

Forced-flow Fire Testing with “cold”-soaked FK-5-1-12, Final Results



Federal Aviation
Administration

Presented to: International Aircraft Systems Fire
Protection Working Group

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Presentation Overview

Major Discussion Points

- **Purposes**
- **Test Conditions and Constraints**
- **Outcomes**
- **Interesting Observations**
- **Appendix Materials**

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



Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

Purposes

- Challenge FK-5-1-12’s fire extinguishment performance in the nacelle fire simulator (NFS) for some “cold” conditions
- Observe the fire extinguishment behavior
 - based upon an acceptable firex agent distribution in the NFS at “high” ventilation¹
 - observe the behavior when the firex agent is :
 - “cold”-soaked
 - injected into a “cold”-walled compartment
 - experiencing a “cool” (ambient) air flow

¹ Reference MPSe revisions 3 & 4 and past presentations regarding FAA nacelle halon replacement activity with FK-5-1-12

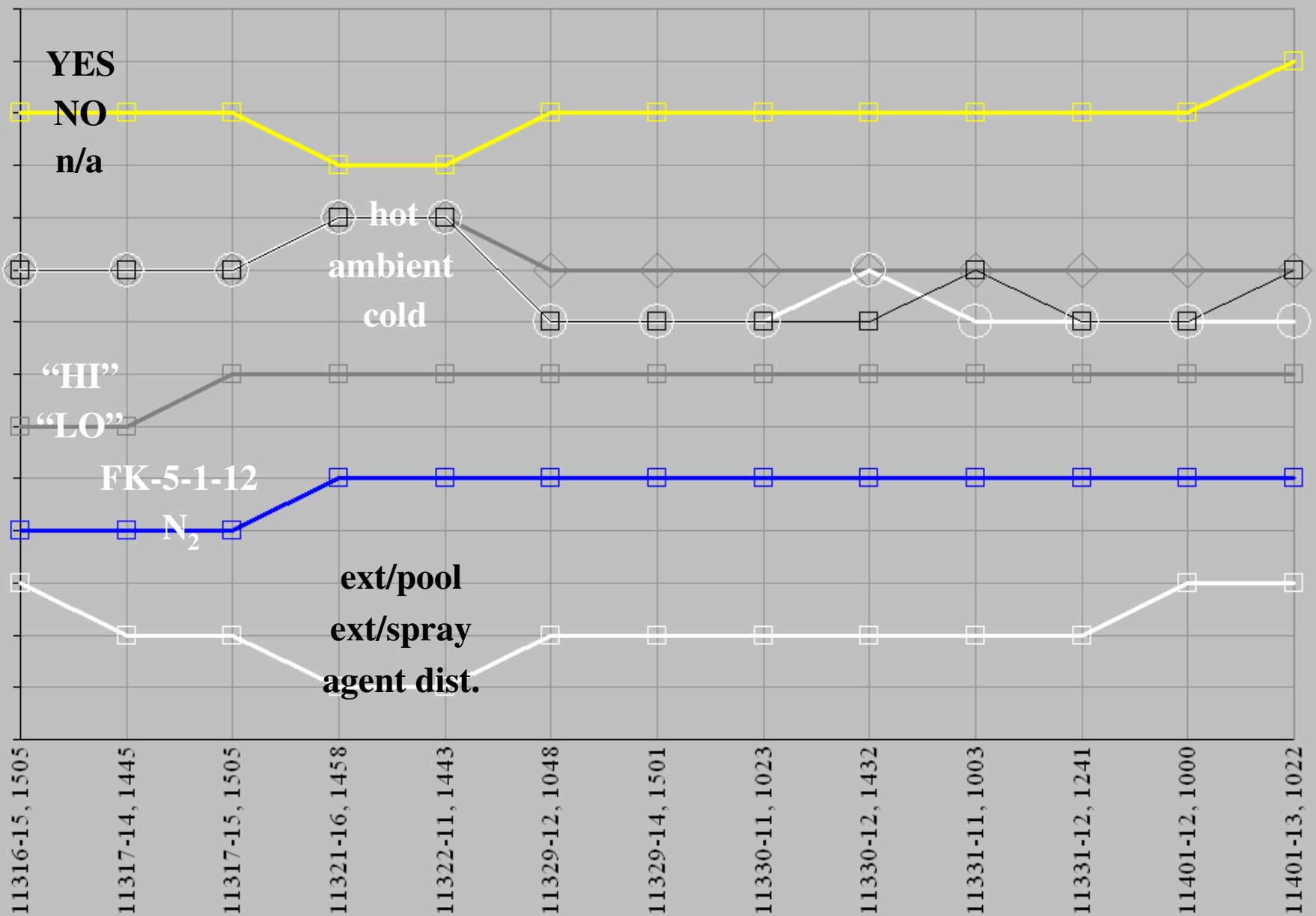
Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

Test Conditions & Constraints

- Varied conditions, as needed, for :
 - NFS ventilation stream : mass flow rate, temperature
 - partial NFS boundary : temperature
 - firex agent : mass/pressure/temperature, injection configuration
 - fire threat : spray or pool
- Demonstrated negligible flame extinction effects other than firex agent concentration; N₂ discharged from largest bottle through least restrictive plumbing
- Sole persistent ignition threat was spray fire’s hot surface

Graphical Representation of Simplified Test Conditions & Outcomes by Test

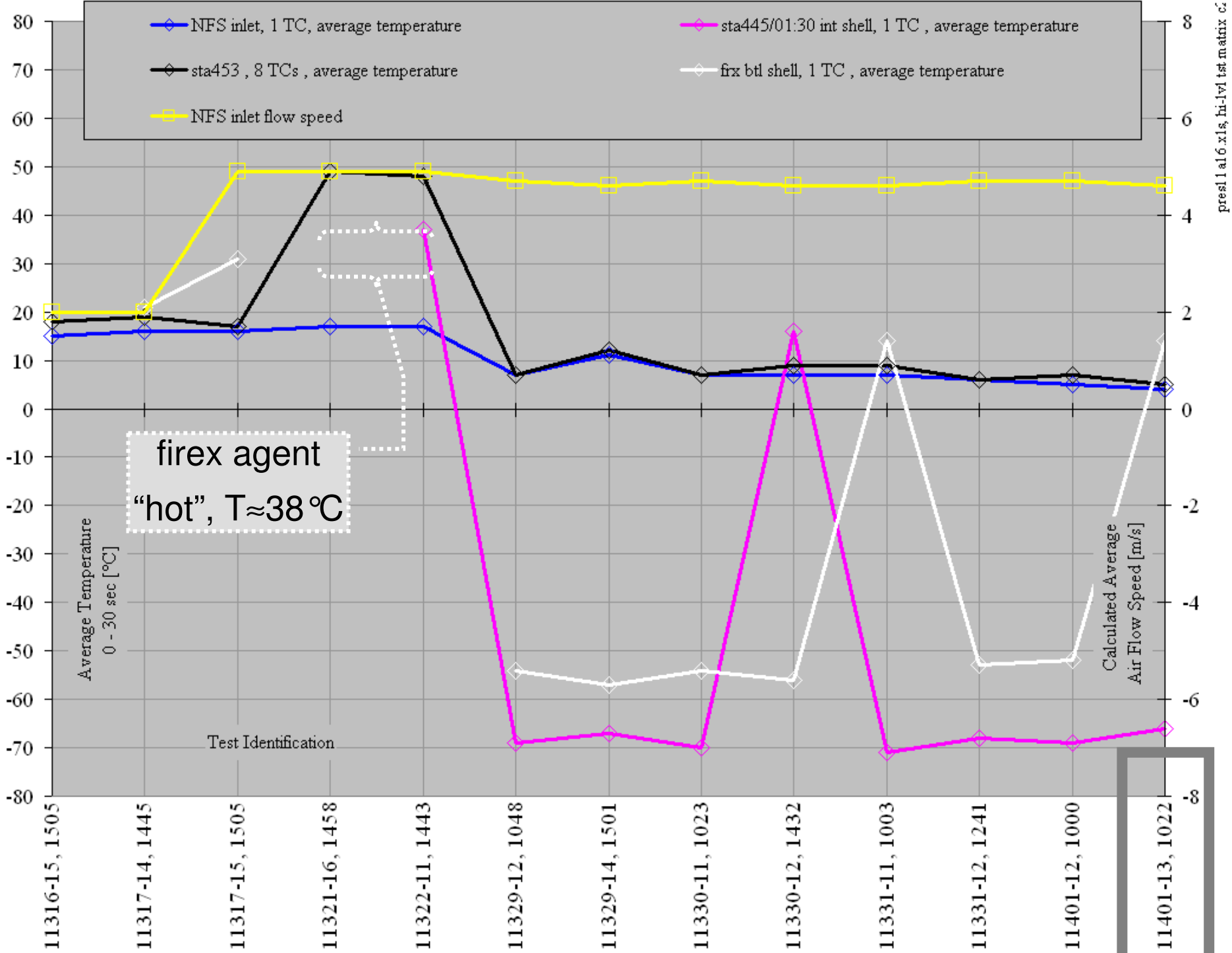
- test type (firex agent distribution, extinguishing/spray, extinguishing/pool)
- NFS stream mass flow rate ("lo" ~ 0.45 kg/s, "hi" ~ 1.5 kg/s)
- NFS wall temperature (cold, ambient, hot)
- fire extinguished ? (not applicable, no, yes)
- firex agent used (N2, FK-5-1-12)
- ◇— NFS stream temperature (ambient, hot)
- firex agent storage temperature (cold, ambient, hot)



pres11a16.xls, hi-1v1 tst matrix c:



