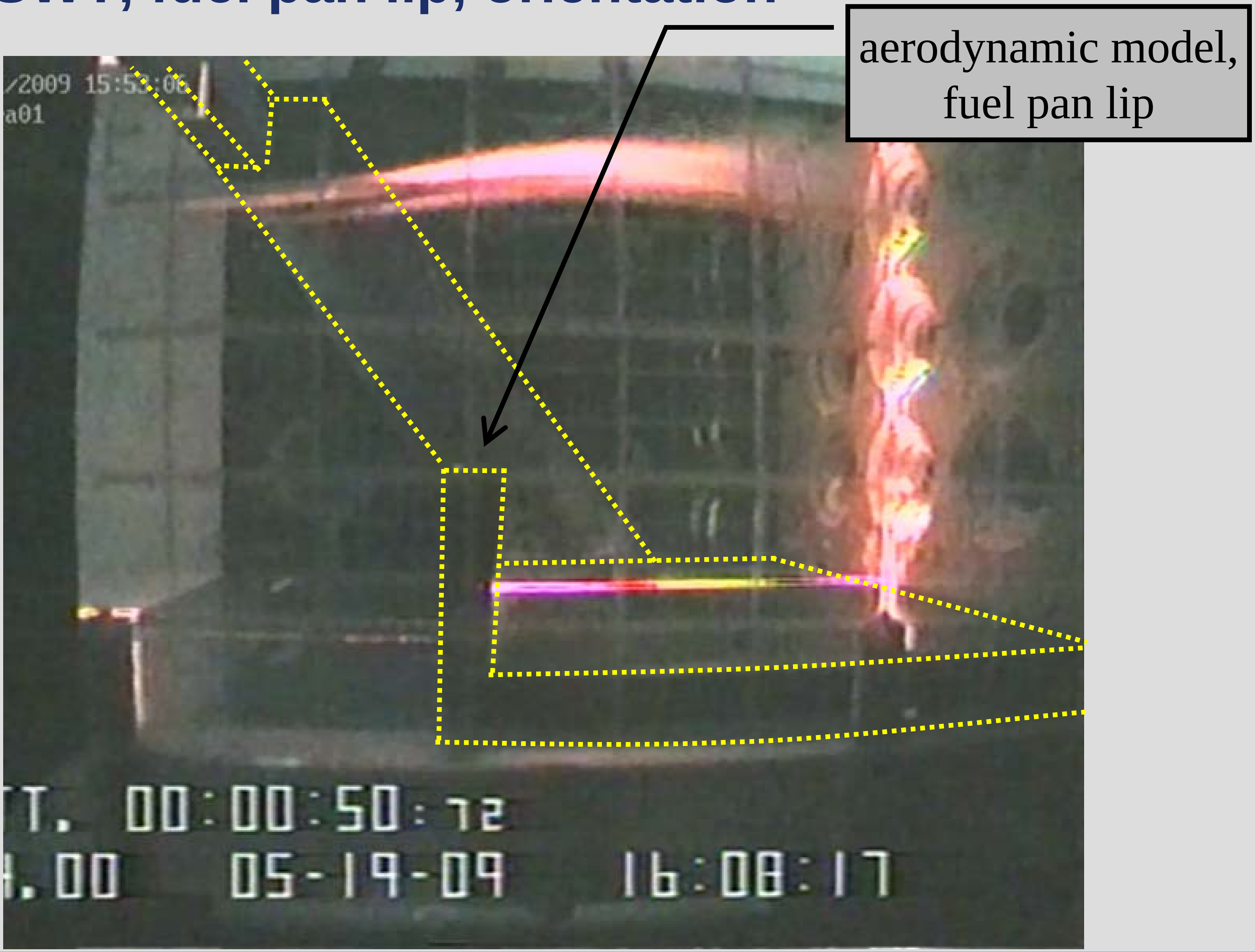
Imagery - SSWT, fuel pan lip, model



Flow visualization, Small-Scale Wind Tunnel

Imagery - SSWT, fuel pan lip, orientation





Flow visualization/I, Small-Scale Wind Tunnel

Imagery - SSWT, fuel pan lip, smoke visualizations

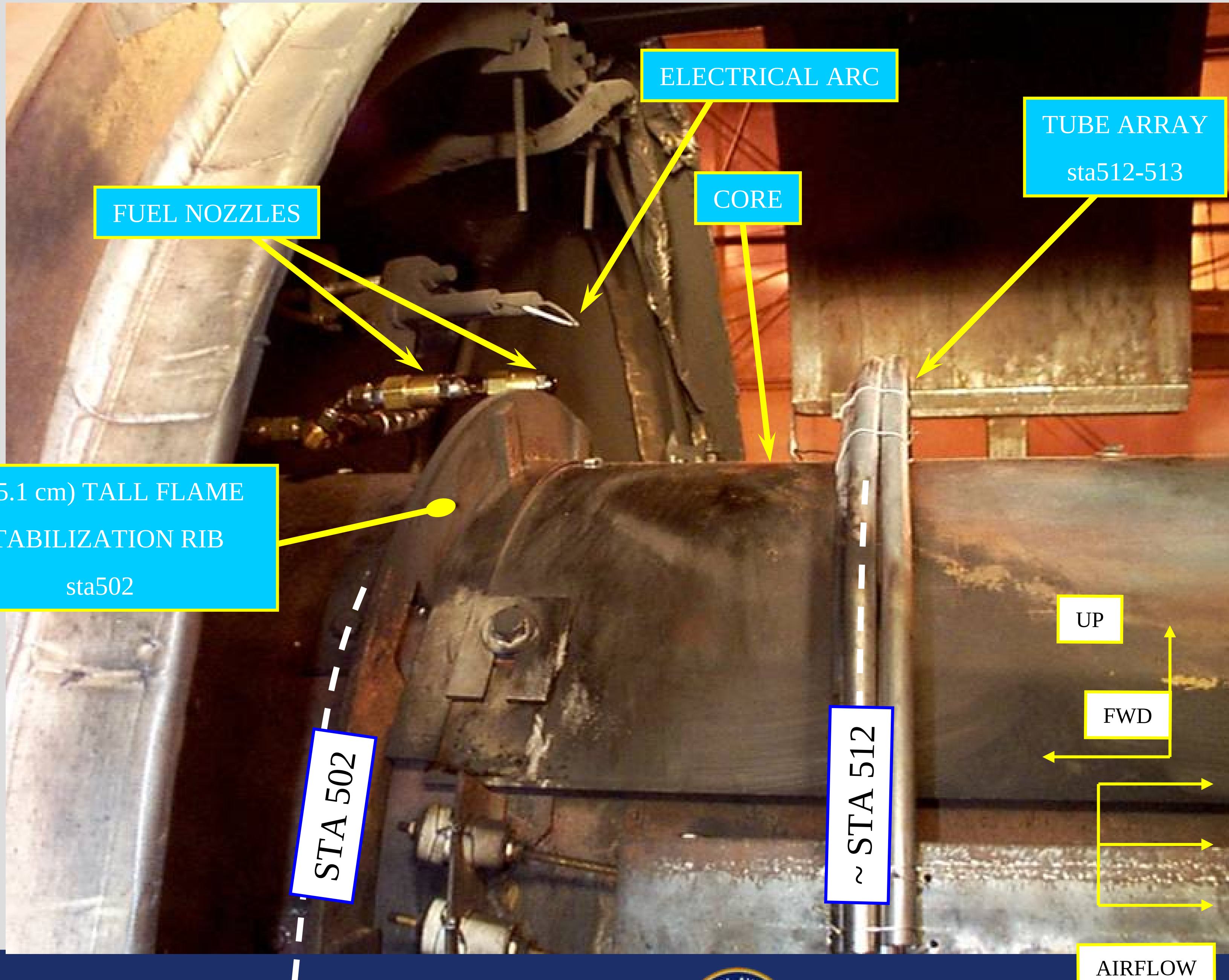
Gas Analysis in the NFS
Overview

- **Investigated sample point placement in the NFS**
  - Purpose?
    - Retain/reinforce “total-flood” concept related to this application
      - “Total flood” fire suppressant protects nacelle fire zone
      - FAA certification is accomplished accordingly
    - To reasonably improve the existing challenge for ANY fire suppressant without breaking historical link to existing work
  - Performed testing with halon 1301, HFC-125, & CF_3I
    - Applied SSWT/visualization outcomes to the NFS work
    - Placed hot-wire anemometers (HWAs) & gas sample points in free-stream & wake regions
    - Used 12 sample points, via 1/8 inch (3 mm) OD x 12 foot (3.7 m) long sample lines

