Halon-Replacement Testing in a Generic Nacelle Fire Simulator with Iodotrifluoromethane [CF_3I].

Errata. Three corrections made to this file 2aug2023, following the presentation of this material. [1] On page 31, removed text box containing “look for a more accurate picture” that should have not been there & add explanation about disagreeing photographic & schematic image details. [2] On page 75, change the sole superscript from “[a]” to “[M]” & provide attendant explanation. [3] Added missing pages numbers to pages 70-74.

Presented to:

The Combined International Aircraft Materials Fire Test & International Aircraft Systems Fire Protection Forum Meeting

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Federal Aviation Administration

There are no product nor service endorsements made within this presentation. Corporate identification is made for the sake of completeness & transparency.

Presentation Content

- **Overview Halon-Equivalence Fire Testing[A]**
  - Assessment concept & its circumstances
  - Test fixture & associated environment

- **Describe the Accomplished CF_3I Testing**
  - 2003-2006, MPSHRe/rev03
  - 2019-2021, MPSHRe/rev04
  - 2022, “cold” testing
  - proposed certification criteria

[A] known in short-hand as “MPSHRe/rev04”, the "Minimum Performance Standards for Halon 1301 Replacement in the Fire Extinguishing Agents/Systems of Civil Aircraft Engine and Auxiliary Power Unit Compartments (MPSHRe rev04)"

Overview, Assessment Concept

- **Alter a Fire Zone Perspective to a Generic One**
  - Used basic elements to generate applicable test results & minimize interfering with understanding them
  - Included basic elements of :
    - forced-ventilation; 2 conditions[B], “low” or “high”
    - representative types of fire; atomized spray[C] & pool[D]
    - “simple” flow-riling, flame-attaching, & “hot”-surface structures
    - representative fuels; turbine fuel, lubricant & hydraulic fluid
    - fire-extinguishing agent injection & migration; total-flooding
    - halon 1301 performance framed by its FAA certification criteria
      - concentration criterion is similar to a peak-inerting concentration[E]

[B] “low” ≈ 0.45 kg/s @ 127°C, “high” ≈ 1.2 @ 38° (~1.0 lbm/s @ 260°F, ~2.7 @ 120°).
[C] fuel spray ≈ 0.95L/min @ 66°C (0.25 US gal/min @ 150°F)
[D] exposed surface 0.52 m long, 0.14 m^2, 1.27 cm deep, T > 49°C (20.5 inches long, 220 in^2, 0.5 in deep, T > 120°F)
[E] see associated appendix material.

Overview, Assessment Concept

- **Task Group Derived; Multiple Revisions**
  - MPSHRe/rev03, 2003-2008, *find* equivalence
    - 4 primary test conditions; 2 ventilation x 2 fire threat
    - metrics :
      - reignition time delay [RTD], fire suppression
      - behavior of a candidate firex agent's concentration field at the respective flame front, without fire
    - empiricism created problems; related to candidate distribution; i.e. flooding versus streaming agents
  - MPSHRe/rev04, 2010-?, *prove* equivalence
    - retain much from rev03, but turn it into a proof-test[F]

[F] any proposed design criteria require plausible definition first, testing will always occur in a generic fixture using those criteria, & subsequent real-scale demonstration testing maybe required contingent upon dissimilarity between halon 1301 & the proposed replacement candidate

Overview, Assessment Concept

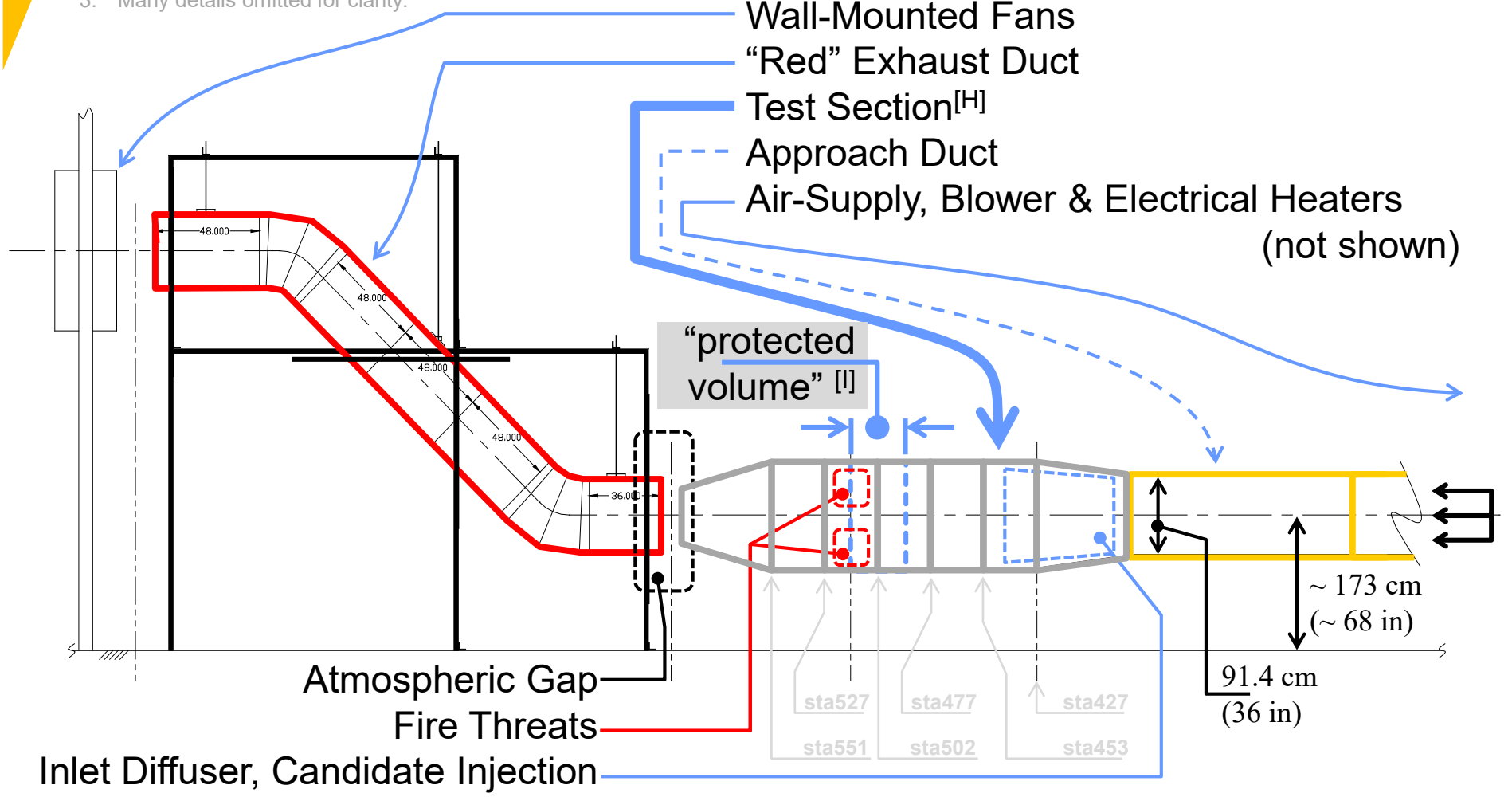
- **General Procedure**
  - Define test condition
  - Implicitly defines ventilation
  - Establish firex agent concentration field
  - Test the concentration field against the fire threats
  - Record/observe behaviors, assess[G] them, & aptly proceed

[G] assessment against historical halon 1301 benchmark test data

Overview, Test Environment

NOTES :
1. This is a schematic elevation view. Not drawn to scale.
2. Station (sta) numbers are incremented as inches.
3. Many details omitted for clarity.

...the generic nacelle fire simulator [gNFS]

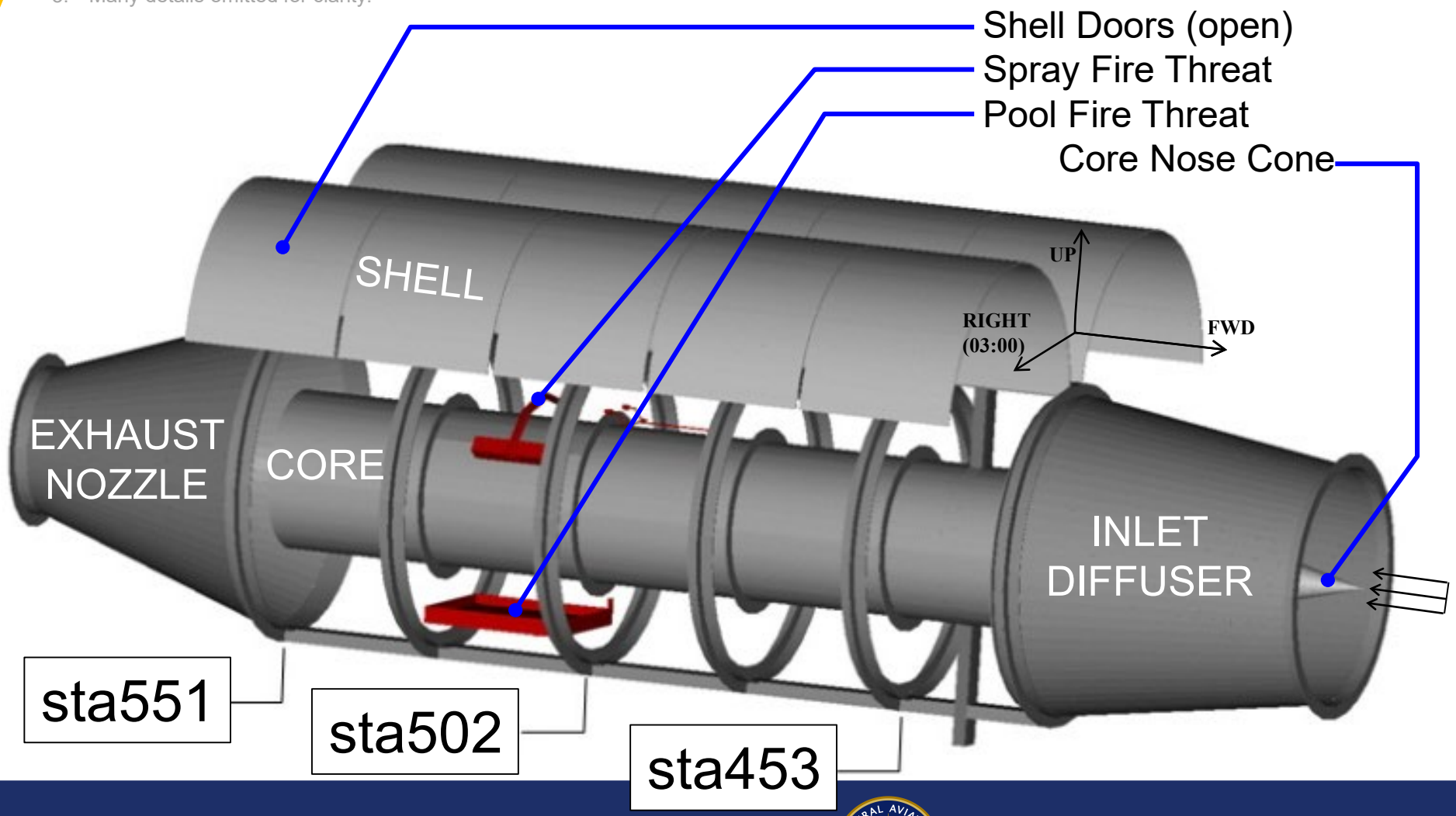


[H] Some idealized/clean dimensional information : inlet diffuser exit flange [sta427] to exhaust nozzle entrance flange [sta551], 3.1 m long x 1.22 m outside diameter x 0.6096 m inside diameter, annular volume ≈ 2.74 m^3 (96.6 ft^3).
[I] sta490 to sta514

Overview, Test Environment

NOTES :
1. This model view is not drawn to scale.
2. Station (sta) numbers are incremented as inches.
3. Many details omitted for clarity.

...the gNFS test section



CF3I Testing, Overview/rev03

- **CF3I Testing, MPSHRe/rev03, 2003-2006**
  - Accomplished by the FAA Fire Safety Branch
    - prioritized by external participants in the working group
  - Finished all spray-fire & high-ventilation/pool-fire testing
  - External interest faded, FAA Fire Safety reprioritized, & discontinued further work with it
    - toxicological uncertainty
    - external participants identified other interests : 2-BTP, FK-5-1-12

CF3I Testing, Overview/rev03

- **CF3I Testing, MPSHRe/rev03** [continued]
  - High-ventilation/spray-fire results generally encouraging
  - Low-vent/spray-fire indirectly discouraging & atypical
    - unexpectedly “large” quantity injected for each test
    - non-optimal injection produced “odd” concentration fields
    - CF3I supply depleted before satisfying test-count requirements
  - High-vent/pool-fire generally encouraging but atypical
    - quantities like high-vent/spray-fire stop flames on fuel surface
    - *but*, fire persists aft of fuel pan, outside the MPSHRe “protected volume”, & eventually reignited pool

CF3I Testing, Overview/rev03

- **CF3I Testing, MPSHRe/rev03** [continued]
  - Per 2003-2006 testing, the largest interim HSRVC was 7.1%v/v CF3I
  - Checked elsewhere for reported *peak-inertion concentrations*, paralleling the FAA rationale for CF_3Br
    - Purdue[J], CF_3I in air/n-heptane : 6.8%v/v CF_3I
    - US NFPA, NFPA 2001, CF_3I in air/propane : 6.5%v/v CF_3I
    - ...7.1%v/v CF_3I considered a plausible concentration criterion
  - Interim proposed criteria = 7.1%v/v CF3I for 1/2 second

[J] Part of the same original body of work substantiating the basis of halon 1301's FAA certification concentration criterion.

CF3I Testing, Overview/rev04

- **CF3I Testing, MPSHRe/rev04, 2018-2022**
  - Boeing/Parker-Meggitt initiative recognized by the FAA
  - Rev04 a *proof* test; prove 7.1%v/v CF3I for 1/2 second
  - Concentration field challenged low-ventilation/pool-fire
  - CF3I low-vent/pool-fire testing proved acceptable
  - Subsequent additional testing occurred; “cold” testing
    - incomplete MPSHRe/rev03 test counts
    - prior atypical test experiences
    - thermodynamic disparity
    - wanted to establish additional confidence in functionality

CF3I Testing, Rev03/04 Test Results

Assessment Procedure	Test Conditions		Assessment Technique & Outcome	
	Internal Forced Ventilation	Fire Threat		
MPSHRe, rev03	high	spray, turbine fuel	direct equivalence	5.6%v/v
		pool, turbine fuel	equivalence by bracket	2.7%v/v
	low	spray, oil	equivalence by bracket	7.1%v/v[L]
		spray, turbine fuel	equivalence by bracket	4.9%v/v
MPSHRe, rev04	low	pool, turbine fuel	shown acceptable by bracket[K]	7.1%v/v[L]

[K] The interim proposed criteria were used to challenge the test environment & performed comparable to or better than halon 1301.
[L] Per MPSHRe/rev04, the largest equivalent concentration is the one recomended as the concentration criiterion for the associated proposed certification criteria.

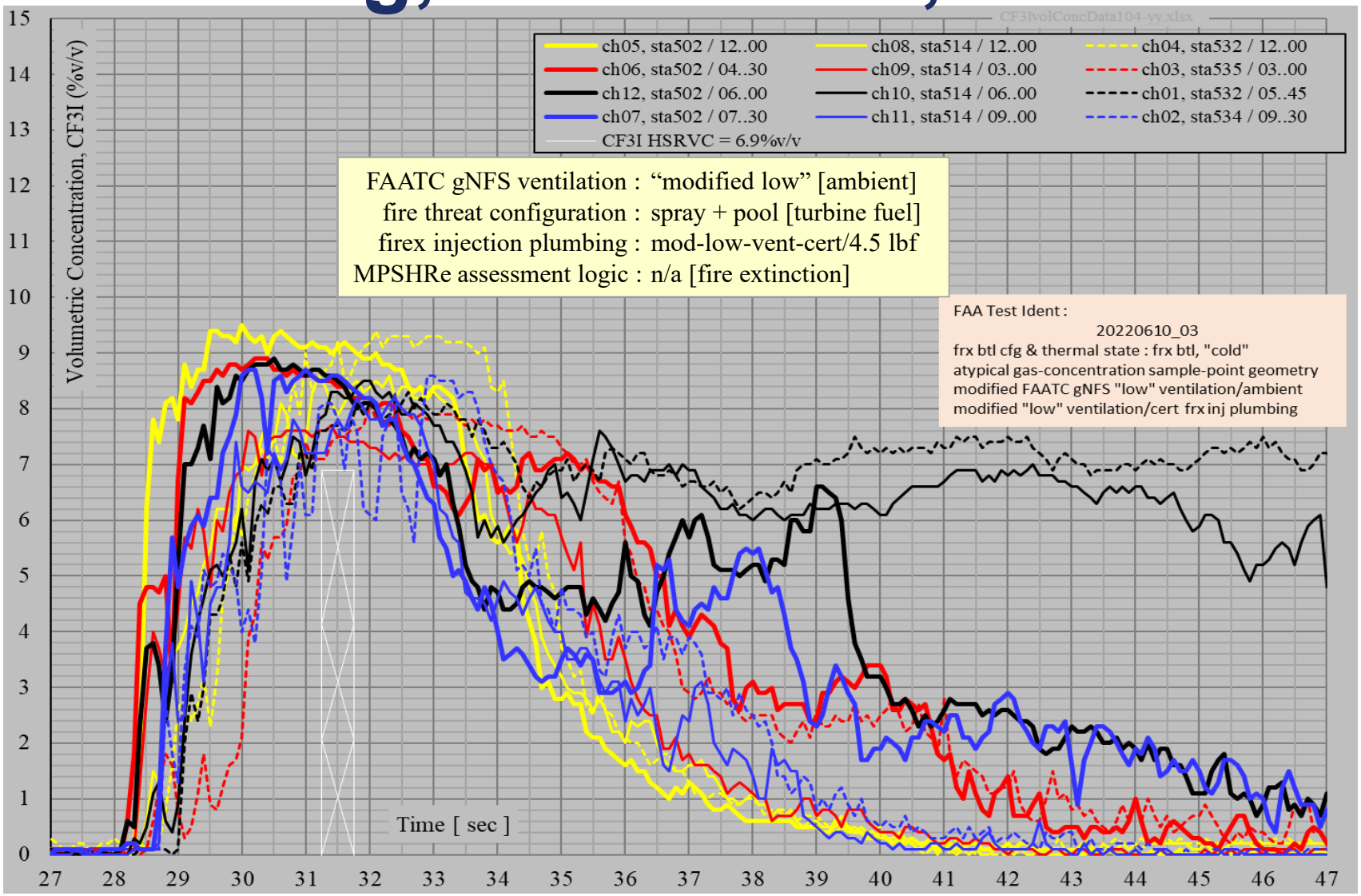
CF3I Testing, Overview/“cold”

- **Challenged CF3I further, given disparities & atypical experiences; “cold” testing**
  - Used modified versions of the 2 gNFS ventilations
    - modified low & modified high
    - ambient air flow only; no heat addition to the ventilation stream
  - Created 2 concentration fields to satisfy proposed criteria
    - enlarged “protected volume”; included fire-related gNFS features
    - injected “cold” firex bottle contents with all else ambient

Test Condition	“cold”/modified-LOW ventilation			“cold”/modified-HIGH ventilation		
Test identification	20220608r07	20220609r03	20220610r03	20220919r03	20220920r03	20220922r03
Average sta453 [°C]	29	22	27	28	26	28
Firex bottle contents [°C]	-52	-51	-51[M]	-54	-55	-56
HSRVC [%v/v CF3I]	7.4	6.7	6.9	6.8	6.9	7.2

Average temperature for the sta453 value is an 8-thermocouple measurement average & the bottle contents 1. The average is calculated with data spanning 2 seconds, sampled at 25 Hz, beginning approximately 5 seconds before CF3I injection.
[M] Faulty institutional thermocouple. Temperature measured by hand-portable reader.

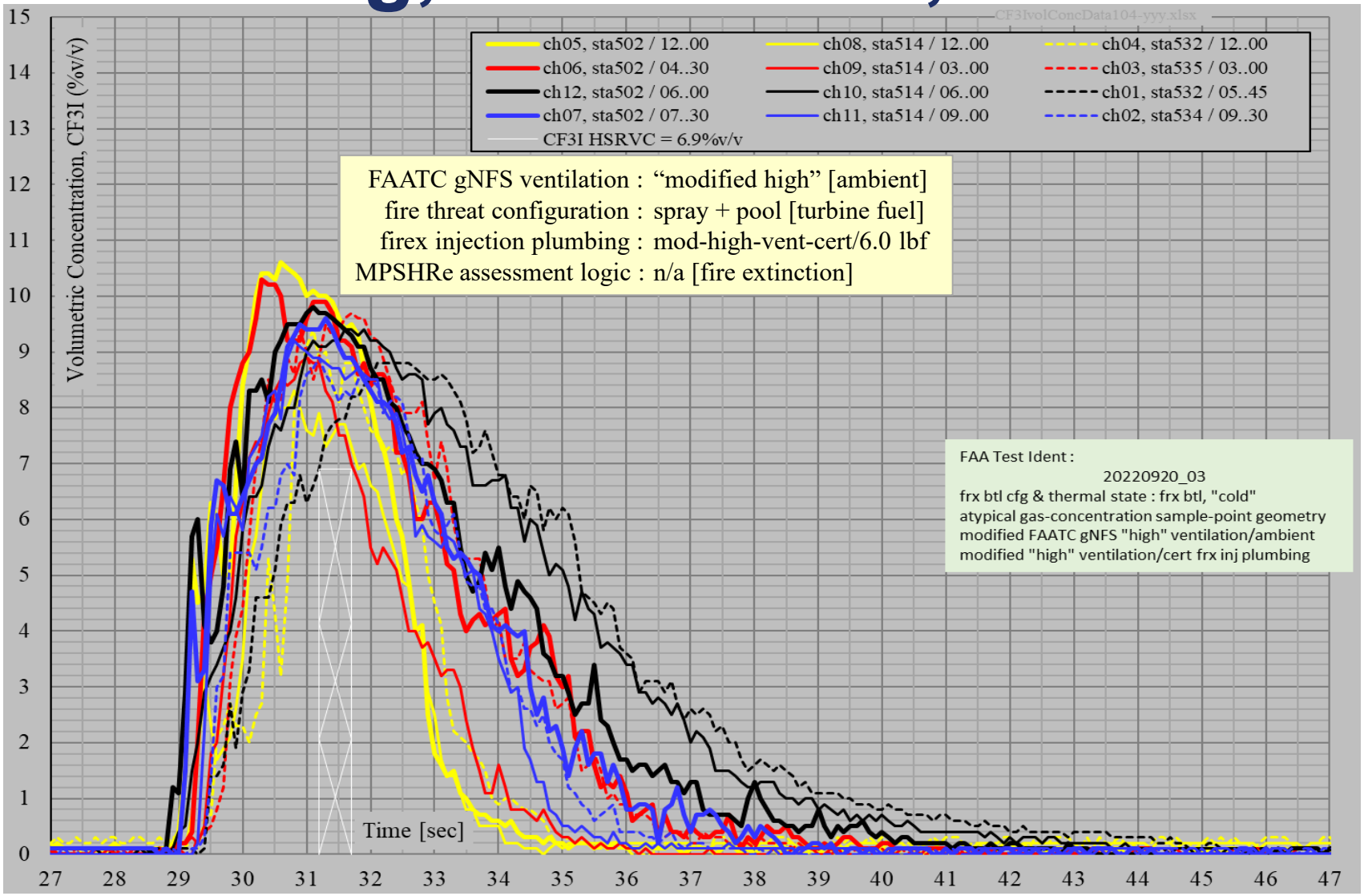
CF3I Testing, Conc. Field, “cold”/lv



Volume concentration data recorded & provided by Parker-Meggitt

Federal Aviation Administration

CF3I Testing, Conc. Field, “cold”/hv



Volume concentration data recorded & provided by Parker-Meggitt

CF3I Testing, Overview/“cold”

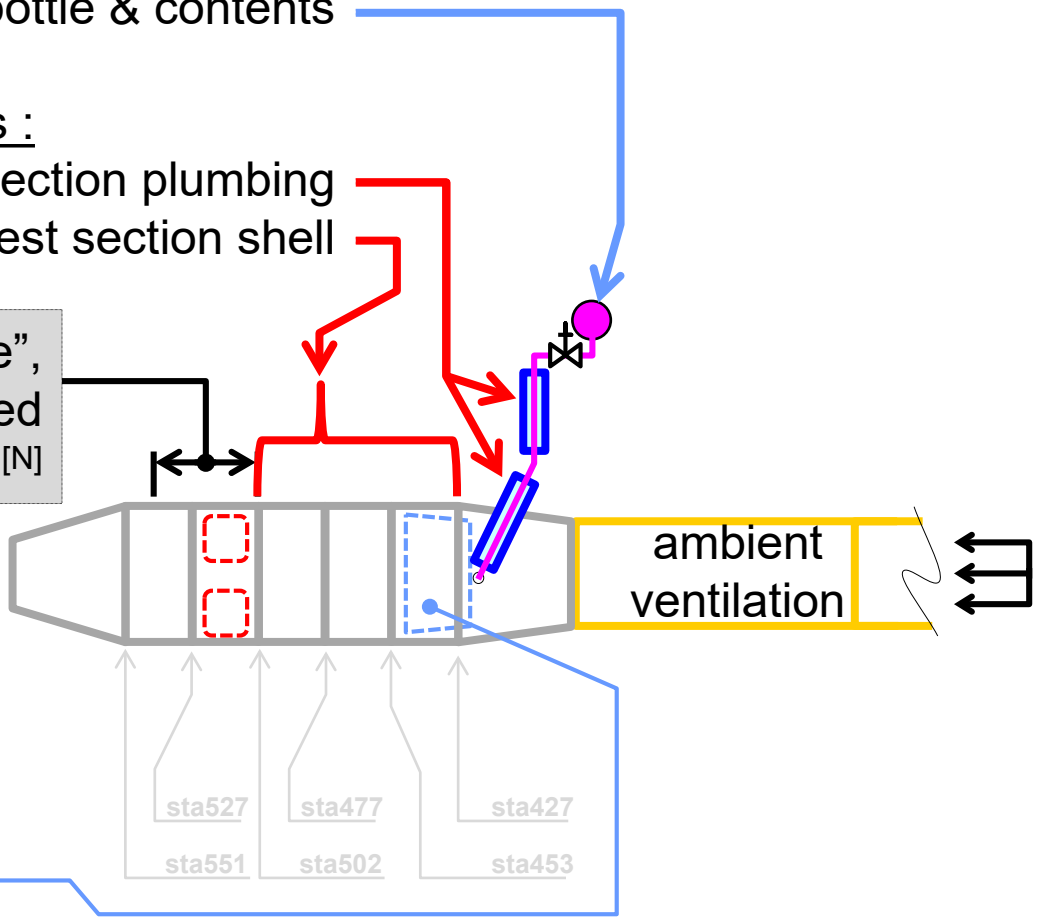
- **Challenged CF3I further, given disparities & the atypical experiences; “cold” testing [continued]**
  - Stressed CF3I further...delivered each concentration field against fire...expected fire extinction
    - injected “cold” firex bottle contents
    - additional “cold” features in the test environment; portions of the :
      - firex injection plumbing; external to the test section
      - test section shell; 5 of 10 doors chilled
    - ignited dual/simultaneous spray & pool fires; fuel above flashpoint
    - needed to *extinguish* all fire
      - turned electrical ignition sources off post-ignition; all else as is
      - spray-fire fuel flow stopped following CF_3I transit

CF3I Testing, Overview/“cold”

“Cold” for concentration-measurement
& fire extinction tests :
firex bottle & contents

“Cold” for the fire extinction tests :
part of the external firex injection plumbing
part of the test section shell

“protected volume”,
sampling points placed
analogous to AC 20-100[N]



NOTES :
1. This is a schematic elevation view. Not drawn to scale.
2. Station (sta) numbers are incremented as inches.
3. Many details omitted for clarity.

Candidate injection,
within cross-sectional plane

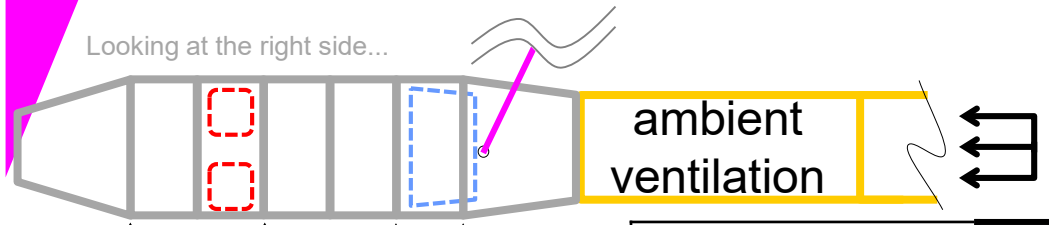
[N] The ”protected” volume spanned sta502 to approximately sta535 for “cold” testing. This differs from that for MPSHRe/rev03 & 04 testing, which spans sta490 to sta514.

CF3I Testing, Overview/“cold”

- **Each f_ext[O] test was 180 seconds long**
  - captured “flat-line” pre-fire ambient ≈ 20 seconds
  - pool fire had 90-sec pre-burn, spray pre-burn 45 sec
  - firex bottle discharge t ≈ 110 sec
  - fuel sprayed 10+ seconds after injection to assure CF3I adequately extinguished the fire, not fuel starvation

[O] f_ext = fire-extinguishment

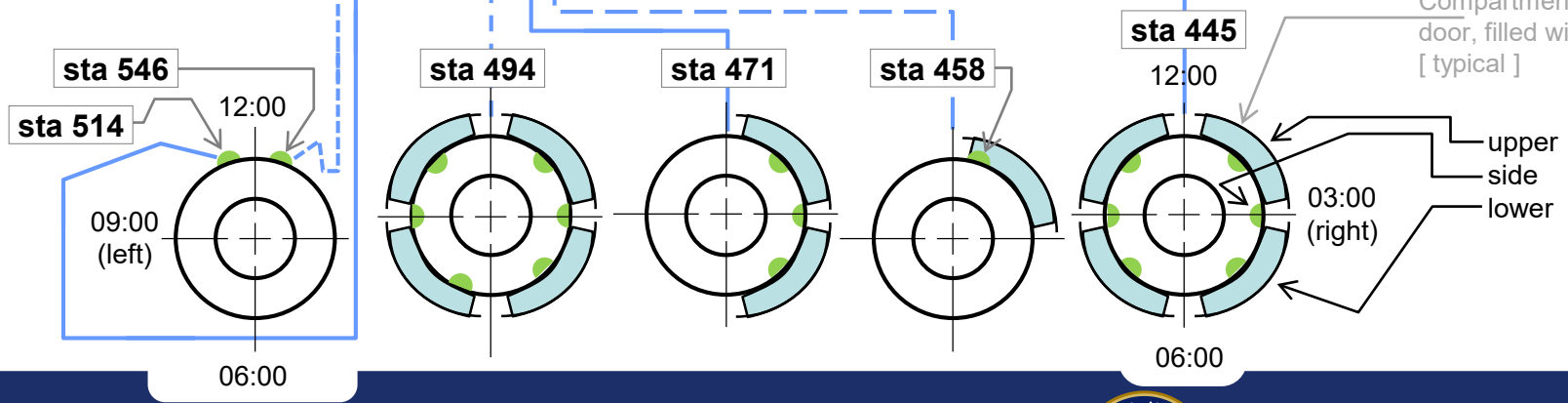
CF3I Testing, Temperatures/"cold"



20220810-04, 1454 EDT

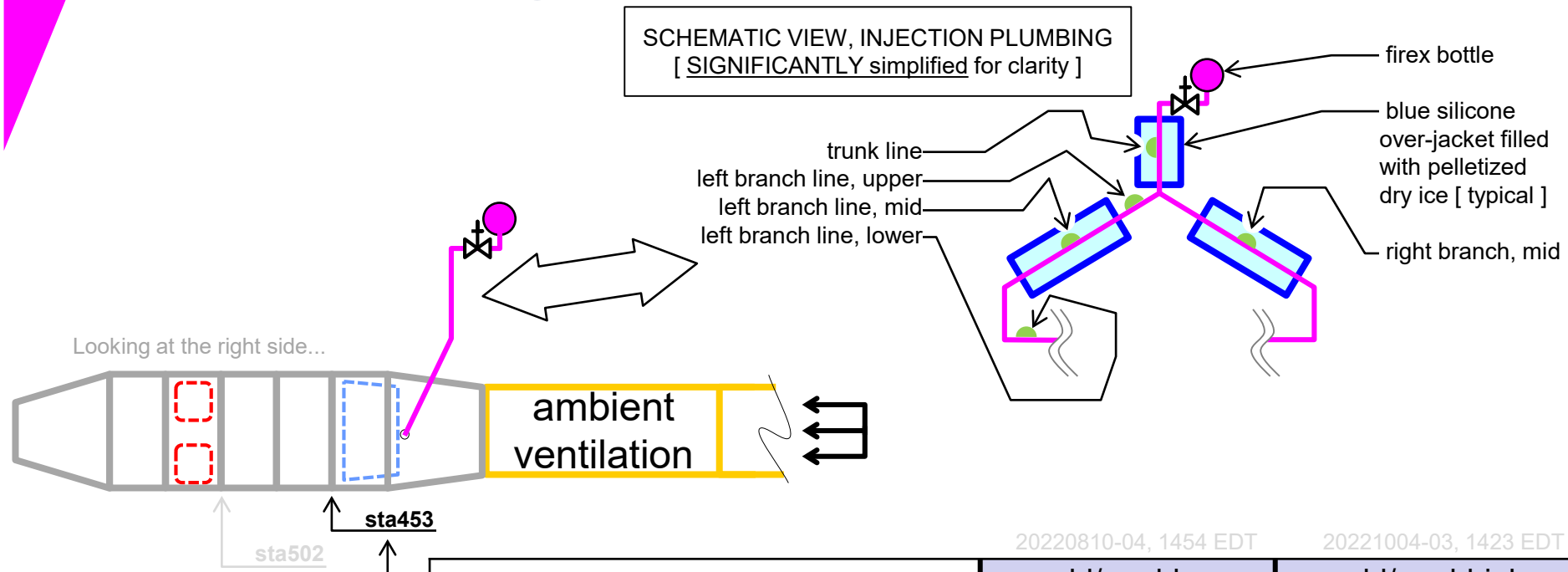
20221004-03, 1423 EDT

Surface Temperatures [°C]		cold/mod-low ventilation			cold/mod-high ventilation		
		upper	side	lower	upper	side	lower
sta# & side	445 right	-66	-2	0	-67	-1	-12
	445 left	-68	11	2	-71	4	-7
	458	-64	n/a	n/a	-76	n/a	n/a
	471 right	-40	6	-16	-54	-1	-19
	494 right	-22	16	3	-50	9	-8
	494 left	-36	14	6	-67	7	3
	514	83	n/a	n/a	121	n/a	n/a
	546	49	n/a	n/a	47	n/a	n/a



These are average temperatures from single thermocouple measurements. The average is calculated with data spanning 2 seconds, sampled at 25 Hz, beginning approximately 5 seconds before CF3I injection.