Graphical Representation of Average Temperatures & Flow by Test

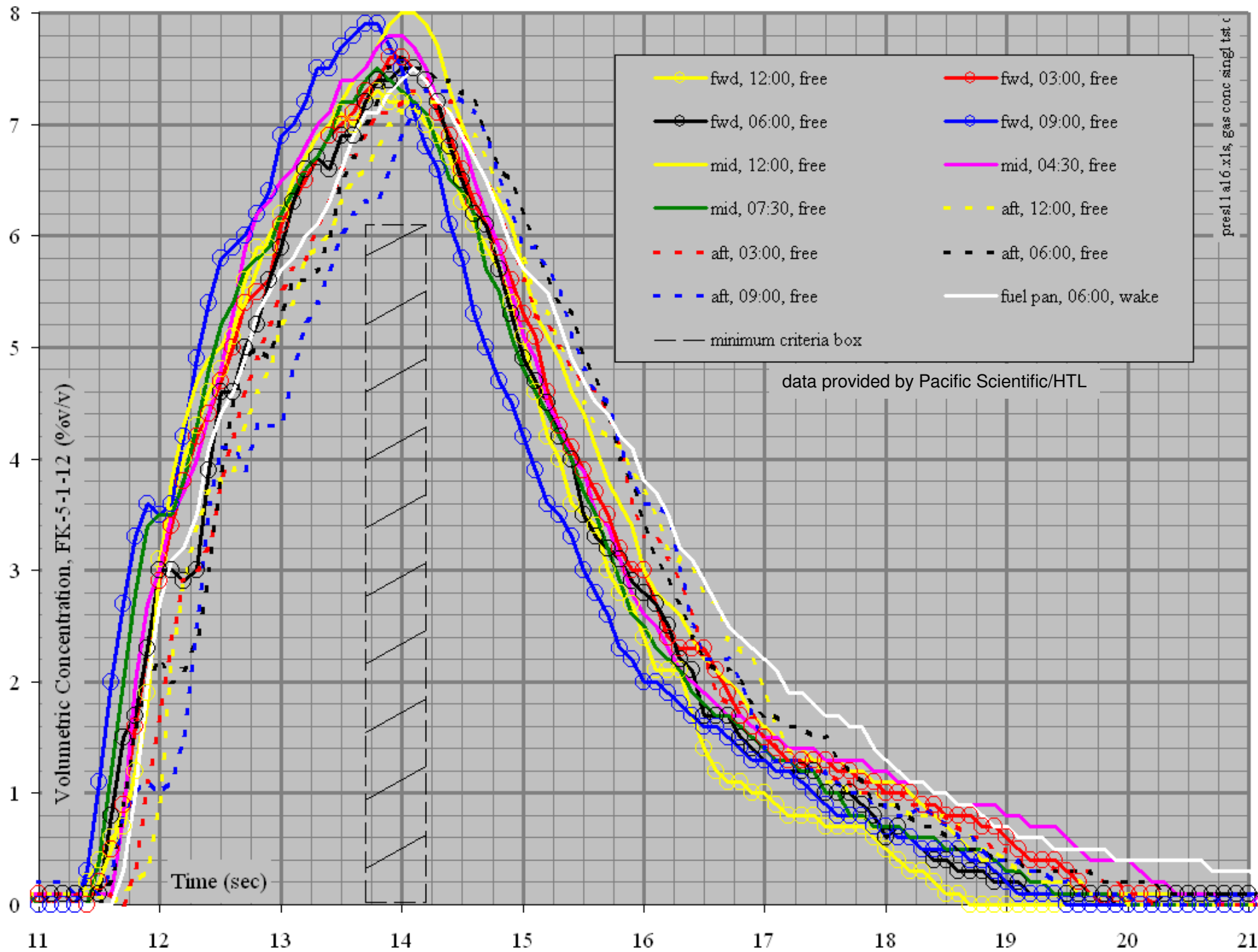


Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

Test Conditions & Constraints

- Established firex configuration for NFS “high” ventilation
 - met intent of MPSe rev03 outcome for FK-5-1-12
 - 12 sample points simultaneously equal/exceed 6.1%v/v for ½ sec; sample points defined per MPSe rev04
 - accomplished for “high” ventilation condition from MPSe testing; ~1.2 kg/s @ 49°C
- Firex plumbing configuration intact throughout project
 - *except* a single 1-test alteration, injection plumbing
 - *otherwise* multiple 1-test variations, mass & pressure

Volumetric Distribution of
FK-5-1-12 within the NFS at "high" Ventilation



Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

Outcomes

- No spray fires extinguished
- One of 2 pool fires extinguished
 - test conditions for extinguished pool fire
 - ambient NFS stream
 - cold NFS boundary
 - ambient firex agent
 - pool reignited & reestablished “stable” combustion

Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

Interesting Observations

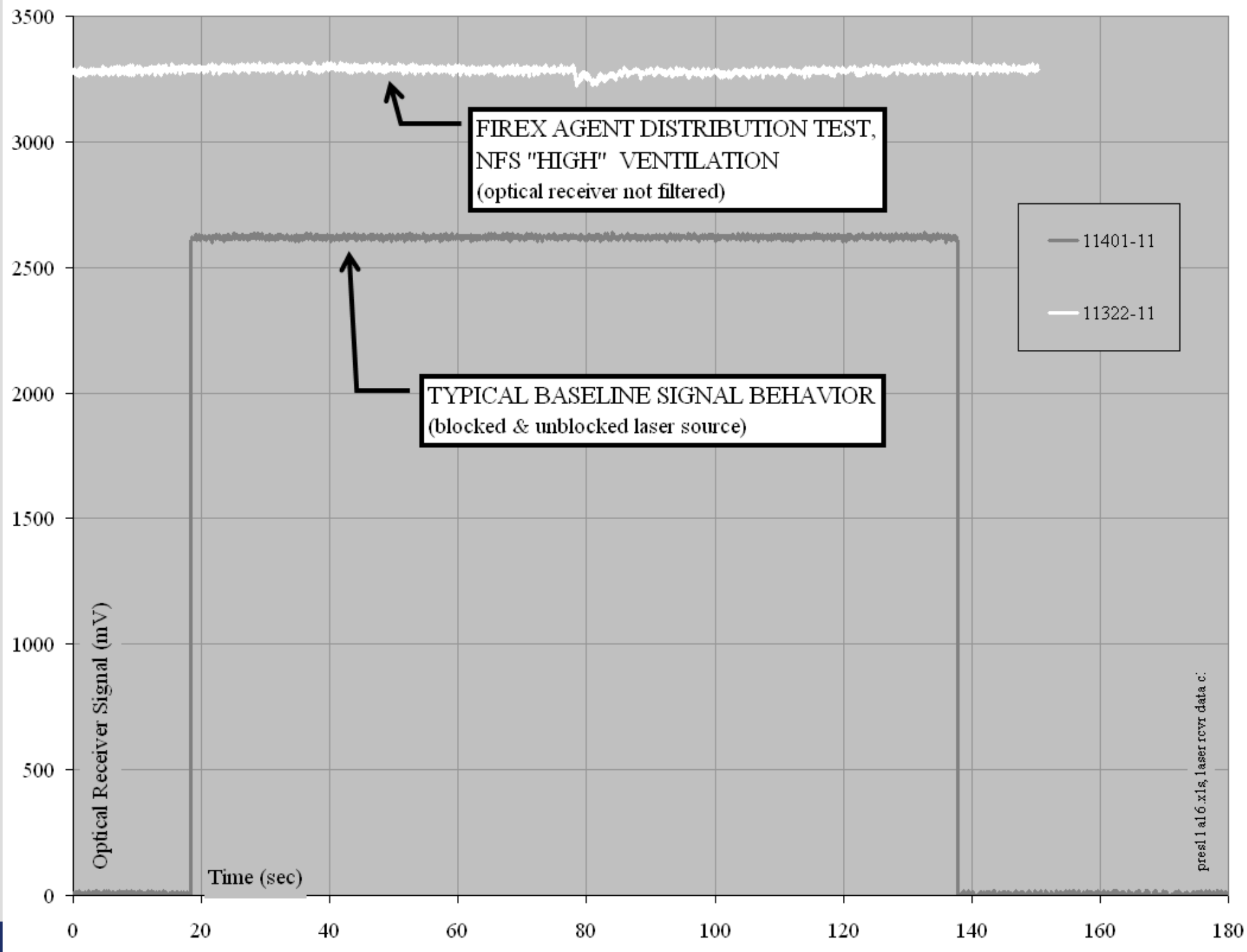
- Pool fire extinguishment observed during final test
 - visible record captures extinguishment and reignition
 - flames on the pool’s fuel surface extinguished
 - flames propagated forward from aft of fuel pan & reestablished on pool surface
 - no hot surfaces reasoned to exist aft of the pool
 - likely illustrated the ability of flames to move through compartments not fully protected

Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

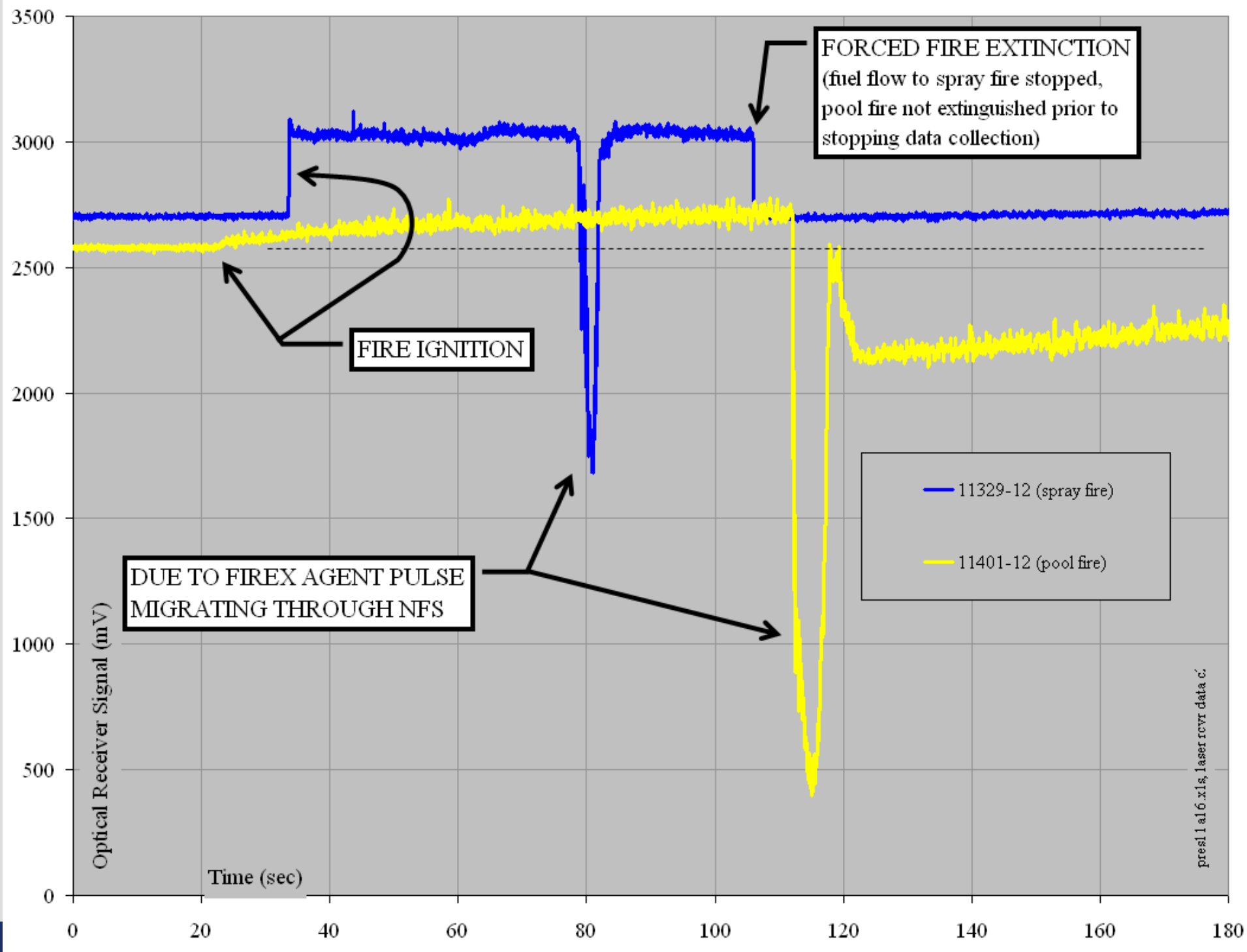
Interesting Observations

- Light Transmission
 - laser & filtered optical receiver forward of each fire threat
 - raw signal illustrated major events of the test
 - signal history/aerosol cloud not easily explained
 - injected “cold”-soaked agent likely :
 - produced liquid aerosol cloud (FK-5-1-12_{LIQUID})
 - condensed atmospheric moisture (H₂O_{LIQUID})
 - “cold” interior NFS walls covered with frost (H₂O_{SOLID})
 - at a minimum, the aerosol contained FK-5-1-12_{LIQUID}, H₂O_{LIQUID}, & H₂O_{SOLID}

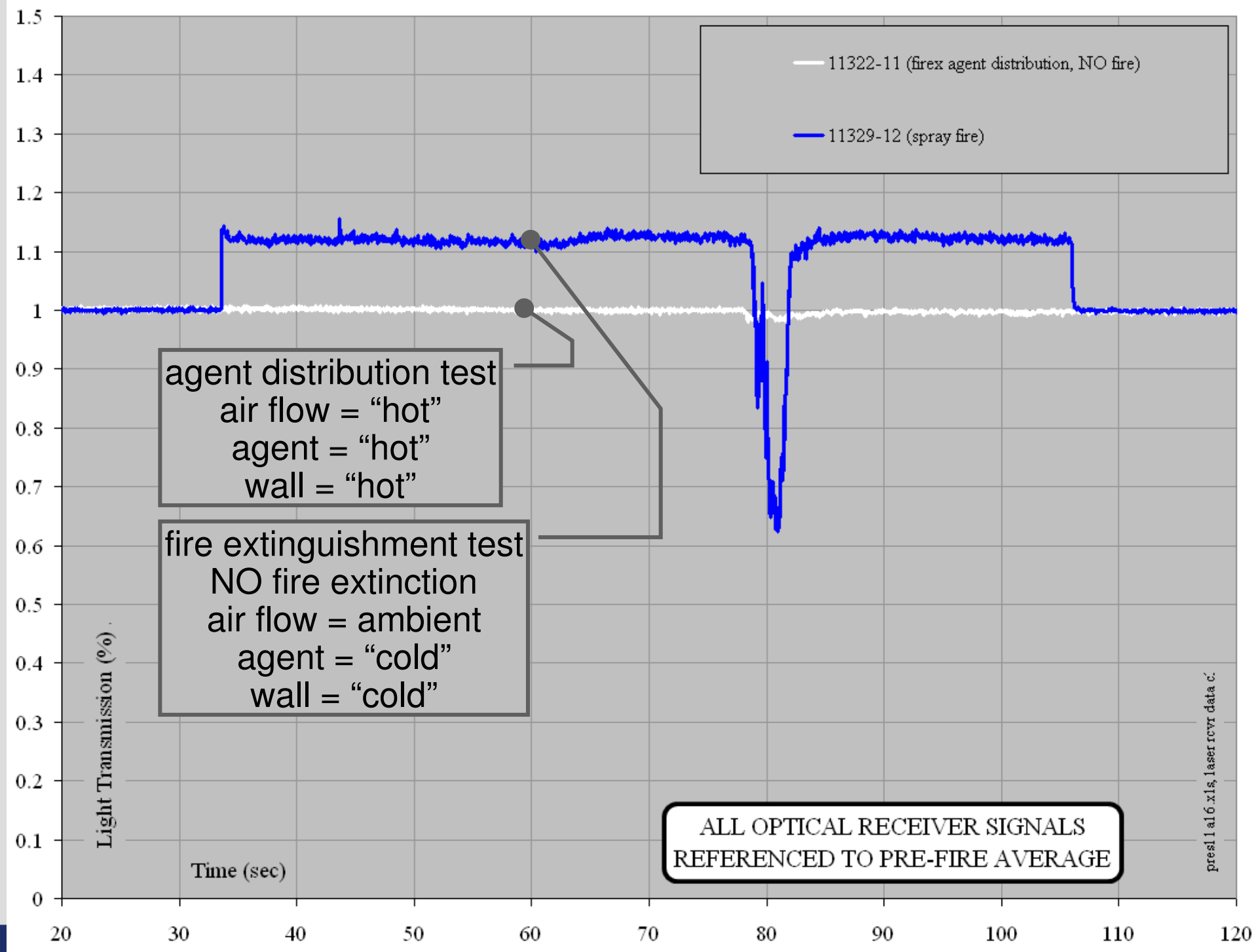
Raw Optical Receiver Signal History
Baseline Behavior &
Firex Agent Distribution Test