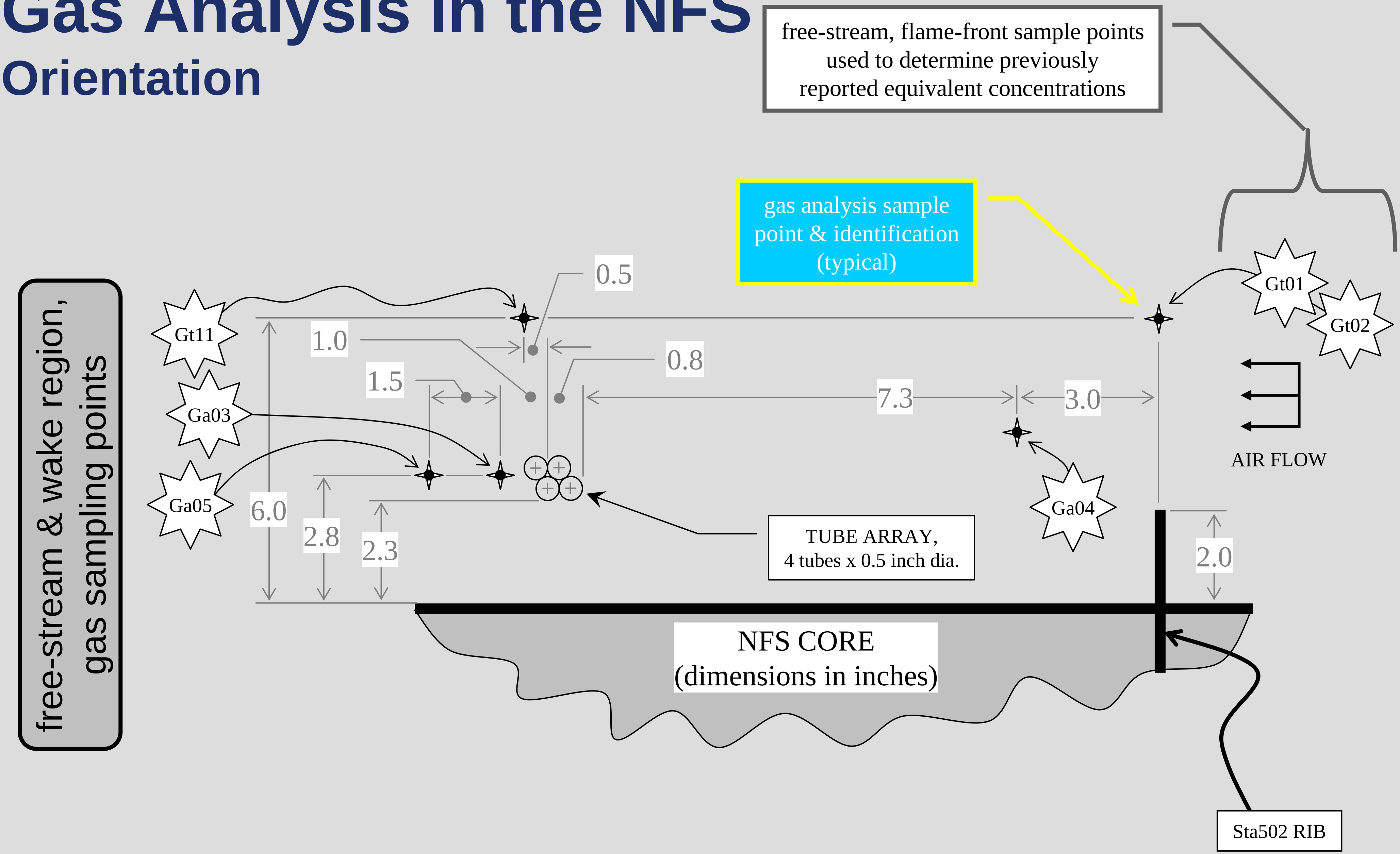
Gas Analysis in the NFS

Orientation

spray fire threat



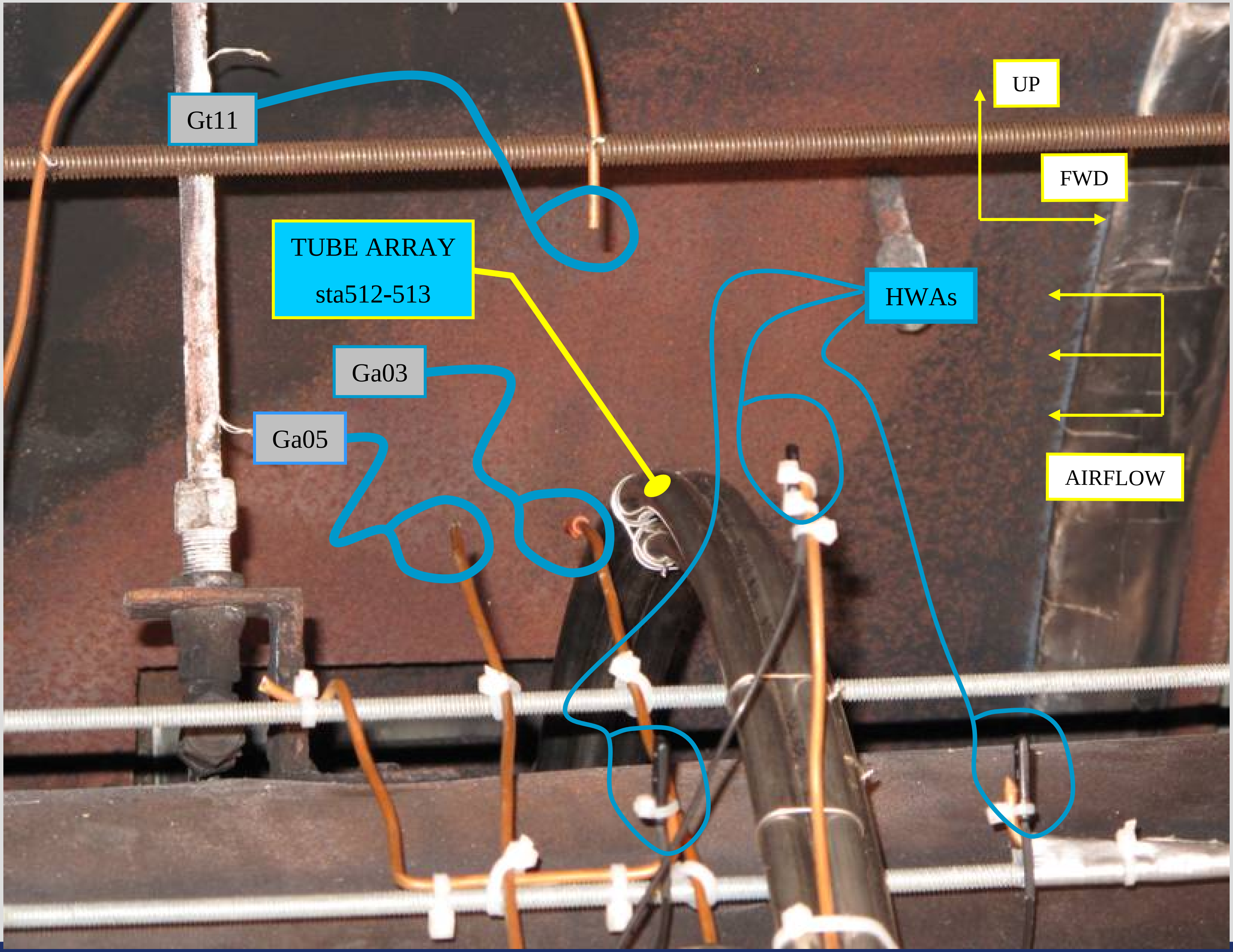
Gas Analysis in the NFS
Orientation



Gas Analysis in the NFS

Orientation

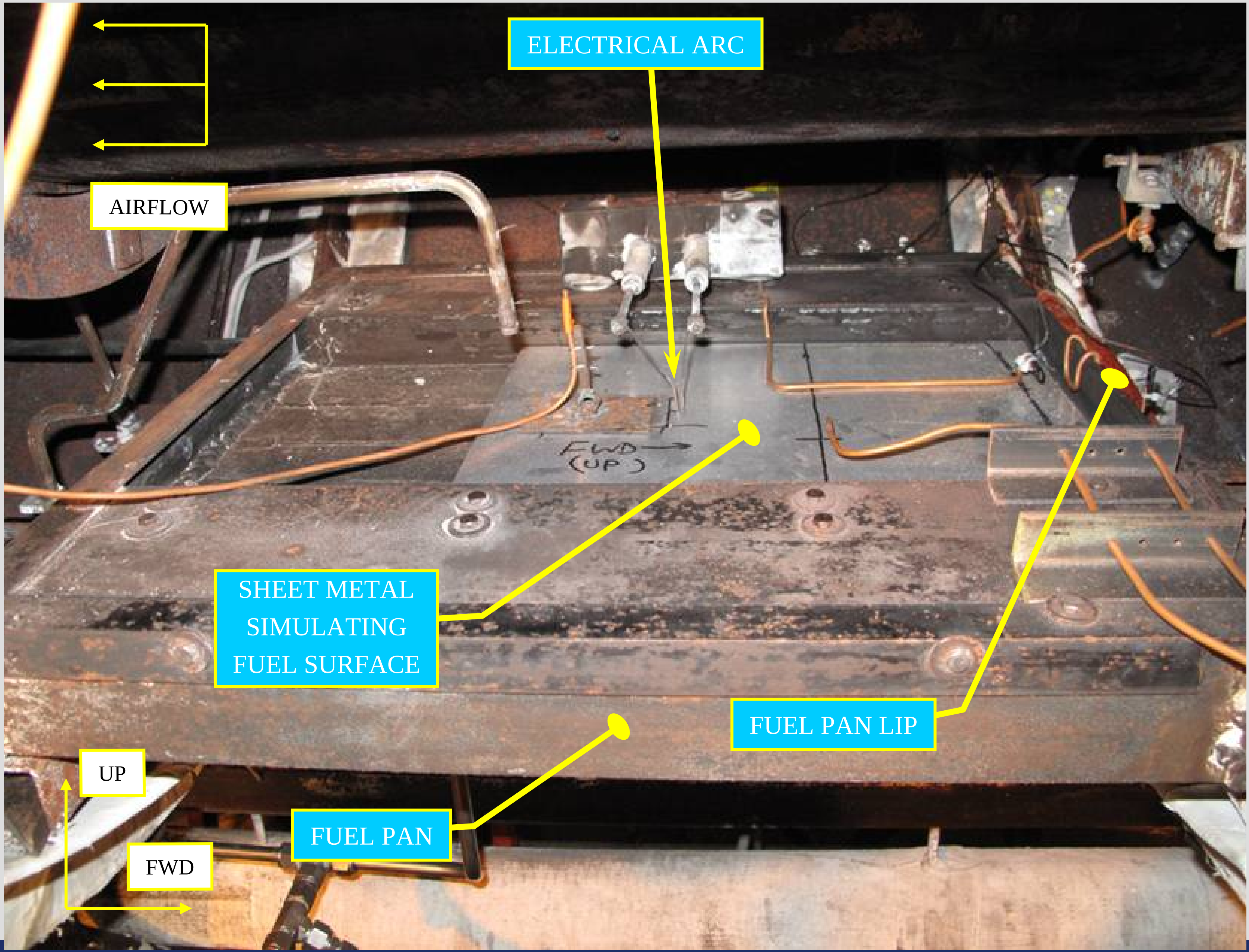
free-stream & wake region,
gas sampling points



