RTCA Development of a New Flammability Test for Electronic Boxes



Presented to: Ninth Triennial International Aircraft Fire and Cabin Safety Research Conference
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Introduction

- **RTCA DO-160G is the current international standard for environmental testing of commercial avionics**
- **Section 26, Category C defines the flammability testing requirements for electronic housings and component parts**
- **Next revision for DO-160(H) is due January 2021**
- **The goal is to create a new test method that will be simpler and require less total testing while maintaining or improving the level of safety**

Current Standards

- **Electronic equipment must be broken down into its individual parts and tested using the various Bunsen Burner tests**

Table 26-2 Type of Test Determination

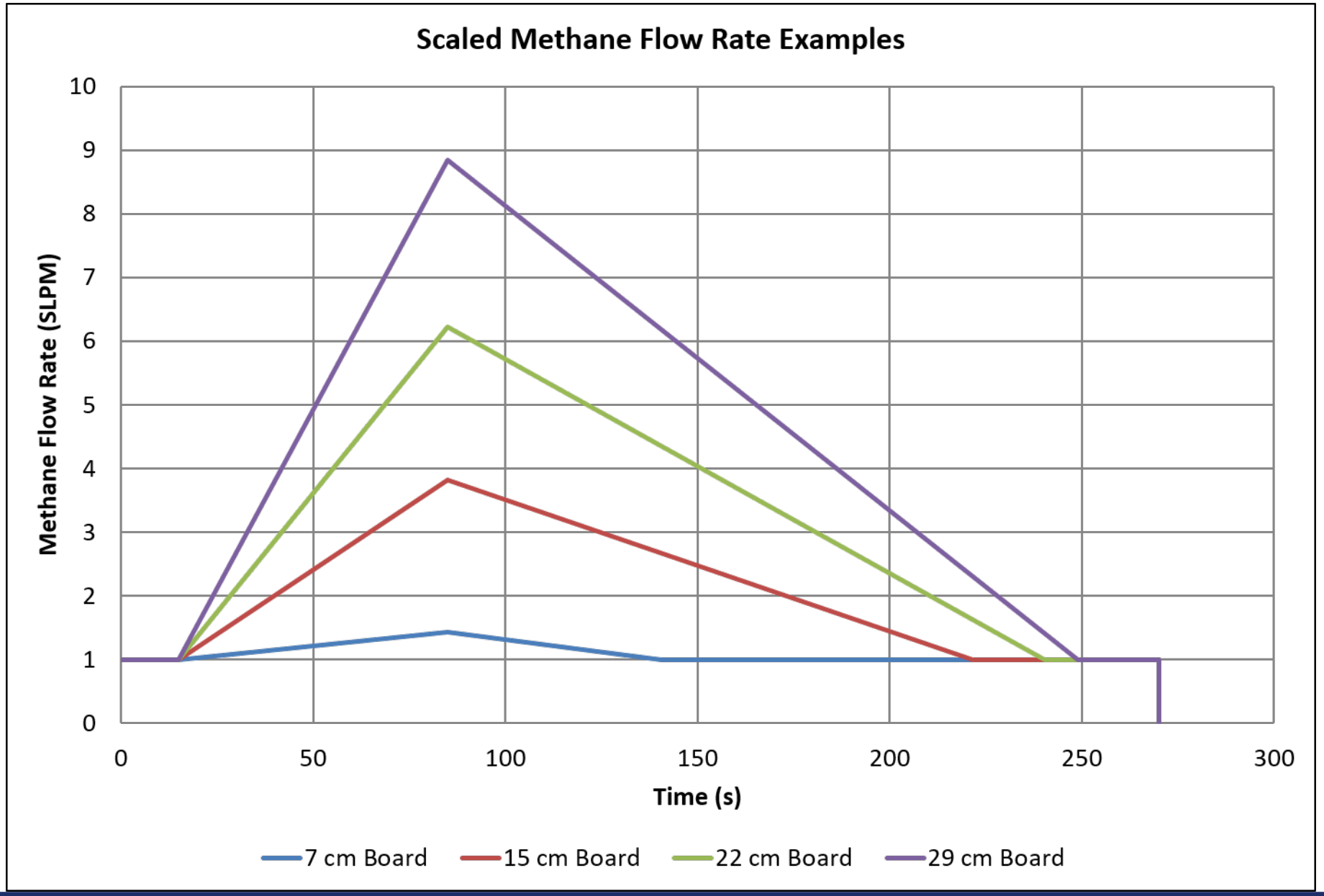
Components	Method	Paragraph
All materials other than rubber or elastomer parts, wire and cable	Vertical 12 second bunsen burner test	26.6.2
Rubber or elastomer parts	Horizontal bunsen burner test	26.6.3
Wire and cable	60 degree bunsen burner test	26.6.4

- **Small part exemptions**

New Test Method

- Based on telecom industry test ANSI T1.319
- 3/8” stainless steel tube with (11) 7/64” holes places 1/2” apart
- Methane Fuel with variable flow rate controlled by computer program
- Flow rate based on circuit board of certain size burning to completion
- Burner holes can be covered for smaller box or lower flow rates



