



Federal Aviation  
Administration

# Aircraft Ducting Flammability Test Method Precision Analysis

**INTERLABORATORY STUDY  
(ROUND-ROBIN) RESULTS**

Presented to: The International Aircraft Material  
Fire Testing Working Group

By: John Reinhardt, Project Manager, PMP

Date: October 2009

Location: Atlantic City, NJ



# Outline



## Presentation will include:

- ✓ Round Robin Participants
- ✓ Round Robin Samples
- ✓ Radiant Panel Test Procedure
- ✓ ASTM E 691-99 Analysis
- ✓ Final Comments

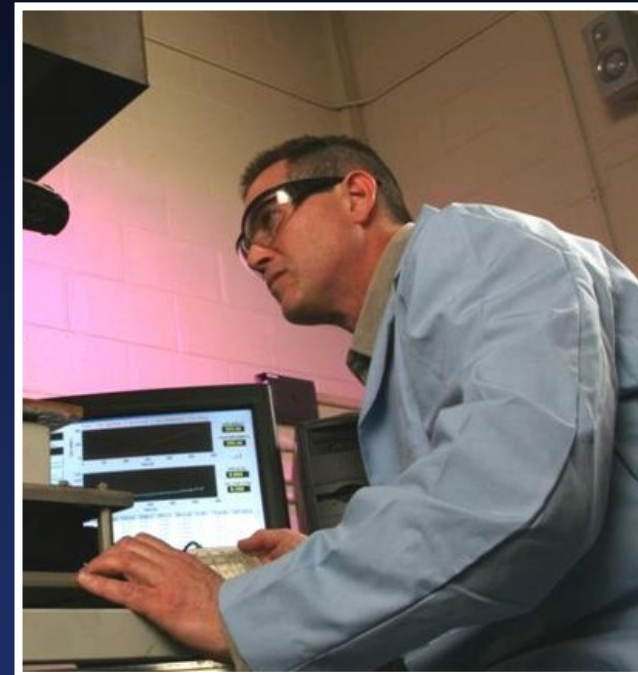


# Participants



## Round Robin Participants:

- ✓ Participants included 6 working group members.
- ✓ Participating laboratories included aircraft manufacturers, national and international government labs, testing equipment manufacturers, material manufacturers, and other aviation component suppliers.
- ✓ Participants wanted to remain anonymous

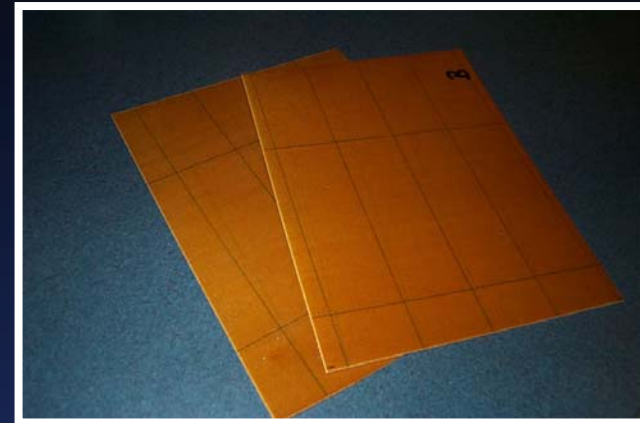


# Outline



## Presentation will include:

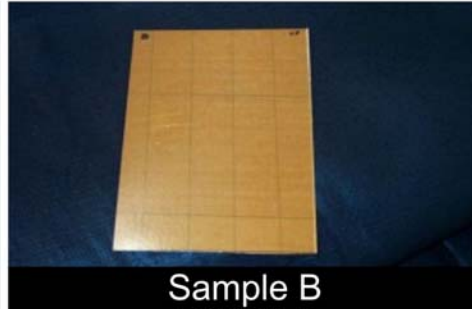
- ✓ Round Robin Participants
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- ✓ Radiant Panel Test Procedure
- ✓ ASTM E 691-99 Analysis
- ✓ Final Comments



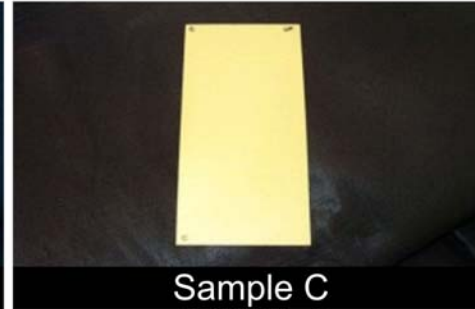
# Tested Samples



Sample A



Sample B



Sample C



Sample D



Sample E



Sample F



Sample G



Sample H



Sample I

# Tested Samples



Sample J



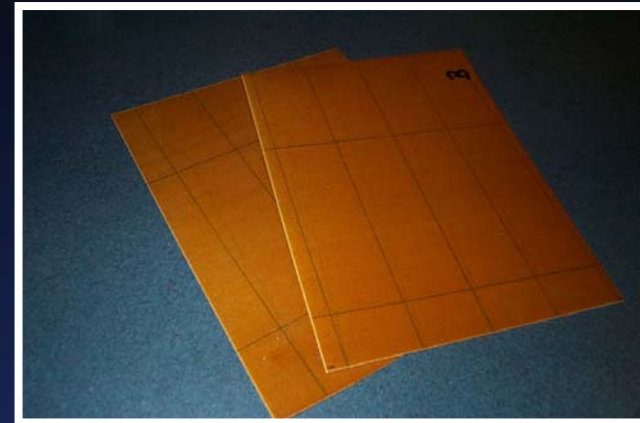
Sample K

# Outline



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# Test Procedures



## Radiant Heat Panel Test Protocol:

**Sample Size:** 21.59 cm x 27.94 cm

**Sample Placement:** 19.05 +/-3 cm below panel

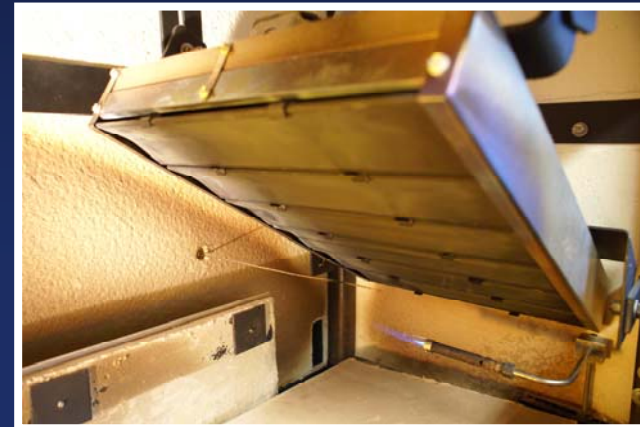
**Heat Source:** Radiant Heat Panel & Propane Flame (1.3 kW/m<sup>2</sup> panel, +1093°C pilot)

**Heat Source Exposure:** 1 minute pre-heat, then pilot flame impingement for 15 seconds

### Acceptance Criteria:

**Max Flame Propagation:** =< 5.08 cm

**Max After Flame Extinguishing Time:** =< 45 seconds



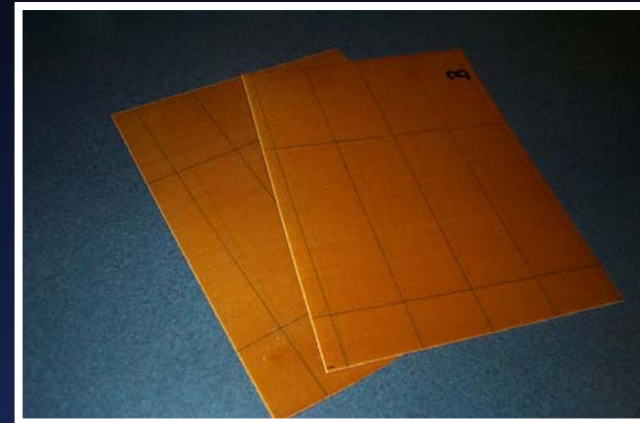


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## ASTM E 691-99 Objectives

- This practice describes the techniques for planning, conducting, analyzing, and treating the results of an Interlaboratory study (ILS).
- Its primary purpose is to develop the information needed for a precision statement pertaining to both within-laboratory repeatability and between-laboratory reproducibility.





## Terminology

- Repeatability Conditions – refers to test results obtained with the same method on identical items in the same laboratory by the same operator using the same equipment within short intervals of time.
- Repeatability Standard Deviation ( $S_r$ ) – it is the standard deviation of test result obtained under repeatability conditions.

$$S_r = \sqrt{\sum_1^p s^2 / p}$$

In where:

s = each lab standard deviation, and

p = the number of laboratories



## Terminology

- Reproducibility Conditions – refers to test results obtained with the same method on identical test items in different laboratories with different operators using different equipment.
- Reproducibility Standard Deviation ( $S_R$ ) – it is the standard deviation of test result obtained under reproducibility conditions.

$$S_R = \sqrt{S_{\bar{X}}^2 + S_r^2(n-1)/n}$$

In where:

$S_{\bar{X}}$  = Standard deviation of laboratories averages

$S_r$  = Repeatability standard deviation

$n$  = Number of tests per sample



## Terminology

- Critical Values of the Consistency Statistics – There are two statistical values calculated to determine the test consistency, h & k. These values give a picture of the overall character of the variability of the test method as well as singling out particular laboratories that should be investigated. The “h” gives the between-laboratory consistency and “k” the within-laboratory consistency.

$$h = d/S_x$$

$$k = s/S_r$$

In where:

d = deviation of one lab/one material average from all labs/one material average

$S_x$  = Standard deviation of laboratories averages

s = standard deviation for one lab/one material

$S_r$  = the repeatability standard deviation (one material)

