

Engine Nacelle Halon Replacement

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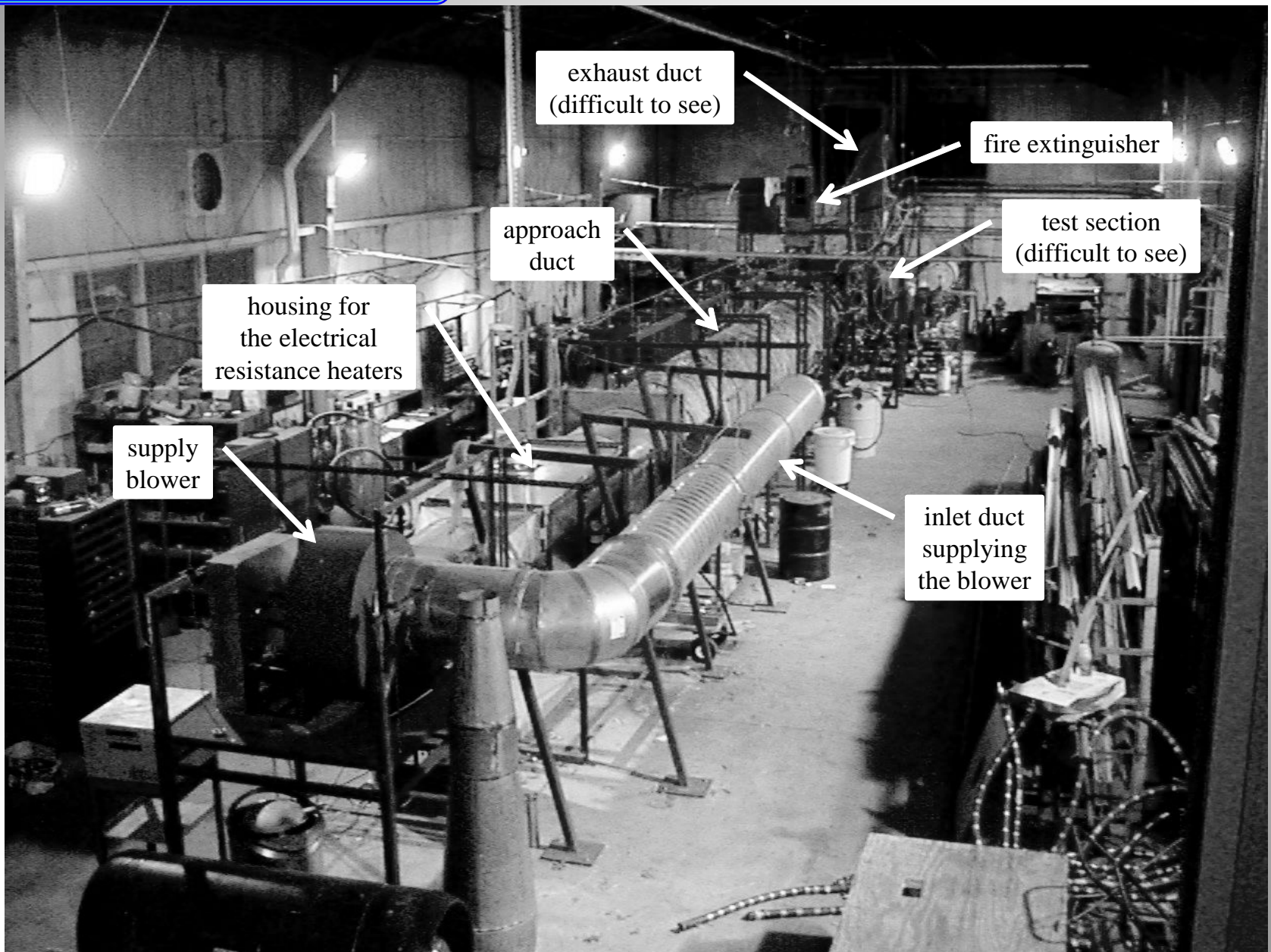
web page: www.fire.tc.faa.gov

- OVERVIEW OF THE EQUIVALENCE METHODOLOGY
- EXAMPLE OF MASS EQUIVALENCE
- EXAMPLE OF GAS CONCENTRATION EQUIVALENCE
- RESULTS
- CONCLUSION

EQUIVALENCE METHODOLOGY

~ OVERVIEW ~

- TESTING OCCURS IN A GENERIC REPRESENTATION OF AN ENGINE NACELLE ENVIRONMENT
- EQUIVALENCE METHODOLOGY IS TWO-PART
 - ◆ ESTABLISH A MASS EQUIVALENCE BETWEEN AGENTS
 - ✦ COMPARES *FIRE EXTINCTION* PERFORMANCE
 - ✦ HALON 1301 (H1301) BENCHMARK IS ESTABLISHED
 - ✦ REPLACEMENT CANDIDATE PERFORMANCE EQUALS OR EXCEEDS THE BENCHMARK
 - ◆ ESTABLISH A CONCENTRATION EQUIVALENCE
 - ✦ MEASURES *AGENT DISTRIBUTION* BEHAVIOR OF THE MASS EQUIVALENT
 - ✦ GAS ANALYSIS IS USED TO CAPTURE PERFORMANCE
 - ✦ RELATES DIRECTLY TO FIRE EXTINCTION PERFORMANCE
- PROCESS IS REPEATED FOR 4 TEST CONFIGURATIONS
 - ◆ 2 VENTILATIONS REGIMES x 2 FIRE THREATS
 - ◆ LARGEST EQUIVALENT CONCENTRATION IS INTENDED AS THE RECOMENDATION FOR CERTIFICATION