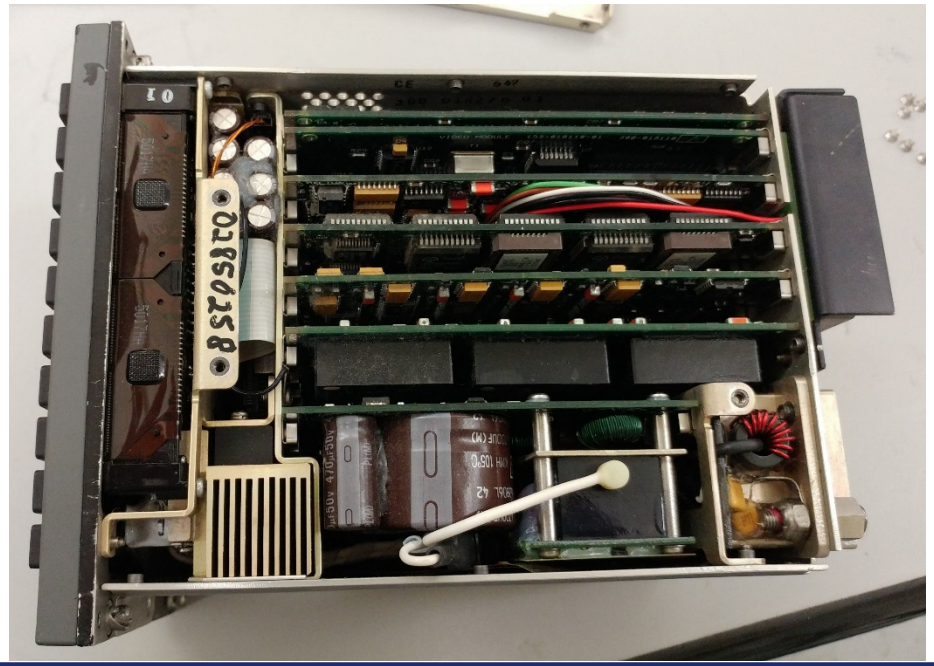

Scaled Methane Flow Rate Examples
Methane Flow Rate (SLPM)
10
9
8
7
6
5
4
3
2
1
0
0
50
100
150
200
250
300
Time (s)
7 cm Board
15 cm Board
22 cm Board
29 cm Board

Test Procedure

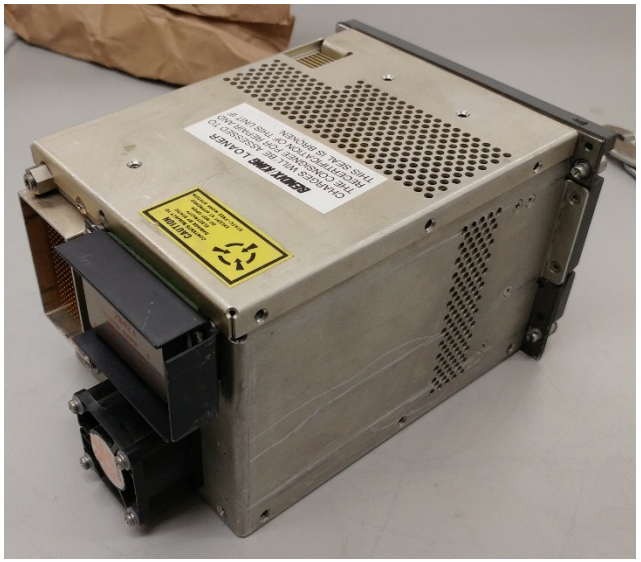
- **Identify printed circuit board (PCB) or other part with the highest fuel load**
- **Remove adjacent PCB and the burner is to be placed in the same general location aimed 45° towards PCB to be tested**
- **Drill 0.75” hole to insert burner**
- **Insert lit burner into enclosure and immediately start 270 s burner program**
- **Evaluate based on pass/fail criteria (TBD)**
- **Certain equipment may require more than one test depending on potential fuel load inside box**