# ASTM E 691-99 Analysis



## Raw Data: Round Robin Test 1

Laboratory	Material																					
	A		B		C		D		E		F		G		H		I		J		K	
	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)
1	0.0	2.0	2.4	3.0	0.6	2.0	1.4	3.0	3.2	2.5	2.5	3	37.2	2.5	12.3	2.5	150 +	12 +	150 +	3.5	0.0	2.0
	0.0	2.0	5.9	3.0	0.2	2.0	1.2	3.0	4.3	2.5	1.6	3.5	41.7	2.5	26.1	2.5	150 +	12 +	150 +	3.0	0.0	2.0
	0.0	2.5	6.9	3.0	0.0	2.0	1.6	3.0	4.1	2.5	1.3	3.2	42.9	2.2	11.2	2.5	150 +	12 +	150 +	3.0	0.0	2.0
2	1.5	2.8	23.4	2.0	0.0	2.6	0.0	2.4	3.4	3.3	0.0	4.2	33.0	2.8	17.7	3.1	120.3	3.4	120.2	7.5	0.0	2.7
	0.0	2.4	10.5	2.4	0.0	2.6	0.0	2.2	4.3	3.2	0.0	4.0	37.4	3.2	6.8	3.1	120.3	3.4	120.1	8.4	1.0	2.9
	0.0	2.6	13.4	2.4	0.0	2.5	0.0	2.5	2.6	3.5	0.0	3.9	35.2	3.0	9.3	3.6	120.4	3.4	120.1	7.0	1.4	3.0
3	0.0	2.4	6.0	4.1	0.0	1.8	2.0	1.8	3.0	2.7	2.0	2.8	41.0	2.0	12.0	2.4	697.0	16.5	519.0	2.0	0.0	2.7
	4.0	2.8	9.0	2.3	0.0	1.8	2.0	1.9	3.0	3.0	0.0	4.2	53.0	2.1	14.0	2.7	604.0	16.5	456.0	2.2	0.0	2.3
	0.0	2.3	6.0	2.5	0.0	2.0	2.0	1.9	4.0	3.6	0.0	3.0	26.0	2.2	15.0	2.5	839.0	16.5	315.0	2.0	0.0	2.0
4	0.0	3.8	7.0	3.8	0.0	2.2	0.0	3.2	3.0	5.4	0.0	6.4	29.0	3.8	19.0	3.2	120+	8.9	120+	8.9	0.0	3.2
	0.0	4.4	6.0	2.9	0.0	2.2	0.0	3.8	3.0	6.4	0.0	6.0	39.0	5.1	15.0	3.2	120+	9.2	120+	10.2	0.0	3.5
	0.0	3.8	5.0	4.1	0.0	2.9	0.0	4.1	4.0	6.0	0.0	5.7	28.0	3.8	13.0	3.2	120+	8.6	120+	10.2	0.0	3.2
5	1.7	3.4	9.0	3.2	2.0	2.7	2.8	2.5	3.0	2.9	0.0	3.9	21.0	2.2	5.7	2.4	305.0	11.8	120	3.9	1.4	3.1
	1.5	3.2	2.0	2.9	3.7	2.9	4.2	2.8	2.3	2.8	0.0	4.3	19.7	2.2	5.6	2.6	129.0	4.1	120	2.2	1.3	3.5
	1.3	3.0	12.0	3.1	1.5	3.0	4.2	2.6	5.0	2.8	0.0	4.3	14.8	2.2	5.9	2.3	120.0	8.5	120	4.0	0.0	3.3
6	0.0	3.0	0.0	2.7	0.0	2.5	1.0	2.5	5.2	2.8	0.0	4.0	39.0	3.0	11.1	3.4	>120	7.6	>120	7.6	0.0	2.3
	0.0	3.0	2.4	2.7	0.0	2.7	1.5	2.9	7.2	3.2	0.0	3.8	48.3	3.3	11.7	3.4	>120	8.8	>120	8.8	0.0	2.3
	1.5	3.5	3.7	2.5	0.0	2.6	1.3	3.1	6.3	2.9	0.0	3.5	35.3	3.3	11.9	3.5	>120	8.9	>120	8.9	0.0	2.6





## Data Consistency

**MATERIAL: SAMPLE A**

Acceptance Criteria: Flame Extinguishing Time

Laboratory No.	Test Results			Average (a)	Standard Dev (s)	Deviation (d) Lab Avg - Total Avg	h = d/Sx	k = s/sr
	1	2	3					
1	0	0	0	0.0000	0.0000	-0.6389	-0.99	0.00
2	1.5	0	0	0.5000	0.8660	-0.1389	-0.22	0.81
3	0	4	0	1.3333	2.3094	0.6944	1.08	2.16
4	0	0	0	0.0000	0.0000	-0.6389	-0.99	0.00
5	1.7	1.5	1.3	1.5000	0.2000	0.8611	1.34	0.19
6	0	0	1.5	0.5000	0.8660	-0.1389	-0.22	0.81

Number of Results (n) = 3  
 Number of Labs (p) = 6  
 Average of Cell Averages (A) = 0.6389  
 Std Dev of Cell Averages (Sx) = 0.6448  
 Repeatability Std Dev (sr) = 1.0703  
 Prov Reproducibility Std Dev (SR\*) = 1.0860  
 Reproducibility Std Dev (SR) = 1.0860

<---- Use larger one for  
 SR

**h: Consistency Between Labs**

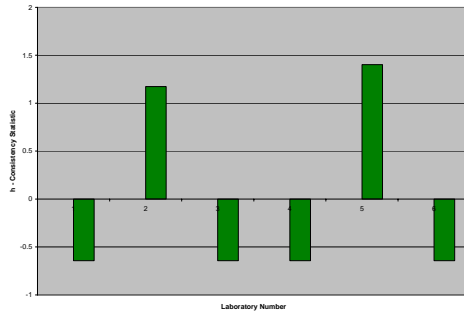
**k: Consistency Within Lab**

Note: The same calculations were performed for the burn length and other materials

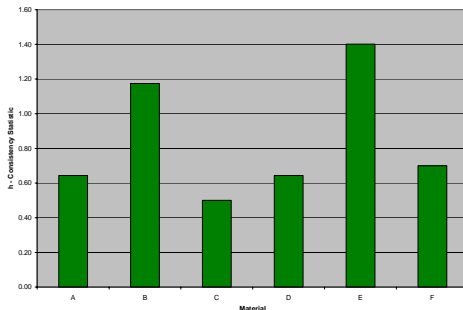


## “h” Consistency Analysis

Balanced Pattern: **Do not Investigate**

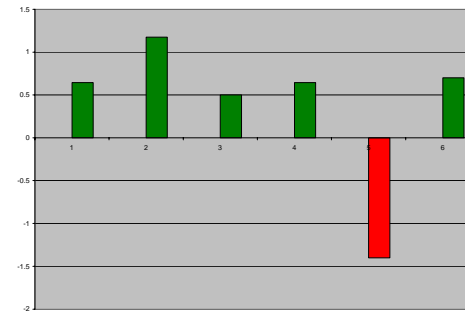


**Pattern 1: All Labs Positive & Negative h (Polarity balanced)**

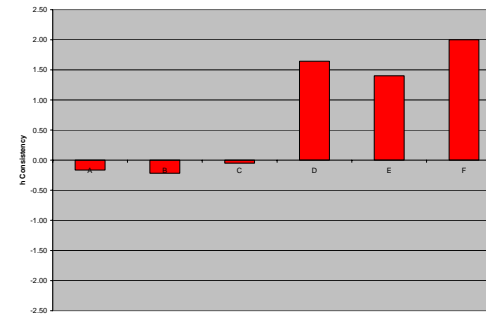


**Pattern 2: One Lab - All Positive or Negative h (But # of Negative Labs = # of Positive Labs)**

Unbalanced Pattern: **Investigate**



**Pattern 3: One Lab, with all h Negatives (or Positives), is opposed to all the other labs, with h Positives**



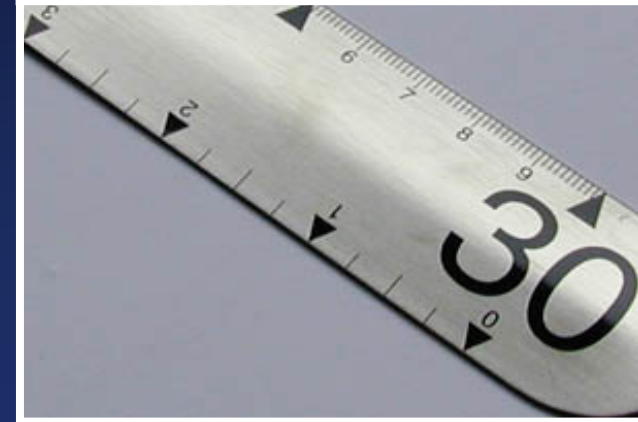
**Pattern 4: One Lab, small h Negative, large h Positive (or vice versa)**





## “k” Consistency Analysis

- **Investigate** laboratory with “**Very Low**” k values
  - ✓ May indicate a very insensitive measurement scale or other measurement problem
- **Investigate** laboratory with “**Very High**” k values
  - ✓ It represent within-laboratory imprecision





## Data Consistency h (Between-laboratories), RR Test 1

Acceptance Criteria: Flame Extinguishing Time

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	-0.99	-0.47	-0.18	0.00	-0.06	1.90	0.71	1.06	-	-	-0.64
2	-0.22	1.85	-0.46	-1.00	-0.44	-0.56	0.08	-0.29	-	-	1.17
3	1.08	-0.06	-0.46	0.43	-0.53	0.35	0.64	0.32	-	-	-0.64
4	-0.99	-0.27	-0.46	-1.00	-0.53	-0.56	-0.29	0.84	-	-	-0.64
5	1.34	0.09	2.03	1.67	-0.44	-0.56	-1.86	-1.71	-	-	1.40
6	-0.22	-1.13	-0.46	-0.10	2.01	-0.56	0.74	-0.22	-	-	-0.64

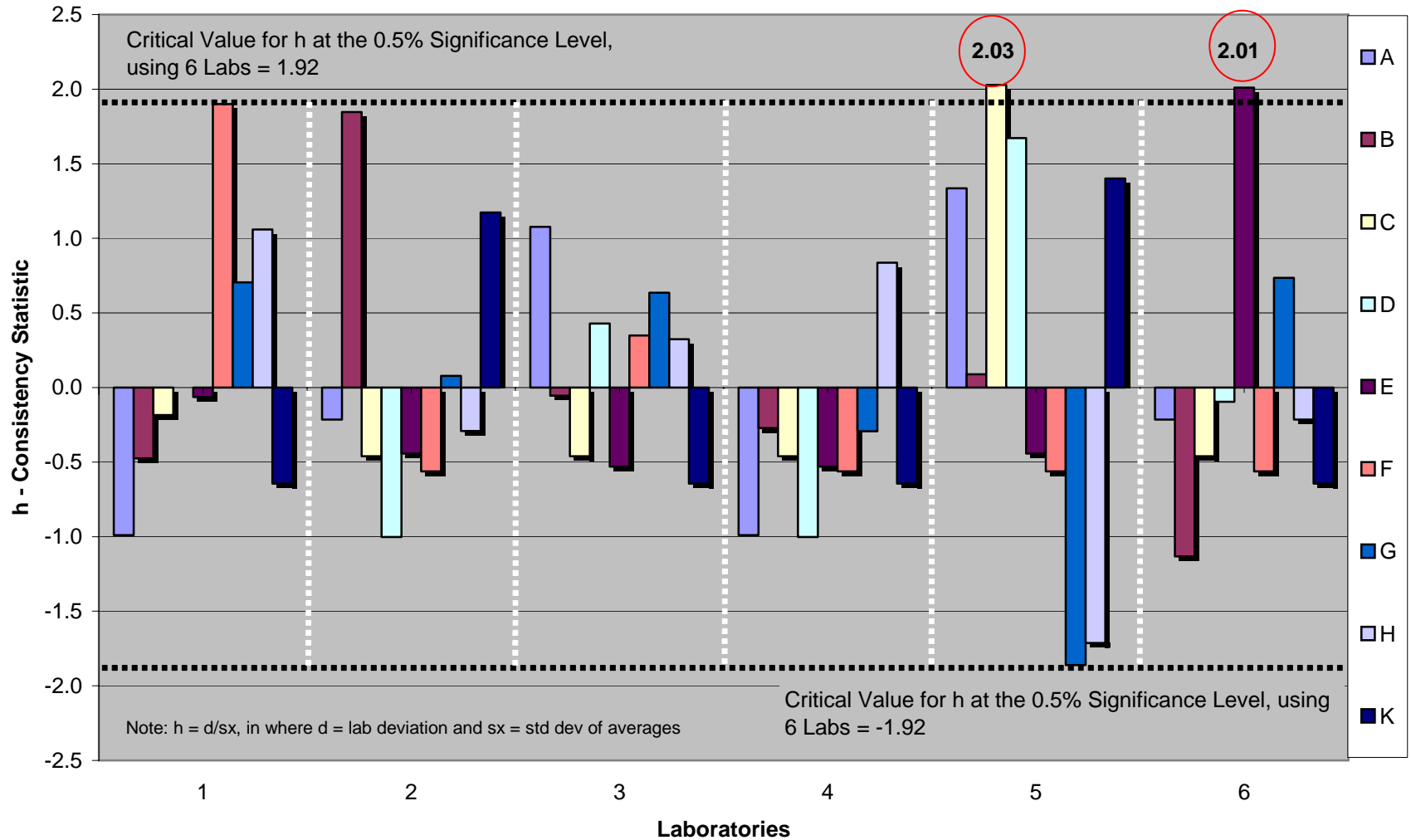
Acceptance Criteria: Burn Length

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	-1.18	0.17	-1.02	0.43	-0.76	-0.84	-0.57	-0.87	0.56	-0.79	-1.29
2	-0.52	-1.46	0.47	-0.59	-0.09	-0.06	0.18	0.82	-1.41	0.58	0.31
3	-0.67	0.10	-1.37	-1.40	-0.28	-0.75	-0.94	-0.80	1.59	-1.13	-0.68
4	1.62	1.51	0.12	1.56	1.99	1.90	1.71	0.68	-0.15	1.24	1.11
5	0.40	0.32	1.25	-0.16	-0.49	0.07	-0.81	-1.02	-0.33	-0.73	1.11
6	0.35	-0.65	0.55	0.16	-0.38	-0.32	0.43	1.19	-0.26	0.83	-0.55

