Observations during MPSe Testing

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PRESENTATION CONTENTS

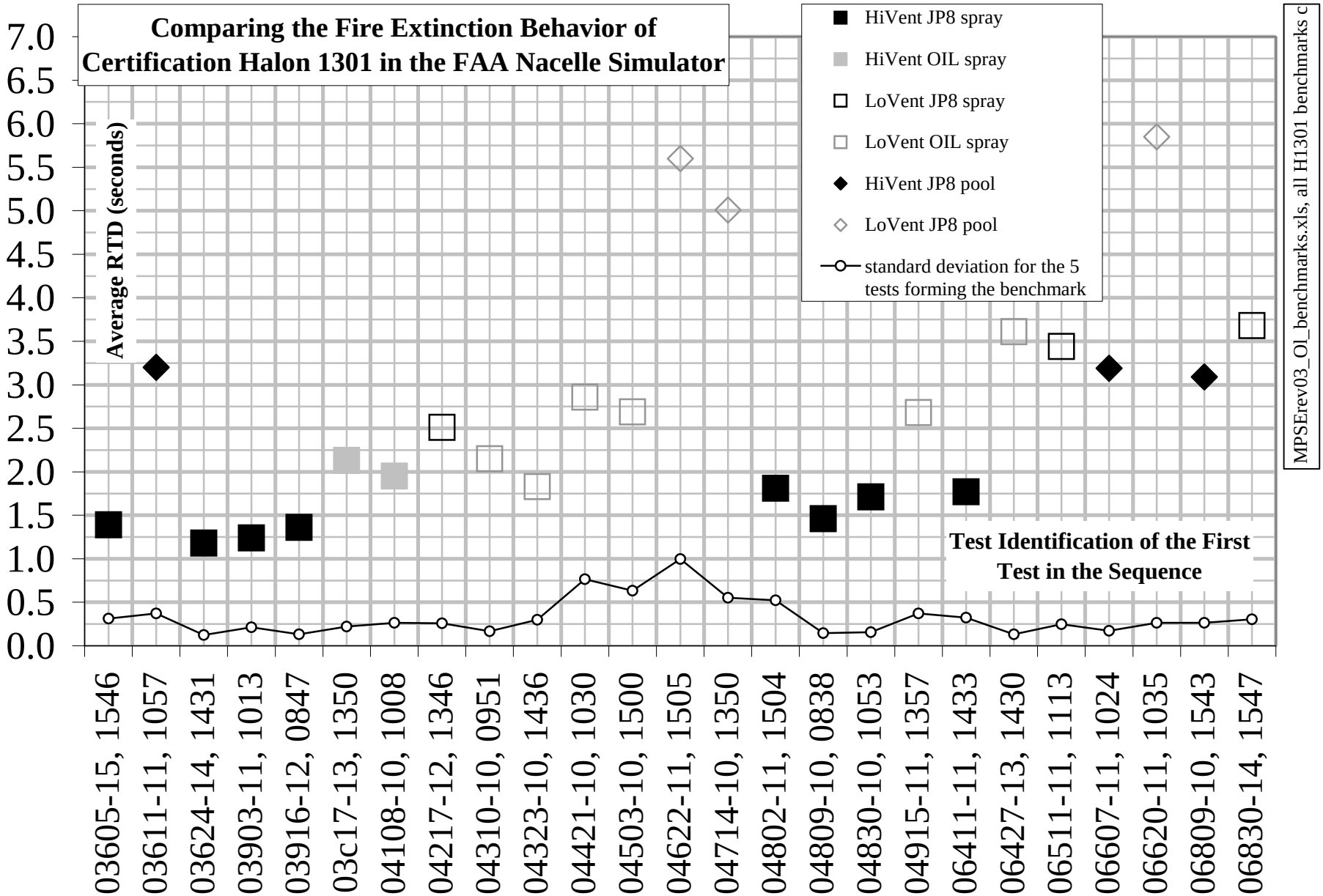
- GENERAL BEHAVIORS
  - HALON 1301 BENCHMARKS OVER TIME
  - INSTABILITIES AT LOW VENTILATION
  - LARGEST EQUIVALENT VS. PEAK INERTING CONCENTRATIONS
- DUCT INTERFACE BEHAVIORS
- FLAME ATTACHMENT BEHAVIORS

GENERAL BEHAVIORS

GENERAL BEHAVIORS – H1301 BENCHMARKS OVER TIME

- H1301 BENCHMARKS HAVE BEEN CATALOGUED OVER TIME FOR THE VARIOUS TESTING CYCLES
- THE BENCHMARKS SHOW DISTINCT RELATIONSHIPS BETWEEN THE FIRE THREATS IN THE TEST FIXTURE
- THE BENCHMARKS INDICATE RELIABILITY IN THE WORK BETWEEN 2003 – 2006
- THIS WORK SPANS THE AGENTS OF CF3I, FK 5-1-12, & HFC-125
- THE STANDARD DEVIATION OF THE BENCHMARKS ALLUDES TO INSTABILITIES FOUND DURING THIS WORK

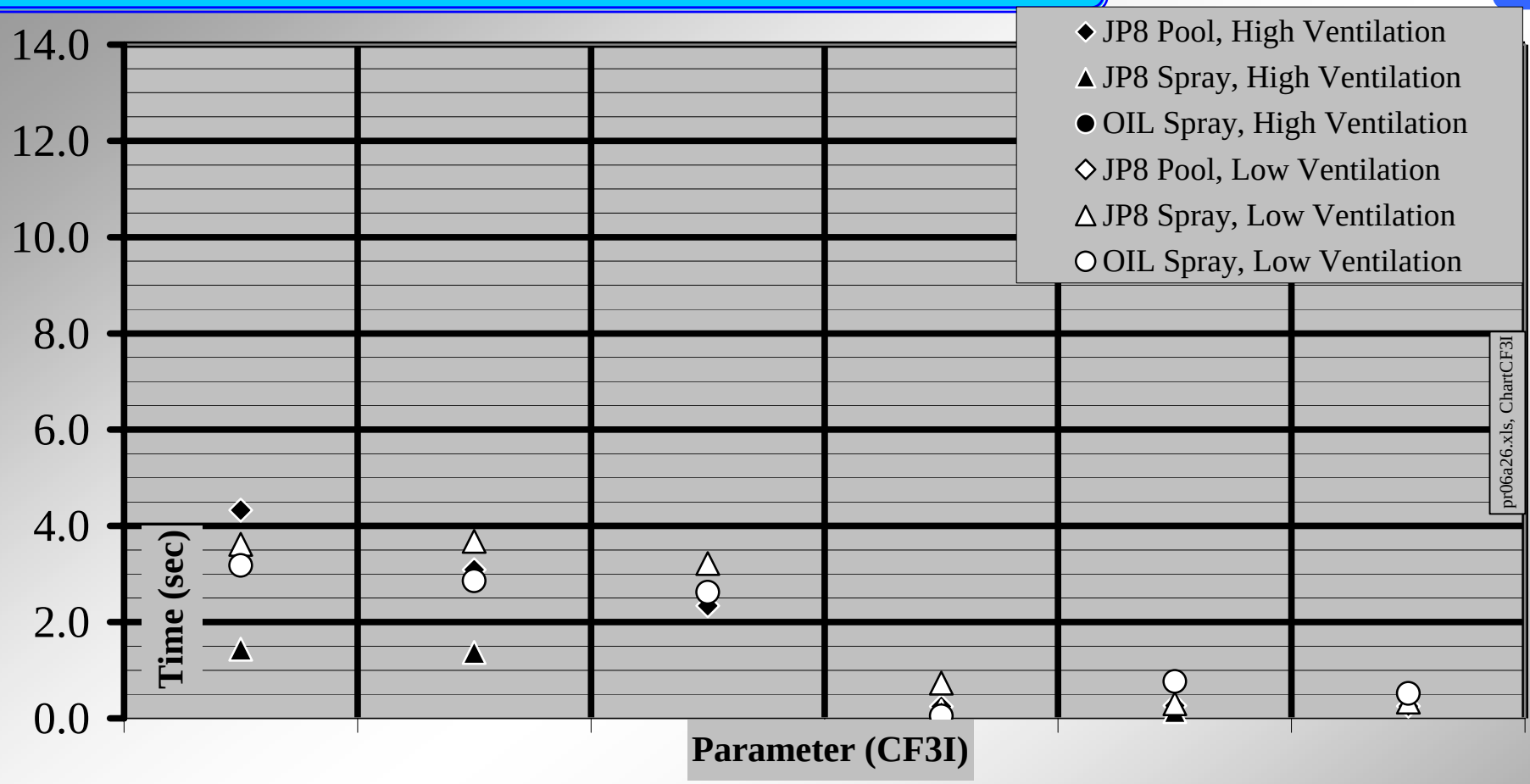
GENERAL BEHAVIORS – H1301 BENCHMARKS OVER TIME