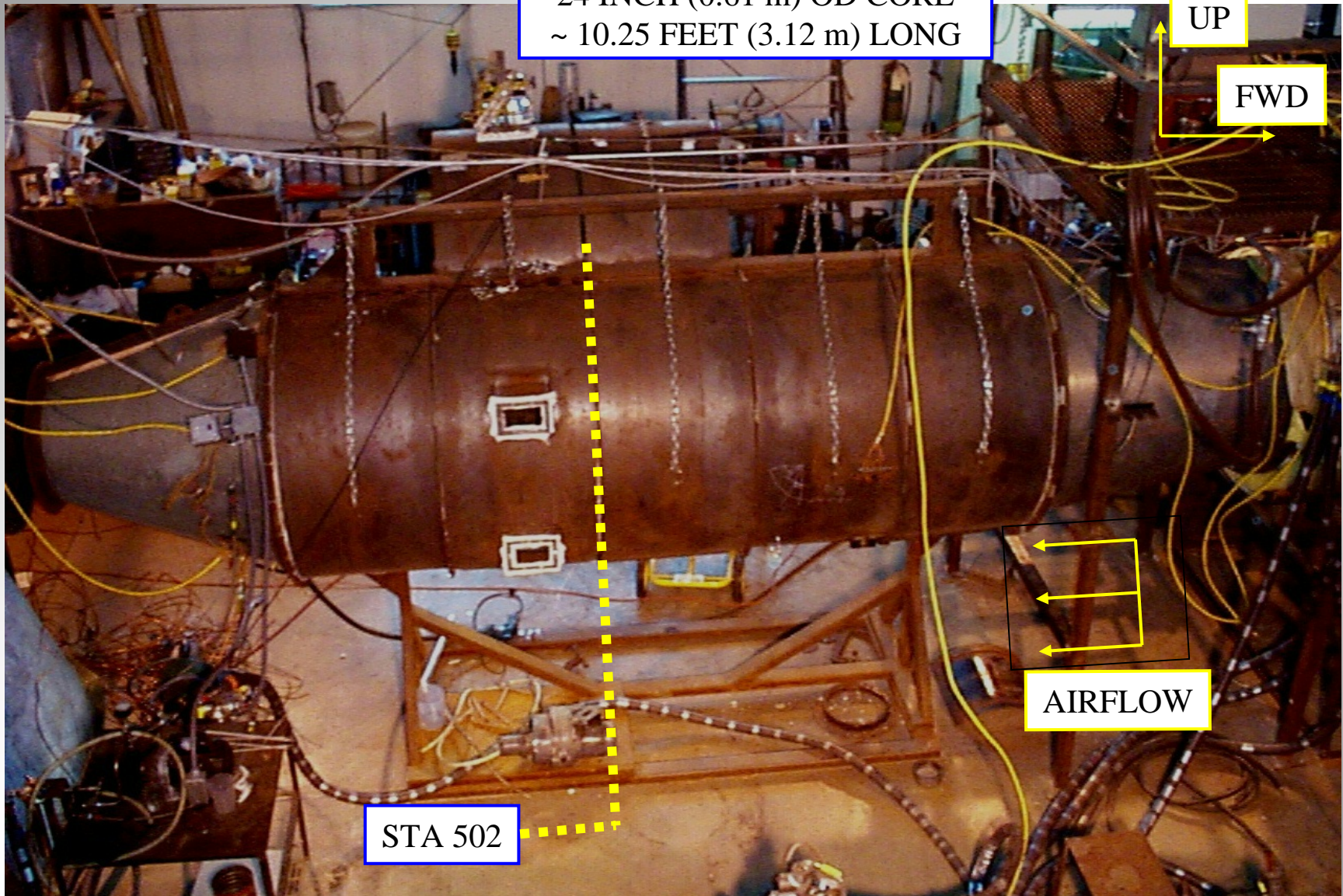
IMAGERY - TEST SECTION

TEST SECTION DIMENSIONS

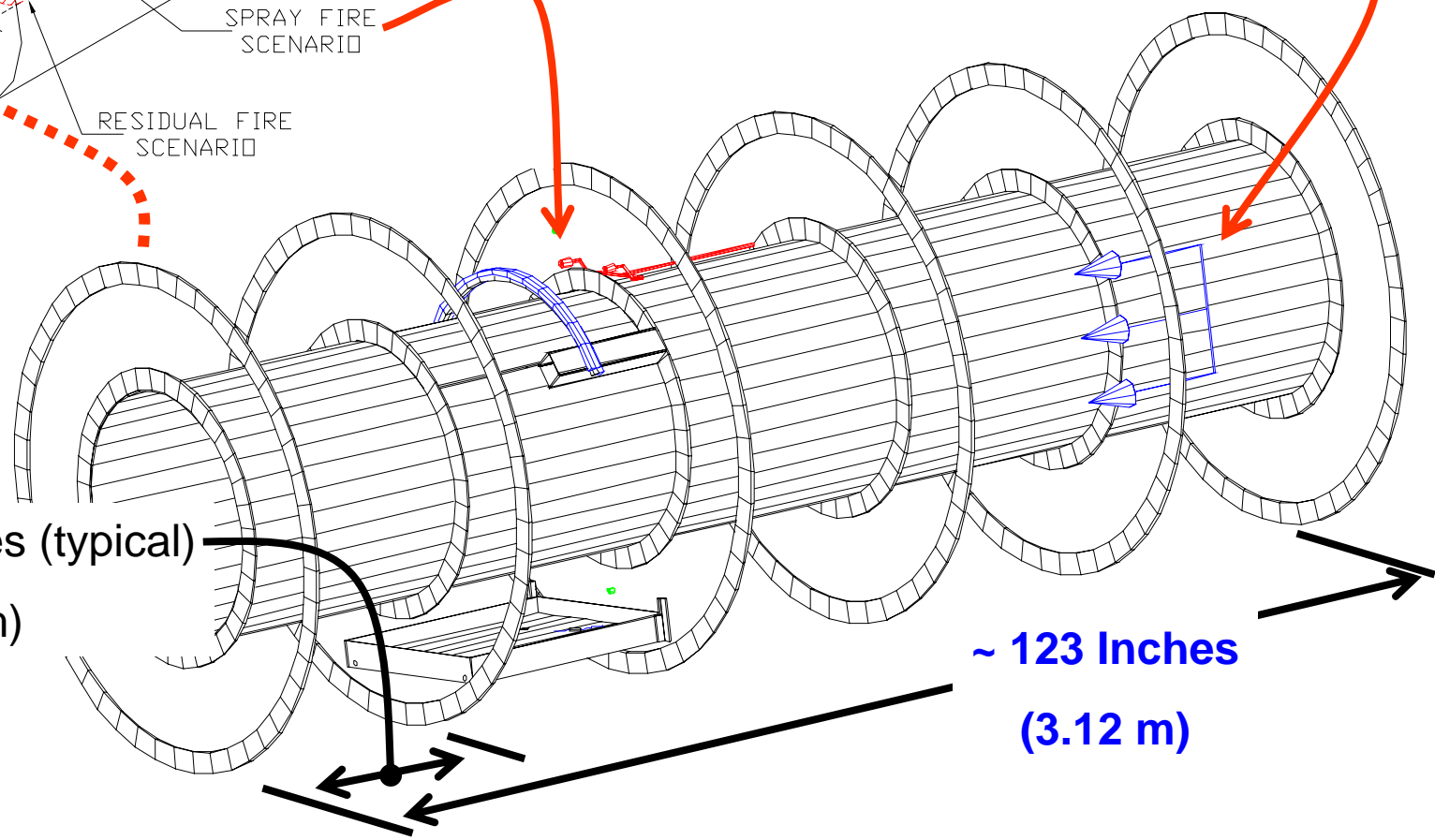
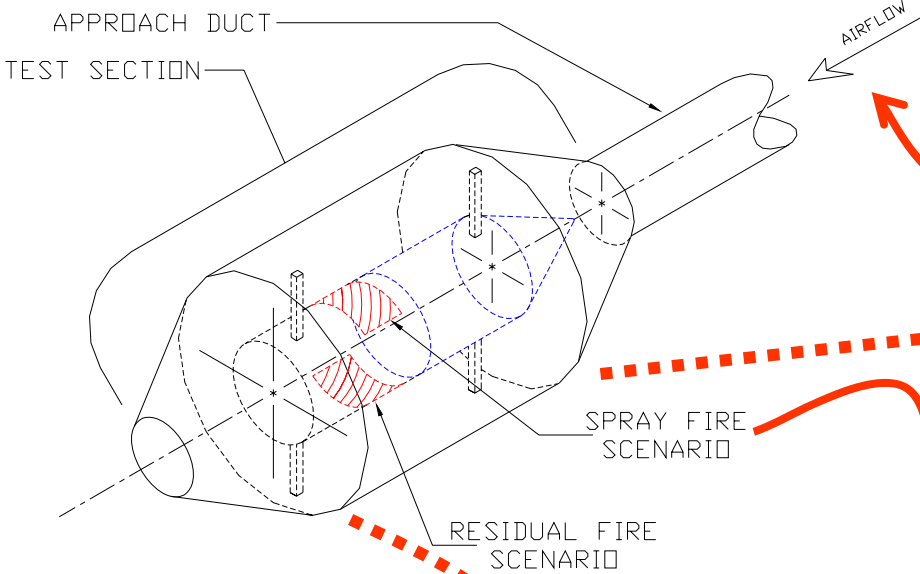
48 INCH (1.22 m) OD SHELL

24 INCH (0.61 m) OD CORE

~ 10.25 FEET (3.12 m) LONG



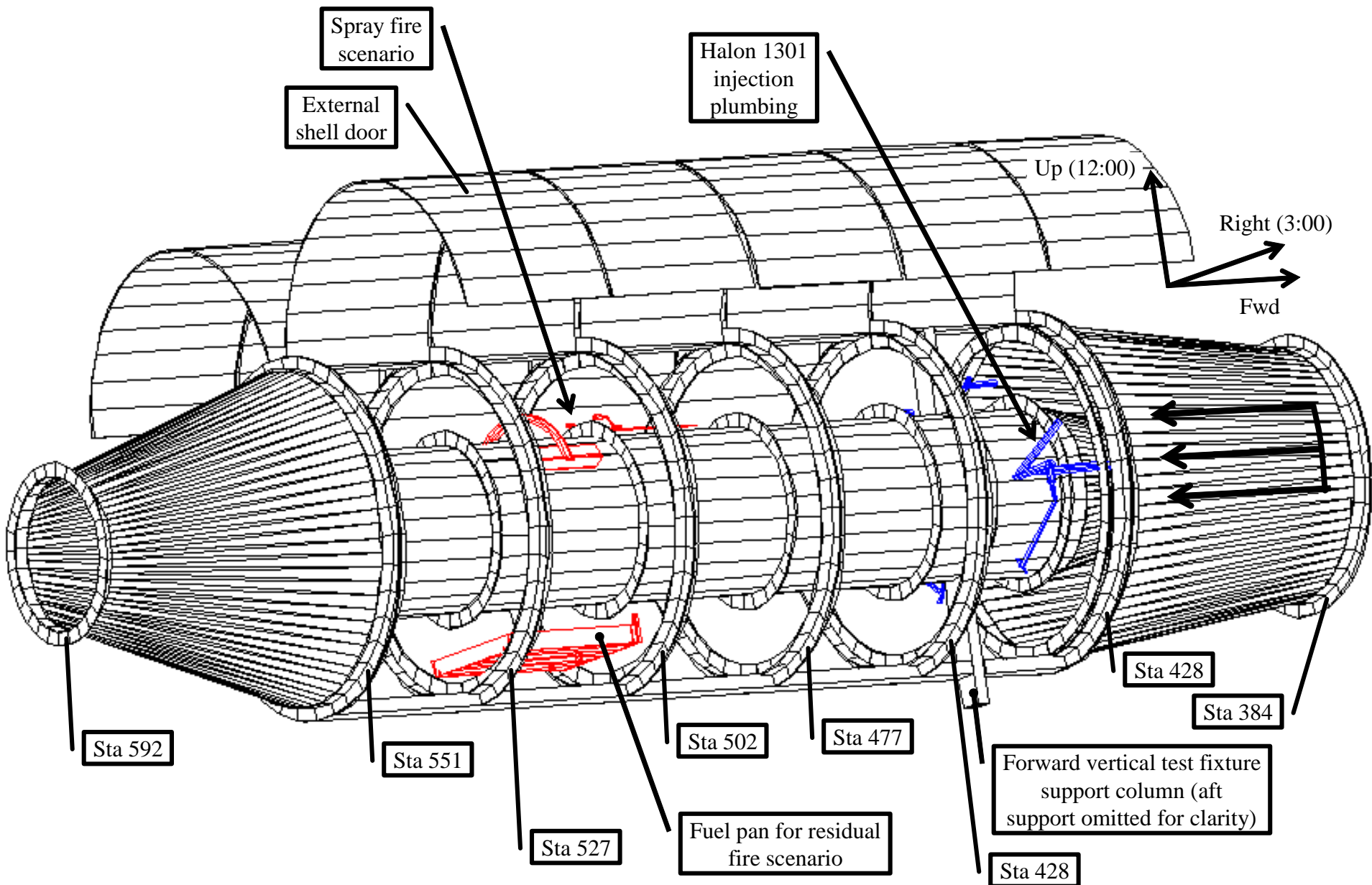
IMAGERY - TEST SECTION (3-D MODEL, CORE)



24 +/- 1 inches (typical)
(61 +/- 2.5 cm)

~ 123 Inches
(3.12 m)

IMAGERY - TEST SECTION (3-D MODEL, +DOORS)



EQUIVALENCE METHODOLOGY, PART I

~ MASS EQUIVALENCE ~

→ PROCESS

- ◆ SELECT VENTILATION REGIME
- ◆ UTILIZE APPROPRIATE H1301 CERTIFICATION INSTALLATION
- ◆ ESTABLISH H1301 BENCHMARK
- ◆ SEARCH, FIND, & DEMONSTRATE EQUIVALENT BEHAVIOR WITH THE REPLACEMENT CANDIDATE