$h = \text{Lab Avg Deviation} / \text{Std Dev All Labs Avg}$

**Aircraft Ducting Material RHP Tests**  
**h - Consistency Statistic**  
**Flame Extinguishing Time Data**

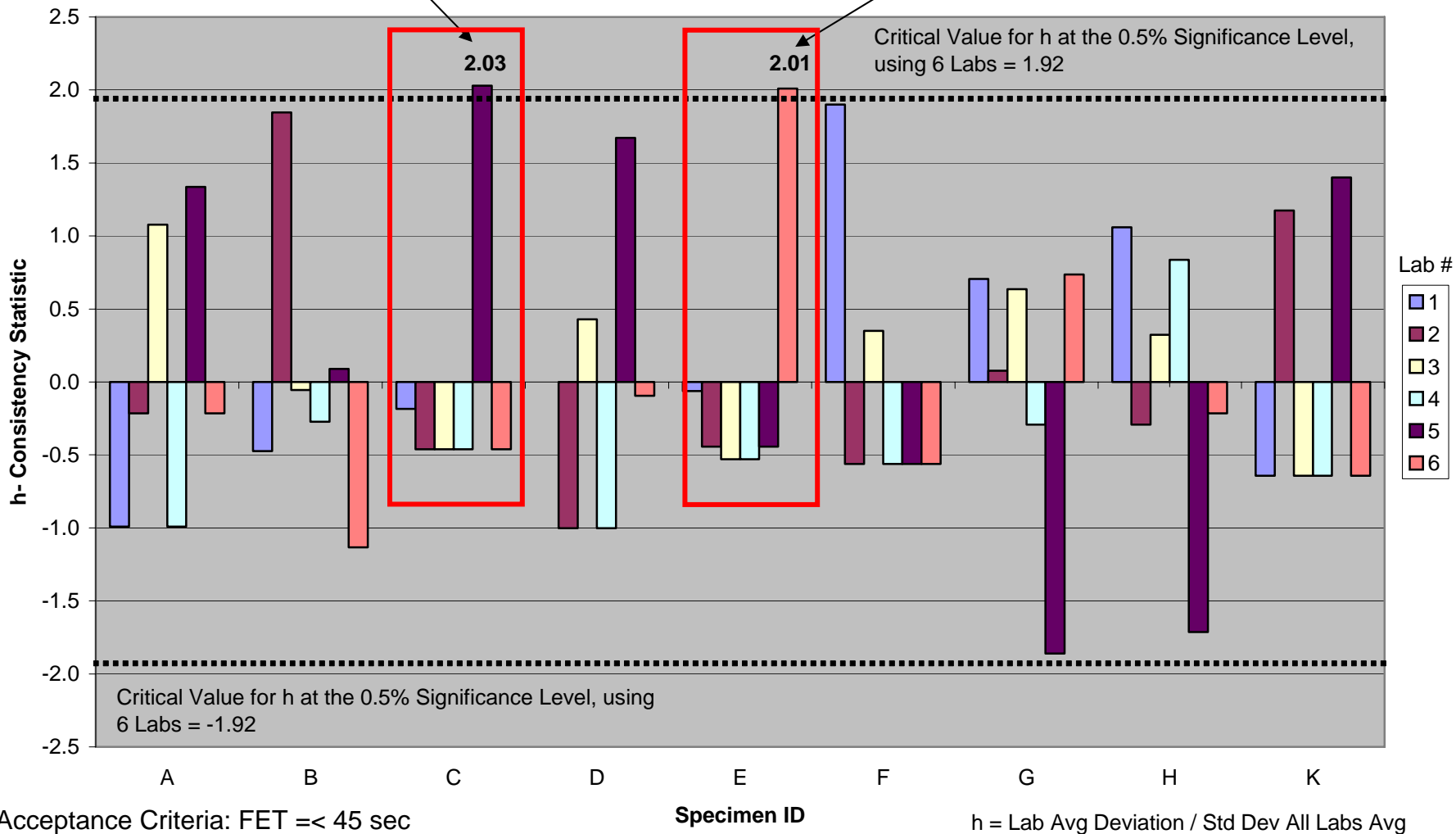
**Balanced: Pattern 1**



Aircraft Ducting Material RHP Test Method  
 h - Consistency Statistic  
 Flame Extinguishing Time Data

Lab 5 = 2.4 sec  
 All Labs Avg = 0.4 sec

Lab 6 = 6.2 sec  
 All Labs Avg = 3.9 sec



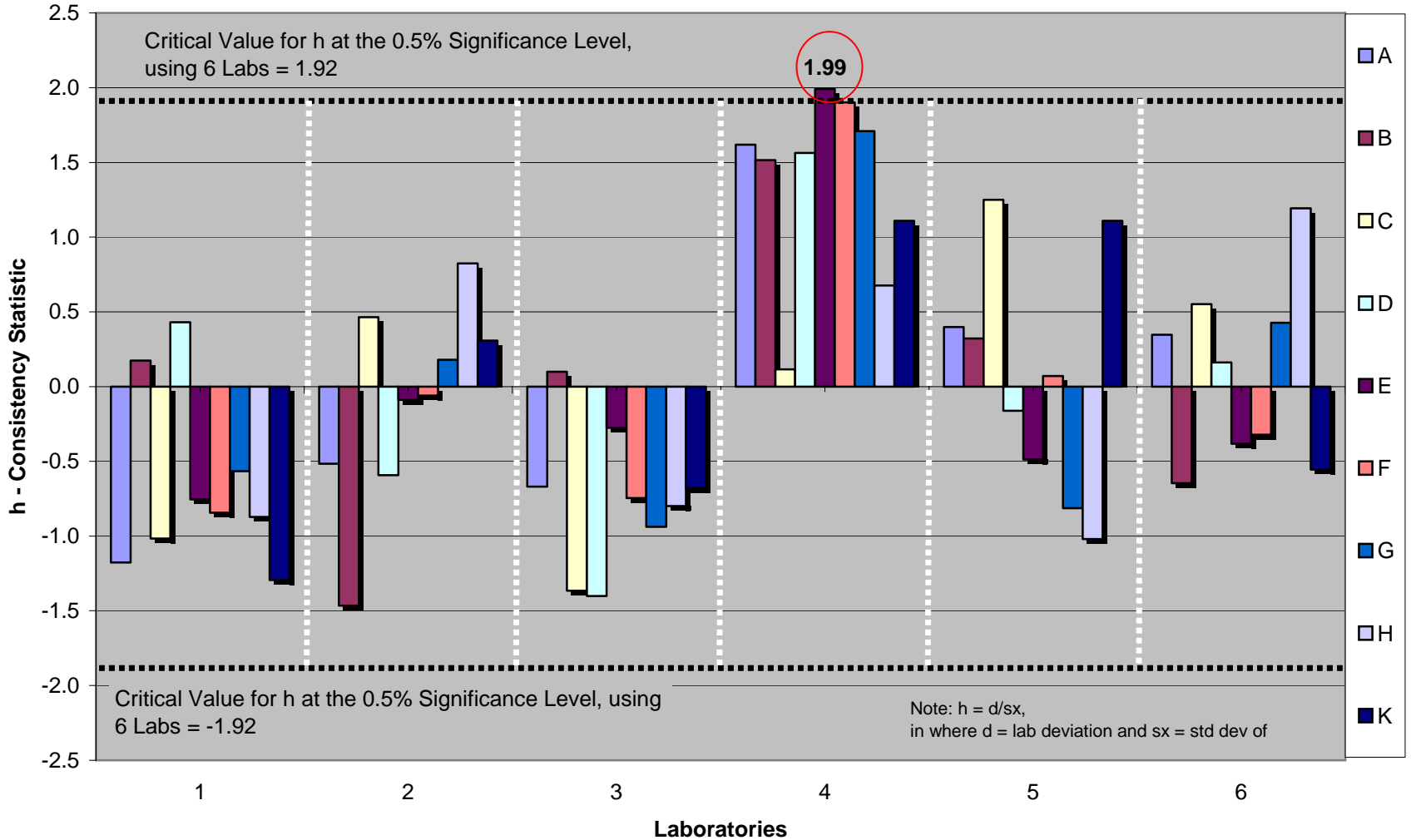


## Analysis of the AFET Consistency h Data (Between-Laboratories)

Material	Lab Exceeded Critical Value	h	Critical Value	AFET (sec)	Average <sub>All</sub> (sec)	Comment
A			+/- 1.92			
B			+/- 1.92			
C	Lab 5	2.03	+/- 1.92	2.40	0.44	Insignificant error when compared to acceptance criteria of 45 seconds
D			+/- 1.92			
E	Lab 6	2.01	+/- 1.92	6.23	3.94	Insignificant error when compared to acceptance criteria of 45 seconds
F			+/- 1.92			
G			+/- 1.92			
H			+/- 1.92			
I			+/- 1.92			
J			+/- 1.92			
K			+/- 1.92			

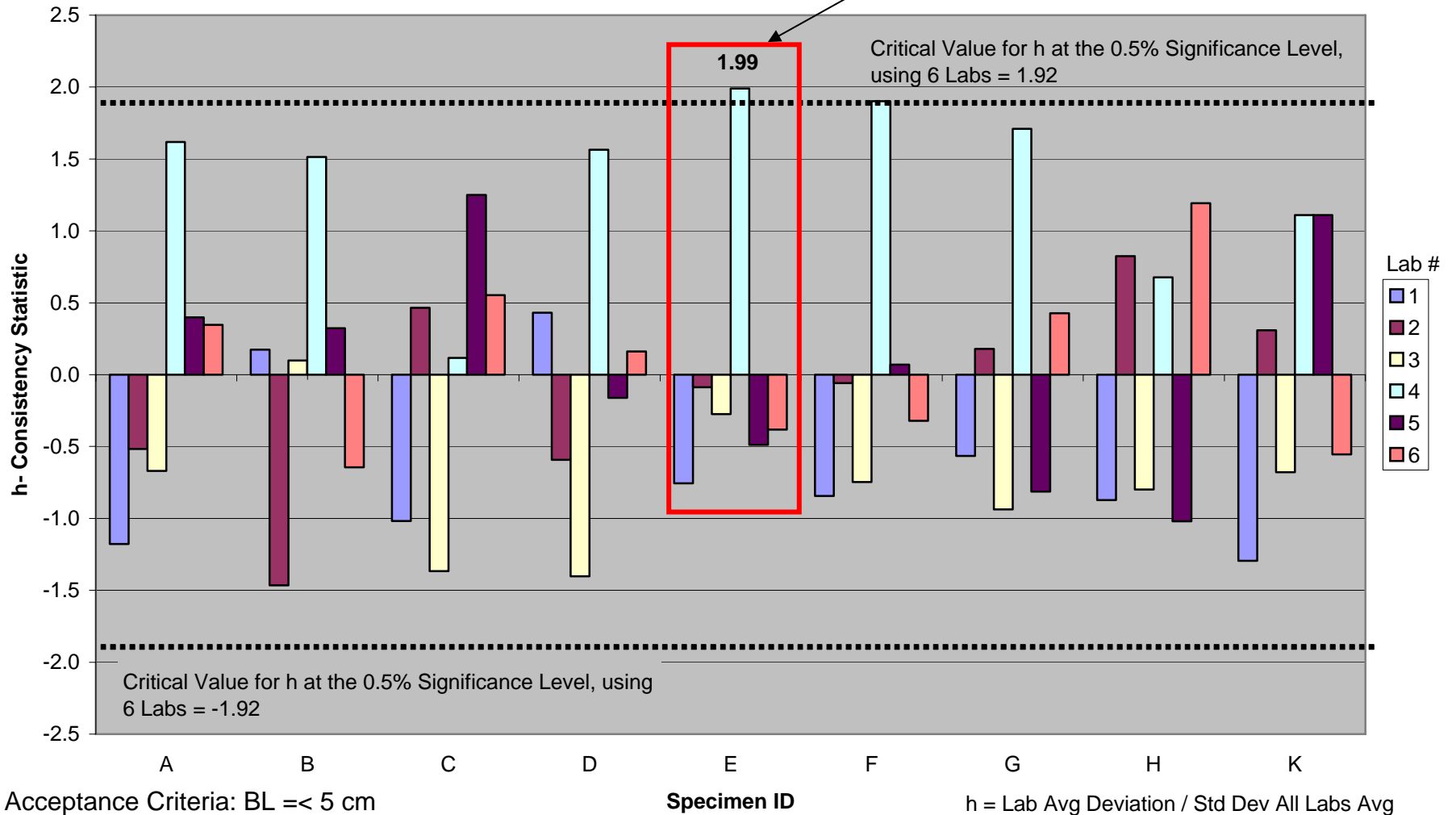
**Aircraft Ducting Material RHP Tests  
h - Consistency Statistic  
Burn Length Data**