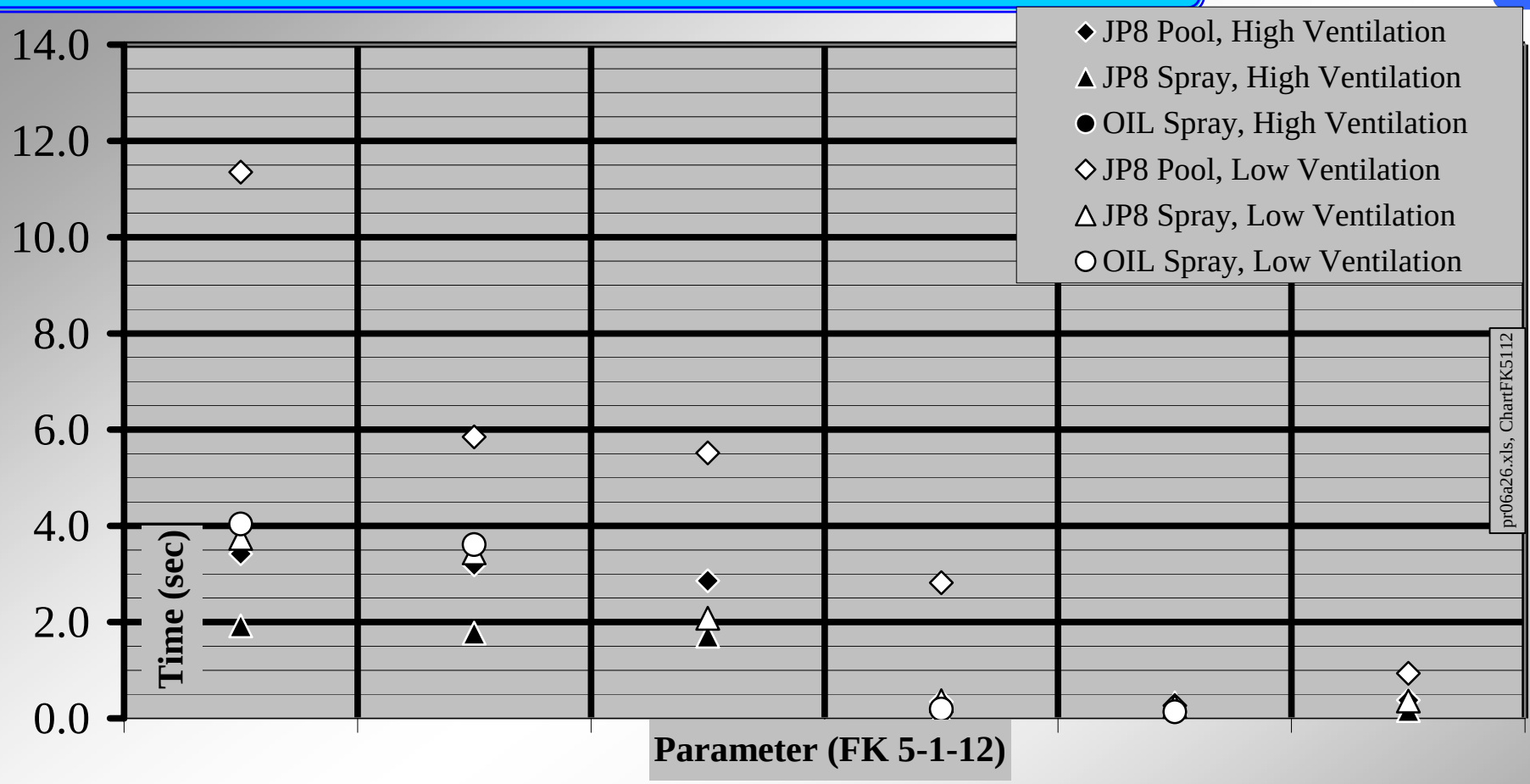
GENERAL BEHAVIORS – INSTABILITIES

- 3 SLIDES FOLLOW; MASS EQUIVALENCE RESULTS FOR CF3I, FK 5-1-12, & HFC-125
- IN SOME INSTANCES, STANDARD DEVIATIONS ARE “LARGE”
  - TYPICALLY THESE ARE LOW VENTILATION, POOL
  - SCATTER SIGNIFICANT ENOUGH THAT CF3I WAS NOT EVALUATED FOR LOW VENTILATION/POOL
    - > \$45/LB * 5? LB/TEST * 12 TESTS VS. 0.3 RTD_ave < σ < 0.5 RTD_ave
  - SUSPECT “LARGE” AGENT MASS INJECTED INTO “WEAK” VENTILATION REGIME PRODUCES THE INSTABILITY
  - “LOW” ENERGY VENTILATION VS. “HIGH” ENERGY AGENT INJECTION
- SIDE NOTE : BRACKETING BECOMES A VALUABLE TOOL TO FIND MASS EQUIVALENCE
  - THROUGHOUT PROJECT, QUESTIONED “HOW MUCH WAS TOO MUCH?”; i.e. TOO SUCCESSFUL...
  - CONSIDER (1) THE BEHAVIOR OF THE EQUIVALENT CONCENTRATION CALCULATION & (2) ECONOMICS OF CARRYING EXTRA AGENT AROUND FOR THE AIRCRAFT’S LIFE SPAN

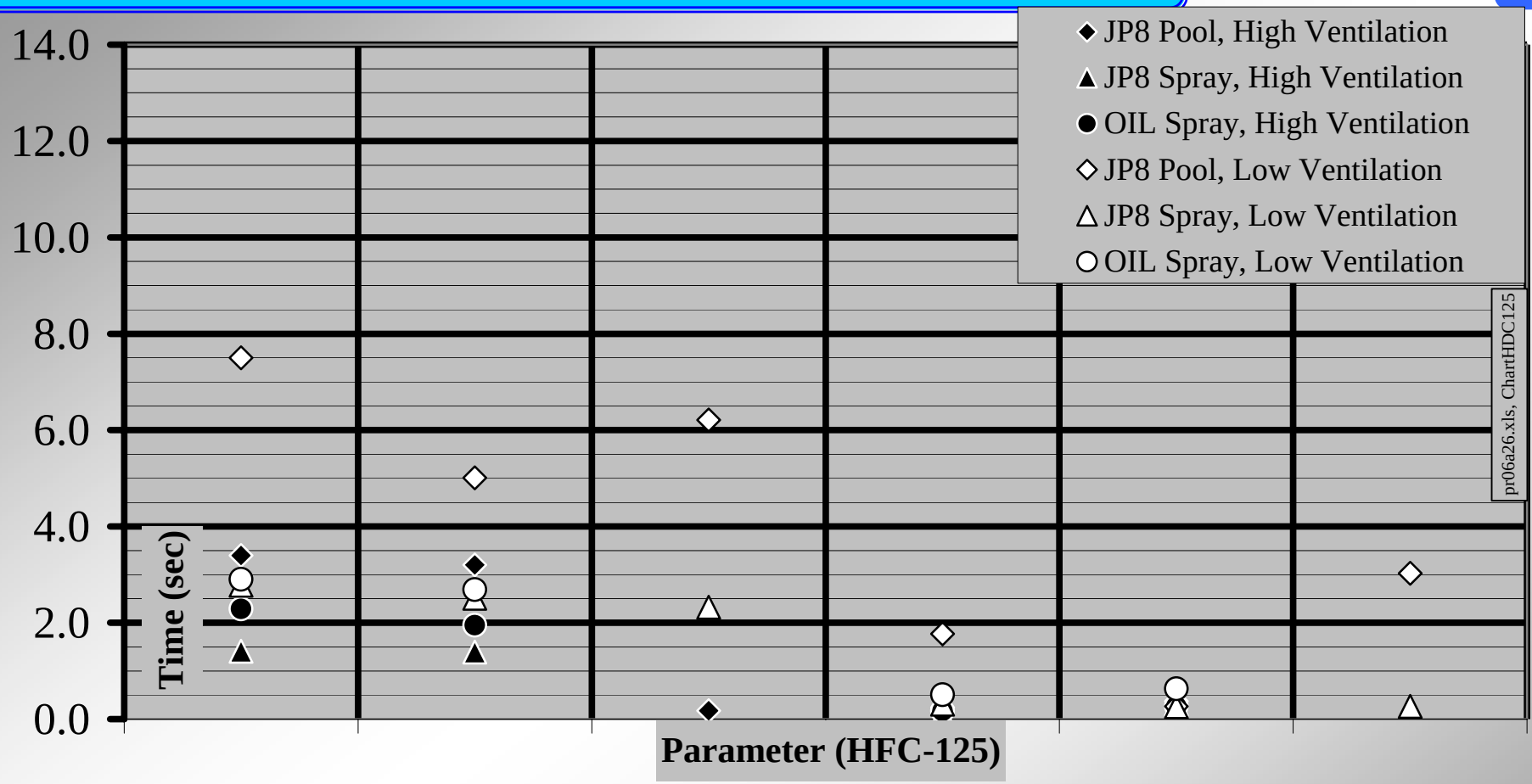
GENERAL BEHAVIORS – MASS EQUIVALENCE, CF3I



