Full-scale Demonstration Testing with a Solid Aerosol Fire Extinguishing Agent, Discussion Transitioning…

Federal Aviation Administration

Presented to: International Aircraft Systems Fire Protection Working Group

By: on behalf of :

Doug Ingerson
Federal Aviation Administration
WJ Hughes Technical Center
Fire Safety Team
Atlantic City Int'l Airport, NJ USA
tel : 609-485-4945
email : douglas.a.ingerson@faa.gov

Date: 15Nov2012

Presentation Overview
~ Major Discussion Points

Testing with a Solid Aerosol

- Purpose
- Test Conditions/Circumstances
- Various Views of the Nacelle Test Article
- Some Observations
- Outcomes
- Conclusions

Current Status, Engine Nacelle Halon Replacement Activity, FAATC

References within this presentation to businesses, their services and/or products does not constitute endorsement.

Full-scale Demonstration Testing, Solid Aerosol
~ Purpose

Purpose

- Boeing/Kidde interested in solid aerosol fire extinguishing (firex) agent for aircraft engine nacelle application
- Firex agent subjected to MPSHRe rev04(1) testing
  - product is manufactured by Kidde & known as KSA
  - generic/“Part A” testing, 2010-2011
    - accomplished in FAATC generic nacelle fire simulator
    - industry established design criteria for “Part B” testing
  - high-fidelity/“Part B” demonstration testing, 2011-2012
    - invoked by the FAA due to notable dissimilarities between this candidate & the typical firex solution of halon 1301
    - parties agreed to use Pratt & Whitney JT9D on an FAA-owned Boeing 747SP

(1) MPSHRe revision 04, http://www.fire.tc.faa.gov/pdf/systems/MPSErev04_MPSeRev04doc-02submtd.pdf

Full-scale Demonstration Testing, Solid Aerosol
~ Test Conditions/Circumstances

Test Conditions/Circumstances

- JT9D nacelle forcibly ventilated externally from atmosphere
  - air mass flow rate ≈ 0.5 kg/s (1 lbm/s)
  - ran engine to “heat” nacelle environment before pertinent tests
- Nacelle fire threat
  - *simultaneously* burning JP-8 spray & pool fires
  - JP-8 spray delivered @ ~180 mL/min @ 46°C (0.05 gpm @ 115°F)
  - JP-8 pool of 19.1 x 26.8 x ~1.3 cm deep (7.5 x 10.5 x ~0.5 in)
  - fires electrically ignited; igniters de-energized after ignition
  - looked for fire *extinguishment*, not reignition behavior
- Industry provided firex system & concentration analyzer
  - sodium bicarbonate-based solid aerosol
  - optical system used to measure agent distribution

Full-scale Demonstration Testing, Solid Aerosol
~ Test Conditions/Circumstances

Test Conditions/Circumstances

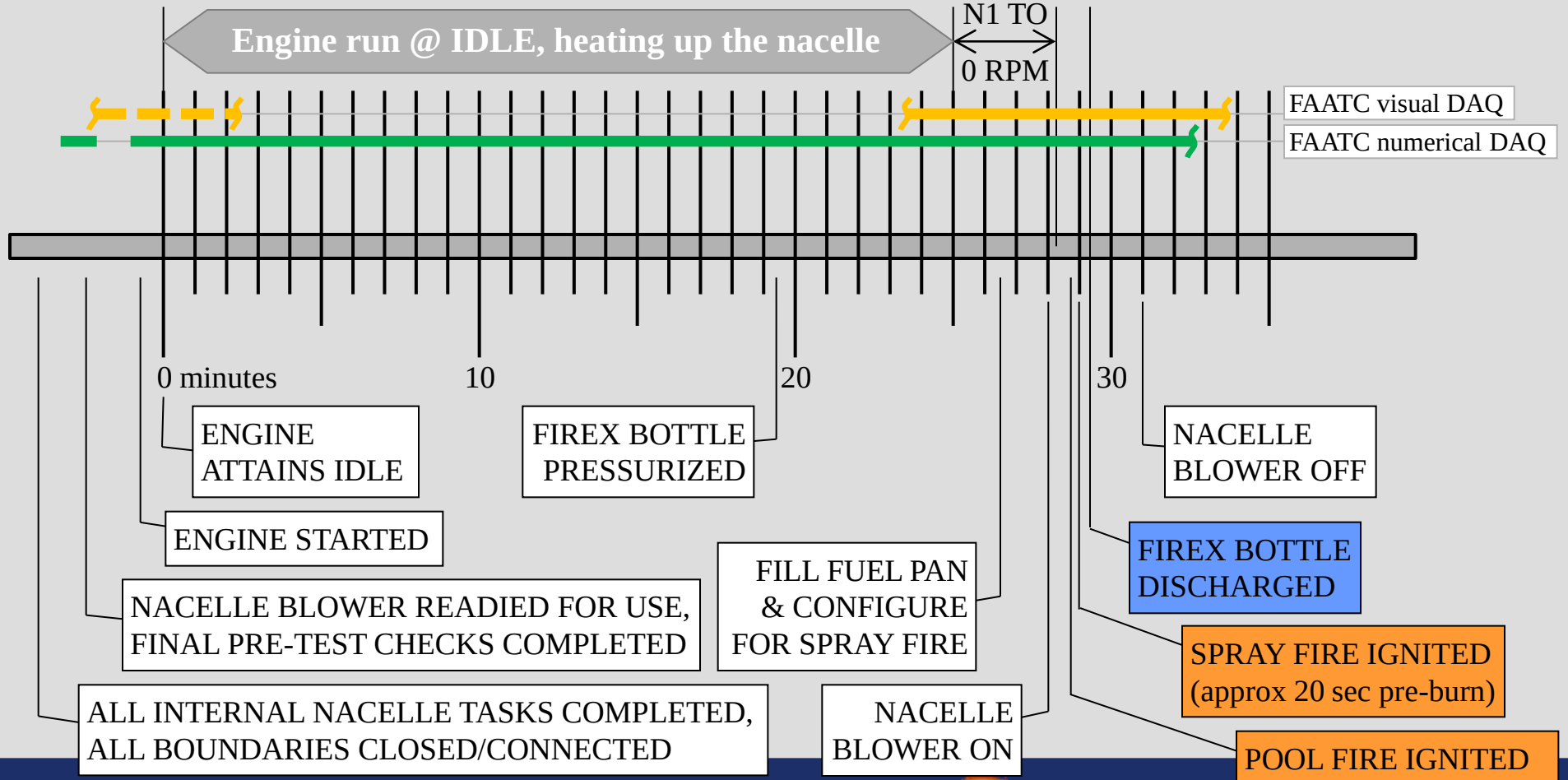
- Additional comments
  - intent of nacelle firex protection changed during “build-up”
    - initial intent to represent design criteria throughout fire zone
    - final design simultaneously represented design criteria solely at both fire regions; 4 concentration sample points per region
  - ran 2 fire extinguishment tests 11Jul2012
    - 1^{ST} test ran with N_2 injection
      - verify fire threats/challenge of sufficient intensity
      - expected NO fire extinction
    - 2^{ND} test ran with solid aerosol injection
      - represent design criteria & demonstrate fire extinguishment
      - expected fire extinguishment

Full-scale Demonstration Testing, Solid Aerosol

~ Test Conditions/Circumstances

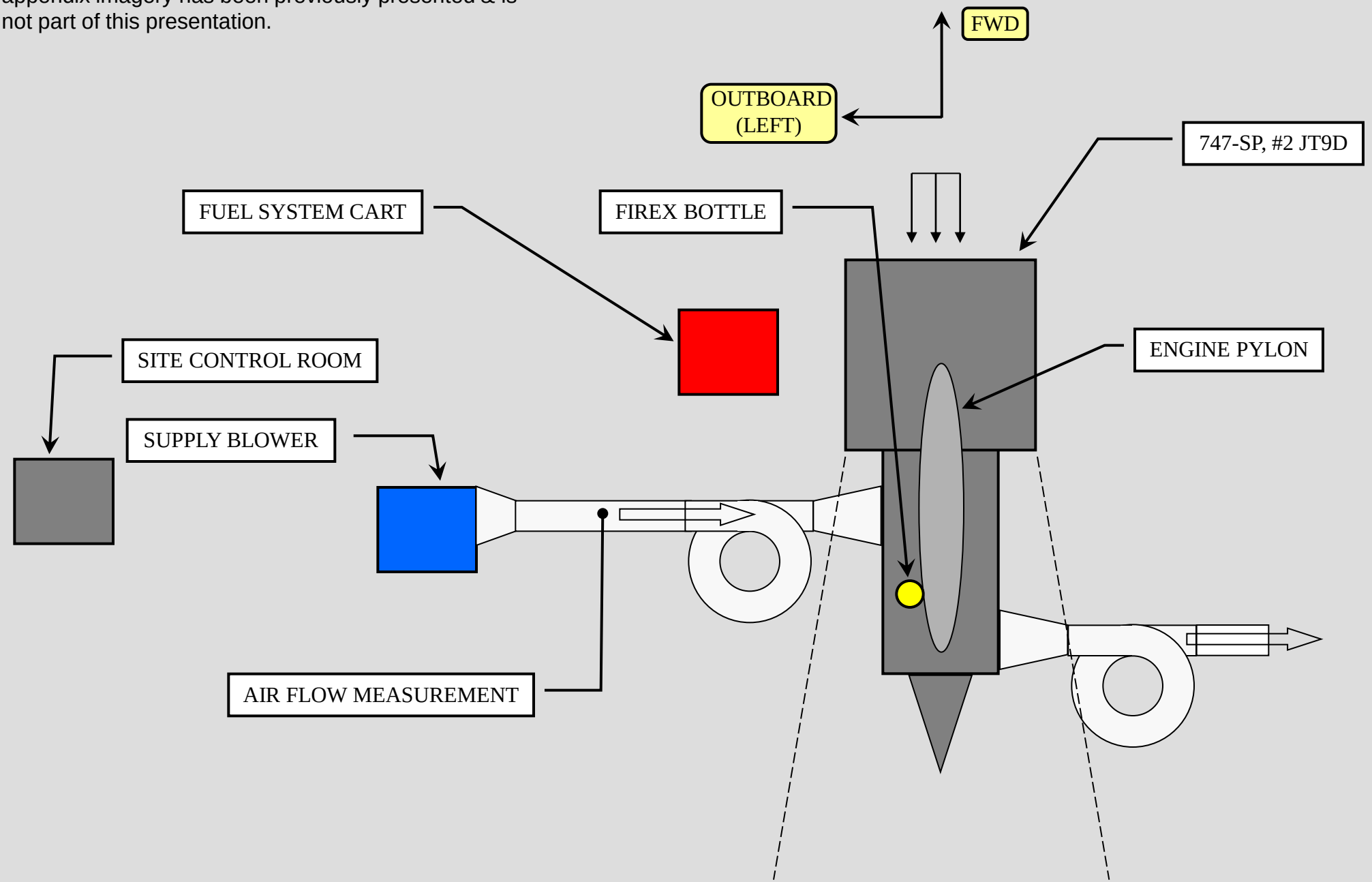
Test Conditions/Circumstances

- General/intended test time line



Various Views, Schematic Site Plan

Imagery of these various details can be found in this presentation & in the appendix of this file. The appendix imagery has been previously presented & is not part of this presentation.