CF3I Testing, Temperatures/"cold"



Temperatures [°C]		cold/mod-low ventilation 20220810-04, 1454 EDT	cold/mod-high ventilation 20221004-03, 1423 EDT
sta453, average, ventilation air [fluid]		30	17
firex injection plumbing network [surfaces]	trunk	ambient	-69
	left branch, upper	20	0
	left branch, mid	-61	-54
	left branch, lower	25	-1
	right branch, mid	-55	-80
firex bottle contents [fluid]		-54	-55

These are average temperatures from single thermocouple measurements, except the sta453 value is an average of 8. The average is calculated with data spanning 2 seconds, sampled at 25 Hz, beginning approximately 5 seconds before CF3I injection.

CF3I Testing, Results/“cold”

- **All fire extinguished, without ambiguity**
  - performed post-test reviews on the numerical/visual data to assure defined constraints were satisfied
  - took 4 attempts to perform an acceptable mod-low-ventilation test; 1 for the mod-high-ventilation test

CF3I Testing, Conclusion

- **An applicable amount of investigation & testing occurred with CF3I per MPSHRe/rev03 & 04[P]**
  - sole focus here is defining proposed certification criteria
  - MPSHRe/rev03 => 7.1%v/v interim concentration criterion
  - literature review affirmed 7.1%v/v as plausible
  - MPSHRe/rev04 => retained 7.1%v/v as plausible
  - local “cold” testing demonstrated 7.1%v/v as plausible
- **Proposed FAA certification criteria for CF_3I :**
  - 7.1%v/v CF_3I for 1/2 second

[P] All activity regarding the search for a set of proposed certification per MPSHRe/rev04 irmplies consistence with the historically-defined residence time of 1/2 second for any given concentration. An alternate residence time is always a possiblity, however advance coordination with the appropriate organizations is strongly advised.

Project Acknowledgements

...my apologies to those I overlooked, as this work sporadically occurred across a span of 20 years & my memory likely is not 100% correct.

- **FAA Technical Center, Fire Safety Branch**

  FAA Fire Safety Branch : Dave Blake, Dick Hill, Gus Sarkos, Larry Fitzgerald, Tim Smith, Tom Carmen, Wayne Eichner, Louise Speitel, Rob Morrison

  Diakon Solutions : Ed Sica, Mark Materio, Gino Zazenski, Jason Fleming

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- **Parker-Meggitt (Pacific Scientific HTL KinTech)**

  Chris Sevilla, Samir Tambe, William “Bill” Meserve

APPENDIX SLIDES

Appendix/ references

Advisory Circular 20-100, 1977, "General Guidelines for Measuring Fire-Extinguishing Agent Concentrations in Powerplant Compartments," United States Department of Transportation, Federal Aviation Administration, Washington, D.C., U.S.A.

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McBee, E.T., et al, 1950, "Final Report on Fire Extinguishing Agents for the Period September 1, 1947 to June 30, 1950 Covering Research Conducted by the Purdue Research Foundation and the Department of Chemistry under Contract W44-009-eng-5057 with Army Engineers Research and Development Laboratories, Fort Belvoir."

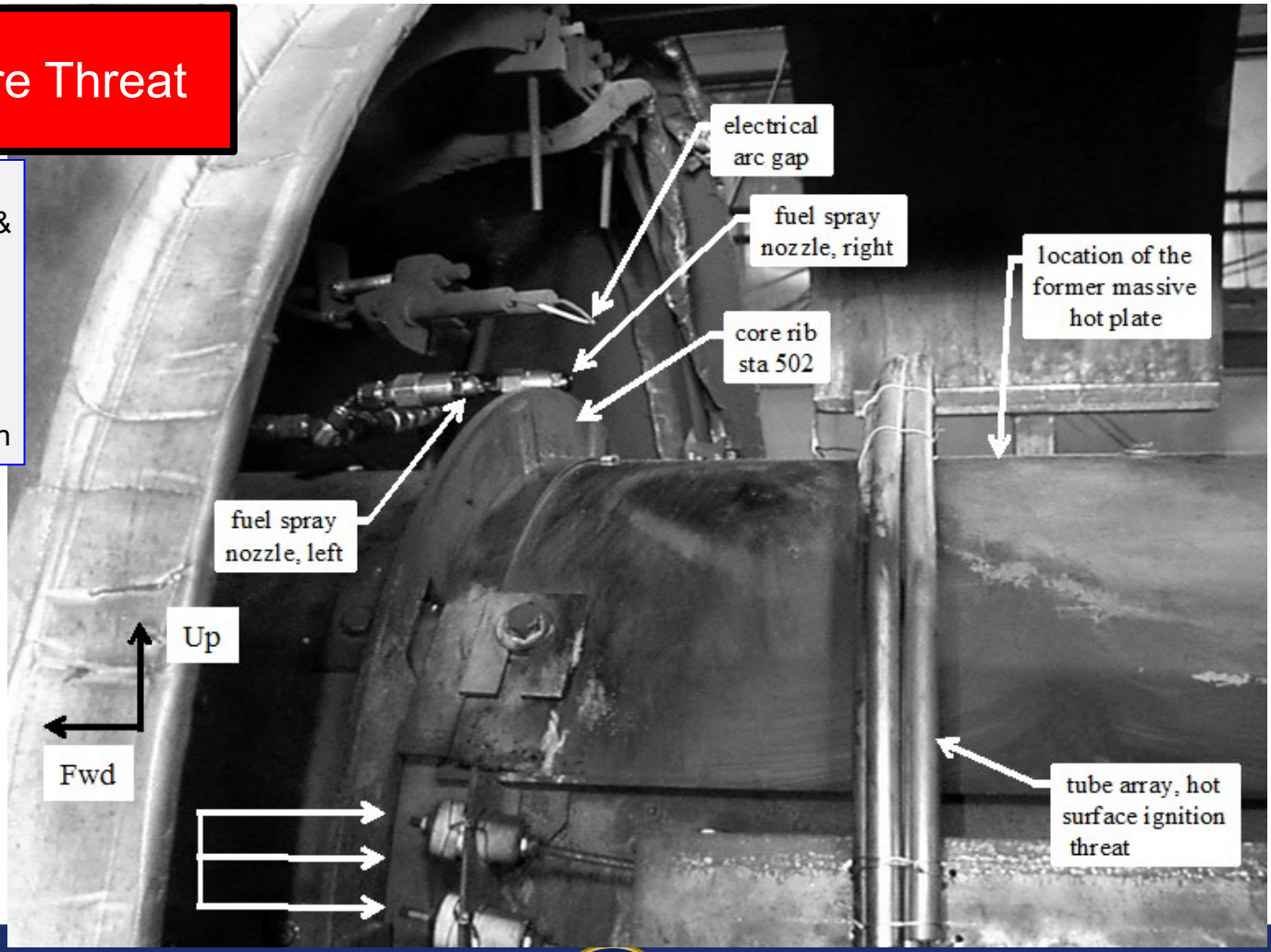
National Fire Protection Association, 2007, "NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems," 2008 Edition, Quincy, MA, U.S.A.

Yang J.C., Manzello S.L., Nyden, M.R., Connaghan, M.D., "Discharge of CF3I in a Cold Simulated Aircraft Engine Nacelle", National Institute of Standards and Technology, Building and Fire Research Laboratory, Gaithersburg, Maryland, U.S.A.

Appendix/ the SPRAY Fire Threat in the FAATC gNFS

Spray Fire Threat

- Fuel flow ≈ 1 L/min @ 67°C
- Fuel flow, electrical ignition arc, & "hot" surface are present during the migration of the fire-extinguishing agent pulse through the test section
- Watching/using the duration the fire is suppressed for comparison

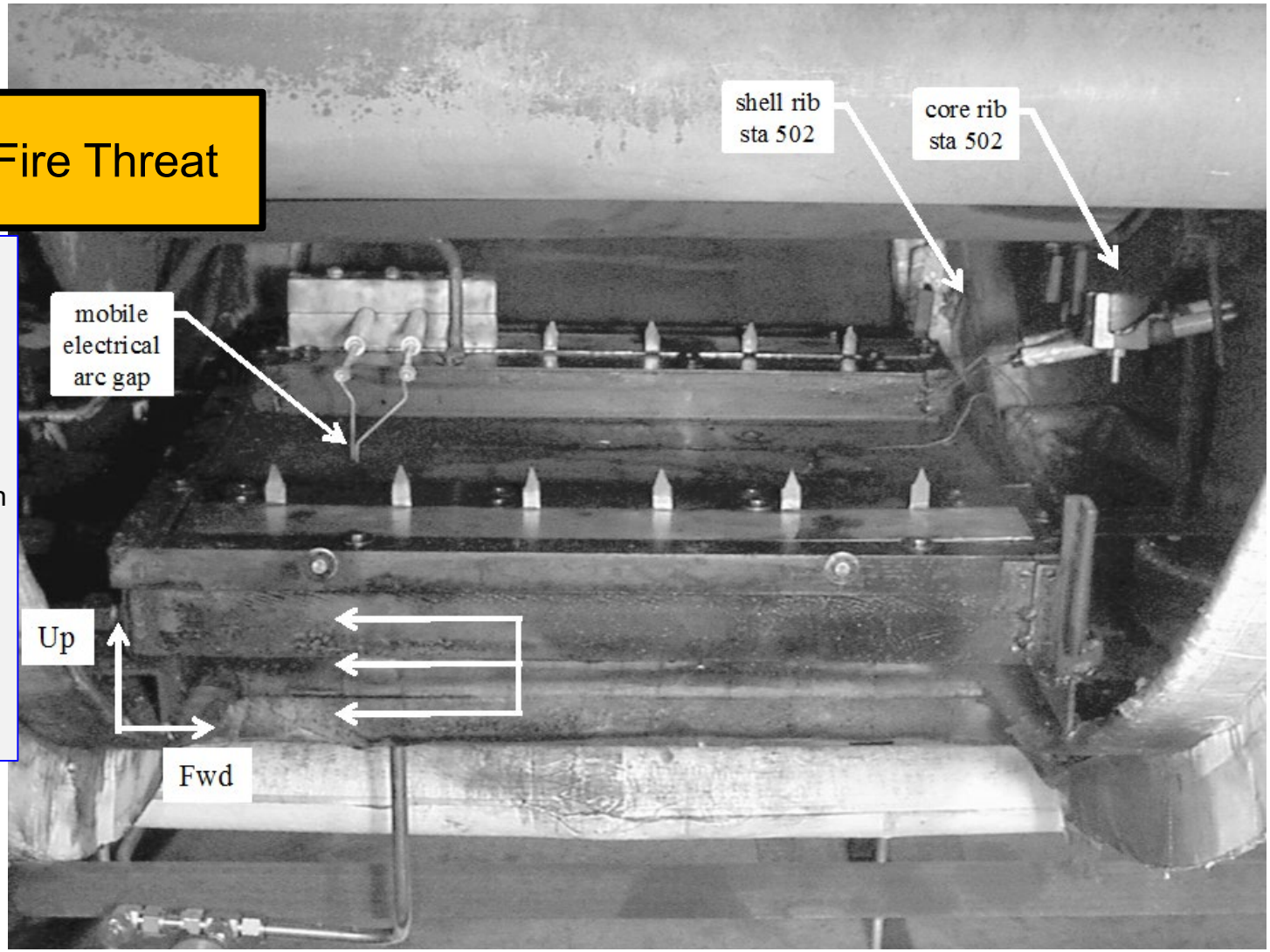


FAATC = Federal Aviation Administration WJ Hughes Technical Center
gNFS = generic nacelle fire simulator

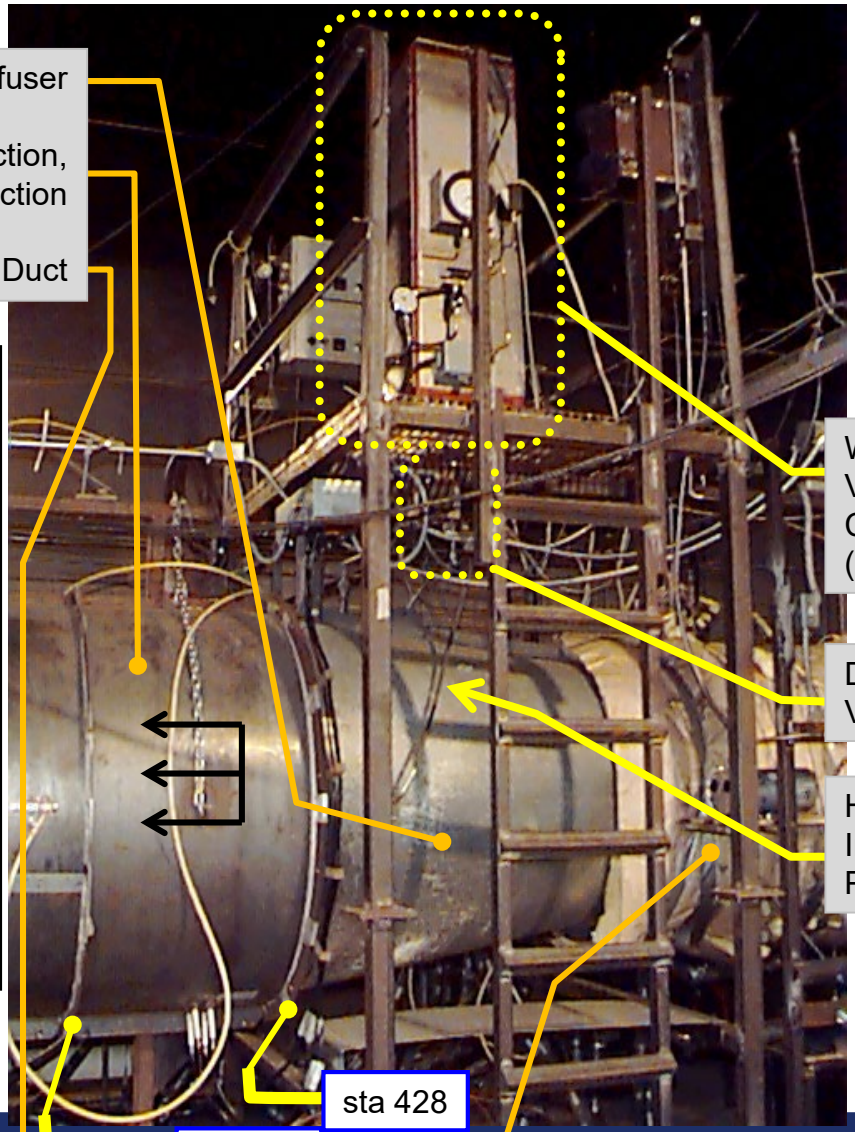
Appendix/ the POOL Fire Threat in the FAATC gNFS

Pool Fire Threat

- Idealized fuel puddle dimensions are :
  - 27.4 cm (10.8 in) wide
  - 52.8 cm (20.8 in) long
  - 13 mm (0.5 in) deep
- Fuel puddle sits in/atop water-jacketed pan
- Fuel flow & electrical ignition arc are present during the migration of the fire-extinguishing agent pulse through the test section
- Again, watching/using the duration the fire is suppressed for comparison

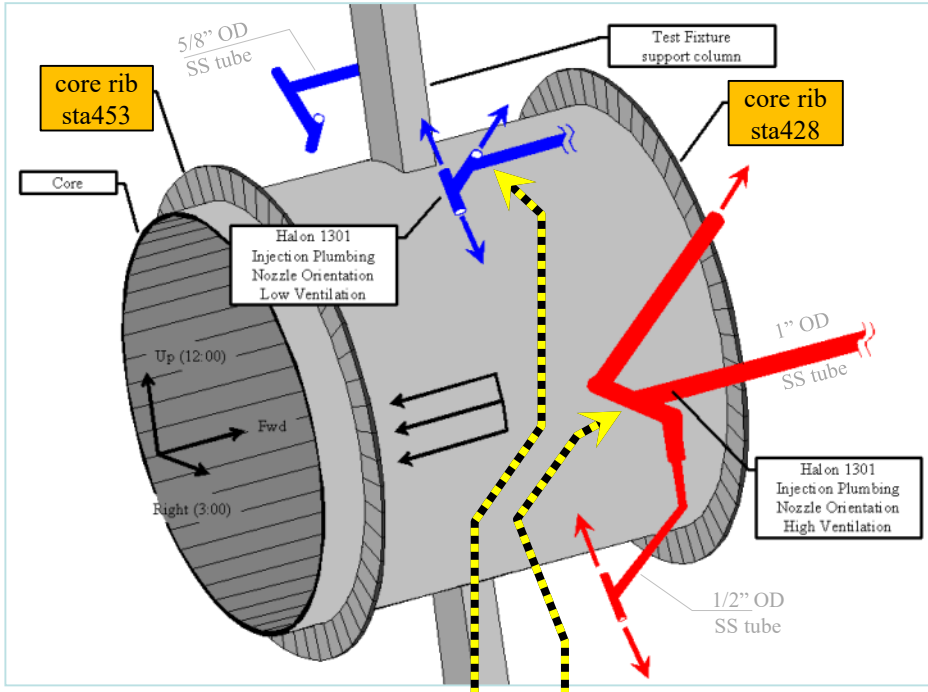


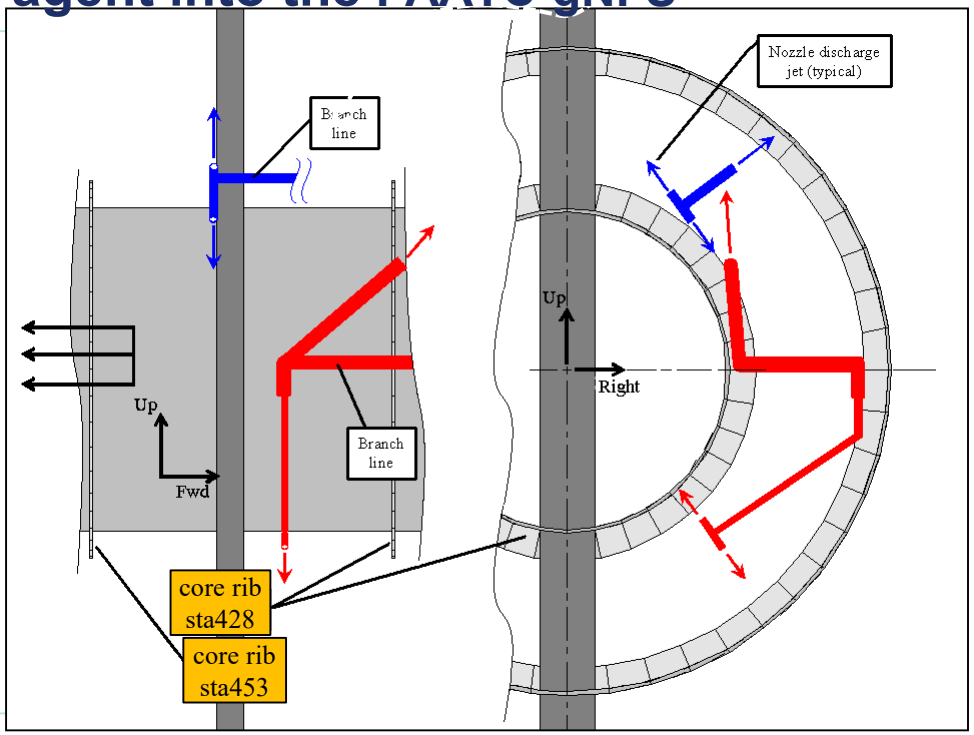
Appendix/ storing/conditioning firex agent for a gNFS test



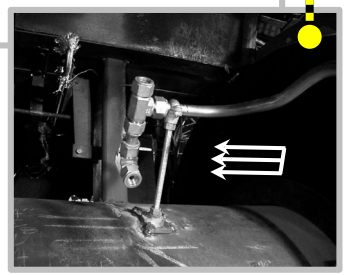
- This assembly & its variations were used for all halon 1301 & CF3I MPSHRe/rev03 testing. Firex agent & nitrogen are introduced as needed into a pre-determined storage volume & then thermally conditioned as needed for test; contents were heated during MPSHRe/rev03 testing.
- A Parker-Meggitt aircraft firex bottle & its preparations for test replaced the WPAFB firex vessel during MPSHRe/rev04 & /"cold" testing. The firex bottle was heated in an FAA-owned oven for MPSHRe/rev04 testing & immersed in a pelletized dry ice bath for the "cold" testing.

Appendix/ injecting firex agent into the FAATC gNFS

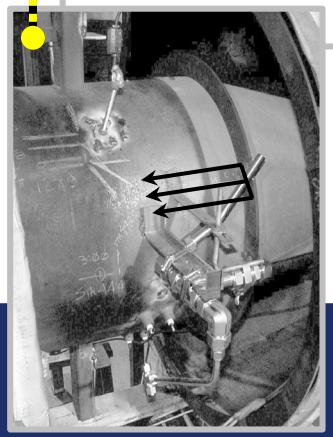




Low-ventilation certification
[low-vent/cert]



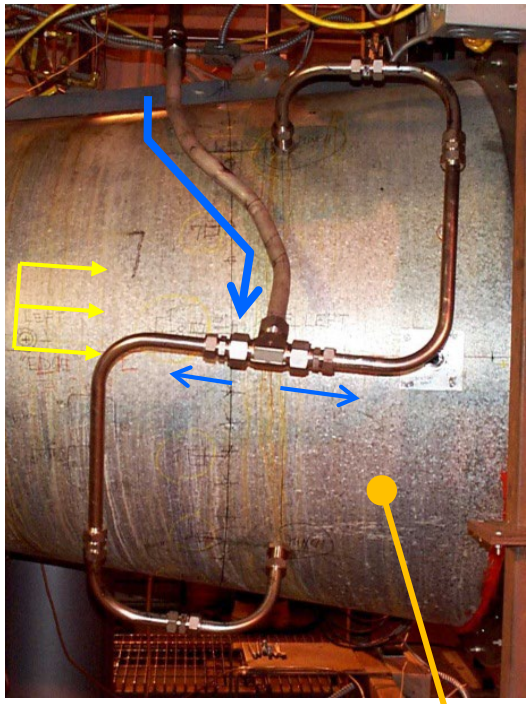
High-ventilation certification
[high-vent/cert]



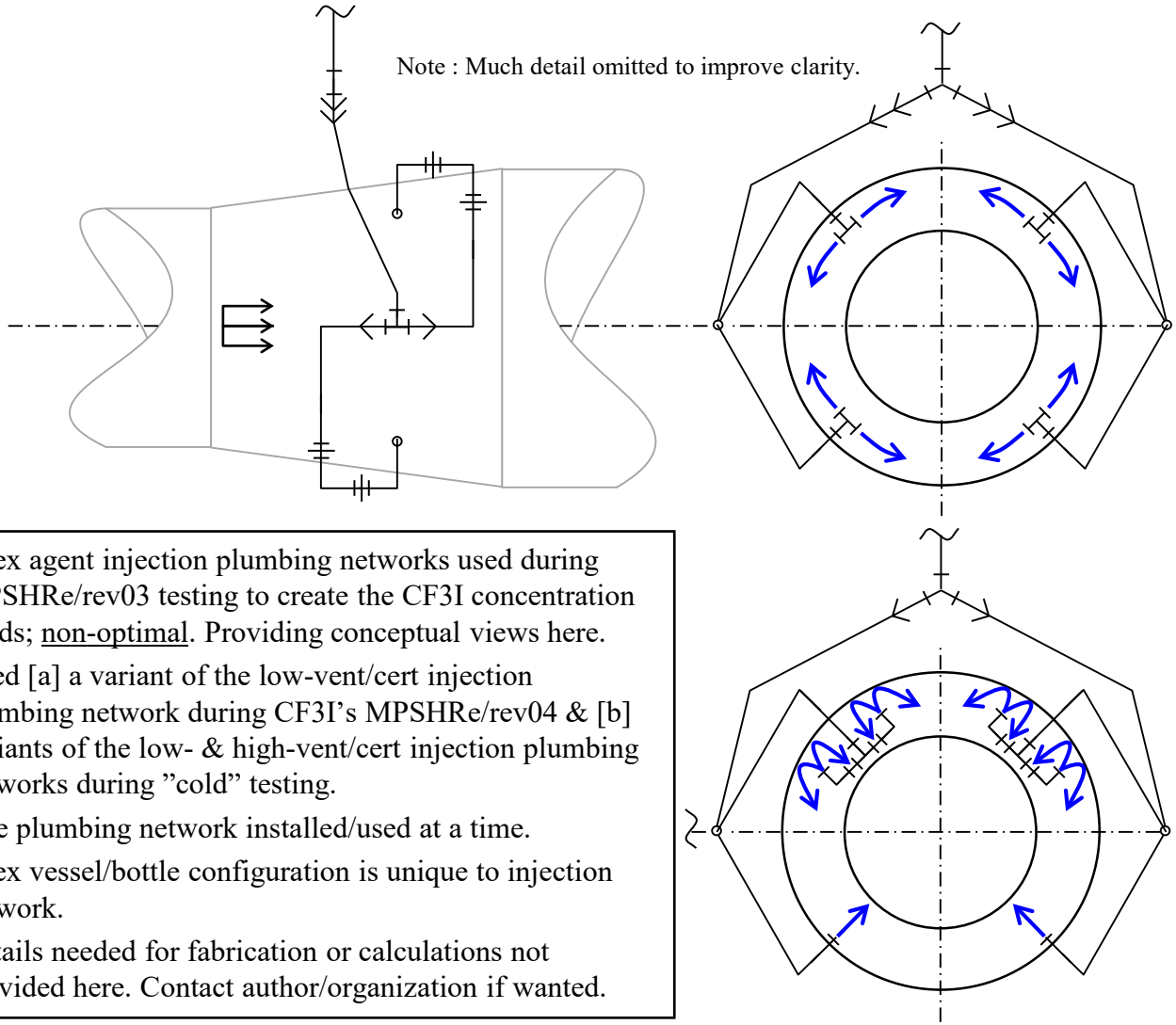
- These networks create the halon 1301 concentration field; optimal. One plumbing network installed/used at a time; "blue" used for "low" ventilation [low-vent/cert], "red" used for "high" ventilation [high-vent/cert].
- These plumbing networks are notably symmetric, although some variation exists. That seen on the right exists on the left.
- Firex vessel configuration is unique to injection network.
- Details needed for fabrication or calculations not provided here. Contact author/organization if wanted.

Appendix/ injecting firex agent into the FAATC gNFS

Generic Candidate Injection Plumbing, [exterior, “non-optimal”]

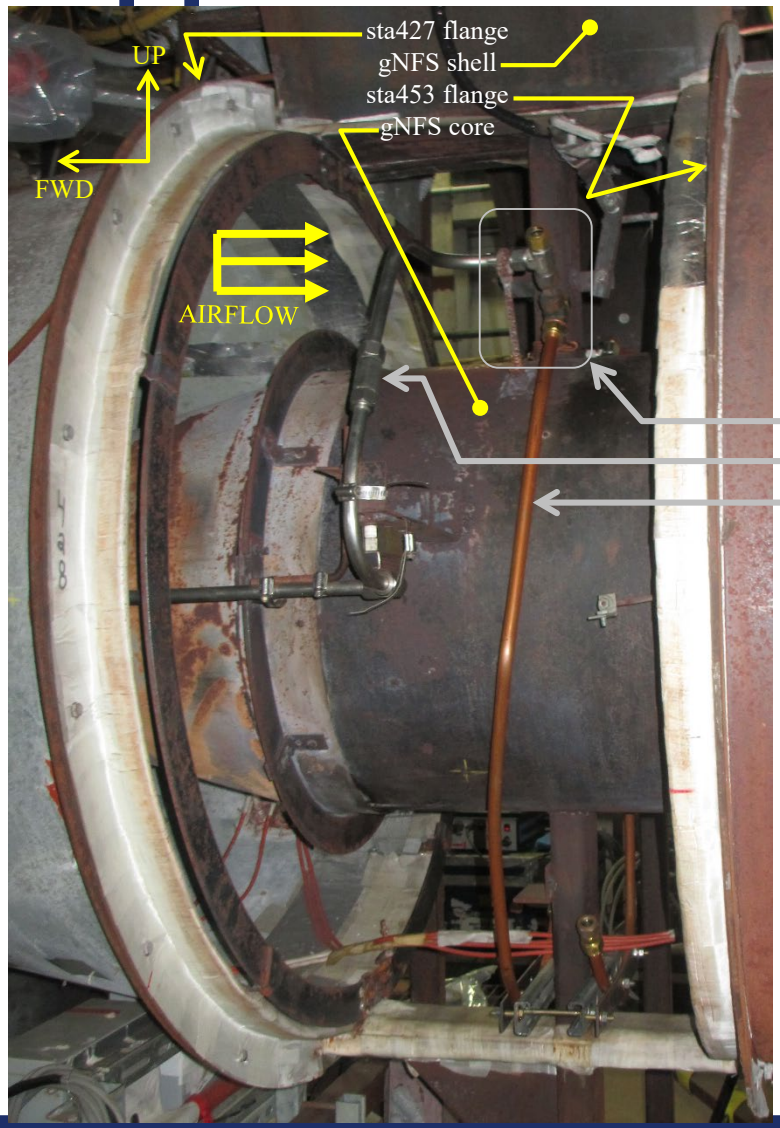


Test Section’s Inlet Diffuser

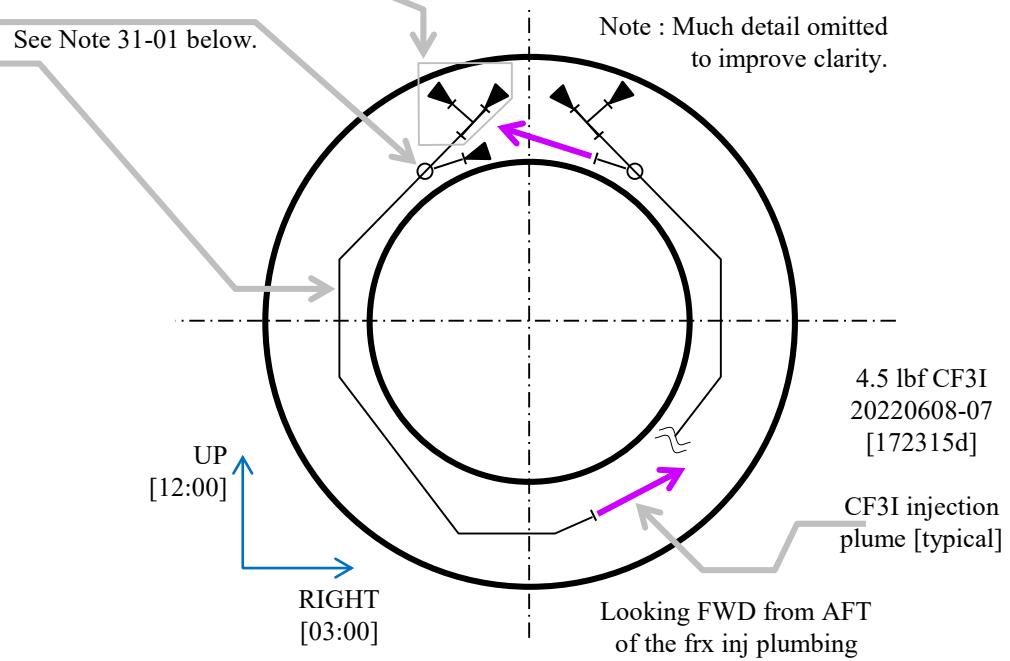


- Firex agent injection plumbing networks used during MPSHRe/rev03 testing to create the CF3I concentration fields; non-optimal. Providing conceptual views here.
- Used [a] a variant of the low-vent/cert injection plumbing network during CF3I’s MPSHRe/rev04 & [b] variants of the low- & high-vent/cert injection plumbing networks during ”cold” testing.
- One plumbing network installed/used at a time.
- Firex vessel/bottle configuration is unique to injection network.
- Details needed for fabrication or calculations not provided here. Contact author/organization if wanted.