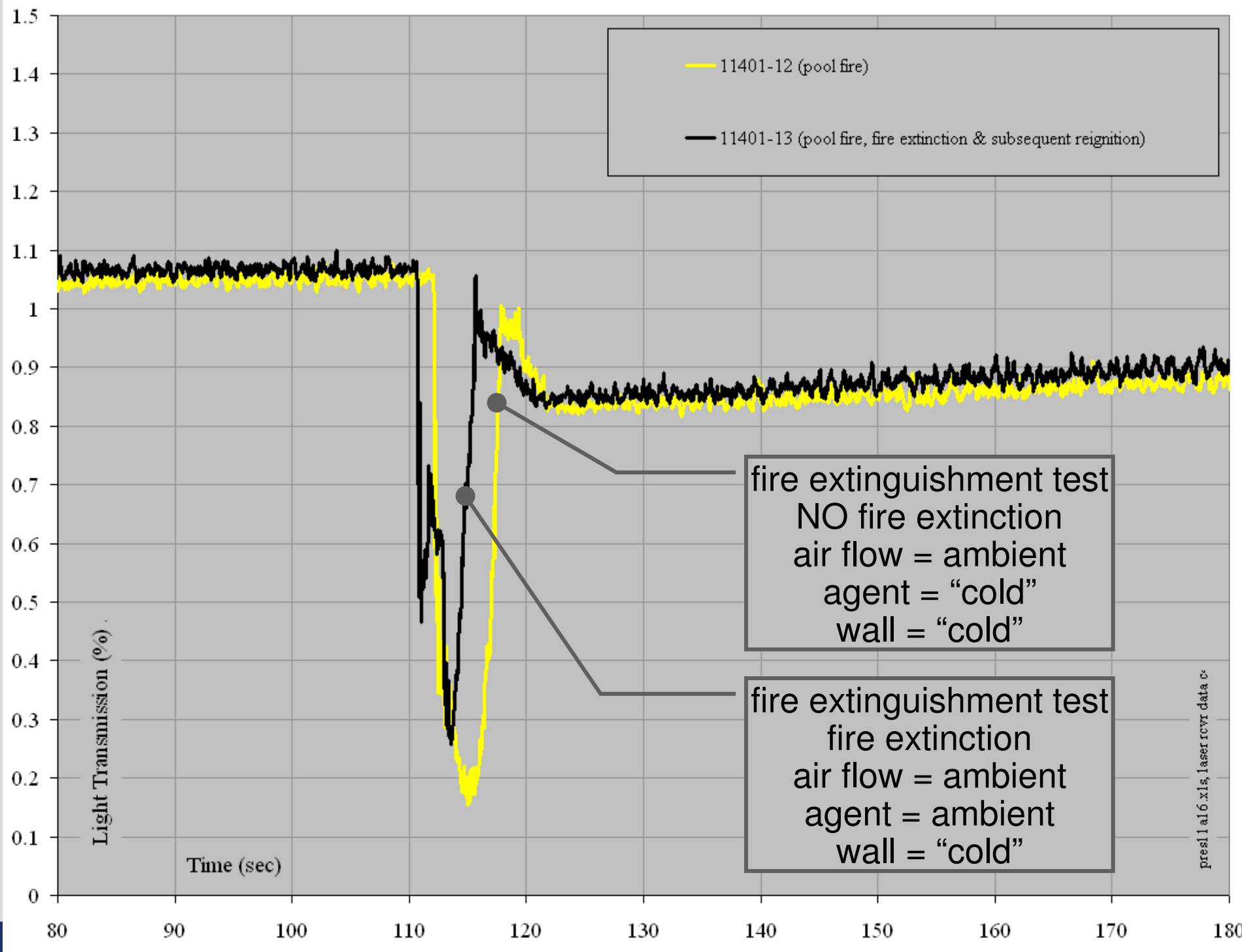
Raw Optical Receiver Signal History
Spray & Pool Fire Extinguishment Tests



Light Transmission
 Firex Agent Distribution Test
 Spray Fire Extinguishment Test



Light Transmission
Pool Fire Extinguishment Tests



End

• Acronyms, definitions, short-hand notations

aft = if referencing gas concentration sampling, aft ring is sta514 cross section

APU = Auxiliary Power Unit

btl = bottle

dist. = distribution, as in firex agent distribution test

ext/pool = fire extinguishment test, firex agent discharged against the NFS pool fire threat

ext/spray = fire extinguishment test, firex agent discharged against the NFS spray fire threat

firex = fire extinguishing agent

frx = fire extinguishing agent

fwd = forward; if referencing gas concentration sampling, fwd ring is sta490 cross section

FK-5-1-12 = 3M Novec 1230

mid = middle; if referencing gas concentration sampling, mid ring is sta502 cross section

MPSe = Minimum Performance Standard for Halon Replacement in Civil Aircraft Engine Nacelle & APU Compartments

n/a = not applicable

NFS = nacelle fire simulator for the MPSe, located at the FAA WJ Hughes Technical Center

OD = outside diameter

rev = revision

sta = station number, longitudinal position in the NFS

TC = thermocouple

vent = ventilation



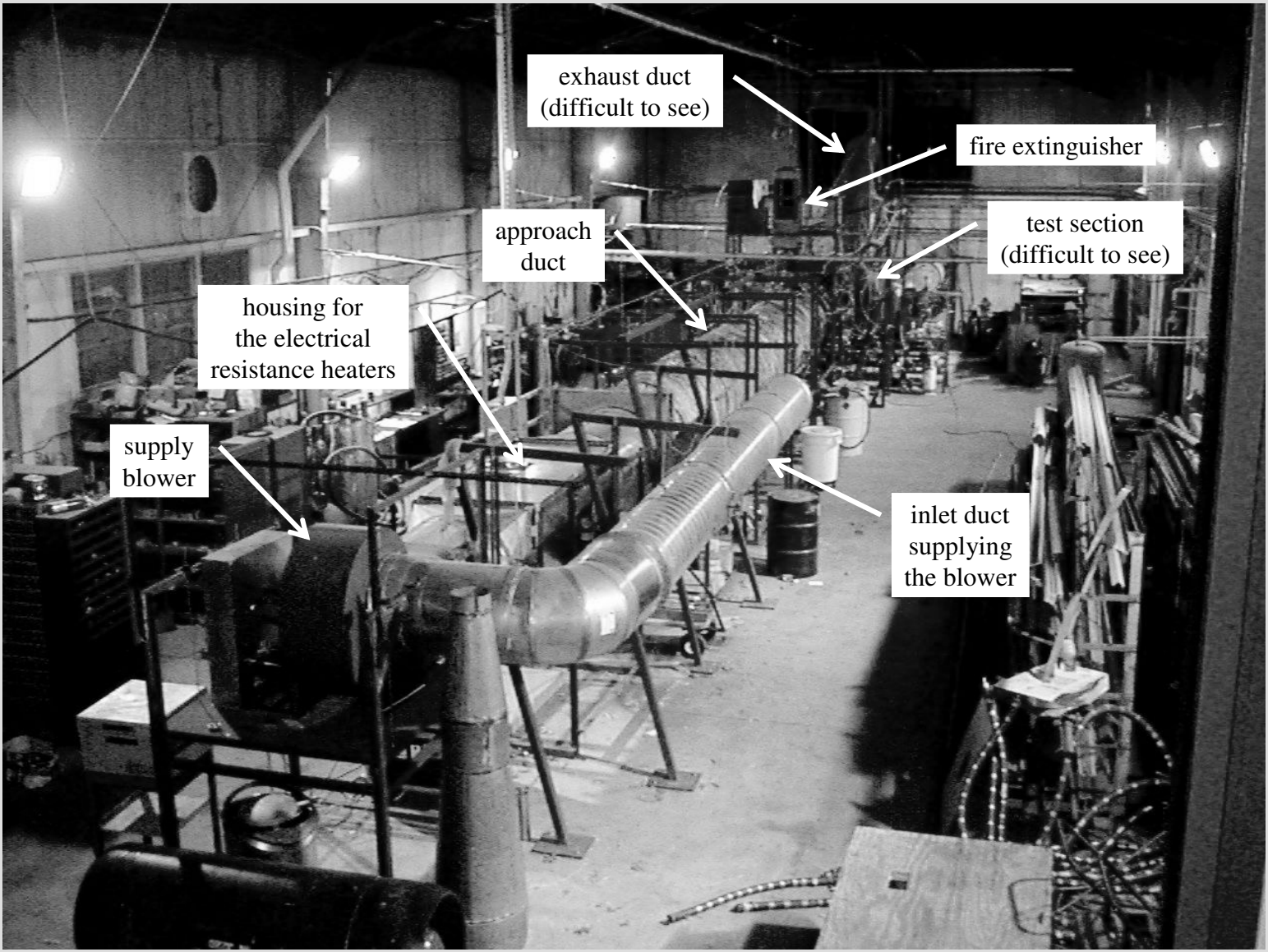
Forced-flow Fire Testing, “cold”-soaked FK-5-1-12