GENERAL BEHAVIORS – MASS EQUIVALENCE, FK 5-1-12



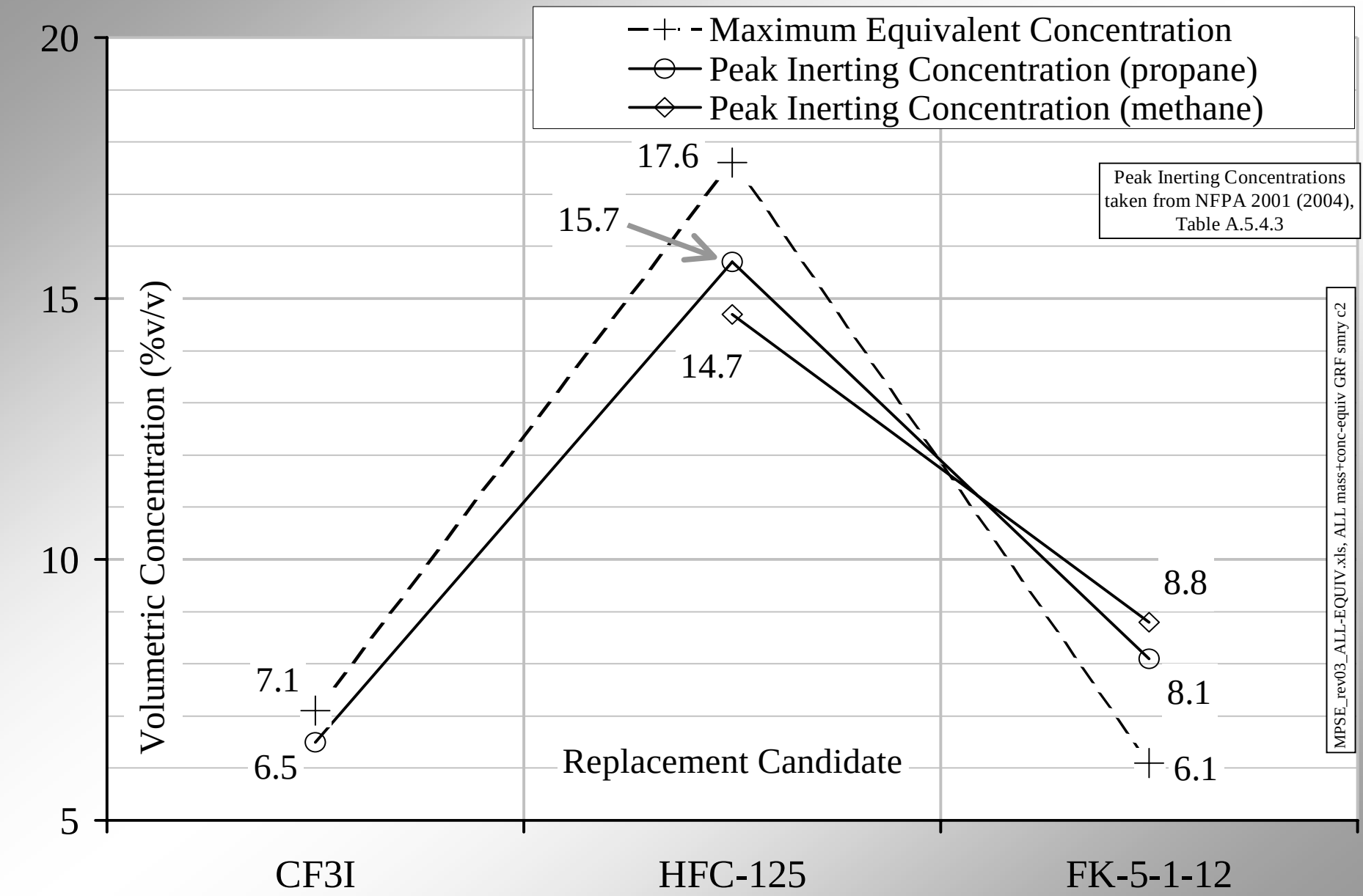
GENERAL BEHAVIORS – MASS EQUIVALENCE, HFC-125



GENERAL BEHAVIORS – CONCENTRATION COMPARISON

- THE LARGEST EQUIVALENT CONCENTRATIONS ARE COLLECTED AND COMPARED TO SOME REPORTED PEAK INERTING CONCENTRATIONS
- USING PEAK INERTING VALUES GIVEN IT IS A WORST-CASE COMBUSTION MODEL (PREMIXED GASEOUS)
- COMPARISON IS FAVORABLE
- FK 5-1-12 DOES NOT EXCEED PEAK INERTING VALUES
  - PER NFPA A.5.4.2, n-HEPTANE CUP BURNER RESULTS IN 4.5%v/v
  - LARGEST EQUIVALENT CONCENTRATION SITS BETWEEN THE 2 COMBUSTION MODELS
  - WHY?
    - AGENT DISCHARGE DURATION DID NOT MATCH H1301 (HFC-125 & CF3I SIMILAR) ?
    - NATURE OF THE AGENT (NOTE THE DIFFERENCE IN INERTING VALUES BETWEEN HFC-125 & FK 5-1-12) ?

GENERAL BEHAVIORS – CONCENTRATION COMPARISON

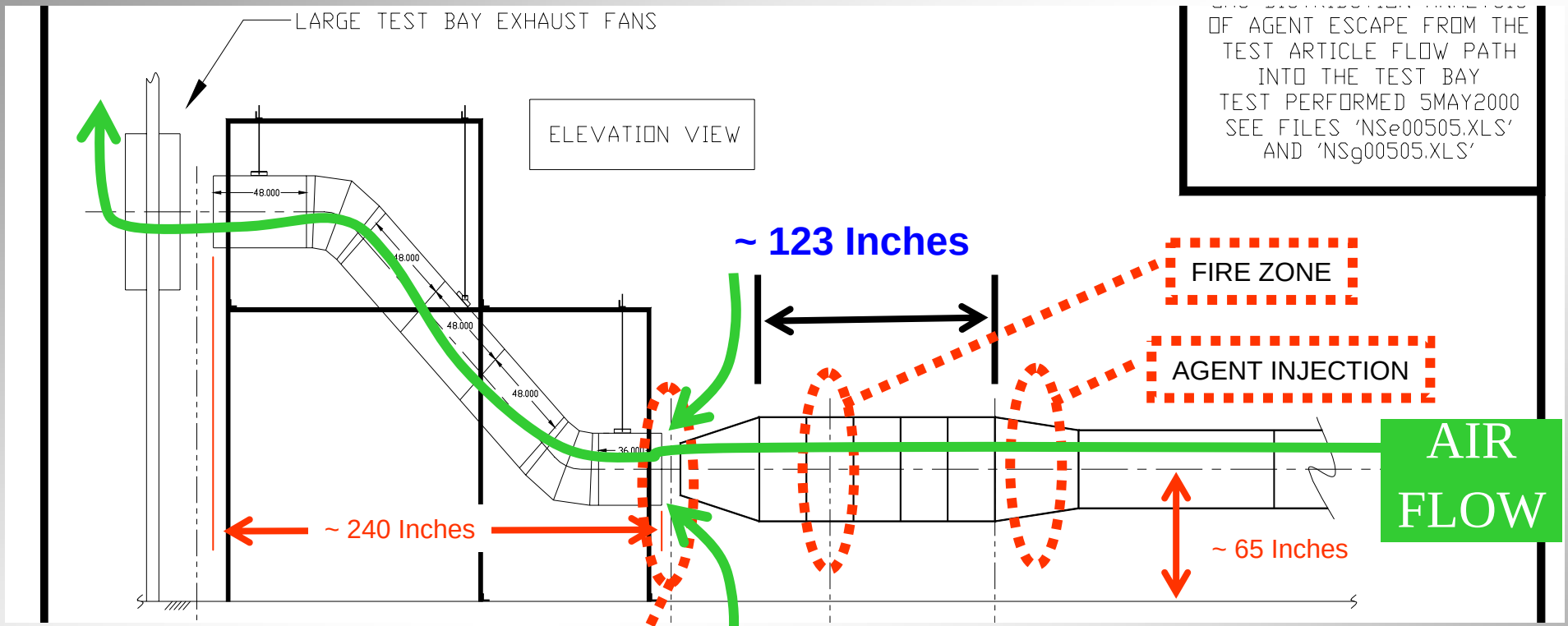


DUCT INTERFACE BEHAVIORS

DUCT INTERFACE BEHAVIOR - OVERVIEW

- DURING TESTING IN SEPTEMBER 2004 ANOMOLOUS BEHAVIOR WAS NOTED IN THE TEST FIXTURE
- BEHAVIOR CHARACTERIZED AS AN OVER-PRESSURE AT AN ATMOSPHERIC GAP IN THE FIXTURE
- WORST-CASE EXAMPLE RESULTED IN FIREBALL & AUDIBLE SIGNATURE
- NO TELEMETRY ORIGINALLY LOCATED IN REGION OF INTEREST
- TEST FIXTURE WAS MODIFIED TO COLLECT DATA FROM THE AREA IN 2005; USED FOR ALL SUBSEQUENT TESTING

