Radiant Panel Update

Federal Aviation Administration
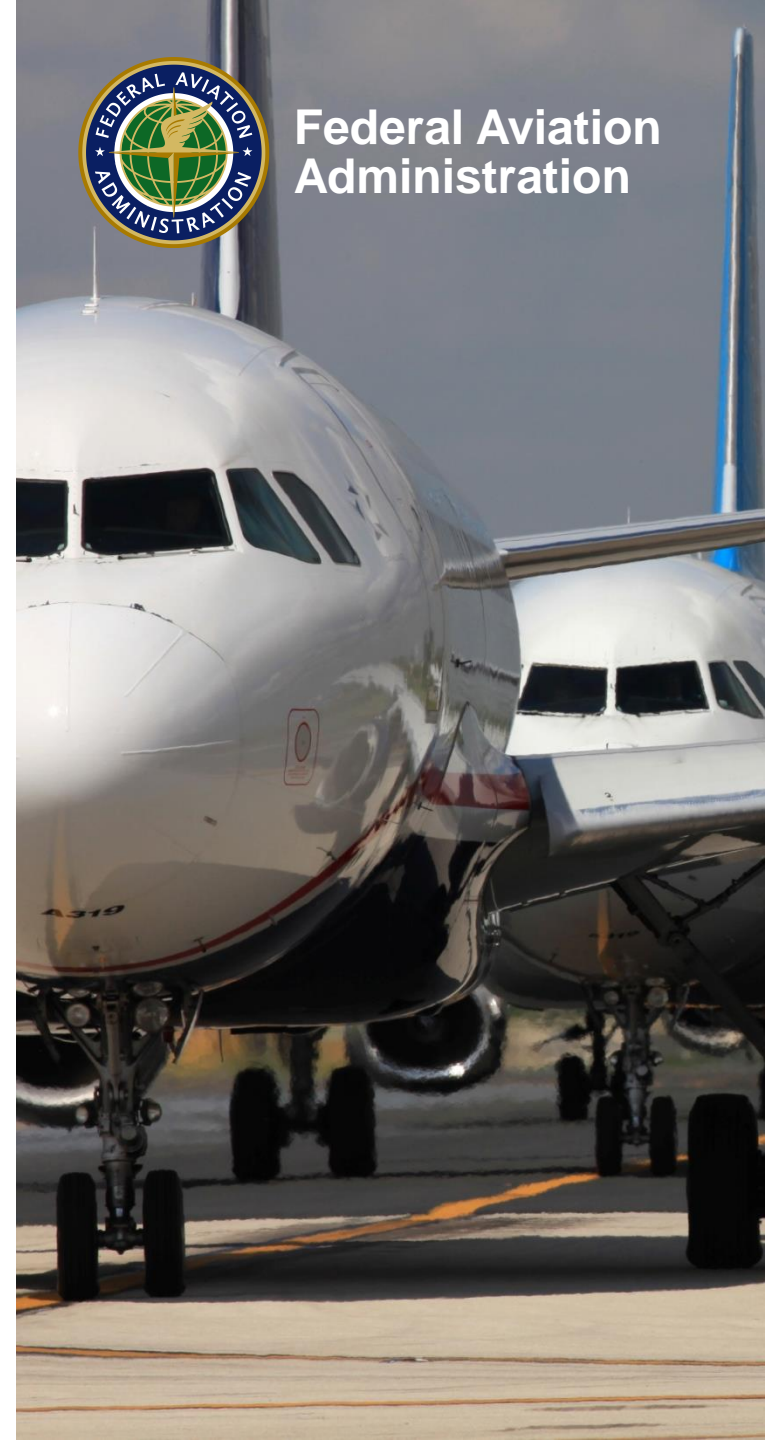
Presented to: International Aircraft Materials Fire
Test Working Group Meeting
By: Steven Rehn
Date: 3/7/2017

Introduction
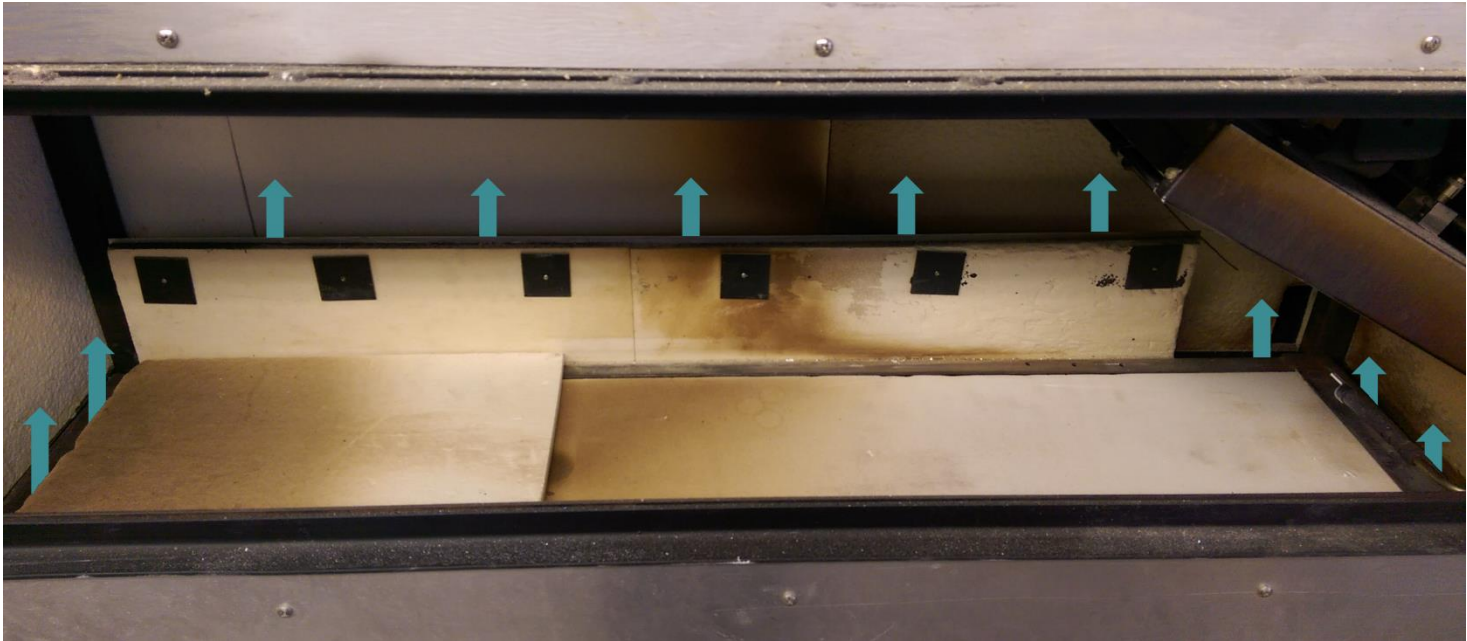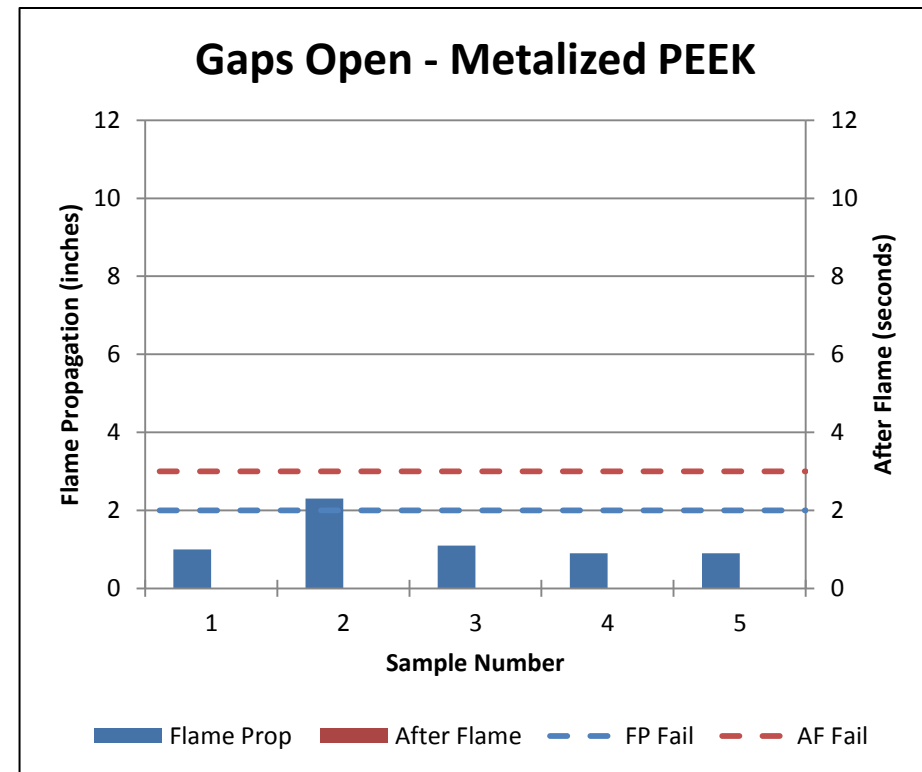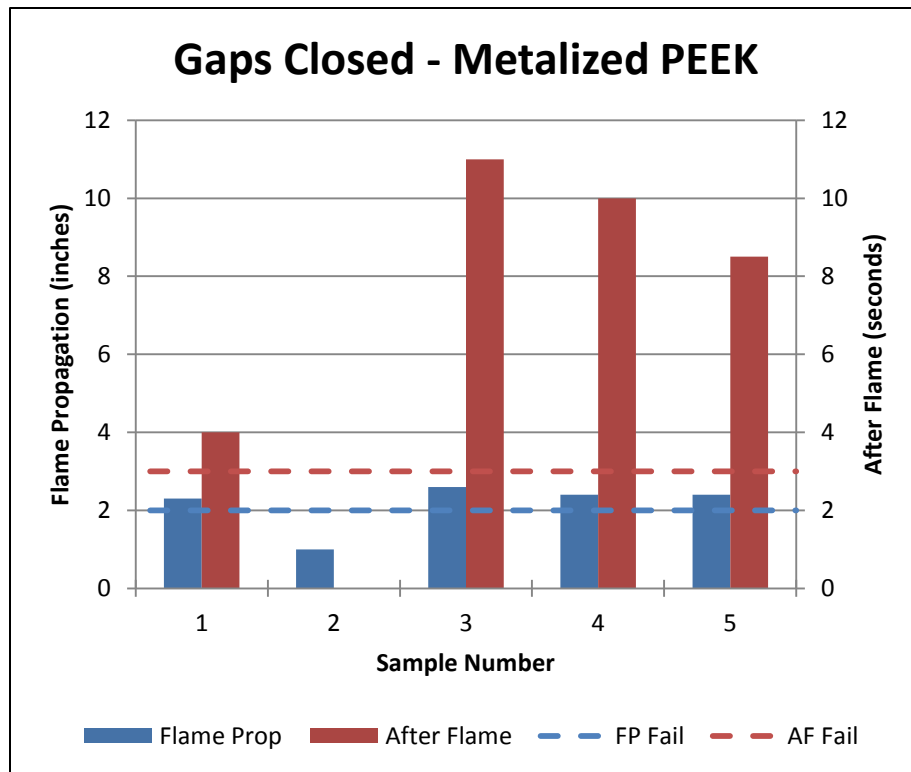
- **Round Robin results from 2016 varied widely**
- **Biggest difference between machines was the gaps around the drawer which allows outside air to flow in**
- **There is nothing in the rule about what size these gaps should be**