Appendix Materials

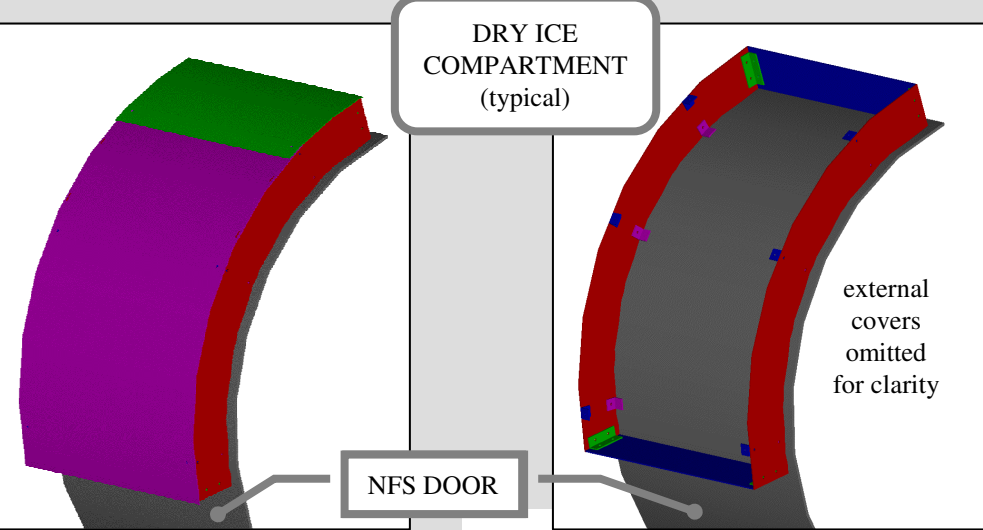
- Various slides included within capture details relating to this testing
- For additional reference, review presentation from the May 2011 International Aircraft Systems Fire Protection working group meeting



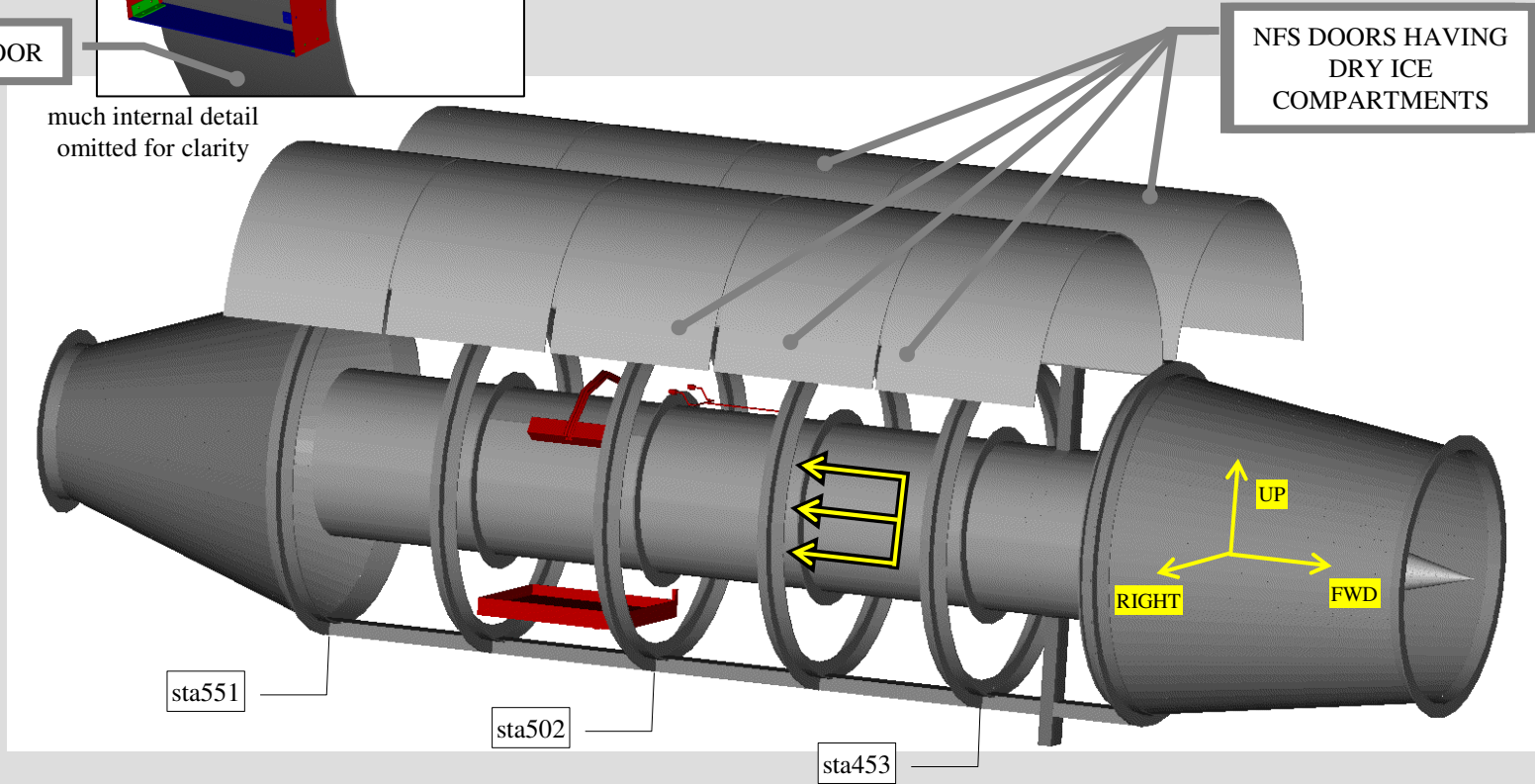
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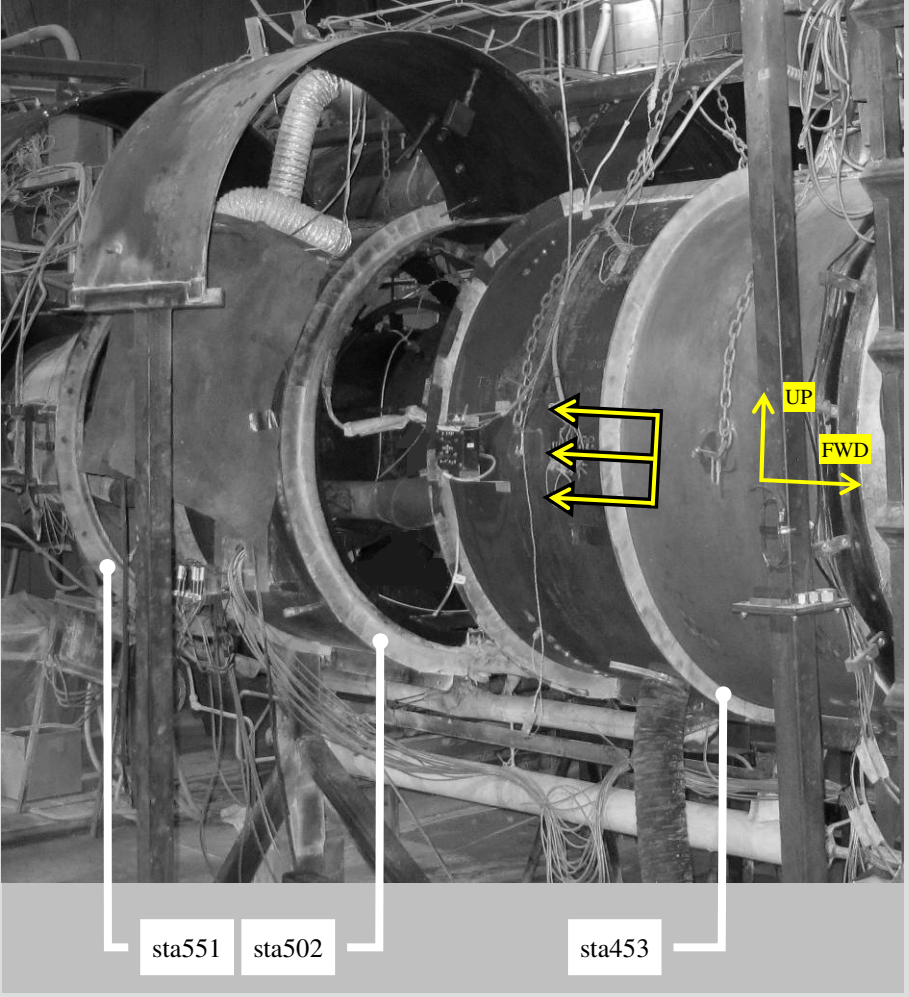