Appendix/ injecting firex agent into the FAATC gNFS

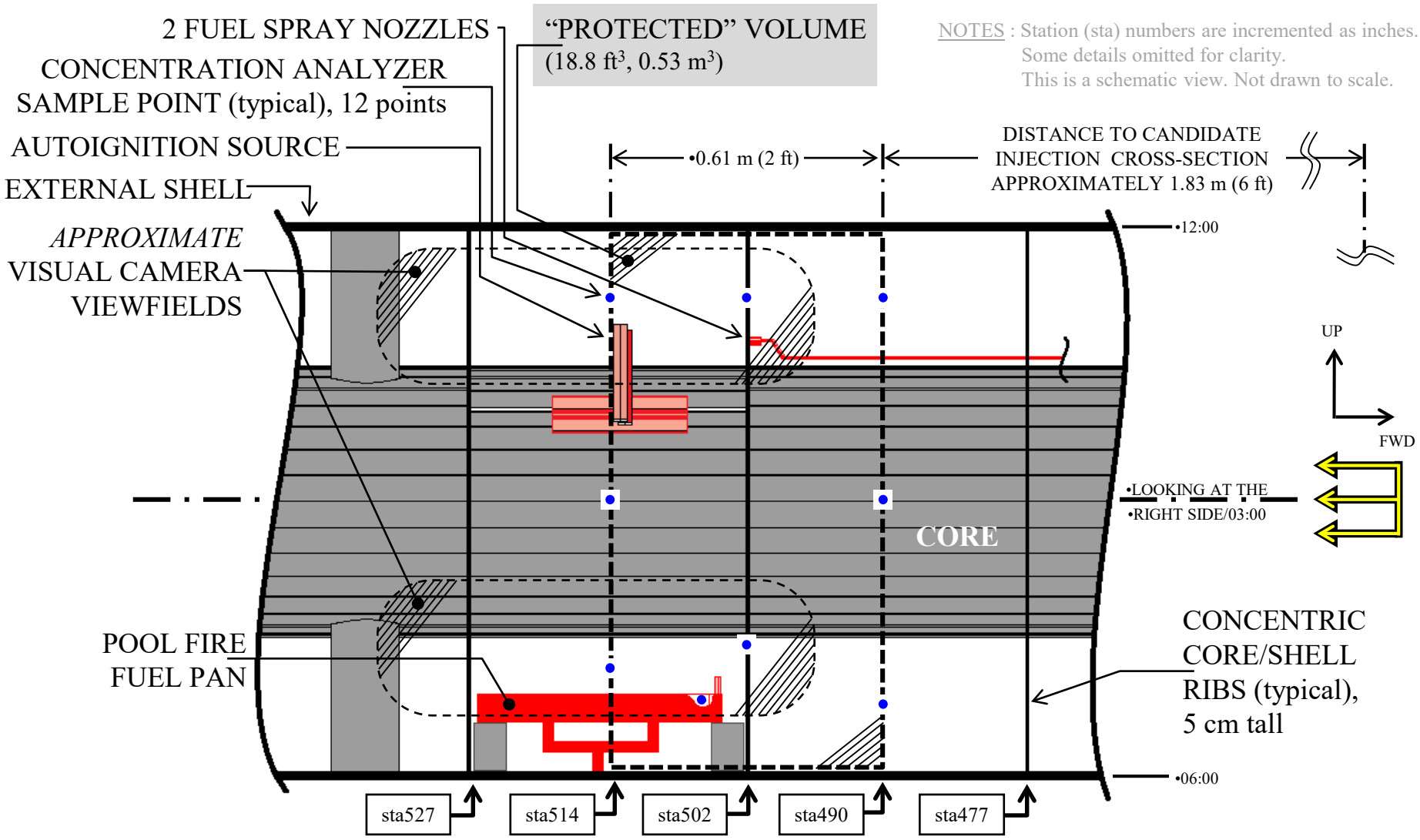


- This is the firex agent injection plumbing network used to create the CF3I concentration field in the modified-low ventilation during "cold" testing.
- Firex bottle configuration is unique to this injection network.
- Details needed for fabrication or calculations not provided here. Contact author/organization if wanted.
- The firex injection plumbing network used for CF3I "cold" testing at modified-high ventilation was a variant of the high-vent/cert network. This plumbing network inside the gNFS test section was not altered, thus is not illustrated here. Variation outside the test occurred & is illustrated elsewhere in this file.



Note 31-01. The time when this image was captured preceded the plumbing configuration indicated in the associated schematic image. The image does not capture the schematically-indicated installation details for the identified tee included in the left branch line nor its peer in the right branch line.

Appendix/ Gas Sampling Geometry, MPSHRe/rev04

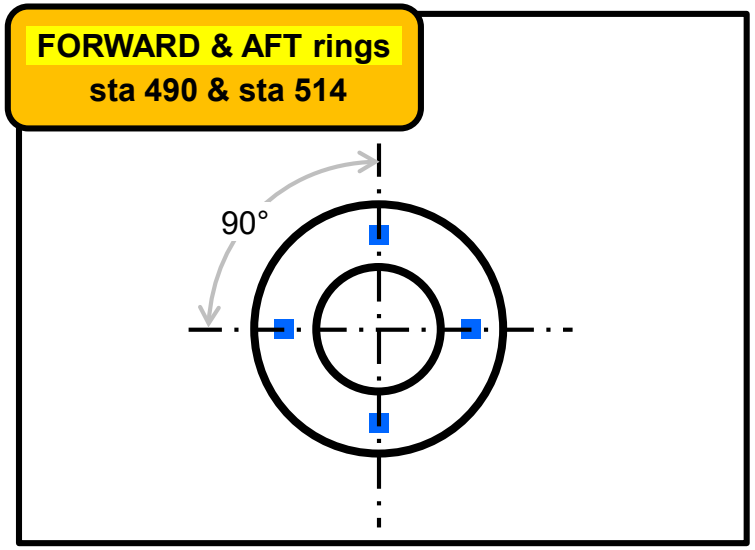


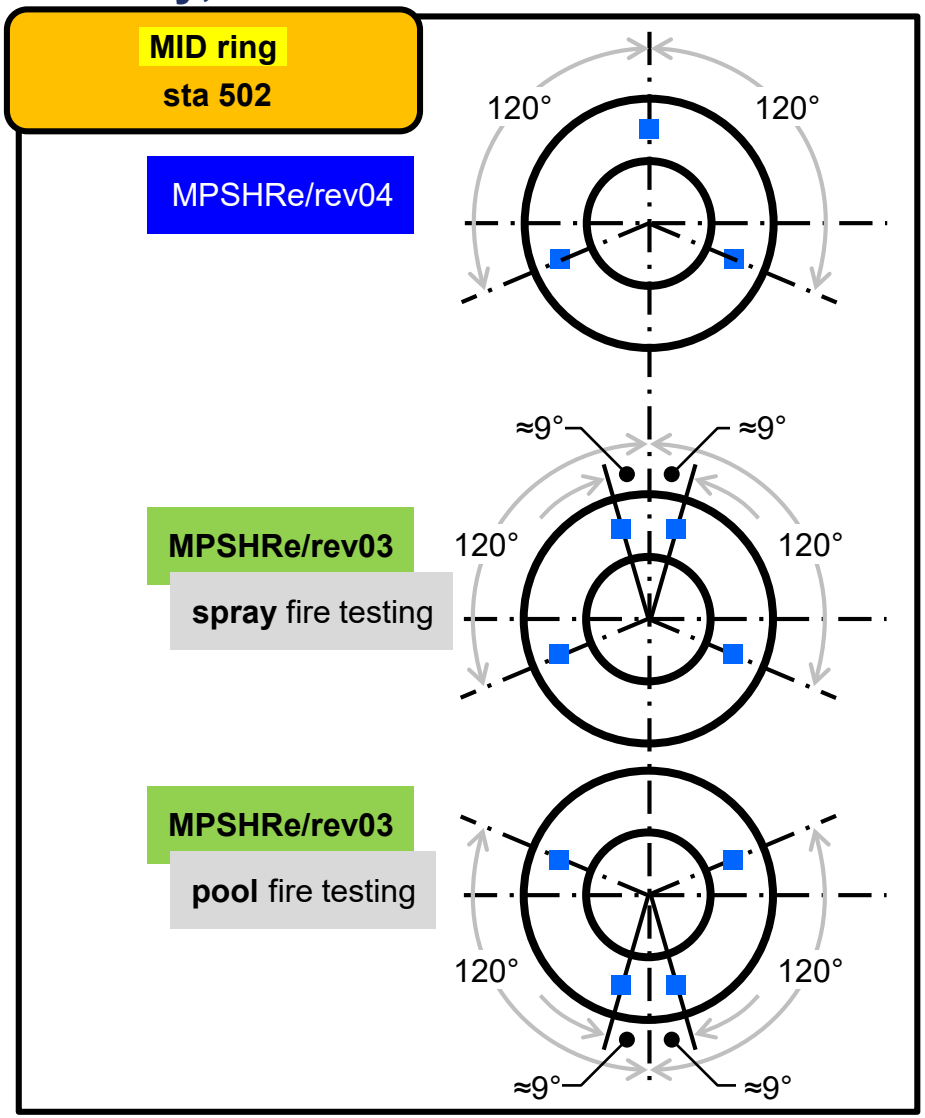
- 11 SAMPLE POINTS IN "FREE" STREAM APPROXIMATELY 0.15 m OFF THE CORE SURFACE
- 12TH SAMPLE POINT IS IN THE FWD WAKE REGION OF THE FUEL PAN
- "PROTECTED" VOLUME : ≈ 0.61 m LONG x 0.61 m ID x 1.2 m OD

Appendix/ Gas Sampling Geometry, MPSHRe/rev04 Versus rev03

NOTES :

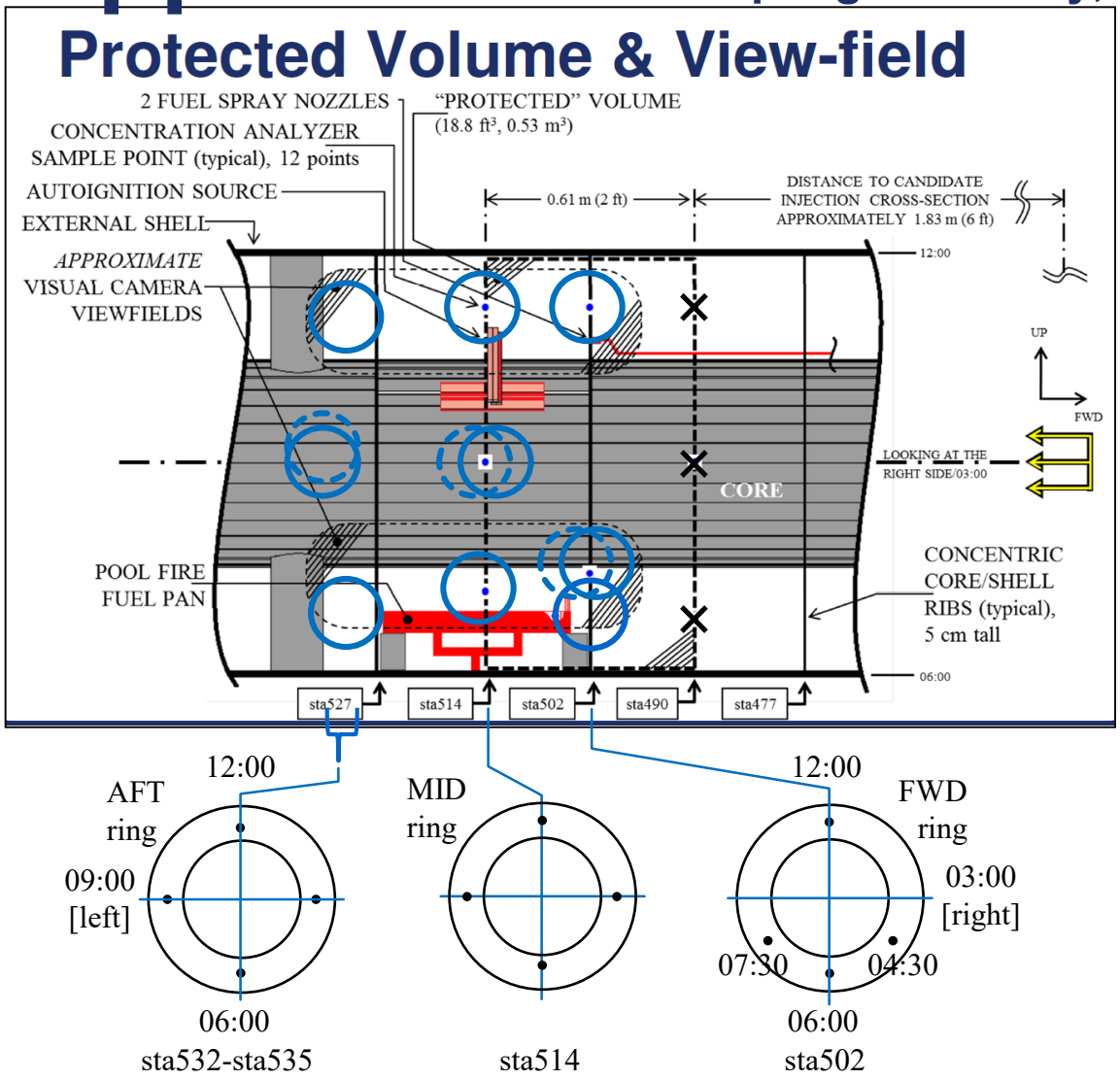
1. Sample-point geometry on the forward [sta490] & aft [sta514] sample rings remains consistent for both MPSHRe revisions; 12:00, 03:00, 06:00, & 09:00.
2. MPSHRe/rev04's wake-region sample point nonexistent for MPSHRe/rev03 testing; point is aft of & below the fuel pan's forward lip
3. Sample points on the mid ring [sta502] changed between MPSHRe/rev04 & /rev03, & during MPSHRe/rev03 testing, this ring's orientation related to the type of fire threat present when testing.





Appendix/ Gas Sampling Geometry, “cold” testing

Protected Volume & View-field



ch#	gNFS sta #	clok pos	stream pos
..01	532	05..45	freestream
..02	534	09..30	freestream
..03	535	03..00	freestream
..04	532	12..00	freestream
..05	502	12..00	freestream
..06	502	04..30	freestream
..07	502	07..30	freestream
..08	514	12..00	freestream
..09	514	03..00	freestream
..10	514	06..00	freestream
..11	514	09..00	freestream
..12	502	06..00	freestream

...length of sample-point geometry approx 33”
[sta535 – sta502 = 33 inches
...all sample points are in the “free stream”

Appendix/ CF_3I test results, table of basic individual test results

Grouping	FAA Test Identification	MPSHRe Revision	Test Type	Firex Agent	Ventilation	Fire Threat	MPSHRe bracket type	Injected Weight [lbf]	EVC [%v/v CF3I]	HSRVC [%v/v CF3I]	RTD [sec]
A01	20030915-10	3	f_ext	halon 1301	high	spray/turbine fuel	benchmark	3.6	5.6	n/a	1.46
A02	20030915-11	3	f_ext	halon 1301	high	spray/turbine fuel	benchmark	3.6	5.6	n/a	1.55
A03	20030916-10	3	f_ext	halon 1301	high	spray/turbine fuel	benchmark	3.6	5.6	n/a	1.20
A04	20030916-11	3	f_ext	halon 1301	high	spray/turbine fuel	benchmark	3.6	5.6	n/a	1.35
A05	20030916-12	3	f_ext	halon 1301	high	spray/turbine fuel	benchmark	3.6	5.6	n/a	1.27
A06	20030917-10	3	f_ext	CF3I	high	spray/turbine fuel	equivalent	4.5	5.6	n/a	1.33
A07	20030917-11	3	f_ext	CF3I	high	spray/turbine fuel	equivalent	4.5	5.6	n/a	1.23
A08	20030917-12	3	f_ext	CF3I	high	spray/turbine fuel	equivalent	4.5	5.6	n/a	1.53
A09	20030917-13	3	f_ext	CF3I	high	spray/turbine fuel	equivalent	4.5	5.6	n/a	1.58
A10	20030918-10	3	f_ext	CF3I	high	spray/turbine fuel	equivalent	4.5	5.6	n/a	1.51
A11	20030922-10	3	f_ext	CF3I	high	spray/oil	equivalent	4.5	5.6	n/a	1.66
A12	20030923-10	3	f_ext	CF3I	high	spray/oil	equivalent	4.5	5.6	n/a	1.78
A13	20030923-11	3	f_ext	CF3I	high	spray/oil	equivalent	4.5	5.6	n/a	1.62
A14	20031002-12	3	f_ext	CF3I	high	spray/hyd fluid	equivalent	4.5	5.6	n/a	1.56
A15	20031002-13	3	f_ext	CF3I	high	spray/hyd fluid	equivalent	4.5	5.6	n/a	1.78
A16	20031002-14	3	f_ext	CF3I	high	spray/hyd fluid	equivalent	4.5	5.6	n/a	1.57
A17	20031008-13	3	a_dis	CF3I	high	n/a	equivalent	4.5	5.6	n/a	n/a
A18	20031009-10	3	a_dis	CF3I	high	n/a	equivalent	4.5	5.6	n/a	n/a
A19	20031009-11	3	a_dis	CF3I	high	n/a	equivalent	4.5	5.6	n/a	n/a

EVC = equivalent volume concentration, resulting from MPSHRe/rev03 procedure
HSRVC = half-second resident volume concentration
a_dis = firex agent distribution test, to measure concentration field
f_ext = fire extinguishment test, to measure reignition time delay

Appendix/ CF_3I test results, table of basic individual test results

Grouping	FAA Test Identification	MPSHRe Revision	Test Type	Firex Agent	Ventilation	Fire Threat	MPSHRe bracket type	Injected Weight [lbf]	EVC [%v/v CF3I]	HSRVC [%v/v CF3I]	RTD [sec]
B01	20060809-10	3	f_ext	halon 1301	high	pool/turbine fuel	benchmark	3.6	2.7	n/a	2.89
B02	20060809-11	3	f_ext	halon 1301	high	pool/turbine fuel	benchmark	3.6	2.7	n/a	2.81
B03	20060810-10	3	f_ext	halon 1301	high	pool/turbine fuel	benchmark	3.6	2.7	n/a	3.25
B04	20060810-11	3	f_ext	halon 1301	high	pool/turbine fuel	benchmark	3.6	2.7	n/a	3.45
B05	20060810-12	3	f_ext	halon 1301	high	pool/turbine fuel	benchmark	3.6	2.7	n/a	3.04
B06	20060823-10	3	f_ext	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	2.63
B07	20060823-11	3	f_ext	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	1.94
B08	20060823-12	3	f_ext	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	2.41
B09	20060824-10	3	f_ext	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	2.44
B10	20060824-11	3	f_ext	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	2.30
B11	20060824-12	3	f_ext	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	4.63
B12	20060824-13	3	f_ext	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	3.97
B13	20060824-14	3	f_ext	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	4.21
B14	20060825-11	3	f_ext	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	4.38
B15	20060825-12	3	f_ext	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	4.44
B16	20060829-14	3	a_dis	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	n/a
B17	20060829-15	3	a_dis	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	n/a
B18	20060829-17	3	a_dis	CF3I	high	pool/turbine fuel	superior	3.5	2.7	n/a	n/a
B19	20060829-18	3	a_dis	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	n/a
B20	20060829-19	3	a_dis	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	n/a
B21	20060830-11	3	a_dis	CF3I	high	pool/turbine fuel	inferior	2	2.7	n/a	n/a

EVC = equivalent volume concentration, resulting from MPSHRe/rev03 procedure
HSRVC = half-second resident volume concentration
a_dis = firex agent distribution test, to measure concentration field
f_ext = fire extinguishment test, to measure reignition time delay

Appendix/ CF_3I test results, table of basic individual test results

Grouping	FAA Test Identification	MPSHRe Revision	Test Type	Firex Agent	Ventilation	Fire Threat	MPSHRe bracket type	Injected Weight [lbf]	EVC [%v/v CF3I]	HSRVC [%v/v CF3I]	RTD [sec]
C01	20040323-10	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	1.47
C02	20040323-11	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	2.15
C03	20040324-10	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	1.80
C04	20040324-11	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	2.12
C05	20040324-12	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	1.62
C06	20040408-10	3	f_ext	CF3I	low	spray/oil	superior	13	7.1	n/a	3.14
C07	20040408-11	3	f_ext	CF3I	low	spray/oil	superior	13	7.1	n/a	3.24
C08	20040408-12	3	f_ext	CF3I	low	spray/oil	superior	13	7.1	n/a	3.17
C09	20040421-10	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	1.57
C10	20040421-11	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	3.12
C11	20040422-10	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	3.57
C12	20040422-11	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	3.19
C13	20040422-12	3	f_ext	halon 1301	low	spray/oil	benchmark	2.5	7.1	n/a	2.85
C14	20040427-10	3	f_ext	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	3.29
C15	20040427-11	3	f_ext	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	2.35
C16	20040428-10	3	f_ext	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	2.10
C17	20040428-11	3	f_ext	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	2.75
C18	20040429-12	3	a_dis	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	n/a
C19	20040429-13	3	a_dis	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	n/a
C20	20040429-14	3	a_dis	CF3I	low	spray/oil	inferior	12.5	7.1	n/a	n/a
C21	20040429-15	3	a_dis	CF3I	low	spray/oil	superior	13	7.1	n/a	n/a
C22	20040429-16	3	a_dis	CF3I	low	spray/oil	superior	13	7.1	n/a	n/a
C23	20040429-17	3	a_dis	CF3I	low	spray/oil	superior	13	7.1	n/a	n/a

EVC = equivalent volume concentration, resulting from MPSHRe/rev03 procedure
HSRVC = half-second resident volume concentration
a_dis = firex agent distribution test, to measure concentration field
f_ext = fire extinguishment test, to measure reignition time delay

Appendix/ CF_3I test results, table of basic individual test results

Grouping	FAA Test Identification	MPSHRe Revision	Test Type	Firex Agent	Ventilation	Fire Threat	MPSHRe bracket type	Injected Weight [lbf]	EVC [%v/v CF3I]	HSRVC [%v/v CF3I]	RTD [sec]
D01	20060830-14	3	f_ext	halon 1301	low	spray/turbine fuel	benchmark	2.5	n/a	n/a	3.57
D02	20060831-10	3	f_ext	halon 1301	low	spray/turbine fuel	benchmark	2.5	n/a	n/a	3.64
D03	20060831-11	3	f_ext	halon 1301	low	spray/turbine fuel	benchmark	2.5	n/a	n/a	3.80
D04	20060831-12	3	f_ext	halon 1301	low	spray/turbine fuel	benchmark	2.5	n/a	n/a	3.27
D05	20060831-13	3	f_ext	halon 1301	low	spray/turbine fuel	benchmark	2.5	n/a	n/a	4.10
D06	20060905-11	3	f_ext	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	3.33
D07	20060905-12	3	f_ext	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	3.33
D08	20060906-11	3	f_ext	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	3.32
D09	20060906-12	3	f_ext	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	3.50
D10	20060906-13	3	f_ext	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	2.63
D11	20060906-14	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	4.20
D12	20060907-11	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	4.34
D13	20060907-12	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	3.04
D14	20060907-14	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	2.67
D15	20060907-15	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	3.87
D16	20060908-11	3	f_ext	CF3I	low	spray/turbine fuel	superior	13.5	4.9	n/a	1.84
D17	20060908-12	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	2.51
D18	20060912-11	3	f_ext	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	2.87
D19	20060913-15	3	a_dis	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	n/a
D20	20060913-16	3	a_dis	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	n/a
D21	20060913-17	3	a_dis	CF3I	low	spray/turbine fuel	superior	14.5	4.9	n/a	n/a
D22	20060913-18	3	a_dis	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	n/a
D23	20060914-12	3	a_dis	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	n/a
D24	20060914-13	3	a_dis	CF3I	low	spray/turbine fuel	inferior	13	4.9	n/a	n/a

EVC = equivalent volume concentration, resulting from MPSHRe/rev03 procedure
HSRVC = half-second resident volume concentration
a_dis = firex agent distribution test, to measure concentration field
f_ext = fire extinguishment test, to measure reignition time delay

Appendix/ CF_3I test results, table of basic individual test results

Grouping	FAA Test Identification	MPSHRe Revision	Test Type	Firex Agent	Ventilation	Fire Threat	MPSHRe bracket type	Injected Weight [lbf]	EVC [%v/v CF3I]	HSRVC [%v/v CF3I]	RTD [sec]
E01	20040622-11	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.34
E02	20040622-12	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	4.77
E03	20040623-10	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	4.87
E04	20040623-11	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.77
E05	20040623-12	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	7.23
E06	20040714-10	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.12
E07	20040714-11	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	4.74
E08	20040714-12	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.24
E09	20040715-10	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	4.23
E10	20040715-11	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.70
E11	20060620-11	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.89
E12	20060620-12	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.81
E13	20060620-13	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	6.27
E14	20060621-11	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.74
E15	20060621-12	4	f_ext	halon 1301	low	pool/turbine fuel	benchmark	2.5	n/a	n/a	5.55

EVC = equivalent volume concentration, resulting from MPSHRe/rev03 procedure
HSRVC = half-second resident volume concentration
a_dis = firex agent distribution test, to measure concentration field
f_ext = fire extinguishment test, to measure reignition time delay

Appendix/ CF_3I test results, table of basic individual test results

Grouping	FAA Test Identification	MPSHRe Revision	Test Type	Firex Agent	Ventilation	Fire Threat	MPSHRe bracket type	Injected Weight [lbf]	EVC [%v/v CF3I]	HSRVC [%v/v CF3I]	RTD [sec]
E16	20191002-03	4	a_dis	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	7.5	n/a
E17	20191003-07	4	a_dis	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	6.8	n/a
E18	20191004-03	4	a_dis	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	5.9	n/a
E19	20191106-04	4	a_dis	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	6.3	n/a
E20	20191114-03	4	f_ext	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	n/a	4.87
E21	20191115-03	4	f_ext	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	n/a	5.67
E22	20191119-03	4	f_ext	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	n/a	5.08
E23	20191120-03	4	f_ext	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	n/a	5.50
E24	20191120-05	4	f_ext	CF3I	low	pool/turbine fuel	inferior	3.1	n/a	n/a	5.53
E25	20211105-03	4	a_dis	CF3I	low	pool/turbine fuel	superior	3.6	n/a	6.8	n/a
E26	20211208-05	4	a_dis	CF3I	low	pool/turbine fuel	superior	3.6	n/a	7.4	n/a
E27	20211209-03	4	a_dis	CF3I	low	pool/turbine fuel	superior	3.6	n/a	6.7	n/a
E28	20191121-03	4	f_ext	CF3I	low	pool/turbine fuel	superior	3.6	n/a	n/a	5.47
E29	20191203-04	4	f_ext	CF3I	low	pool/turbine fuel	superior	3.6	n/a	n/a	6.11
E30	20191204-03	4	f_ext	CF3I	low	pool/turbine fuel	superior	3.6	n/a	n/a	7.24
E31	20191205-03	4	f_ext	CF3I	low	pool/turbine fuel	superior	3.6	n/a	n/a	5.63
E32	20211214-06	4	f_ext	CF3I	low	pool/turbine fuel	superior	3.6	n/a	n/a	5.10

EVC = equivalent volume concentration, resulting from MPSHRe/rev03 procedure
HSRVC = half-second resident volume concentration
a_dis = firex agent distribution test, to measure concentration field
f_ext = fire extinguishment test, to measure reignition time delay

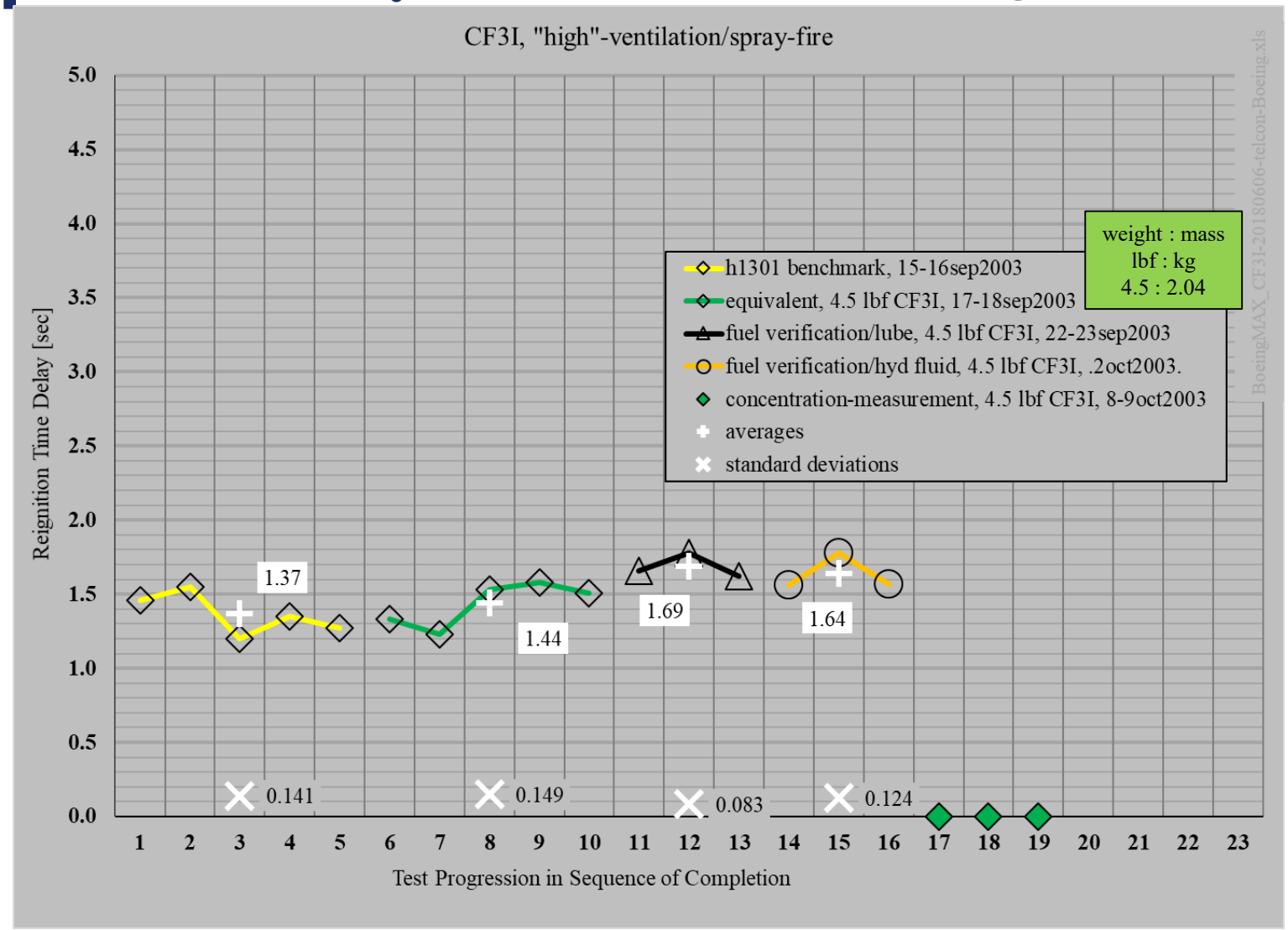
Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation

	high vent / spray fire				high-vent / pool fire		
firex agent	CF_3Br	CF_3I			CF_3Br	CF_3I	
dates of testing	15sep-2oct2003				9-30aug2006		
fuel	turbine	turbine	oil	hyd	turbine		
firex injection plumbing configuration	high-vent/cert	generic			high-vent/cert	generic	
injected weight [lbf]	3.6	equivalent 4.5			3.6	inferior 2.0	superior 3.5
RTD 01 [sec]	1.46	1.33	1.66	1.56	2.89	2.63	4.63
02	1.55	1.23	1.78	1.78	2.81	1.94	3.97
03	1.20	1.53	1.62	1.57	3.25	2.41	4.21
04	1.35	1.58	-	-	3.45	2.44	4.38
05	1.27	1.51	-	-	3.04	2.30	4.44
RTD, average	1.37	1.44	1.69	1.64	3.09	2.34	4.33
RTD, standard deviation	0.141	0.149	0.083	0.124	0.263	0.255	0.249
effective equivalent CF_3I volume concentration	5.6				2.7		
comments	none				ignored flame attachment in the fuel pan's wake region		

weight : mass
lbf : kg
3.6 : 1.63
4.5 : 2.04
2.0 : 0.907
3.5 : 1.59

halon 1301 = CF_3Br = bromotrifluoromethane
RTD = reignition time delay, the duration fire was suppressed

Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation



h1301 = halon 1301 = CF_3Br = bromotrifluoromethane
lube = lubricant [Mobil Jet Oil II]
hyd fluid = hydraulic fluid [Skydrol LD4]