Gas Analysis in the NFS

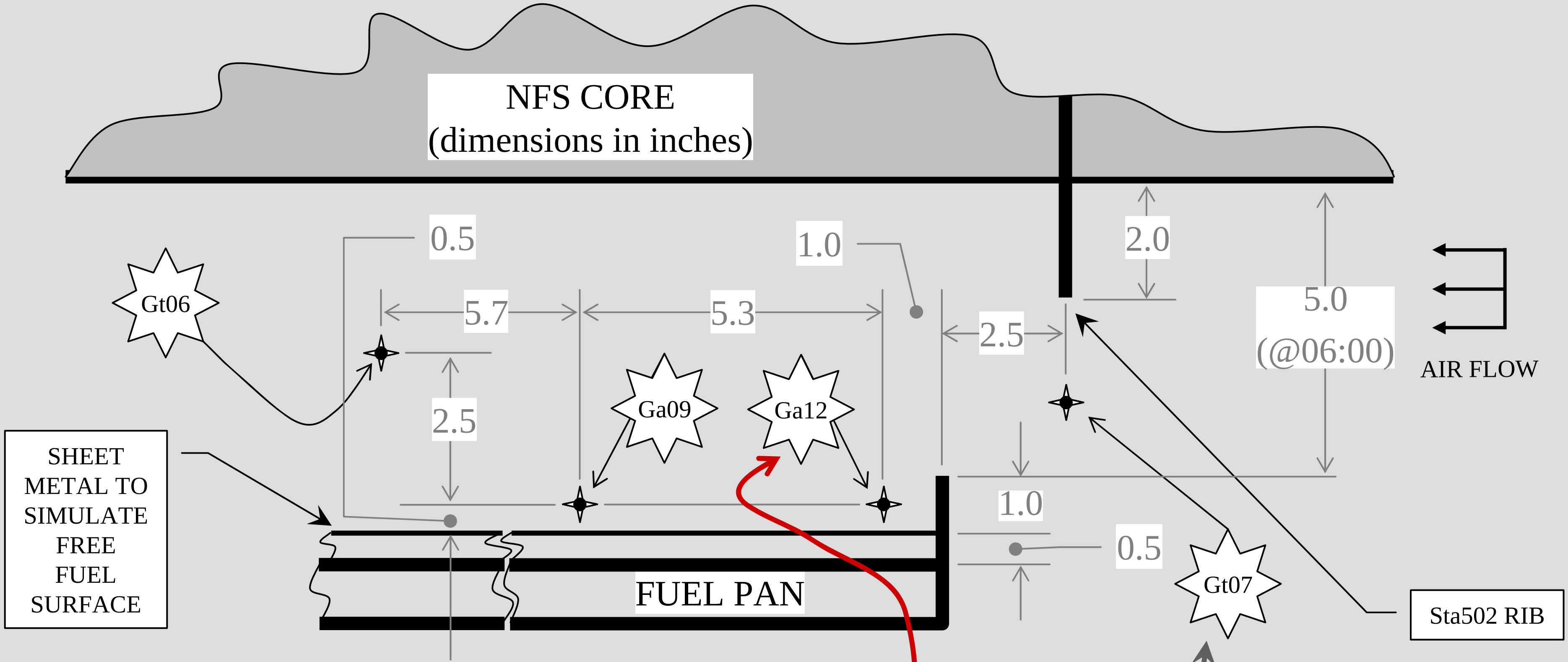
Orientation

pool fire threat



Gas Analysis in the NFS
Orientation

free-stream & wake region, gas sampling points



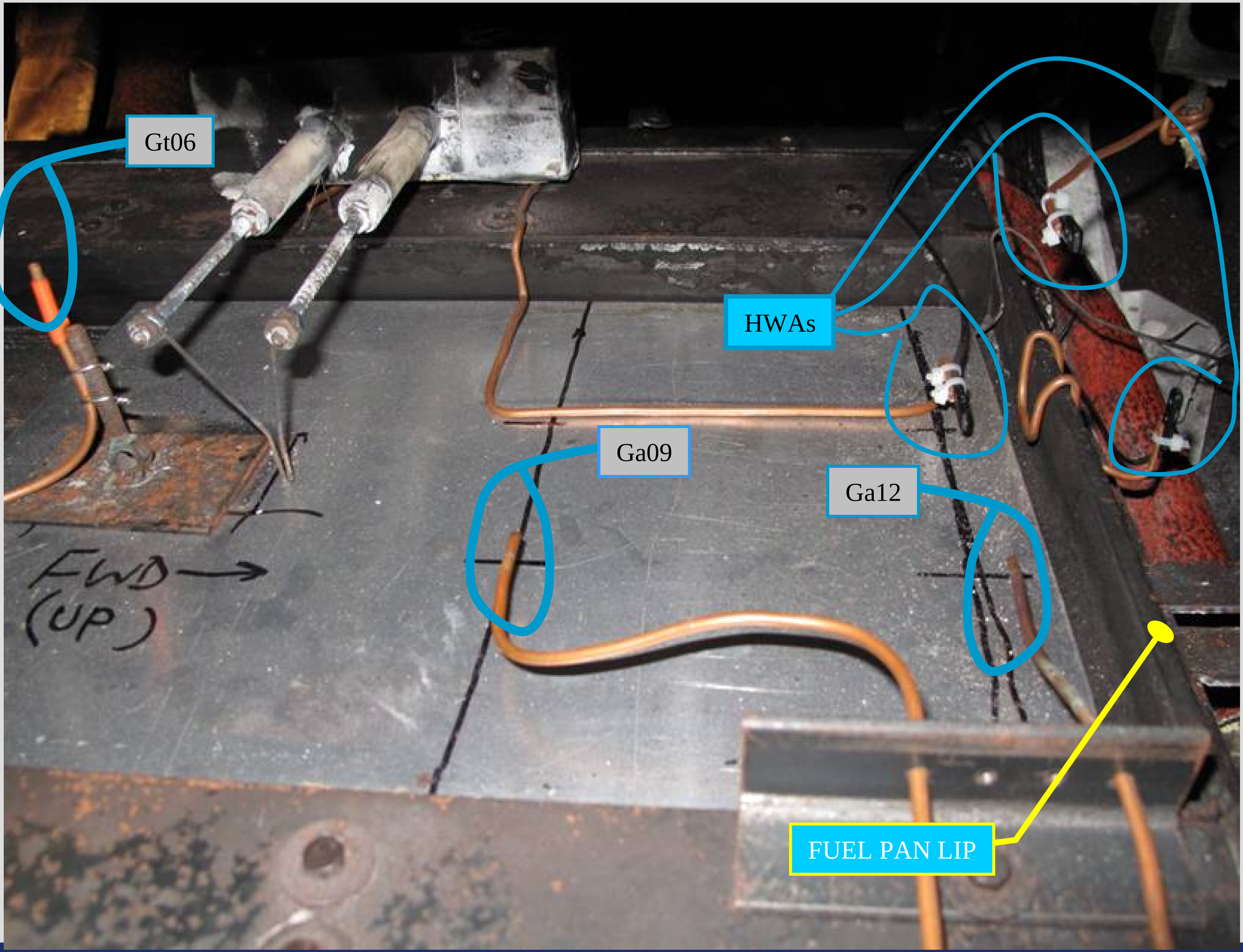
note channel #12,
1 inch aft of the fuel pan lip

1 of 2 free-stream, flame-front sample points used to determine previously reported equivalent concentrations

Gas Analysis in the NFS

Orientation

free-stream & wake region,
gas sampling points



Gas Analysis in the NFS
Halon 1301

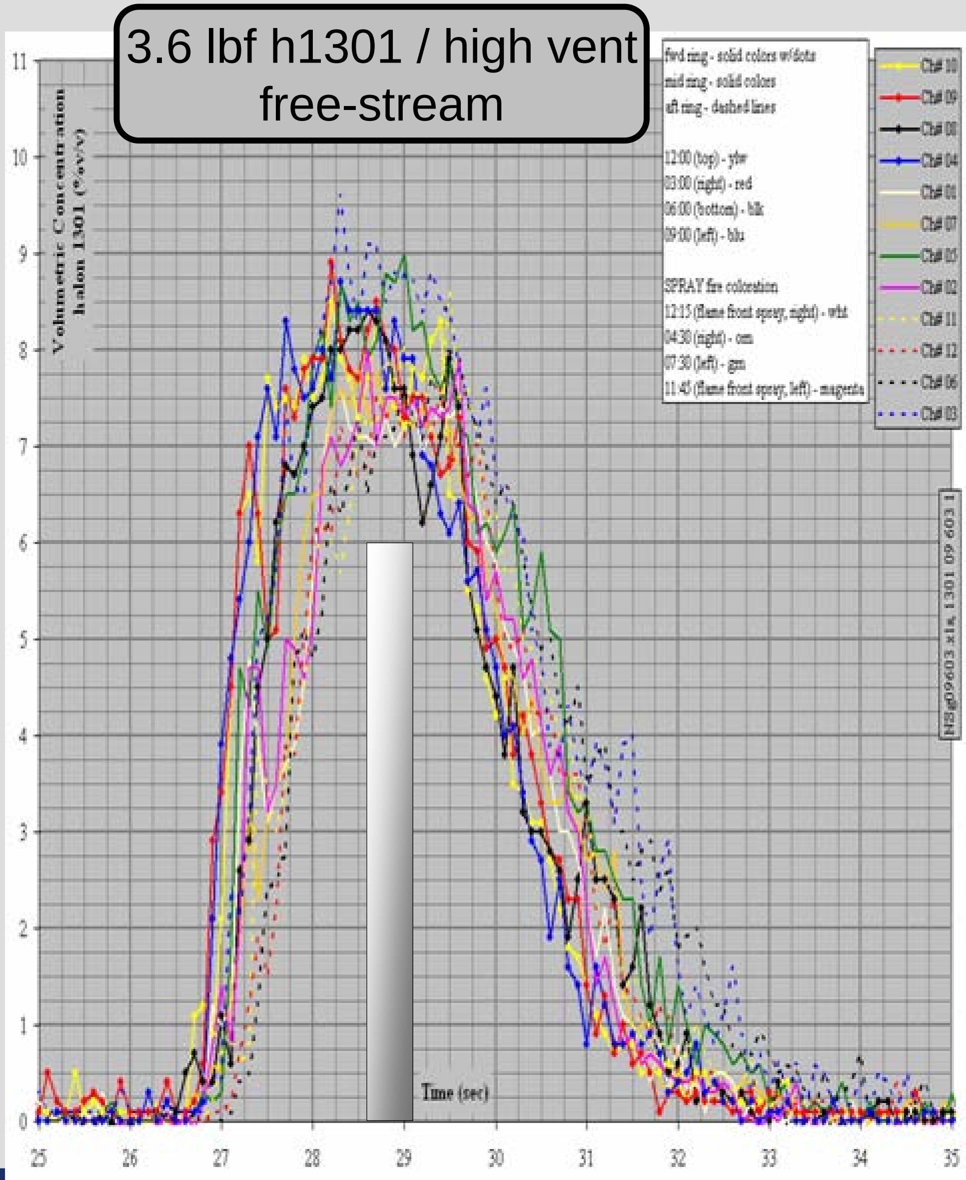
- **Principal curiosity about wake region behaviors related to the halon 1301 distributions**
  - Would halon 1301 still meet the intent of FAA certification if sample points were placed in wake regions in the NFS?
  - Per MPSe rev03, halon 1301 is delivered to the NFS meeting FAA certification intent for each ventilation condition, as measured in the free-stream
  - Outcome = halon 1301 again met the intent of FAA certification with sample points located in wake regions