Full-scale Demonstration Testing, Solid Aerosol
~ Some Observations, General Comments

Some Observations, General Comments

- Data is provided here for “high” level review; data :
  - is from the 2ND test of 11jul (test 201271106)
  - represents the test challenging the solid aerosol’s design criteria
- Data is visual & numerical
  - related to the :
    - general nacelle area, thermal
    - spray fire region, visual & thermal
    - pool fire region, visual & thermal
  - the following slides are provided in an organized manner
    - grouped by region; general nacelle, fire region
    - leads with pertinent imagery for familiarization
    - follows with numerical data in graph format, as applicable

Full-scale Demonstration Testing, Solid Aerosol
~ Some Observations/Visual Behaviors

Some Observations, Visual Behaviors

- Fire behaviors were recorded by cameras viewing the pool & spray fire regions
- Camera details
  - housed in windowed/metal boxes ventilated from/to nacelle exterior
  - principally recording visible spectrum
  - captured at frame rate ≈15 frames per second
- Other comments
  - images are shown which were taken from the digital video records
  - 8 images shown for each fire region, incrementing at ≈1.6 sec
  - images span the firex agent pulse, pre-discharge to post-migration
  - as solid aerosol injects, it creates a cloud that obscures visibility
  - looked for light to indicate whether fire remained or not

Full-scale Demonstration Testing, Solid Aerosol
~ Some Observations/Temperatures

Some Observations, Thermal Conditions

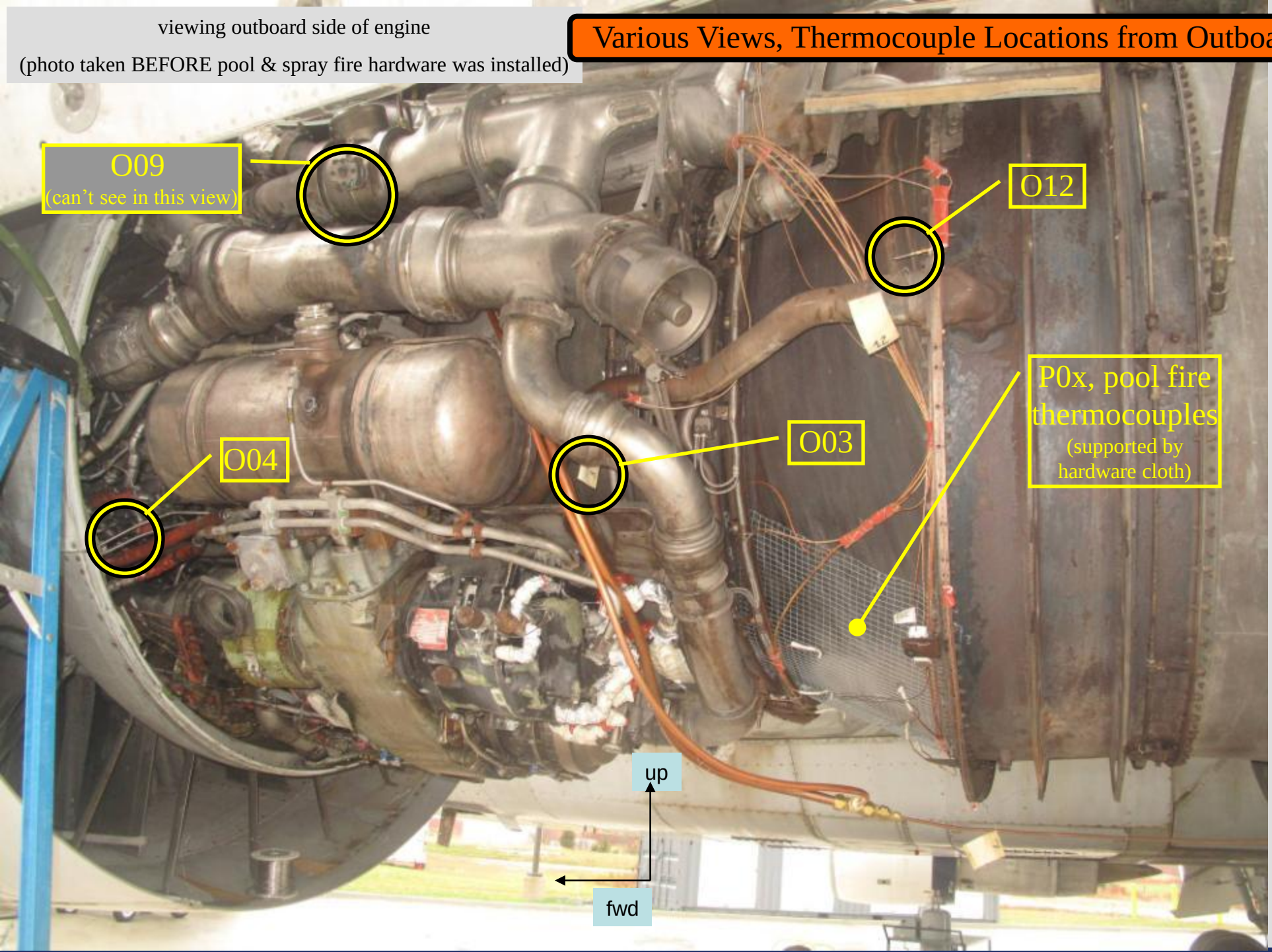
- Some temperature behaviors are included here

- Thermocouple descriptions
  - all type-K
  - all here are sampling the nacelle gas stream
  - the data here represents positions principally in the nacelle
    - several scattered about the nacelle (3 graphs)
      - 1 point sampling the inlet air entering the engine
      - 12 points in the nacelle
    - 8 points local to the spray fire (1 graph)
    - 8 points local to the pool fire (1 graph)

Various Views, Thermocouple Locations from Outboard View

viewing outboard side of engine

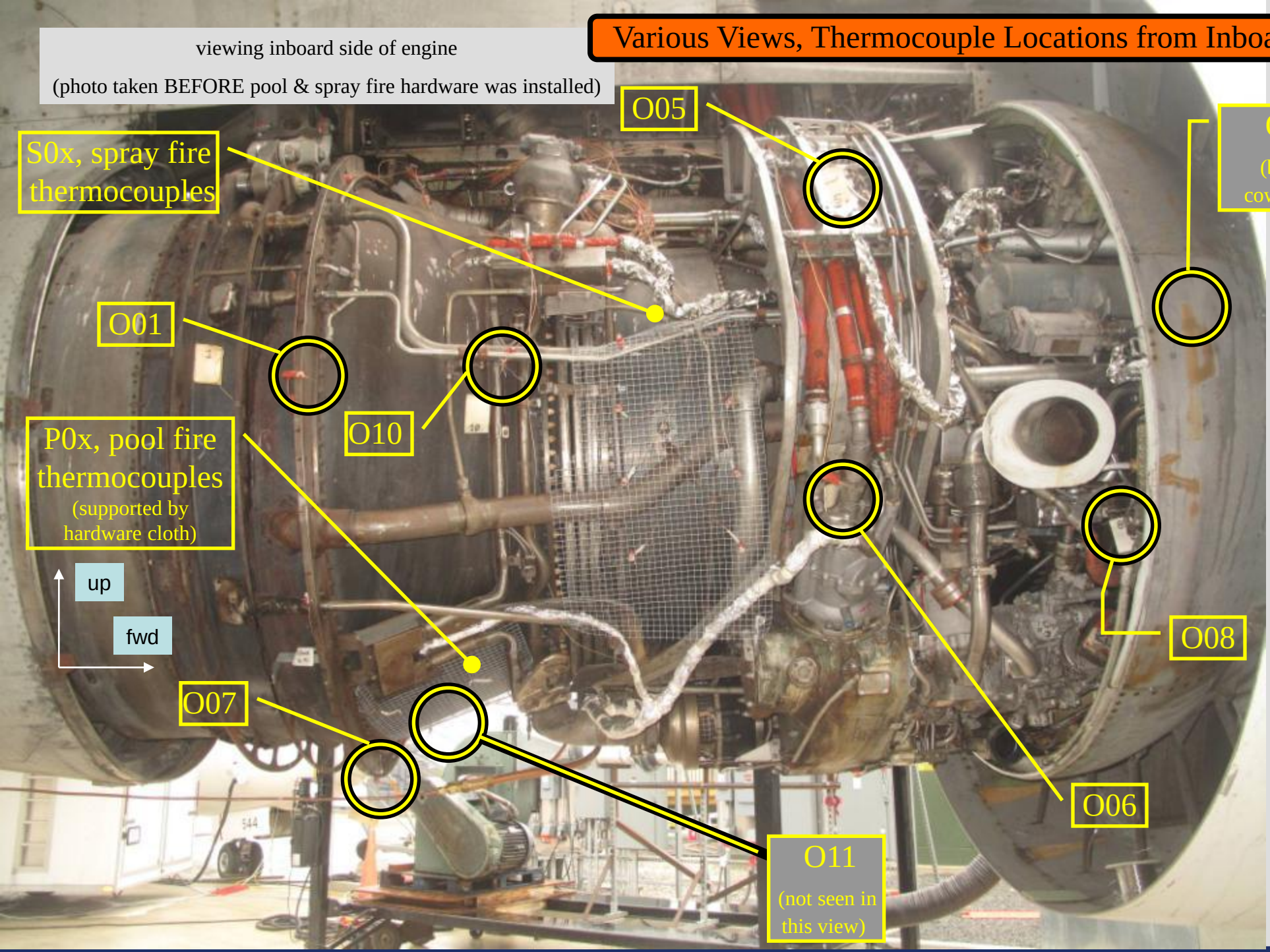
(photo taken BEFORE pool & spray fire hardware was installed)