Preliminary Testing

- Tested several materials with air gaps opened and closed
- Metalized PEEK from the round robin showed the biggest difference

Air Flow Study

- **June 2016 we started planning an experiment to determine the effect these gaps have on this test method**

- **Goal is to change the handbook to make test results more repeatable across all labs**

- **Changes will likely involve standardizing the size of the air gaps around the drawer**

- **This experiment will determine how best to do that**

Air Flow Study

- **Conduct tests with 3 different air gap levels**
  - Fully open (different for each lab)
  - Partially open (1/2" gap in back and both sides)
  - Fully closed
- **Place array of thermocouples in the retaining frame to test how material temperature changes**
- **Material tests with Metalized PEEK – 20 samples per air gap setting for each lab**
- **Four participating labs:**
  - FAA Technical Center – Steve Rehn
  - Boeing – Randy Smith
  - Damping Technologies Inc. (DTI) – Kris Notestine
  - Triumph Insulation Systems (TIS) – Brad Gustavesen
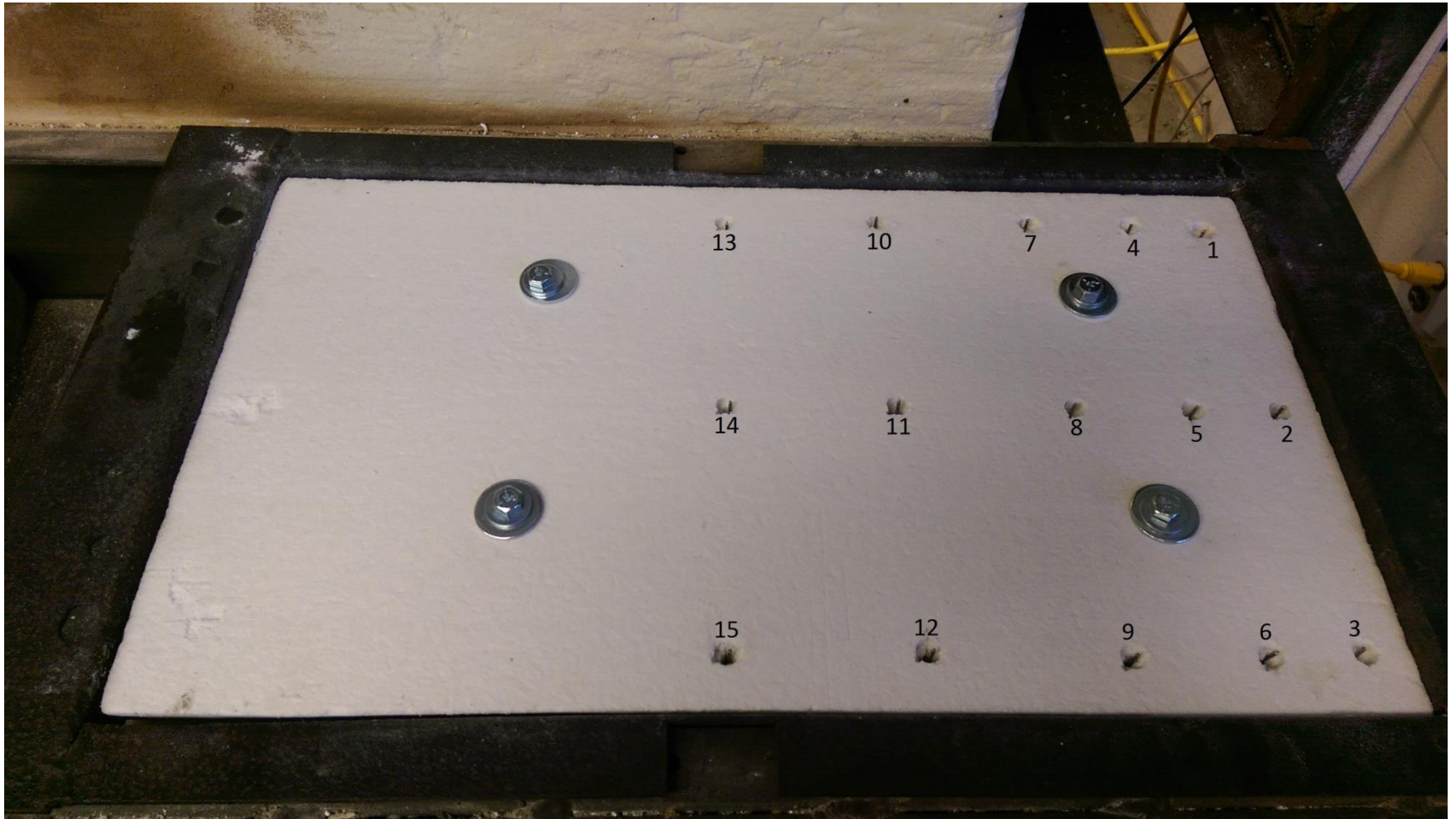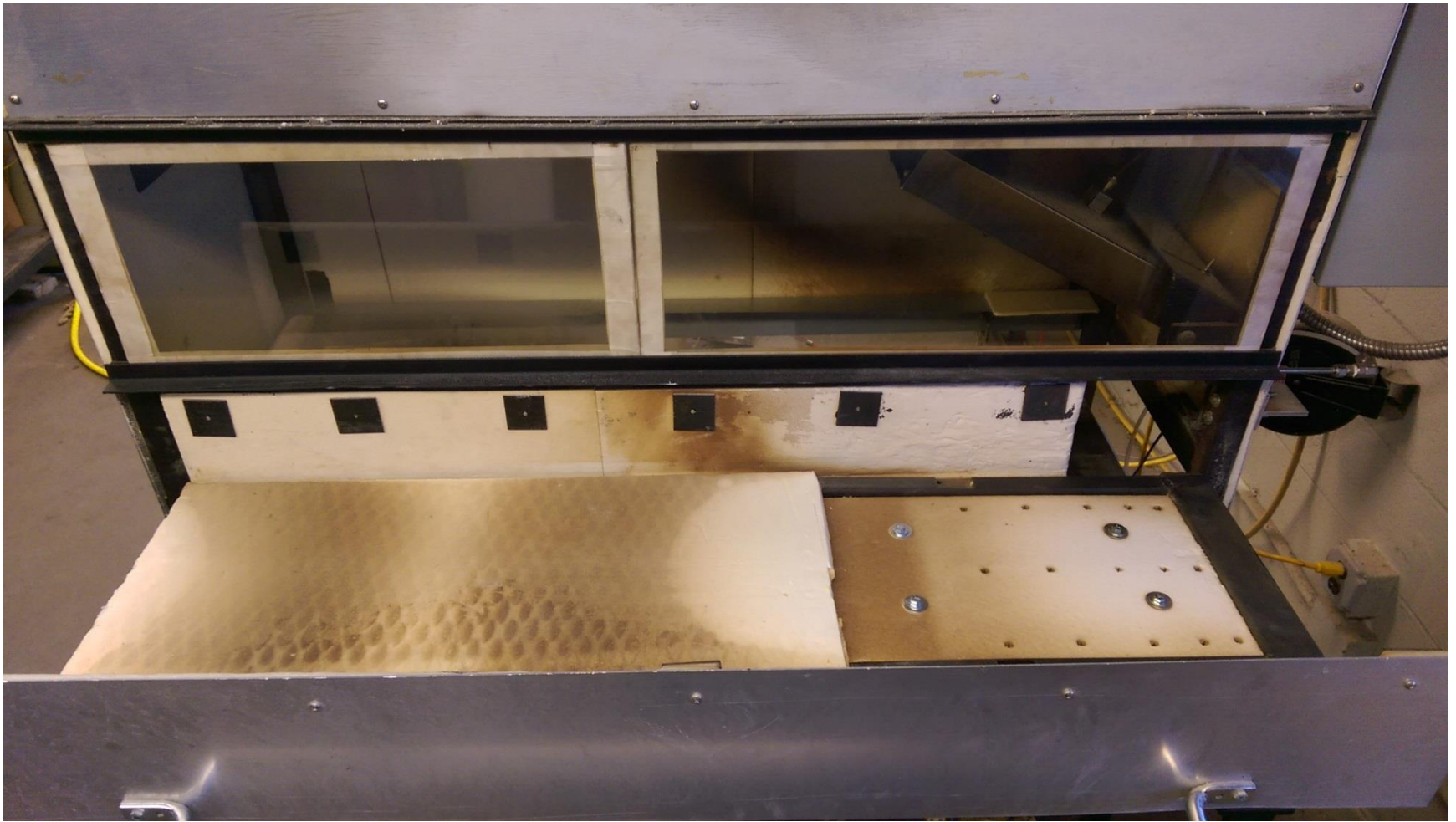- **Testing is still in progress**