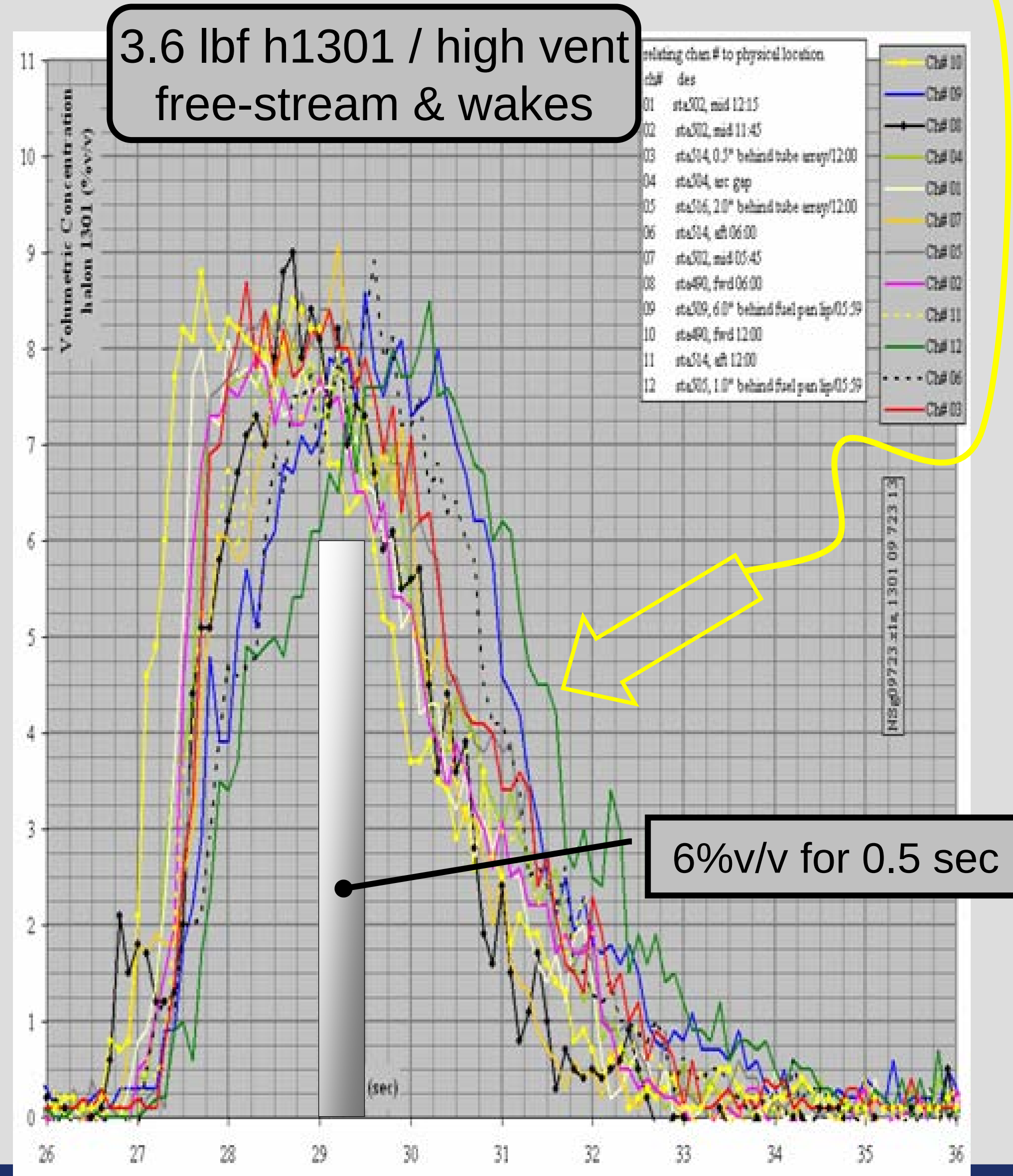
return to CF_3I

Gas Analysis in the NFS

Halon 1301

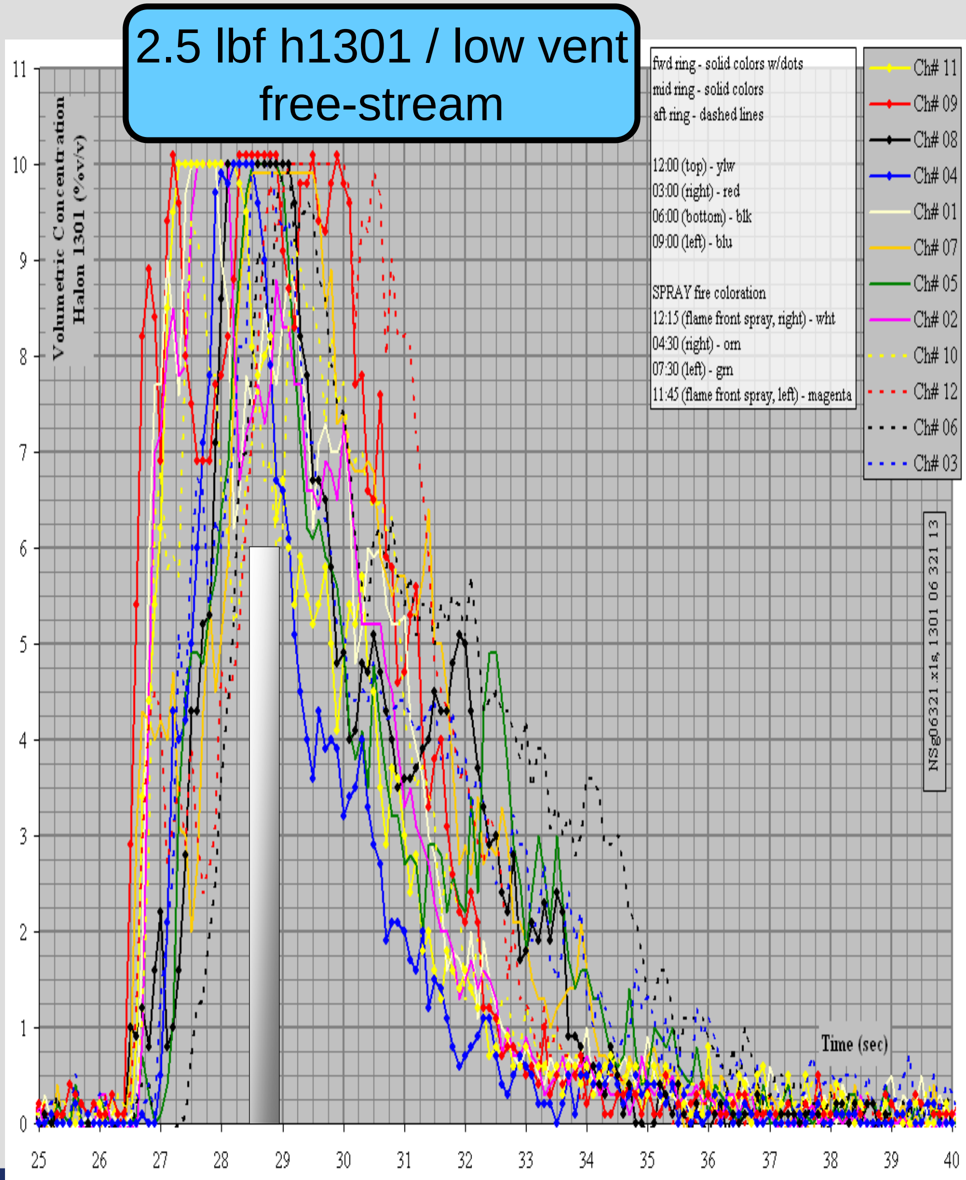
note channel #12,
1 inch aft of the fuel pan lip

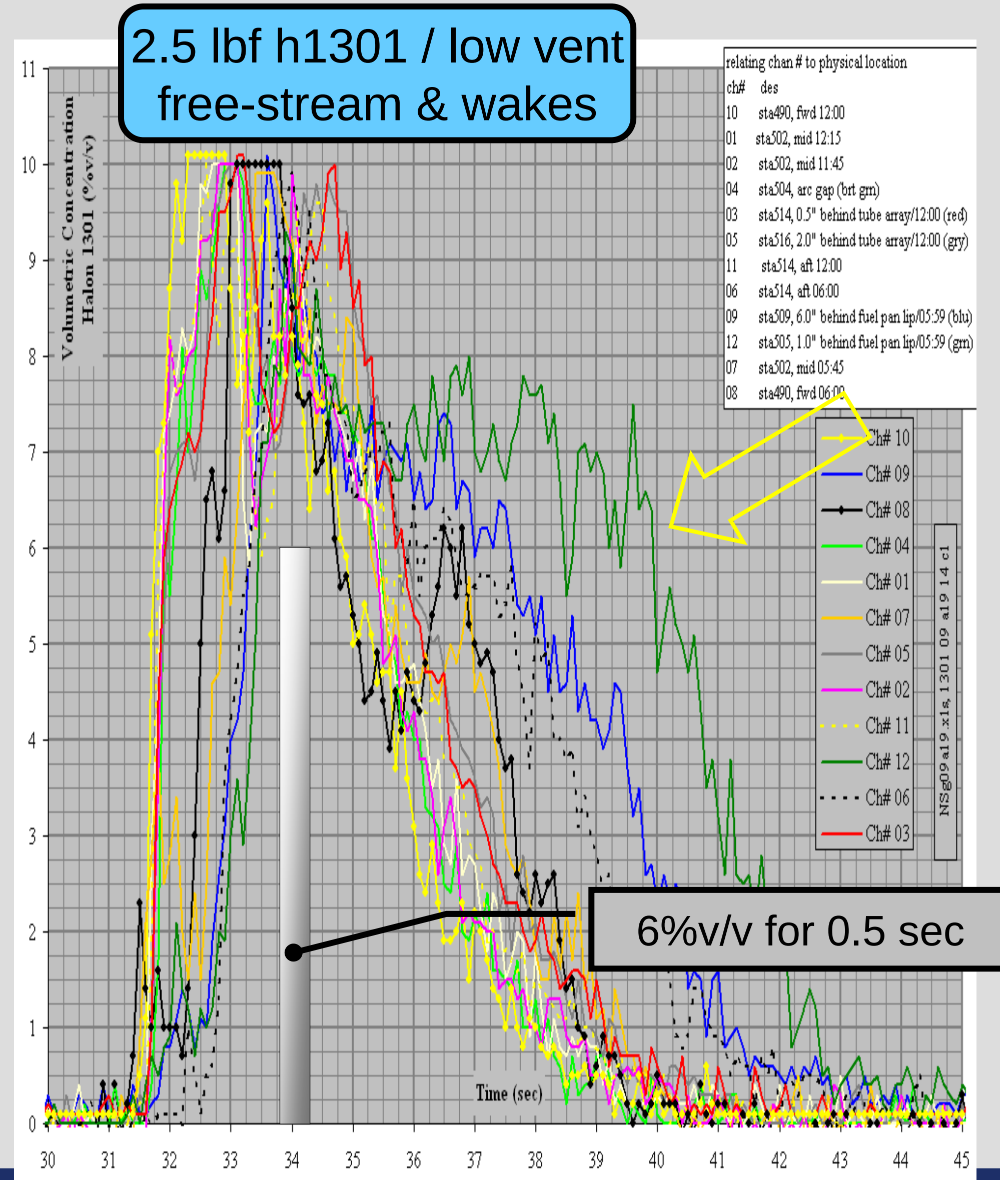




Gas Analysis in the NFS

Halon 1301





Gas Analysis in the NFS

HFC-125 & CF_3I

- **Secondary curiosities about wake region behaviors related to HFC-125 & CF_3I distributions**
  - What do the wake region behaviors look like?