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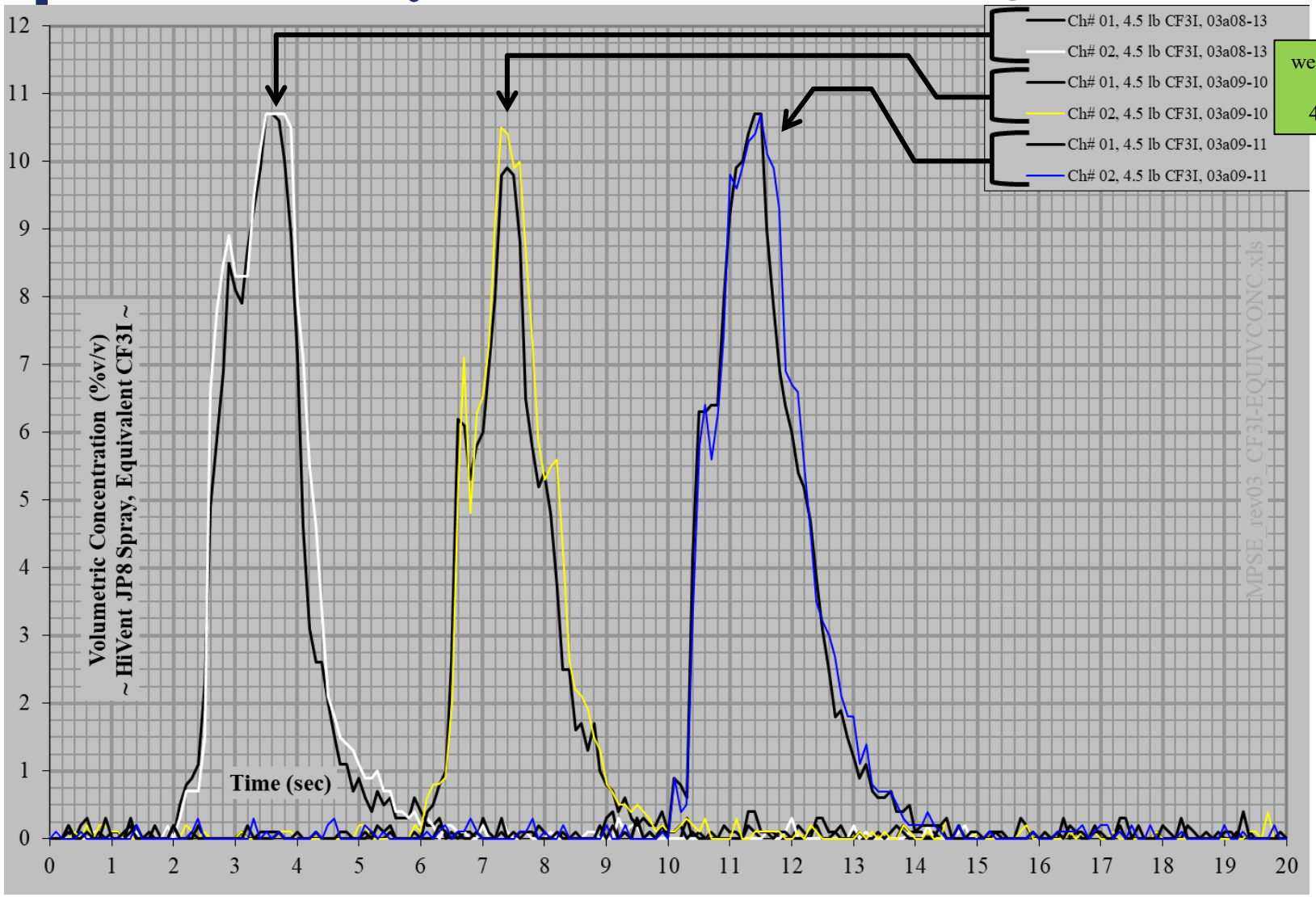
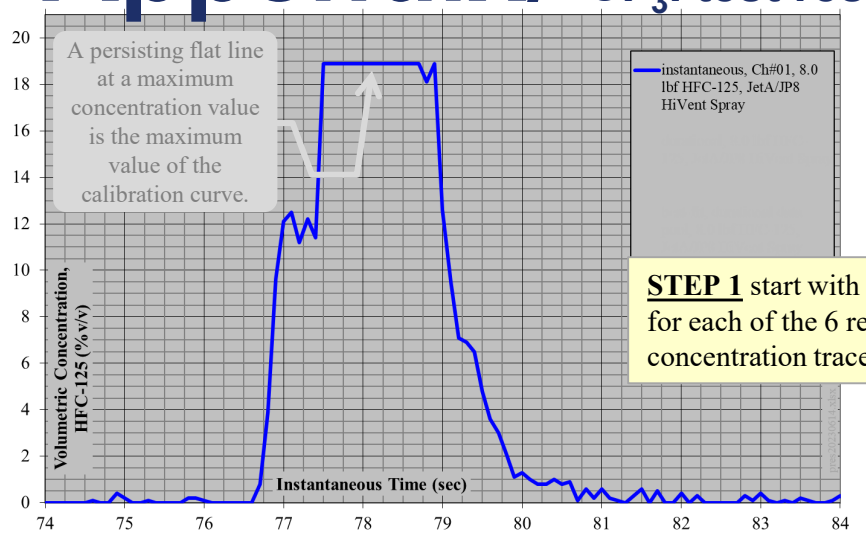
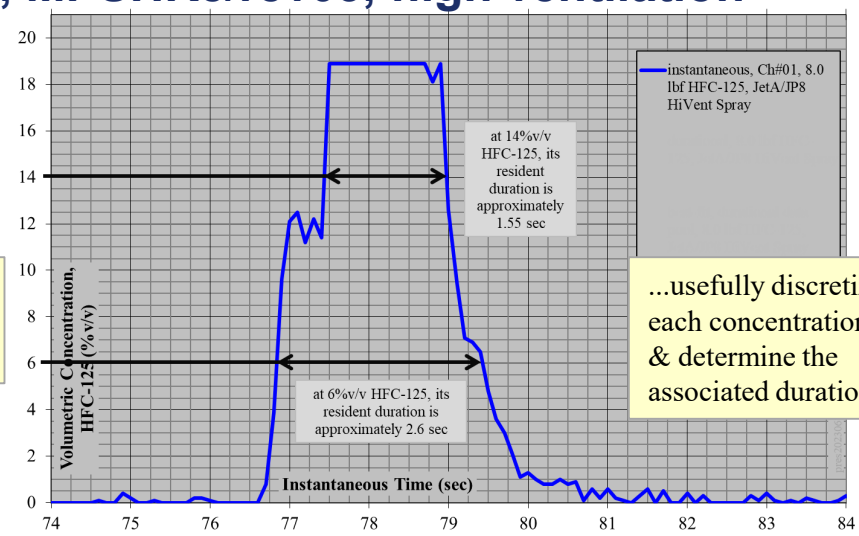
Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation



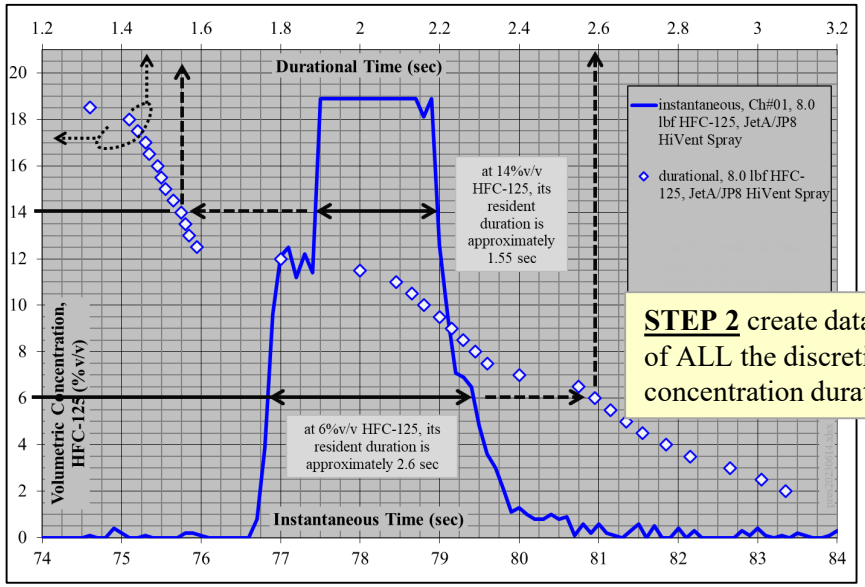
Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation



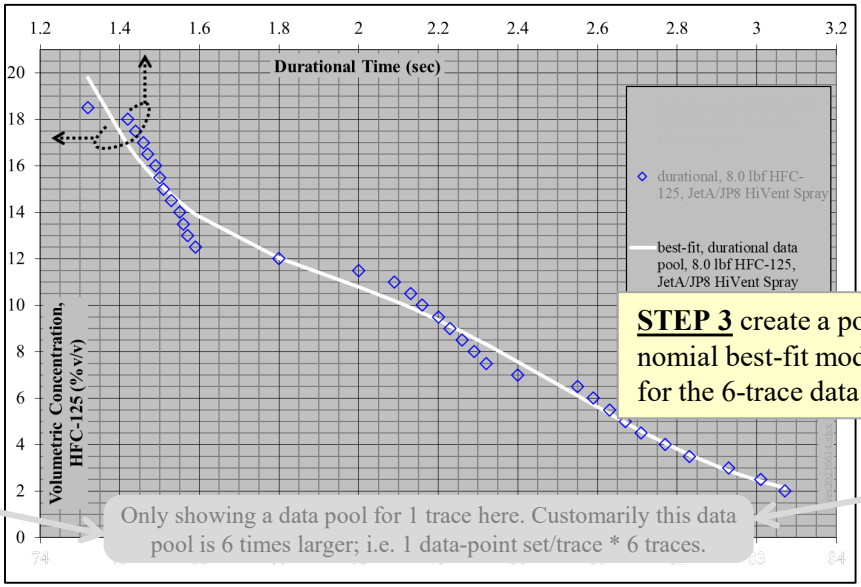
STEP 1 start with & do for each of the 6 related concentration traces...



...usefully discretize each concentration trace & determine the associated durations



STEP 2 create data pool of ALL the discretized concentration durations

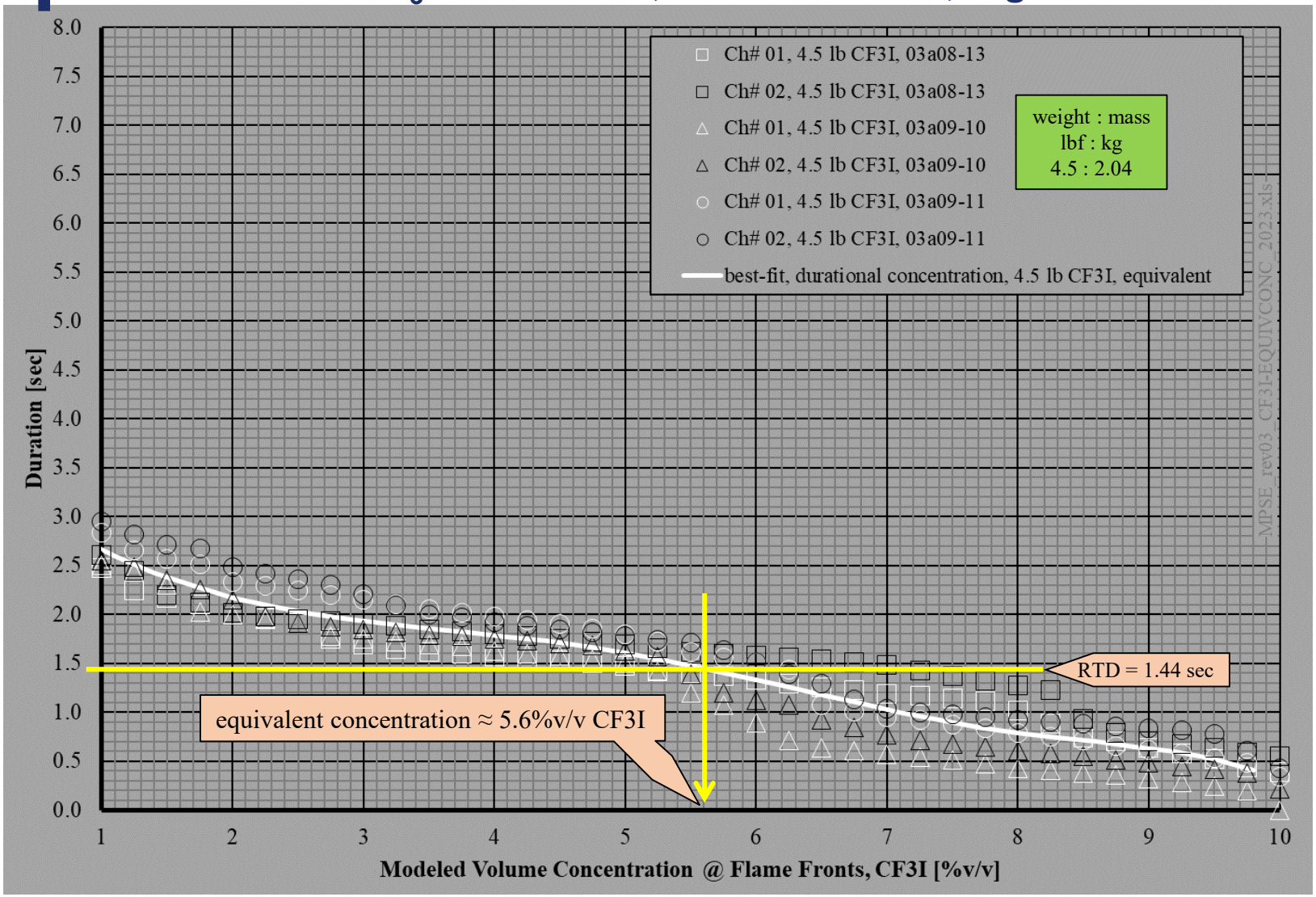


STEP 3 create a poly-nomial best-fit model for the 6-trace data pool

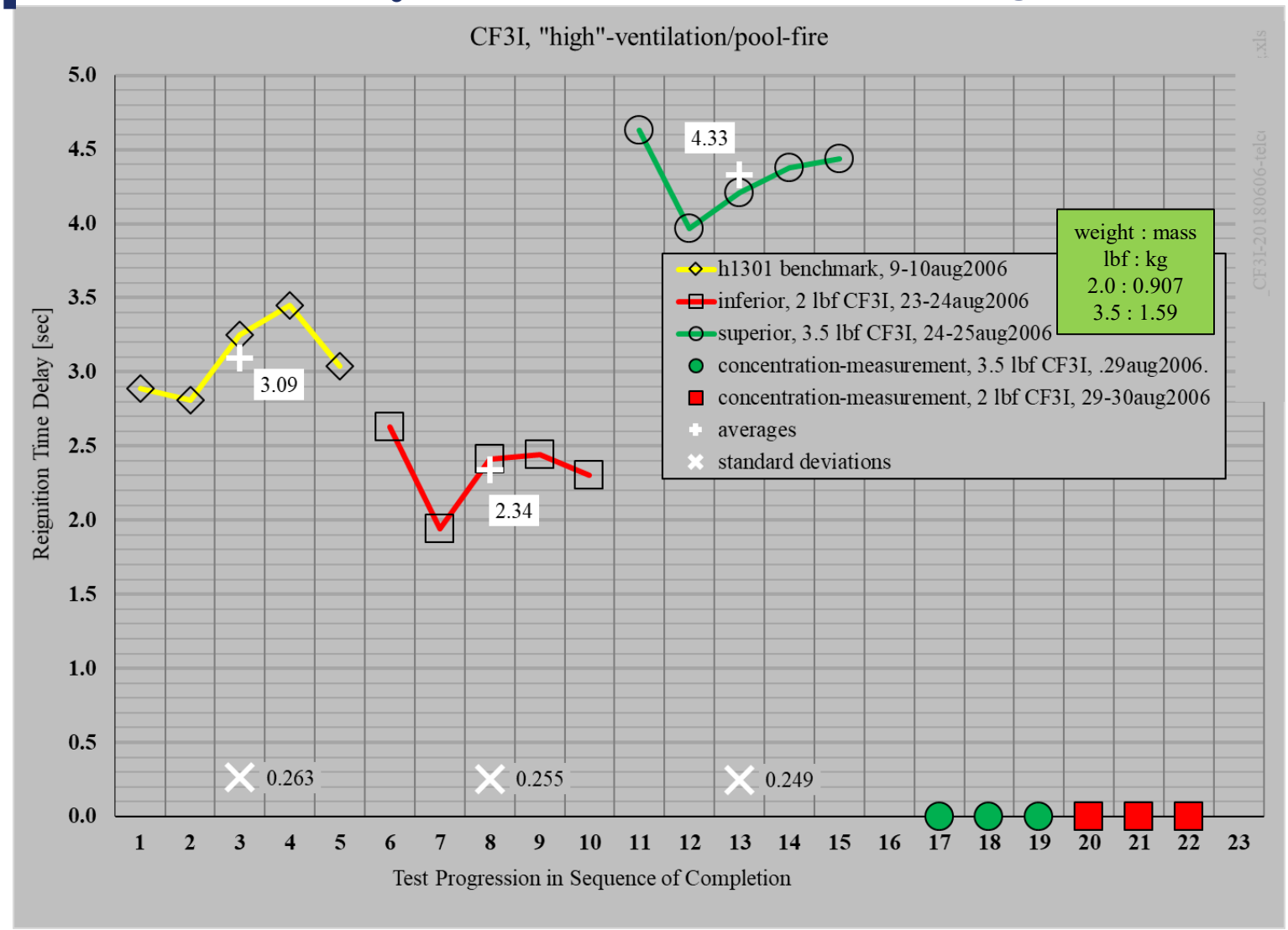
Only showing a data pool for 1 trace here. Customarily this data pool is 6 times larger; i.e. 1 data-point set/trace * 6 traces.

Notes : An arbitrarily-chosen, single concentration trace is used here to illustrate the concentration transformation process of MPSHRe/rev03. This procedure starts by transforming each of 6 concentration traces, 3 pairs resulting from 3 repeated tests, then representing them with a single best-fit polynomial equation. The transformed concentration behavior is then used with the associated fire suppression behavior [RTD] to determine an equivalent concentration.

Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation

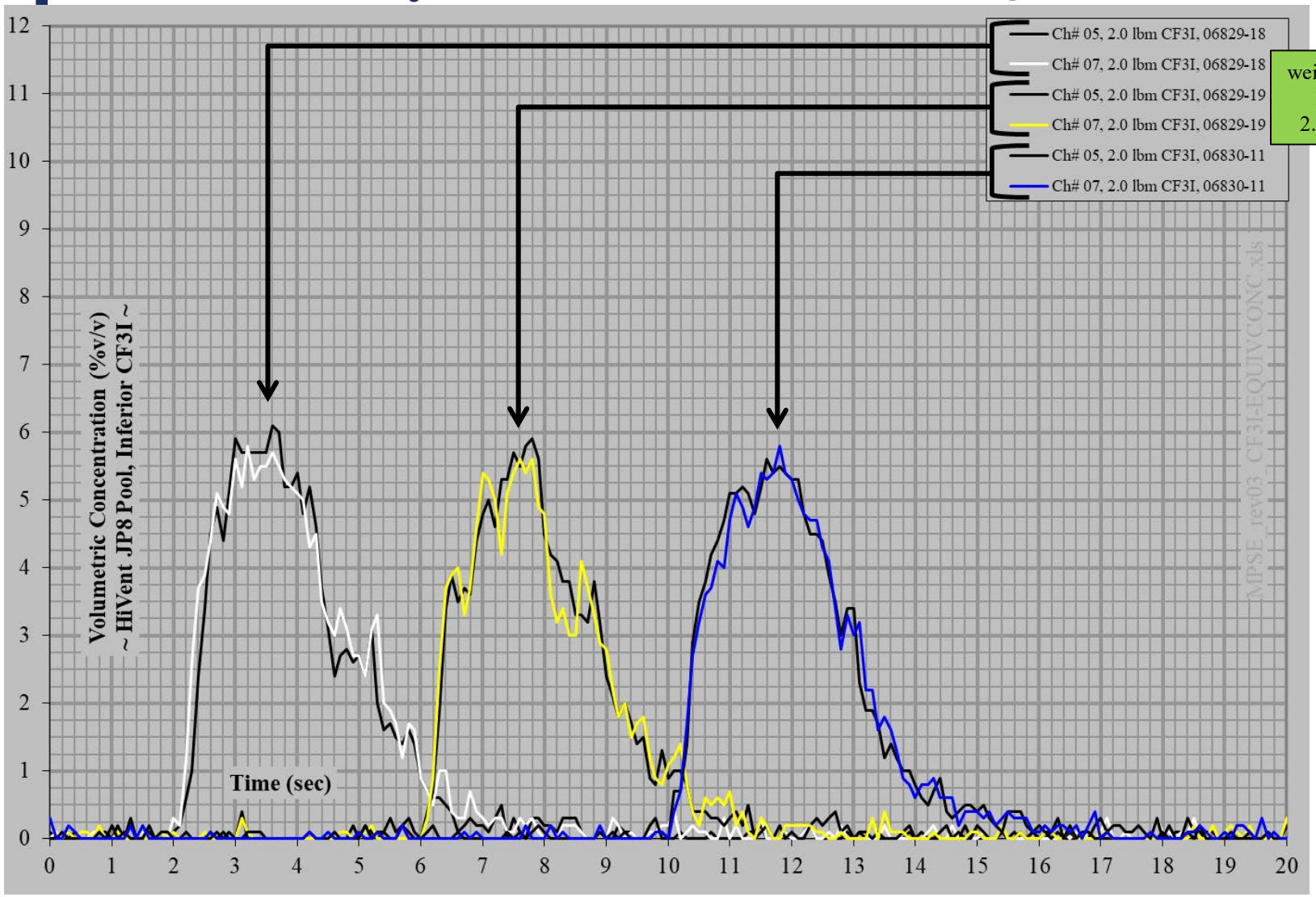


Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation

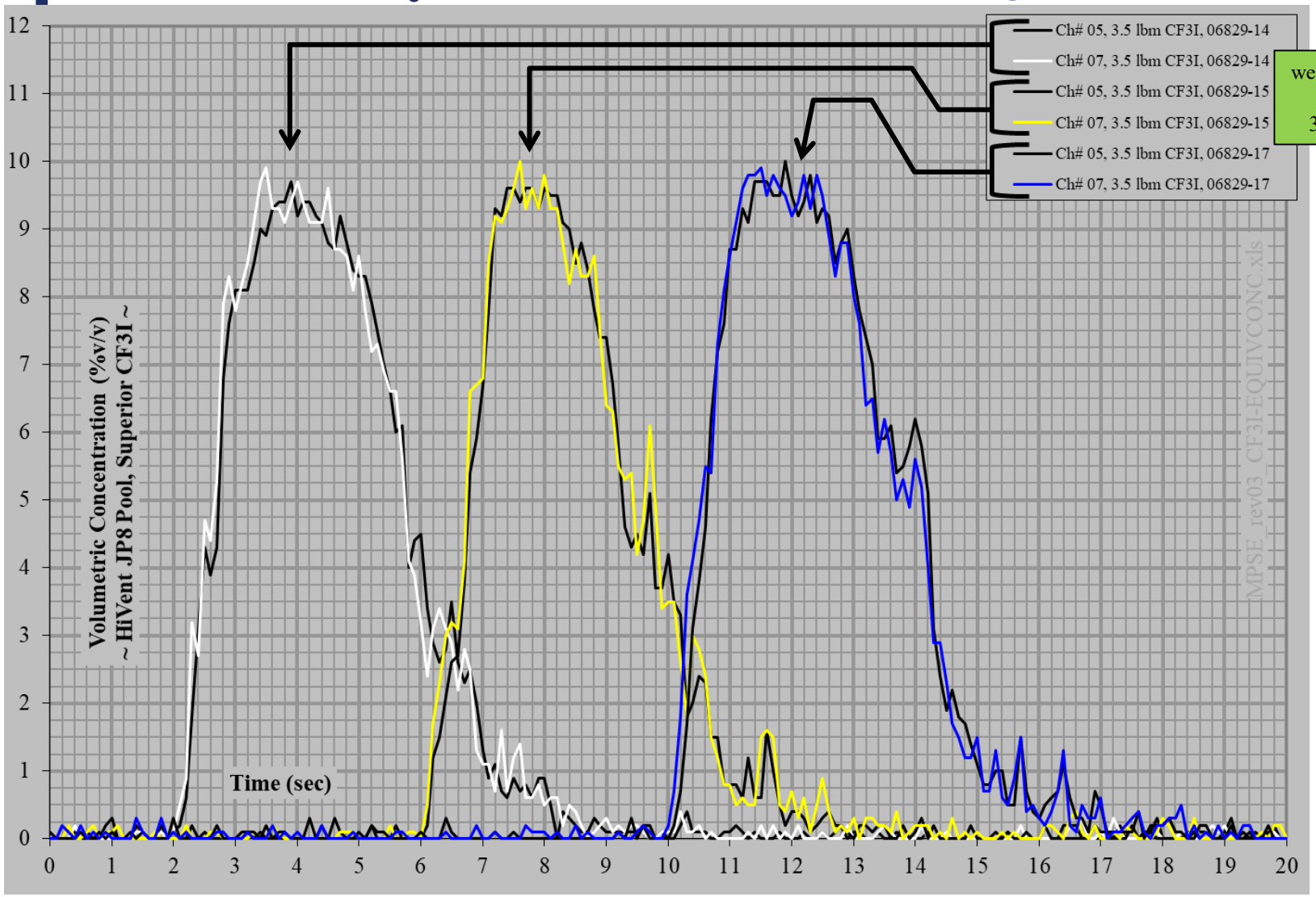


NOTE : During this testing flames remained present in the wake region of the fuel pan, outside of & downstream from the protected volume. Doubling the injected CF3I quantity did not eliminate them. Flames on the pan's fuel surface were completely extinguished.

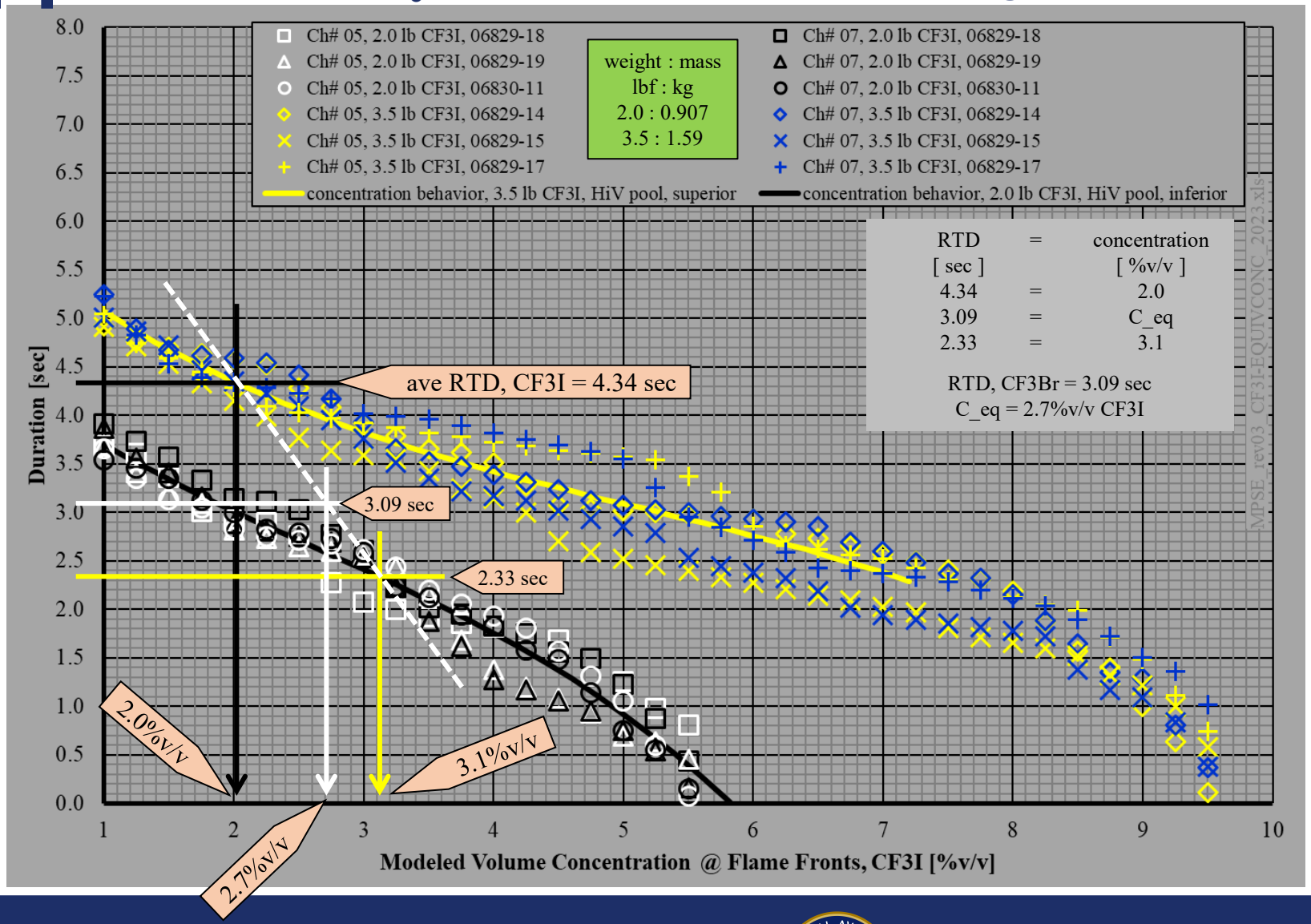
Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation



Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation



Appendix/ CF_3I test results, MPSHRe/rev03, high ventilation



NOTE : During this testing flames remained present in the wake region of the fuel pan, outside of & downstream from the protected volume. Doubling the injected CF3I quantity did not eliminate them. Flames on the pan's fuel surface were completely extinguished.