Air Flow Study
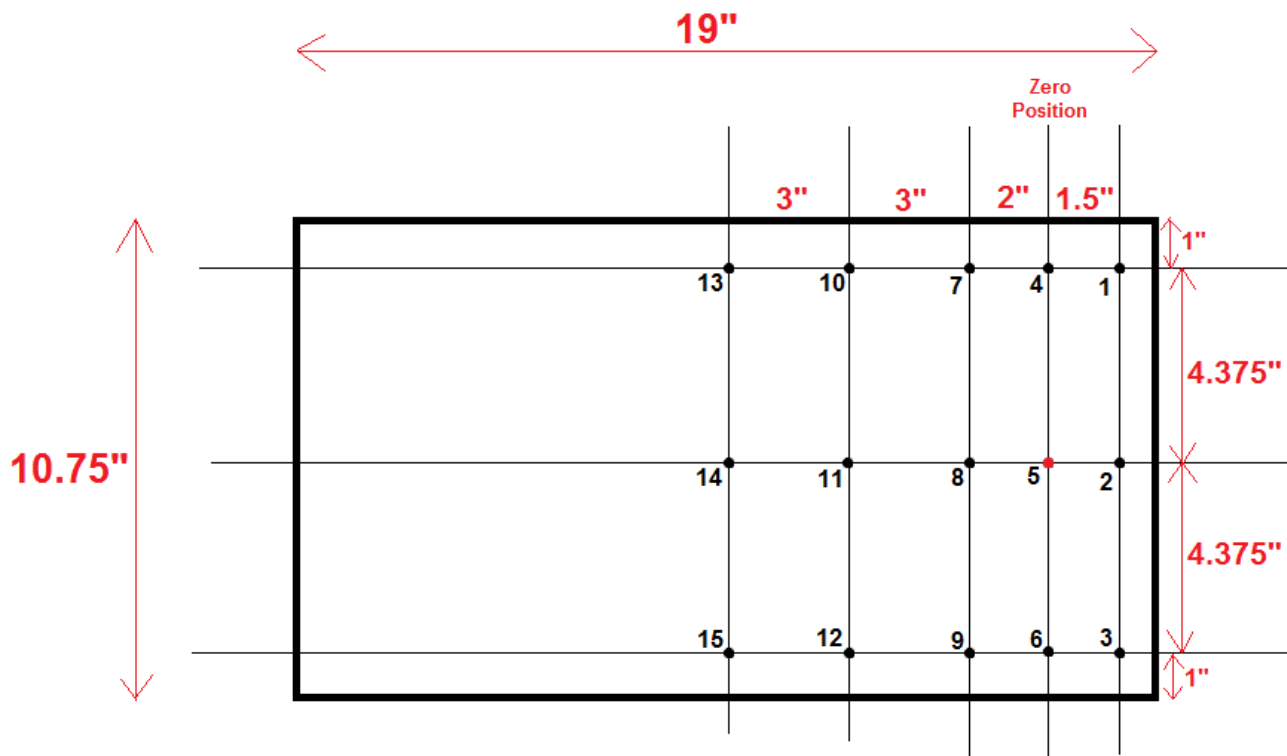
- Array of 15 thermocouples placed inside retaining frame

- Tested at each air-gap configuration

- Calibrated with calorimeter to 1.5 Btu/ft^{2}s each time

- Temperature averaged over 5 minute period

- Array sent around to each lab so there were no differences in thermocouples

Air Flow Study

Air Flow Study

Fully Open
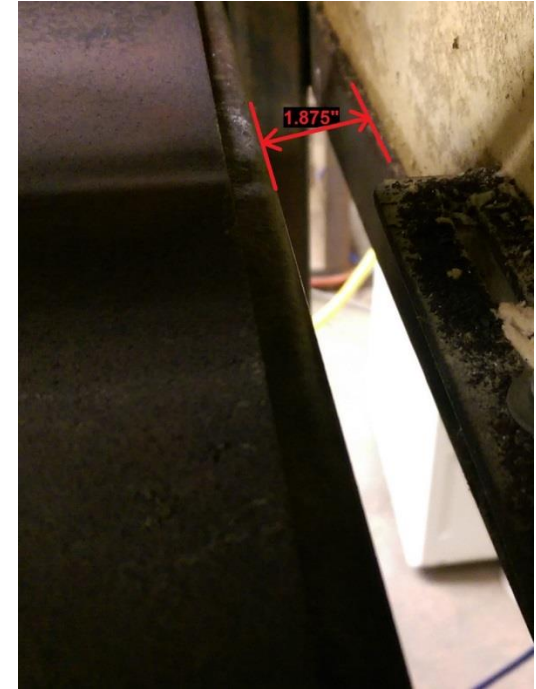
Left: 2.125"   Rear: 2.25"   Right: 1.875"

	FAA	DTI	Boeing	TIS
Right Gap (in)	1.875	3	2.5	2.5
Left Gap (in)	2.125	8.3	2.5	2.25
Rear Gap (in)	2.25	1.2	0.5	1
Front Gap (in)	0	0	1.5	1.5

Partially Open

½" Gap on each side

Left

Rear

Right

Fully Closed

Left

Rear
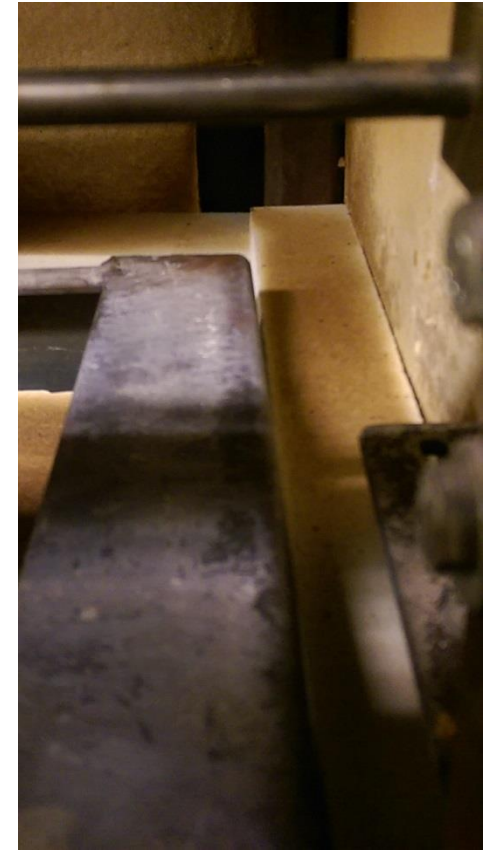
Right

Fully Closed - DTI

Air Flow Study

Closed

Open

Partial (1/2" gap on left, right, and rear)