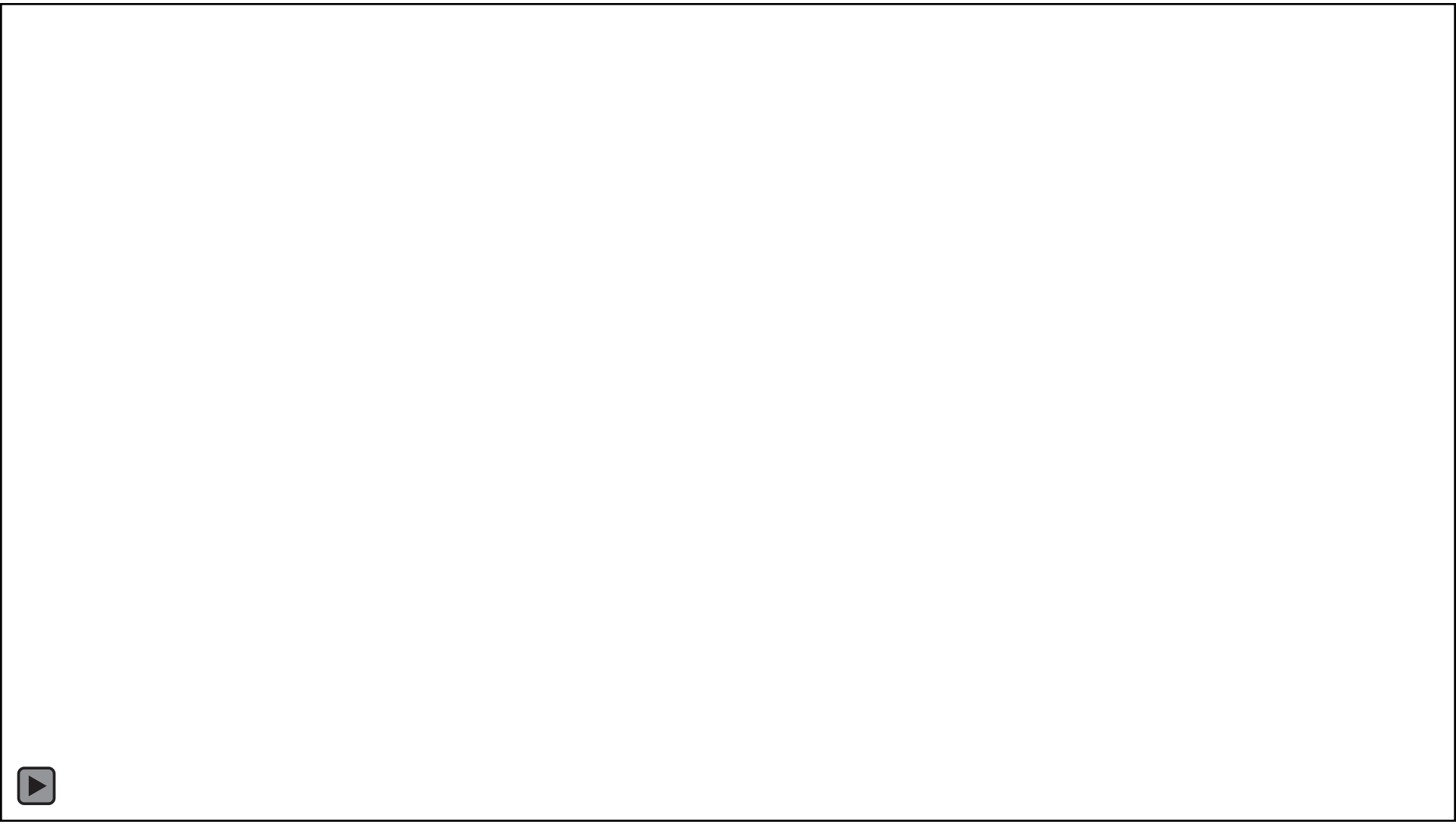
Test Example

- 5V intake fan, 24V exhaust fan
- Must remove 1 board in order to fit line burner
- 9.5 cm PCB height
- PCB long enough to fit 8 out of 11 burner holes
- 0.73 L/min initial flow rate, 1.55 L/min max.