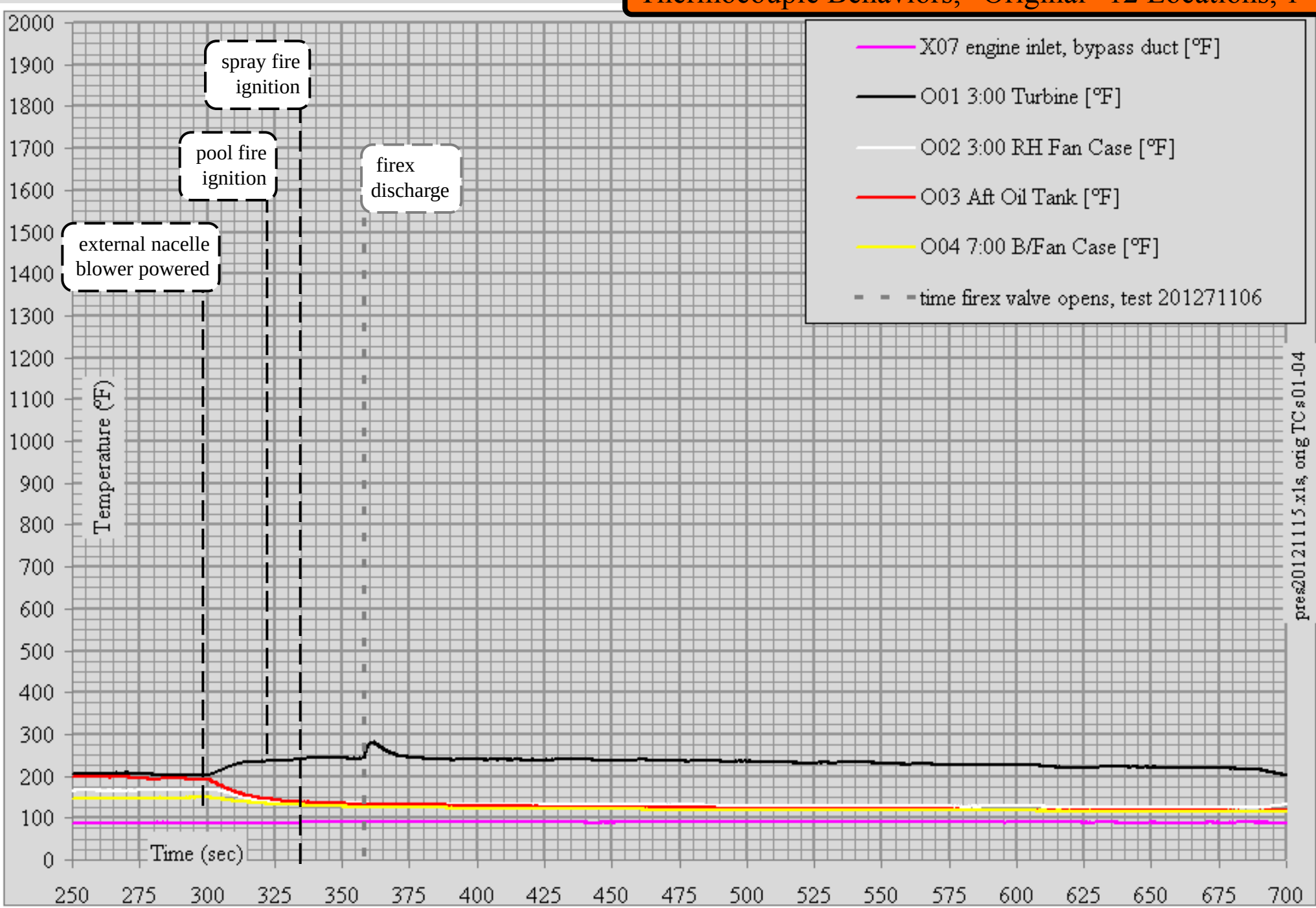
Various Views, Thermocouple Locations from Inboard View

viewing inboard side of engine

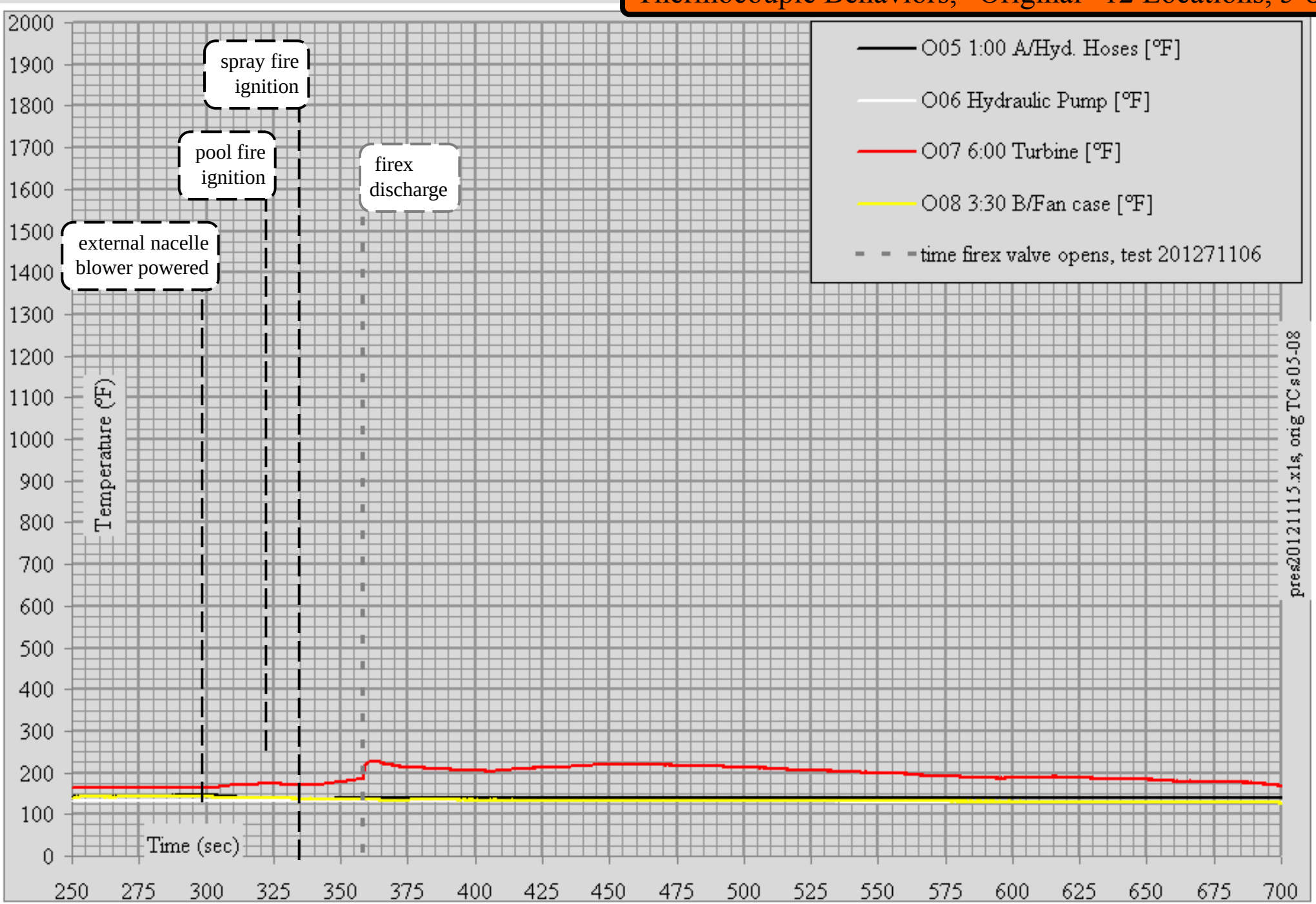
(photo taken BEFORE pool & spray fire hardware was installed)



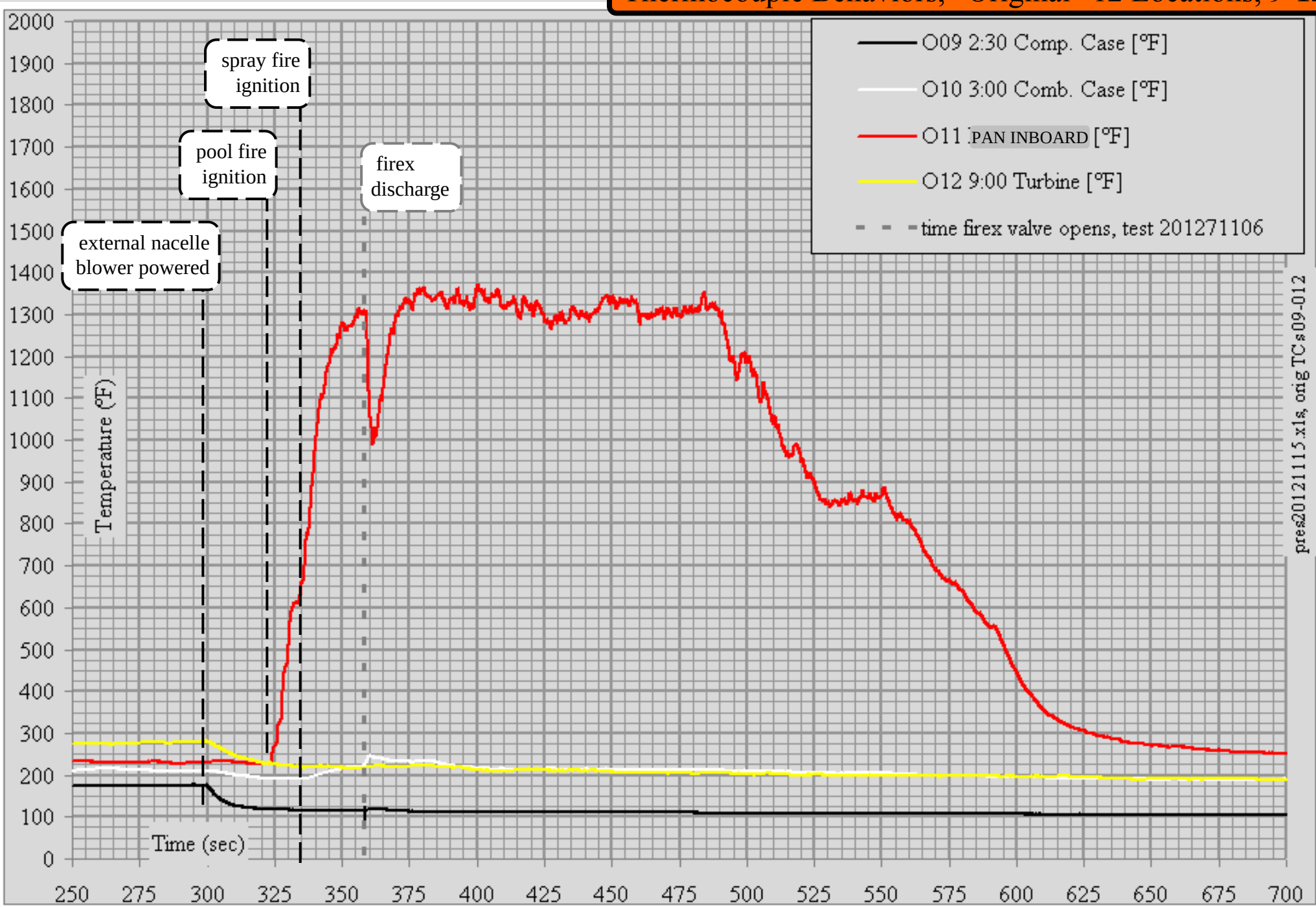
Thermocouple Behaviors, "Original" 12 Locations, 1-4