**Balanced: Pattern 1**



Aircraft Ducting Material RHP Test Method  
 h - Consistency Statistic  
 Burn Length Data

Lab 4 = 5.9 cm  
 All Labs Avg = 3.4 cm





## Analysis of the Burn Length Consistency h Data (Between-Laboratories)

Material	Lab Exceeded Critical Value	h	Critical Value	Burn Length (cm)	Average <sub>All</sub> (cm)	Comment
A			+/- 1.92			
B			+/- 1.92			
C			+/- 1.92			
D			+/- 1.92			
E	Lab 4	1.99	+/- 1.92	5.93	3.44	Significant error because exceeded acceptance criteria of 5.08 cm
F			+/- 1.92			
G			+/- 1.92			
H			+/- 1.92			
I			+/- 1.92			
J			+/- 1.92			
K			+/- 1.92			





## Data Consistency k (Within-laboratory), RR Test 1

Acceptance Criteria: Flame Extinguishing Time

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	0.00	0.63	0.63	0.56	0.66	1.17	0.43	1.91	-	-	0.00
2	0.81	1.80	0.00	0.00	0.96	0.00	0.32	1.31	-	-	1.66
3	2.16	0.46	0.00	0.00	0.65	2.15	1.95	0.35	-	-	0.00
4	0.00	0.27	0.00	0.00	0.65	0.00	0.88	0.70	-	-	0.00
5	0.19	1.36	2.37	2.28	1.58	0.00	0.47	0.04	-	-	1.80
6	0.81	0.50	0.00	0.71	1.13	0.00	0.96	0.10	-	-	0.00

Acceptance Criteria: Burn Length

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	1.07	0.00	0.00	0.00	0.00	0.65	0.52	0.00	0.00	0.43	0.00
2	0.74	0.47	0.31	0.63	0.51	0.39	0.60	1.94	0.00	1.06	0.75
3	0.98	2.00	0.61	0.24	1.54	1.96	0.30	1.02	0.00	0.17	1.73
4	1.28	1.27	2.14	1.89	1.69	0.91	2.24	0.00	0.19	1.12	0.85
5	0.74	0.31	0.81	0.63	0.19	0.60	0.00	1.02	2.40	1.51	0.99
6	1.07	0.23	0.53	1.26	0.70	0.65	0.52	0.39	0.45	1.08	0.85

# Aircraft Ducting Material RHP Test Method

## k - Consistency Statistic

### Flame Extinguishing Time Data

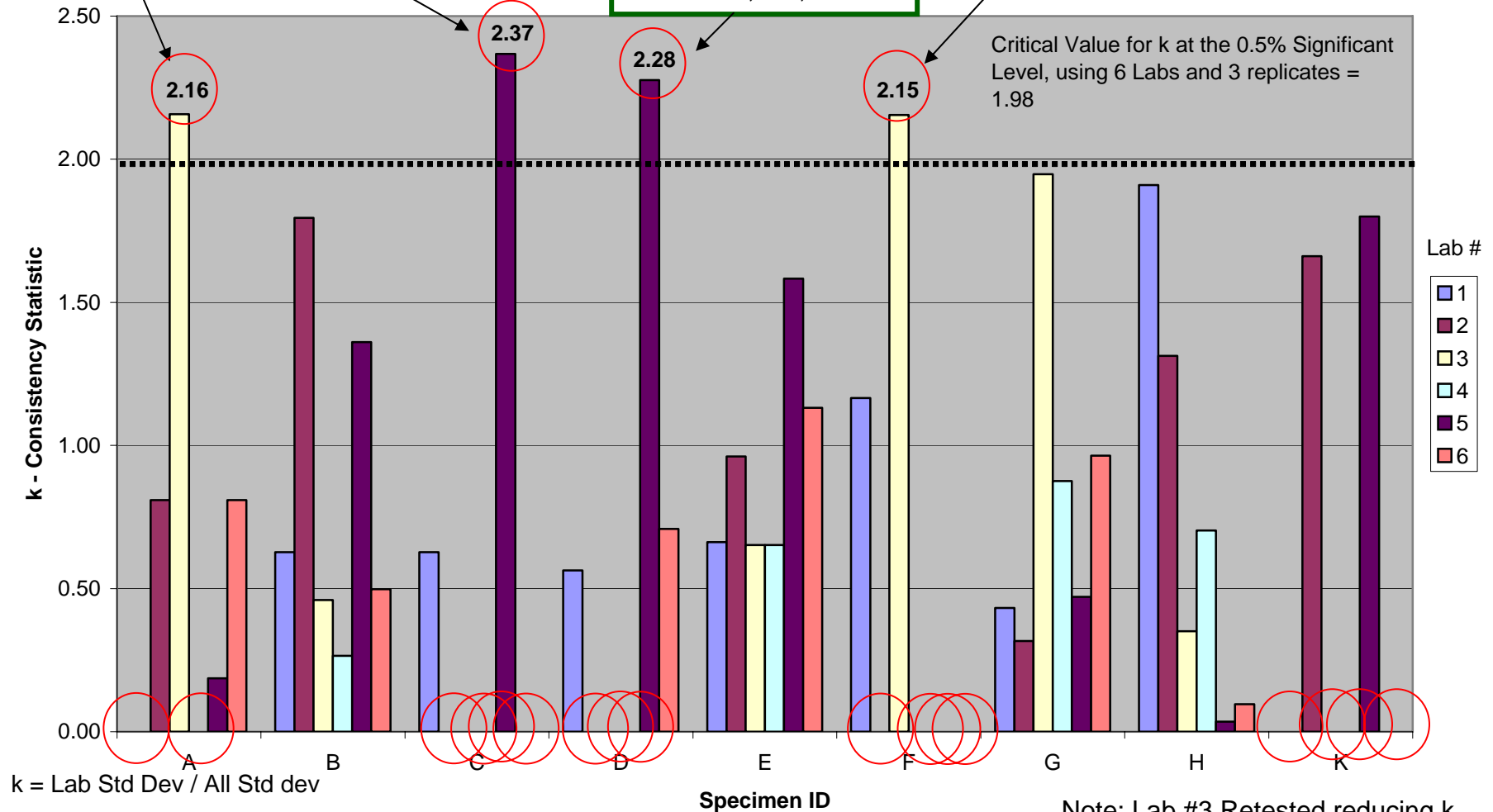
Lab 3: 0, 4, 0 sec

Lab 5: 2, 3.7, 1.5 sec

Lab 5: 2.8, 4.2, 4.2 sec

Lab 3: 2, 0, 0 sec

Critical Value for k at the 0.5% Significant Level, using 6 Labs and 3 replicates = 1.98



$k = \text{Lab Std Dev} / \text{All Std dev}$

Acceptance Criteria: FET  $\leq$  45 sec

Note: Lab #3 Retested reducing k below critical value





## Analysis of the AFET Consistency k Data (Within-laboratory)

Material	Very Low "k"	AFET (sec)	Very High "k"	AFET (sec)	Comment
A	Lab 1 Lab 4	(0, 0, 0) (0, 0, 0)	Lab 3	(0, 4, 0)	Not Significant
B					
C	Lab 2 Lab 3 Lab 4 Lab 6	(0, 0, 0) (0, 0, 0) (0, 0, 0) (0, 0, 0)	Lab 5	(2.0, 3.7, 1.5)	Not Significant, in VHk error range is 2.2 seconds
D	Lab 2 Lab 3 Lab 4	(0, 0, 0) (0, 0, 0) (0, 0, 0)	Lab 5	(2.8, 4.2, 4.2)	Not Significant, in VHk error range is 1.4 seconds
E					
F	Lab 2 Lab 4 Lab 5 Lab 6	(0, 0, 0) (0, 0, 0) (0, 0, 0) (0, 0, 0)	Lab 3	(2, 0, 0)	Not Significant
G					
H					
I					
J					
K	Lab 1 Lab 3 Lab 4 Lab 6	(0, 0, 0) (0, 0, 0) (0, 0, 0) (0, 0, 0)			Not Significant