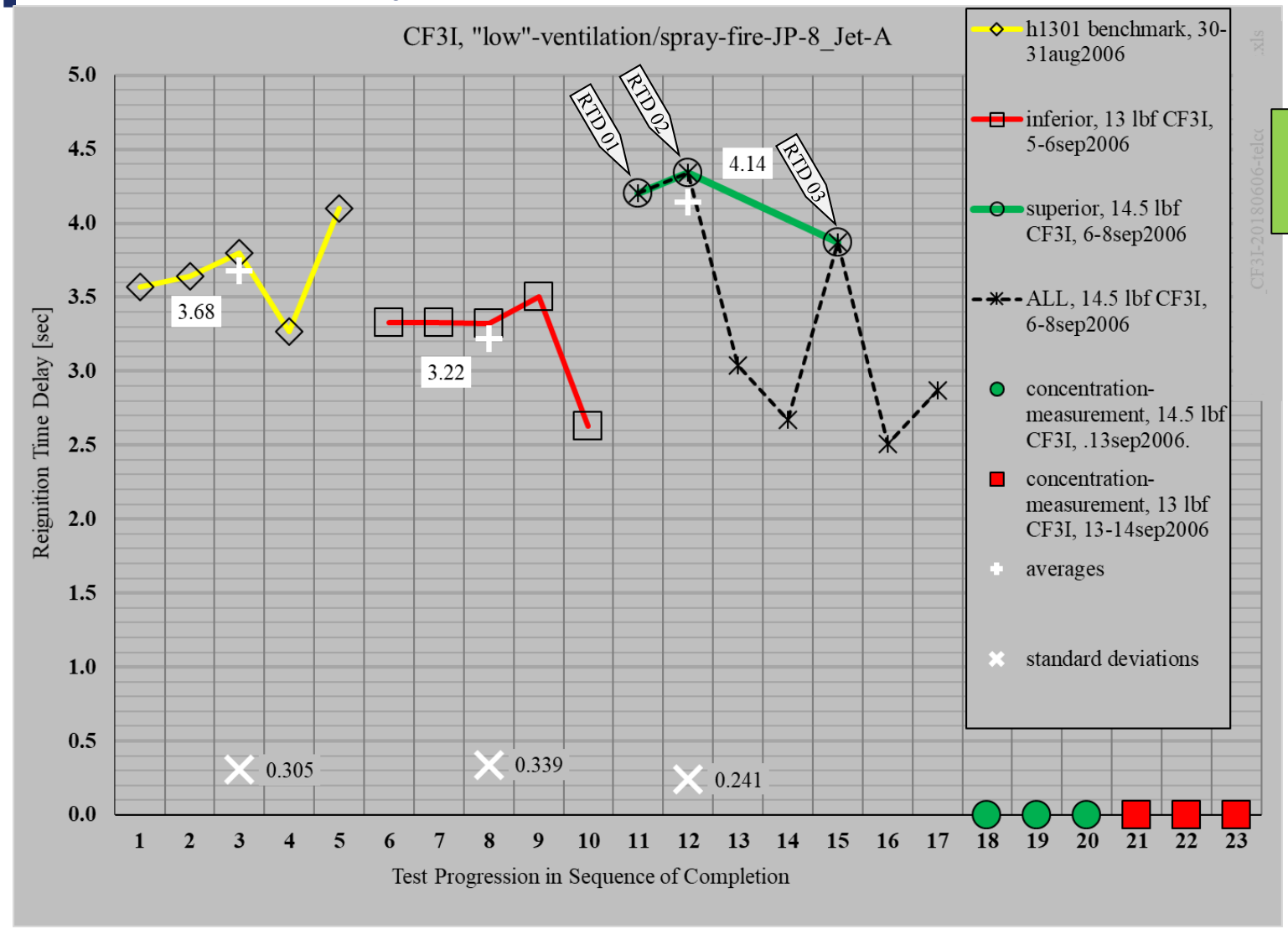
Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire

	low vent / spray fire						
firex agent	CF_3Br	CF_3I		CF_3Br	CF_3I	CF_3Br	CF_3I
dates of testing	30aug-14sep2006			23mar-29apr2004		21-29apr2004	
fuel	turbine fuel			oil [lubricant]			
firex injection plumbing configuration	low-vent/cert	generic		low-vent/cert	generic	low-vent/cert	generic
injected weight [lbf]	2.5	superior 14.5	inferior 13.0	2.5	superior 13.0	2.5	inferior 12.5
RTD 01 [sec]	3.57	4.20 *	3.33	1.47	3.14	1.57	3.29
02	3.64	4.34 *	3.33	2.15	3.24	3.12	2.35
03	3.80	3.04	3.32	1.80	3.17	3.57	2.10
04	3.27	2.67	3.50	2.12	-	3.19	2.75
05	4.10	3.87 *	2.63	1.62	-	2.85	-
06	-	2.51	-	-	-	-	-
07	-	2.87	-	-	-	-	-
RTD, average	3.68	3.86 *	3.22	1.83	3.18	2.86	2.62
RTD, standard deviation	0.305	0.241 *	0.339	0.300	0.051	0.766	0.529
effective equivalent CF_3I volume concentration	4.9			7.1			
comments	several atypical situations addressed during this collection of work						

weight : mass
lbf : kg
2.5 : 1.13
12.5 : 5.67
13.0 : 5.90
14.5 : 6.58

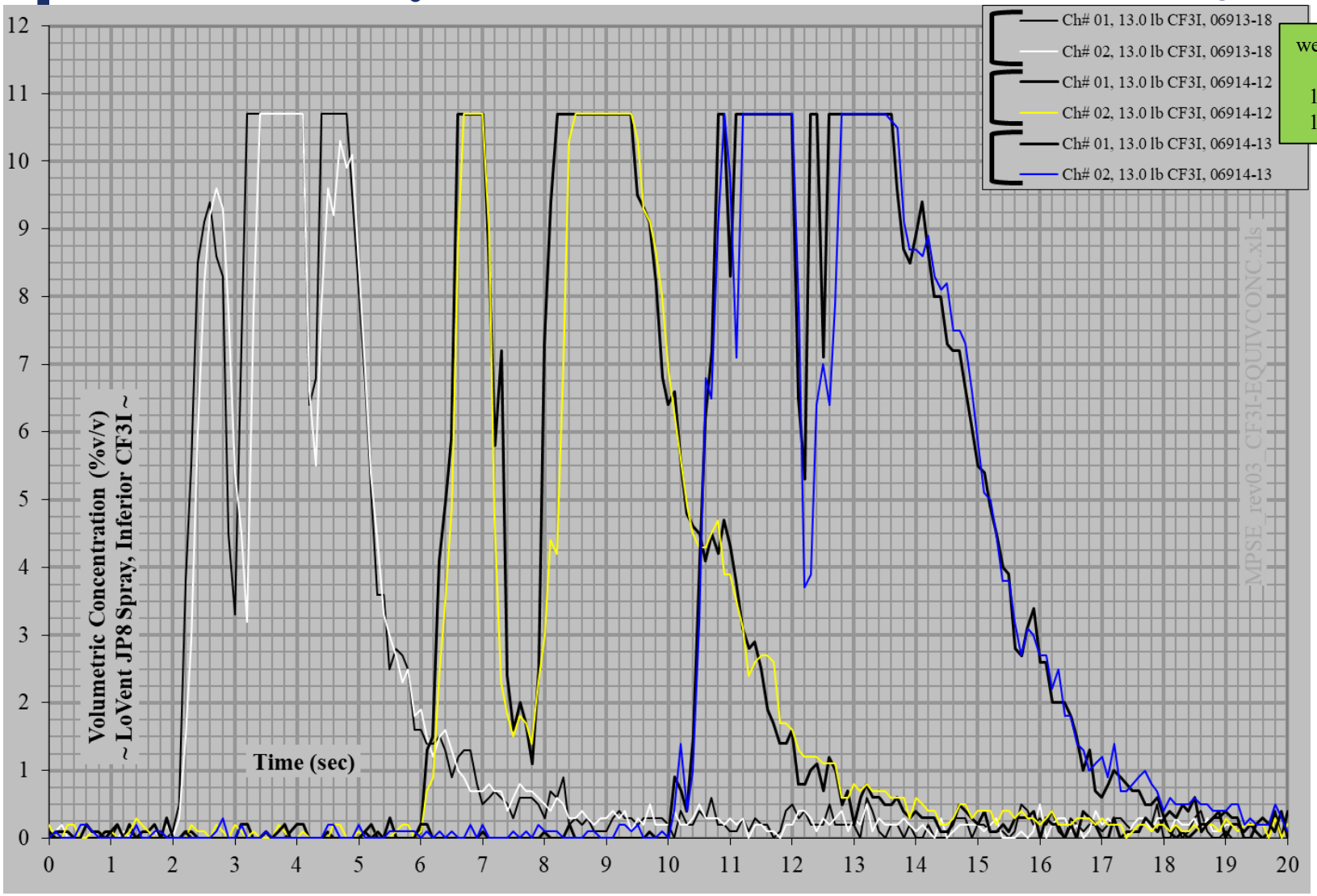
Note: The 3 asterisked [*] values were used to calculate the RTD average & standard deviation. Done so to create a conservative equivalent concentration given the observed scatter in the test results.

Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_trb

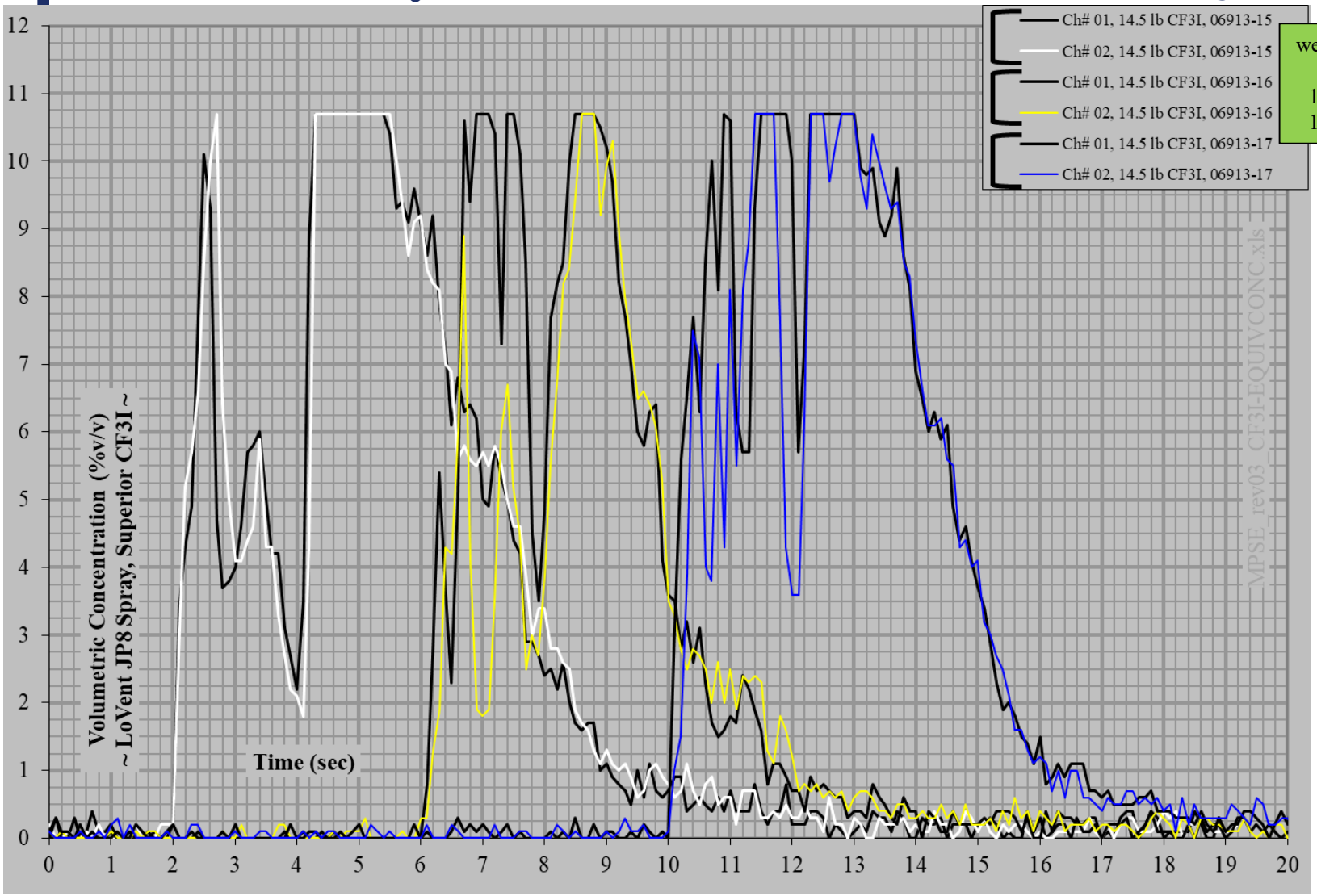


Note: The 3 values retained & used to calculate the RTD average & standard deviation are pointed out on this graph by arrows. Done so to create a plausible equivalent concentration given the observed scatter in the test results.

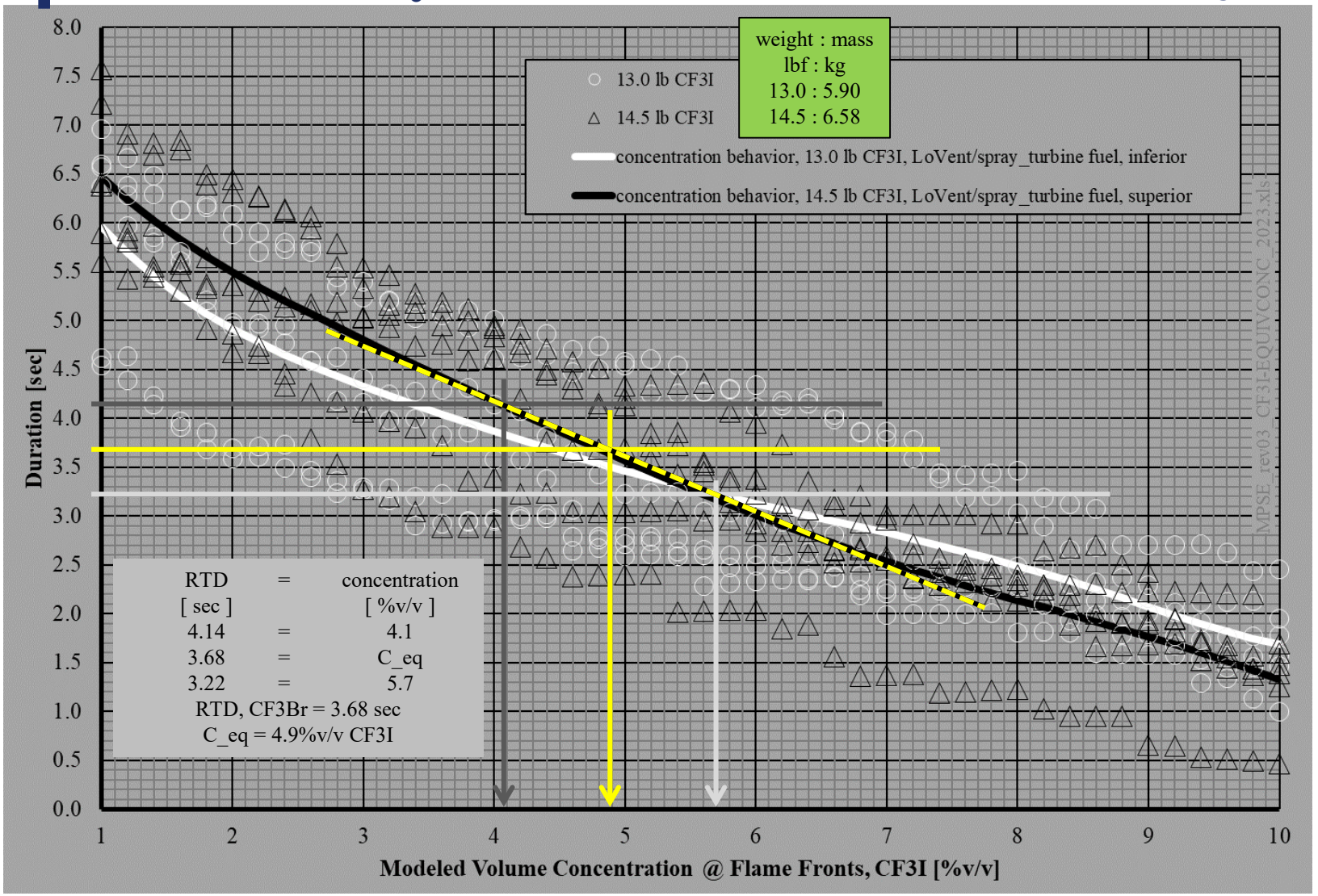
Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_trb



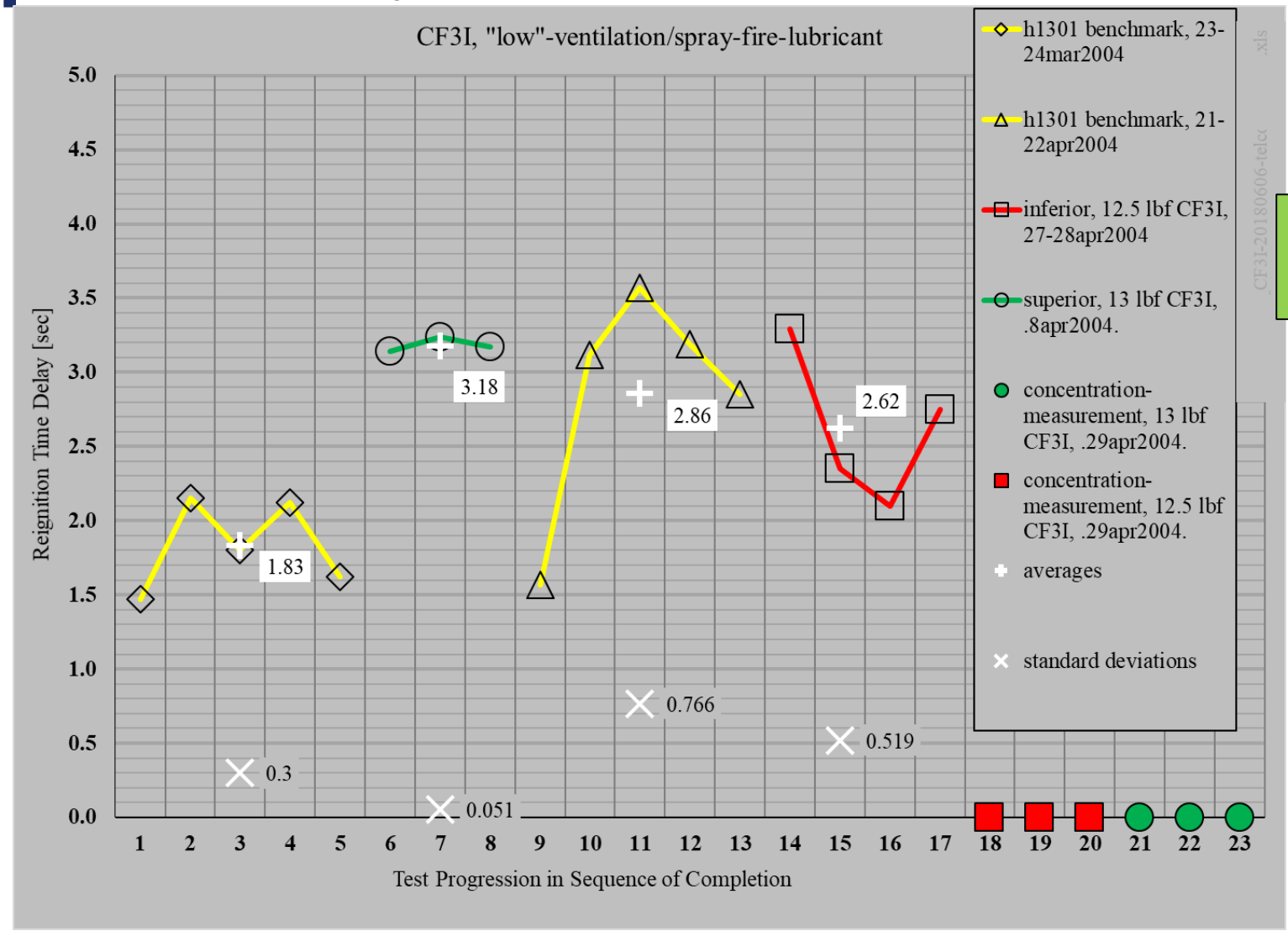
Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_trb



Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_trb

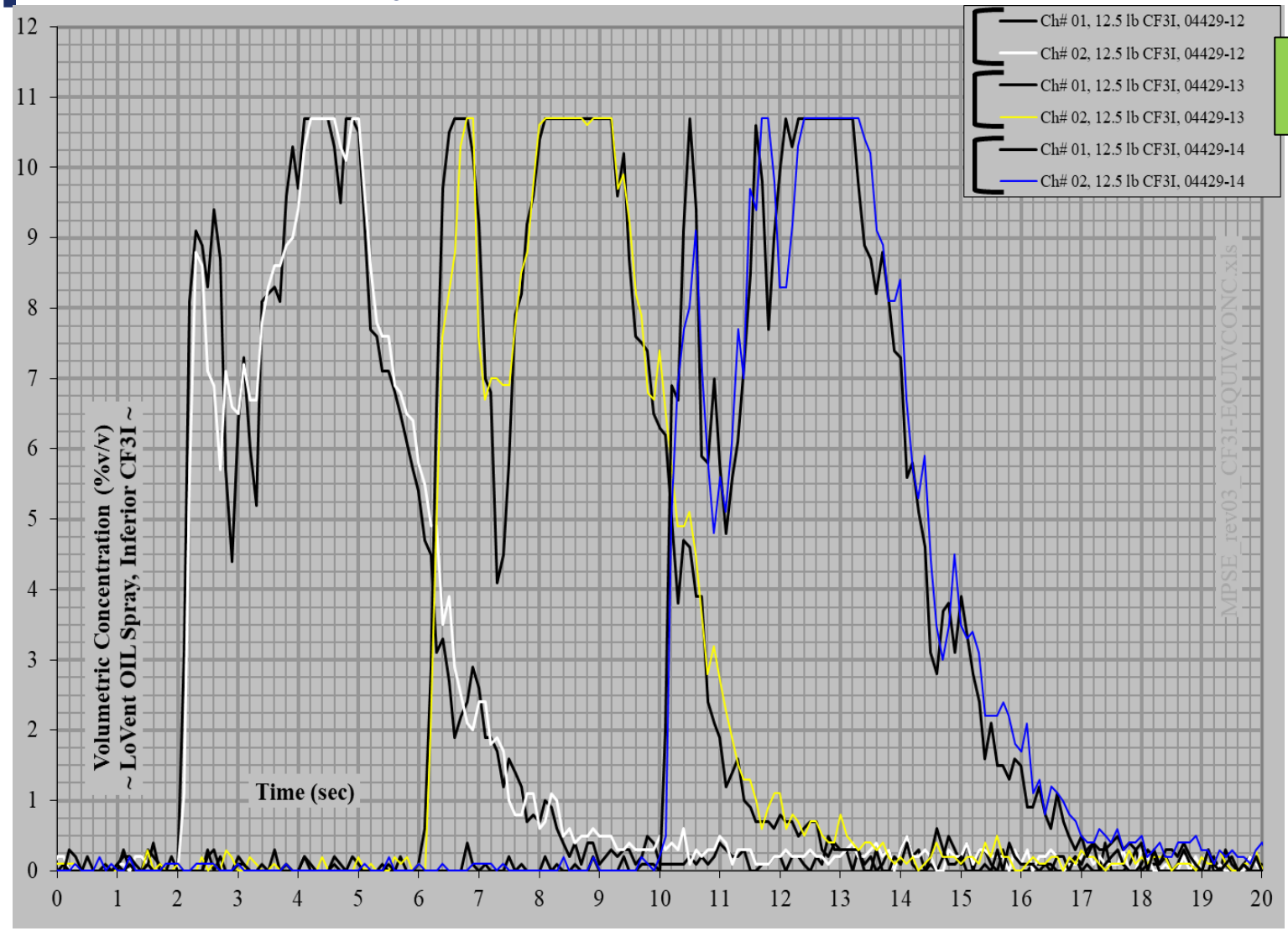


Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_oil

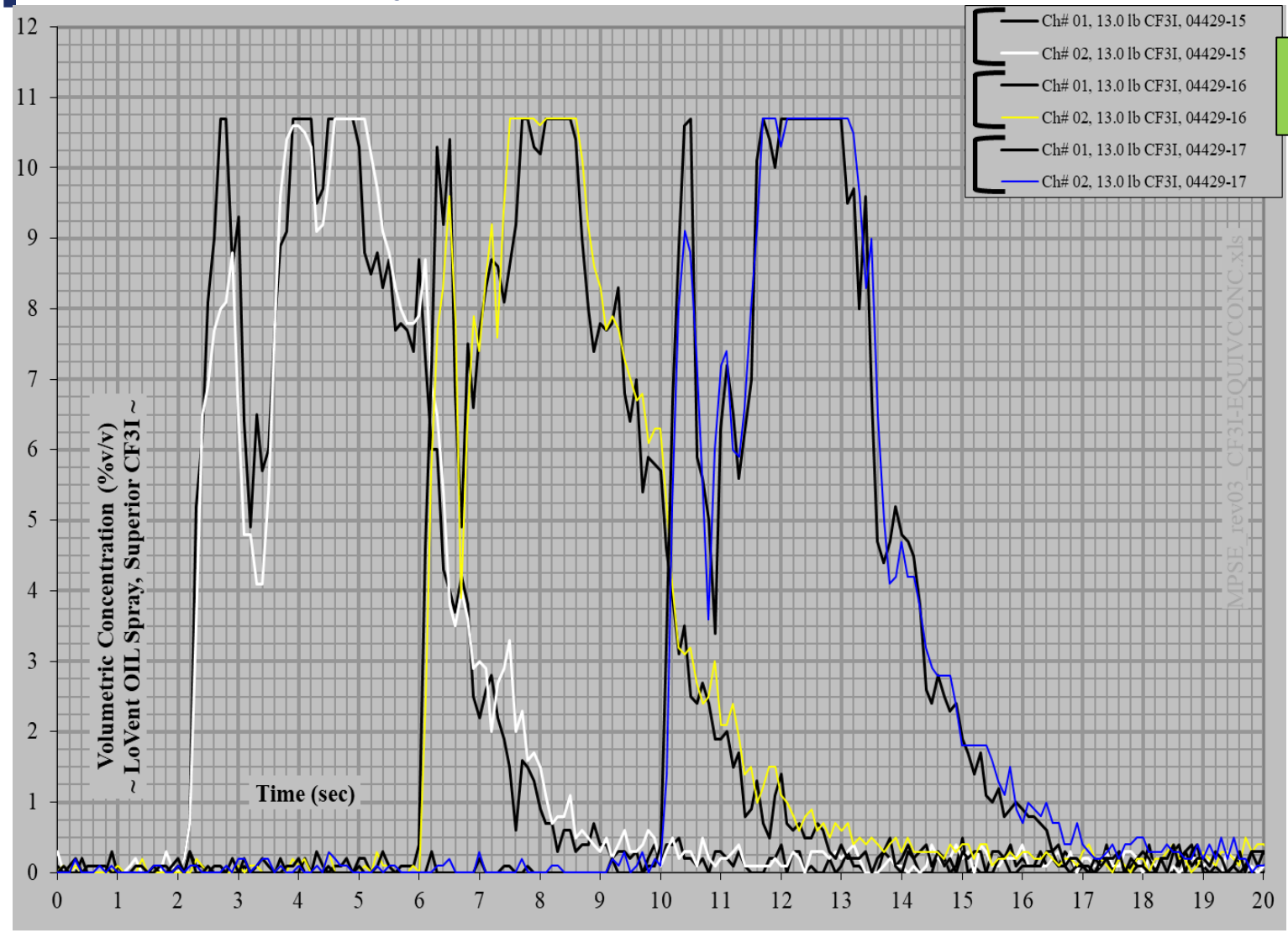


No obvious faulty equipment, faulty procedure[s] nor explanation found to explain the shift in the halon 1301 performance. Basis for the outcome regarding CF3I here utilized the second benchmark grouping due to it apparently fitting better to the CF3I behaviors.

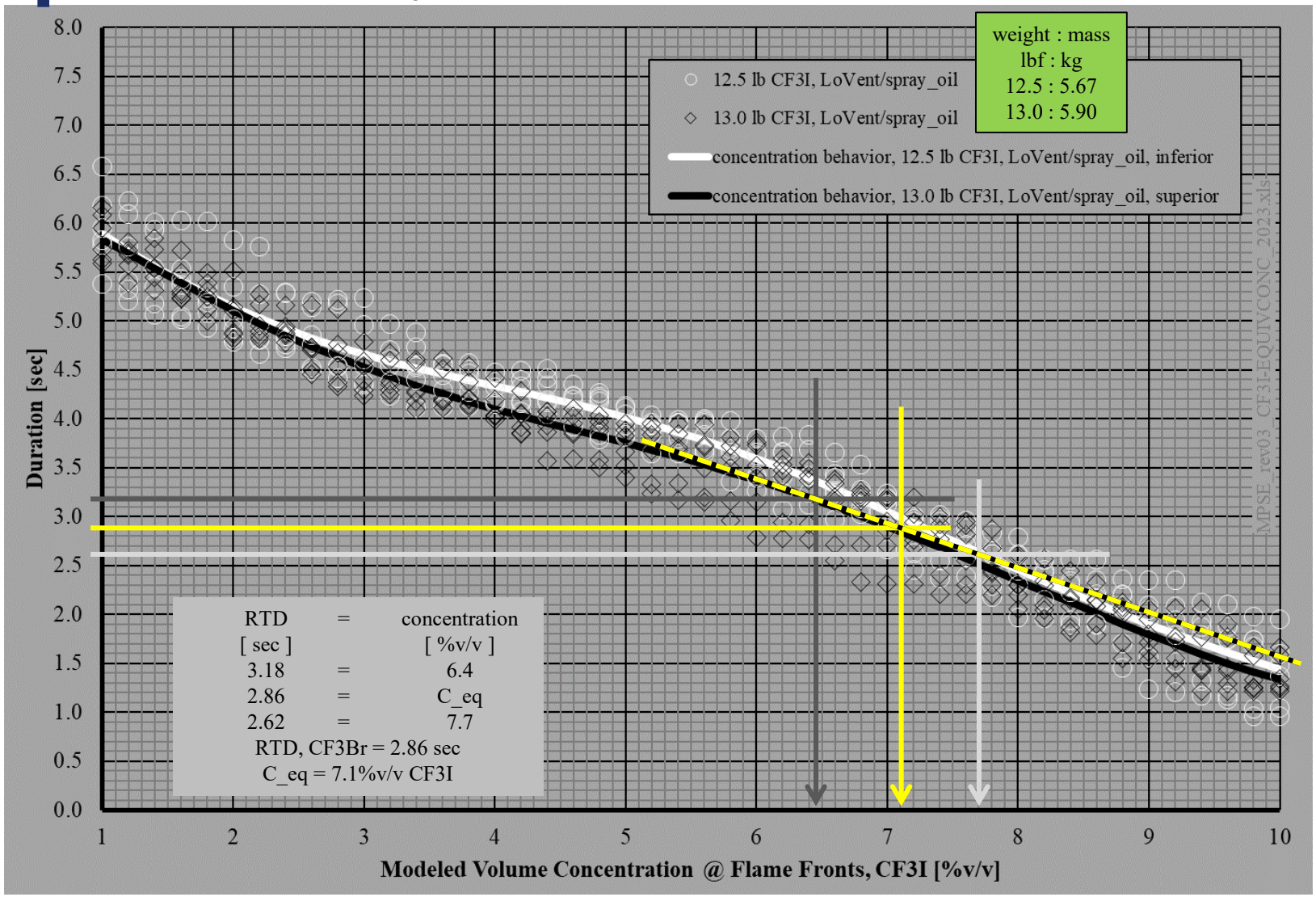
Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_oil



Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_oil



Appendix/ CF_3I test results, MPSHRe/rev03, low-vent/spray-fire_oil



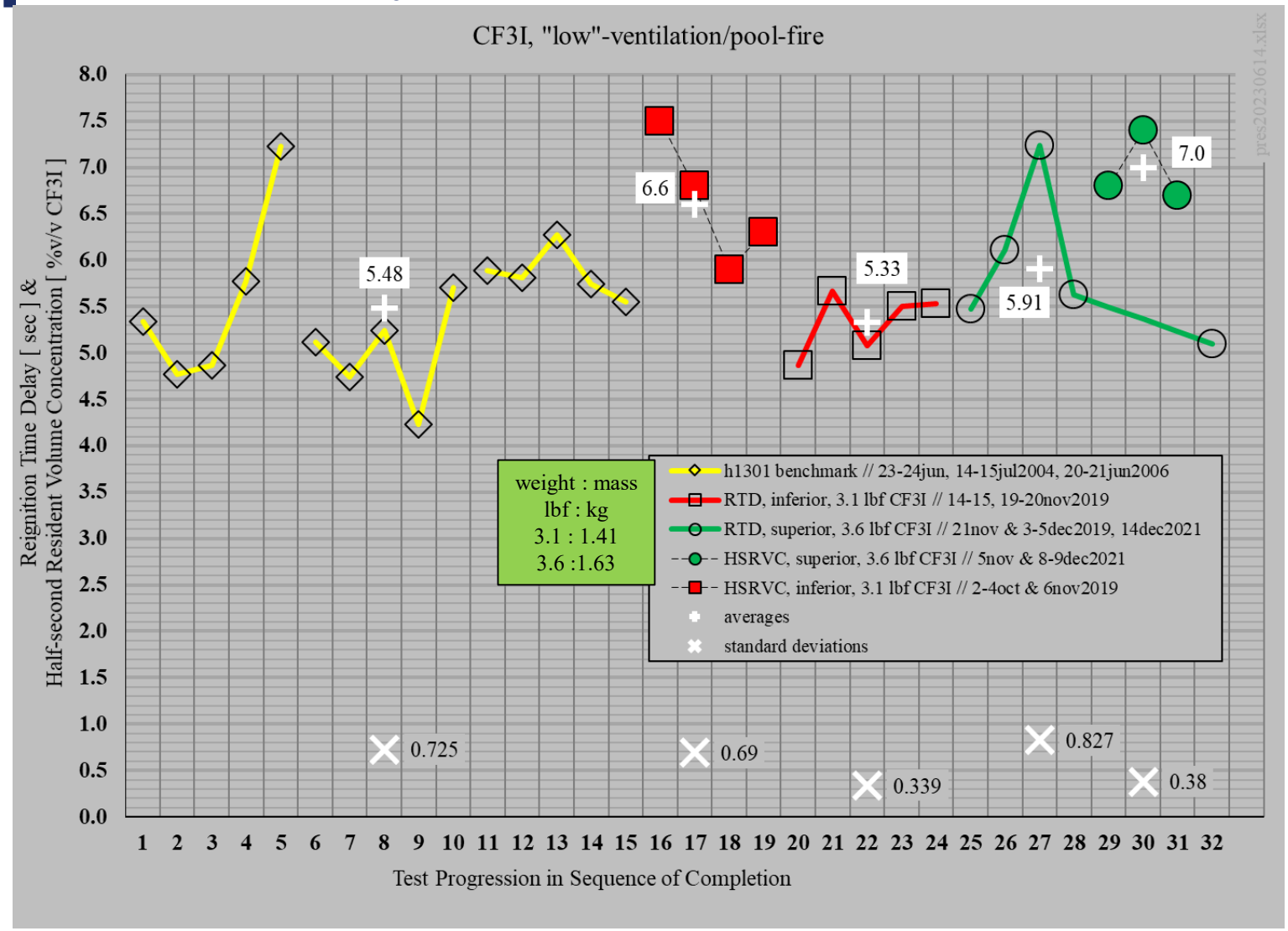
Appendix/ CF_3I test results, MPSHRe/rev04, low-vent/pool-fire

	low vent / pool fire		
firex agent	CF_3Br	CF_3I	
dates of testing	2004, 2006	2oct-5dec2019, 5nov-14dec2021	
fuel	turbine		
firex injection plumbing configuration	low-vent/cert	modified low-vent/cert	
injected weight [lbf]	2.5	3.1 [inferior]	3.6 [superior]
HSRVC 01 [%v/v]	n/a	7.5	6.8
02	n/a	6.8	7.4
03	n/a	5.9	6.7
04	n/a	6.3	none
average, HSRVC	n/a	6.6	7.0
standard deviation	n/a	0.69	0.38
RTD 01 [sec]	5.34[i], 5.12[ii], 5.89[iii]	4.87	5.47
02	4.77, 4.74, 5.81	5.67	6.11
03	4.87, 5.24, 6.27	5.08	7.24
04	5.77, 4.23, 5.74	5.50	5.63
05	7.23, 5.70, 5.55	5.53	5.10
average, RTD	5.48	5.33	5.91
standard deviation	0.725	0.339	0.827

weight : mass
lbf : kg
2.5 : 1.13
3.1 : 1.41
3.6 :1.63

HSRVC = half-second resident volume concentration
RTD = reignition time delay, the duration fire was suppressed
NOTE : The CF_3BR benchmark data shown in this table represent a collection of 15 tests, 5 each completed [i] 22-23jun2004, [ii] 14-15jul2004, & [iii] 20-21jun2006

Appendix/ CF_3I test results, MPSHRe/rev04, low-vent/pool-fire



NOTE : The CF_3BR benchmark data shown in this graph represent a collection of 15 tests, 5 each completed 22-23jun2004, 14-15jul2004, & 20-21jun2006