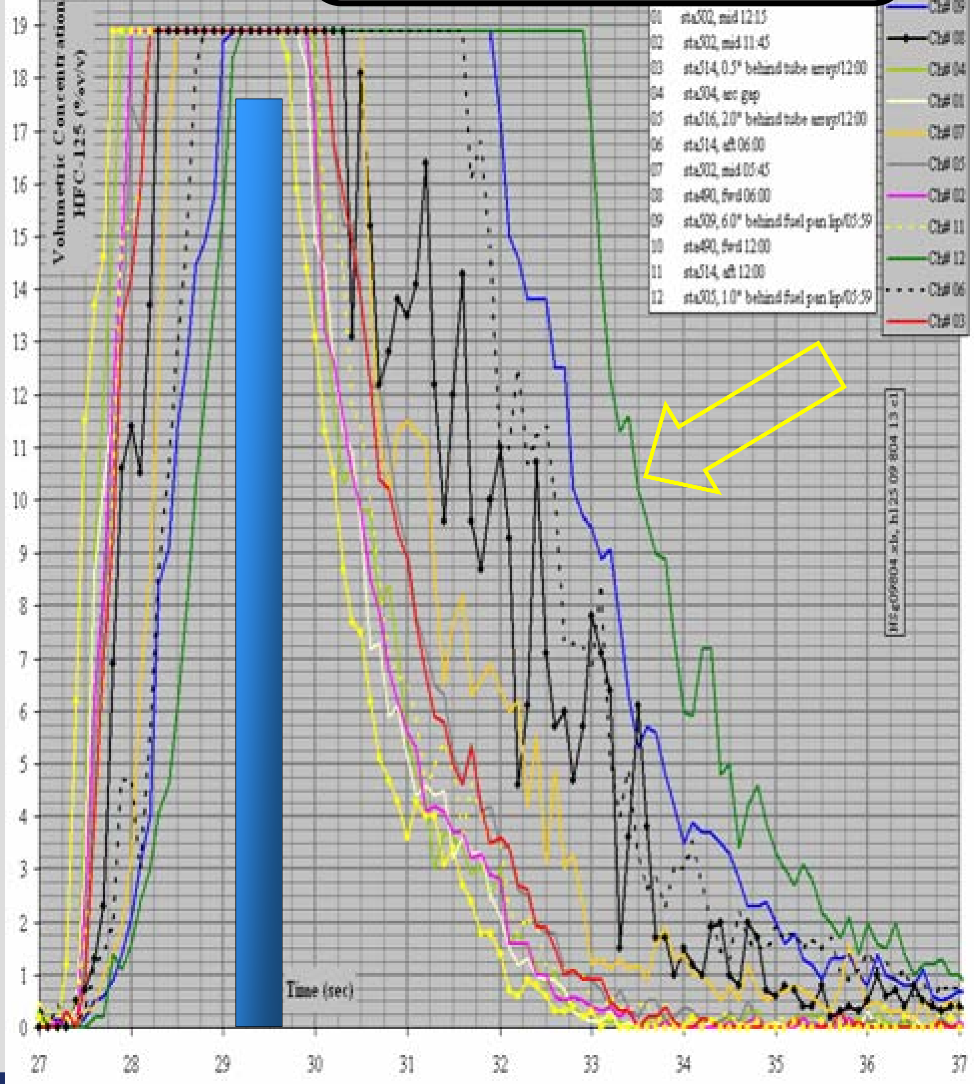
	halon 1301	HFC-125	CF3I
normal boiling point (°F)	-72	-55	-8
superheated vapor density, T=10°F (lbf/ft^3)	0.44	0.33	0.58
design concentration (%v/v)	6	" 17.6 "	" 7.1 "

  - Looked at limited configurations which were found equivalent per MPSe rev03
  - Attention is drawn to HFC-125 given pending work to define conditions for the surrogate benchmark concept

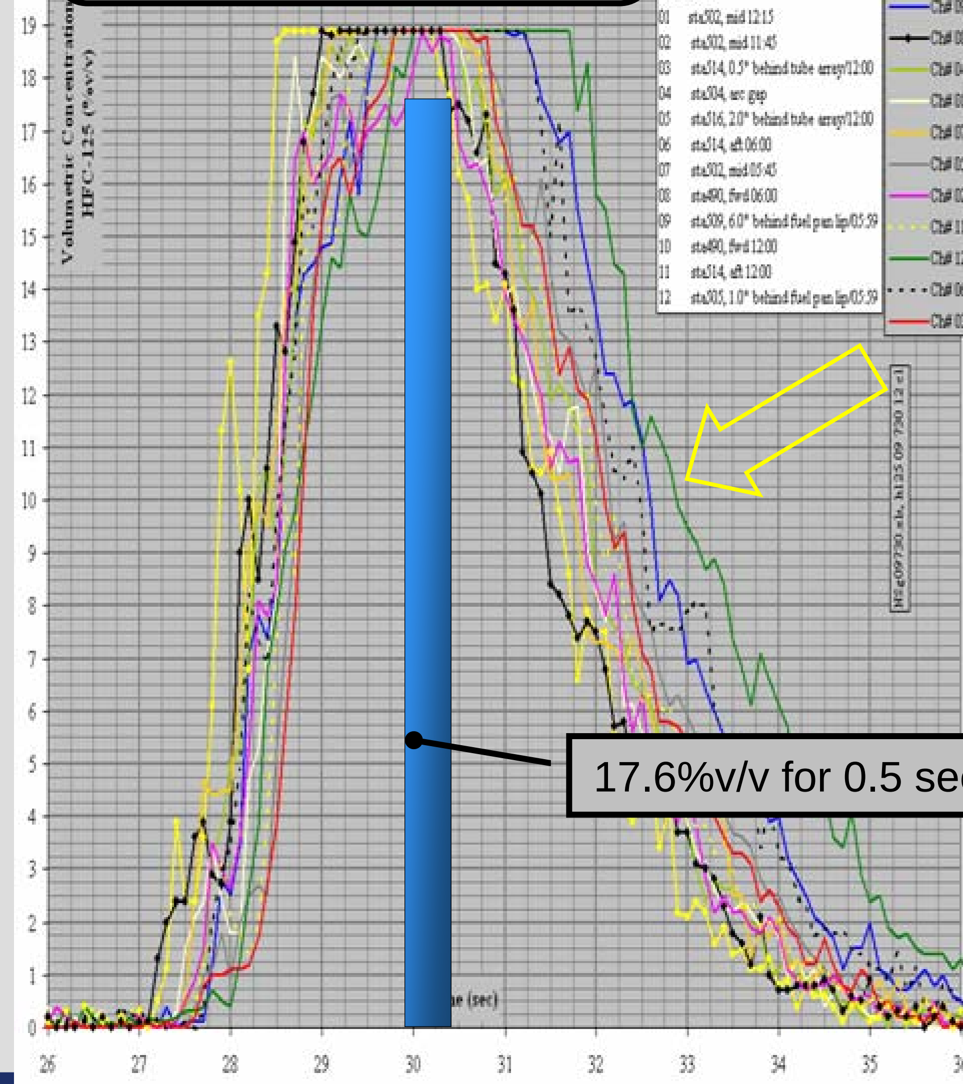
Gas Analysis in the NFS

HFC-125

8.0 lbf HFC-125 / high vent
free-stream & wakes
generic injection plumbing



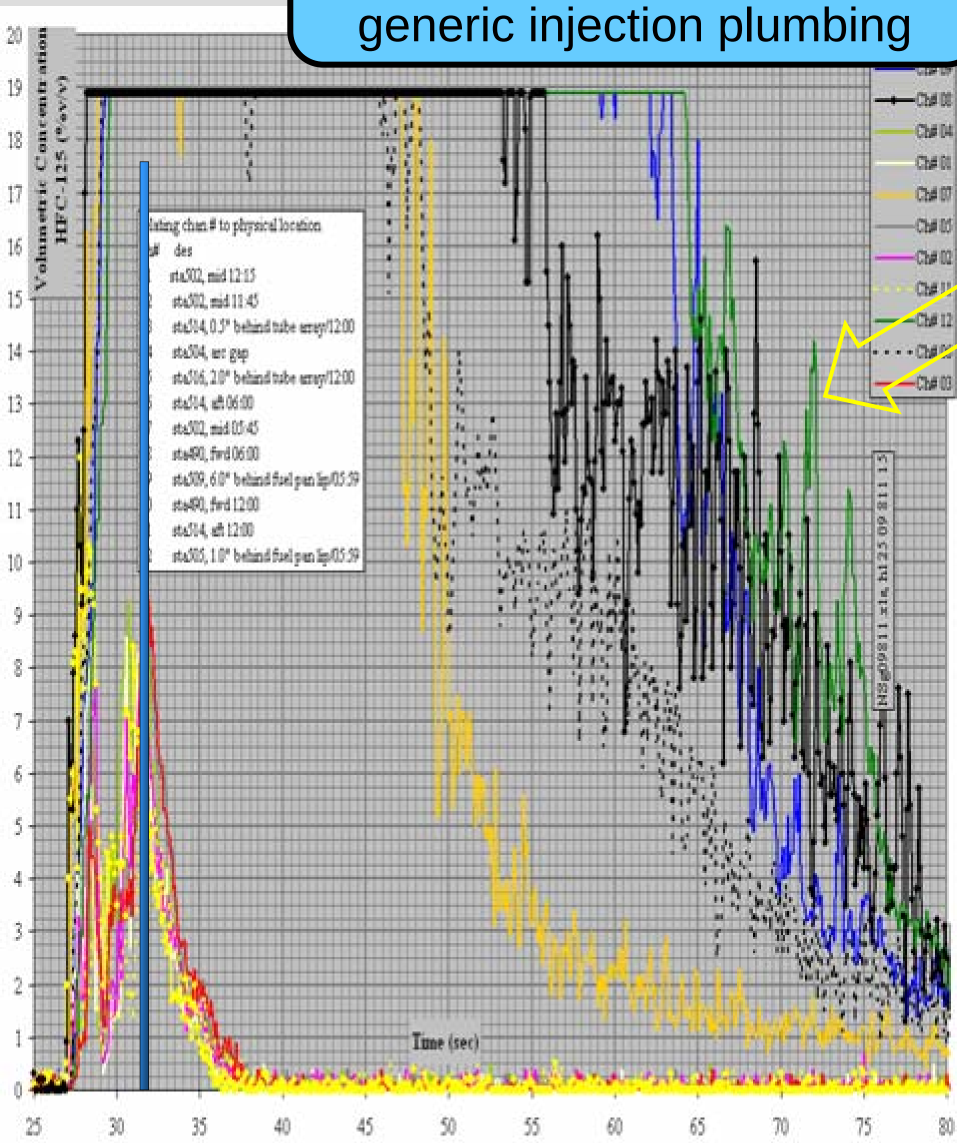
8.0 lbf HFC-125 / high vent
free-stream & wakes
HiVent h1301 inj. plumbing