# Aircraft Ducting Material RHP Test Method

## k - Consistency Statistic

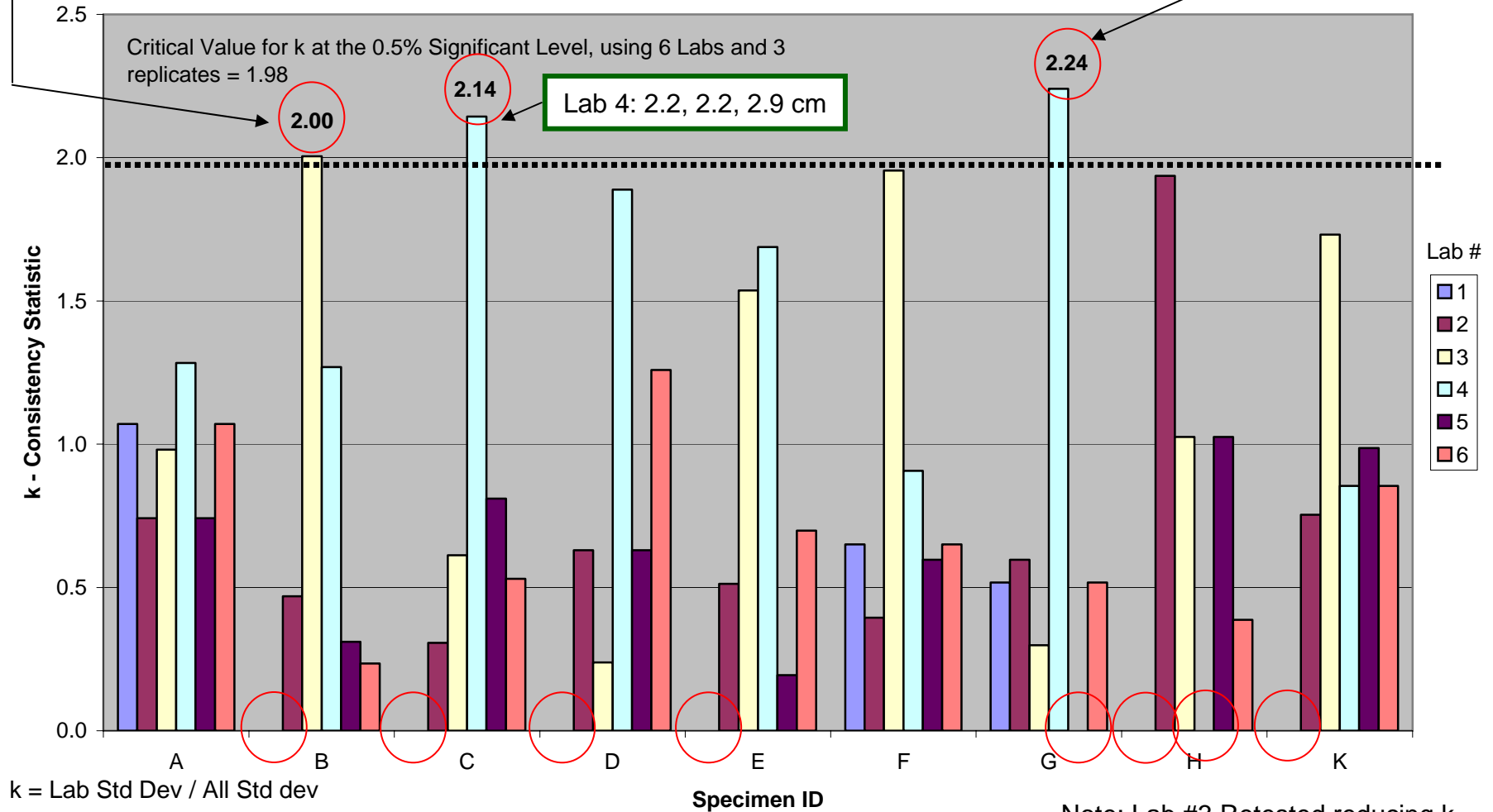
### Burn Length Data

Lab 3: 4.1, 2.3, 2.5 cm

Lab 4: 3.8, 5.1, 3.8 cm

Lab 4: 2.2, 2.2, 2.9 cm

Critical Value for k at the 0.5% Significant Level, using 6 Labs and 3 replicates = 1.98



Note: Lab #3 Retested reducing k below critical value





## Analysis of the BL Consistency k Data (Within-laboratory)

Material	Very Low "k"	Burn Length (cm)	Very High "k"	Burn Length (cm)	Comment
A					
B	Lab 1	(3.0, 3.0, 3.0)	Lab 3	(4.1, 2.3, 2.5)	Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
C	Lab 1	(2.0, 2.0, 2.0)	Lab 4	(2.2, 2.2, 2.9)	Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
D	Lab 1	(3.0, 3.0, 3.0)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
E	Lab 1	(2.5, 2.5, 2.5)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
F					
G	Lab 5	(2.2, 2.2, 2.2)	Lab 4	(3.8, 5.1, 3.8)	
H	Lab 1 Lab 4	(2.5, 2.5, 2.5) (3.2, 3.2, 3.2)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
I					
J					
K	Lab 1	(2.0, 2.0, 2.0)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.



## Investigation

- Labs #3, #4, #5, and #6 exceeded some of the critical consistency values. But Labs #5 & #6 AFET deviation was insignificant – ~2 sec)
- Contacted Laboratories #3 and #4 to determine source of within-lab imprecision.
  - ✓ Specimen placement
  - ✓ Material fabrication variability
  - ✓ Burn Length measuring technique (measuring in-place vs. removed)
  - ✓ AFET reported decimal place
- Ordered new materials to conduct re-test
- Offered courtesy equipment examination
- Lab #3 re-tested, but Lab #4 did not respond



# ASTM E 691-99 Analysis



## Raw Data: With Lab #3 Retest Data

Laboratory	Material																					
	A*		B*		C		D		E		F*		G		H		I		J		K*	
	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)	Flame Ext. Time (sec)	Burn Length (cm)
1	0.0	2.0	2.4	3.0	0.6	2.0	1.4	3.0	3.2	2.5	2.5	3	37.2	2.5	12.3	2.5	150 +	12 +	150 +	3.5	0.0	2.0
	0.0	2.0	5.9	3.0	0.2	2.0	1.2	3.0	4.3	2.5	1.6	3.5	41.7	2.5	26.1	2.5	150 +	12 +	150 +	3.0	0.0	2.0
	0.0	2.5	6.9	3.0	0.0	2.0	1.6	3.0	4.1	2.5	1.3	3.2	42.9	2.2	11.2	2.5	150 +	12 +	150 +	3.0	0.0	2.0
2	1.5	2.8	23.4	2.0	0.0	2.6	0.0	2.4	3.4	3.3	0.0	4.2	33.0	2.8	17.7	3.1	120.3	3.4	120.2	7.5	0.0	2.7
	0.0	2.4	10.5	2.4	0.0	2.6	0.0	2.2	4.3	3.2	0.0	4.0	37.4	3.2	6.8	3.1	120.3	3.4	120.1	8.4	1.0	2.9
	0.0	2.6	13.4	2.4	0.0	2.5	0.0	2.5	2.6	3.5	0.0	3.9	35.2	3.0	9.3	3.6	120.4	3.4	120.1	7.0	1.4	3.0
3*	0.0	2.6	7.5	2.1	0.0	1.8	2.0	1.8	3.0	2.7	1.1	3.0	41.0	2.0	12.0	2.4	697.0	16.5	519.0	2.0	0.0	2.9
	0.0	2.6	9.0	2.3	0.0	1.8	2.0	1.9	3.0	3.0	0.0	2.9	45.1	2.3	14.0	2.7	604.0	16.5	456.0	2.2	0.0	2.9
	0.0	2.8	6.0	2.5	0.0	2.0	2.0	1.9	4.0	3.6	0.0	3.0	26.0	2.2	15.0	2.5	839.0	16.5	315.0	2.0	0.0	2.9
4	0.0	3.8	7.0	3.8	0.0	2.2	0.0	3.2	3.0	5.4	0.0	6.4	29.0	3.8	19.0	3.2	120+	8.9	120+	8.9	0.0	3.2
	0.0	4.4	6.0	2.9	0.0	2.2	0.0	3.8	3.0	6.4	0.0	6.0	39.0	5.1	15.0	3.2	120+	9.2	120+	10.2	0.0	3.5
	0.0	3.8	5.0	4.1	0.0	2.9	0.0	4.1	4.0	6.0	0.0	5.7	28.0	3.8	13.0	3.2	120+	8.6	120+	10.2	0.0	3.2
5	1.7	3.4	9.0	3.2	2.0	2.7	2.8	2.5	3.0	2.9	0.0	3.9	21.0	2.2	5.7	2.4	305.0	11.8	120	3.9	1.4	3.1
	1.5	3.2	2.0	2.9	3.7	2.9	4.2	2.8	2.3	2.8	0.0	4.3	19.7	2.2	5.6	2.6	129.0	4.1	120	2.2	1.3	3.5
	1.3	3.0	12.0	3.1	1.5	3.0	4.2	2.6	5.0	2.8	0.0	4.3	14.8	2.2	5.9	2.3	120.0	8.5	120	4.0	0.0	3.3
6	0.0	3.0	0.0	2.7	0.0	2.5	1.0	2.5	5.2	2.8	0.0	4.0	39.0	3.0	11.1	3.4	>120	7.6	>120	7.6	0.0	2.3
	0.0	3.0	2.4	2.7	0.0	2.7	1.5	2.9	7.2	3.2	0.0	3.8	48.3	3.3	11.7	3.4	>120	8.8	>120	8.8	0.0	2.3
	1.5	3.5	3.7	2.5	0.0	2.6	1.3	3.1	6.3	2.9	0.0	3.5	35.3	3.3	11.9	3.5	>120	8.9	>120	8.9	0.0	2.6
*Note: Retested																						



## Data Consistency h (Between-laboratories), RR Lab #3 Re-Test

Acceptance Criteria: Flame Extinguishing Time

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	-0.71	-0.49	-0.18	0.00	-0.06	2.00	0.78	1.06	-	-	-0.64
2	0.14	1.83	-0.46	-1.00	-0.44	-0.50	0.13	-0.29	-	-	1.17
3	-0.71	0.03	-0.46	0.43	-0.53	0.01	0.39	0.32	-	-	-0.64
4	-0.71	-0.29	-0.46	-1.00	-0.53	-0.50	-0.25	0.84	-	-	-0.64
5	1.85	0.07	2.03	1.67	-0.44	-0.50	-1.87	-1.71	-	-	1.40
6	0.14	-1.15	-0.46	-0.10	2.01	-0.50	0.81	-0.22	-	-	-0.64

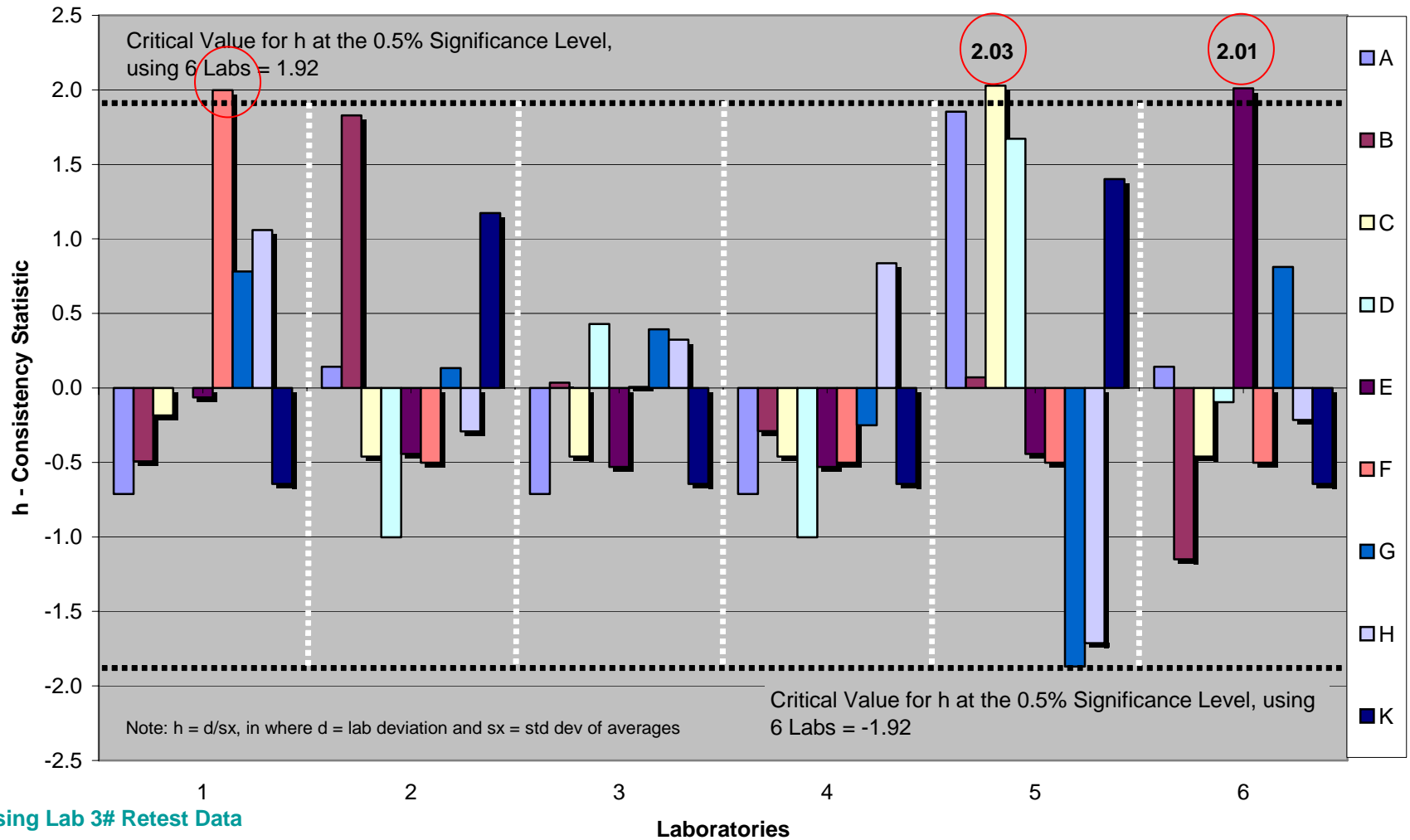
Acceptance Criteria: Burn Length

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	-1.26	0.37	-1.02	0.43	-0.76	-0.74	-0.59	-0.87	-	-	-1.55
2	-0.58	-1.06	0.47	-0.59	-0.09	0.00	0.17	0.82	-	-	0.14
3	-0.47	-1.00	-1.37	-1.40	-0.28	-0.98	-0.88	-0.80	-	-	0.21
4	1.62	1.54	0.12	1.56	1.99	1.85	1.72	0.68	-	-	0.99
5	0.37	0.50	1.25	-0.16	-0.49	0.12	-0.84	-1.02	-	-	0.99
6	0.31	-0.35	0.55	0.16	-0.38	-0.25	0.42	1.19	-	-	-0.77