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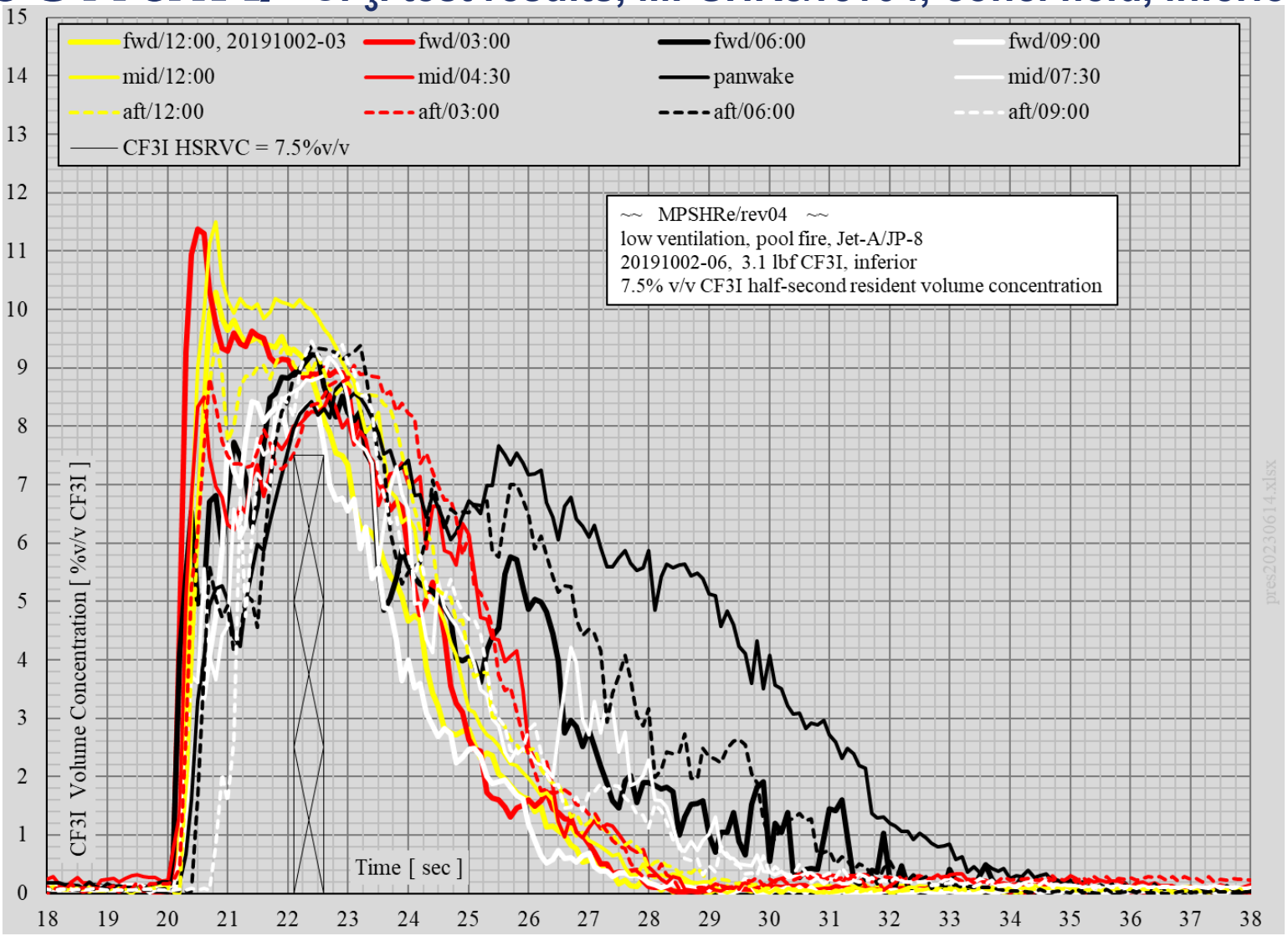
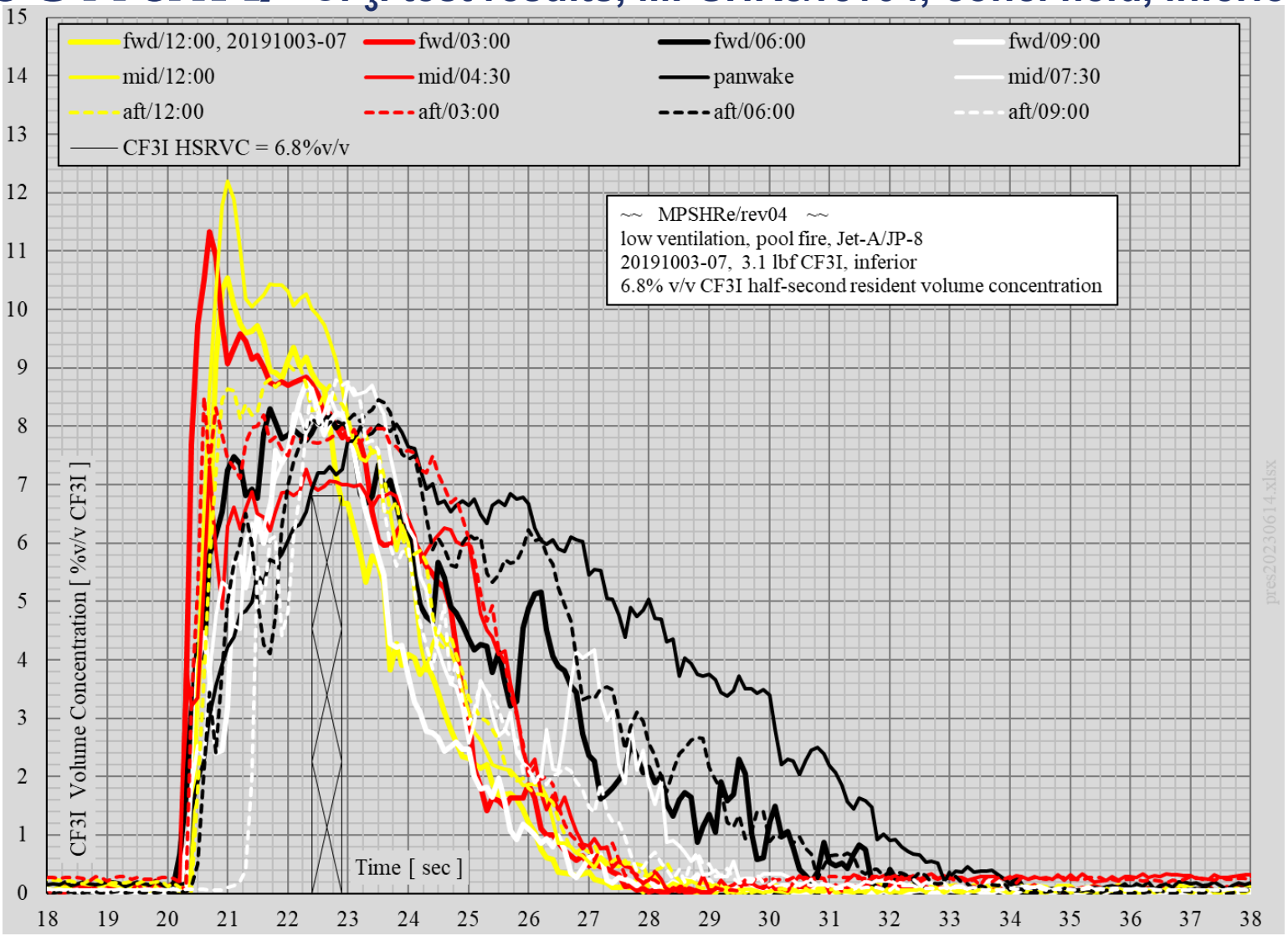
Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, inferior



Volume concentration data recorded & provided by Parker-Meggitt

Federal Aviation Administration

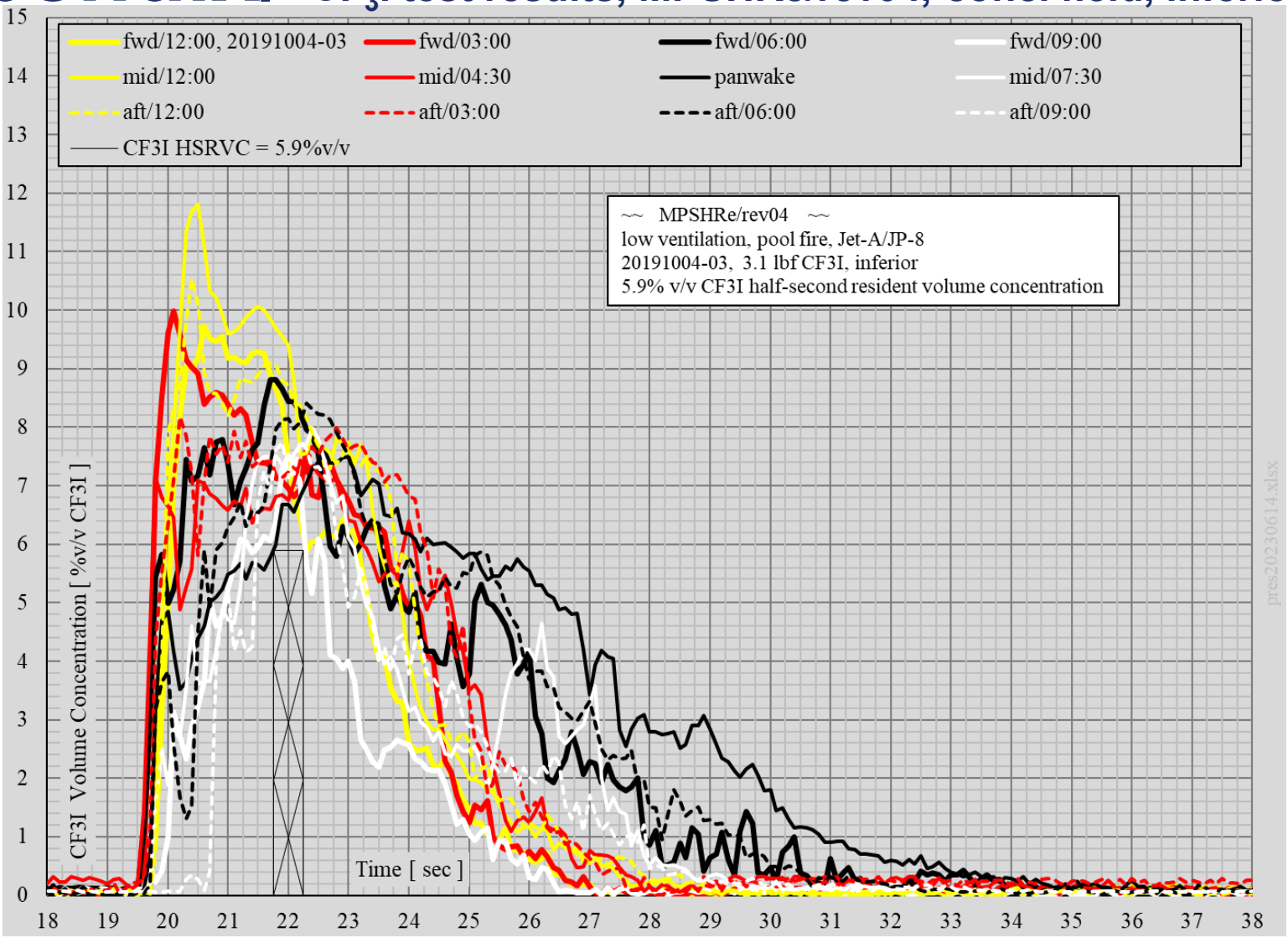
Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, inferior



Volume concentration data recorded & provided by Parker-Meggitt

Federal Aviation Administration

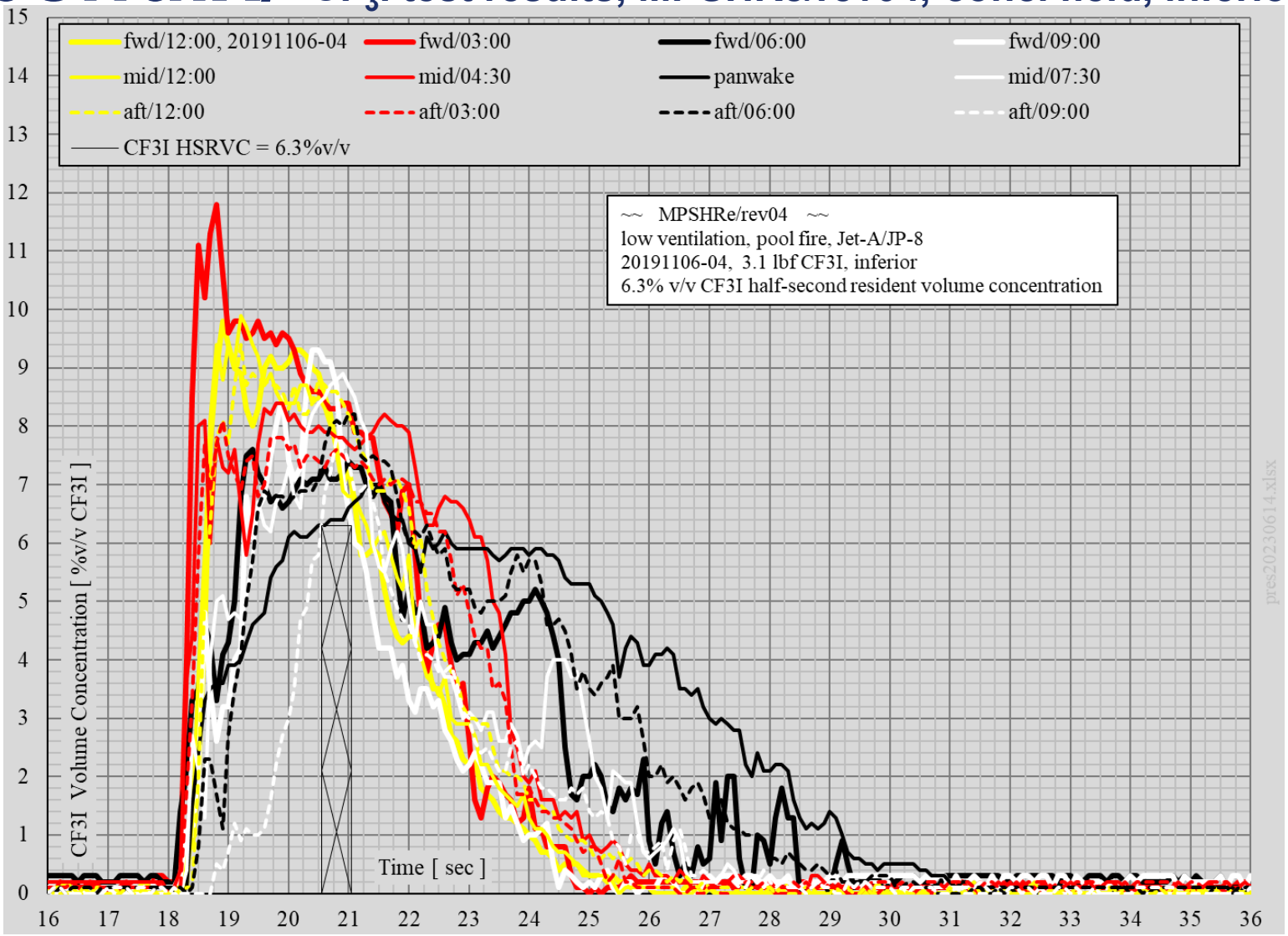
Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, inferior



Volume concentration data recorded & provided by Parker-Meggitt

Federal Aviation Administration

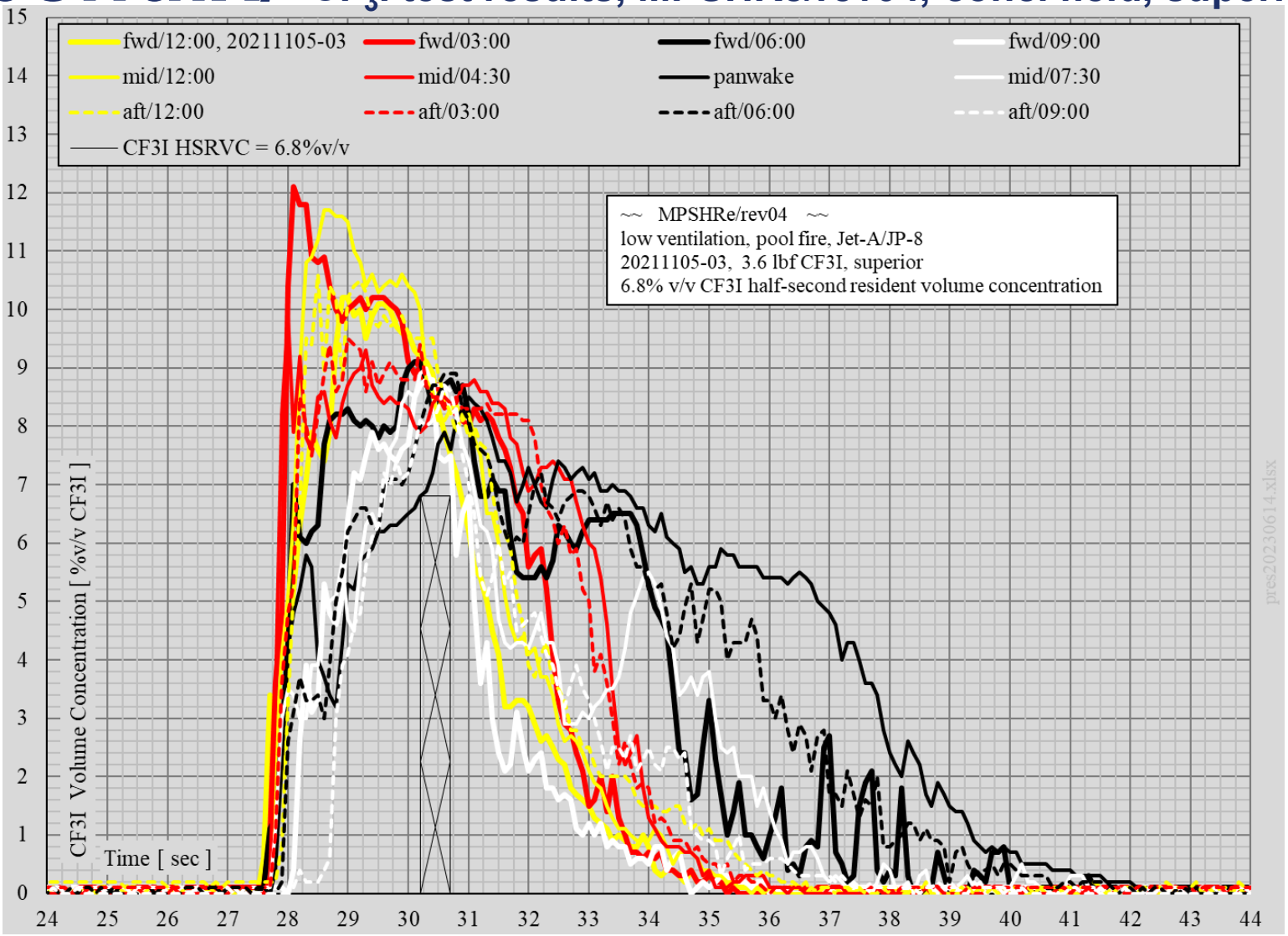
Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, inferior



Volume concentration data recorded & provided by Parker-Meggitt

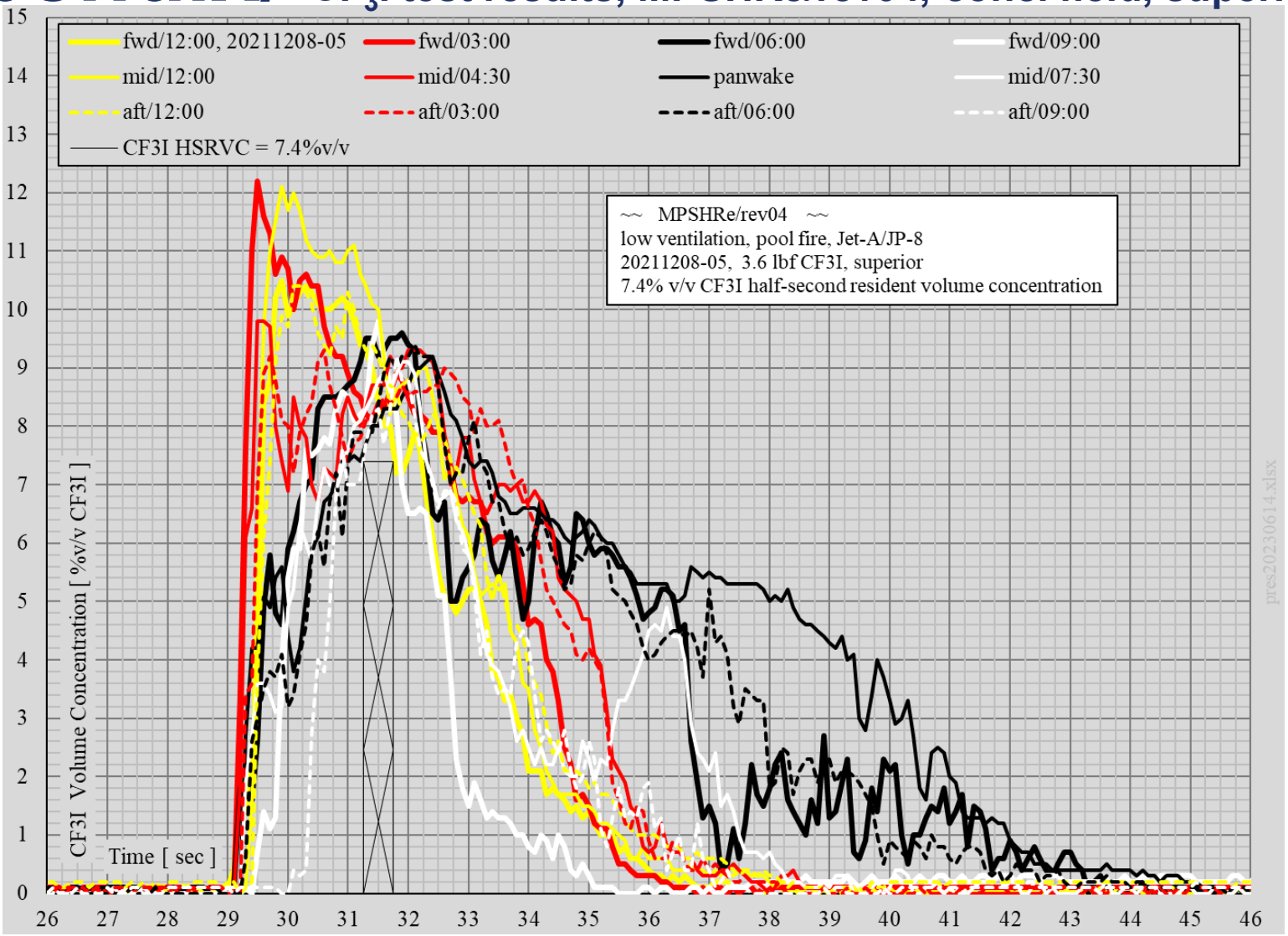
Federal Aviation Administration

Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, superior



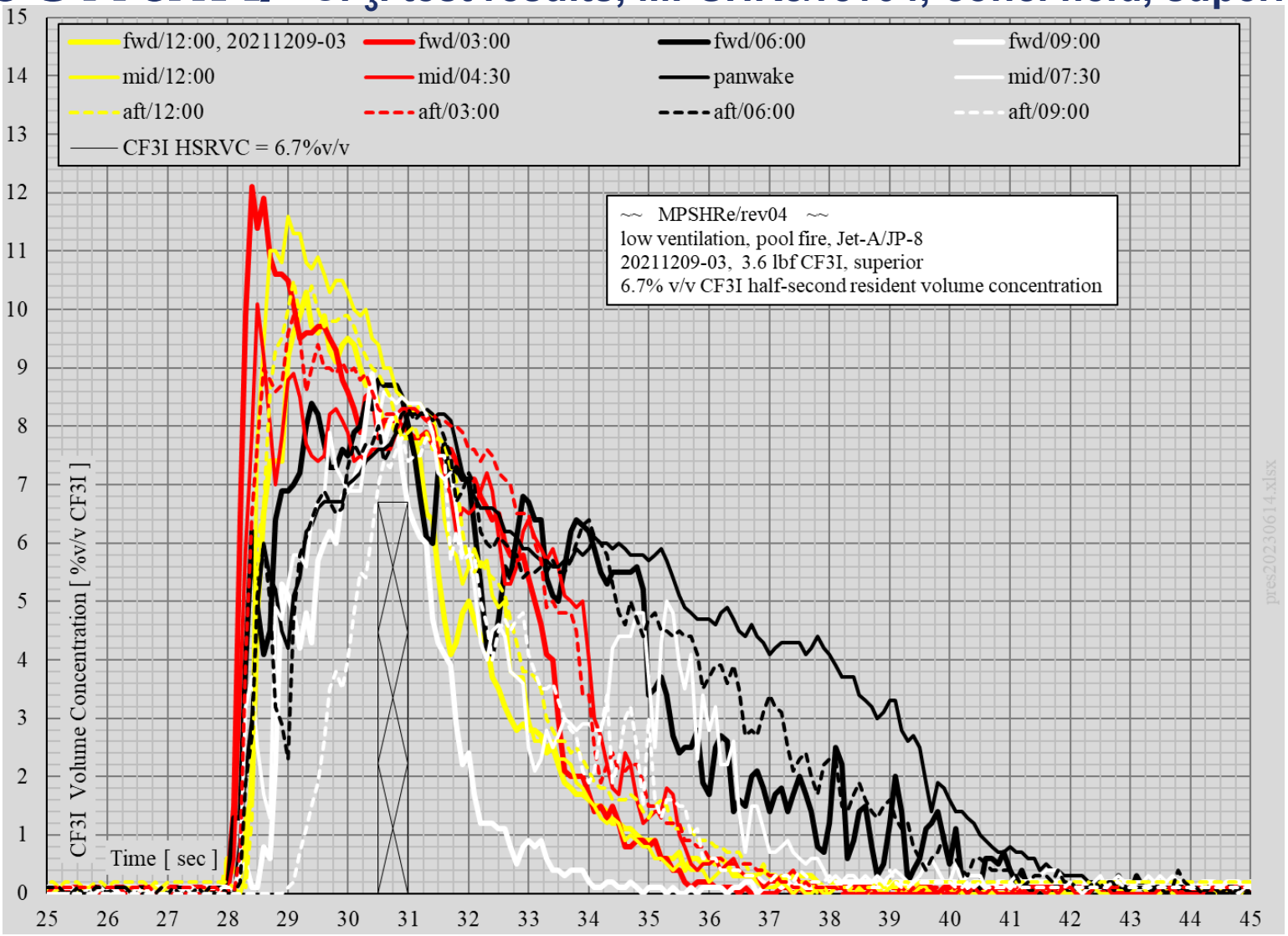
Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, superior



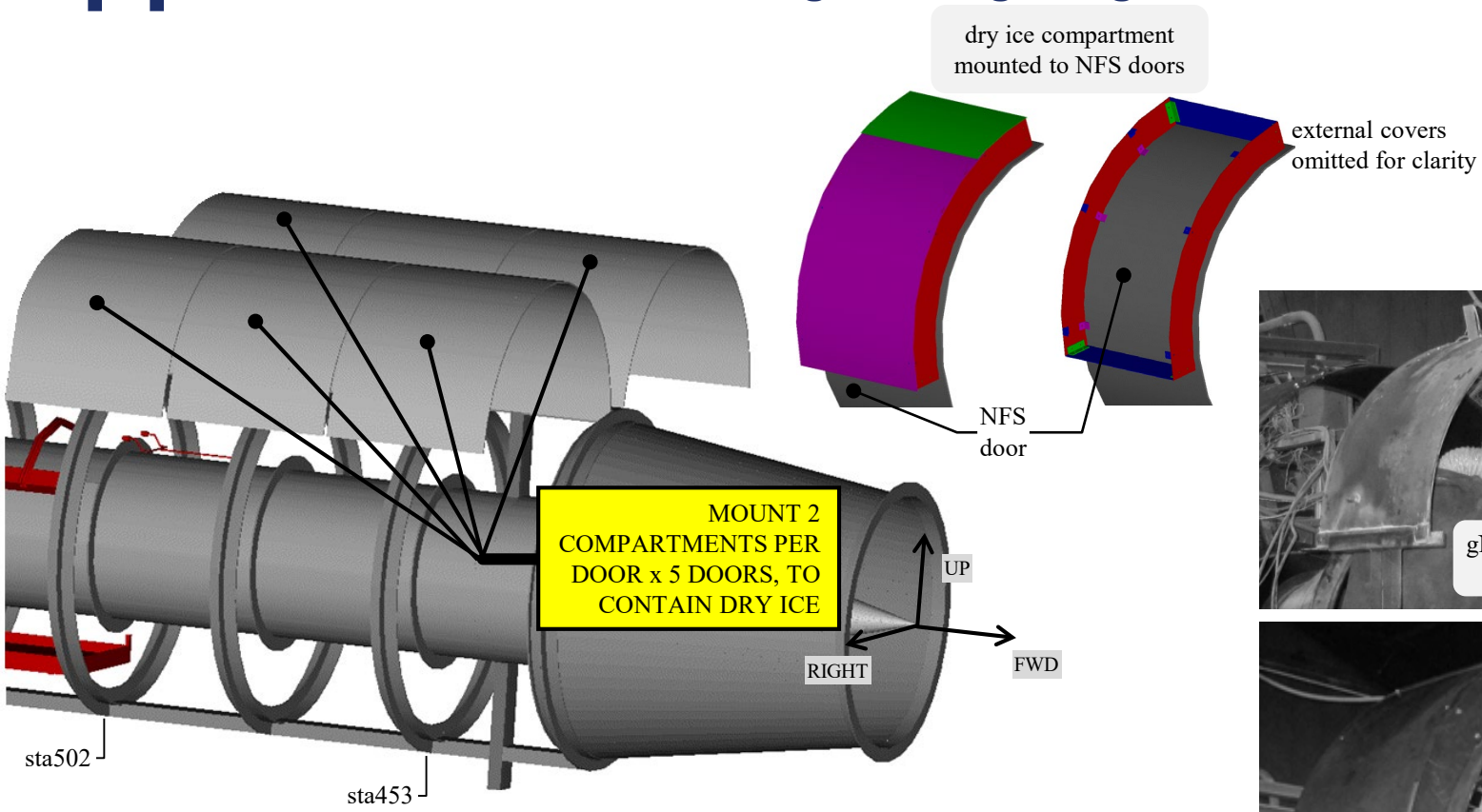
Volume concentration data recorded & provided by Parker-Meggitt

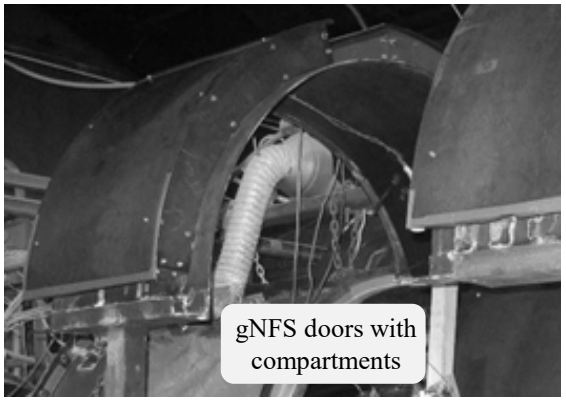
Appendix/ CF_3I test results, MPSHRe/rev04, conc. field, superior



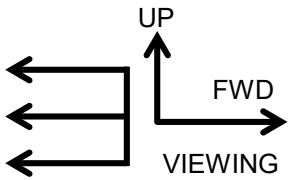
Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ ”cold” testing, chilling the gNFS test section shell





Dry-ice compartments loaded with dry ice already having chilled the FAATC gNFS shell; this is long after the test [typical]



Appendix/ ”cold” testing, chilled firex injection plumbing, lo-vent

...distances here are ALONG the injection tubing

Approximate distances along the injection tubing :

‘A’ to ‘C’	= 21 inches
‘C’ to ‘D’	= 12
‘C’ to ‘E_d’	= 60

Four thermocouples clamped to branch line tube exteriors & insulated from ambient test bay air & dry ice. Approximate distances from point ‘C’ to :

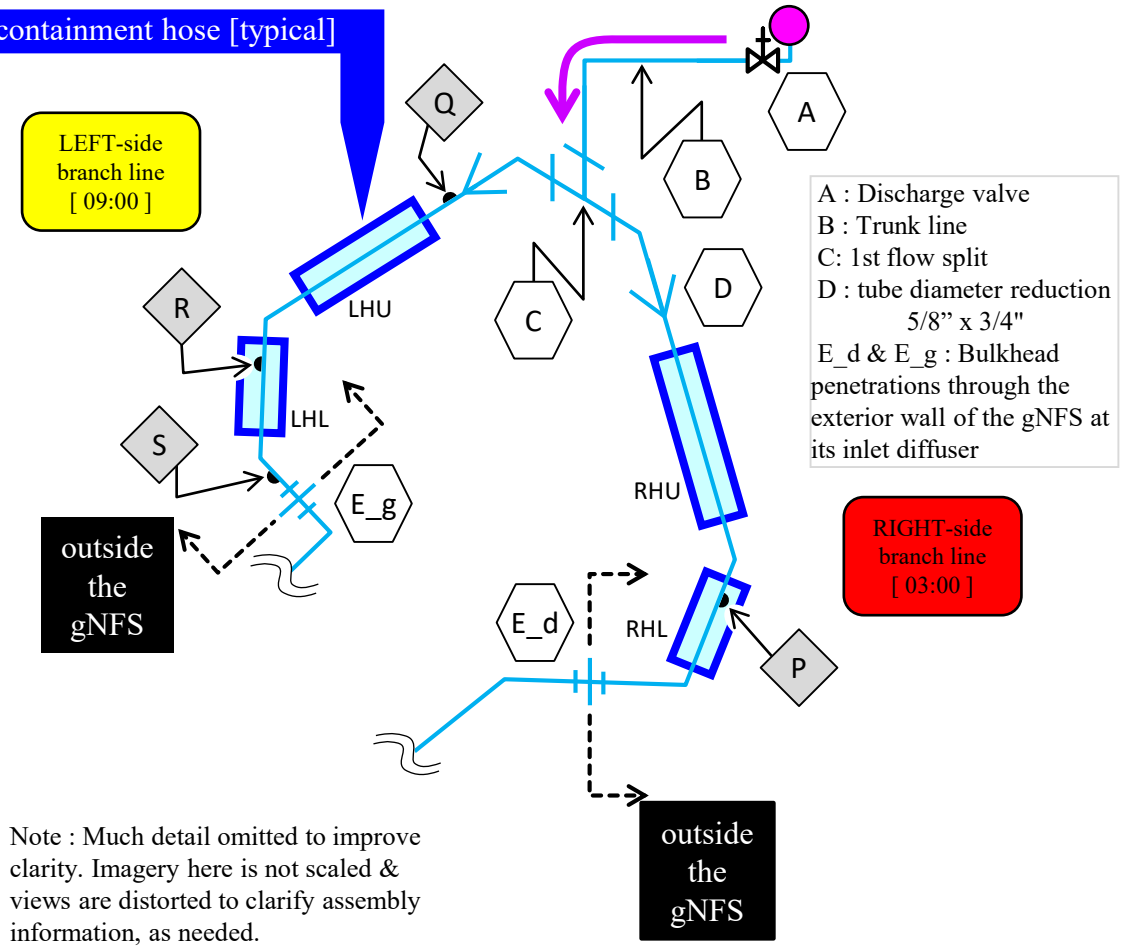
P [rightEXTsfc, mid]	= 30.25 inches
Q [leftEXTsfcUPR]	= 5.50
R [leftEXTsfc, mid]	= 31.13
S [leftEXTsfcLWR]	= 55.38

Dry-ice containment hoses, lengths that wetted the exterior surfaces of the injection plumbing.