- ADDED COMPARTMENTS ON NFS EXTERIOR TO ACCEPT DRY ICE SO THE INTERIOR DOOR SURFACES COULD BE "COLD"-SOAKED
- ADDED 10 COMPARTMENTS TO 5 DOORS; 2 COMPARTMENTS/DOOR; RIGHT/FWD 3 DOORS & LEFT/1ST & 3RD DOORS



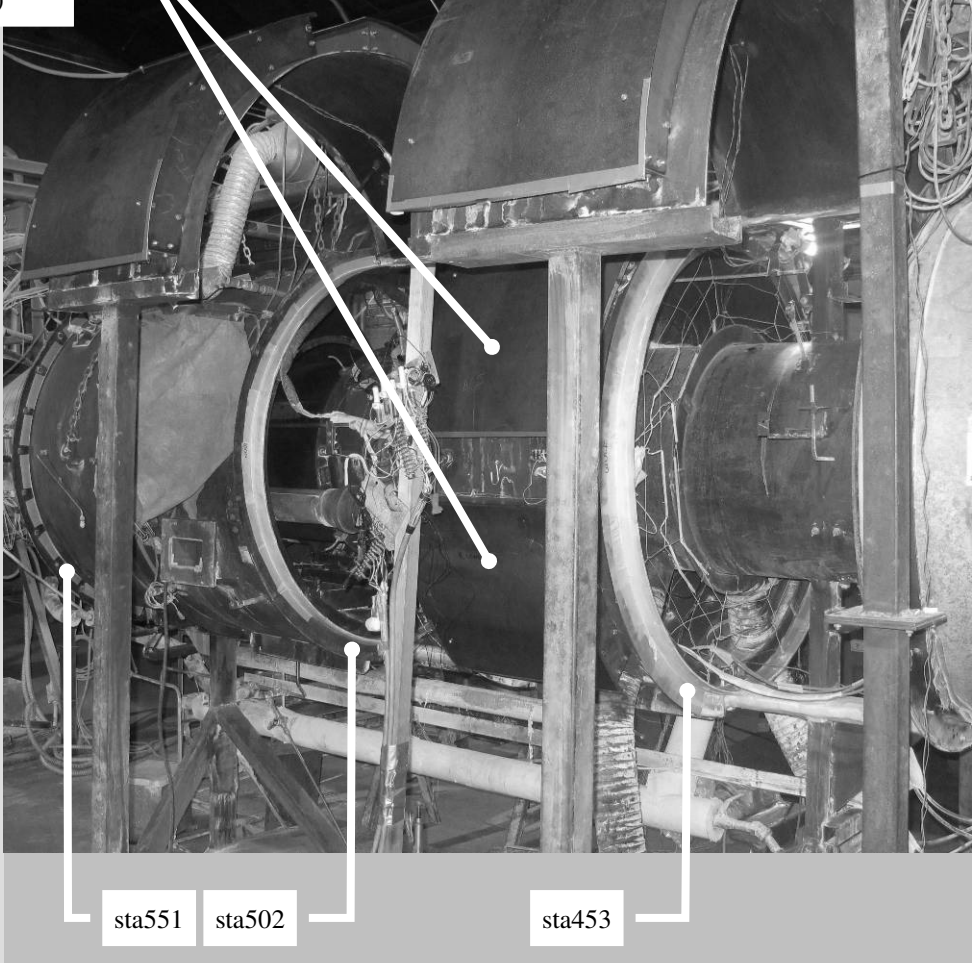
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NFS DOORS WITHOUT DRY ICE COMPARTMENTS

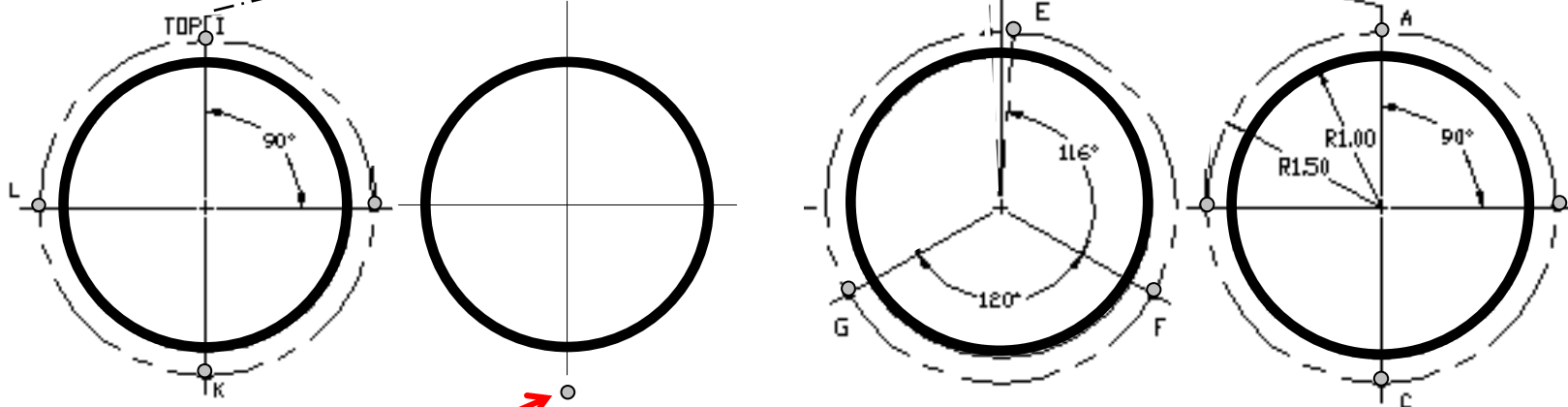
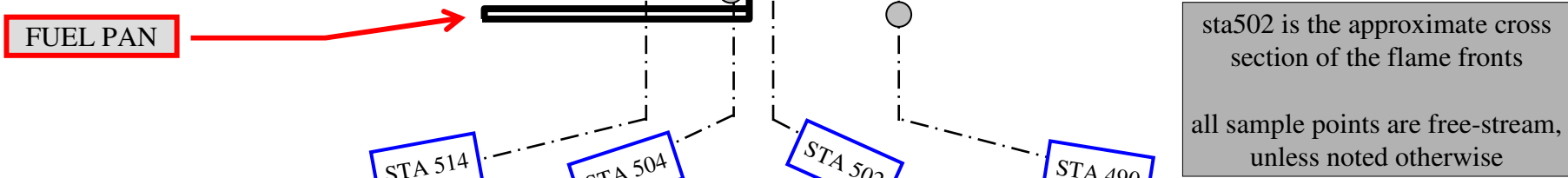
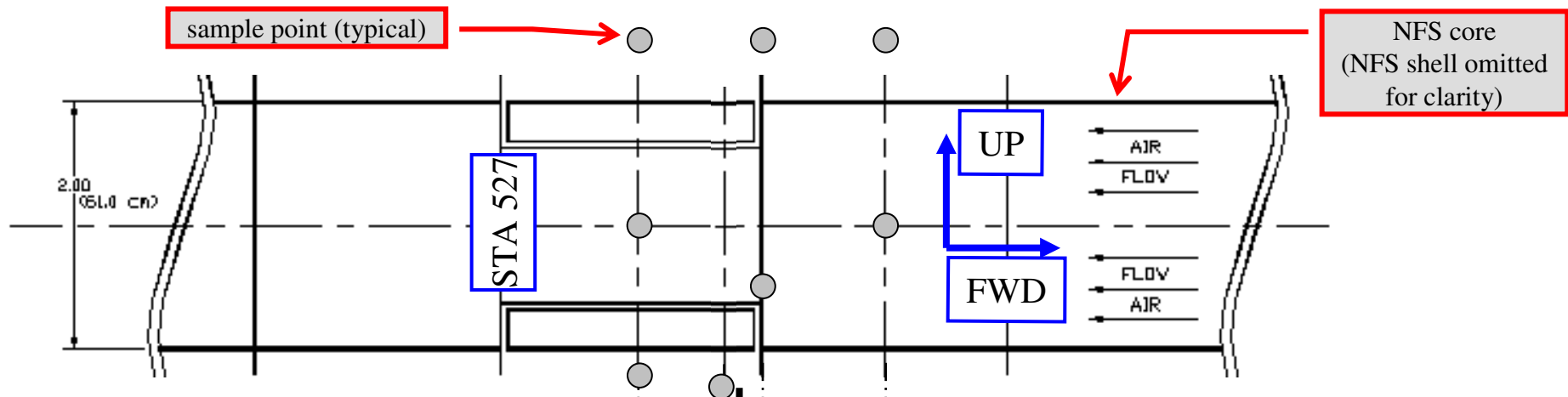