DUCT INTERFACE BEHAVIOR, PERTINENT TEST FIXTURE GEOMETRY



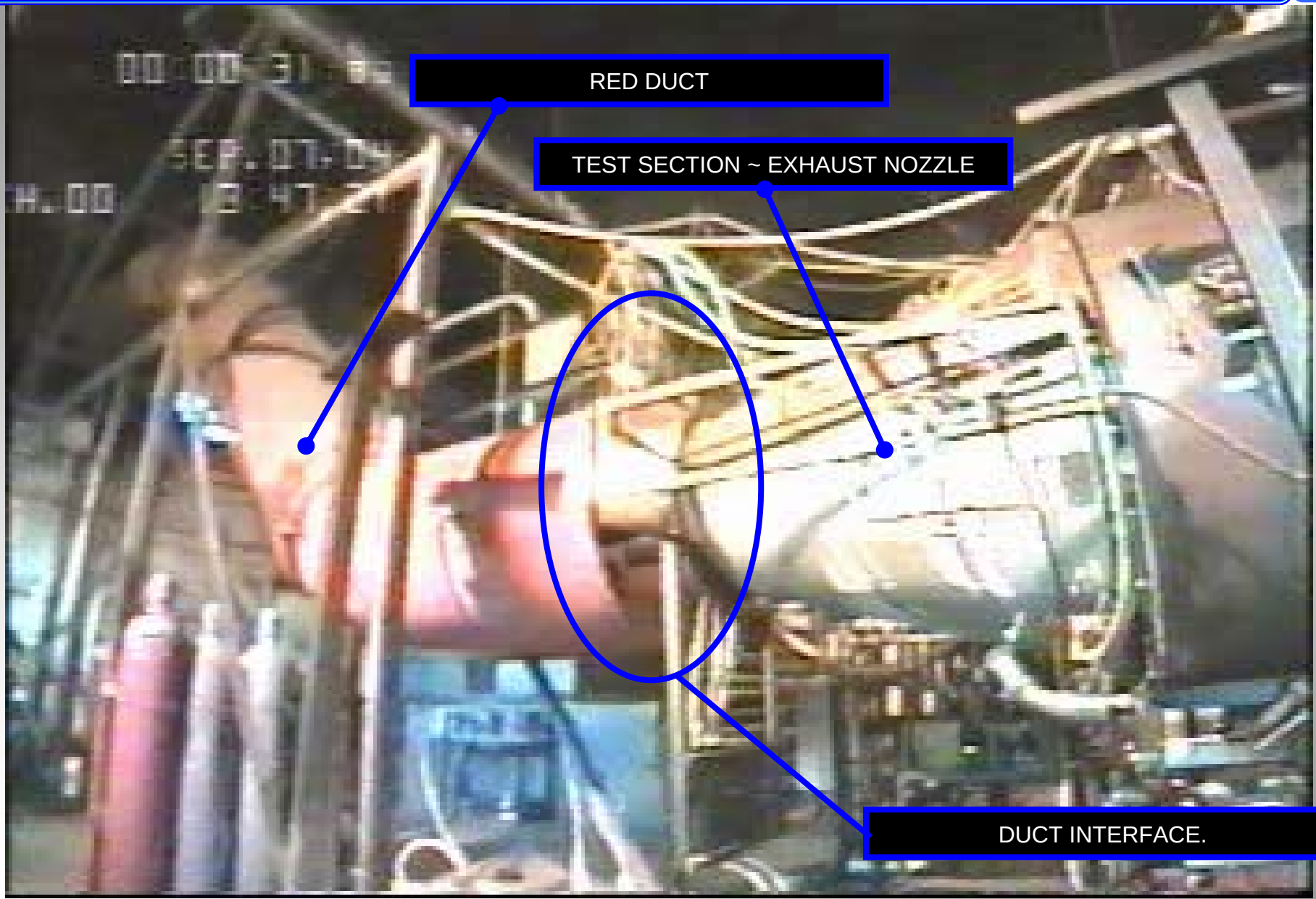
DUCT INTERFACE.

TEST SECTION EXIT = 22” DIA

EXHAUST DUCT ENTRANCE = 33” DIA

GAP BETWEEN CIRCULAR PLANES = 8”

DUCT INTERFACE BEHAVIOR, PERTINENT TEST FIXTURE GEOMETRY



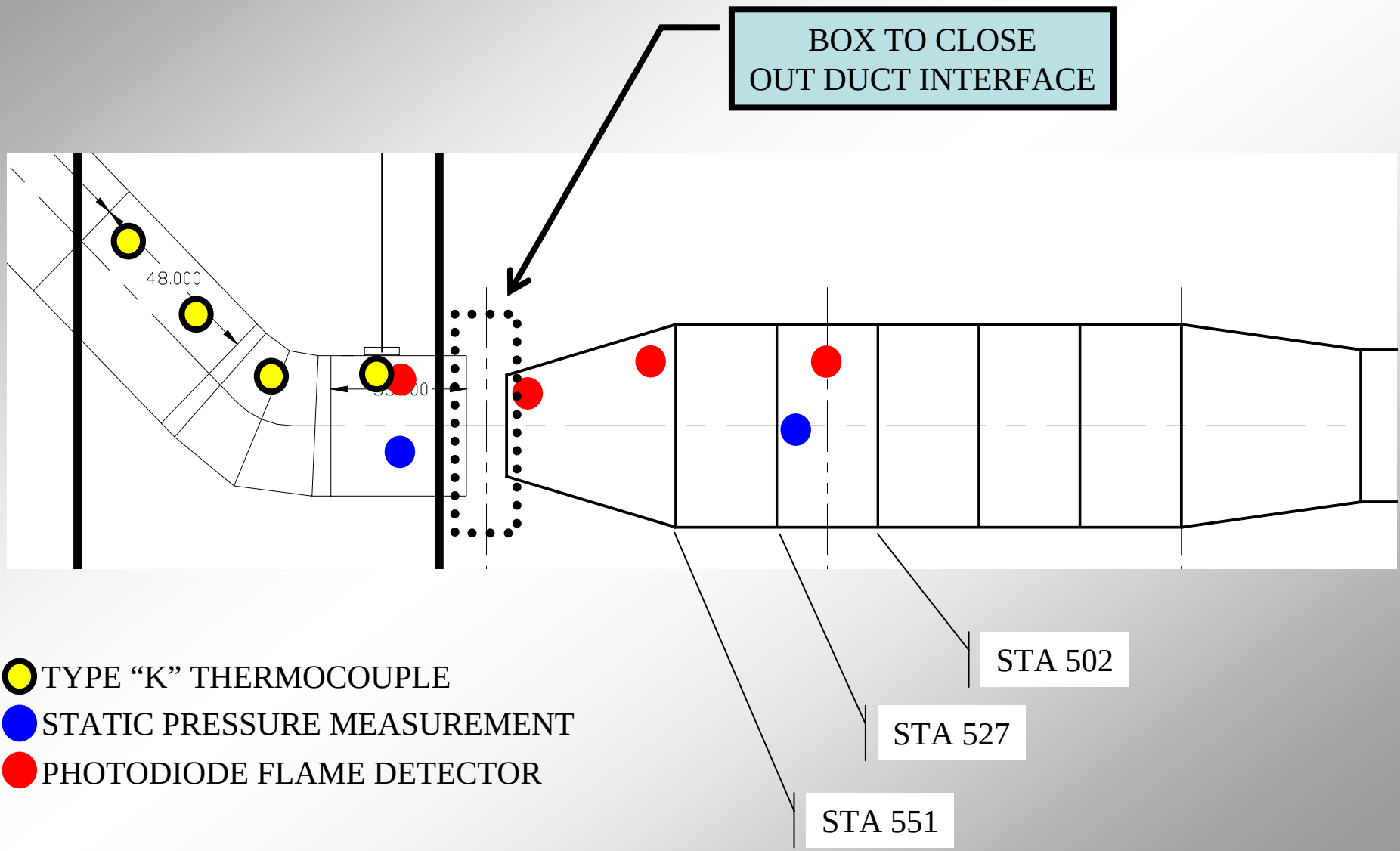
DUCT INTERFACE BEHAVIOR – FIXTURE MODIFICATIONS

- ADDED 4 THERMOCOUPLES IN RED DUCT
  - ALL ALONG 12:00
  - STARTED 2 FEET IN FROM INLET, PLACED EVERY 2 FEET
  - BEADS ARE 8 INCHES OFF WALL
- ADDED 2 STATIC PRESSURE MEASUREMENT LOCATIONS
  - 0-5” H2O PSID (REFERENCE TO TEST BAY)
  - 1 POINT IN TEST SECTION, 03:00, STA 522
  - 1 POINT IN RED DUCT SECTION, 04:30, 21 INCHES IN FROM INLET
  - USING STATIC PORTS OFF 1/8”OD PITOT-STATIC TUBES INSERTED INTO FLOW FIELD