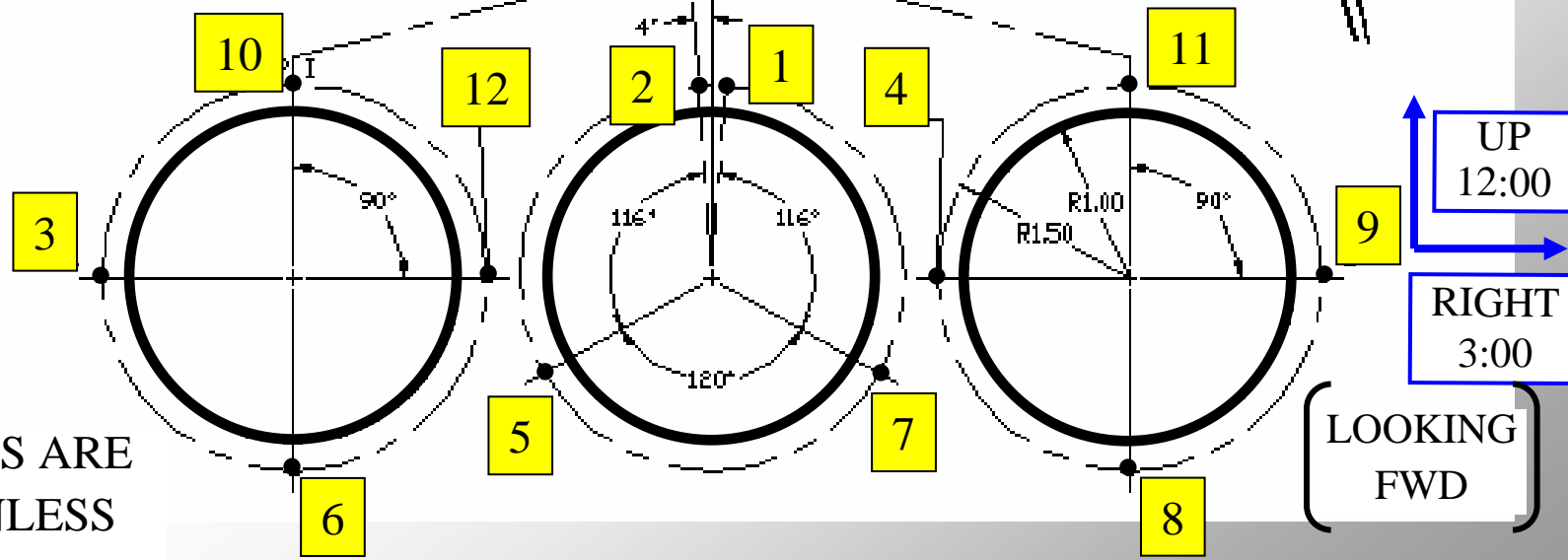
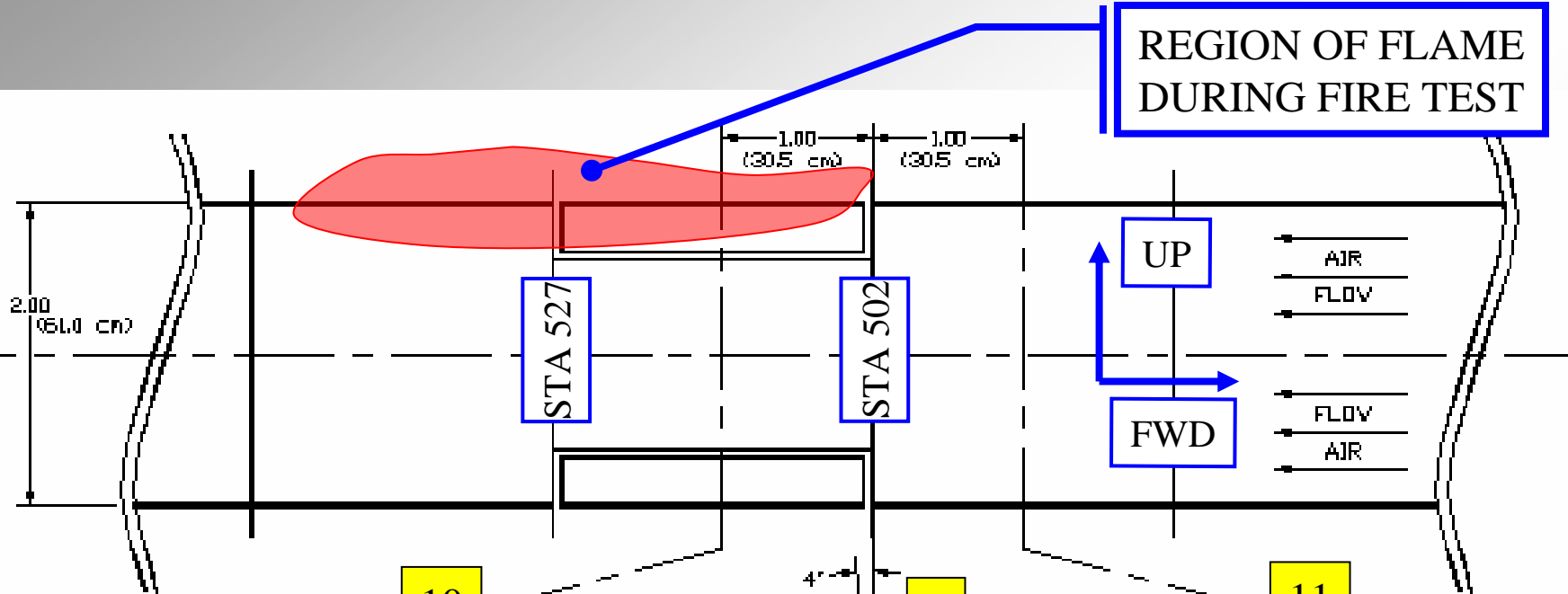
→ TEST FIXTURE VENTILATION IS SET TO 1 OF 2 POINTS

- ◆ WANT TO SPAN AND OBSERVE BEHAVIOR
- ◆ HIGH VENTILATION (HiVent) ≈ 2.7 LBM/S @ 100°F (1.2 kg/s @ 38°C)
- ◆ LOW VENTILATION (LoVent) ≈ 1.0 LBM/S @ 260°F (0.5 kg/s @ 127°C)

→ H1301 CERTIFICATION IS KNOWN FOR BOTH CASES

- ◆ AGENT IS STORED AT 100°F (38°C)
- ◆ AGENT DISCHARGE IS ≈ 1 SECOND
- ◆ H1301 BENCHMARK (FIRE TESTING) IS ACCOMPLISHED WITH THE APPLICABLE CERTIFICATION PROFILE
- ◆ H1301 DISTRIBUTION IS REASONABLY SYMMETRIC
- ◆ DISCHARGE IS NOT DIRECTED AT THE FIRE THREAT
- ◆ MINIMUM DISTANCE OF 5 FT (1.52 m) SEPARATES AGENT INJECTION AND THE FLAME FRONTS

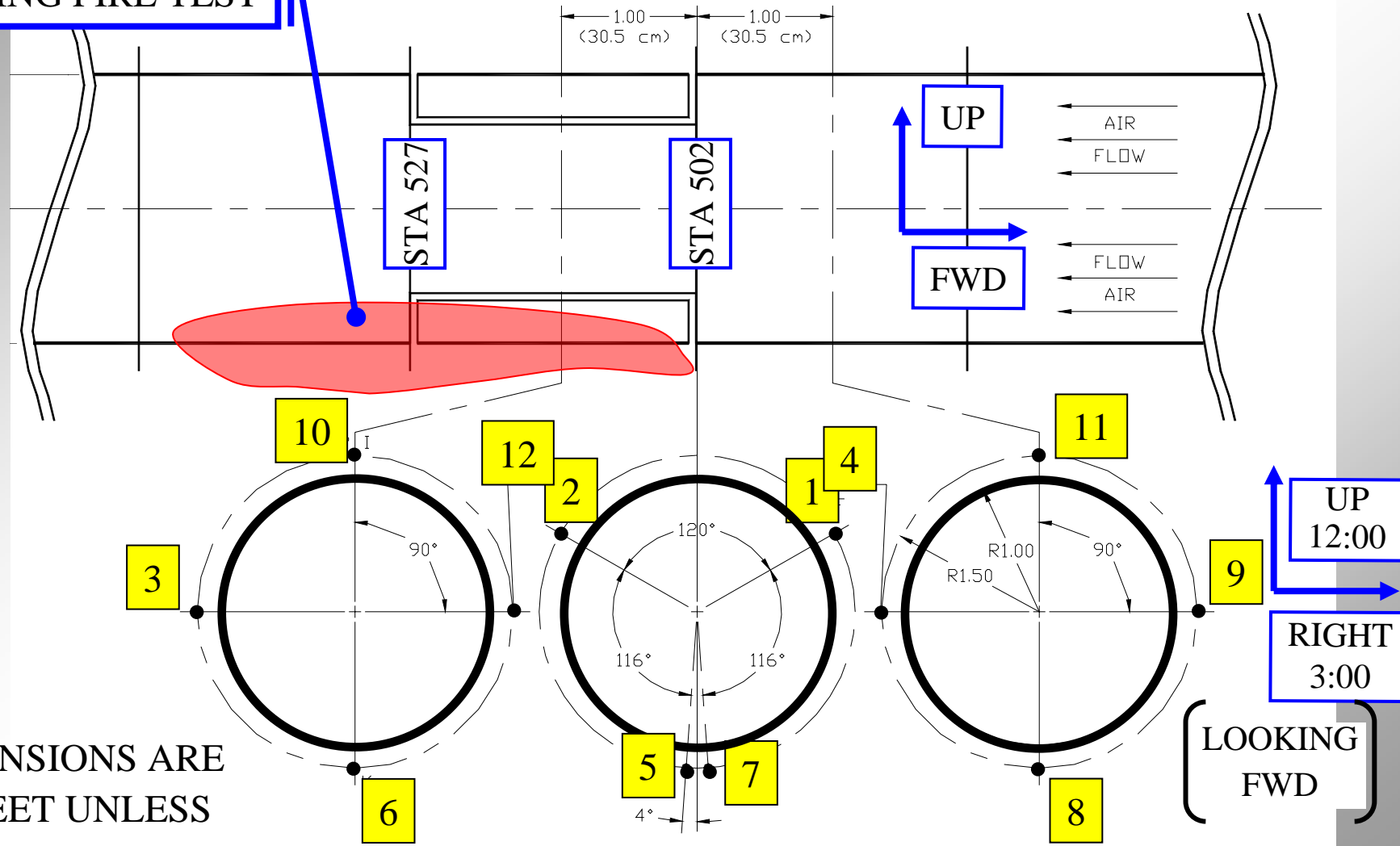
IMAGERY – SAMPLING PROBE LOCATIONS, SPRAY



DIMENSIONS ARE
IN FEET UNLESS
NOTED OTHERWISE

IMAGERY – SAMPLING PROBE LOCATIONS, POOL

REGION OF FLAME DURING FIRE TEST



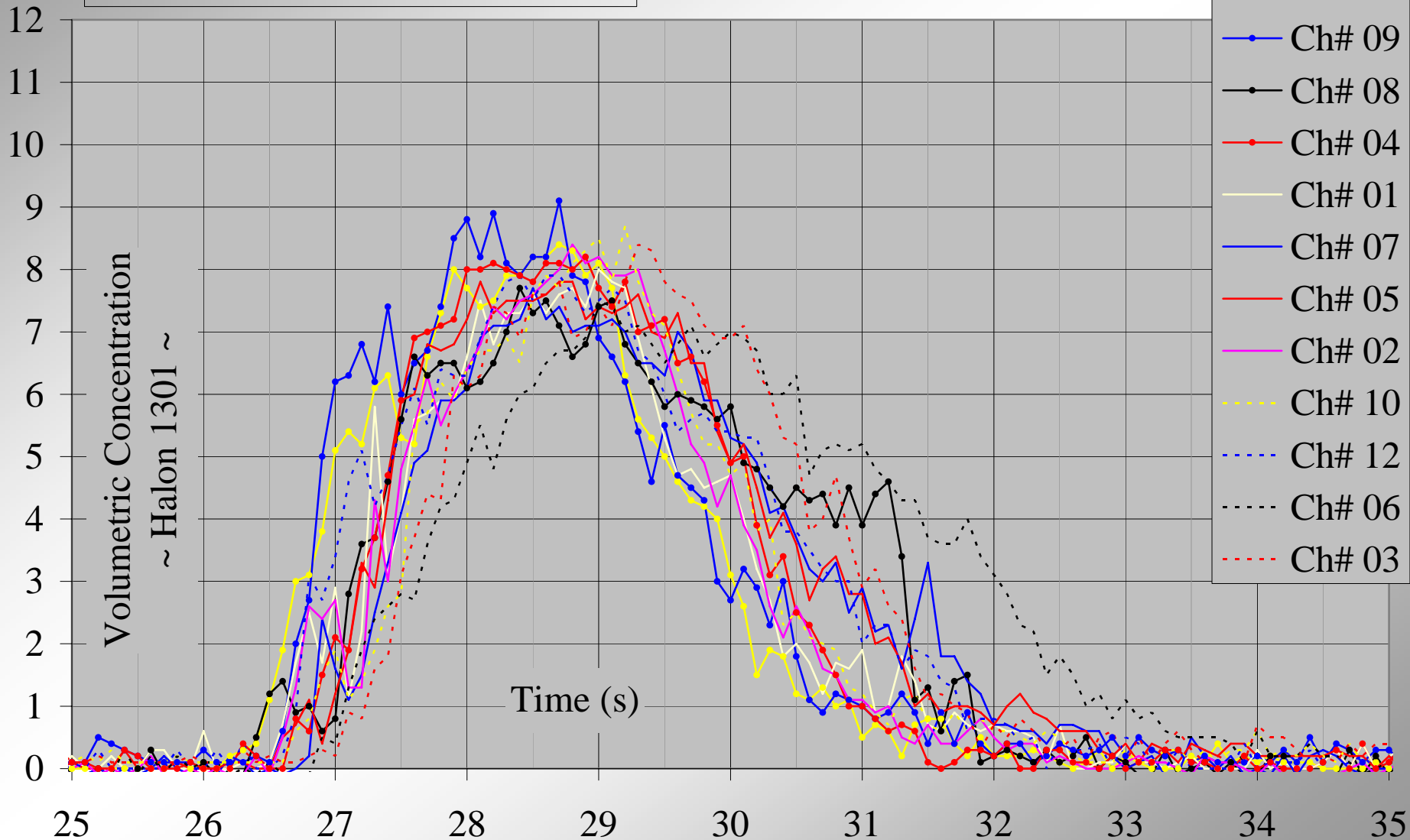
DIMENSIONS ARE IN FEET UNLESS NOTED OTHERWISE