Boeing

Panel Set Point: 1185°F
During Mat'l Test: 1127°F

Panel Set Point: 1185°F
During Mat'l Test: 1170°F

Panel Set Point: 1185°F
During Mat'l Test: 1150°F
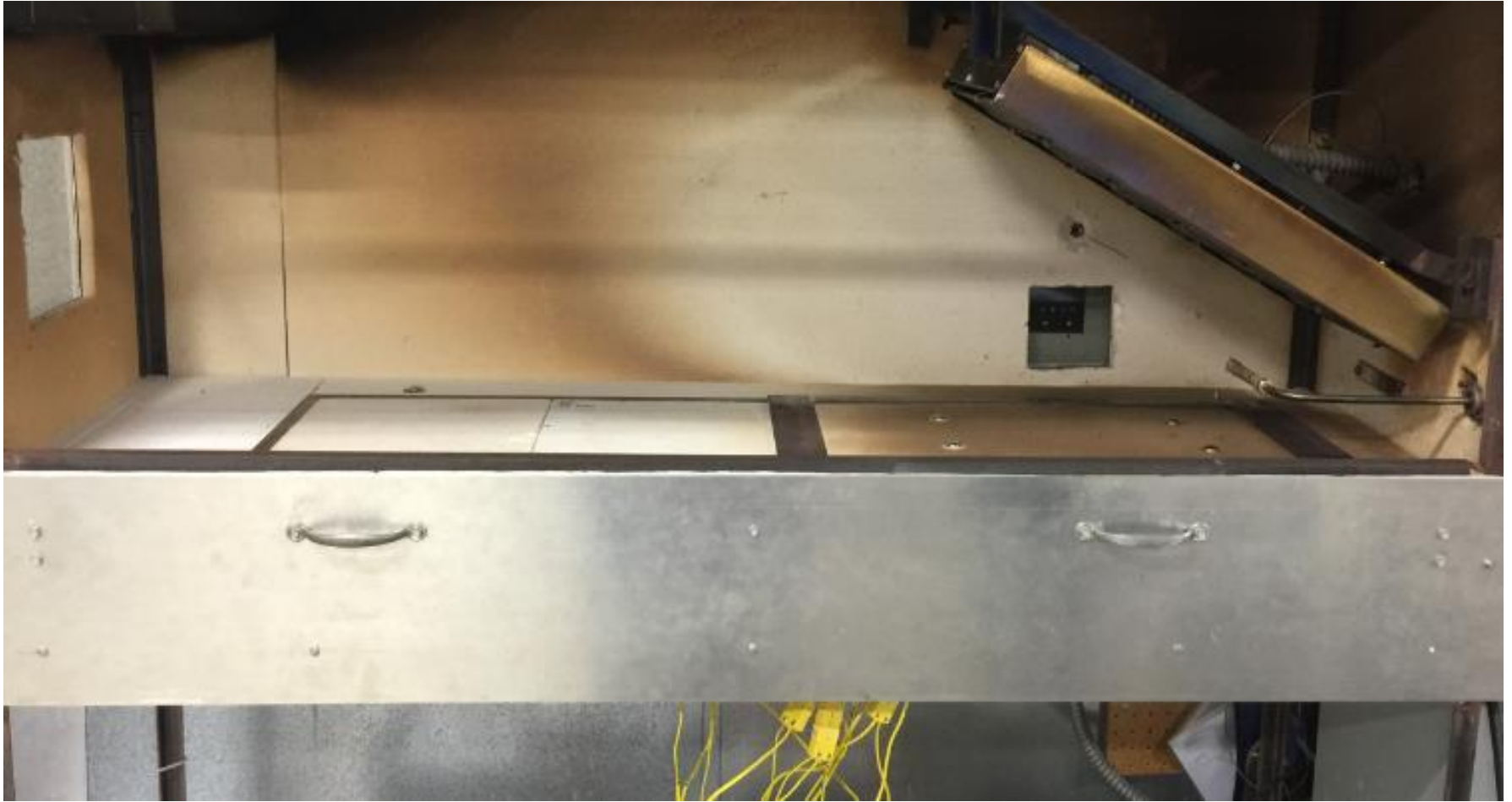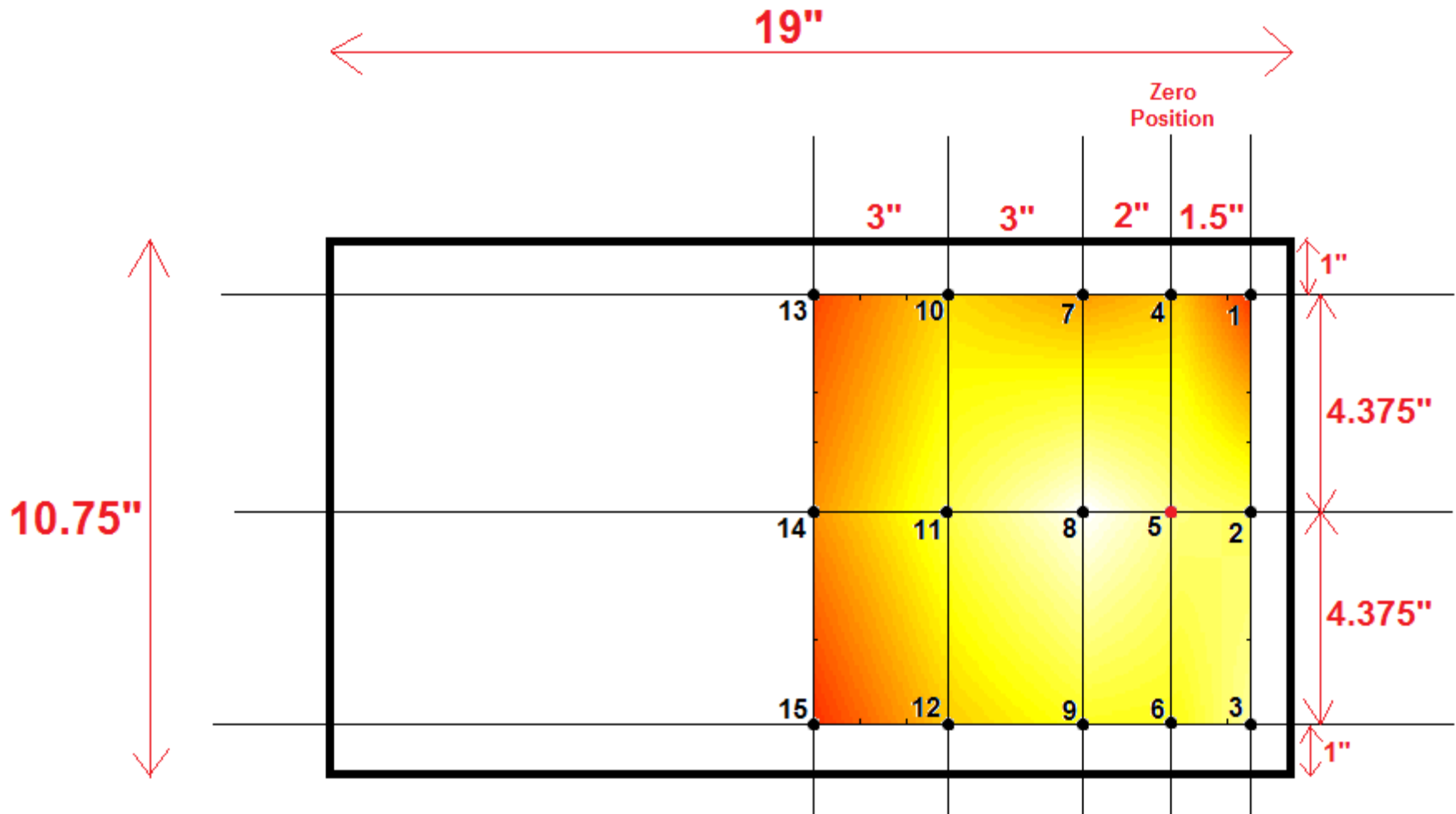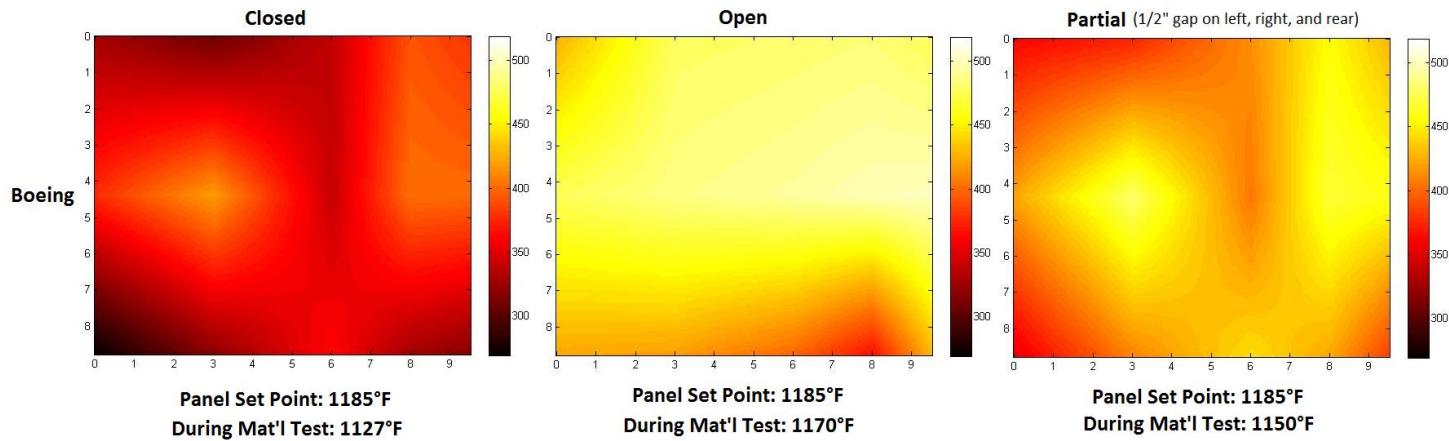
*Tested all at same setpoint, need to re-do
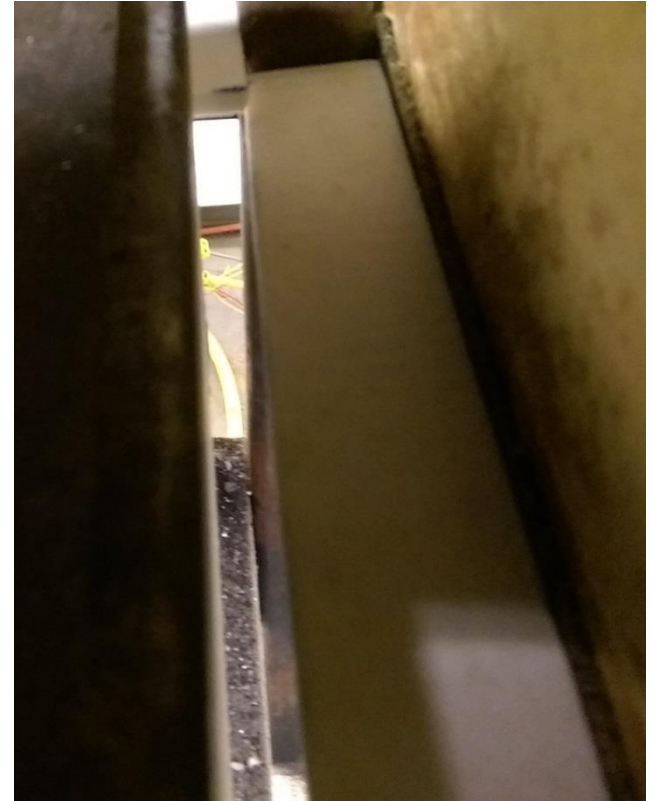
DTI