NFS DOORS WITH DRY ICE COMPARTMENTS

DRY ICE COMPARTMENT (typical)



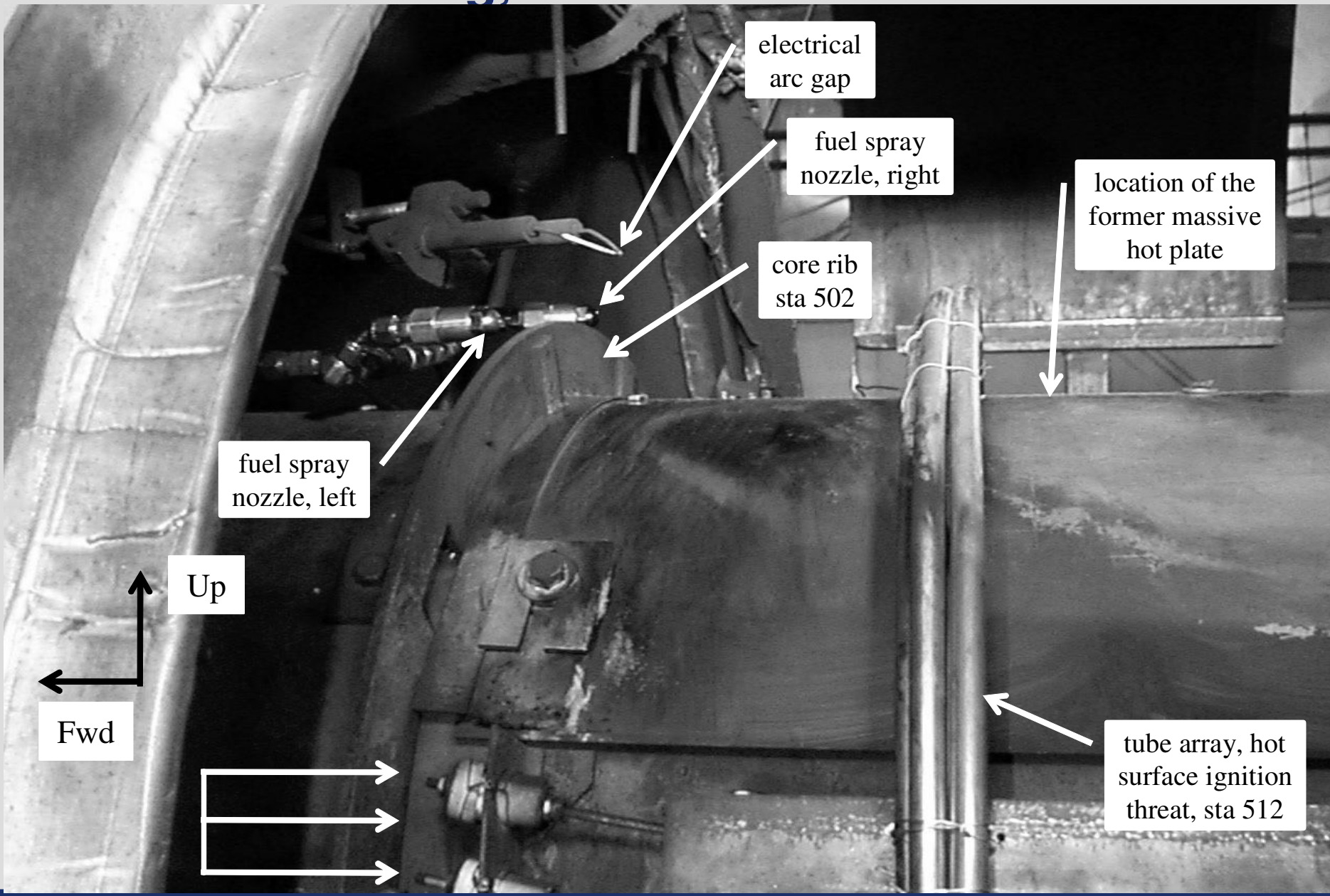
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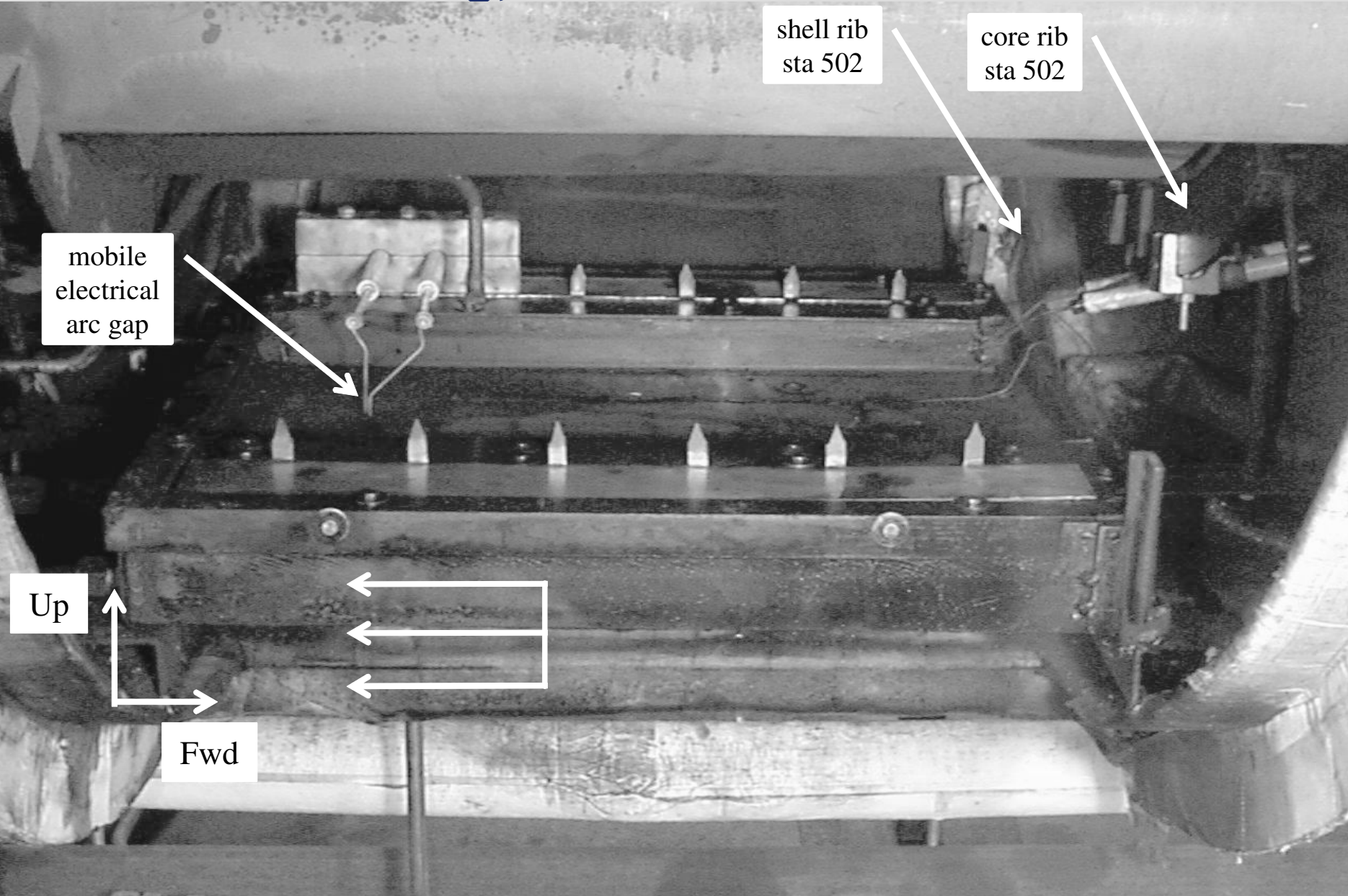
sample point, 1.0 inch aft & 0.5 inch below the top of the fuel pan lip, sta504 @ 06:00 (wake region aft of fwd fuel pan lip)