IMAGERY – TYPICAL H1301 CERTIFICATION GRAPH, HiVent

1301 03 324 12 c

Agent Concentration Profile

~ Ventilation @ 2.7 lb/s @ 100°F ~ (1.2 kg/s @ 38°C)

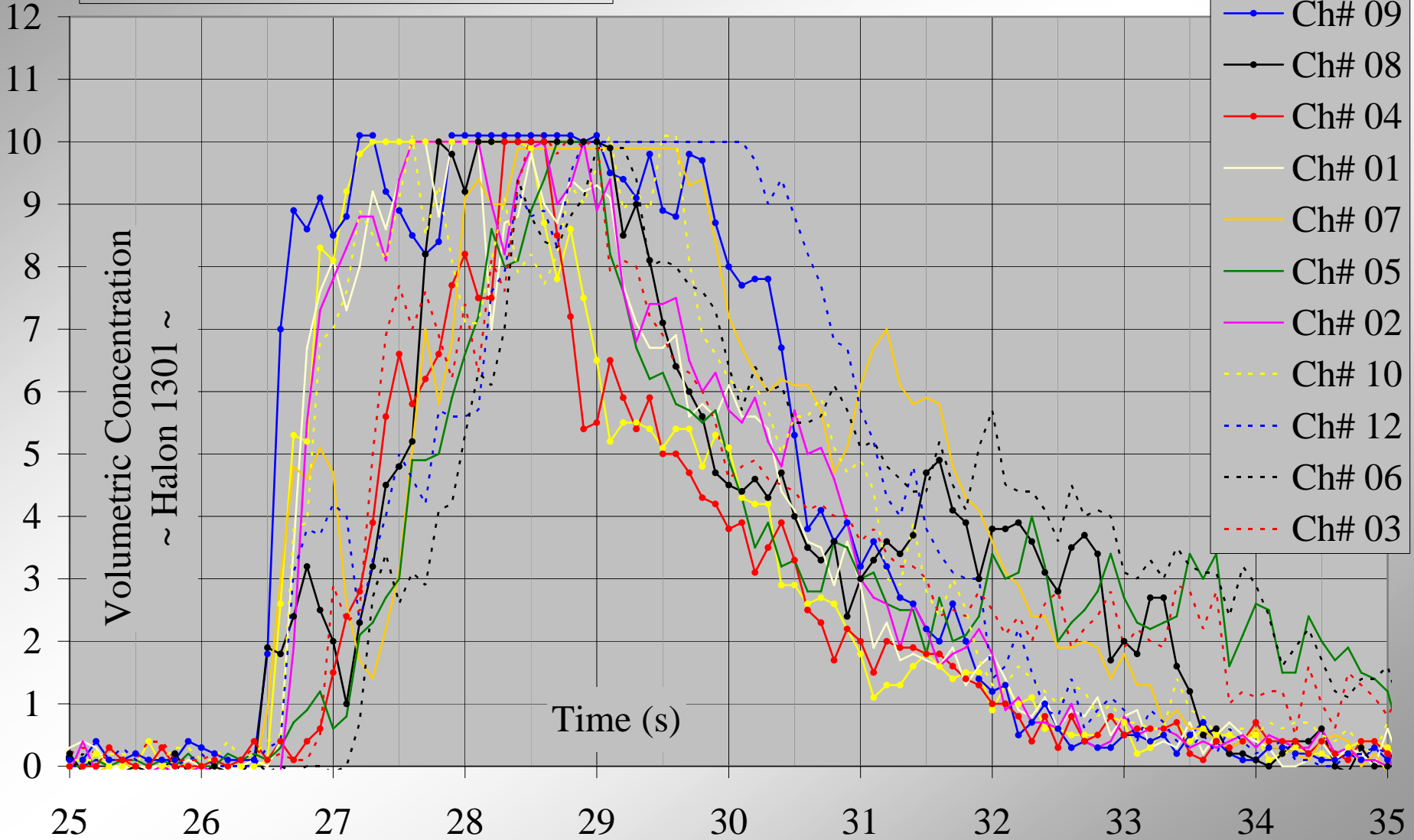


IMAGERY – TYPICAL H1301 CERTIFICATION GRAPH, LoVent

1301 03 506 16 c

Agent Concentration Profile
~ Ventilation @ 1.0 lb/s @ 260°F ~

(0.5 kg/s @ 127°C)

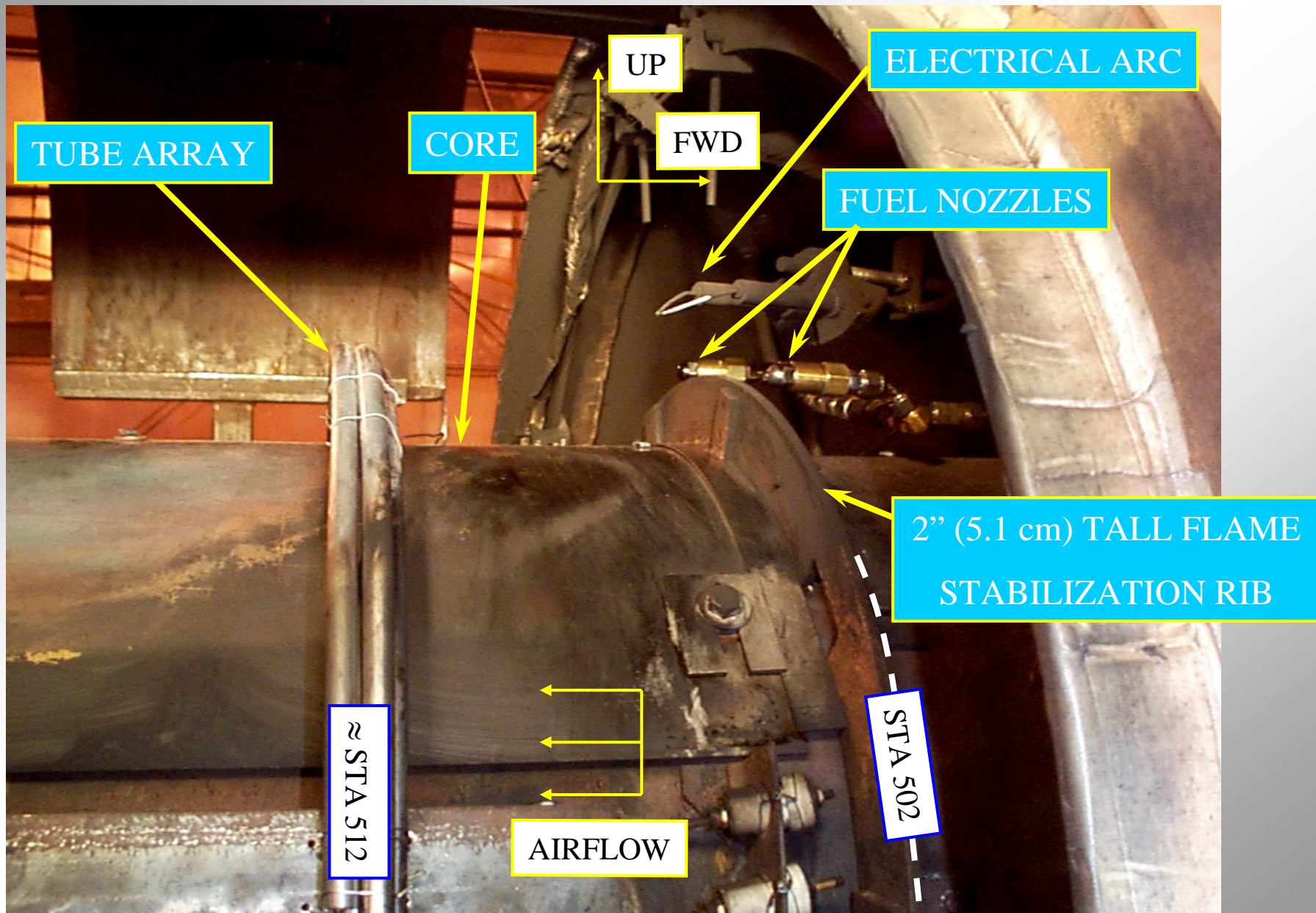


EQUIVALENCE METHODOLOGY – MASS

→ DEFINING THE H1301 BENCHMARK

- ◆ DETERMINED FOR EACH TEST CONFIGURATION
 - ✦ RESULT FROM 1 FIRE TEST = REIGNITION TIME DELAY (RTD)
 - ✦ $RTD = \text{time (FIRE EXTINCTION)} - \text{time (FIRE REIGNITION)}$
 - ✦ RTD IS ASSESSED FROM VIDEO RECORD OF EACH FIRE TEST
 - ✦ H1301 BENCHMARK = AVERAGED RTDs FROM 5 REPEATED FIRE TESTS = $RTD_{ave} (H1301)$
- ◆ SPRAY FIRE THREAT – JP8, LUBRICANT OR HYDRAULIC FLUID
 - ✦ $\approx 155^{\circ}\text{F @ } 0.25 \text{ GPM (} 68^{\circ}\text{C @ } 0.95 \text{ LPM)}$
 - ✦ FUEL SPRAY, ELECTRICAL ARC, & HOT SURFACE PERSIST DURING AGENT INJECTION
 - ✦ SUFFICIENTLY INTENSE; $RTD(1/2 \text{ H1301 CERTIFICATION}) \approx 0 \text{ SECOND}$
- ◆ POOL FIRE THREAT – JP8
 - ✦ $\approx 155^{\circ}\text{F @ } 220 \text{ IN}^2 \times 0.5 \text{ IN DEEP (} 68^{\circ}\text{C @ } 0.14 \text{ m}^2 \times 1.27 \text{ cm)}$
 - ✦ ELECTRICAL ARC PERSISTS DURING AGENT INJECTION
 - ✦ SUFFICIENTLY INTENSE; $RTD(1/2 \text{ H1301 CERTIFICATION}) \approx 0 \text{ SECOND}$