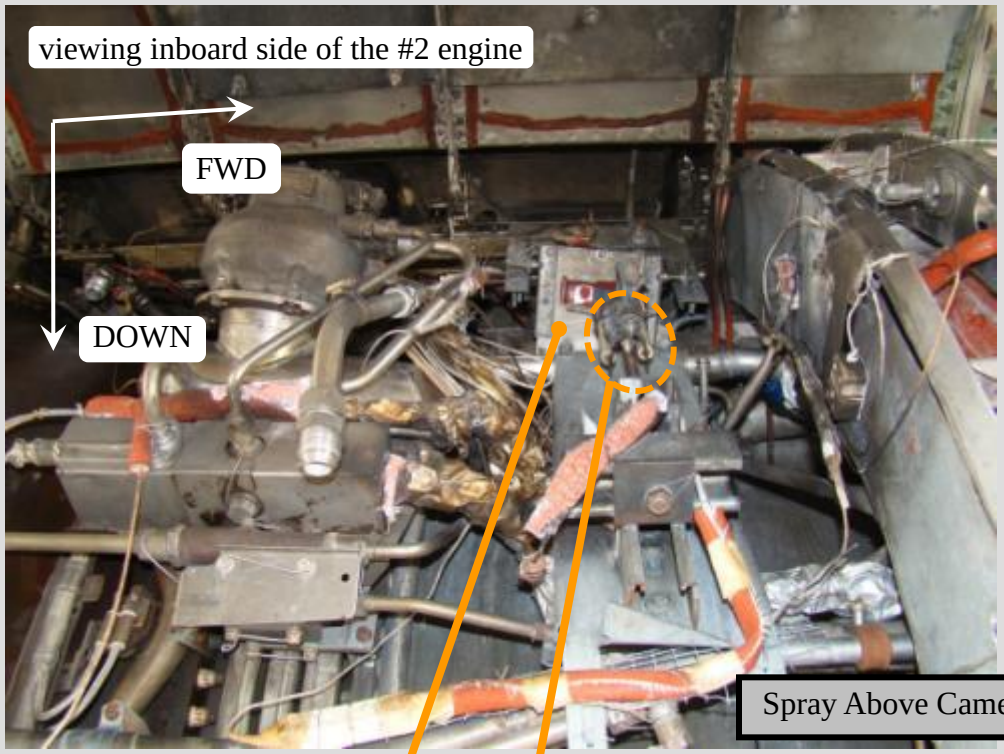
Thermocouple Behaviors, "Original" 12 Locations, 5-8



Thermocouple Behaviors, "Original" 12 Locations, 9-12



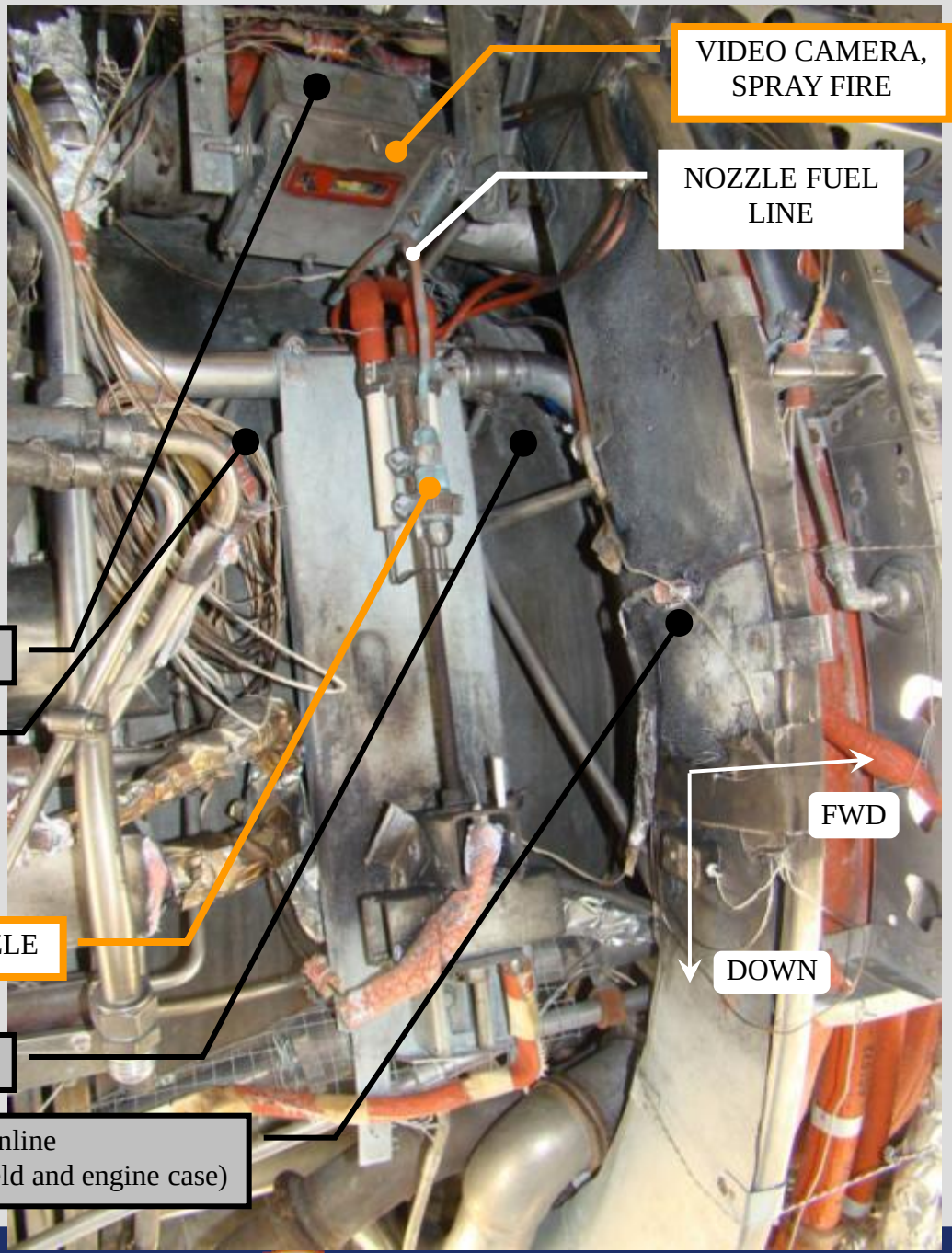
Various Views, Nacelle Spray Fire Threat, Concentration Sample Points & Video Camera Location



VIDEO CAMERA, SPRAY FIRE

FUEL SPRAY NOZZLE

CONCENTRATION SAMPLE POINT (typical)



Spray Above Camera

Spray Nozzle

FUEL SPRAY NOZZLE

Spray Between 16/17

Spray Inline (between thermal shield and engine case)

Full-scale Demonstration Testing, Solid Aerosol

~ Some Observations/Spray Fire Visual Record

NOZZLE FUEL LINE

with OBVIOUS FIRE

ELAPSING TIMER, HH:MM:SS.SS

DOOR SEALS

NOZZLE FUEL LINE

with minimal FIRE

Full-scale Demonstration Testing, Solid Aerosol

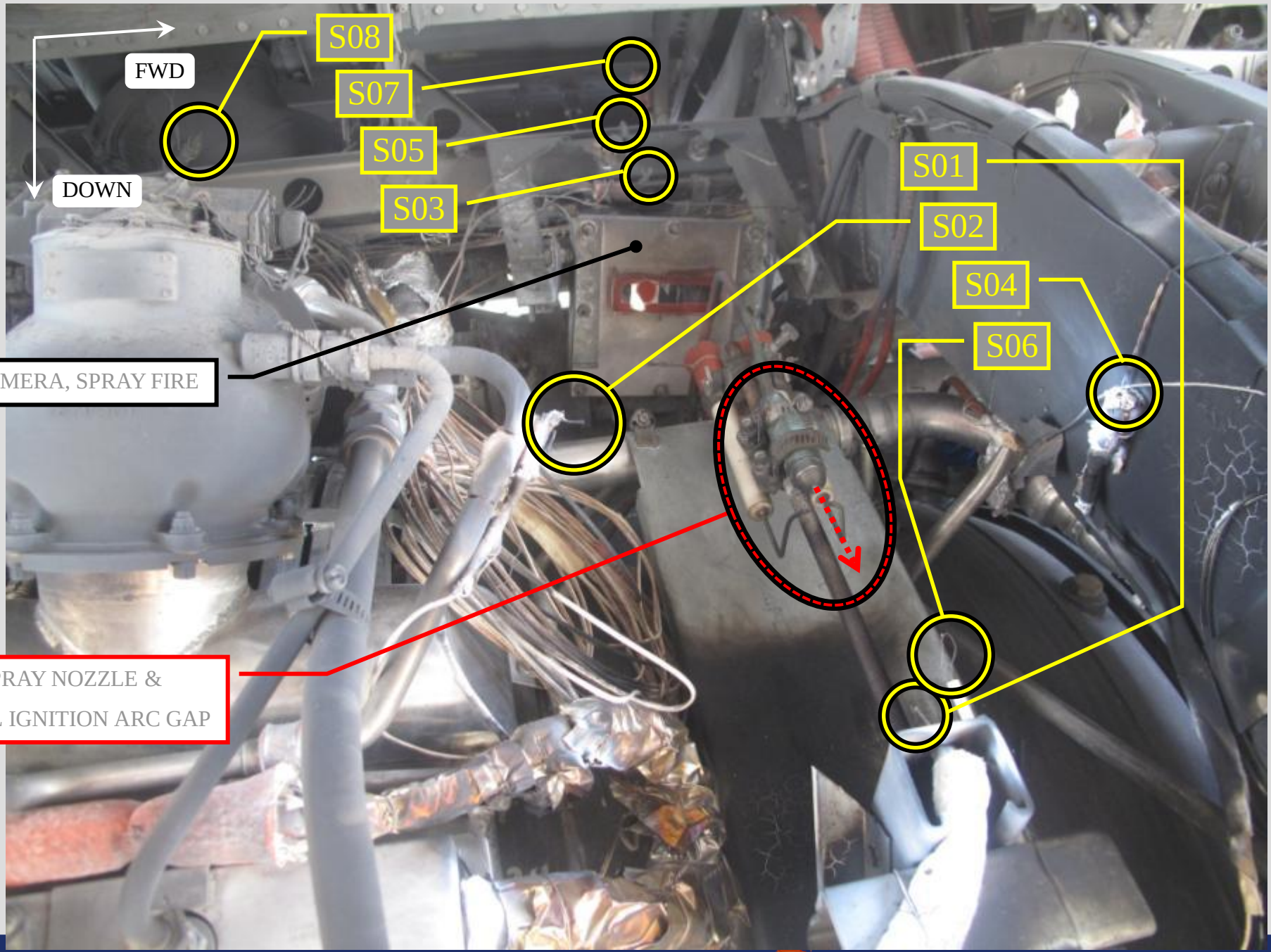
~ Some Observations/Spray Fire Visual Record