Panel Set Point: 1070°F
During Mat'l Test: 1063°F

Panel Set Point: 1128°F
During Mat'l Test: 1128°F

Panel Set Point: 1127°F
During Mat'l Test: 1130°F

FAA

Panel Set Point: 1112°F
During Mat'l Test: 1109°F

Panel Set Point: 1158°F
During Mat'l Test: 1155°F

During Mat'l Test: 1115°F
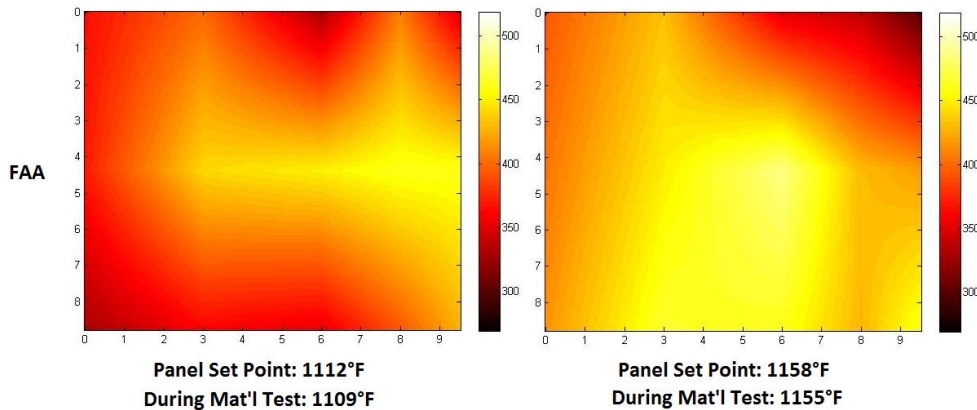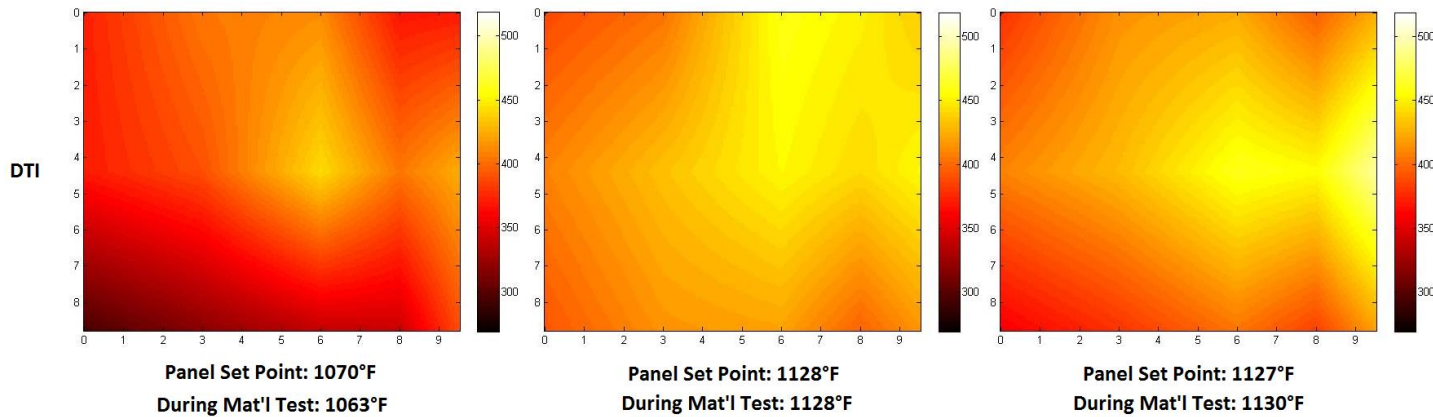
*Didn't have ½" gaps decided yet when tested, need to re-do

Metalized PEEK

- **Metalized PEEK material used in this test was not the same as the round robin – this test's material had more flame retardant treatment**
- **We didn't realize this until all of the samples were made**