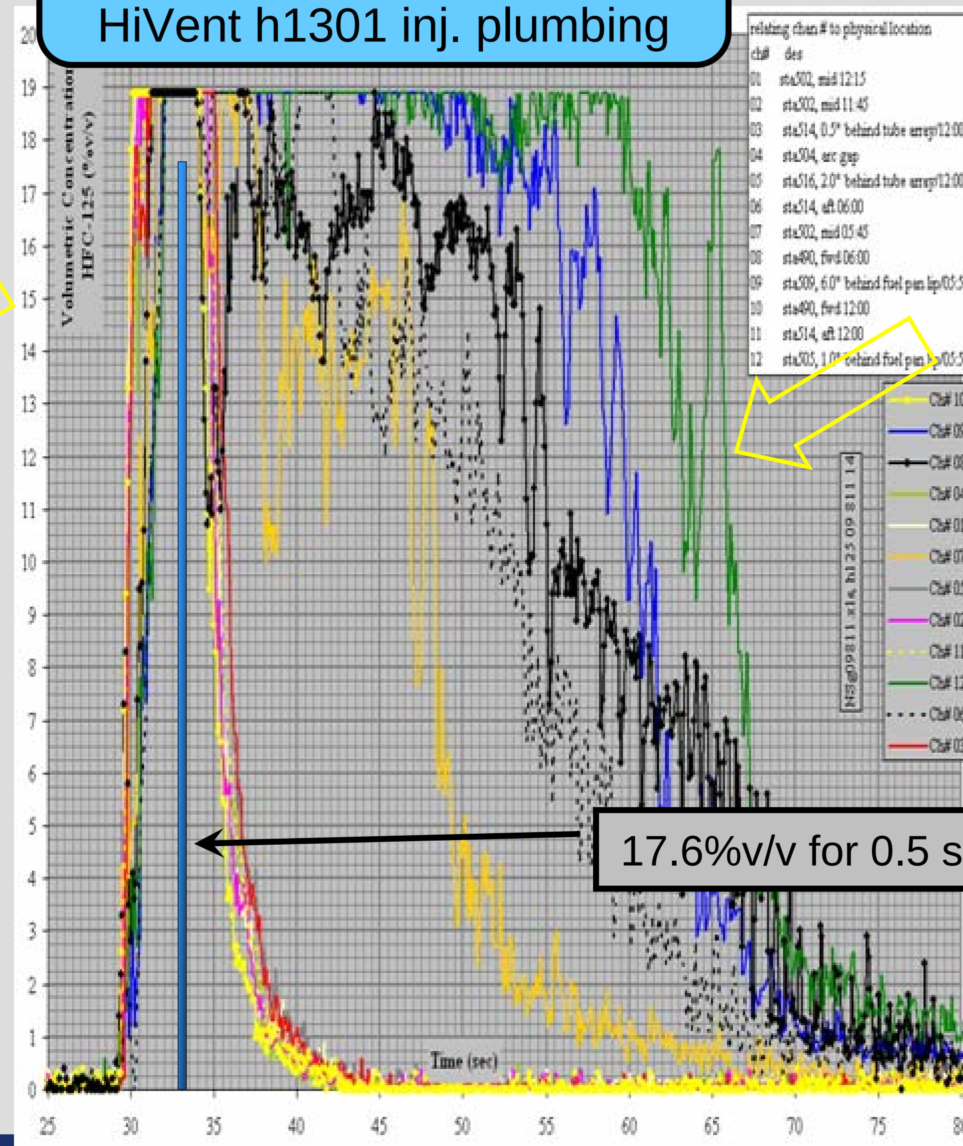
Gas Analysis in the NFS

HFC-125

7.4 lbf HFC-125 / mod-low vent
free-stream & wakes
generic injection plumbing



7.4 lbf HFC-125 / mod-low vent
free-stream & wakes
HiVent h1301 inj. plumbing

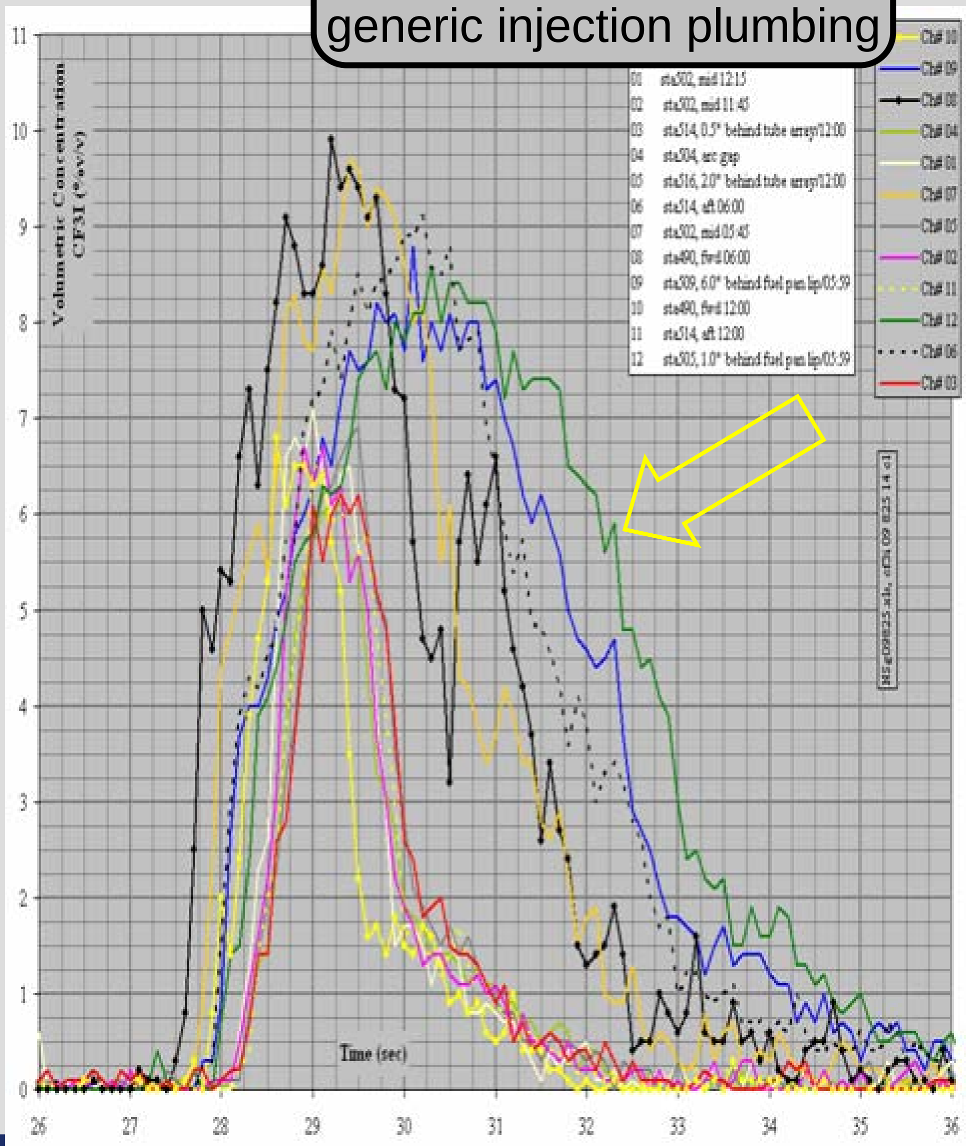


go to H1301

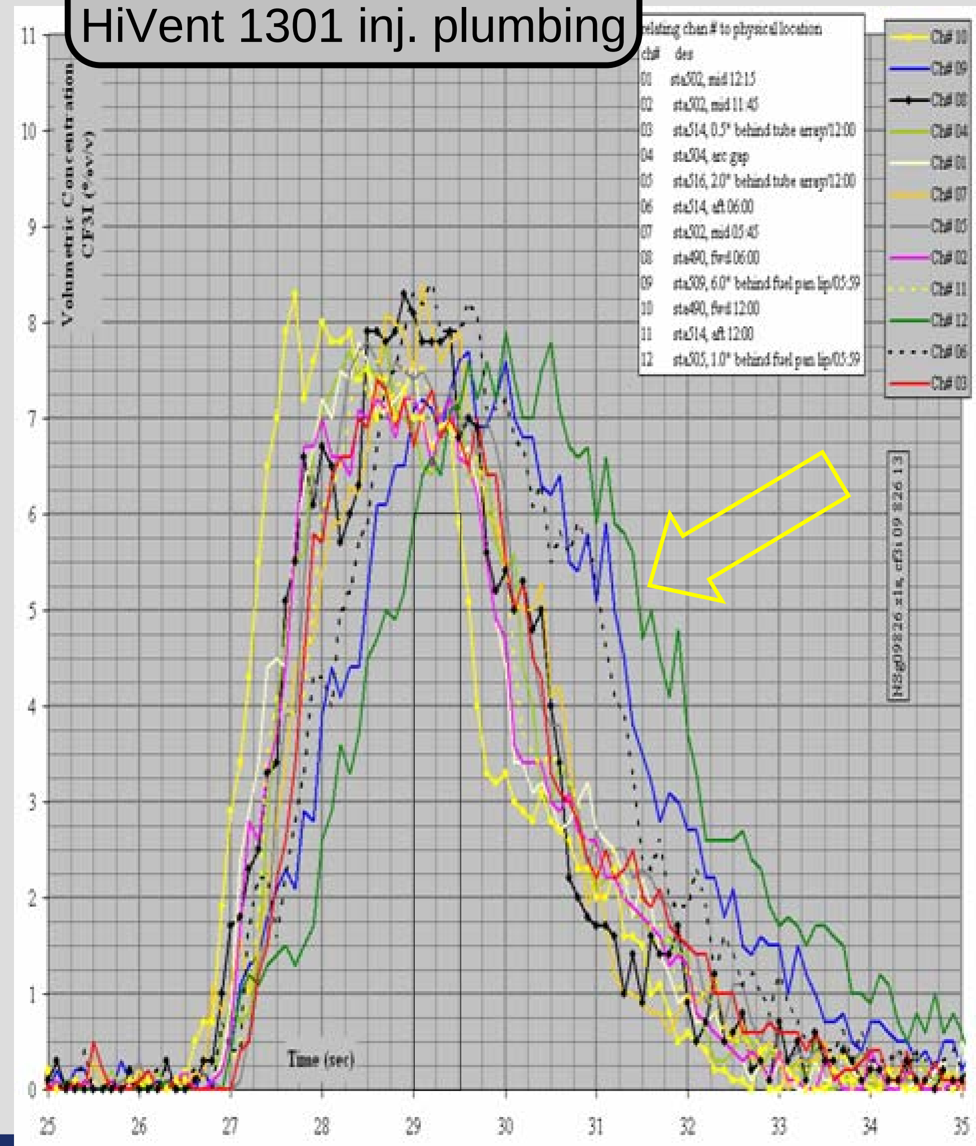
Gas Analysis in the NFS

CF_3I

3.5 lbf CF_3I / high vent
free-stream & wakes
generic injection plumbing



3.5 lbf CF_3I / high vent
free-stream & wakes
HiVent 1301 inj. plumbing



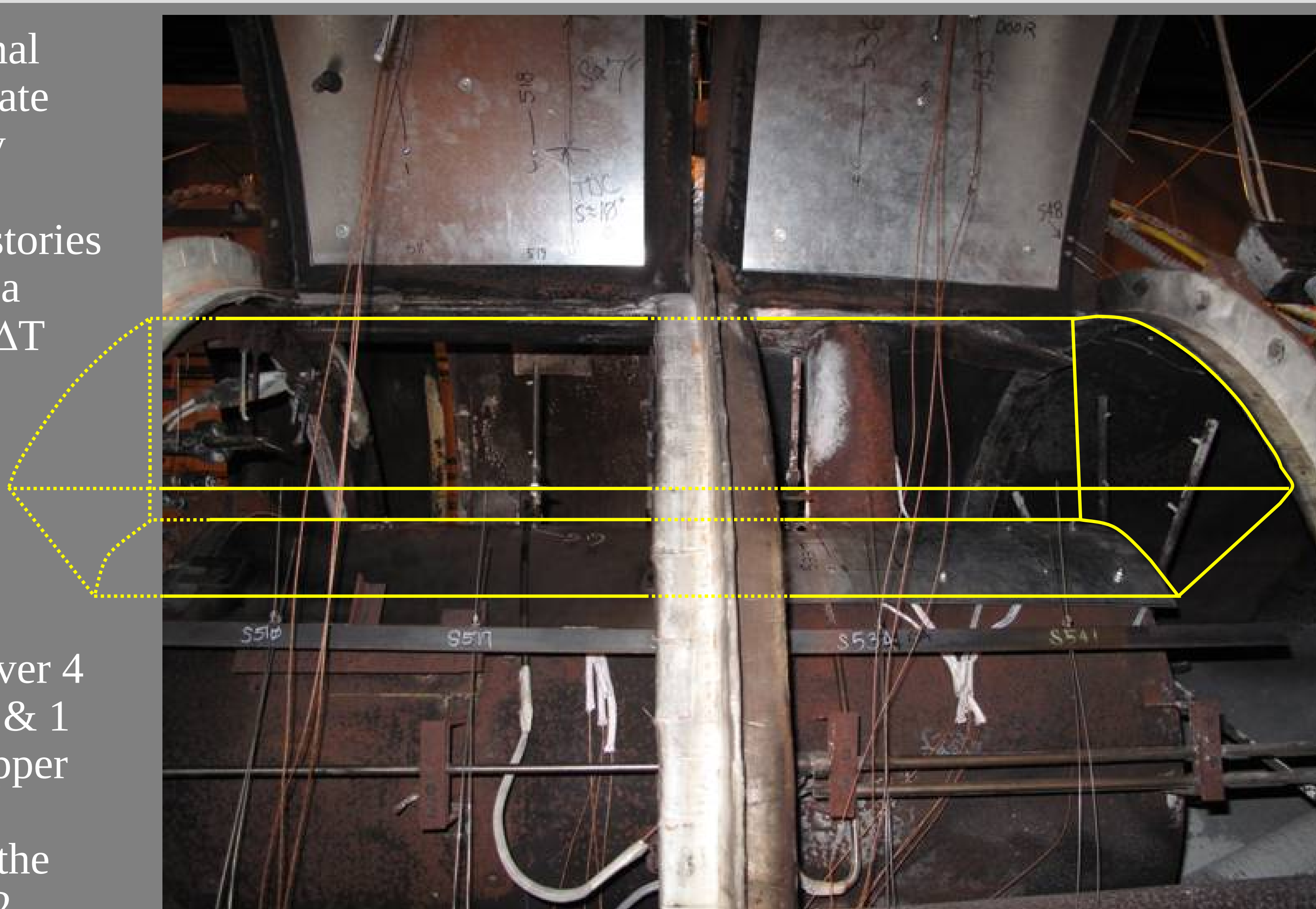
Gas Analysis in the NFS

Qualitative comments regarding hot-wire anemometry

- **Complex issues challenge the HWA calibration during exposures to mixtures at varying temperature** **(casually/quiescently working this issue in the background)**
- **Qualitatively :**
  - Velocity excursions expectedly occurred
  - Character of excursion depended on configuration
  - Observations suggest the wake regions were relatively undisturbed during the transient suppressant pulse
  - Localized agitation from the h1301 injection plumbing, as compared to the generic plumbing, was :
    - degraded during injection at high ventilation
    - intensified during injection at low ventilation

Thermal Characterization of the NFS Fires

- Plan to capture thermal transients to approximate the combustion energy release
- Transient thermal histories will be coordinated in a summation of $Q = mc\Delta T$ then doubled