Full-scale Demonstration Testing, Solid Aerosol

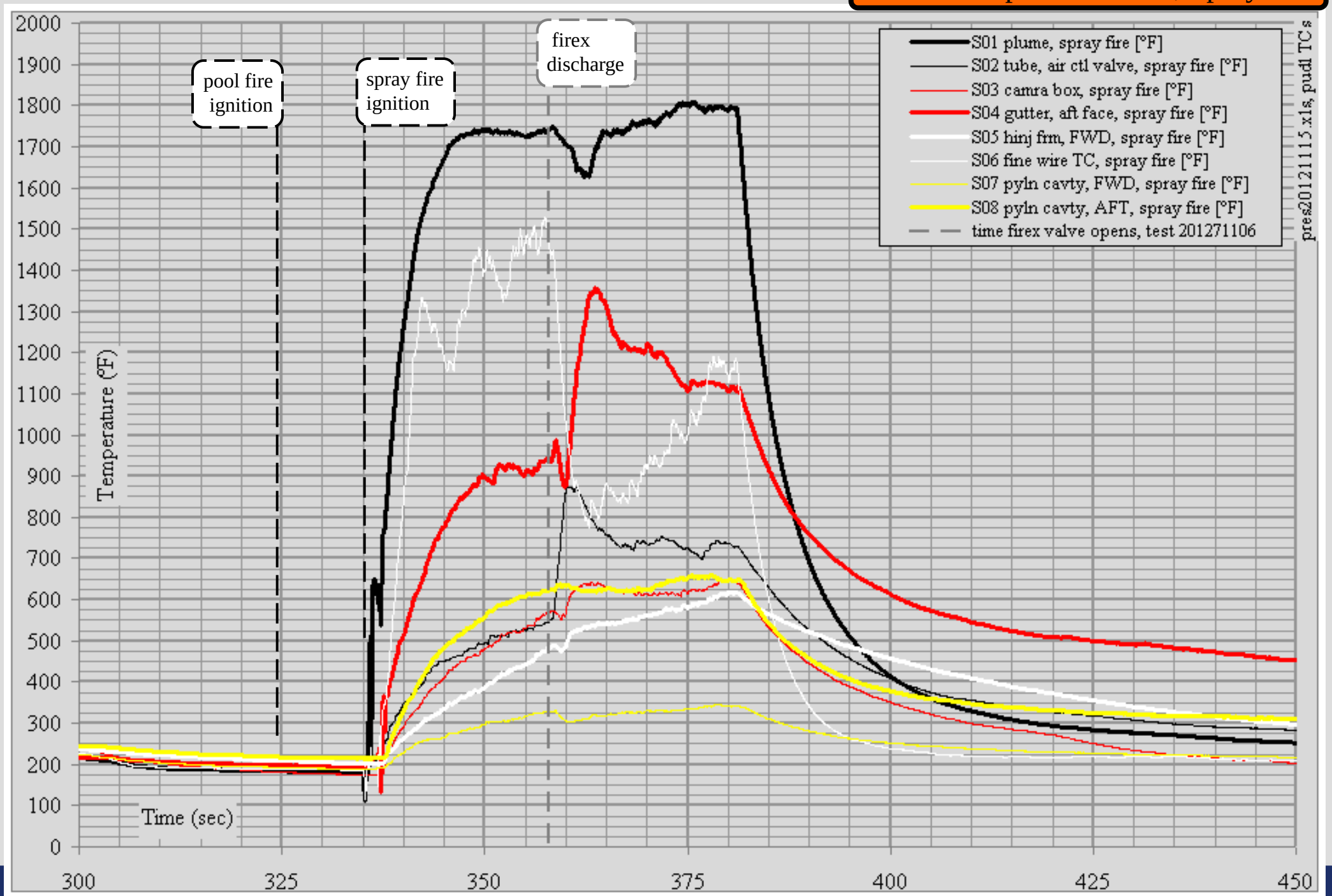
~ Some Observations/Spray Fire Visual Record

viewing outboard side of engine in spray fire region

Various Views, Thermocouple Locations, Spray Fire Threat



Thermocouple Behaviors, Spray Fire

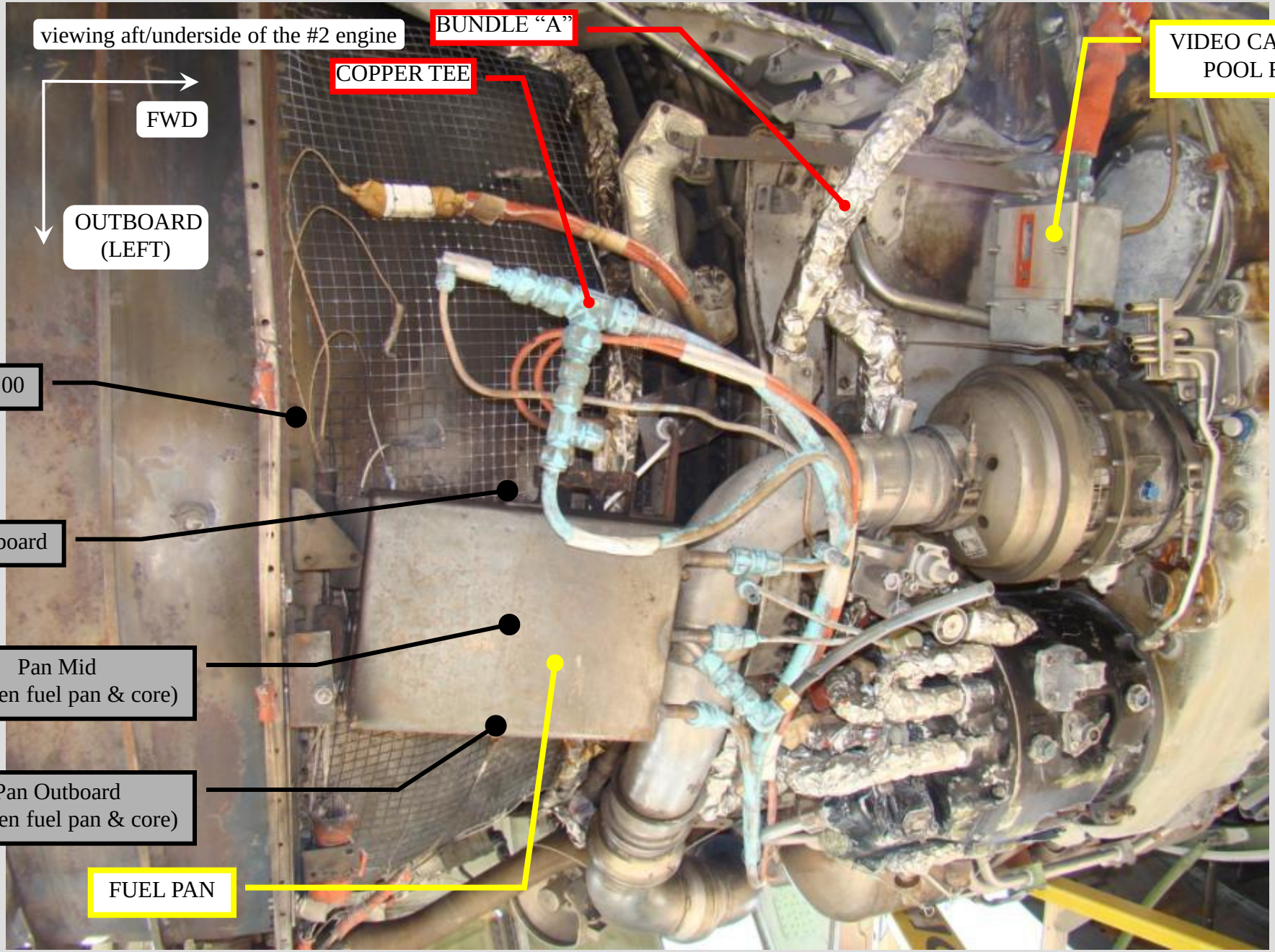


Full-scale Demonstration Testing, Solid Aerosol
~ Some Observations/Summary – Spray Fire Region

Some Observations, Summary/Spray Fire Region

- 1ST test/11Jul (test 201271103)
  - N_2 injection did not extinguish the spray fire
  - parts of 2 door seals continued burning after fuel flow stopped
    - seals are located on cowl door's inner face near the spray fire
    - similar to fiberglass/"high-temperature" silicone gasket material
- 2ND test/11Jul (test 201271106)
  - region remained illuminated throughout the firex agent exposure
  - after the firex agent pulse passed, the spray fire was burning
  - seals continued burning after fuel flow stopped
  - thermal traces
    - indicates flames are pushed around during injection
    - average trend remained steady to increasing

Various Views, Nacelle Pool Fire Threat, Concentration Sample Points & Video Camera Location