Material from this study

Round Robin material
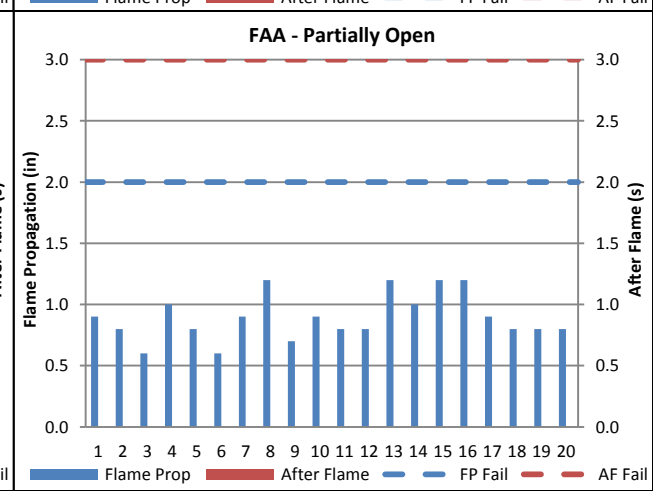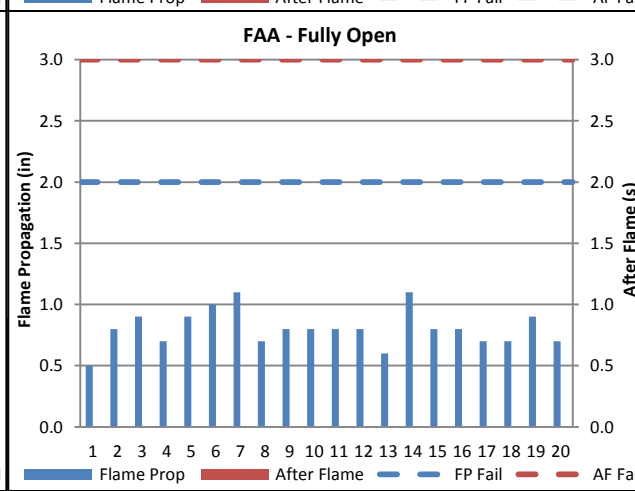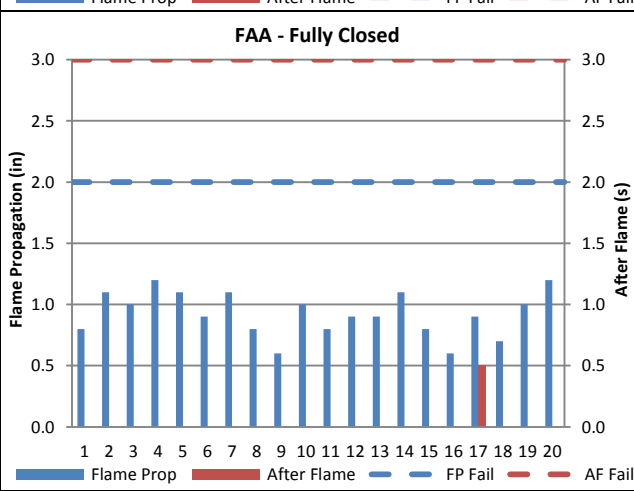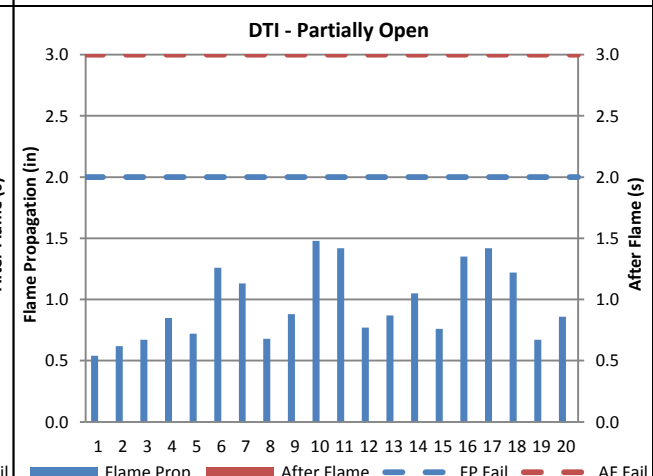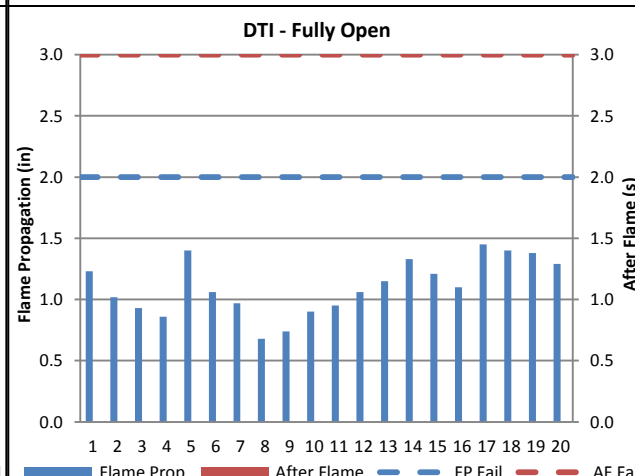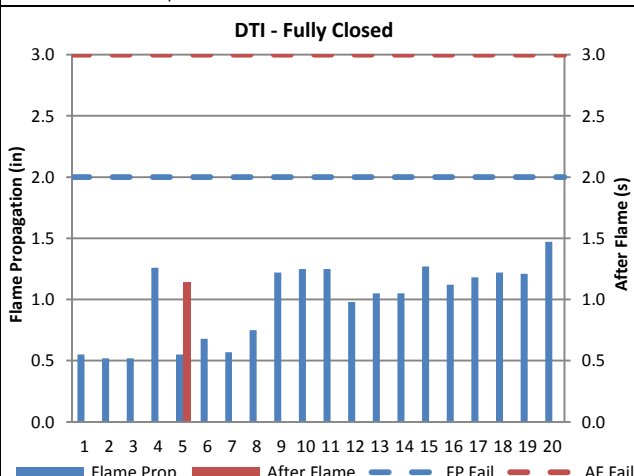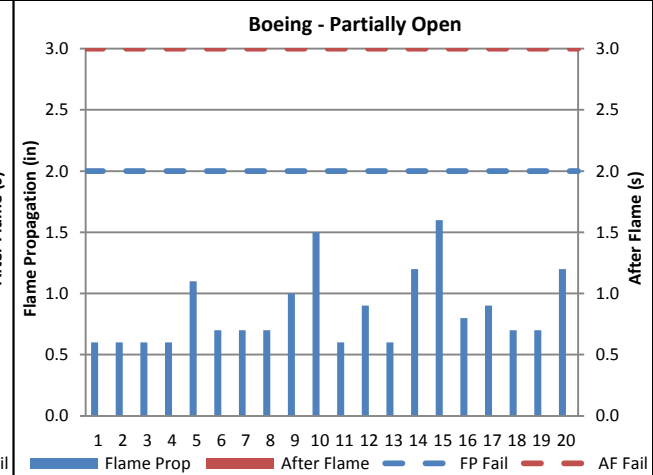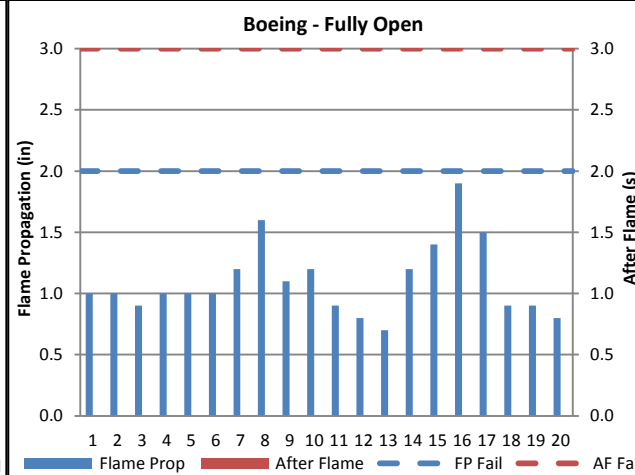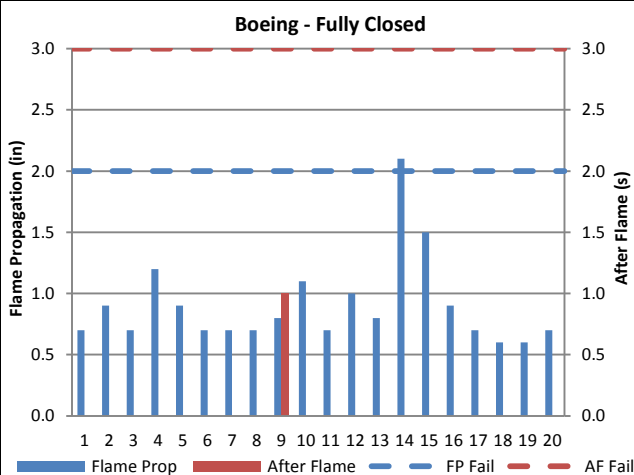
Boeing Statistical Analysis

- **Sent test results to Boeing as planned**
- **Analysis of Variance (ANOVA) and Median testing as appropriate at 5% significance level**
- **Determine if changing air gaps made significant difference in test results**
- **Compared flame propagation only since there was almost no after flame time**

Boeing Statistical Analysis
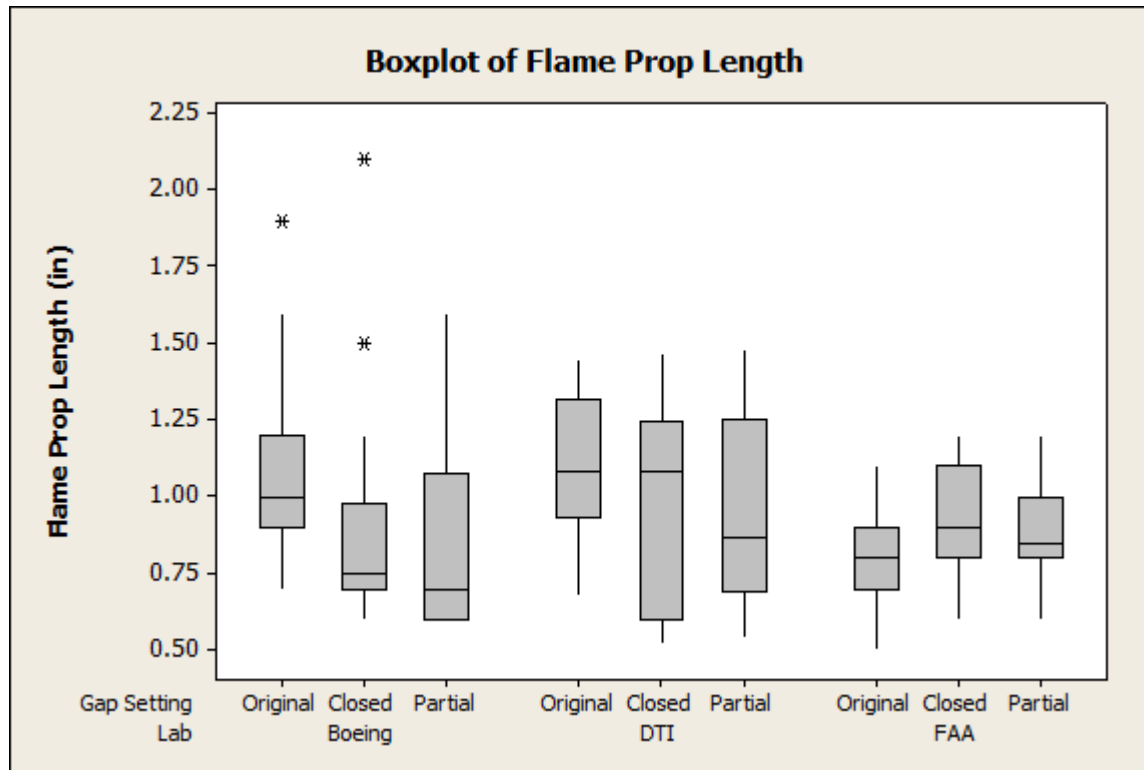
Boeing Statistical Analysis