IMAGERY - SPRAY FIRE ZONE



BATT. 00:07:37:43
CH.00 SEP.14,04 14:00:15

TUBE ARRAY

ELECTRICAL ARC

FUEL NOZZLES

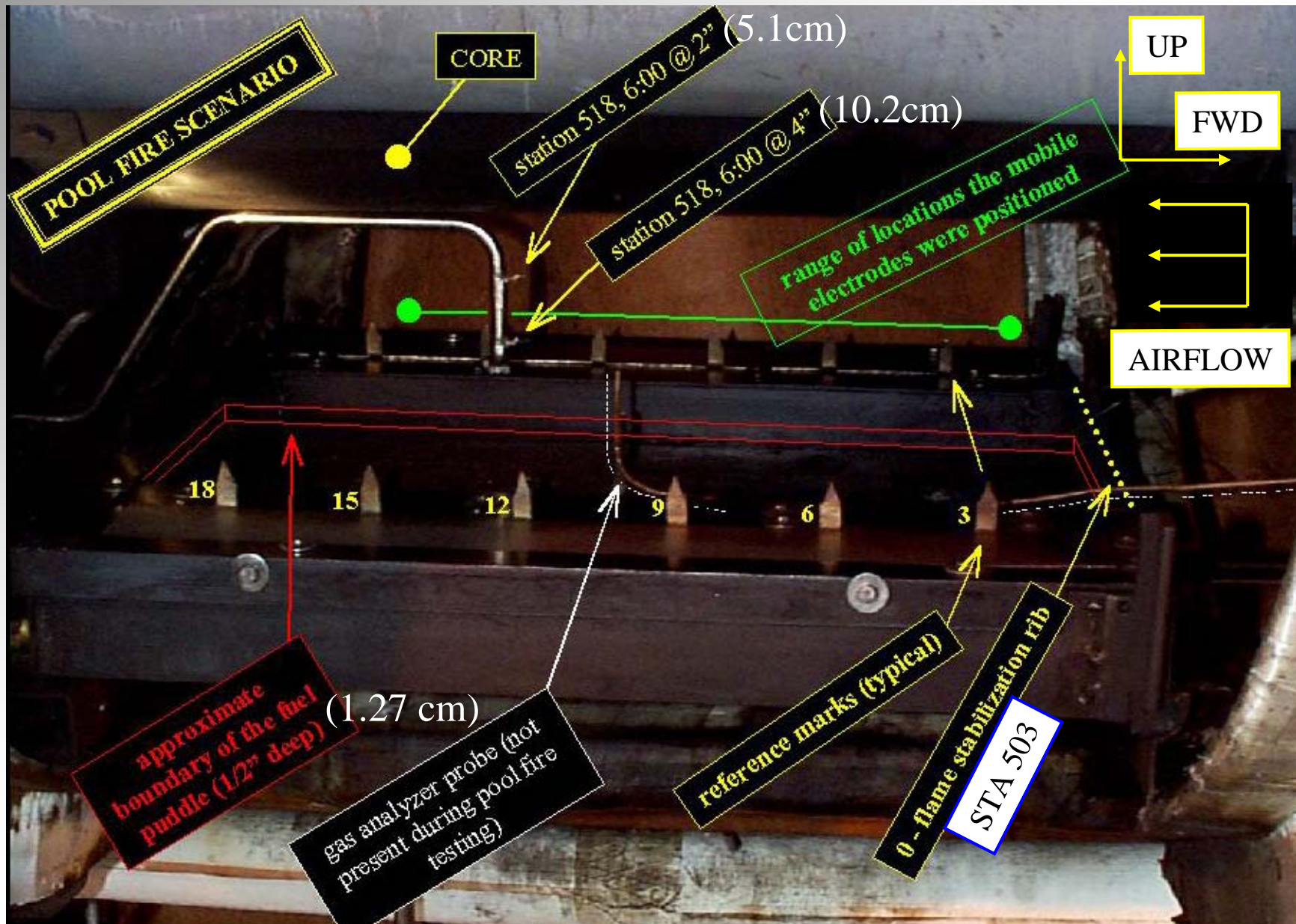
≈ STA 512

STA 502

AIRFLOW

(04914_14, Halon 1301, HiVent OIL SPRAY)

IMAGERY - POOL FIRE ZONE



IMAGERY – POOL FIRE VIDEO CLIP



(03610-12, Halon 1301, HiVent jp8 POOL)

→ MASS EQUIVALENCE FOR A REPLACEMENT CANDIDATE

- ◆ COMPARISON BASIS : AVERAGE RTD FROM 5 REPEATED TESTS
- ◆ EQUIVALENCE DEFINED AS :

$$\text{RTD_ave (H1301)} \leq \text{RTD_ave (EQUIVALENT MASS)}$$

- ◆ IF A SPRAY FIRE THREAT, USE EQUIVALENT MASS AND VERIFY SUCCESS AGAINST OTHER FUELS

- ✦ HiVent VERIFICATION – LUBRICANT & HYDRAULIC FLUID
- ✦ LoVent VERIFICATION – JP8
- ✦ REPEAT 3 TESTS FOR EACH FUEL
- ✦ SUCCESS DEFINED AS :

$$\text{RTD_ave (EQUIVALENT MASS)} \leq \text{RTD_ave (VERIFICATION)}$$

EQUIVALENCE METHODOLOGY, PART II ~ CONCENTRATION EQUIVALENCE ~

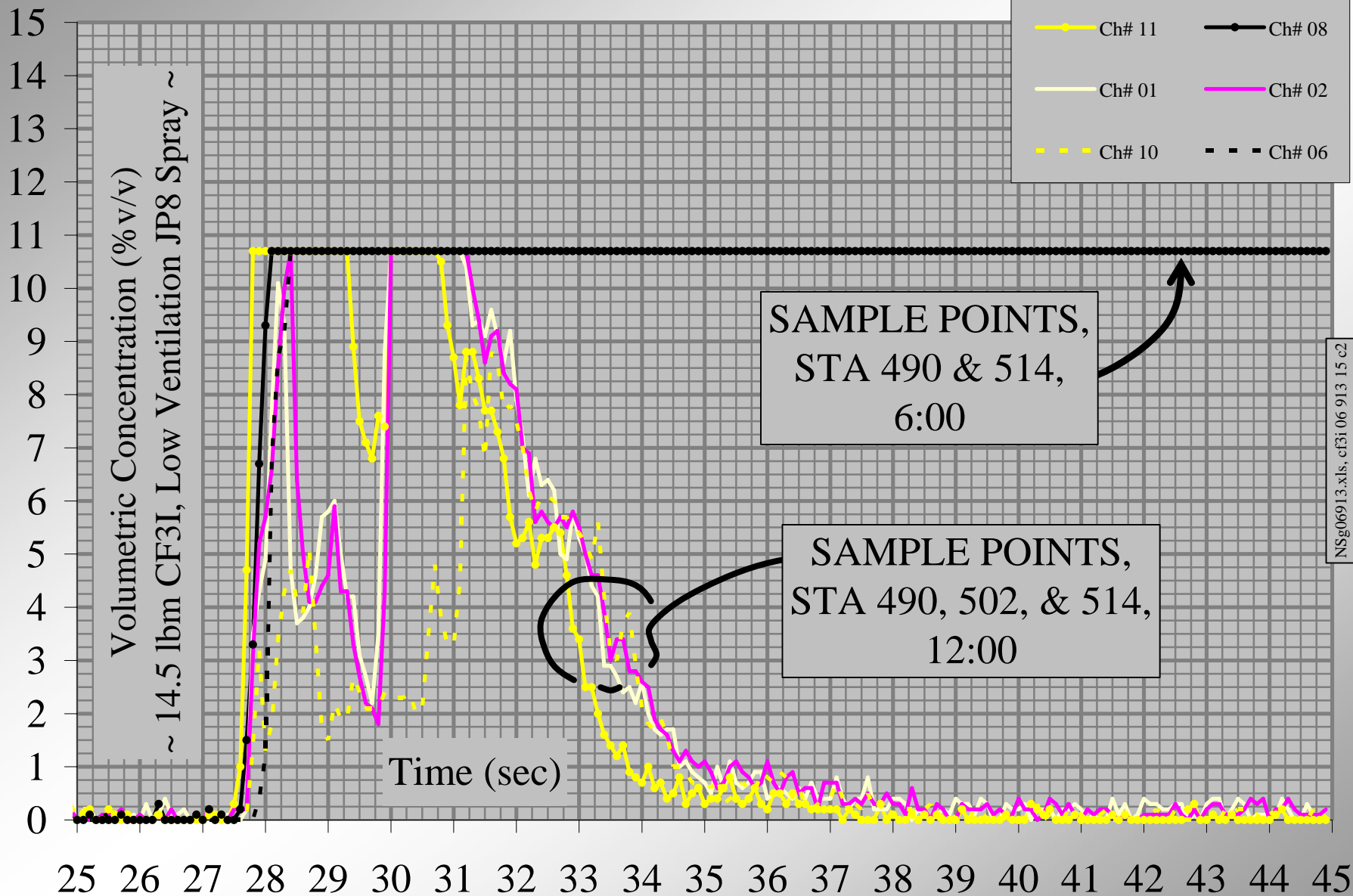
→ TREATING THE VOLUMETRIC GAS CONCENTRATION AS THE PARAMETER FOR EQUIVALENCE (NOT CITING ANY MASS USED IN THE FIREX AS A BASIS FOR EQUIVALENCE!!)