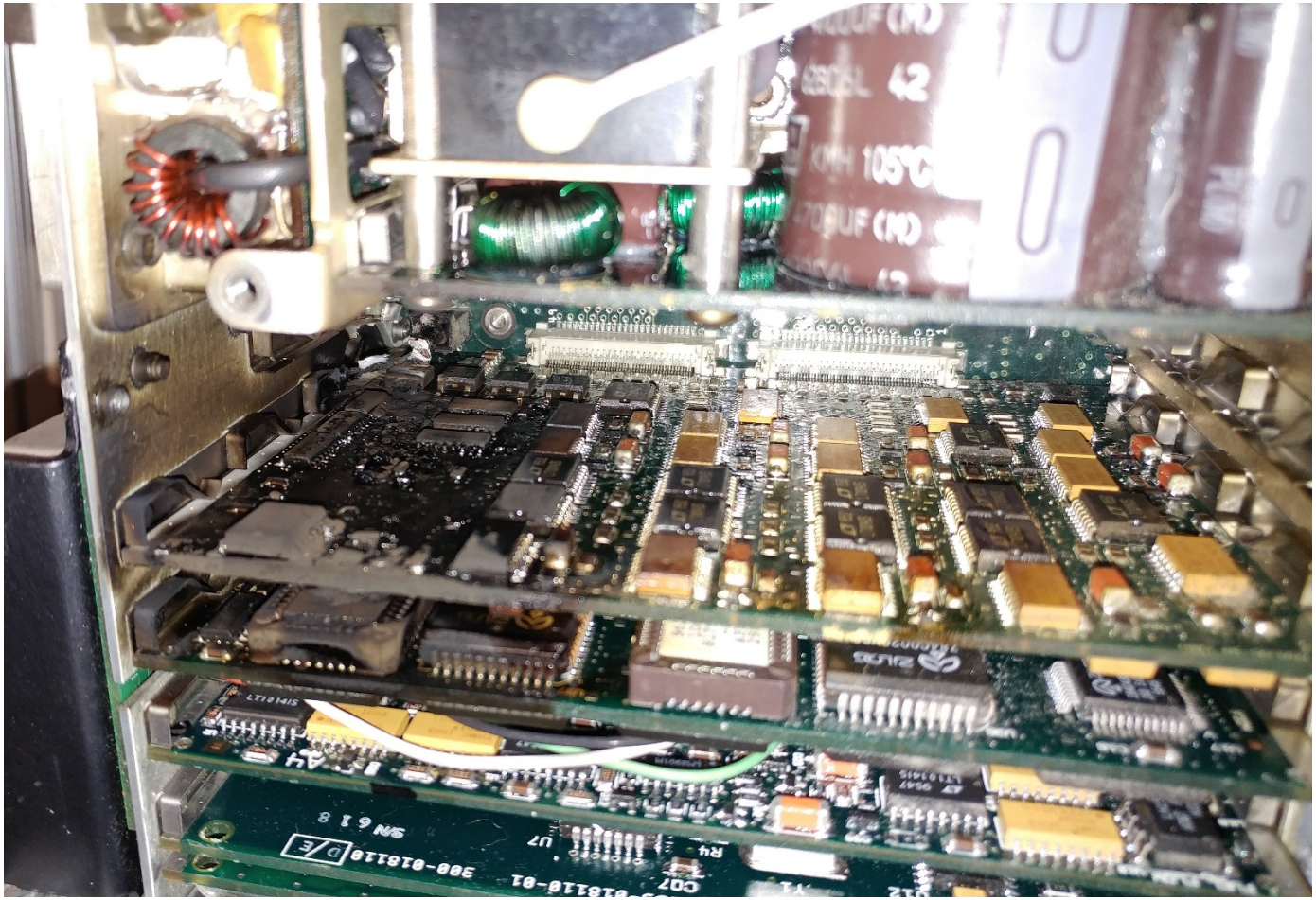






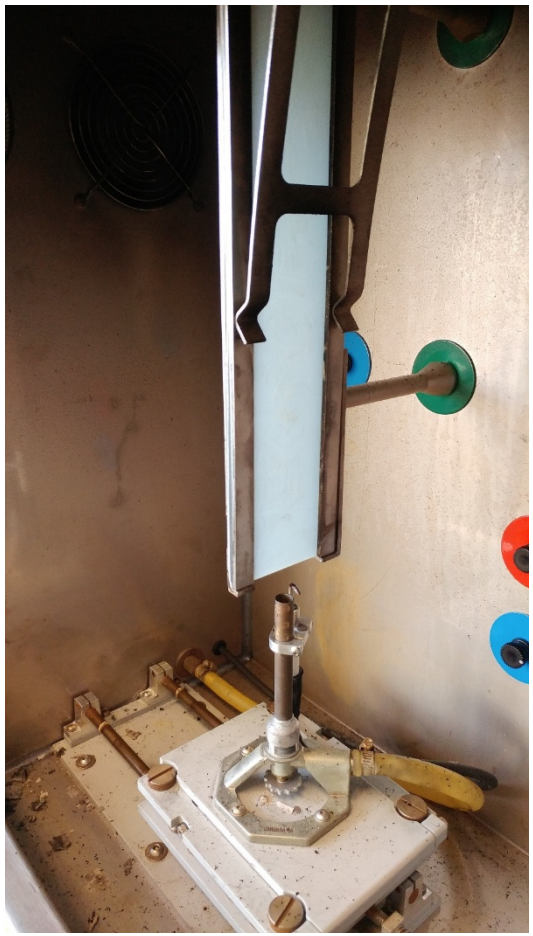
5V Intake fan, 24V Exhaust fan running at 8V, 2:20 after start of test