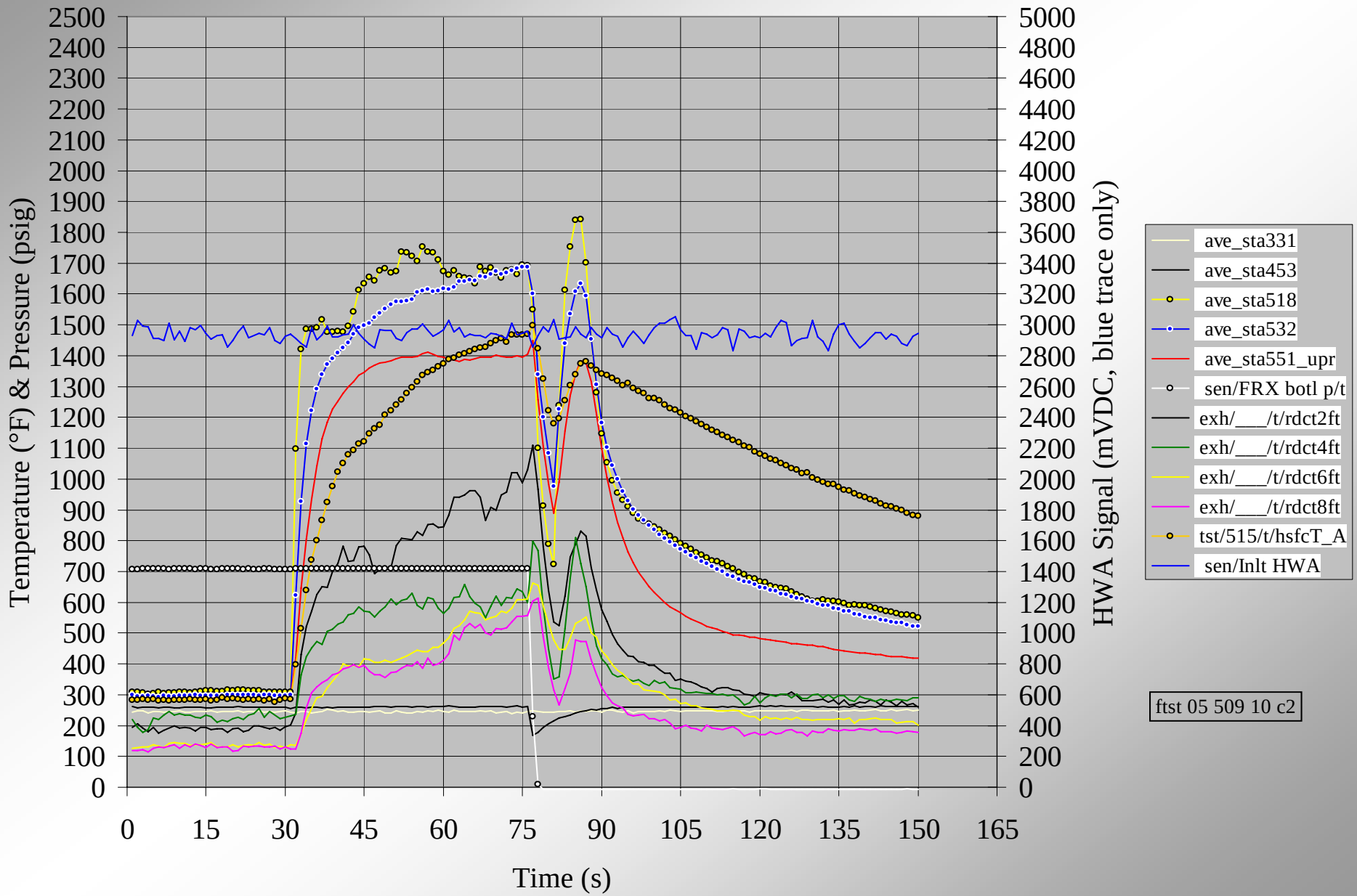
DUCT INTERFACE BEHAVIOR – FIXTURE MODIFICATIONS

- ADDED 4 OPTO-ELECTRONIC DEVICES TO DETECT FLAME PROPRAGATION THROUGH TEST FIXTURE
  - PHOTODIODE PHOTOCONDUCTIVE CIRCUITS
  - SENSOR VALUES
    - ≈ 0 VDC, DARK/NO FIRE
    - ≈ 6.1 VDC, SATURATES WHEN VIEWING FLAMES OF TEST FIRE
  - 1 VIEWS TUBE ARRAY IN FIRE ZONE
  - REMAINING 3 LOOK AT 12:00
    - ENTRANCE TO EXHAUST NOZZLE
    - EXIT OF EXHAUST NOZZLE
    - RED DUCT
- A BOX CAN BE MOUNTED WHICH CLOSES OUT THE DUCT INTERFACE COMPLETELY
  - ALTERS STATIC PRESSURE PROFILES IN RED EXHAUST DUCT AND TEST SECTION
  - MINIMIZE CHANGE IN STATIC PRESSURE BY OPENING LOUVERS IN RED DUCT

DUCT INTERFACE BEHAVIOR, NEW TELEMETRY LOCATIONS AND STRUCTURE CHANGES



DUCT INTERFACE BEHAVIOR, OBSERVATIONS



DUCT INTERFACE BEHAVIOR, OBSERVATIONS

- SEPTEMBER, 2004 / 2-BROMOTRIFLUOROPROPENE
  - FIRE & SMOKE ISSUE FROM INTERFACE ALONG WITH THE OCCASIONAL AUDIBLE CUE
  - SUBSEQUENTLY ADD TELEMETRY
- HFC-125 / DECEMBER, 2005
  - ESTABLISHED 17.5% FOR 0.5 SECOND (5.8 LBM) FOR LOW VENTILATION
  - RUN TESTS AT 50, 75, 100, & 125% EQUIVALENCE
  - 2 OF 17 TESTS PUSH SMOKE INTO TEST BAY; NO FIRE
- CF3I / AUGUST & SEPTEMBER 2006
  - REVIEWED BEHAVIORS DURING COMPLETION OF JP8 LOW VENTILATION SPRAY AND HIGH VENTILATION POOL FIRE WORK
  - NOTABLE SMOKE OBSERVED TO PUSH INTO TO TEST BAY DURING LOW VENTILATION WORK; NO FIRE

DUCT INTERFACE BEHAVIOR, OBSERVATIONS

- MARCH - JULY 2006, FK 5-1-12
  - SMOKE OBSERVED TO PUSH INTO TEST BAY; NO FIRE
  - MOST PREVALENT AT LOW VENTILATION
  - CLOSED DUCT INTERFACE (OPENED LOUVERS IN RED DUCT)
    - 100 IN^2 VENT AREA IN THE ENCLOSING BOX BOUNDARY
    - VENT AREA COVERED BY 0.001 IN THICK ALUMINUM FOIL
    - DELIVERED MASS EQUIVALENTS TO SPRAY FIRE THREATS
    - FOIL REMAINED INTACT; OVER-PRESSURES DID NOT DEFEAT THE SEALS
- CONCLUSIONS
  - FIXTURE PROVIDES ENVIRONMENT FOR CANDIDATES TO OVER-PRESSURE BY LESS THAN P = 0.5 IN H20 (WHY NOT H1301??)
  - FK 5-1-12 DID NOT BURST 0.001 INCH TIN FOIL SHEET IN THE BLOW-OUT PANELS WITH THE DUCT INTERFACE CLOSED OFF
  - SMOKE EXITING THE DUCT INTERFACE INTO THE TEST BAY DOES NOT APPEAR TO PRESENT A SAFETY ISSUE FOR CF3I, HFC-125, AND FK 5-1-12

DUCT INTERFACE BEHAVIOR, VIDEO

(04914-14, Halon 1301,HiVent OIL SPRAY)

DUCT INTERFACE BEHAVIOR, VIDEO

(04922-12, 2-BTP,HiVent OIL SPRAY)

DUCT INTERFACE BEHAVIOR, VIDEO

(04c15-10, HFC-125,HiVent OIL SPRAY)

DUCT INTERFACE BEHAVIOR, VIDEO

(06504-12, FK 5-1-12,LoVent OIL SPRAY)

DUCT INTERFACE BEHAVIOR, VIDEO

(06908-11, CF3I,LoVent JP8 SPRAY)

FLAME ATTACHMENT BEHAVIORS

FLAME ATTACHMENT, INTRODUCTION

- MARCH - JULY 2006, FK 5-1-12
  - DURING THE MAJORITY OF TESTING, FIRE WAS OBSERVED TO EXIST IN THE FIXTURE DURING THE REIGNITION TIME DELAY (RTD)
  - FIRE WAS TYPICALLY INDICATED BY REFLECTION
  - FIRE ALSO OBSERVED DIRECTLY DURING THE RTD
  - POOL FIRE WORK PRODUCED THE MOST READILY OBSERVED FIRE DURING THE RTD