LHU	= 15.50 inches
LHL	= 21.75
RHU	= 15.75
RHL	= 21.00

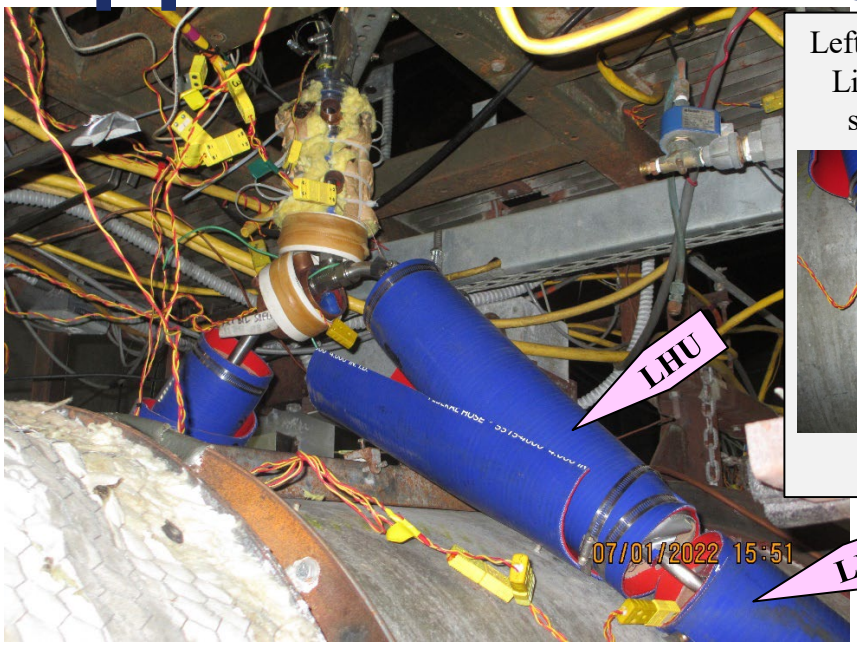
Other distances of interest.

‘C’ to upstream end, LHU	= 7.13 inches
gap between LHU & LHL	= 4.00
upstream end, LHL to R	= 4.50
downstream end, LHL to E_g	= 9.88
‘C’ to upstream end, RHU	= 5.00
gap between RHU to RHL	= 6.25
upstream end, RHL to P	= 3.25
downstream end, RHL to ‘E_d’	= 11.00

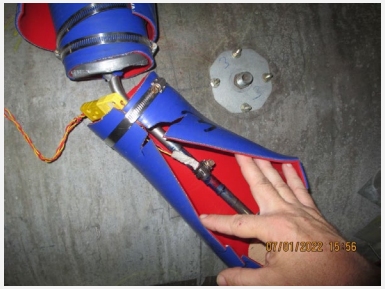


Note : Much detail omitted to improve clarity. Imagery here is not scaled & views are distorted to clarify assembly information, as needed.

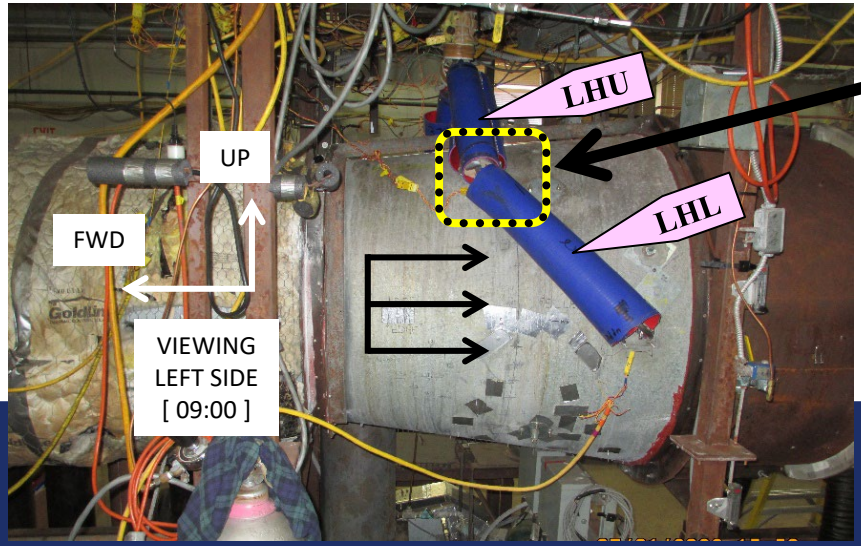
Appendix/ ”cold” testing, chilled firex injection plumbing, lo-vent



Left Firex Injection Branch Line, cold region [mid], surface thermocouple



[typical]



Appendix/ ”cold” testing, chilled firex injection plumbing, hi-vent

...distances here are ALONG the injection tubing

Approximate distances along the injection tubing :

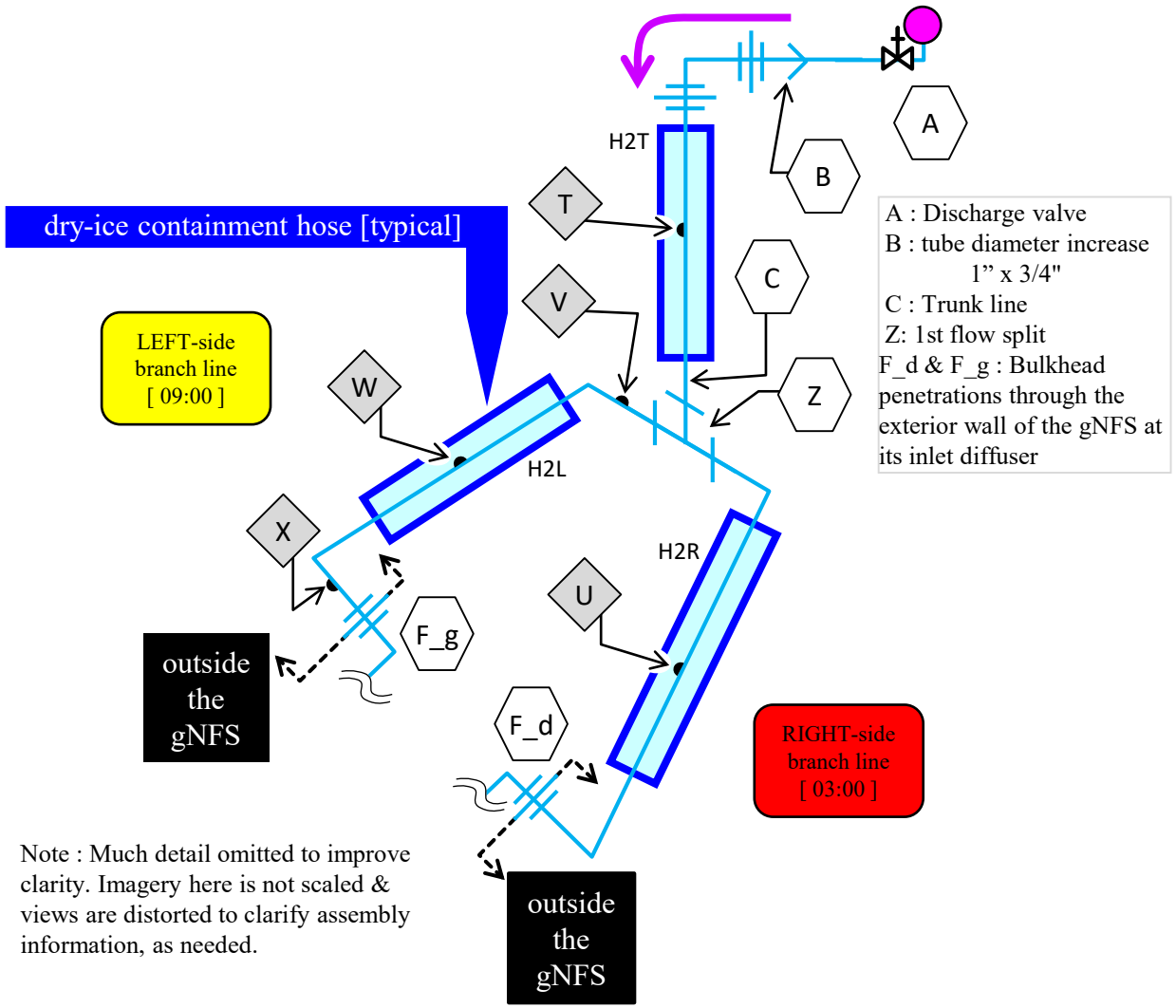
‘A’ to ‘Z’ = 44 inches
‘Z’ to ‘F_g’ = 55
‘Z’ to ‘F_d’ = 54

Five thermocouples clamped to branch line tube exteriors & insulated from ambient test bay air & dry ice. Approximate distances from point ‘Z’ to :

T [trunkEXTsfc, mid] = 18.00 inches
U [rightEXTsfc, mid] = 27.00
V [leftEXTsfcUPR] = 4.00
W [leftEXTsfc, mid] = 26.00
X [leftEXTsfcLWR] = 51.50

Dry-ice containment hoses, lengths that wetted the exterior surfaces of the injection plumbing.

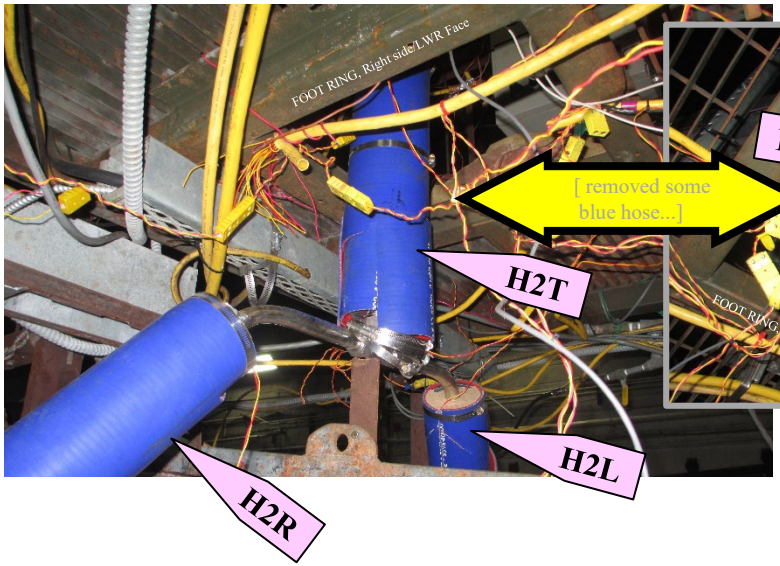
H2T = 29.50 inches
H2L = 32.00
H2R = 31.00

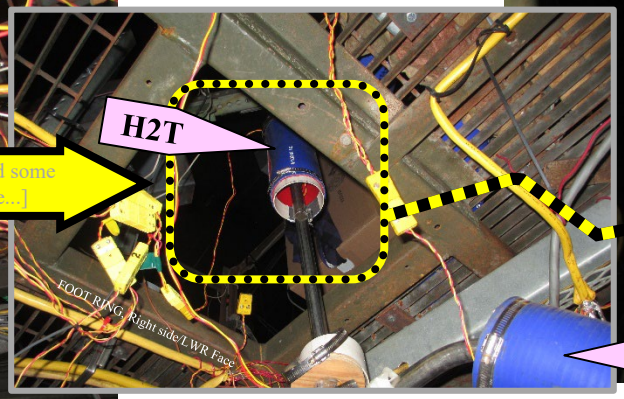


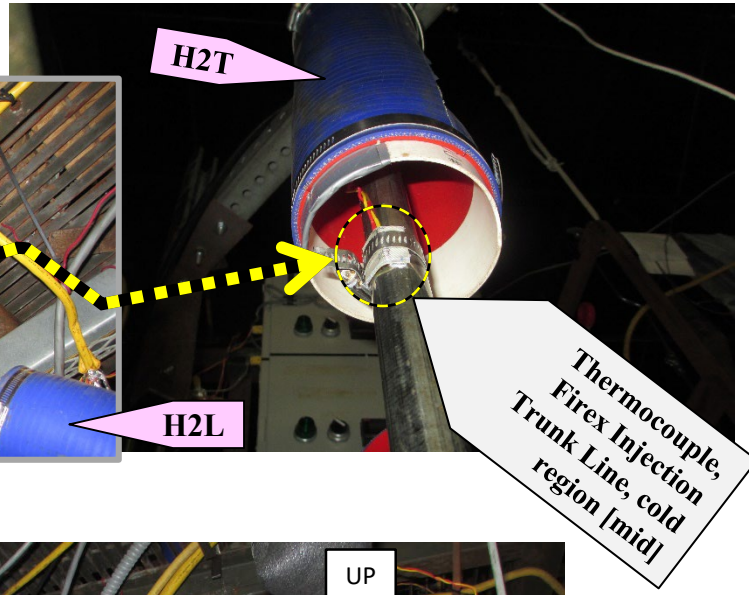
A : Discharge valve
B : tube diameter increase 1” x 3/4"
C : Trunk line
Z: 1st flow split
F_d & F_g : Bulkhead penetrations through the exterior wall of the gNFS at its inlet diffuser

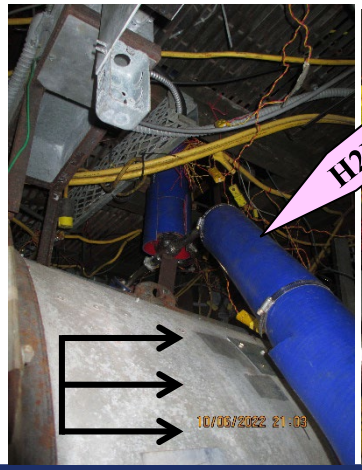
Note : Much detail omitted to improve clarity. Imagery here is not scaled & views are distorted to clarify assembly information, as needed.

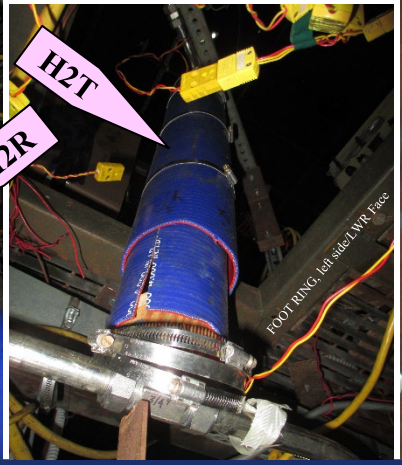
Appendix/ ”cold” testing, chilled firex injection plumbing, hi-vent

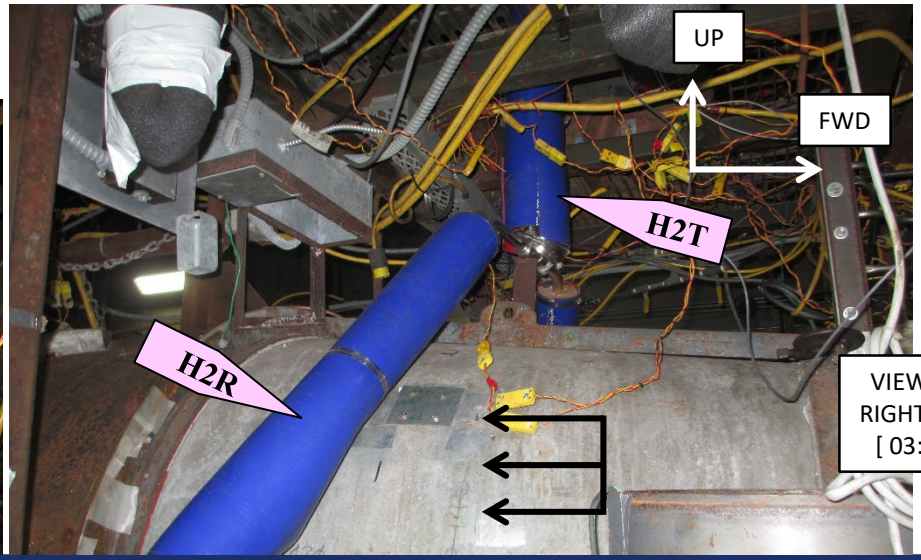




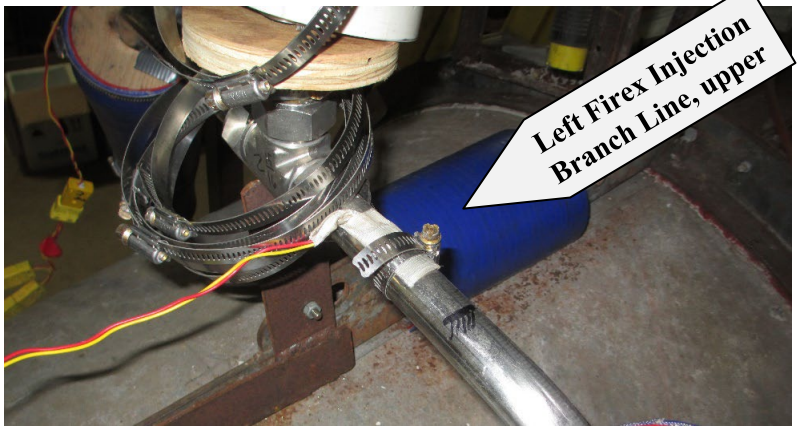


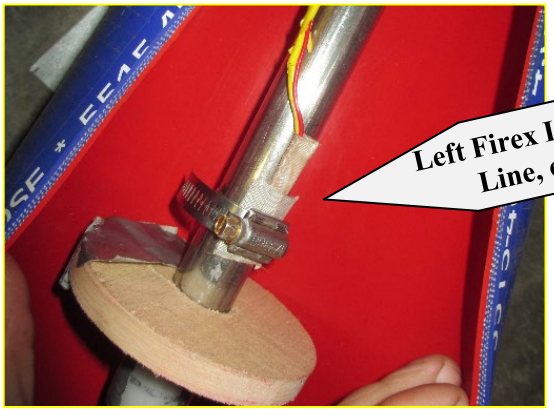


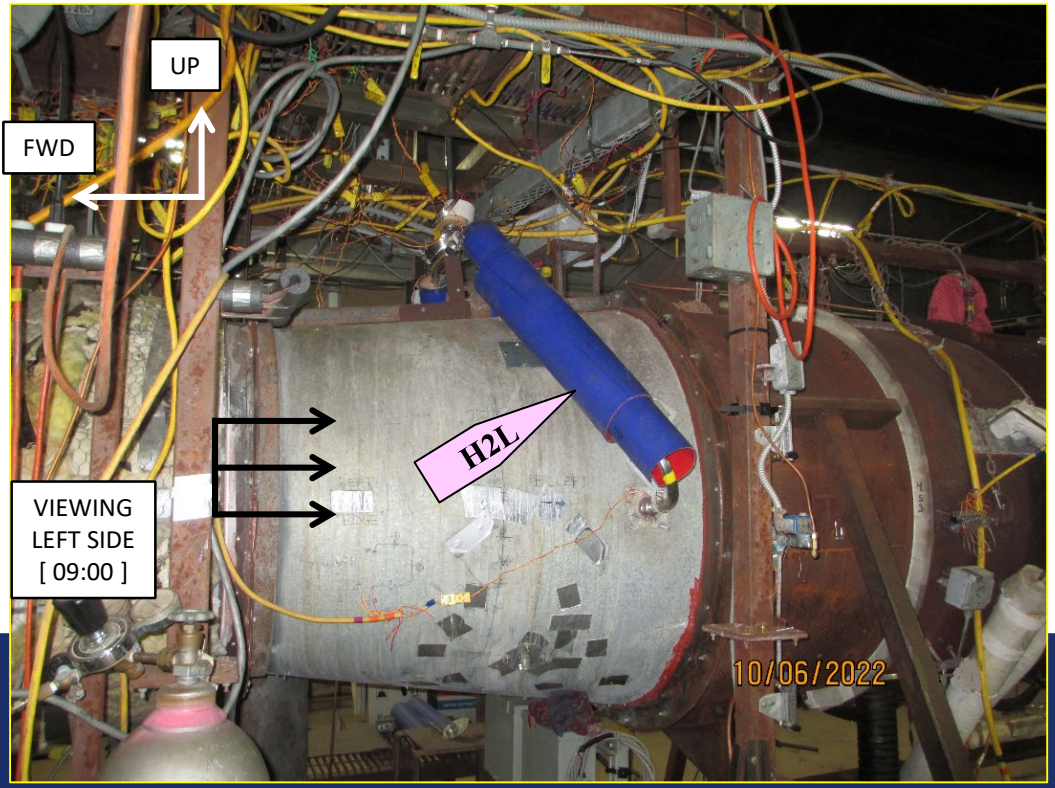


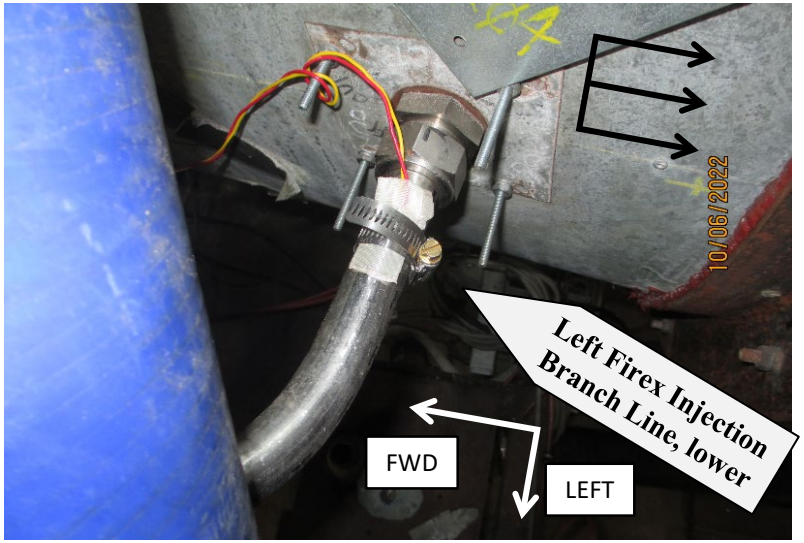


Appendix/ ”cold” testing, chilled firex injection plumbing, hi-vent

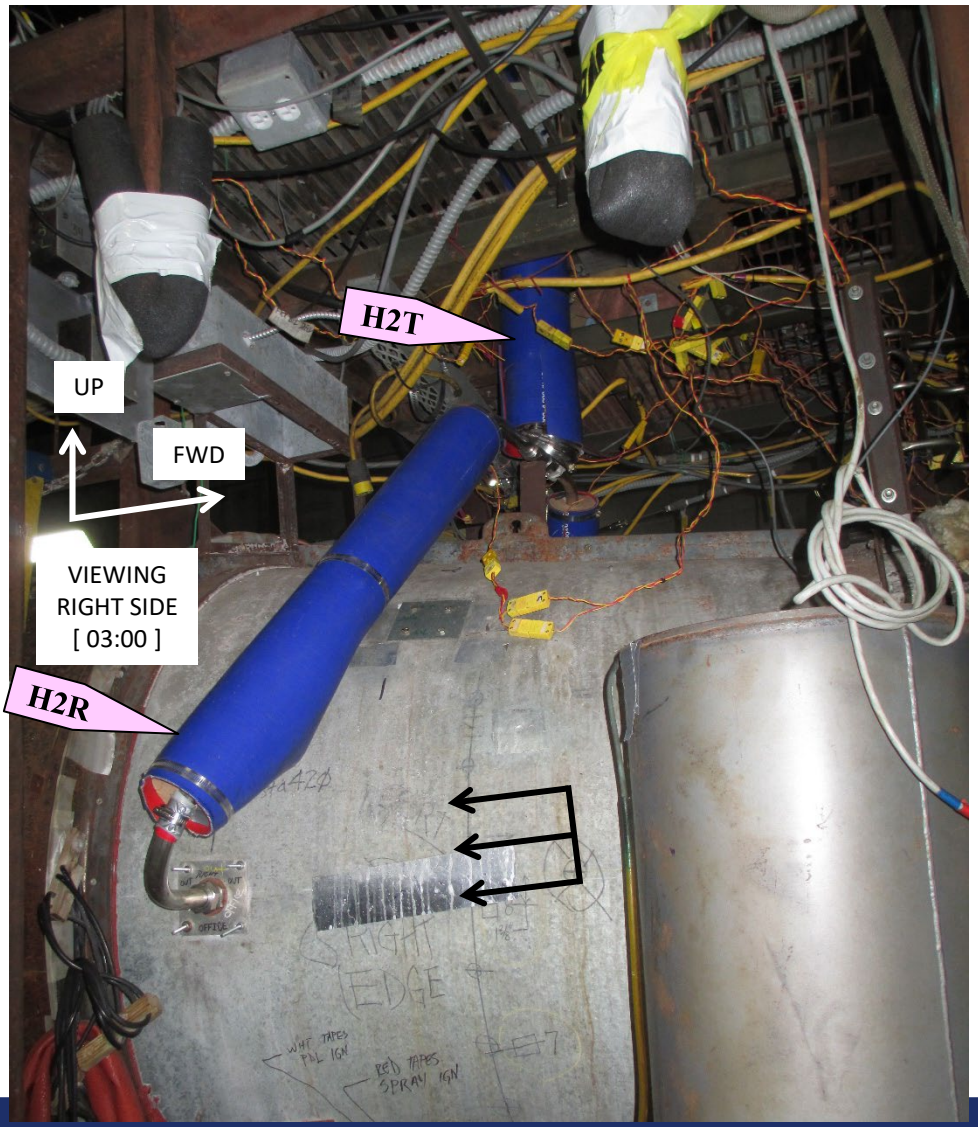


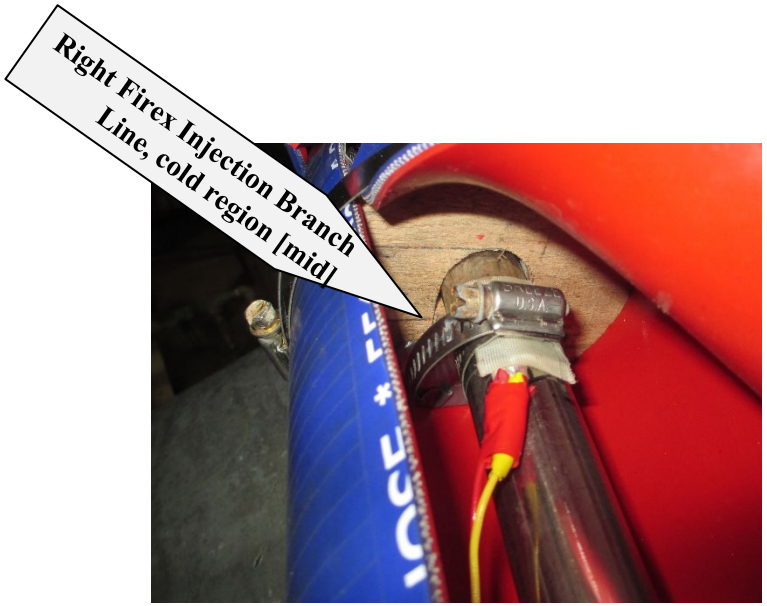






Appendix/ ”cold” testing, chilled firex injection plumbing, hi-vent



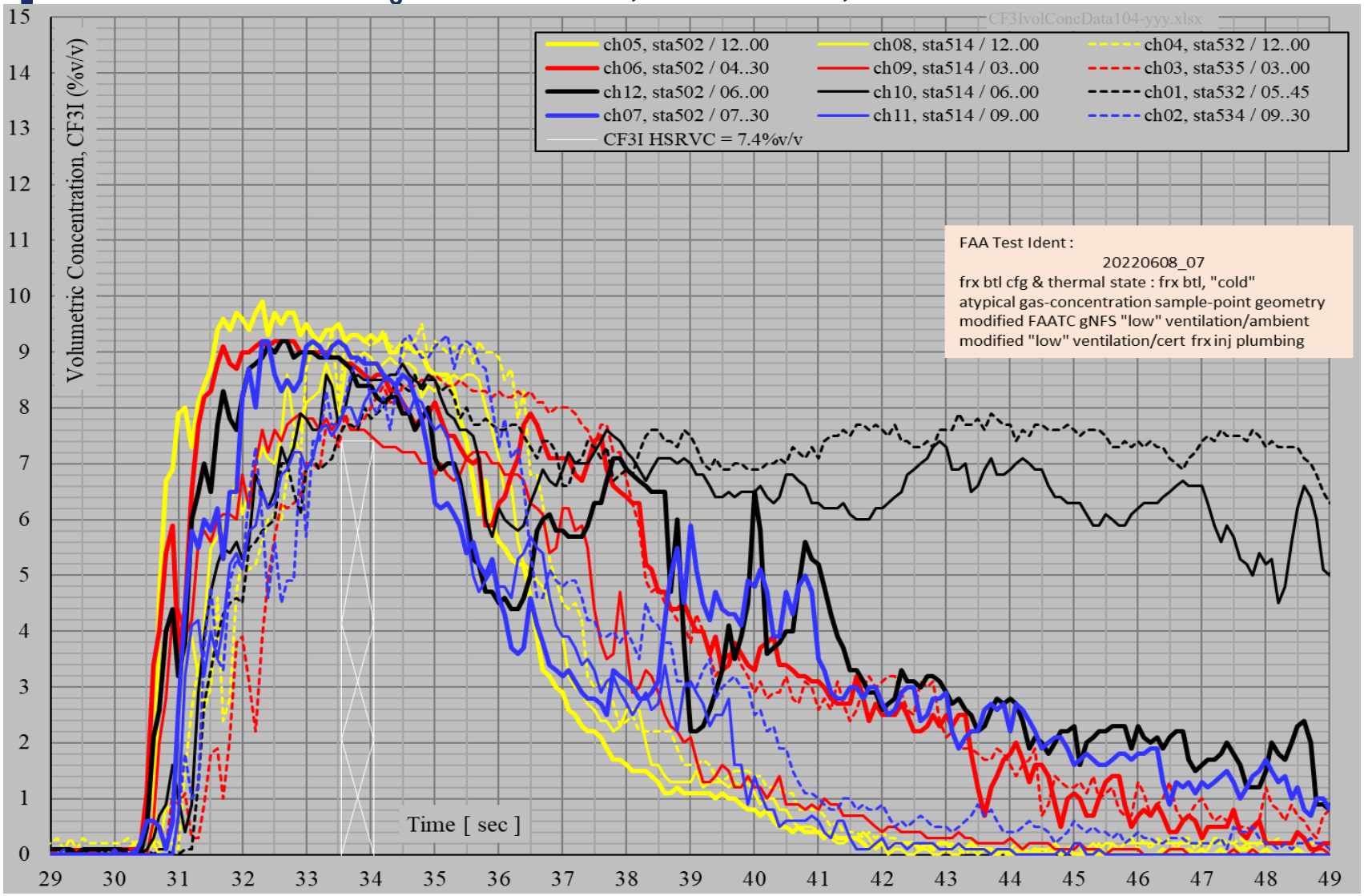


Appendix/ CF_3I test results, conc. field, “cold”/mod-low-ventilation

Test Condition	“cold”/modified-LOW ventilation		
Test identification	20220608r07	20220609r03	20220610r03
Average sta453 [°C]	29	22	27
Firex bottle contents [°C]	-52	-51	-51[M]
HSRVC [%v/v CF3I]	7.4	6.7	6.9

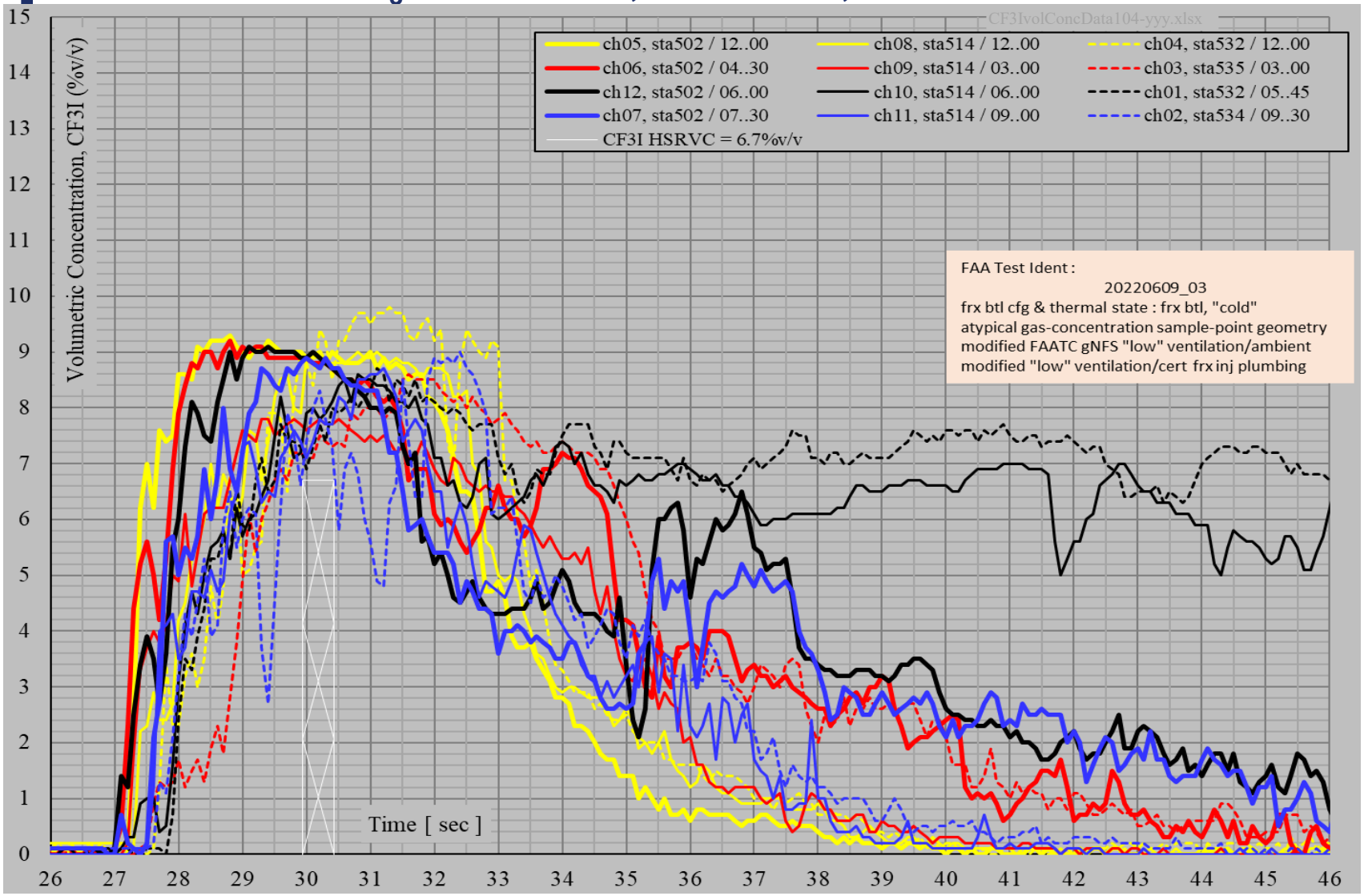
[M] Faulty institutional thermocouple. Temperature measured by hand-portable reader.