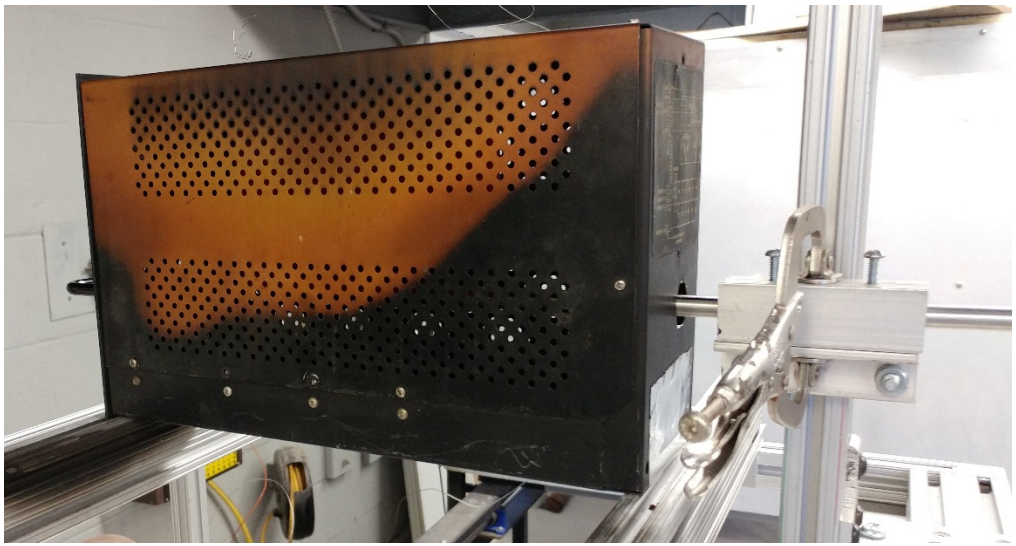
Post-Test Picture



- Damage to first PCB, appears to have spread to second PCB

Bunsen Burner Comparison



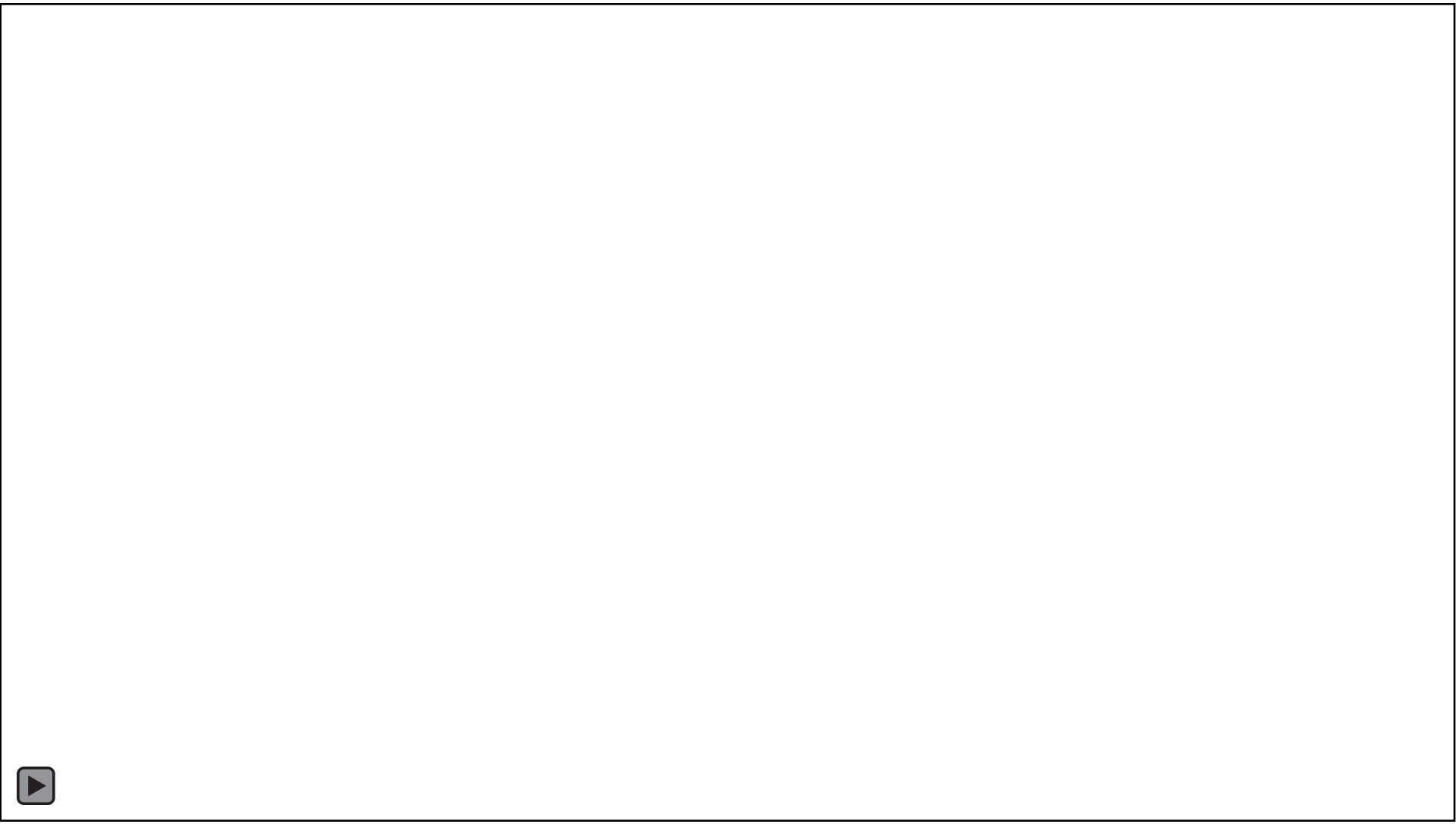


Bunsen Burner

- 12” × 3” Sample Size
  - (12 × 2” exposed)
- 12-second burn time
- 1.5” methane flame

Line Burner

- 6” × 4” Sample Size
- 270-second burn time
- Methane flow rate from 1 L/min to 2.27 L/min
- Worst case scenario enclosure – not airflow limited