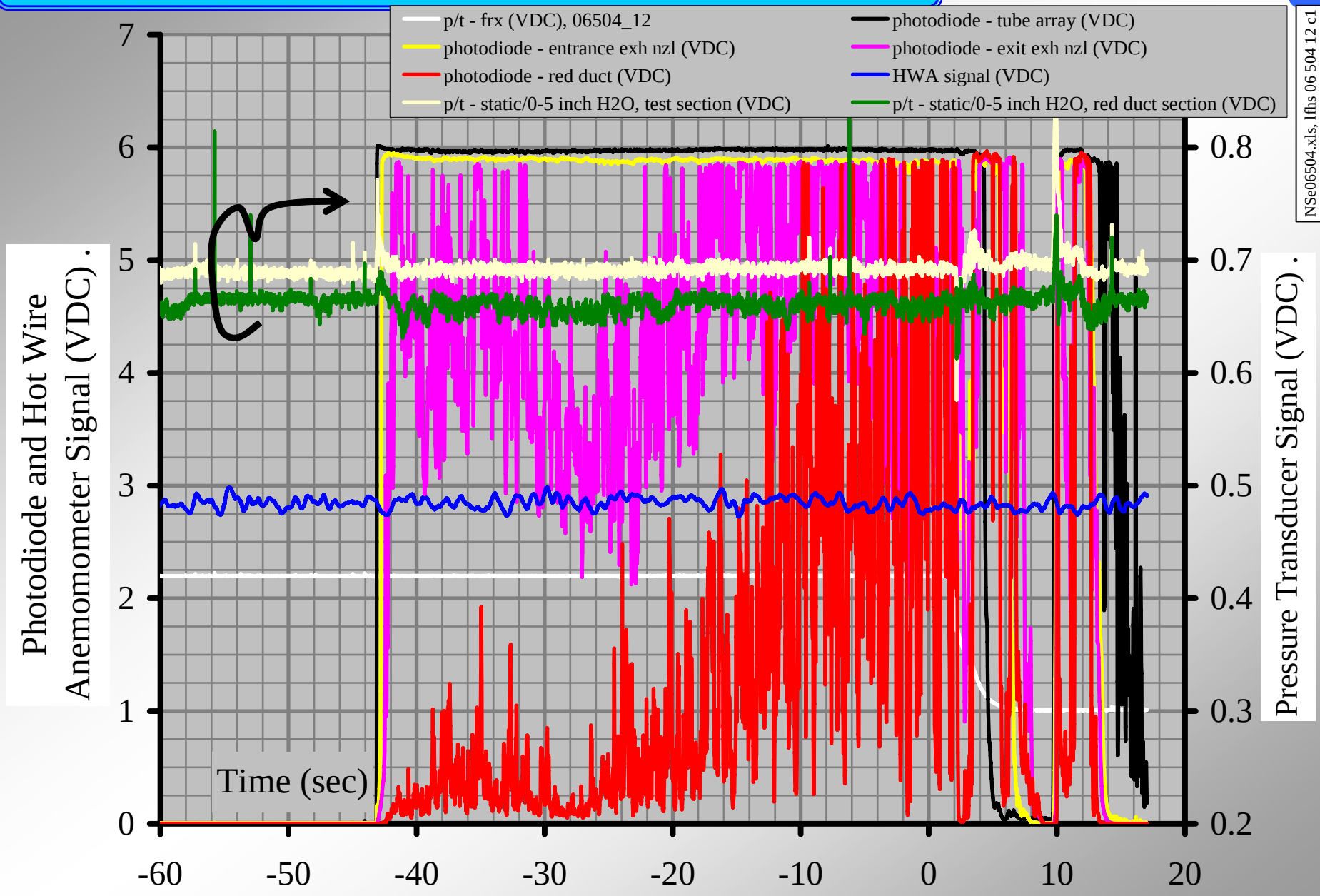
- AUGUST-SEPTEMBER 2005, CF3I
  - DURING THE MAJORITY OF TESTING, FIRE IS OBSERVED TO EXIST IN THE FIXTURE DURING THE RTD
  - DURING HIGH VENTILATION POOL FIRE,
    - FLAME ATTACHMENT AT DOWNSTREAM LIP OF THE FUEL PAN COULD NOT BE ELIMINATED WITH 8 LBM OF AGENT
    - MASS EQUIVALENCE ESTABLISHED WITH 2-4 LBM

FLAME ATTACHMENT, INTRODUCTION

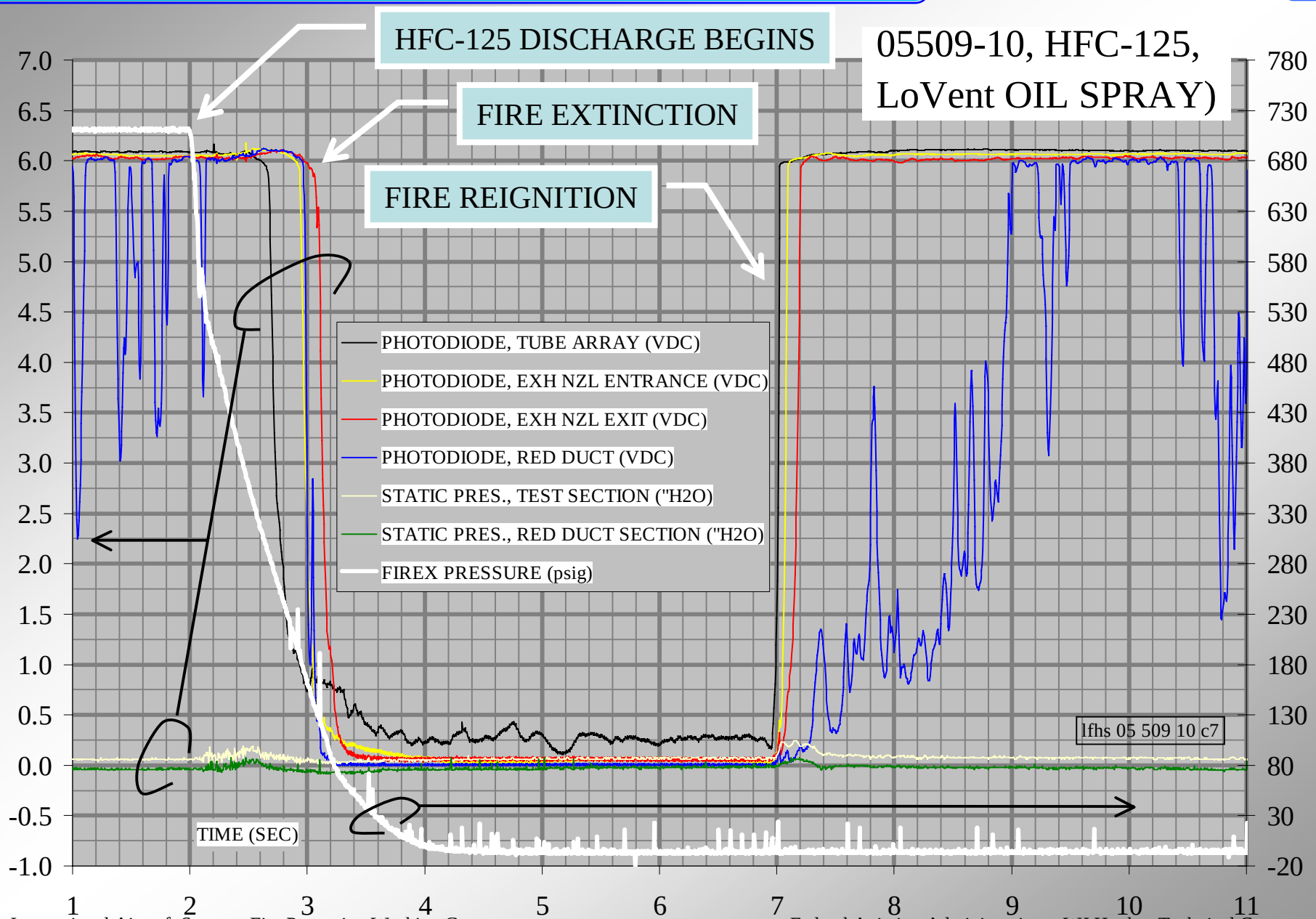
- WHY A CONCERN ?
  - NOT EQUIVALENT TO H1301
  - THE FIRE IS NOT FULLY SUPPRESSED
- PHOTODIODE BEHAVIORS ILLUSTRATE THE ISSUE
  - PHOTODIODE BEHAVIORS ONLY VALUABLE IN SPRAY FIRE WORK (THEY LOOK AT 12:00 ALONG FIXTURE LENGTH)
  - CALCULATED AN AVERAGE OF 4 CHANNELS FOR A DURATION OF TIME (8 OR 11 SECONDS) AT 3 PLACES IN THE TEST TIMELINE
  - 3 PLACES IN THE TIMELINE DURING : (1) NON-FIRE BASELINE, (2) FIRE IN PREBURN, AND (3) SURROUNDING THE RTD
  - COMPARED H1301 AND FK 5-1-12 BEHAVIORS