Full-scale Demonstration Testing, Solid Aerosol

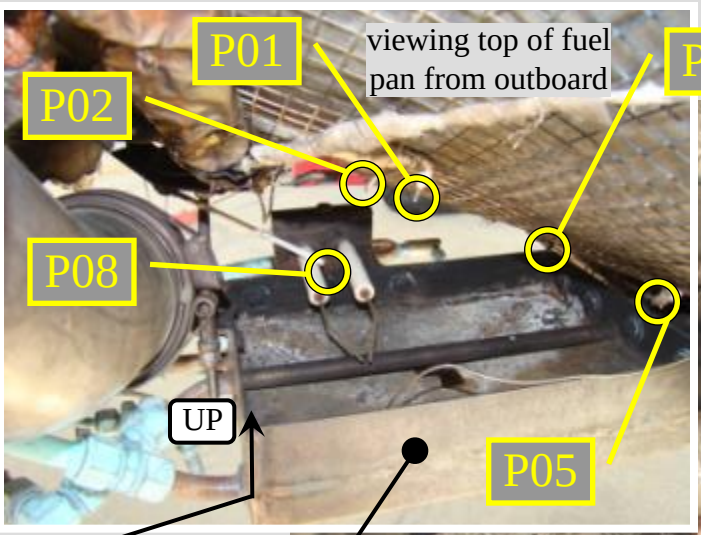
~ Some Observations/Pool Fire Visual Record

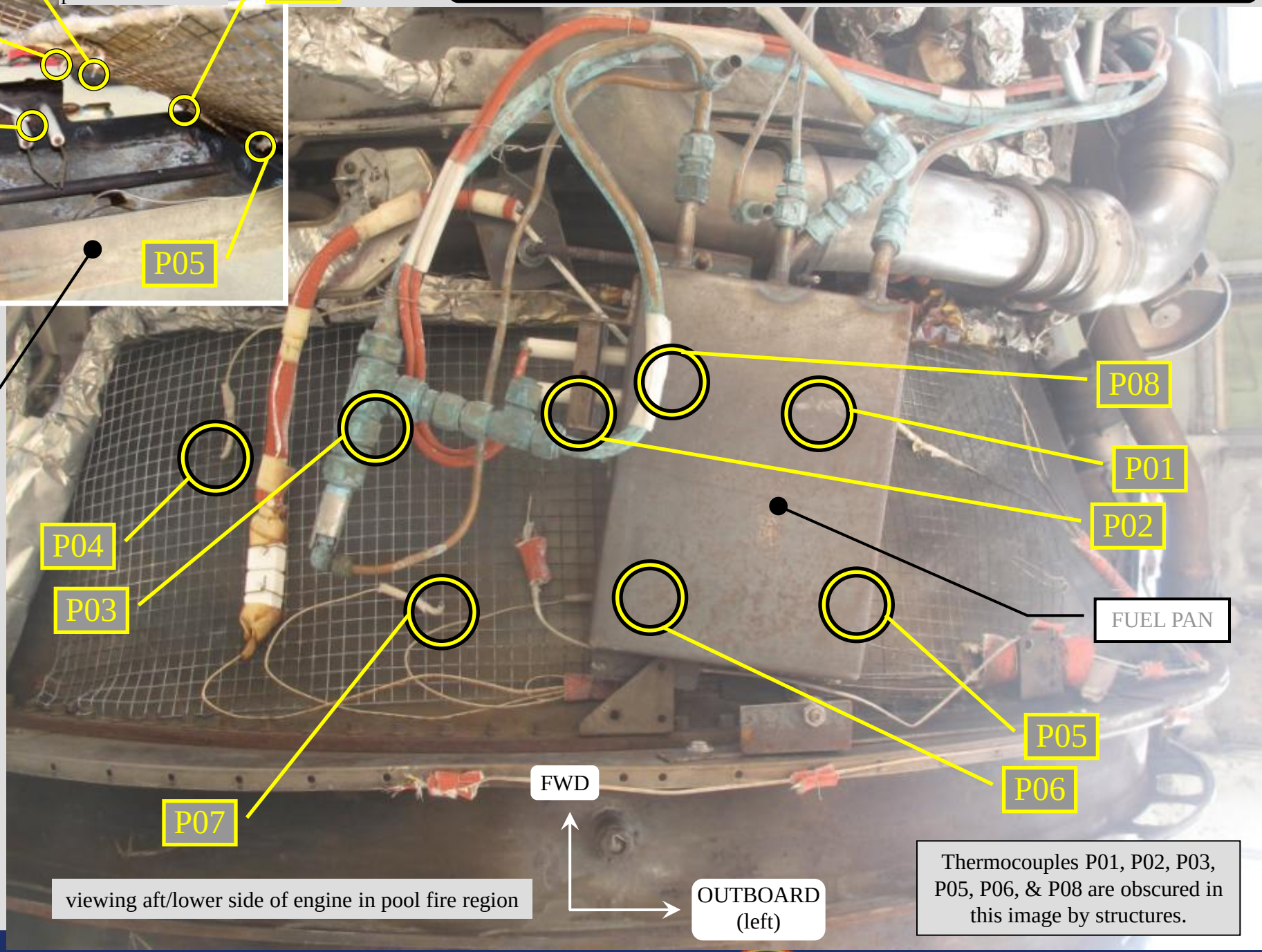
ELAPSING TIMER, HH:MM:SS.SS

Full-scale Demonstration Testing, Solid Aerosol

~ Some Observations/Pool Fire Visual Record

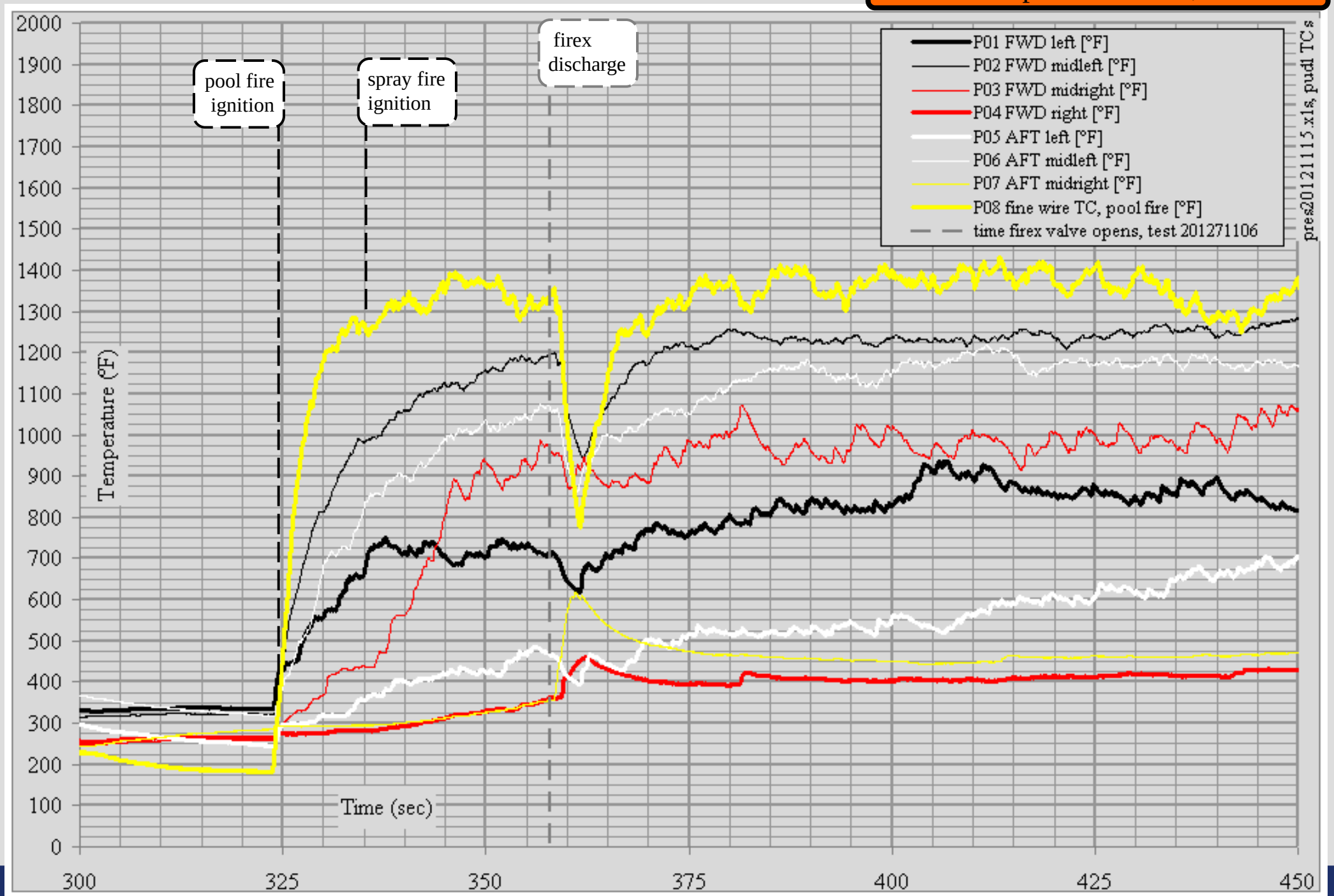
Various Views, Thermocouple Locations, Pool Fire Threat





Thermocouples P01, P02, P03, P05, P06, & P08 are obscured in this image by structures.

Thermocouple Behaviors, Pool Fire



Full-scale Demonstration Testing, Solid Aerosol
~ Some Observations/Summary – Pool Fire Region

Some Observations, Summary/Pool Fire Region

- N_2 did not extinguish the pool fire in 1ST test/11Jul
- 2ND test/11Jul
  - region remained mostly illuminated during the firex agent pulse
  - analog video record captured interesting behavior (not shown here)
    - occurred 00:09:46 – 00:09:48 (elapsing timer)
    - flames are pushed inboard, rotated around engine core beyond inboard limit of view field, view field briefly (t < 0.23 sec) went dark, then light intensity obviously increased near 06:00/BDC
  - after the firex agent pulse passed, the pool fire was burning
  - thermal traces
    - indicated flames are pushed around during injection
    - average trend decreased briefly but regained steady-state

Full-scale Demonstration Testing, Solid Aerosol
~ Outcomes

Outcomes

- The challenge to the design criteria was reasonable.
  - occurred in a “real” engine nacelle environment
  - spray & pool fire threats were present
  - all added to create the spray & pool fire threats were similar in character to that already in the nacelle
- The firex system “protected” part of the nacelle fire zone.
- The firex agent distribution surrounded each fire region simultaneously while representing the design criteria.
- The spray & pool fires did not extinguish in either test.
- 2 cowl door seals near the spray fire continued burning after fuel flow stoppage.