Electrical Grade Fiberglass (GP03), 105 seconds after start of test

Bunsen Burner Comparison

Electrical Grade Fiberglass (GP03) (Glass Polyester) UL94 V-0 Certified



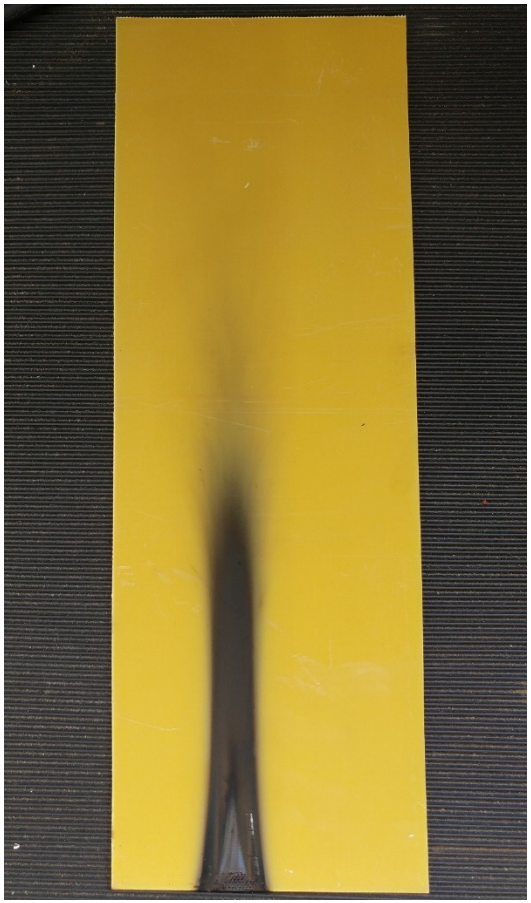


Bunsen Burner
- 0.1-inch Burn Length
- No After Flame

Line Burner
- No flames escaped box
- Material completely consumed above burner

Bunsen Burner Comparison

SLIIM Material – Glass epoxy used as ignition indicator in Telecom industry test
FR4 UL94 V-0 Certified