FLAME ATTACHM ENT – PHOTODIODE BEHAVIOR

FLAME ATTACHM ENT – PHOTODIODE BEHAVIOR



FLAME ATTACHM ENT – PHOTODIODE BEHAVIOR



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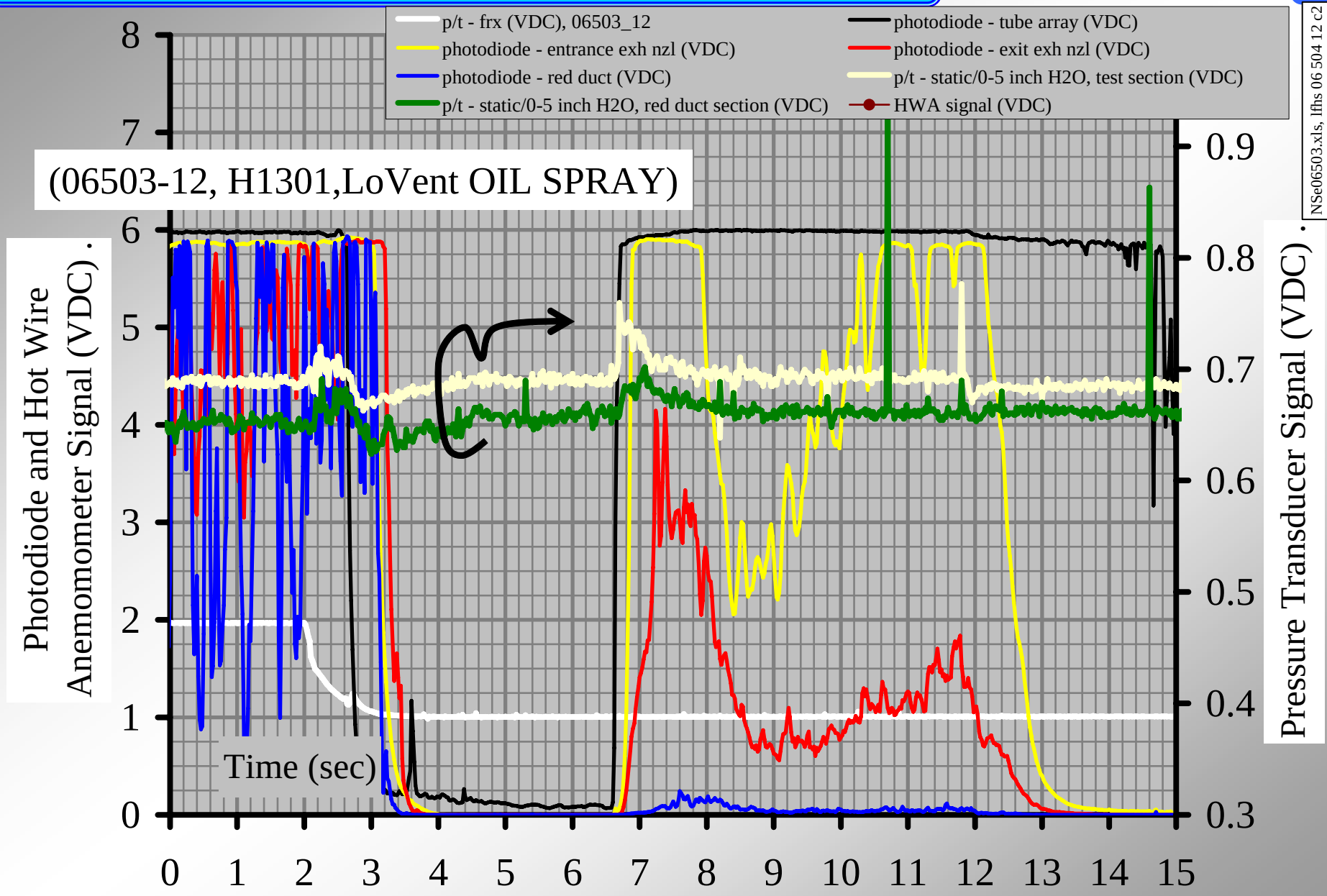

FLAME ATTACHM ENT – PHOTODIODE BEHAVIOR

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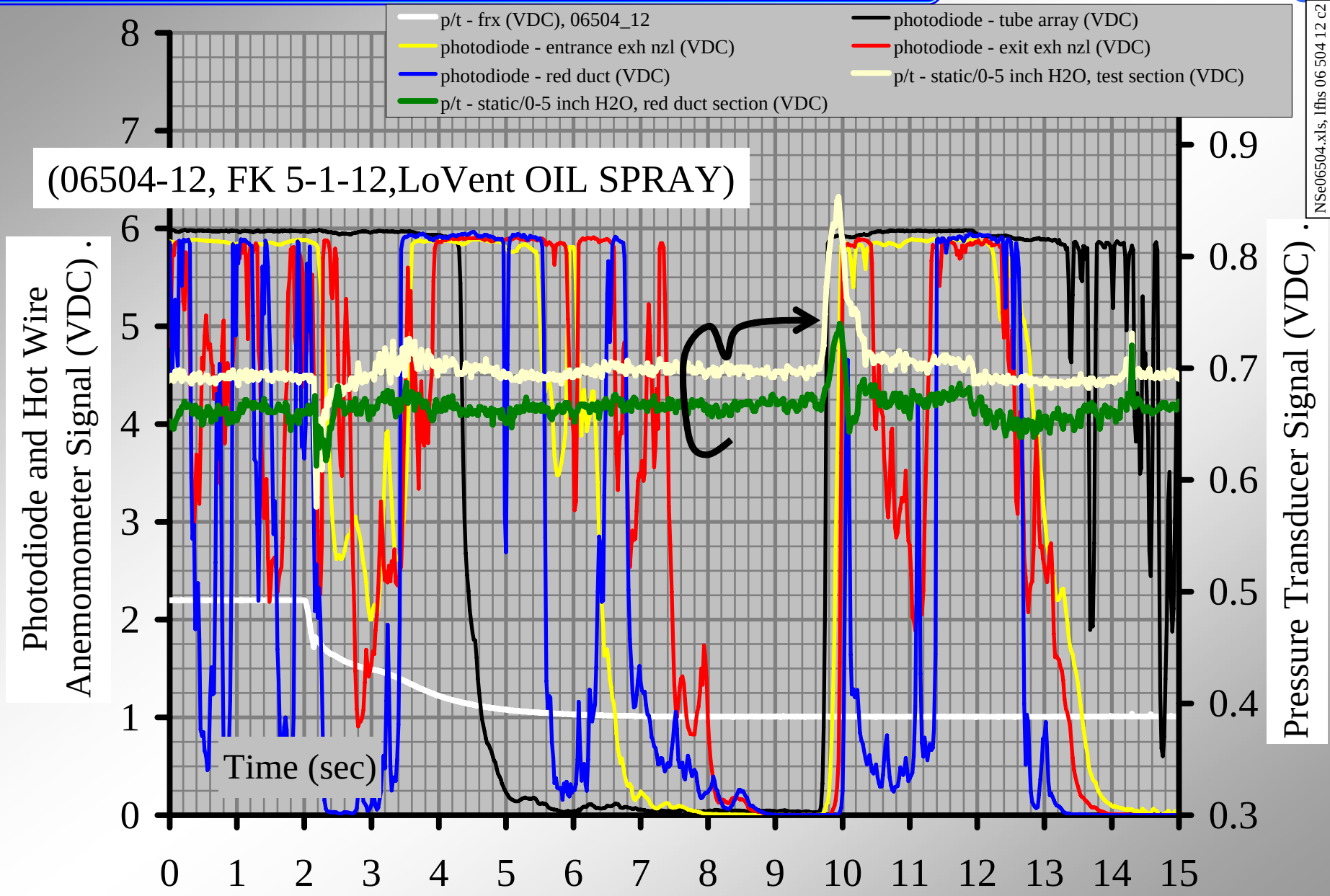