Full-scale Demonstration Testing, Solid Aerosol
~ Outcomes/Next Steps

Outcomes/Next Steps

- Following 11Jul test outcome, industry/FAA discussion continued; opinions differed about the next steps.

- Given the test outcome, FAA & industry goals diverged.
  - industry reasonably wants to understand the test outcome
  - FAA support falters because progression to a recommendation for certification, the basis for support, is not possible in the near-term

- FAATC offered additional/constrained support.
  - focus to understand the test environment, not the candidate
  - any focus on the candidate taken as development work, the obligation of the industry team

Full-scale Demonstration Testing, Solid Aerosol
~ Outcomes/Next Steps

Outcomes/Next Steps

- FAATC offer of further 747SP support
  - work to better understand fire behaviors/intensities
  - assess the situation with something “familiar”; use halon 1301
    - represent 6%v/v for 0.5 sec across the same 8 sample points
    - firex system creation at industry expense
    - FAATC-imposed deadline
  - assess intensity via extinguishment; i.e. if not extinguished, threats too severe, else threats reasonably severe; react accordingly

- Given the difference here between FAA & industry constraints, industry declined the offer of this support.

Full-scale Demonstration Testing, Solid Aerosol
~ Conclusions

- Given no fire extinguishment subject to N_2 injection, the fire threats were considered sufficiently intense.
- Given no fire extinguishment when subject to the solid aerosol injection, the represented design criteria did not demonstrate fire extinguishment.
- The firex agent & its distribution measurement observably differ from history. Change in firex design rationale, acknowledging these differences, may alter outcome.
- Currently, the FAATC provides no further significant support regarding this solid aerosol. Industry action continues.
  - resuming FAA support remains possible, contingent upon the development of plausible knowledge
  - the form of any future support is not known at this time

Current Status

~ Engine Nacelle Halon Replacement Activity, FAATC

- No significant testing planned.
- Significant report creation planned.
  - MPSHRe report, to include :
    - test process development
    - work with :
      - HFC-125
      - CF_3I
      - 2-BTP
      - FK-5-1-12
      - KSA
    - MPSHRe rev03; given HFC-125 & CF_3I outcomes per rev03
    - MPSHRe rev04
  - "cold" FK-5-1-12 technical note

End of Presentation

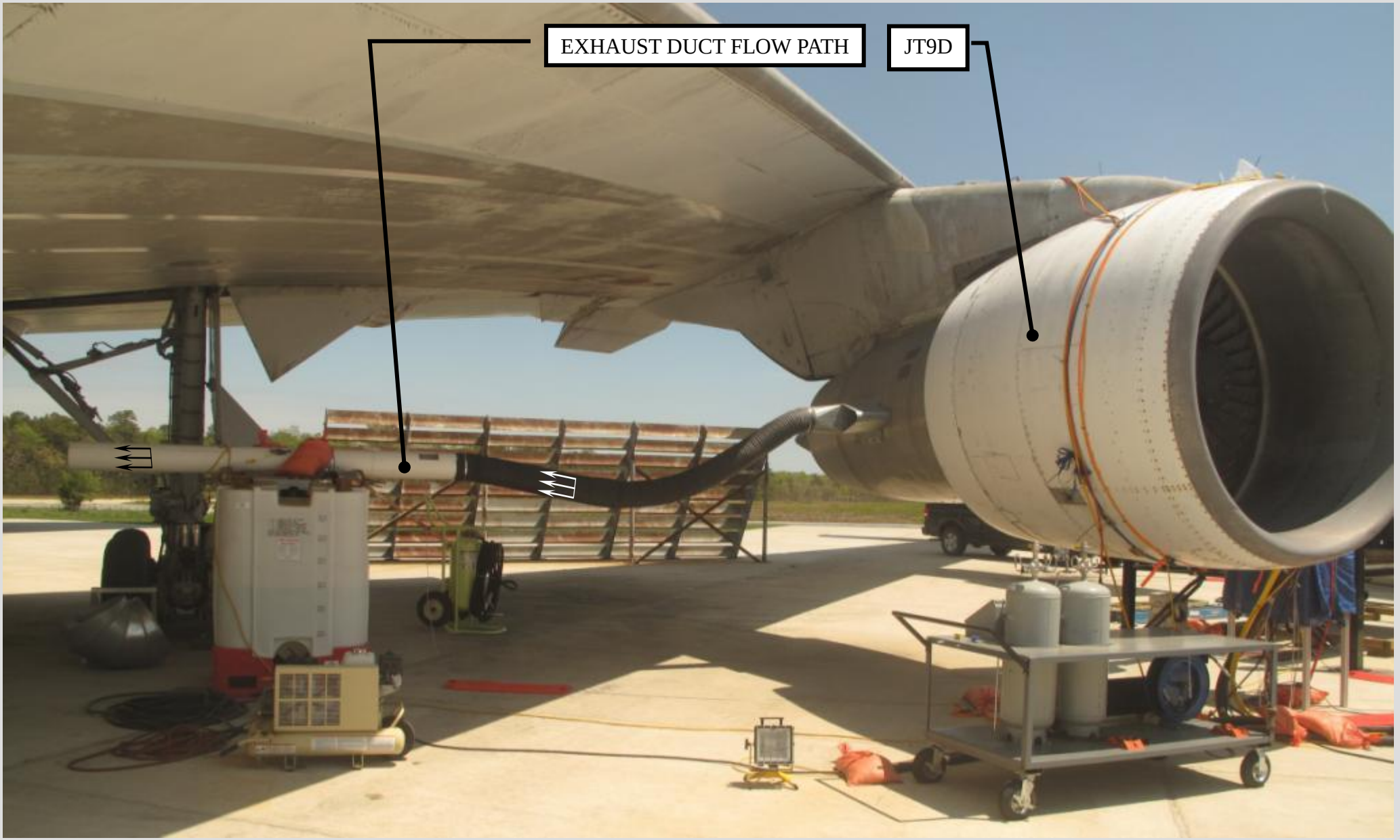
- **Acronyms, definitions, short-hand notations**

approx = approximately
BDC = bottom dead center
FAA = United States Federal Aviation Administration
FAATC = FAA W.J. Hughes Technical Center
firex = fire extinguishing or fire extinguishing system
FWD = forward
MPSHRe = Minimum Performance Standard for Halon Replacement in Civil Aircraft Engine Nacelle & APU Compartments
rev = revision

Appendix Imagery

Various Views, Nacelle Ventilation, Supply

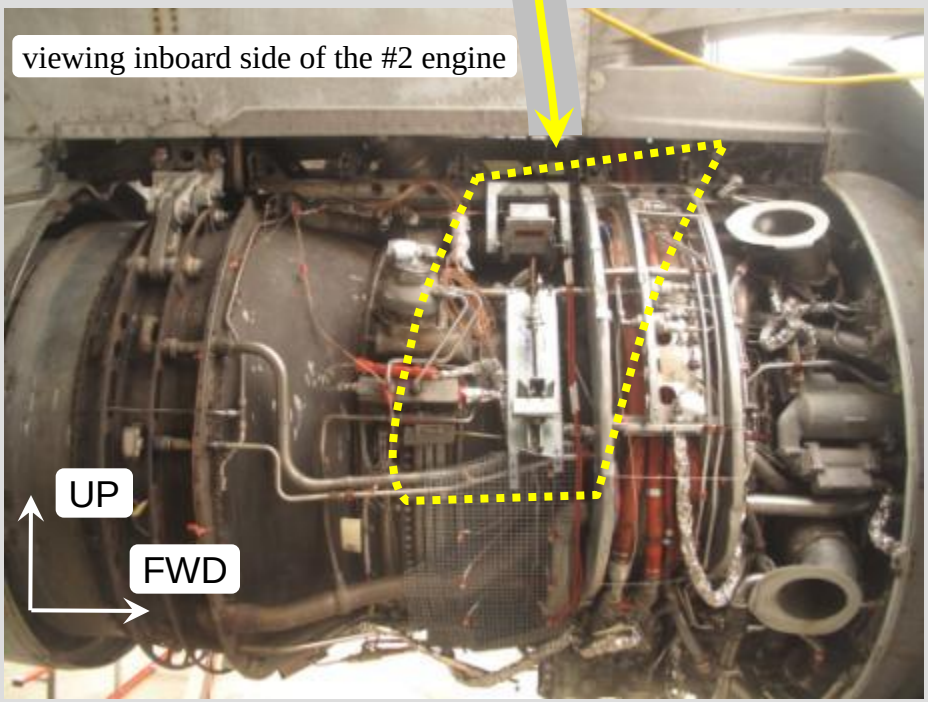
Various Views, Nacelle Ventilation, Exhaust