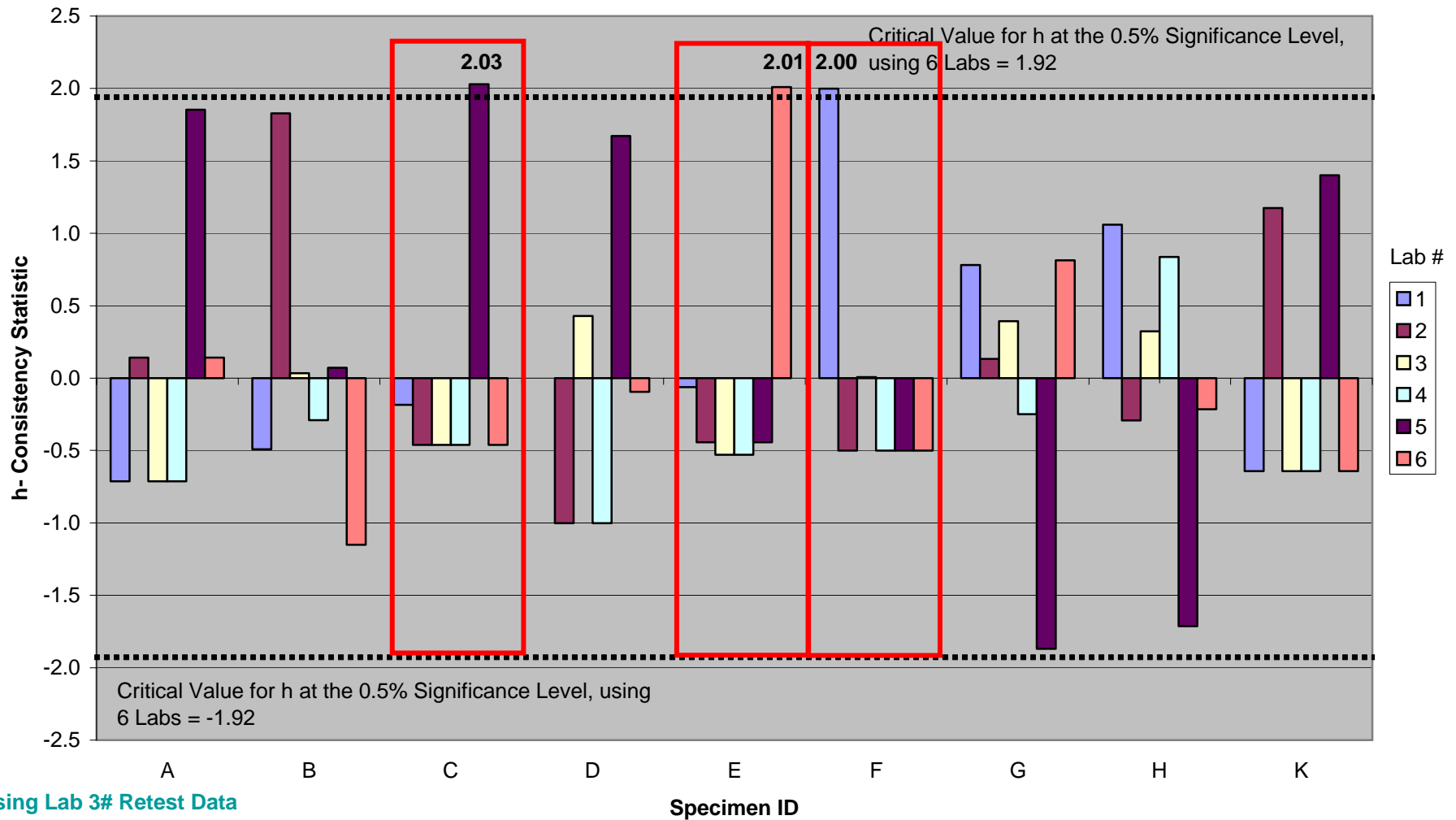


**Aircraft Ducting Material RHP Tests**  
**h - Consistency Statistic**  
**Flame Extinguishing Time Data**

**Balanced: Pattern 1**



Aircraft Ducting Material RHP Test Method  
h - Consistency Statistic  
Flame Extinguishing Time Data





## Analysis of the AFET Consistency h Data (Between-Laboratories)

Material	Lab Exceeded Critical Value	h	Critical Value	AFET (sec)	Average <sub>All</sub> (sec)	Comment
A			+/- 1.92			
B			+/- 1.92			
C	Lab 5	2.03	+/- 1.92	2.40	0.44	Insignificant error when compared to acceptance criteria of 45 seconds
D			+/- 1.92			
E	Lab 6	2.01	+/- 1.92	6.23	3.94	Insignificant error when compared to acceptance criteria of 45 seconds
F	Lab 1	2.00	+/- 1.92	1.80	0.36	Insignificant error when compared to acceptance criteria of 45 seconds
G			+/- 1.92			
H			+/- 1.92			
I			+/- 1.92			
J			+/- 1.92			
K			+/- 1.92			