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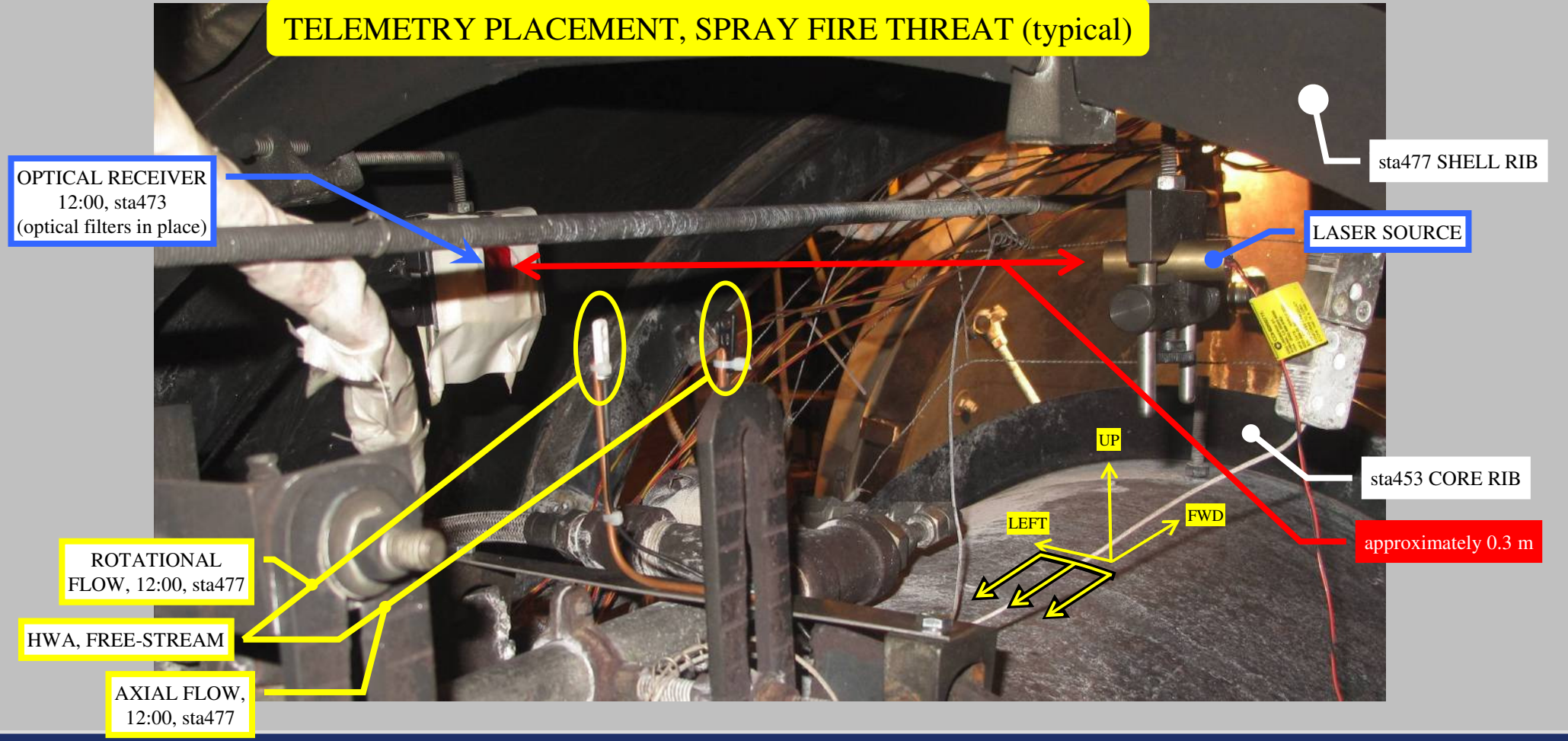
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COMPLIMENTED EXISTING TELEMETRY WITH ADDITIONAL SENSORS TO CAPTURE BEHAVIORS

- THERMOCOUPLES : CERTAIN WALL & FIRE EXTINGUISHER THERMAL BEHAVIORS
- HOT-WIRE ANEMOMETERS (HWAs) : RELATIVE FLOW-FIELD SPEED IN SELECT LOCATIONS
- LASER-EXCITED OPTICAL RECEIVER : RELATIVE AEROSOL DENSITIES IN SELECT LOCATIONS



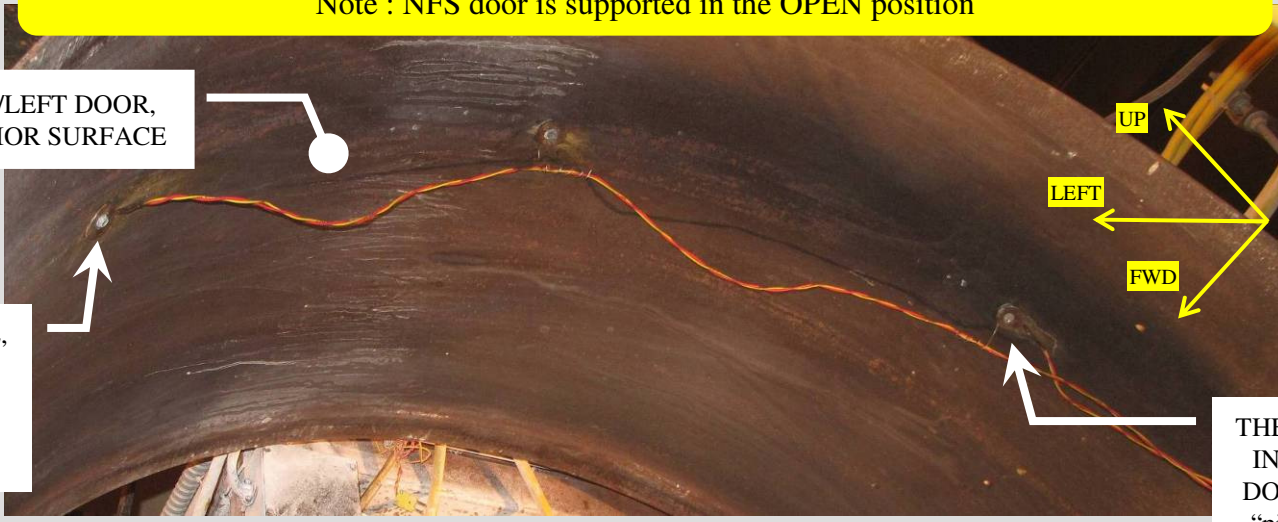
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THERMOCOUPLE PLACEMENT, INTERIOR NFS DOOR (typical)

Note : NFS door is supported in the OPEN position

sta440/LEFT DOOR,
INTERIOR SURFACE

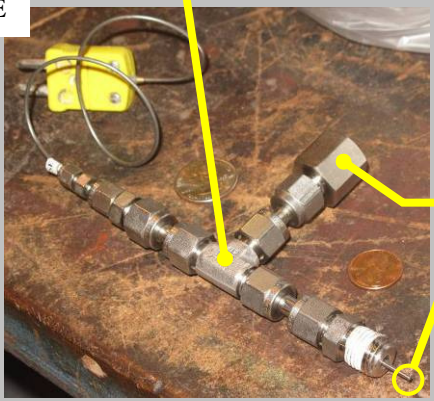
THERMOCOUPLE,
INTERNAL NFS
DOOR SURFACE,
“pinch”-mounted,
sta445/07:30



THERMOCOUPLE,
INTERNAL NFS
DOOR SURFACE,
“pinch”-mounted,
sta445/10:30

TELEMETRY, FIREX BOTTLE (typical)

PLUMBING ASSEMBLY
USED TO SENSE INTERNAL
TEMPERATURE & PRESSURE



THERMOCOUPLE,
SURFACE MOUNTED

TAP FOR PRESSURE
TRANSDUCER

THERMOCOUPLE TIP