- ◆ REPLACEMENT CANDIDATE IS DELIVERED THROUGH NON-OPTIMIZED PLUMBING
- ◆ SOME NON-OPTIMIZED QUANTITY OF THE REPLACEMENT CANDIDATE WILL ACHIEVE PARITY WITH H1301 BENCHMARK
- ◆ CONCENTRATION EQUIVALENCE EVALUATED AT THE FLAME FRONT ONLY (2 CHANNELS PER TEST)

→ EQUIVALENT GAS CONCENTRATION IS BASED ON :

- ◆ CAPTURED GAS ANALYSIS DATA AT FLAME FRONT
- ◆ OBSERVED FIRE EXTINCTION BEHAVIOR

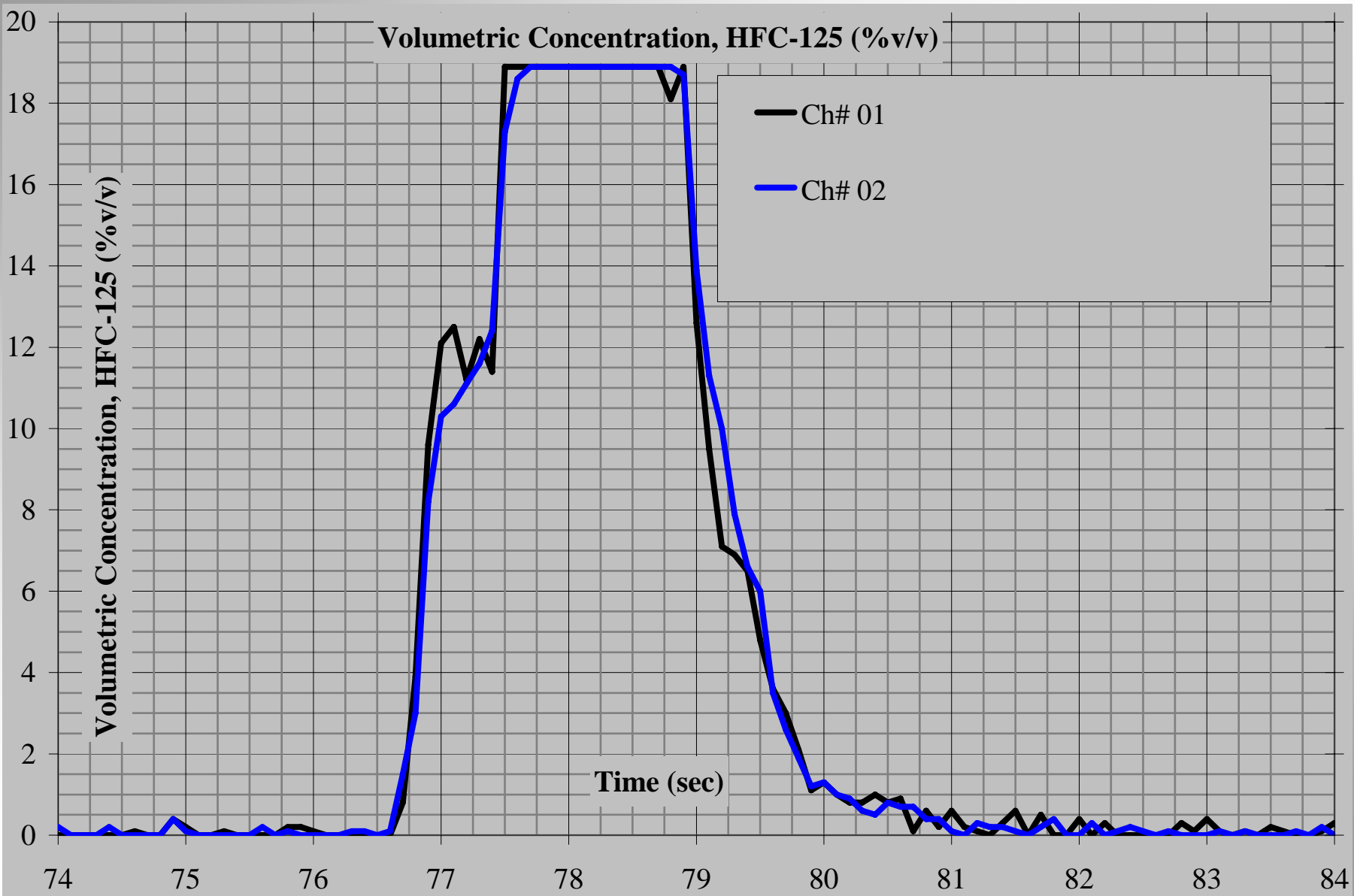
EQUIVALENCE METHODOLOGY – CONCENTRATION



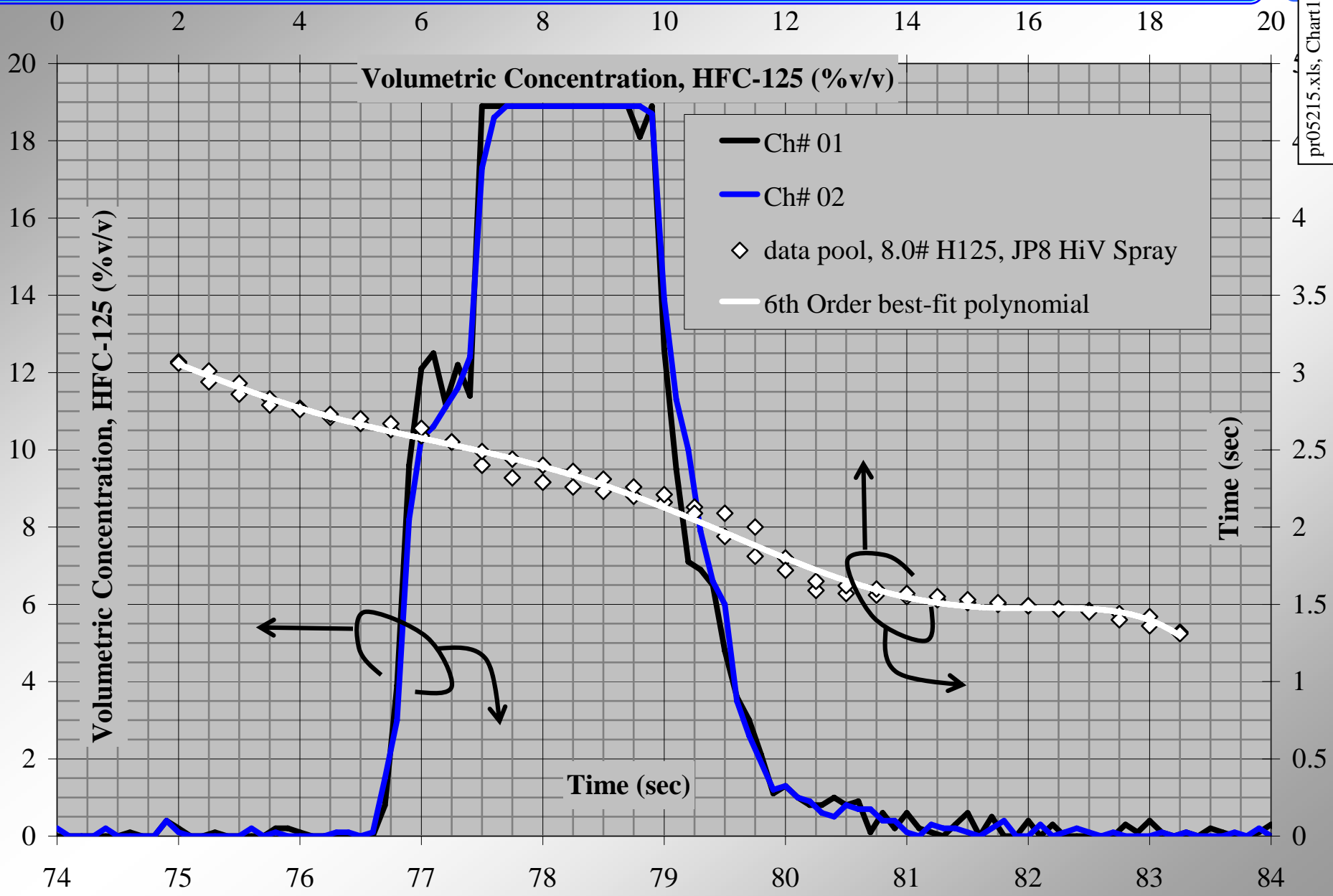
→ PROCESS

- ◆ CAPTURE GAS DISTRIBUTION OF THE EQUIVALENT MASS WITH 3 REPEATED TESTS
- ◆ COLLECT THE 2 FLAME FRONT CURVES FOR EACH TEST
- ◆ TRANSFORM FLAME FRONT, GAS CONCENTRATION CURVES
 - ✦ CURVES ARE TYPICALLY EXPONENTIAL GROWTH/DECAY
 - ✦ TRANSFORM EACH CURVE TO “CONCENTRATION vs. DURATION@CONCENTRATION”
 - ✦ CREATE A SINGLE DATA POOL OF ALL POINTS FROM THE TRANSFORMED CURVES
- ◆ MODEL THE DATA POOL WITH POLYNOMIAL BEST-FIT FUNCTION
- ◆ RECALL AVERAGE RTD FROM REPLACEMENT CANDIDATE
- ◆ USE AVERAGE RTD OF THE EQUIVALENT MASS IN THE BEST-FIT FUNCTION TO CALCULATE EQUIVALENT CONCENTRATION

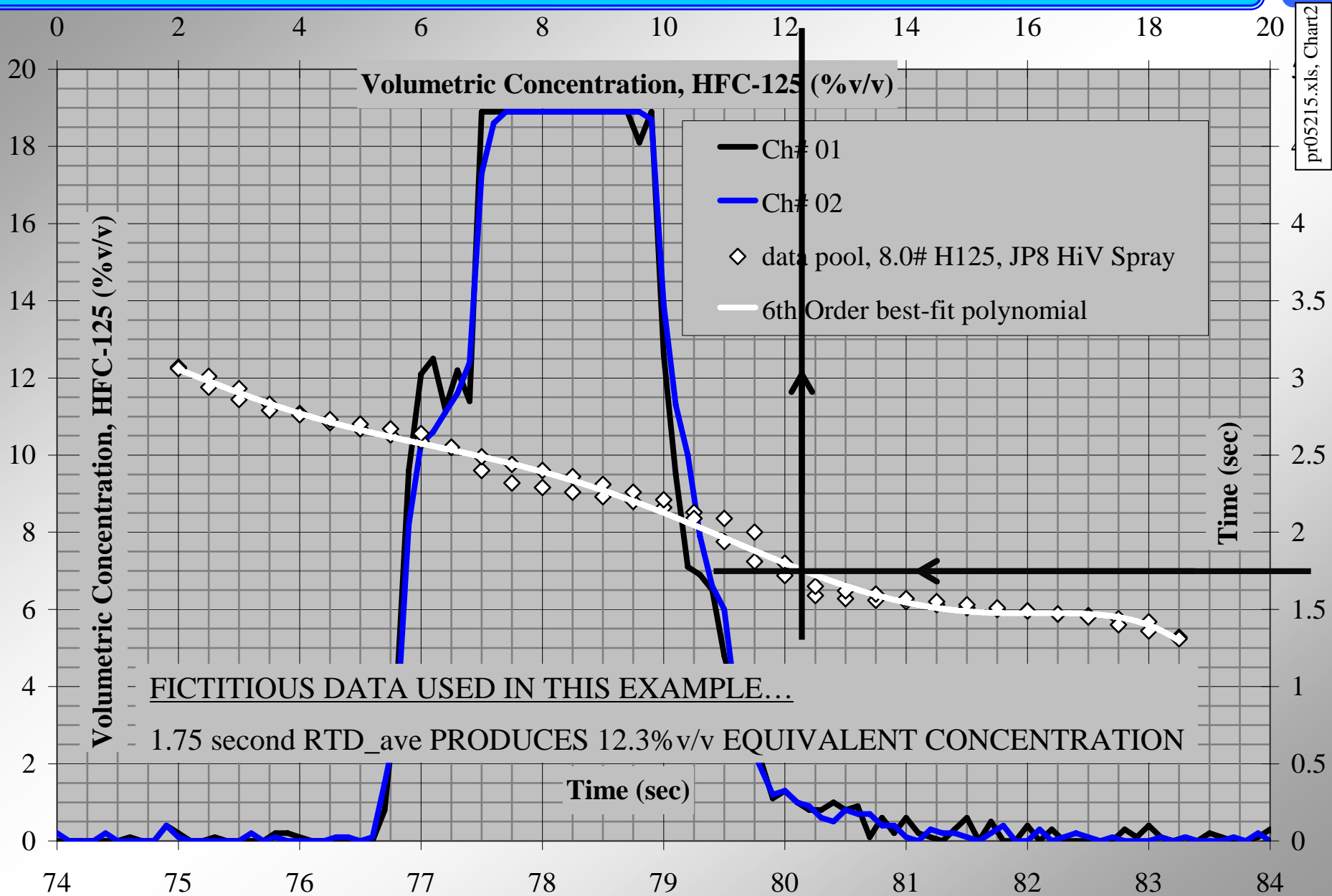
EQUIVALENCE METHODOLOGY – ILLUSTRATE TRANSFORMED CURVES