- **Original Gaps**

```
Source   DF     SS       MS        F       P
Lab       2   1.1824   0.5912   10.76   0.000
Error    57   3.1318   0.0549
Total    59   4.3142

S = 0.2344   R-Sq = 27.41%   R-Sq(adj) = 24.86%

                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level     N    Mean    StDev   ---+---------+---------+---------+-----
Boeing   20   1.1000   0.3009                   (------*------)
DTI      20   1.1055   0.2274                   (------*------)
FAA      20   0.8050   0.1504   (------*------)
                                ---+---------+---------+---------+-----
                                 0.75      0.90      1.05      1.20

Pooled StDev = 0.2344


Grouping Information Using Tukey Method

Lab       N    Mean   Grouping
DTI      20   1.1055   A
Boeing   20   1.1000   A
FAA      20   0.8050       B

Means that do not share a letter
are significantly different
```


Boxplot of Flame Prop Length (in)
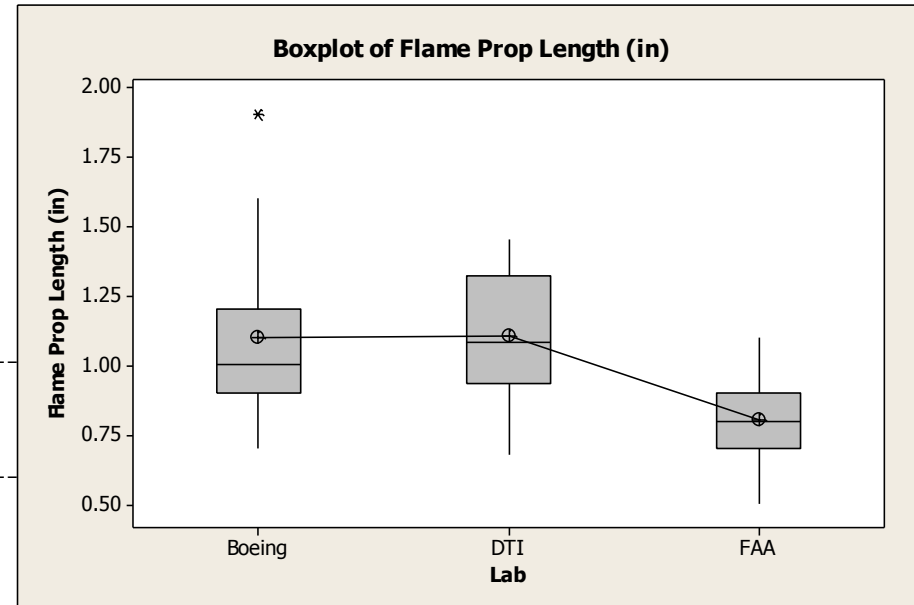
Boeing Statistical Analysis

■ **Partial Gaps**

```
Source  DF      SS      MS      F      P
Lab      2  0.0965  0.0482  0.65  0.525
Error   57  4.2242  0.0741
Total   59  4.3207

S = 0.2722   R-Sq = 2.23%   R-Sq(adj) = 0.00%

                   Individual 95% CIs For Mean Based on
                   Pooled StDev
Level   N    Mean   StDev  ------+---------+---------+---------+-
Boeing  20  0.8650  0.3083  (-----------*------------)
DTI     20  0.9610  0.3034            (-----------*----------)
FAA     20  0.8950  0.1877     (------------*-----------)
                           ------+---------+---------+---------+-
                             0.80      0.90      1.00      1.10

Pooled StDev = 0.2722

Grouping Information Using Tukey Method

Lab     N    Mean   Grouping
DTI     20  0.9610  A
FAA     20  0.8950  A
Boeing  20  0.8650  A

Means that do not share a letter are significantly different.


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Lab

Individual confidence level = 98.05%
```


Boxplot of Flame Prop Length (in)

```
Kruskal-Wallis Test on Flame Prop Length (in)

Lab        N  Median  Ave Rank      Z
Boeing    20  0.7000     26.1  -1.38
DTI       20  0.8650     33.1   0.83
FAA       20  0.8500     32.3   0.55
Overall   60            30.5

H = 1.93  DF = 2  P = 0.381
H = 1.95  DF = 2  P = 0.378  (adjusted for ties)
```

Boeing Statistical Analysis

- **Closed Gaps**

```
Source  DF     SS      MS     F      P
Lab      2  0.0735  0.0367  0.42   0.658
Error   57  4.9672  0.0871
Total   59  5.0406

S = 0.2952   R-Sq = 1.46%   R-Sq(adj) = 0.00%

                      Individual 95% CIs For Mean Based on
                      Pooled StDev
Level     N    Mean    StDev  ---+---------+---------+---------+------
Boeing   20  0.9000  0.3598  (------------*------------)
DTI      20  0.9835  0.3154          (-------------*--------------)
FAA      20  0.9250  0.1803    (-------------*-------------)
                              ---+---------+---------+---------+------
                               0.80      0.90      1.00      1.10

Pooled StDev = 0.2952


Grouping Information Using Tukey Method

Lab       N    Mean  Grouping
DTI      20  0.9835  A
FAA      20  0.9250  A
Boeing   20  0.9000  A

Means that do not share a letter are significantly different.
```
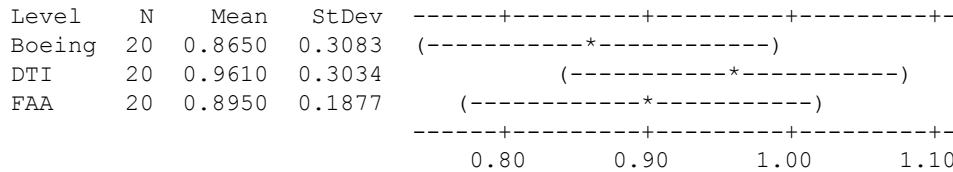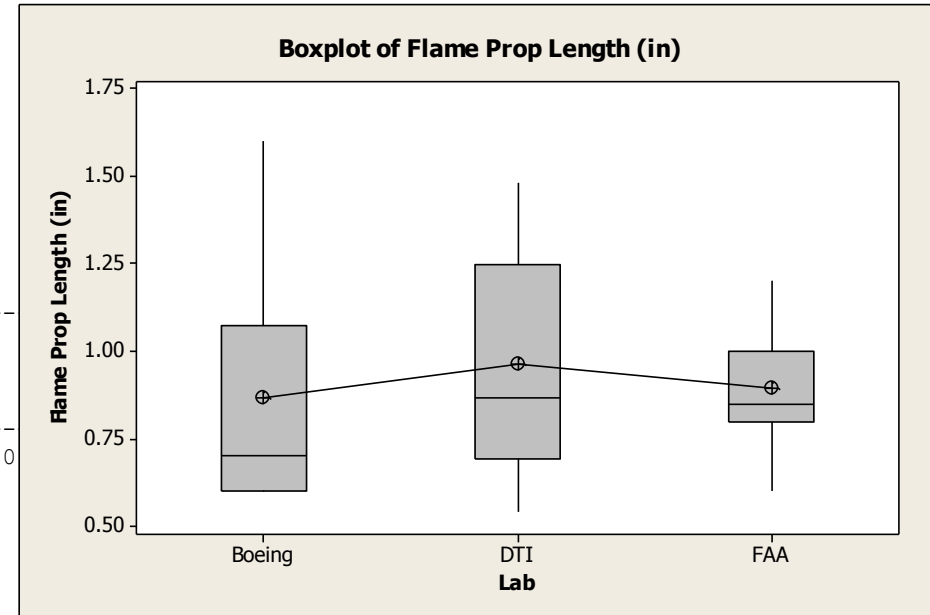