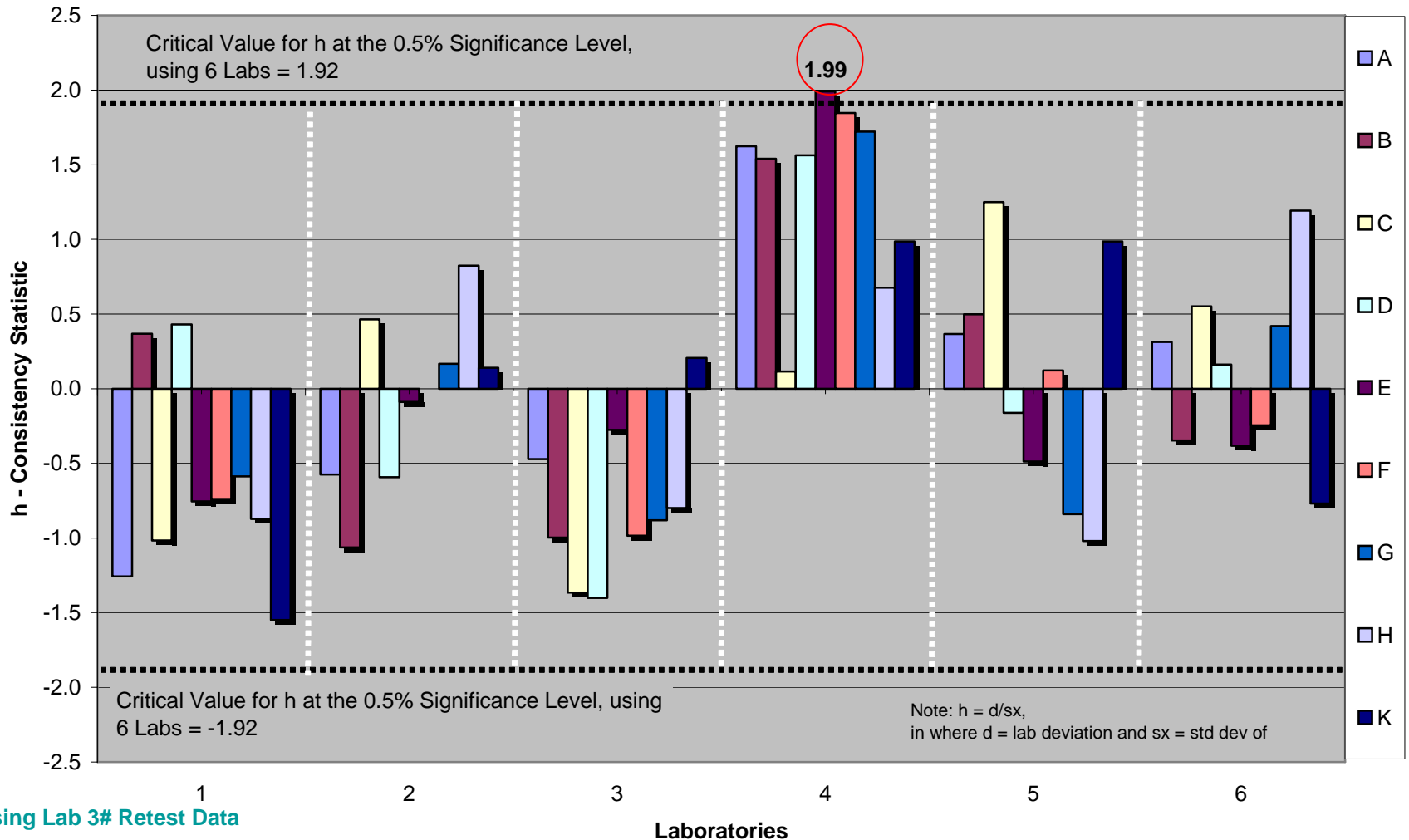
Using Lab 3# Retest Data

# Aircraft Ducting Material RHP Tests

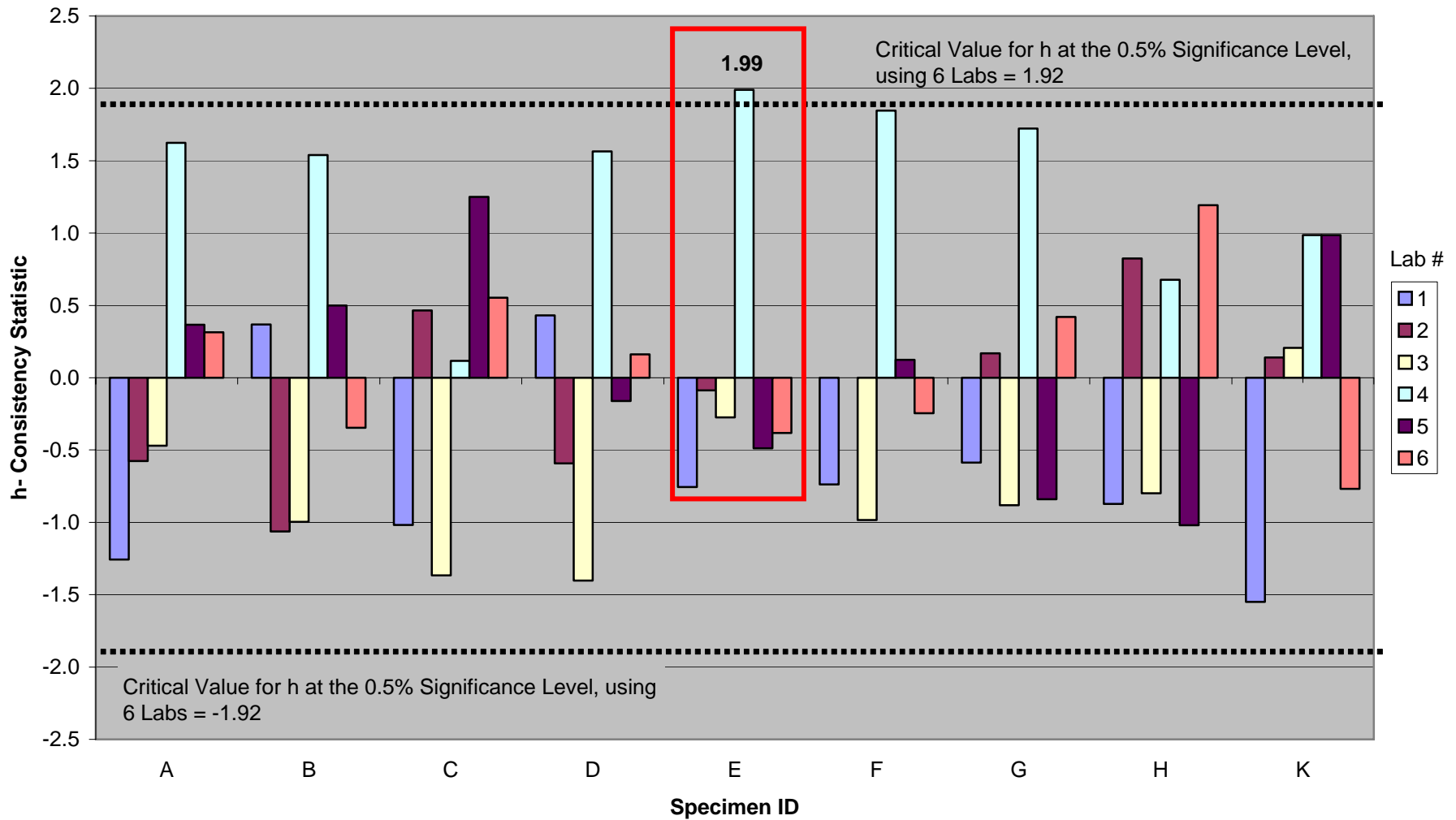
## h - Consistency Statistic

### Burn Length Data

Balanced: Pattern 1



Aircraft Ducting Material RHP Test Method  
h - Consistency Statistic  
Burn Length Data





## Analysis of the Burn Length Consistency h Data (Between-Laboratories)

Material	Opposite "h" Polarity	Burn length (cm)	Average <sub>All</sub> (cm)	Comment
A				
B				
C				
D				
E	Lab 4	5.93	3.44	Significant error because exceeded acceptance criteria of 5.08 cm
F				
G				
H				
I				
J				
K				

Using Lab 3# Retest Data



## Data Consistency k (Within-laboratory), Lab 3# Retest

Acceptance Criteria: Flame Extinguishing Time

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	0.00	0.63	0.63	0.56	0.66	1.72	0.51	1.91	-	-	0.00
2	1.71	1.80	0.00	0.00	0.96	0.00	0.37	1.31	-	-	1.66
3	0.00	0.40	0.00	0.00	0.65	1.75	1.71	0.35	-	-	0.00
4	0.00	0.27	0.00	0.00	0.65	0.00	1.03	0.70	-	-	0.00
5	0.39	1.37	2.37	2.28	1.58	0.00	0.56	0.04	-	-	1.80
6	1.71	0.50	0.00	0.71	1.13	0.00	1.14	0.10	-	-	0.00

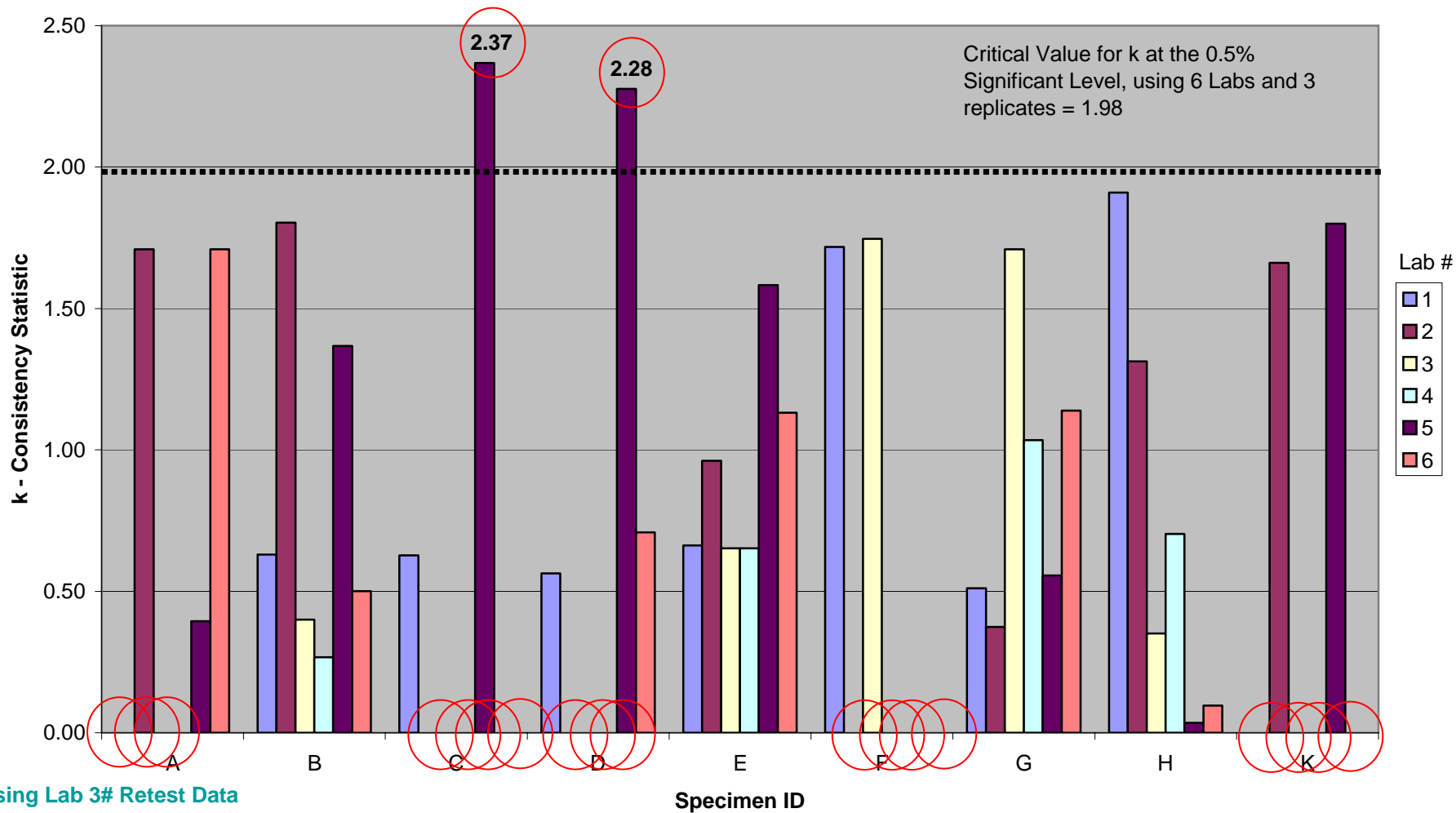
Acceptance Criteria: Burn Length

Laboratory No.	Specimen ID										
	A	B	C	D	E	F	G	H	I	J	K
1	1.15	0.00	0.00	0.00	0.00	1.07	0.51	0.00	0.00	0.43	0.00
2	0.79	0.78	0.31	0.63	0.51	0.65	0.59	1.94	0.00	1.06	1.07
3	0.46	0.68	0.61	0.24	1.54	0.25	0.45	1.02	0.00	0.17	0.00
4	1.38	2.12	2.14	1.89	1.69	1.50	2.22	0.00	0.19	1.12	1.21
5	0.79	0.52	0.81	0.63	0.19	0.98	0.00	1.02	2.40	1.51	1.39
6	1.15	0.39	0.53	1.26	0.70	1.07	0.51	0.39	0.45	1.08	1.21

# Aircraft Ducting Material RHP Test Method

## k - Consistency Statistic

### Flame Extinguishing Time Data



Using Lab 3# Retest Data







## Analysis of the AFET Consistency k Data (Within-laboratory)

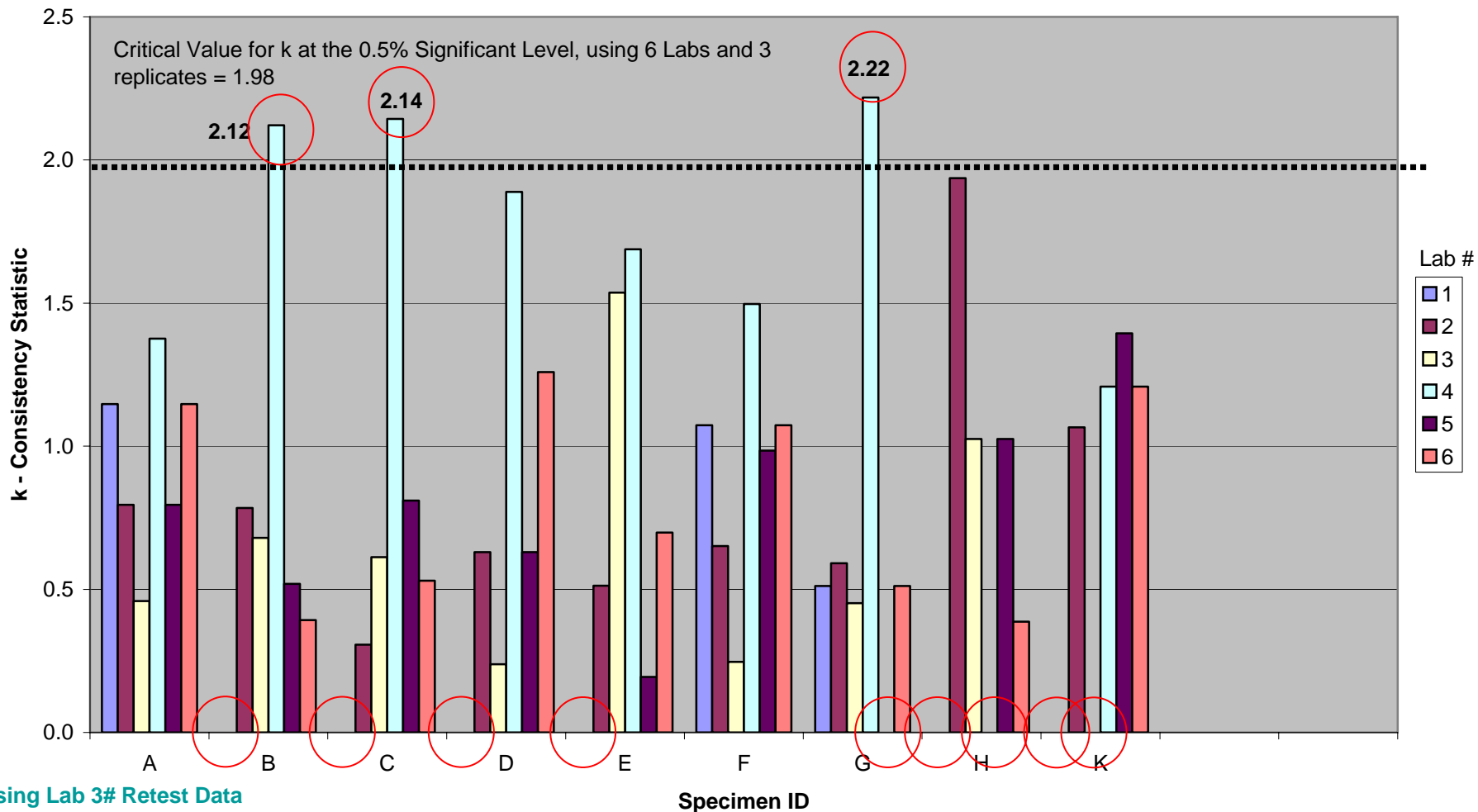
Material	Very Low "k"	AFET (sec)	Very High "k"	AFET (sec)	Comment
A	Lab 1	(0, 0, 0)			Not Significant
	Lab 3	(0, 0, 0)			
	Lab 4	(0, 0, 0)			
B					
C	Lab 2	(0, 0, 0)	Lab 5	(2.0, 3.7, 1.5)	Not Significant, in Vhk error range is 2.2 seconds
	Lab 3	(0, 0, 0)			
	Lab 4	(0, 0, 0)			
	Lab 6	(0, 0, 0)			
D	Lab 2	(0, 0, 0)	Lab 5	(2.8, 4.2, 4.2)	Not Significant, in Vhk error range is 1.4 seconds
	Lab 3	(0, 0, 0)			
	Lab 4	(0, 0, 0)			
E					
F	Lab 2	(0, 0, 0)			Not Significant
	Lab 4	(0, 0, 0)			
	Lab 5	(0, 0, 0)			
	Lab 6	(0, 0, 0)			
G					
H					
I					
J					
K	Lab 1	(0, 0, 0)			Not Significant
	Lab 3	(0, 0, 0)			
	Lab 4	(0, 0, 0)			
	Lab 6	(0, 0, 0)			