- Will use 36 thermocouples
- Sixteen distributed over 4 metallic plates (3 new & 1 existing) and the aft/upper structural support
- Remaining 20 sense the air stream; 5 each for 2 similar cross-sections & 8 longitudinally

Conclusions

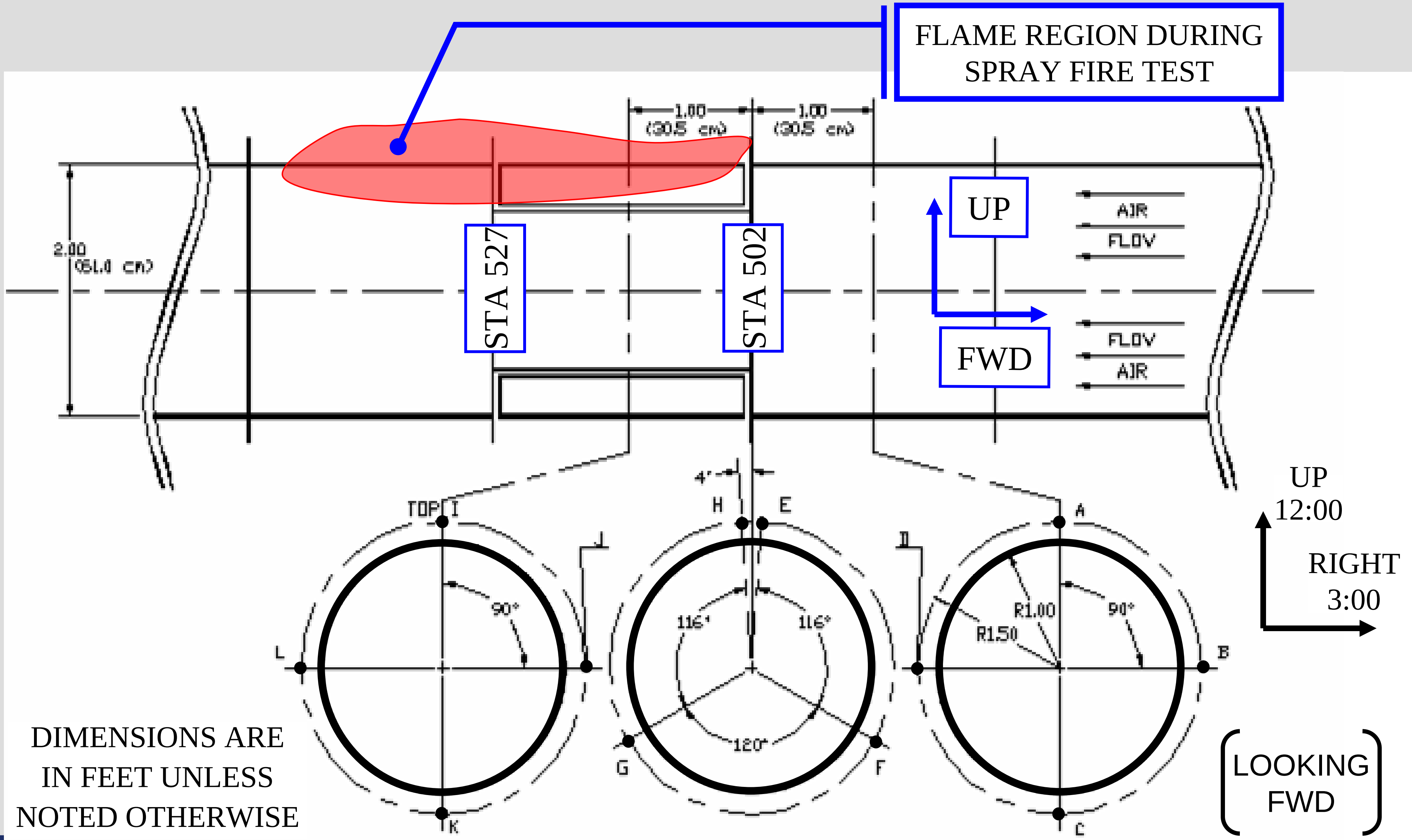
- **Transition from MPSe rev03 to rev04 continues**
  - Testing to investigate the HFC-125 surrogate concept will commence momentarily
  - Expecting task group review for draft rev04 in the Dec2009/Jan2010 time frame
- **The *halon 1301 distributions* met the intent of FAA certification with gas analysis sample points "buried" in the wake regions of certain flame-holding structures in the NFS**
  - Historical fire & gas distribution observations remain intact
  - Sampling configuration is currently indeterminate

End

- **Acronyms, short-hand notations**
  - APU = Auxiliary Power Unit
  - fwd = forward
  - HWA = hot-wire anemometer
  - mod-low = modified low
  - MPSe = Minimum Performance Standard for Halon Replacement in Civil Aircraft Engine Nacelle & APU Compartments
  - NFS = nacelle fire simulator for the MPSe, located at the FAA WJ Hughes Technical Center
  - OD = outside diameter
  - rev = revision
  - SSWT = small-scale wind tunnel
  - sta = station number, longitudinal position in the NFS
  - vent = ventilation

Appendix A1

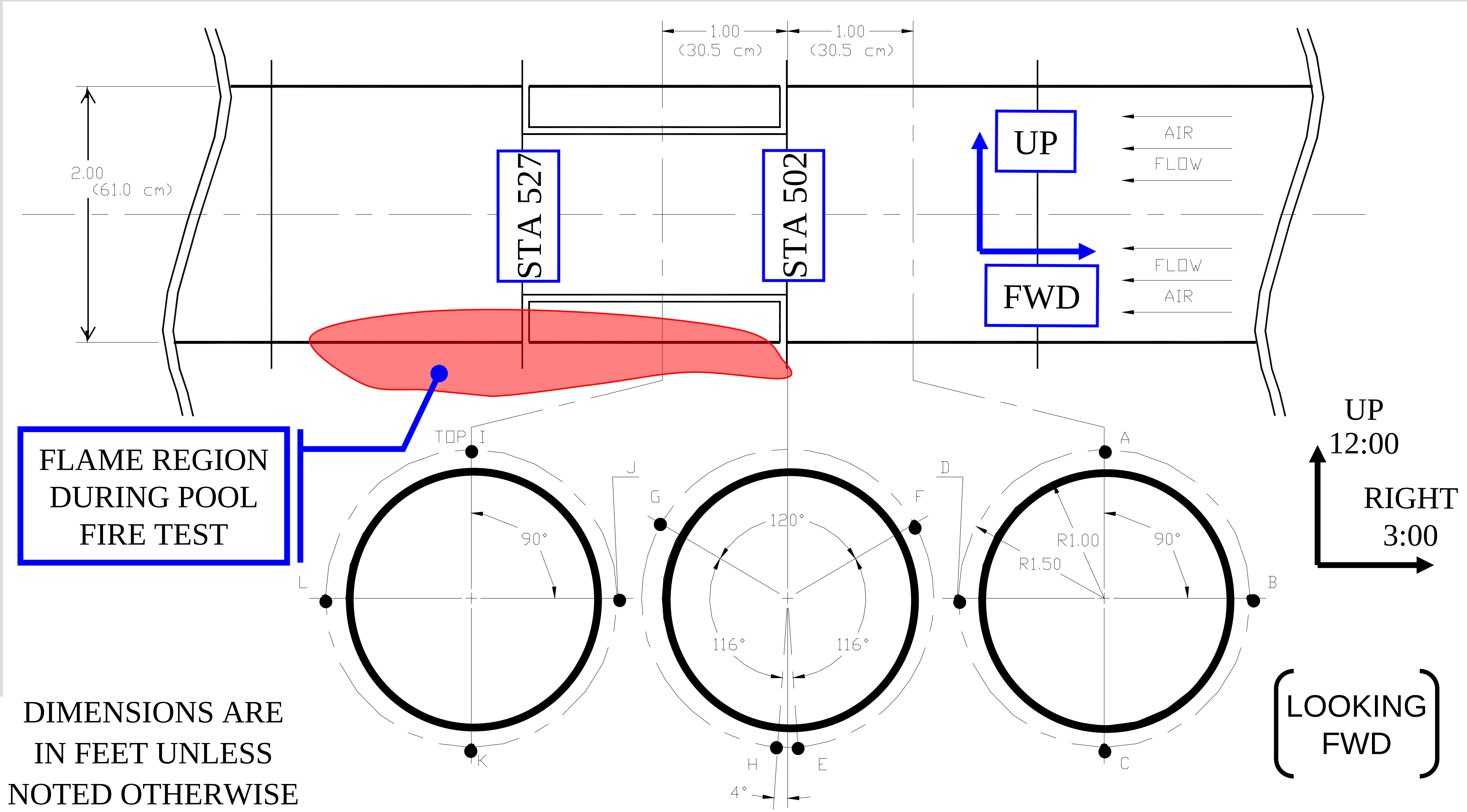
Typical gas sample points for the NFS spray fire threat