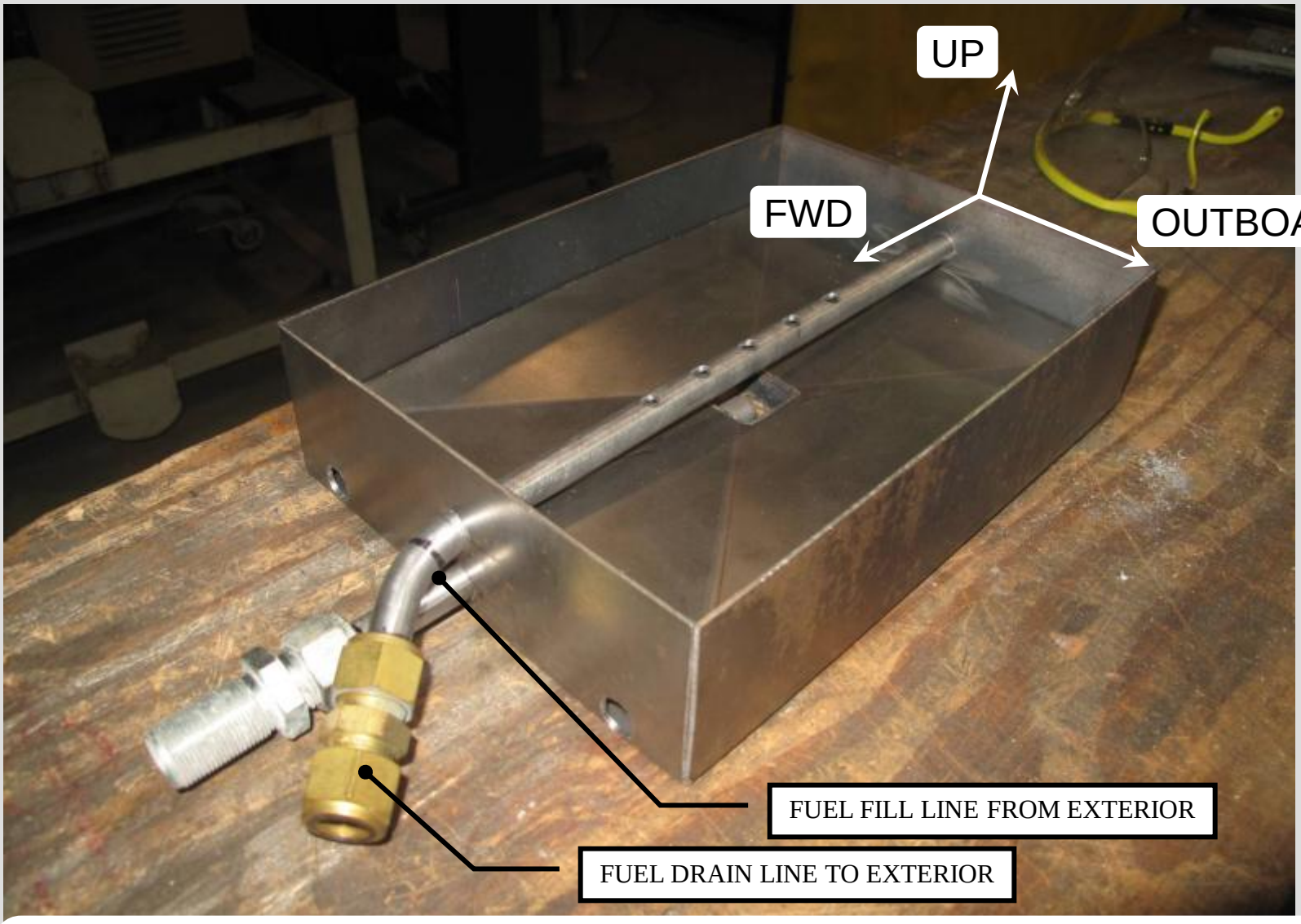
Various Views, Nacelle Spray Fire Threat, General Site Orientation

CAMERA, SPRAY FIRE

FUEL SPRAY NOZZLE &
ELECTRICAL IGNITION ARC GAP

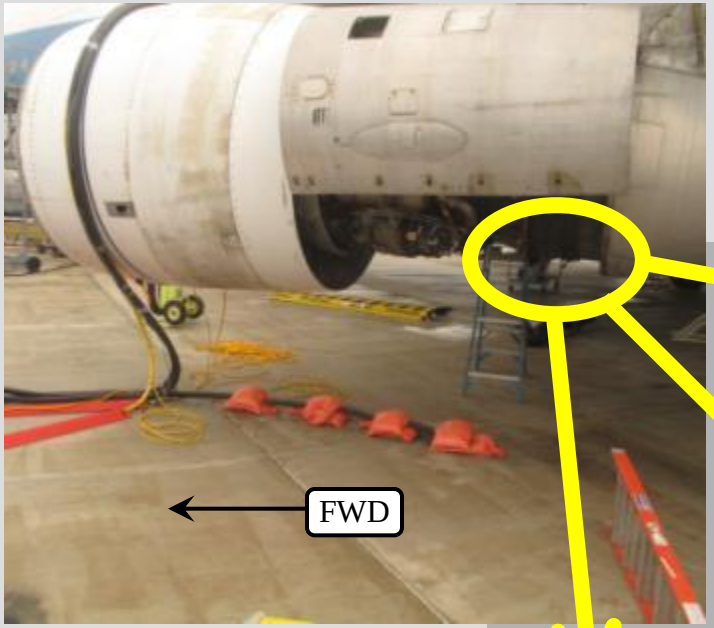


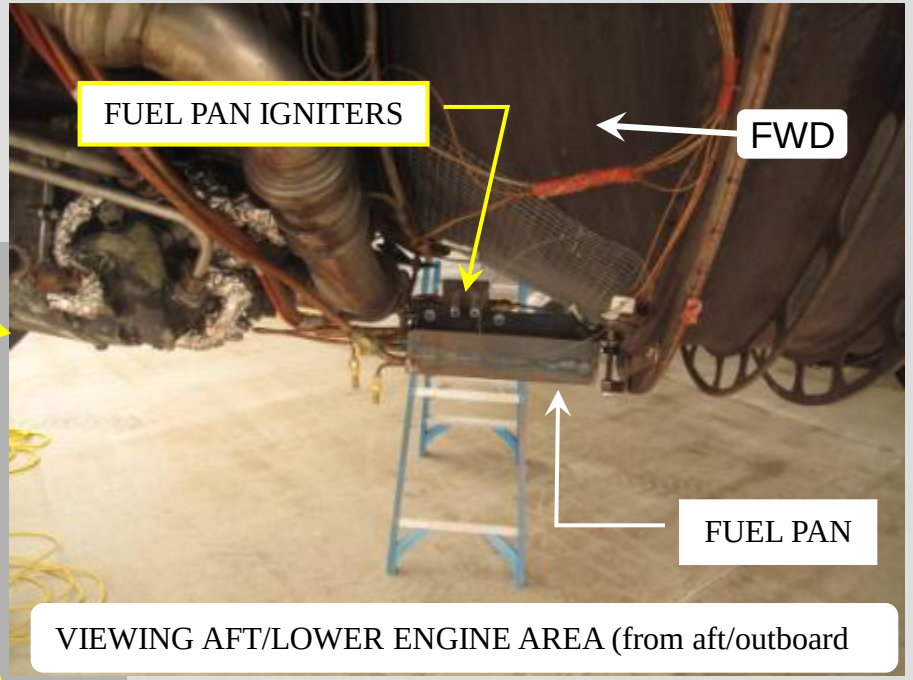
Various Views, Nacelle Pool Fire Threat, Fuel Pan Details



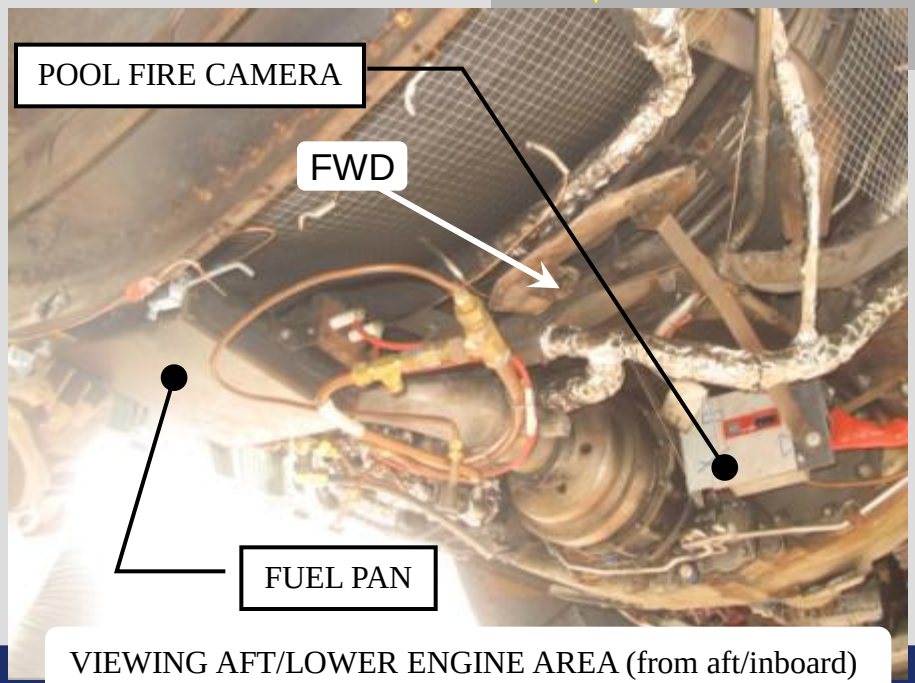
- Fuel pan is made from 14 ga steel & approximately 191 x 267 x 64 x mm tall (7.5 x 10.5 x 2.5 in tall)
- Fuel puddle depth approximately 13 mm (0.5 in) & freeboard (dry lip) height approximately 25 mm (1 in)
- Base of fuel pan is hollow permitting water flow from a water jacket

Various Views, Nacelle Pool Fire Threat, General Site Orientation

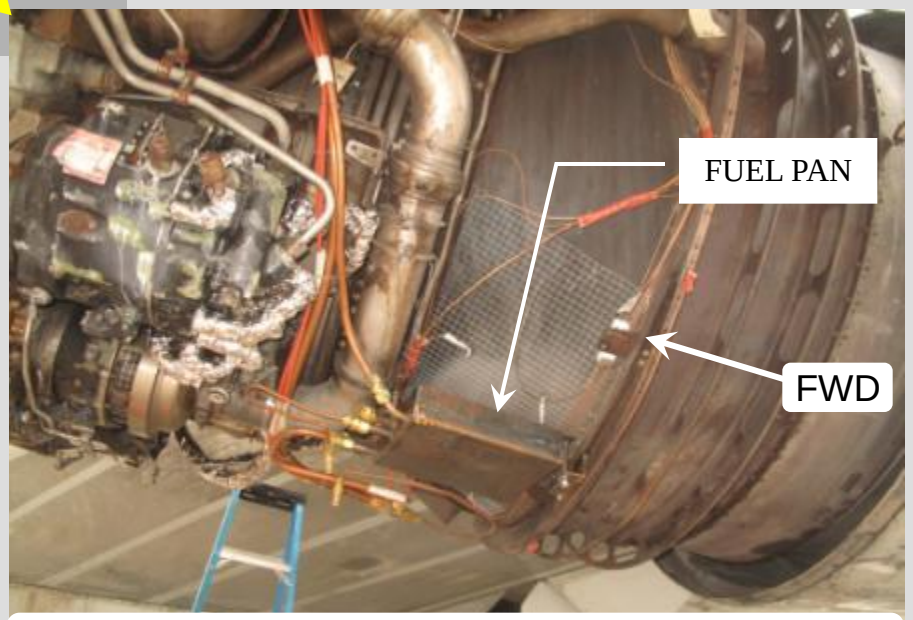




VIEWING AFT/LOWER ENGINE AREA (from aft/outboard



VIEWING AFT/LOWER ENGINE AREA (from aft/inboard)



VIEWING AFT/LOWER ENGINE AREA (from mid/outboard)