Boxplot of Flame Prop Length (in)
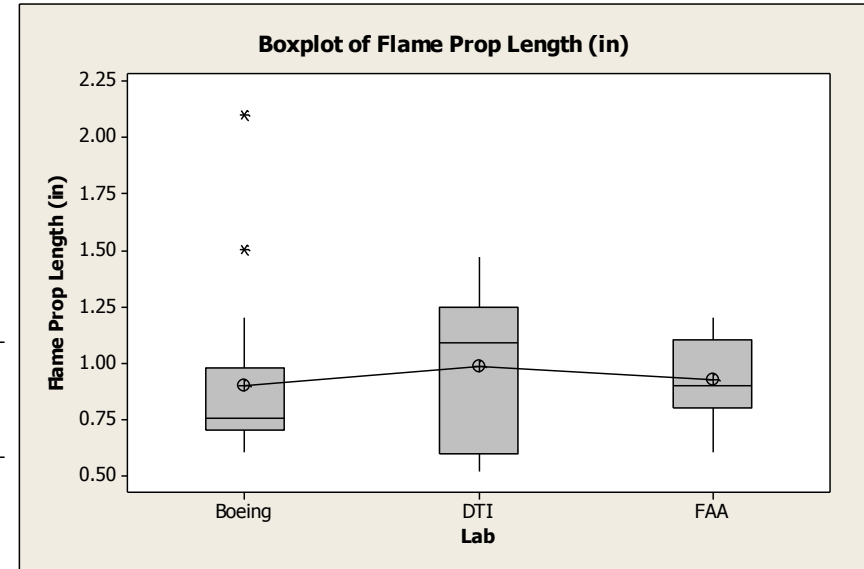
```
Kruskal-Wallis Test on Flame Prop Length (in)

Lab       N  Median  Ave Rank      Z
Boeing   20  0.7500      26.0  -1.42
DTI      20  1.0850      34.4   1.21
FAA      20  0.9000      31.2   0.21
Overall  60                30.5

H = 2.34  DF = 2  P = 0.310
H = 2.36  DF = 2  P = 0.307  (adjusted for ties)
```
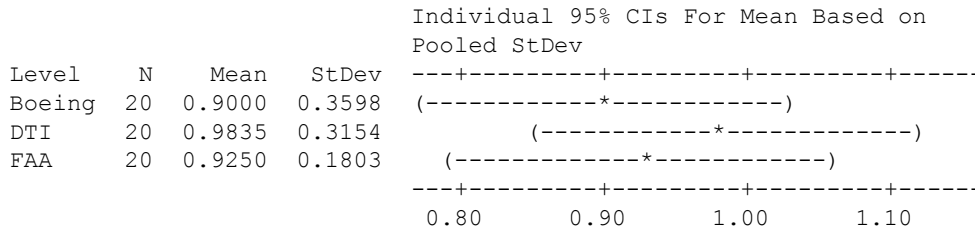
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Boeing Statistical Analysis

▪ Partial vs. Closed Gaps (All Labs Combined)

```
Source          DF      SS      MS      F      P
Gap Setting      1   0.0255  0.0255  0.32  0.572
Error          118   9.3613  0.0793
Total          119   9.3868


S = 0.2817   R-Sq = 0.27%   R-Sq(adj) = 0.00%

                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level     N    Mean   StDev  ---+---------+---------+---------+------
Closed   60  0.9362  0.2923         (-------------*--------------)
Partial  60  0.9070  0.2706  (-------------*--------------)
                            ---+---------+---------+---------+------
                             0.850     0.900     0.950     1.000


Pooled StDev = 0.2817

Grouping Information Using Tukey Method

Gap Setting    N    Mean  Grouping
Closed        60  0.9362  A
Partial       60  0.9070  A

Means that do not share a letter are significantly different.
```


Boxplot of Flame Prop Length (in)
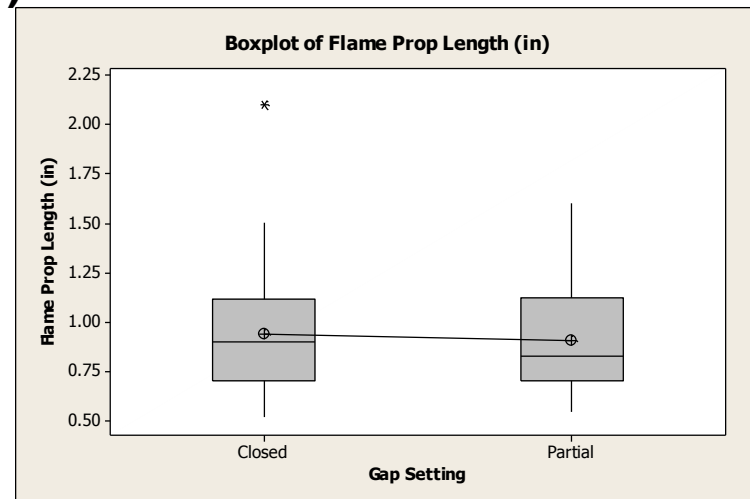
```
Kruskal-Wallis Test on Flame Prop Length (in)

Gap Setting    N   Median   Ave Rank      Z
Closed        60   0.9000     62.4     0.60
Partial       60   0.8250     58.6    -0.60
Overall      120                       60.5

H = 0.36  DF = 1  P = 0.550
H = 0.36  DF = 1  P = 0.548  (adjusted for ties)
```

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Boeing Statistical Analysis

- **Original vs. Closed Gaps (All Labs Combined Minus FAA Original)**

```
Source         DF     SS      MS      F      P
Gap Setting    1   0.6660  0.6660  8.43  0.005
Error          98  7.7432  0.0790
Total          99  8.4092

S = 0.2811   R-Sq = 7.92%   R-Sq(adj) = 6.98%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level       N    Mean    StDev  ----+---------+---------+---------+--
Original    40  1.1027  0.2632                   (--------*--------)
Closed      60  0.9362  0.2923  (-------*------)
                               ----+---------+---------+---------+--
                               0.90      1.00      1.10      1.20

Pooled StDev = 0.2811

Grouping Information Using Tukey Method

Gap Setting    N    Mean   Grouping
Original      40  1.1027   A
Closed        60  0.9362       B

Means that do not share a letter are significantly different.
```
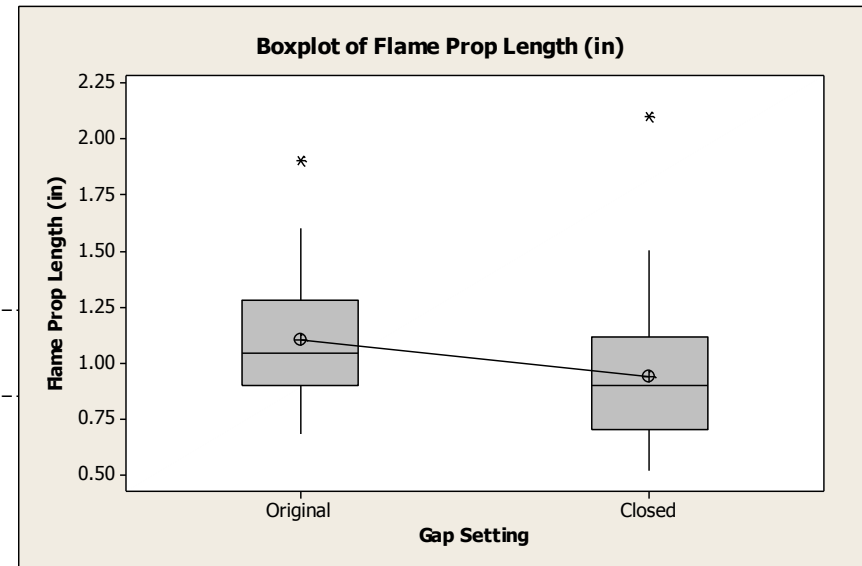
D = (1.1027 − 0.9362) / 0.2811 = 0.59

Boxplot of Flame Prop Length (in)

```
Kruskal-Wallis Test on Flame Prop Length (in)

Gap Setting    N   Median   Ave Rank      Z
Original      40   1.0400      60.9    2.92
Closed        60   0.9000      43.6   -2.92
Overall      100               50.5

H = 8.53   DF = 1   P = 0.004
H = 8.57   DF = 1   P = 0.003   (adjusted for ties)
```

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Conclusion

- **FAA was statistically different from Boeing and DTI when fully open (1.27 std. deviations)**
  - Each lab's air gaps were different
- **No difference when each lab closed and each lab partially open**
- **Statistical difference between fully open and fully closed (0.59 std. deviations)**
- **No difference between closed and partially open**
- **Metalized PEEK had too much flame retardant to fail at any condition**
- **Need to repeat material tests with more sensitive material**

Questions?

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