DIMENSIONS ARE IN FEET UNLESS NOTED OTHERWISE

Appendix A2

Typical gas sample points for the NFS pool fire threat

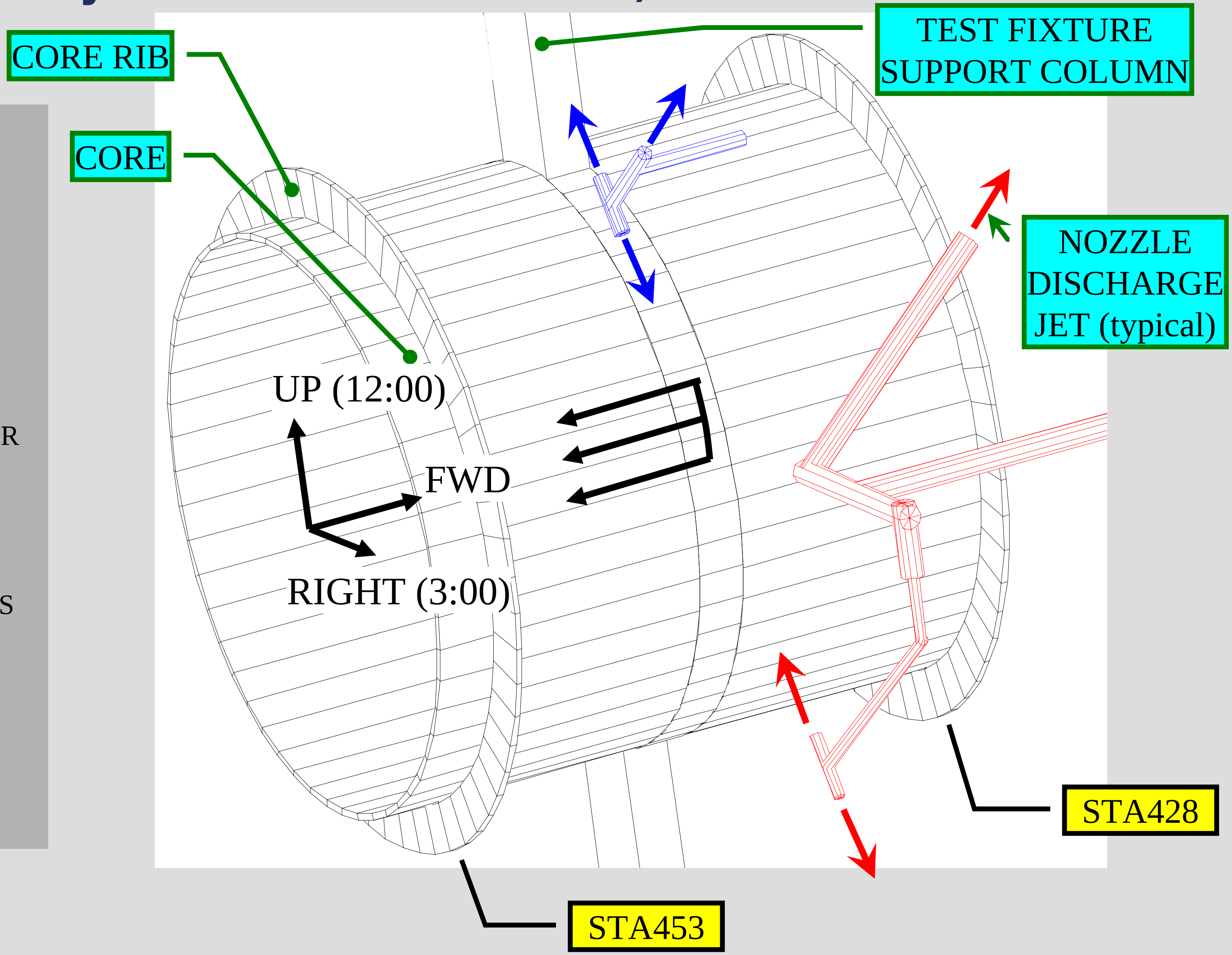


Appendix B1a

Fire Suppressant Injection into the NFS, halon 1301

NOTES REGARDING THE INJECTION OF HALON 1301

- **BLUE-**COLORED PLUMBING IS FOR **LOW VENTILATION-CERTIFICATION** INJECTION
- **RED-**COLORED PLUMBING IS FOR **HIGH VENTILATION-CERTIFICATION** INJECTION
- ONLY ONE INJECTION SYSTEM IS INSTALLED PER TEST
- ONLY THE PLUMBING ON THE RIGHT SIDE OF THE ANNULAR CROSS SECTION IS SHOWN (LEFT/RIGHT SYMMETRY APPLIES)



Appendix B1b

Fire Suppressant Injection into the NFS, halon 1301

NOTES REGARDING THE
INJECTION OF HALON 1301

- **BLUE-**COLORED PLUMBING IS FOR **LOW VENTILATION-CERTIFICATION** INJECTION
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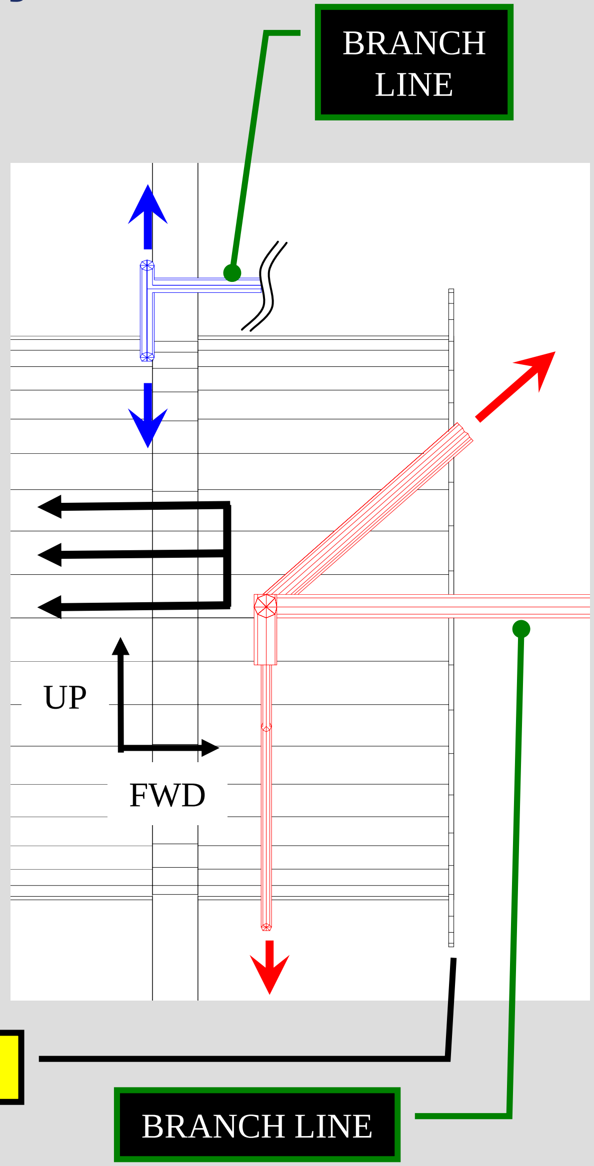

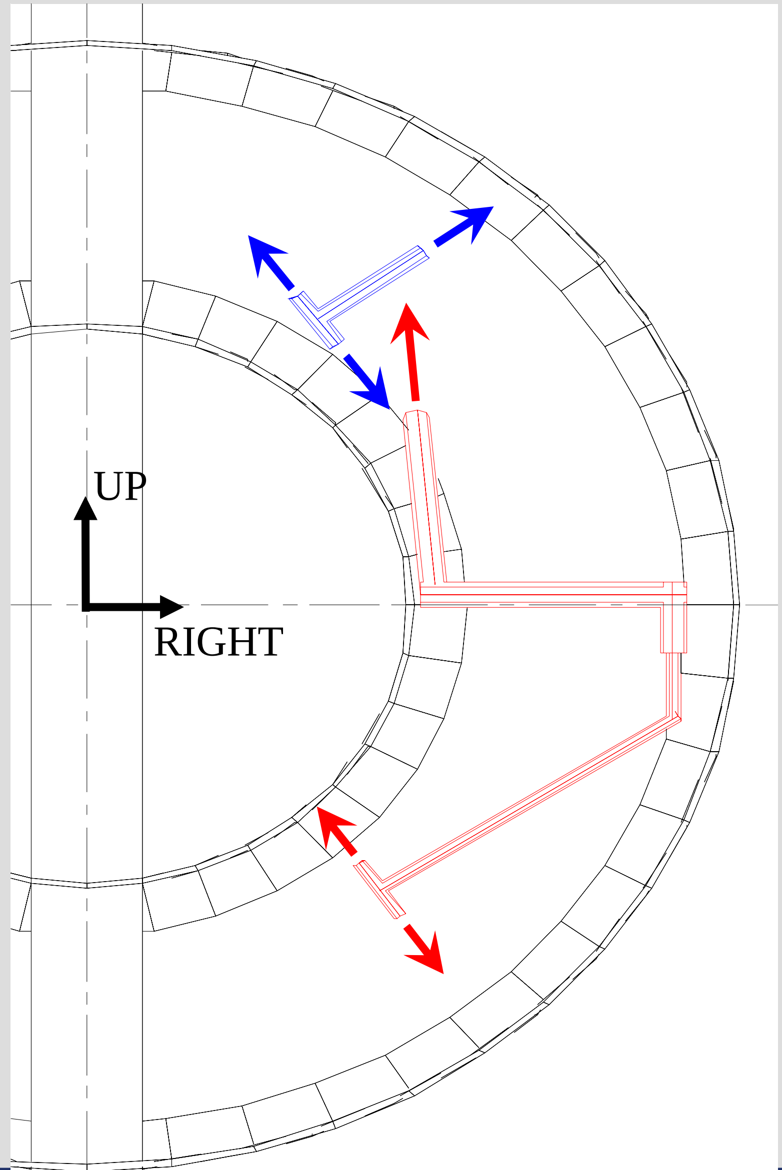

Appendix B2

Fire Suppressant Injection into the NFS, replacement