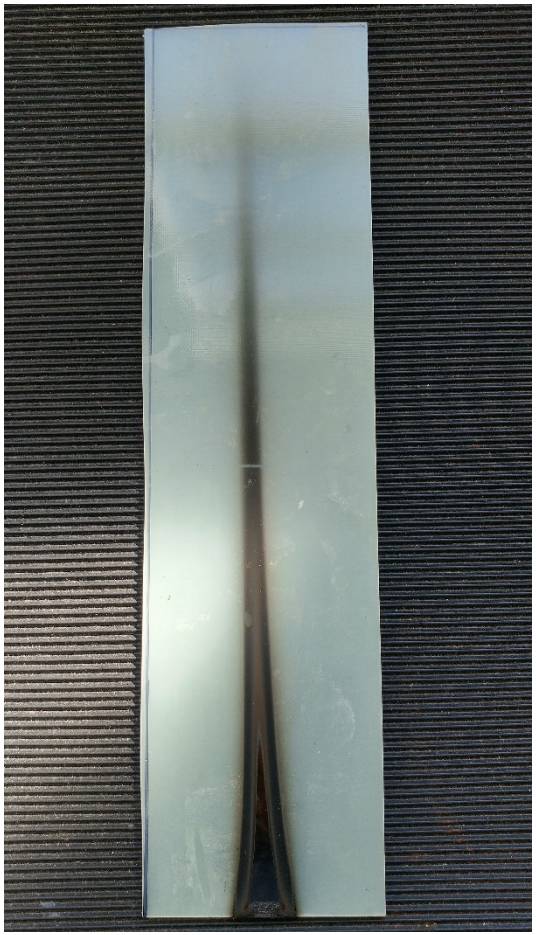


Bunsen Burner
- 0.3-inch Burn Length
- 1-second After Flame

Line Burner
- No flames escaped box
- Material completely consumed above burner

Bunsen Burner Comparison

FR4 Glass Epoxy UL94-V0 Certified





Bunsen Burner

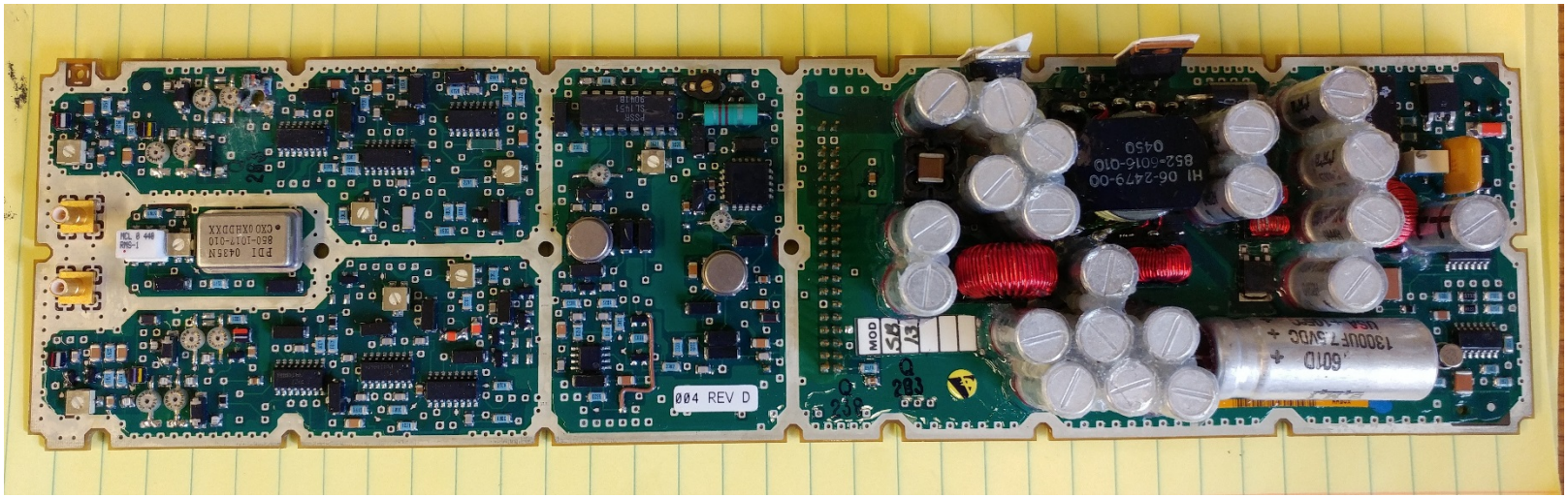
- 0.2-inch Burn Length
- No After Flame

Line Burner

- No flames escaped box
- Material completely consumed above burner

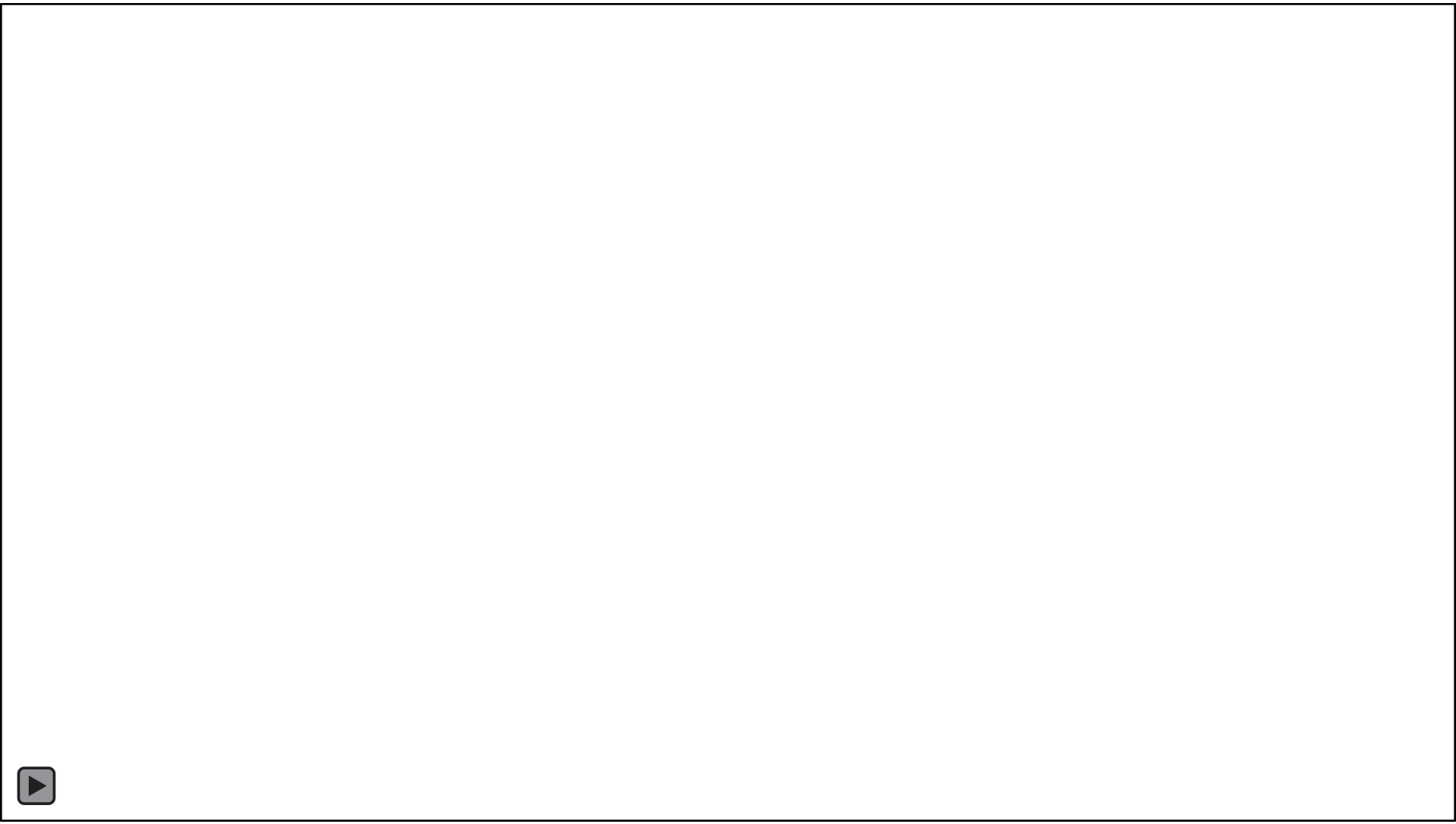
Bunsen Burner Comparison

- 3” × 10” circuit board from a sealed box (would not normally be tested)
- (21) 60V, 15 µF capacitors and (1) 7.5V, 1300 µF capacitor
- Smaller circuit board with the same capacitors from the same box tested in 12-second vertical Bunsen burner