EQUIVALENCE METHODOLOGY – ILLUSTRATE TRANSFORMED CURVES



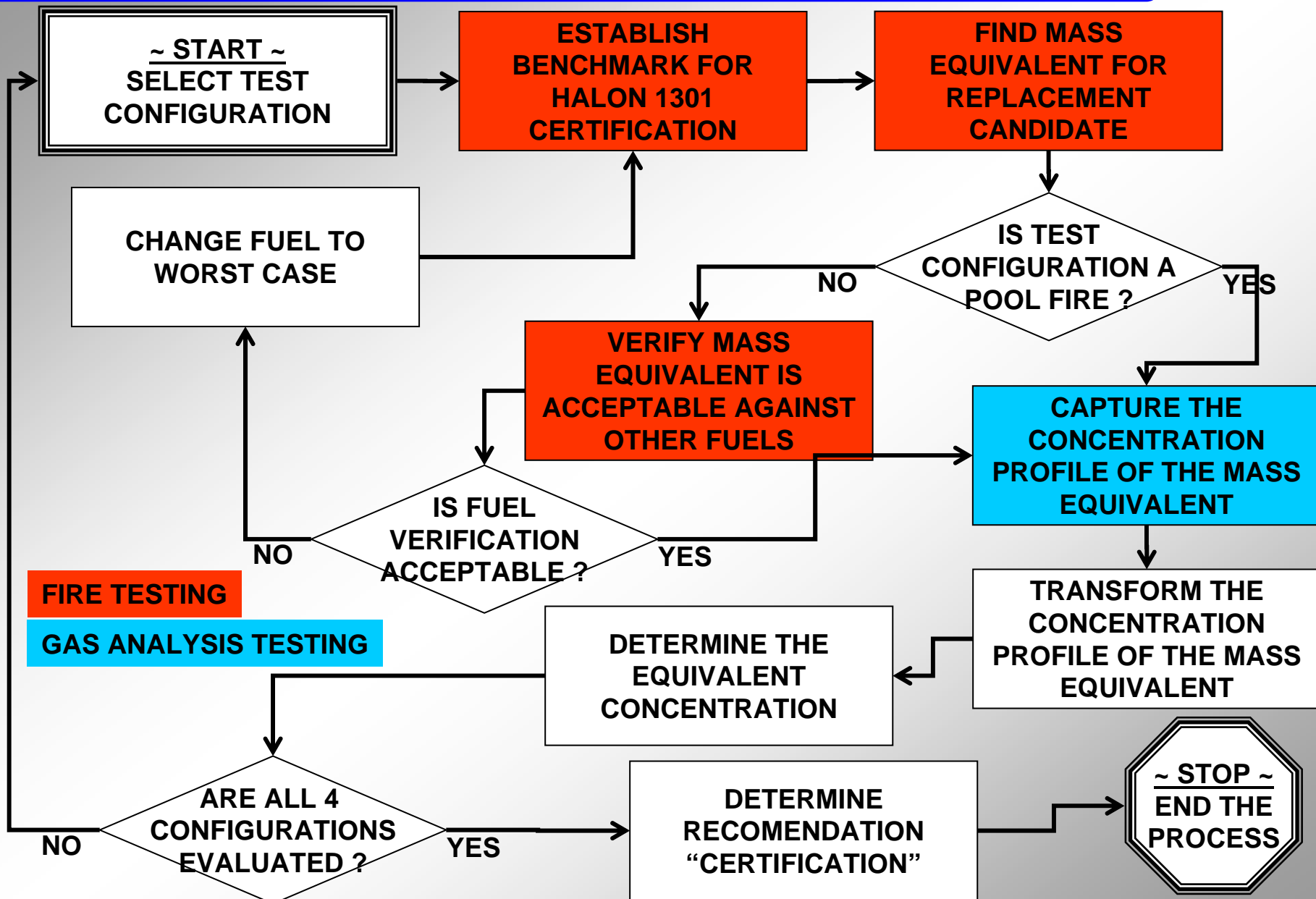
EQUIVALENCE METHODOLOGY – FIND EQUIVALENT CONCENTRATION



EQUIVALENCE METHODOLOGY

~ FLOW CHART ~

EQUIVALENCE METHODOLOGY – PROCEDURAL FLOW CHART



EQUIVALENCE METHODOLOGY

~ EXAMPLE ~

- MASS EQUIVALENCE EXAMPLE (actual data)
- EQUIVALENCE ITERATION = HiVent JP8 SPRAY FIRE
- H1301 BENCHMARK = RTD_{ave} (H1301) = 1.39 SECONDS

RTD =>	RTD#01	RTD#02	RTD#03	RTD#04	RTD#05	AVERAGE
RESULT =>	1.76	1.03	1.18	1.31	1.66	1.39

- REPLACEMENT CANDIDATE WORK WITH HFC-125

GUESSED MASS OF HFC-125 (LBM)	RTD					AVERAGE
	1	2	3	4	5	
8 (3.7 kg)	1.45	1.52	1.30	1.45	1.34	1.41
7.5 (3.4 kg)	1.48	1.26	1.32	1.19	1.09	1.27
8.0 (3.7 kg) *	1.72	2.13	1.75	--	--	1.87
8.0 (3.7 kg) **	2.32	2.19	2.5	--	--	2.34