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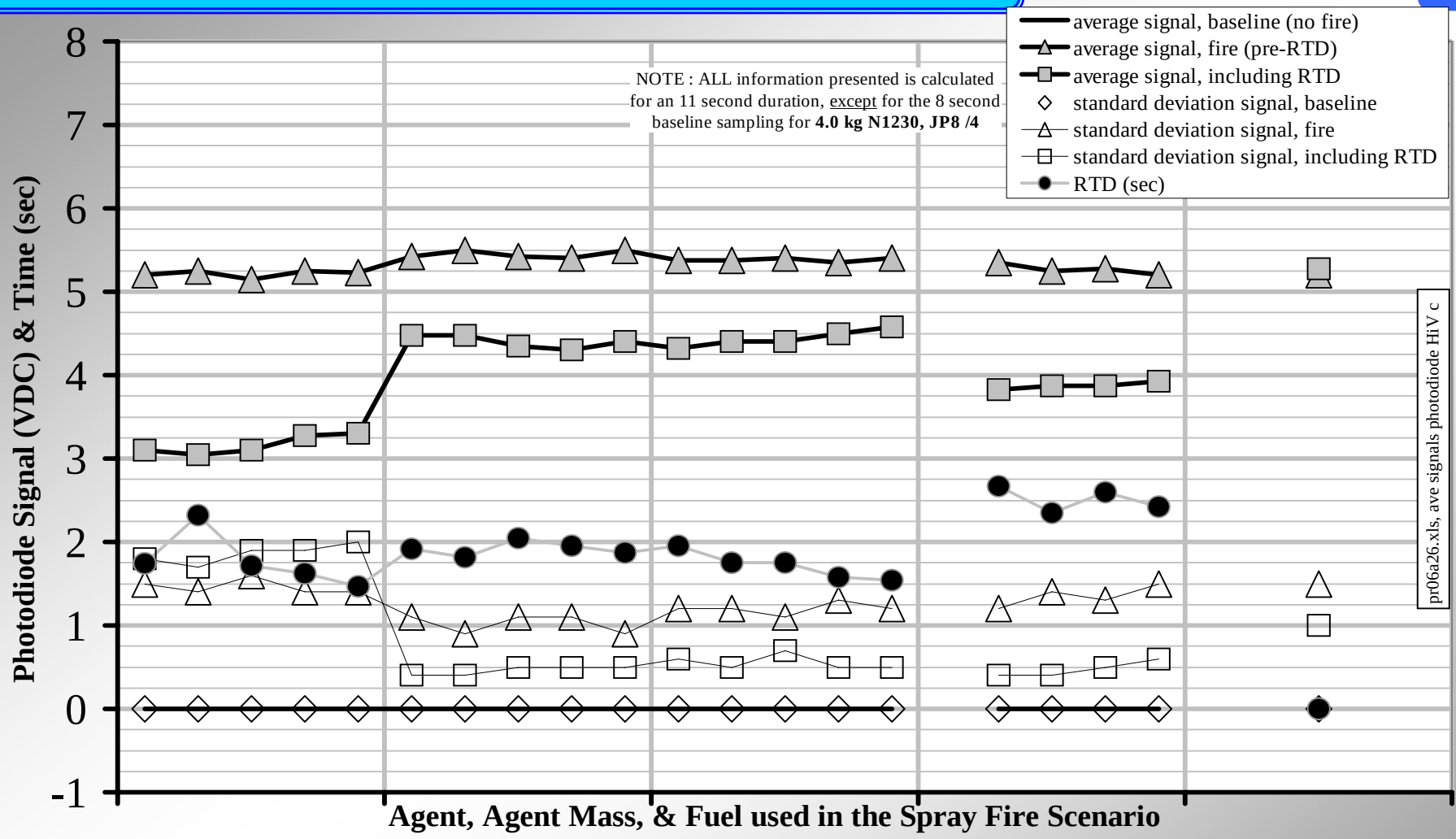
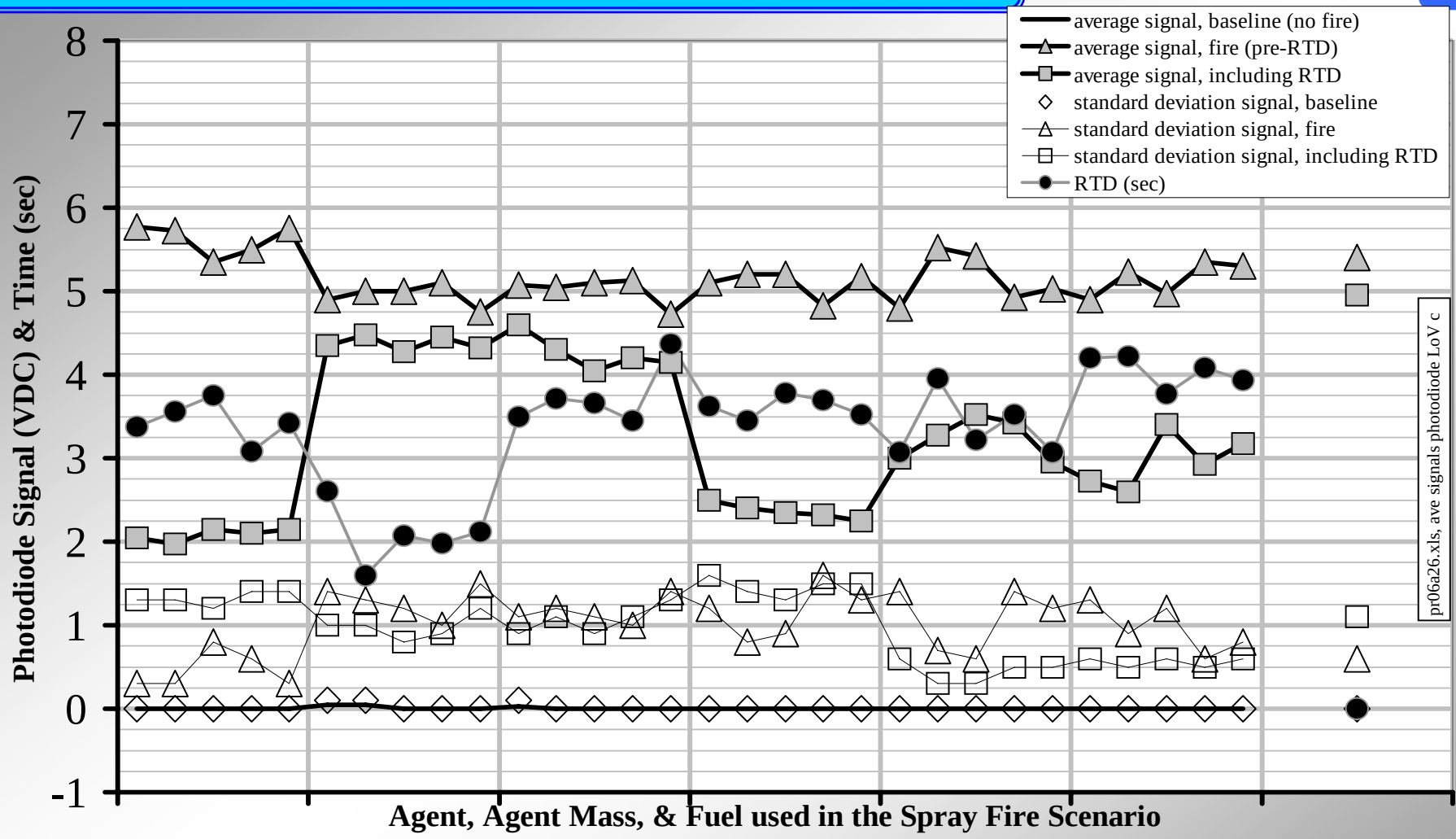


FLAME ATTACHM ENT – PHOTODIODE BEHAVIOR



FLAME ATTACHM ENT – OBSERVATIONS

- NON-FIRE BASELINES REASONABLY REPEATABLE
- FIRE BEHAVIOR (NON-RTD DURATION) REASONABLY REPEATABLE
- FK 5-1-12 AND H1301 FIRE SUPPRESSION BEHAVIORS ARE CLEARLY DIFFERENT
- FK-5-1-12 FLAME ATTACHMENT BEHAVIOR IS INDEPENDENT FROM RTD; CF3I BEHAVIOR ASSUMED TO BE SIMILAR
- HIGH VENTILATION FOR THE 4.0 KG FK 5-1-12 MASS
  - 2 NOZZLE INJECTION BEHAVIOR :
    - 40-50% INCREASE IN PHOTODIODE ACTIVITY ABOVE H1301
    - NEGLIGIBLE CHANGE IN RTD
  - 4 NOZZLE INJECTION BEHAVIOR ("…/4" REFERENCES IN GRAPH)
    - 30% INCREASE IN PHOTODIODE ACTVITITY ABOVE H1301
    - INCREASED RTD ABOVE H1301 BY 25%

FLAME ATTACHM ENT – OBSERVATIONS

- LOW VENTILATION INDICATES NO RELATIONSHIP BETWEEN PHOTODIODE ACTIVITY AND RTD
- STANDARD DEVIATIONS DURING THE FIRE HISTORIES CLEARLY ILLUSTRATE ISSUE ADDITIONALLY
  - “LARGE” DEVIATION = “GOOD”; SOME PHOTODIODES SEE NO OR MINIMAL FIRE YET OTHERS SEE FIRE
  - “SMALL” DEVIATION = “BAD”; ALL PHOTODIODES SEEING SIMILAR BEHAVIOR (FIRE)
- AGENT IS TRANSPORTING 5-8 FEET PRIOR TO INTERACTING WITH FIRE
- CF3I (-9°F) & FK 5-1-12 (120°F) NORMAL BOILING POINTS > H1301 (-72°F)

FLAME ATTACHM ENT – OBSERVATIONS

- CONSIDERING THE FOLLOWING, THE DISTRIBUTION PLUMBING OF THESE AGENTS WOULD BE A LOGICAL EXPLANATION FOR THE FLAME ATTACHMENT PROBLEMS
  - TRANSPORT DISTANCE IN THE FIXTURE
  - DIFFERENCE IN NORMAL BOILING POINTS (H1301, CF3I, FK 5-1-12)
  - THE NON-OPTIMIZED INJECTION PLUMBING (CF31, FK 5-1-12)
- HOWEVER, TESTING HAS NOT BEEN COMPLETED TO VERIFY THE PRECEDING OPINION. OTHER POSSIBILITIES TO REMEDY THE PROBLEM MAY LIE WITH :
  - INCREASING THE AGENT CONCENTRATION ABOVE THE EQUIVALENT CONCENTRATION
  - INCREASING THE AGENT DWELL TIME (SOMETHING LARGER THAN 0.5 SECOND; i.e. UK MoD H1211 specification)
  - BOTH

CONCLUSIONS

- THE PERFORMANCE OF THE TEST FIXTURE HAS BEEN REASONABLE; WORK RESULTING IS RELIABLE
- INSTABILITY IS OBSERVED AND RELATED TO :
  - "HIGH" BOILING POINT AGENTS THAT REQUIRED "LARGE" MASSES TO MEET MASS EQUIVALENCE
  - THE QUIESCENT FLOW REGIME OF LOW VENTILATION
- THE LARGEST EQUIVALENT CONCENTRATIONS COMPARE REASONABLY WITH REPORTED DESIGN CONCENTRATIONS
- THE REPLACEMENT CANDIDATES EACH EXHIBITED SOME OVER-PRESSURE BEHAVIOR AT THE DUCT INTERFACE; GIVEN THE PRESSURES INVOLVED MOVED SMOKE ALONE AND DEMONSTRATED NO FIRE EVOLUTION, THERE IS NO REASON TO BELIEVE A SAFETY ISSUE REMAINS
- FLAME ATTACHMENT ATYPICAL OF H1301 WAS OBSERVED DURING TESTING WITH CF3I & FK 5-1-12
  - THE AGENT DISTRIBUTION PLUMBING MAY BE THE EXPLANATION
  - FURTHER TESTING IS ADVISED TO REFUTE OR ACCEPT THE LARGEST EQUIVALENT CONCENTRATION FOR EACH