Using Lab 3# Retest Data

# Aircraft Ducting Material RHP Test Method

## k - Consistency Statistic

### Burn Length Data



Using Lab 3# Retest Data





## Analysis of the BL Consistency k Data (Within-laboratory)

Material	Very Low "k"	Burn Length (cm)	Very High "k"	Burn Length (cm)	Comment
A					
B	Lab 1	(3.0, 3.0, 3.0)	Lab 4	(3.8, 2.9, 4.1)	Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
C	Lab 1	(2.0, 2.0, 2.0)	Lab 4	(2.2, 2.2, 2.9)	Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
D	Lab 1	(3.0, 3.0, 3.0)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
E	Lab 1	(2.5, 2.5, 2.5)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
F					
G	Lab 5	(2.2, 2.2, 2.2)	Lab 4	(3.8, 5.1, 3.8)	
H	Lab 1 Lab 4	(2.5, 2.5, 2.5) (3.2, 3.2, 3.2)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.
I					
J					
K	Lab 1 Lab 3	(2.0, 2.0, 2.0) (2.9, 2.9, 2.9)			Lab 1 has a measuring device to measure the burn length with the specimen mounted on the RHP tray.

Using Lab 3# Retest Data



## \*\* Precision Statement Information For AFET \*\*

Material	Precision Statistics					
	Average ( $\bar{x}$ , sec)	Std Dev of Avg ( $s_x$ )	Repeatability Std Dev ( $s_r$ )	Reproducibility Std Dev (SR)	Repeatability Limit (r)	Reproducibility Limit (R)
A	0.4167	0.5845	0.5066	0.7161	1.4033	1.9836
B	7.3389	4.6101	3.7526	5.5355	10.3948	15.3332
C	0.4444	0.9639	0.4871	1.0428	1.3491	2.8884
D	1.4000	1.3959	0.3551	1.4257	0.9837	3.9491
E	3.9389	1.1414	0.8851	1.3510	2.4516	3.7421
F	0.3611	0.7200	0.3636	0.7788	1.0072	2.1573
G	34.0889	8.3389	5.8811	9.6227	16.2908	26.6548
H	12.4056	3.8932	4.3476	5.2686	12.0429	14.5939
I	120	-	-	-	-	-
J	120	-	-	-	-	-
K	0.2833	0.4401	0.4340	0.5650	1.2021	1.5650

### Using Lab 3# Retest Data

95% Repeatability Limit (Within Lab) =  $2.77 \times s_r$

95% Reproducibility Limit (Between Labs) =  $2.77 \times SR$



## Precision Limits vs RHP Acceptance Criteria: AFET

Material	Average ( $\bar{x}$ , sec)	Actual Acceptance Decision	Repeatability Limit (r)	Reproducibility Limit (R)	Max FET 95% C.L. (sec)	FET Acceptance Criteria	Possible Acceptance Decision at 95% C.L.
A	0.6	Passed	1.4	2.0	2.6	45.0	Pass
B	7.3	Passed	10.4	15.3	22.6	45.0	Pass
C	0.4	Passed	1.3	2.9	3.3	45.0	Pass
D	1.4	Passed	1.0	3.9	5.3	45.0	Pass
E	3.9	Passed	2.5	3.7	7.7	45.0	Pass
F	0.4	Passed	1.0	2.2	2.6	45.0	Pass
G	34.5	Passed	16.3	26.7	61.2	45.0	Fail
H	12.4	Passed	12.0	14.6	27.0	45.0	Pass
I	>120	Failed	-	-	-	45.0	Fail
J	>120	Failed	-	-	-	45.0	Fail
K	0.3	Passed	1.2	1.6	1.8	45.0	Pass

Using Lab 3# Retest Data



## \*\* Precision Statement Information For Burn Length \*\*

Material	Precision Statistics					
	Average ( $\bar{x}$ , cm)	Std Dev of Avg ( $s_x$ )	Repeatability Std Dev ( $s_r$ )	Reproducibility Std Dev ( SR )	Repeatability Limit ( r )	Reproducibility Limit ( R )
A	2.9667	0.6367	0.2517	0.6690	0.6971	1.8531
B	2.8111	0.5124	0.2944	0.5659	0.8155	1.5677
C	2.3889	0.3822	0.1886	0.4120	0.5223	1.1414
D	2.7333	0.6182	0.2427	0.6492	0.6722	1.7983
E	3.4444	1.2505	0.2981	1.2740	0.8259	3.5290
F	4.0333	1.0832	0.2345	1.1000	0.6496	3.0470
G	2.8667	0.7936	0.3383	0.8403	0.9371	2.3276
H	2.8944	0.4519	0.1491	0.4680	0.4129	1.2963
I	-	-	-	-	-	-
J	-	-	-	-	-	-
K	2.7944	0.5127	0.1434	0.5259	0.3971	1.4567

Using Lab 3# Retest Data

95% Repeatability Limit (Within Lab) =  $2.77 \times s_r$

95% Reproducibility Limit (Between Labs) =  $2.77 \times SR$



## Precision Limits vs RHP Acceptance Criteria: Burn Length

Material	Average ( $\bar{x}$ , cm)	Actual Acceptance Decision	Repeatability Limit (r, cm)	Reproducibility Limit (R, cm)	Max FET 95% C.L. (cm)	FET Acceptance Criteria (cm)	Possible Acceptance Decision at 95% C.L.
A	2.94	Passed	0.70	1.85	4.79	5.08	Pass
B	2.92	Passed	0.82	1.57	4.49	5.08	Pass
C	2.39	Passed	0.52	1.14	3.53	5.08	Pass
D	2.73	Passed	0.67	1.80	4.53	5.08	Pass
E	3.44	Passed	0.83	3.53	4.27	5.08	Pass
F	4.09	Passed	0.65	3.05	7.14	5.08	Fail
G	2.86	Passed	0.94	2.33	5.18	5.08	Fail
H	2.89	Passed	0.41	1.30	3.31	5.08	Pass
I	>5.08	Failed	-	-	-	5.08	Fail
J	>5.08	Failed	-	-	-	5.08	Fail
K	2.70	Passed	0.40	1.46	3.10	5.08	Pass

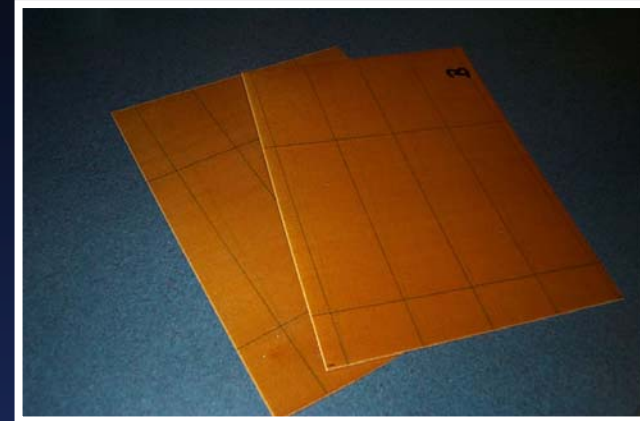
Using Lab 3# Retest Data

# Outline



## Presentation will include:

- ✓ Round Robin Participants
- ✓ Round Robin Samples
- ✓ Radiant Panel Test Procedure
- ✓ ASTM E 691-99 Analysis
- ✓ Final Comments



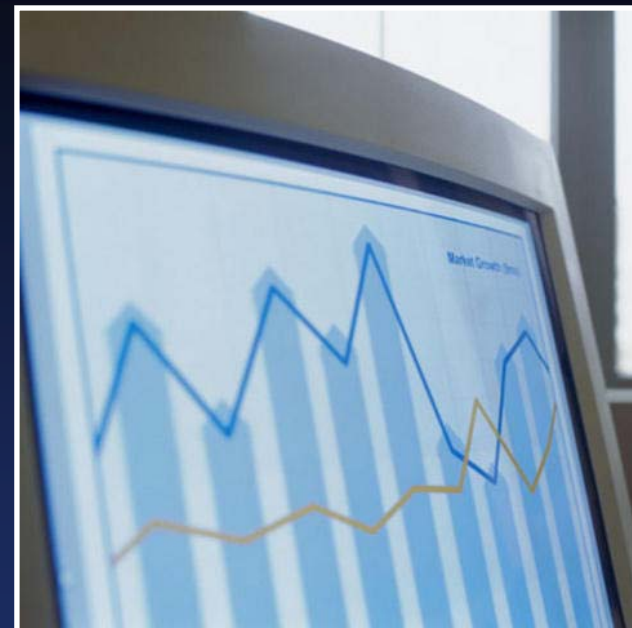


# Final Comments



## Conclusion:

- The consistency statistic “h” indicated that the ILS data is balanced.
- The consistency statistic “k” indicated that some labs needed to improve their measuring precision
  - ✓ Error Sources – measuring (in-place vs out of fixture), decimal points, hand speed with stop watch, sample placement (procedure), material fabrication variability
- Lab #3 improved “k” after it considered error sources and re-tested





## Conclusion (Cont.):

- Lab #4 did not respond to re-testing request or to obtain courtesy equipment examination.
- There is a possibility that the difference in results of Lab #4 could be attributed to sample placement inside RHP.
- Reproducibility std dev (between labs) was greater than the repeatability std dev: (1) AFET – 1:1.5, (2) BL – 1:3.1
- The deviation between labs was greater than the deviation within a lab.



# Final Comments



## Conclusion (Cont.):

- Without Lab# 4 re-testing, the precision information indicates that:
  - ✓ There is a 95% confidence level that all labs will obtain the same results for 9, out of 11, materials.
  - ✓ For marginal materials (2), there is a 68% chance or less that all labs will have the same results because of the larger standard deviations.



# Final Comments



Questions?