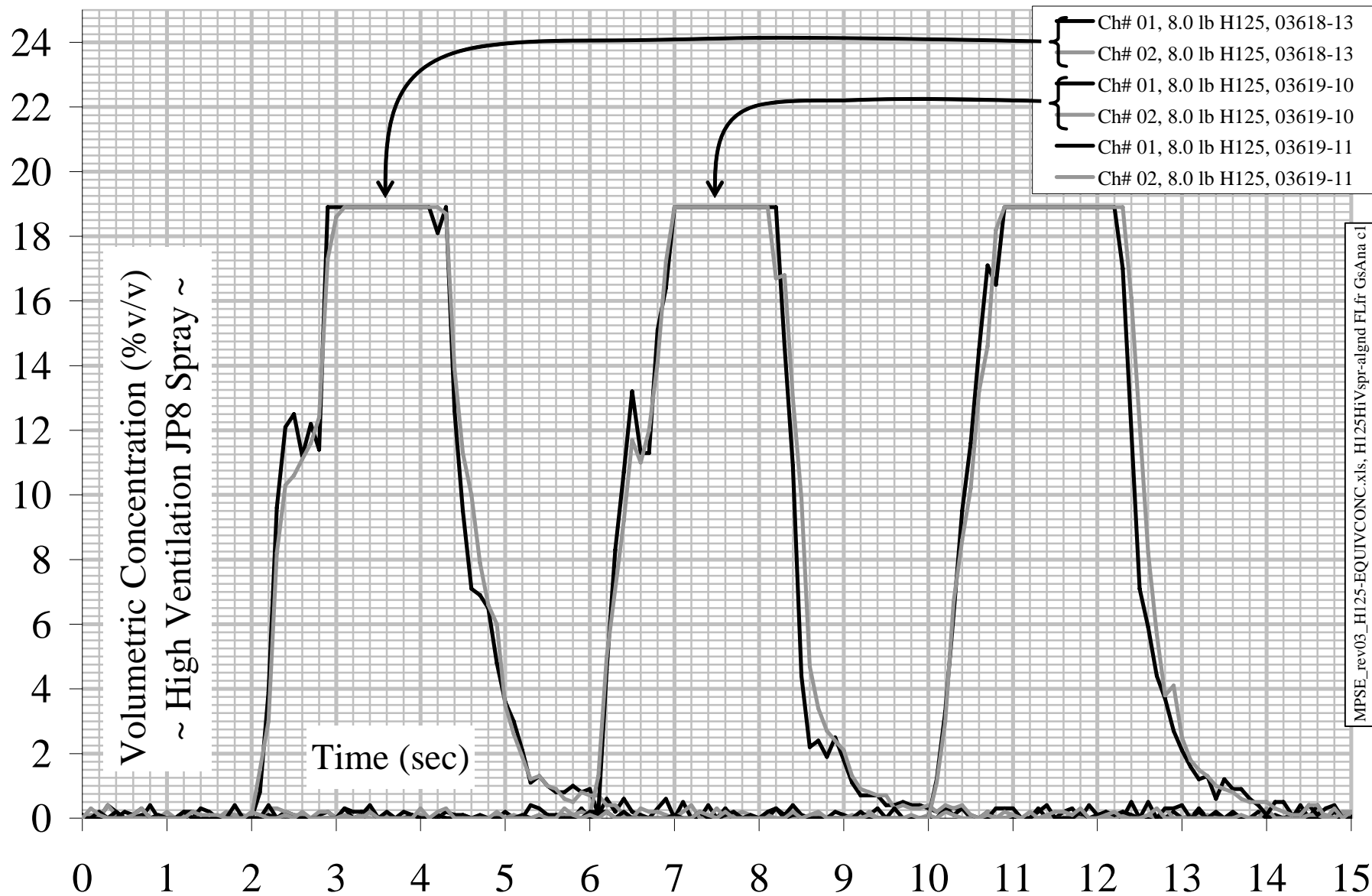
* VERIFICATION TESTS AGAINST LUBRICANT

** VERIFICATION TESTS AGAINST HYDRAULIC FLUID

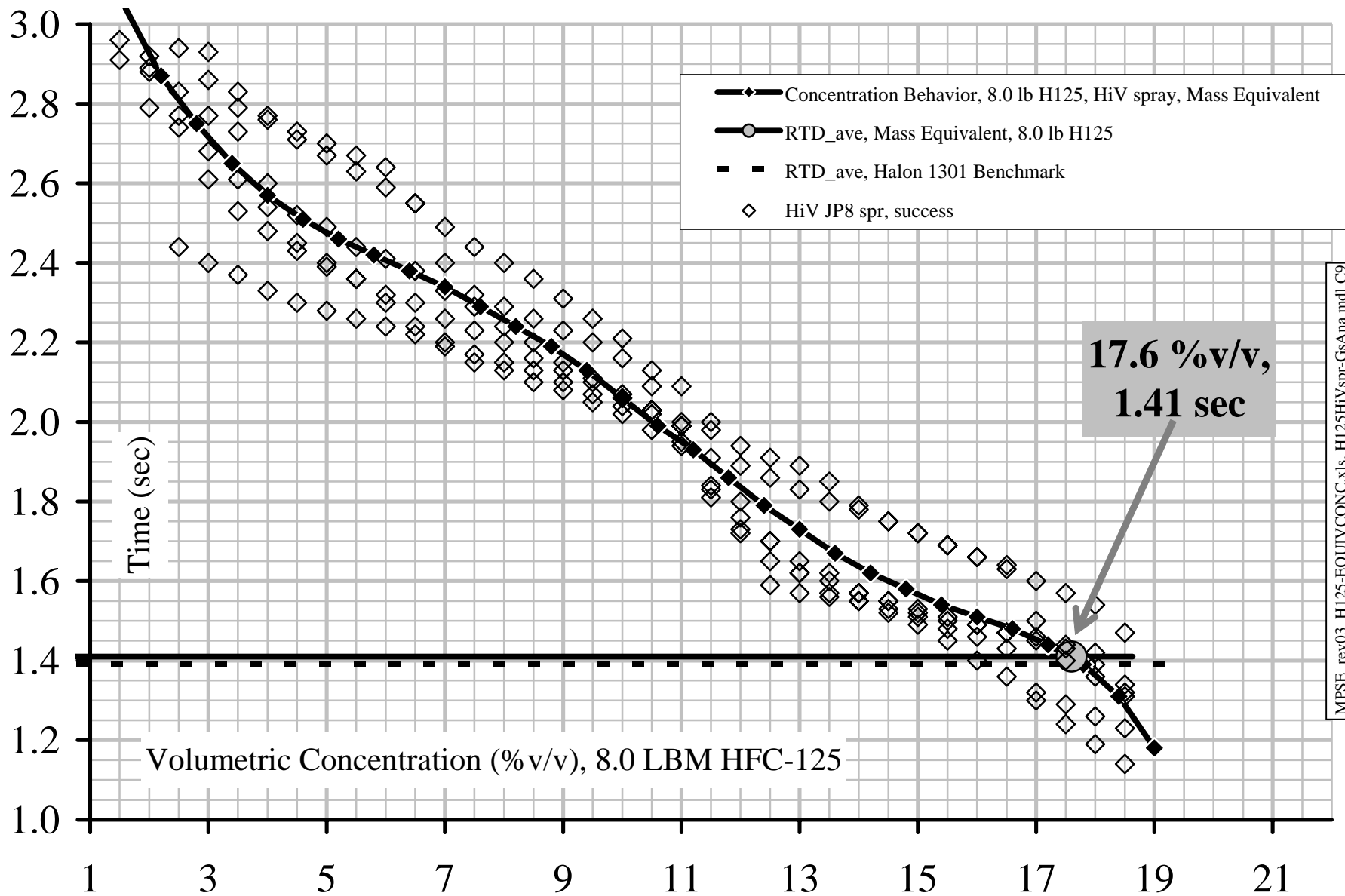
- EQUIVALENT MASS = 8.0 LBM (3.7 kg) HFC-125

- EQUIVALENT CONCENTRATION EXAMPLE
- THIS EXAMPLE IS BASED UPON DATA FOR THE DISTRIBUTION OF 8.0 LBM (3.7 kg) HFC-125
- RESTRICT DATA REVIEW TO THE 2 ANALYZER CHANNELS LOCATED AT THE SPRAY FLAME FRONT
- CALCULATION FOLLOWS IN GRAPHICAL FORMAT

EQUIVALENCE METHODOLOGY – EXAMPLE, CONCENTRATION



EQUIVALENCE METHODOLOGY – EXAMPLE, CONCENTRATION



MPSE_rev03_H125-EQUIVCONC.xls, H125HiVspr-GsAna mdl C9

RESULTS

Agent	Fire Threat	Equivalent Concentration (% v/v)	
		high ventilation	low ventilation
HFC-125	JP8 spray	17.6	14.3 (a)
	OIL spray	12.2	16.9 (b)
	pool	7.7	7.4 (a, b)
CF3I	JP8 spray	5.6	4.8 (a, c)
	OIL spray	not evaluated	7.1(a, b, c)
	pool	2.7(a, c)	not evaluated
FK-5-1-12	JP8 spray	6.1(a, c)	5.7(a, c)
	OIL spray	not evaluated	not evaluated
	pool	5.2(a, c)	5.5(a, c)

(a) Two mass equivalents used to calculate concentration equivalent

(b) Methods other than “normal” process used to determine equivalent concentration

(c) Flame attachment or existence elsewhere in the test fixture during RTD

→ “BRACKETING” MASS EQUIVALENCE

→ USE 2 DIFFERENT MASSES OF THE REPLACEMENT CANDIDATE

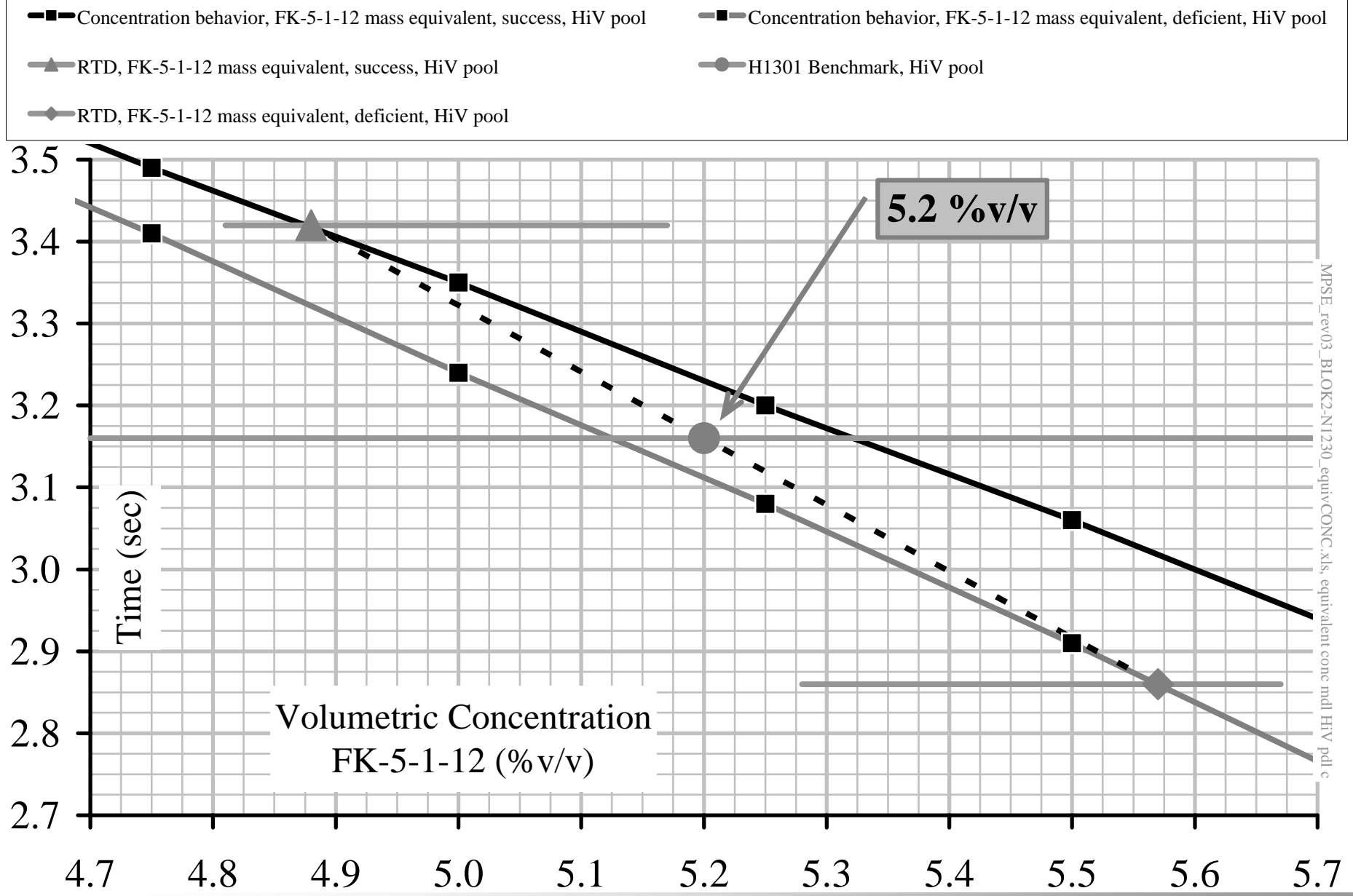
- ◆ ONE MASS PRODUCES AVERAGE RTD < BENCHMARK (DEFICIENT)
- ◆ ONE MASS PRODUCES AVERAGE RTD > BENCHMARK (SUCCESS)
- ◆ CAPTURE THE AGENT DISTRIBUTION PROFILES OF BOTH

→ CALCULATE EQUIVALENT CONCENTRATIONS FOR EACH

- ◆ SINGLE ORDERED PAIR RESULTS FOR EACH MASS EQUIVALENT
- ◆ ORDERED PAIR= (AVERAGE RTD, EQUIVALENT CONCENTRATION)

→ USE THE 2 ORDERED PAIRS AND THE BENCHMARK TO CALCULATE THE EQUIVALENT CONCENTRATION VIA LINEAR INTERPOLATION

RESULTS – EXPLAINING FOOTNOTES (a) IN TABULAR RESULTS



MPSE_rev03_BLOK2-N1230_equivCONC.xls; equivalent conc mdl HiV pdl c

→ CF3I; LOW VENTILATION, OIL SPRAY FIRE (7.1 % v/v)

- ◆ BULK AGENT ON-HAND RUNNING LOW
- ◆ RAN 3 FIRE TESTS FOR DEFICIENT MASS EQUIVALENT
- ◆ RAN 4 FIRE TESTS FOR SUCCESSFUL MASS EQUIVALENT
- ◆ CAPTURED EACH MASS WITH 3 REPEATED GAS ANALYZER TESTS

→ HFC-125; LOW VENTILATION, JP8 POOL (7.4 % v/v)

- ◆ TWO MASS EQUIVALENTS USED; BOTH SUCCESSFUL
- ◆ EXTRAPOLATION USED TO CALCULATE EQUIVALENT CONCENTRATION
- ◆ NO PHYSICAL WAY TO PRODUCE THE LARGEST EQUIVALENT CONCENTRATION (...17.6% v/v for JP8 HiVent SPRAY)

→ HFC-125; LOW VENTILATION, OIL SPRAY (16.9 % v/v)

- ◆ DETERMINED ONE SUCCESSFUL MASS EQUIVALENT
- ◆ DETERMINED SLOPE FROM PREVIOUS TESTING USING 2 MASS EQUIVALENCES AT LOW VENTILATION, JP8 SPRAY
- ◆ RAN JP8 SLOPE THROUGH THE OIL DATA POINT

SUMMARY/STATUS

→ CONCLUDED (for now?)

→ LARGEST EQUIVALENT CONCENTRATIONS DETERMINED

- ◆ CF3I, 7.1 % v/v
- ◆ FK-5-1-12, 6.1 % v/v
- ◆ HFC-125, 17.6 % v/v

→ REPORT FOR THE RELATED WORK PLACED IN FAA DOCUMENT REVIEW PROCESS

- ◆ PUBLICATION DATE UNKNOWN
- ◆ MINIMUM PREFORMANCE STANDARD IS APPENDIX A