Appendix/ CF_3I test results, conc. field, “cold”/mod-low-ventilation



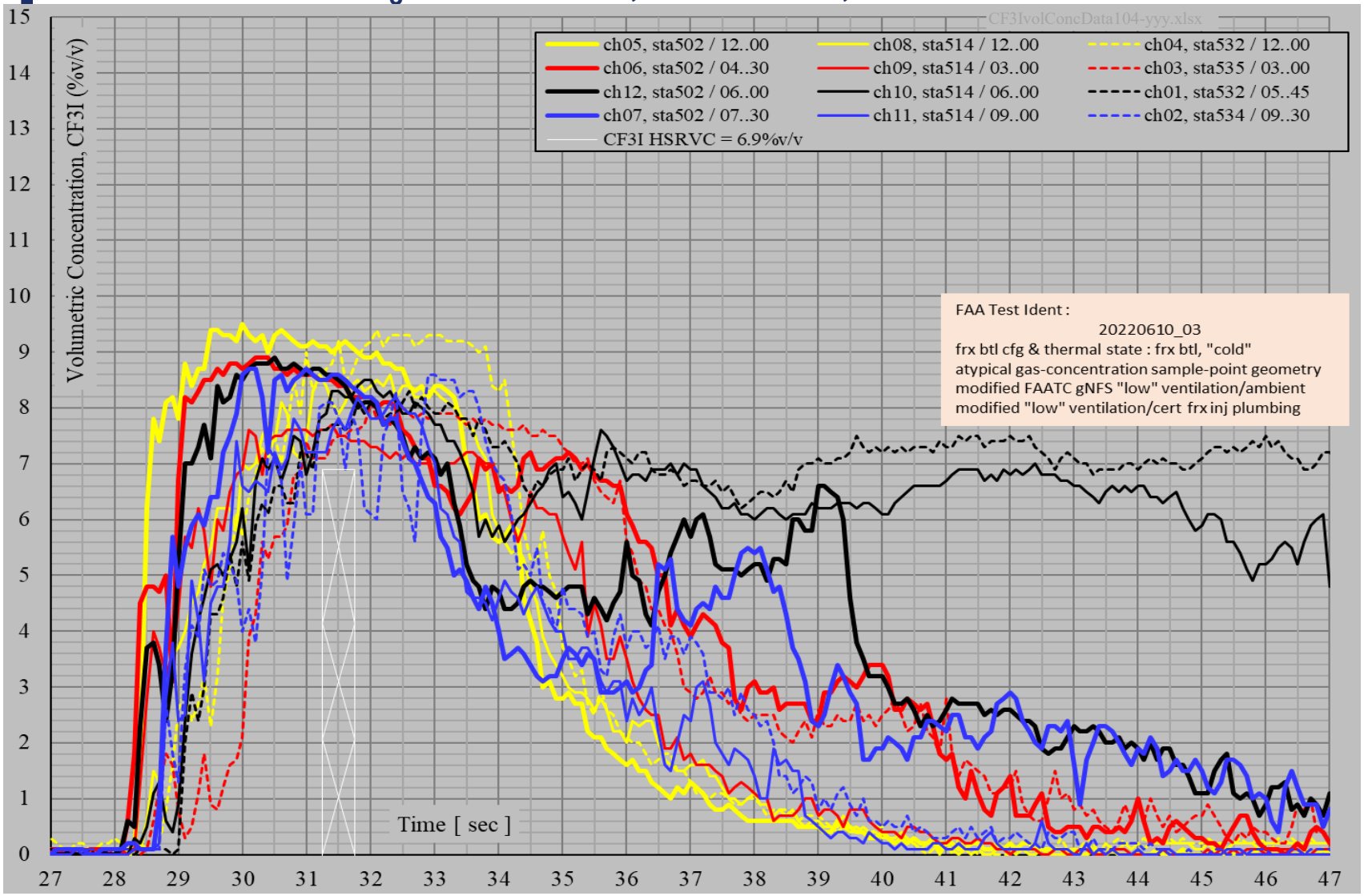
Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ CF_3I test results, conc. field, “cold”/mod-low-ventilation



Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ CF_3I test results, conc. field, “cold”/mod-low-ventilation

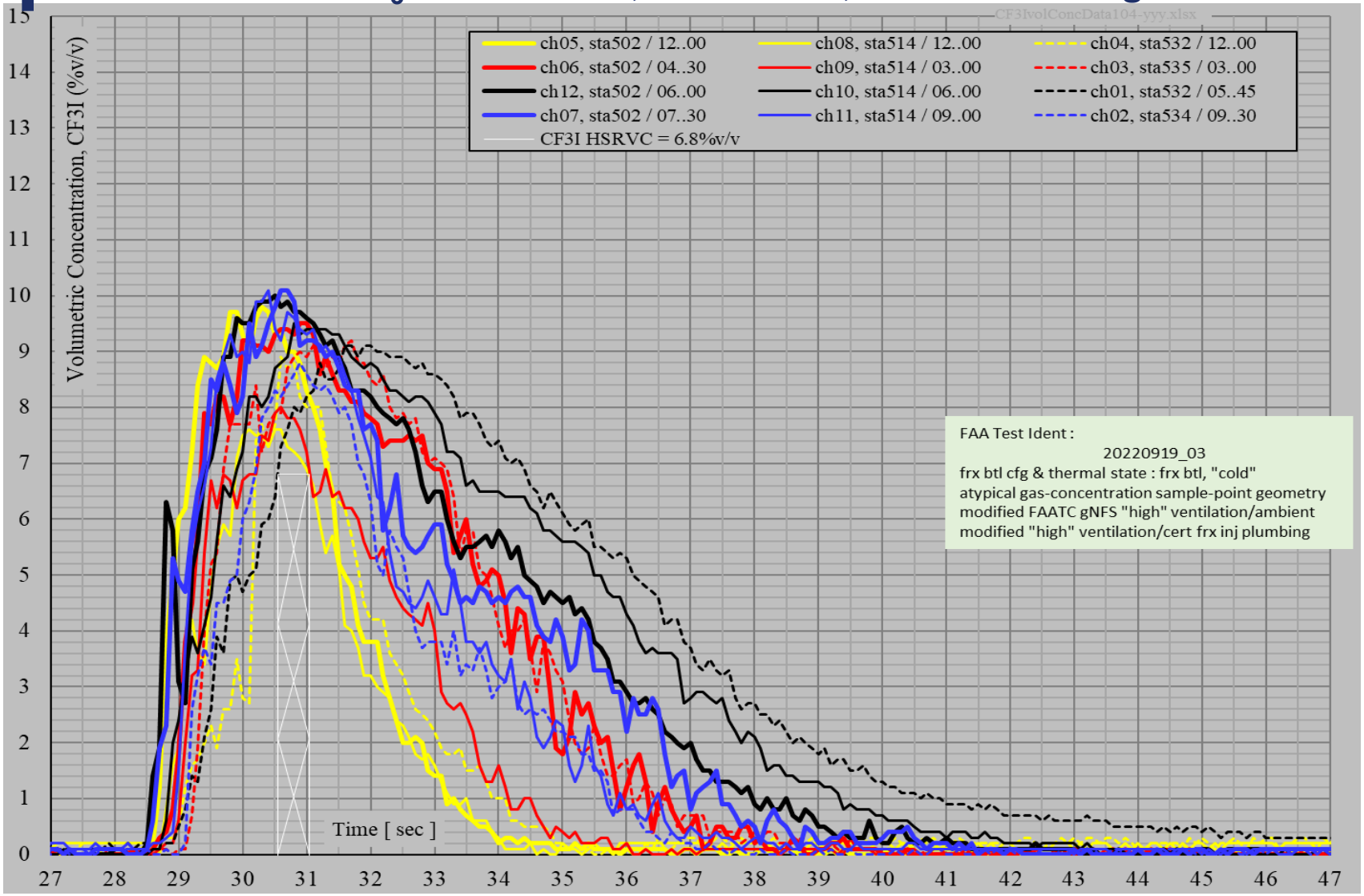


Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ CF_3I test results, conc. field, “cold”/mod-high-ventilation

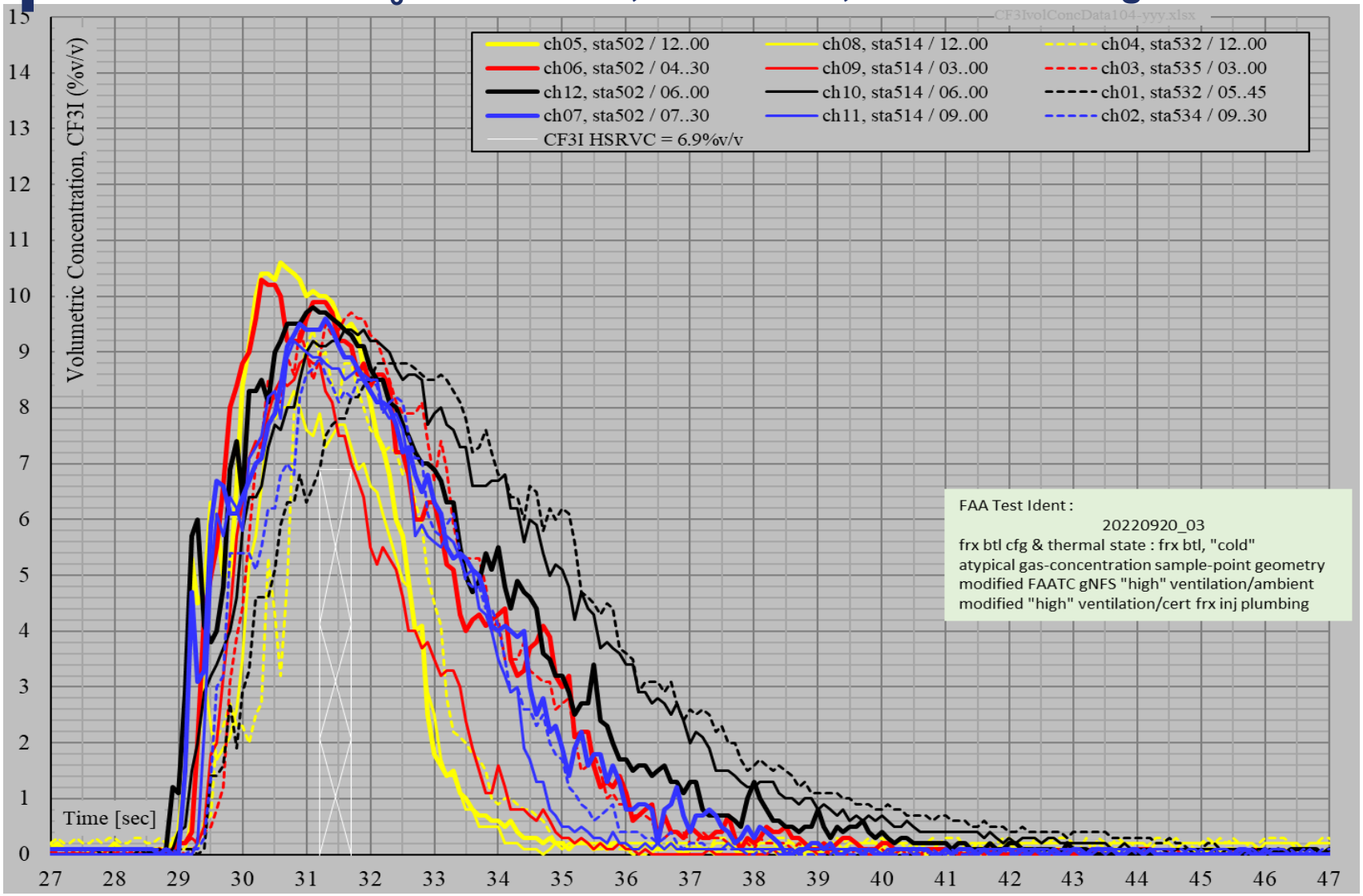
Test Condition	“cold”/modified-HIGH ventilation		
Test identification	20220919r03	20220920r03	20220922r03
Average sta453 [°C]	28	26	28
Firex bottle contents [°C]	-54	-55	-56
HSRVC [%v/v CF3I]	6.8	6.9	7.2

Appendix/ CF_3I test results, conc. field, “cold”/mod-high-ventilation



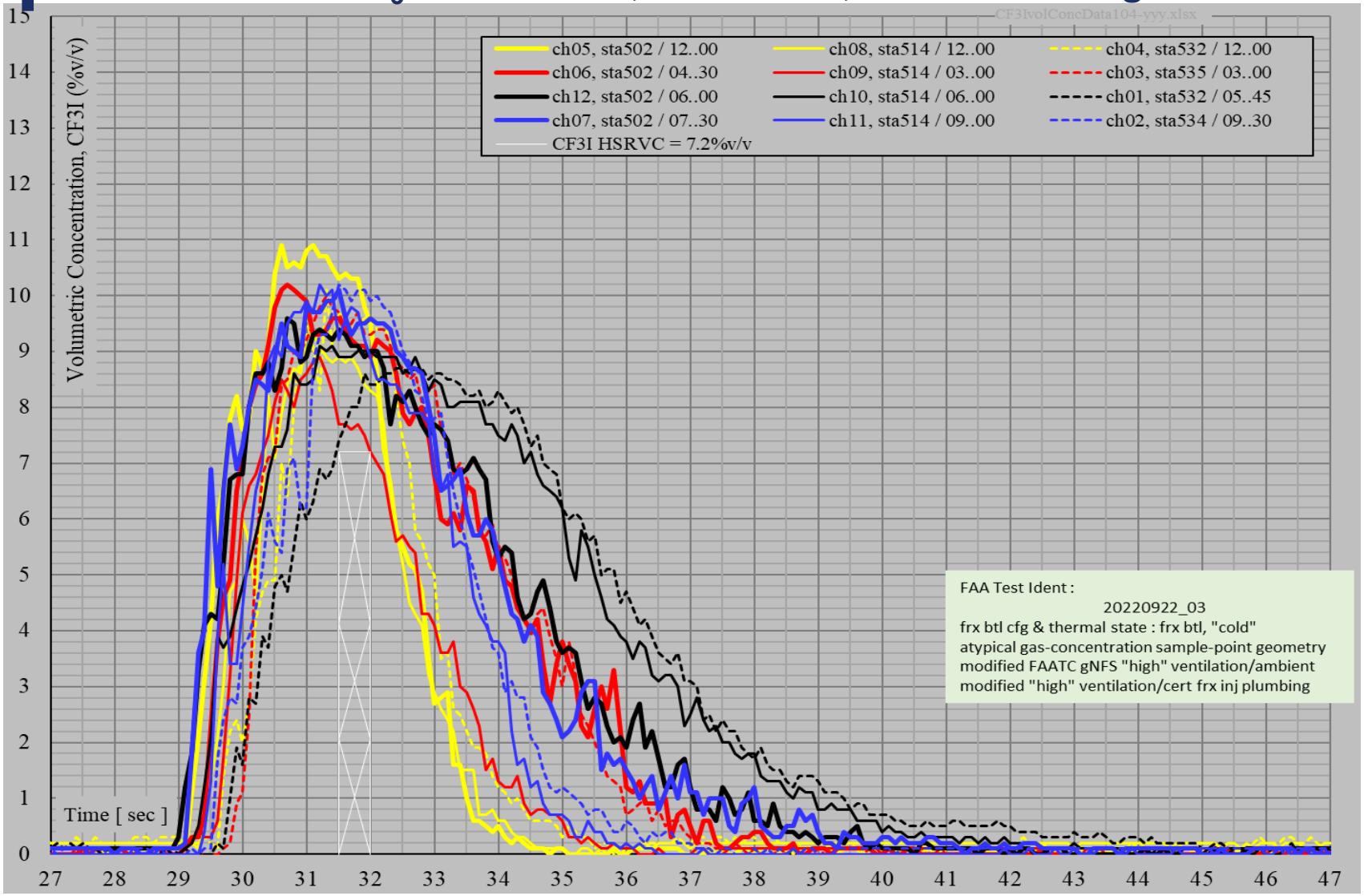
Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ CF_3I test results, conc. field, “cold”/mod-high-ventilation



Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ CF_3I test results, conc. field, “cold”/mod-high-ventilation



Volume concentration data recorded & provided by Parker-Meggitt

Appendix/ Brief History of 6%v/v CF_3Br relative to the FAA

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ADVISORY CIRCULAR

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

SUBJECT: GENERAL GUIDELINES FOR MEASURING FIRE-EXTINGUISHING AGENT CONCENTRATIONS IN POWERPLANT COMPARTMENTS

1. PURPOSE. The purpose of this Advisory Circular is to describe the installation and use of a model GA-2A fire extinguisher agent concentration recorder in determining the distribution and concentration of fire-extinguishing agents when discharged in an aircraft powerplant compartment.

2. REFERENCE.

   a. Report No. FAA-DS-70-3, "Criteria for Aircraft Installation and Utilization of an Extinguishing Agent Concentration Recorder," is available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151, under Accession No. AD 712 191.

   b. FAR Sections 25.1195(b), 29.1195(b), and 29.1195(c).

   c. FAR 21.21(b)(2) as it affects powerplant fire-extinguisher installations accomplished on an optional basis.

3. BACKGROUND. From 1959 to 1968, the Federal Aviation Administration (FAA) was actively engaged in the evaluation of aircraft powerplant fire-extinguishing systems. During this period, the FAA provided, without charge, specialized fire-extinguishing agent concentration recorder equipment and knowledgeable personnel to organizations requesting assistance in the evaluation of aircraft fire-extinguishing systems. Testing was conducted and data was obtained for STOL, VTOL, helicopters, large transport category aircraft, military aircraft, executive aircraft, turbojet, turbopropellers, and reciprocating engine-powered aircraft. This evaluation program provided information helpful in establishing criteria for the installation and utilization of the fire-extinguishing agent concentration recorder. The FAA no longer makes evaluations. This type of work is now being performed by private companies for a fee. The FAA

Initiated by: AFS-140

Examples of minimum concentrations sufficient to extinguish fire and prevent its recurrence are as follows:

AGENT	CONCENTRATION BY WEIGHT	IN PERCENT BY VOLUME	RELATIVE CONCENTRATION PERCENT
CO_2	49	37	40
CH_3Br	30	11	15
CH_2BRCl	36	11	25
CF_2Br_2	26.5	5	15
CF_3Br	22	6	15

FAA AC 20-100, halon 1301 certification concentration criterion => 6%v/v CF3Br ...refers to report FAA-DS-70-3

Appendix/ Brief History of 6%v/v CF_3Br relative to the FAA

Report No. FAA-DS-70-3

CRITERIA FOR AIRCRAFT INSTALLATION AND UTILIZATION OF AN EXTINGUISHING AGENT CONCENTRATION RECORDER

George Chamberlain
National Aviation Facilities Experimental Center
Atlantic City, New Jersey 08405

MARCH 1970

FINAL REPORT

Prepared for

FEDERAL AVIATION ADMINISTRATION
Aircraft Development Service
Washington D. C., 20590

relative concentrations above 15-percent recorder indication have little practical extinguishment value. This can be illustrated by a typical fuel/air versus agent concentration flammability limit curve shown in Figure 11. This curve indicates that above approximately 6 percent of $CBrF_3$ by volume, no mixture of fuel and air is flammable. The indicated 6 percent corresponds to a 15-percent volumetric relative recorder indication. Therefore, reducing high concentrations to values approaching 15-percent relative concentration will not adversely affect the agent's

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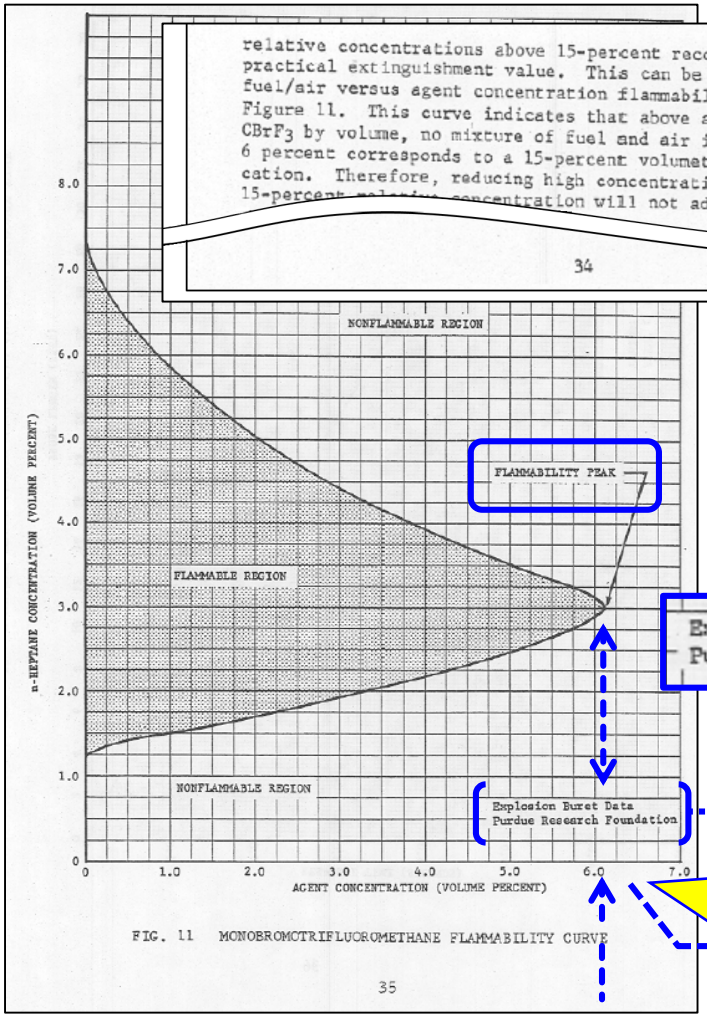

FIG. 11 MONOBROMOTRIFLUOROMETHANE FLAMMABILITY CURVE

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Explosion Buret Data
Purdue Research Foundation

FAA-DS-70-3, halon 1301 certification concentration criterion ≈ 6%v/v CF3Br
...refers to the Purdue Research Foundation

Appendix/ Brief History of 6%v/v CF_3Br relative to the FAA

AD-654322

Final Report

on

Fire Extinguishing Agents

for the period

September 1, 1947 to June 30, 1950

covering research conducted by

Purdue Research Foundation and Department of Chemistry

Purdue University

under contract
W44-009-eng-5057
with
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Purdue Research Foundation, foundation of this value...

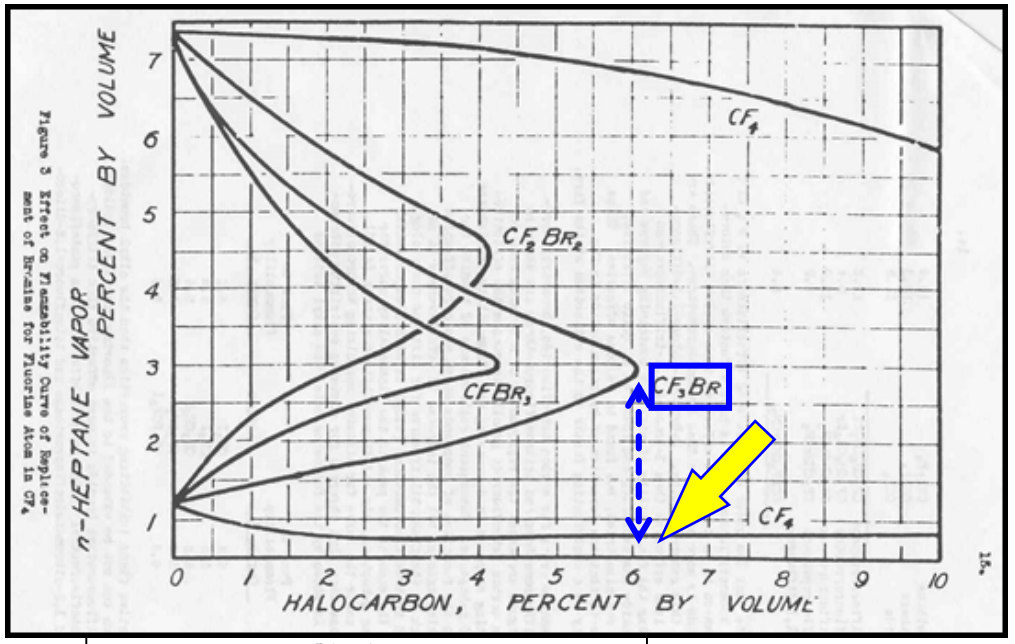

Figure 3 Effect on Flammability Curve of Replacement of Bromine for Fluorine Atom in CF_4

Table 1a

FLAMMABILITY OF MIXTURES OF n-HEPTANE, AIR AND BROMOTRIFLUORO-METHANE
(Total Pressure = 400 mm. Hg)

Pressure, mm. Hg		Volume, %		
$n\text{-}C_7H_{16}$	$CBrF_3$	$n\text{-}C_7H_{16}$	$CBrF_3$	Result
5.0	0.0	1.3	0.0	-
6.0	0.0	1.5	0.0	+
28.0	0.0	7.0	0.0	+
29.0	0.0	7.3	0.0	-
11.0	22.0	2.8	5.5	-
13.0	21.0	3.3	5.0	-
6.0	8.0	1.5	2.0	-
7.0	8.0	1.8	2.0	+
8.0	16.0	2.0	4.0	-
9.0	16.0	2.3	4.0	+
20.0	8.0	5.0	2.0	-
16.0	16.0	4.0	4.0	-
12.0	24.0	3.0	6.0	+
12.0	25.0	3.0	6.3	-
10.0	20.0	2.5	5.0	+
13.0	23.0	3.3	5.8	-
9.0	20.0	2.3	5.0	-
15.0	16.0	3.8	4.0	+
19.0	8.0	4.8	2.0	+
14.0	20.0	3.5	5.0	+
24.0	4.0	6.0	1.0	-

- from Purdue [1950]
- [n-heptane = $n\text{-}C_7H_{16}$]

[a "+" means the mixture ignited & flame propagated through the detonation tube; "-" means the mixture did not ignite or did ignite but did not propagate]

Appendix/ A Parallel in History for CF_3I

AD-654322

Final Report

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Fire Extinguishing Agents

for the period

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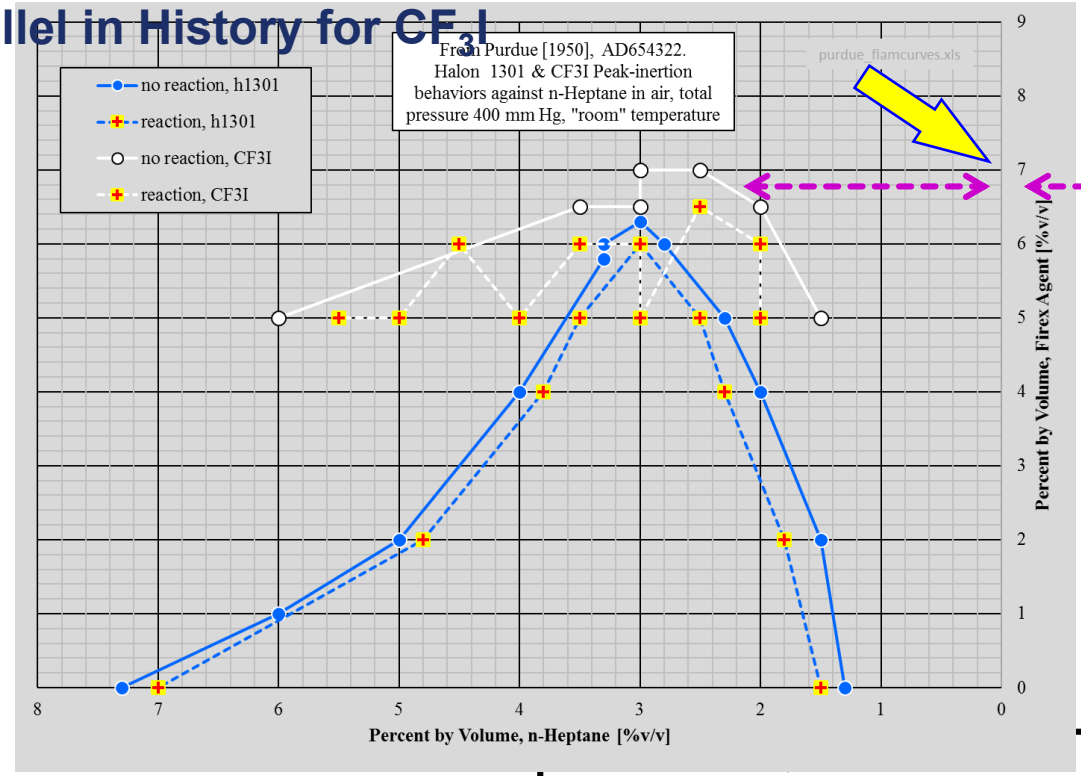

- from Purdue [1950]
- [n-heptane = n-C_7H_{16}]

Table 22

FLAMMABILITY OF MIXTURES OF N-HEPTANE, AIR AND TRIFLUORO-IODOMETHANE
(Total Pressure = 400 mm. Hg.)

Pressure, mm. Hg. C_7H_{16}	Pressure, mm. Hg. CF_3I	Volume % C_7H_{16}	Volume % CF_3I	Result
12.0	20.0	3.0	5.0	+
12.0	28.0	3.0	7.0	-
12.0	24.0	3.0	6.0	+
12.0	26.0	3.0	6.5	-
10.0	26.0	2.5	6.5	+
14.0	26.0	3.5	6.5	-
10.0	28.0	2.5	7.0	-
16.0	20.0	4.0	5.0	+
8.0	26.0	2.0	6.5	-
8.0	20.0	2.0	5.0	+
20.0	20.0	5.0	5.0	+
6.0	20.0	1.5	5.0	-
24.0	20.0	6.0	5.0	-
8.0	24.0	2.0	6.0	+
22.0	20.0	5.5	5.0	+
14.0	24.0	3.5	6.0	+
18.0	24.0	4.5	6.0	+

Purdue [1950] : 6.8 %v/v CF3I, in air & vaporous n-heptane

[a "+" means the mixture ignited & flame propagated through the detonation tube;
"-" means the mixture did not ignite or did ignite but did not propagate]