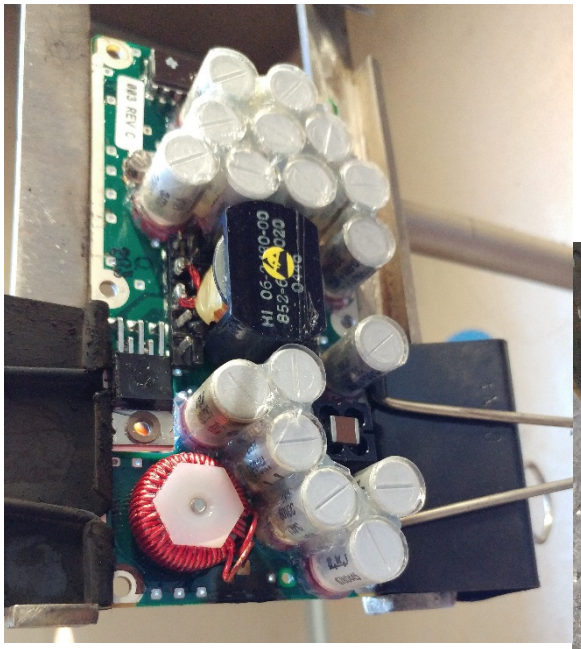


No After flame, 0.1-inch burn length



2:45 after start of test, 1.60 L/min max. flow rate

Bunsen Burner Comparison



Bunsen Burner

Line Burner



Round Robin

- Four labs received identical boxes

- 12.5” × 7.5” × 7.5” box
- Ventilation on top and bottom only

- Four Labs Testing:
  - FAA – Steve Rehn
  - Element – Alan Thompson
  - Airbus – Thomas Krause
  - Wichita State University – Kyle McMullen

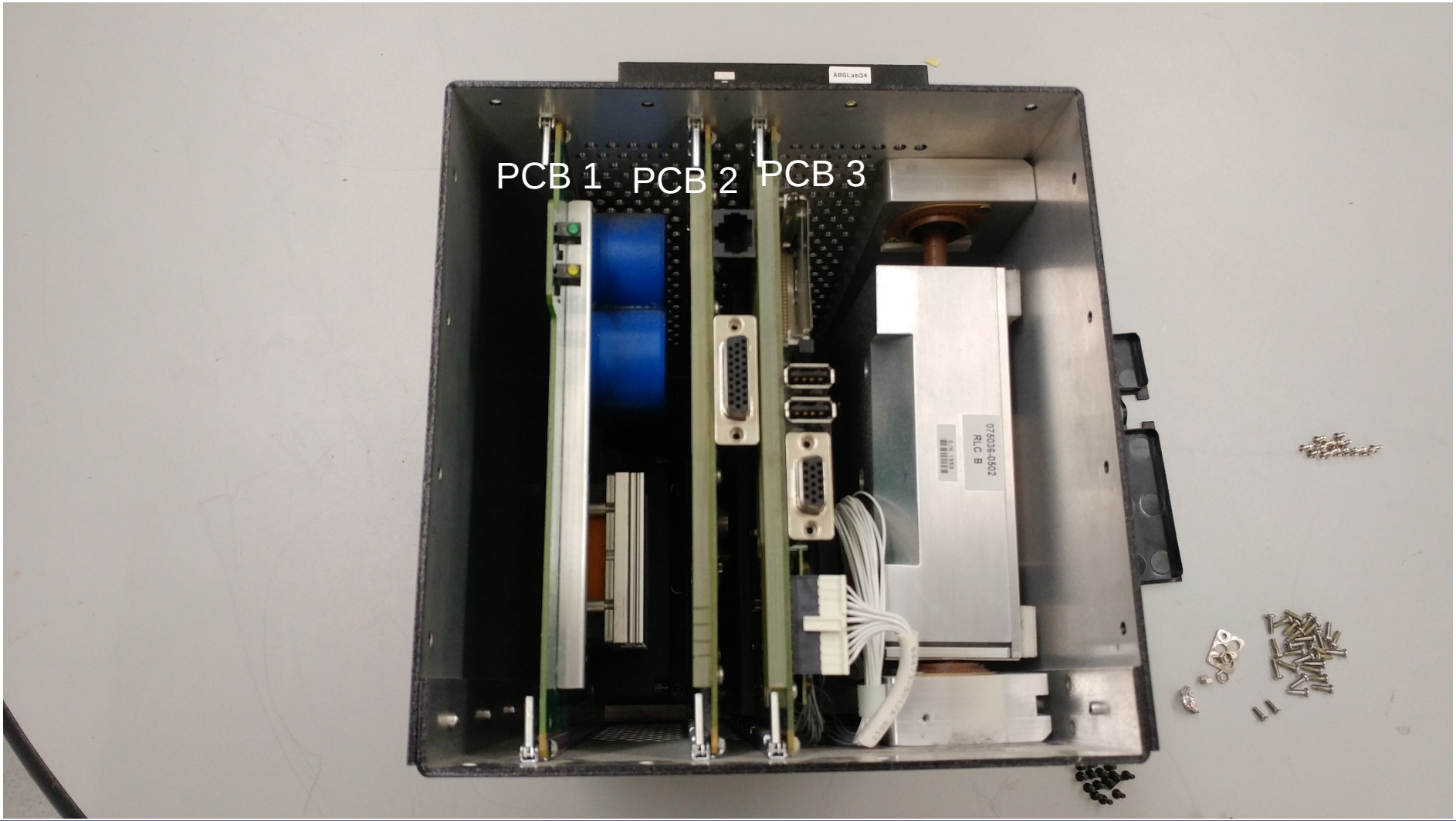
- Received full data from three labs, some data from 4th lab



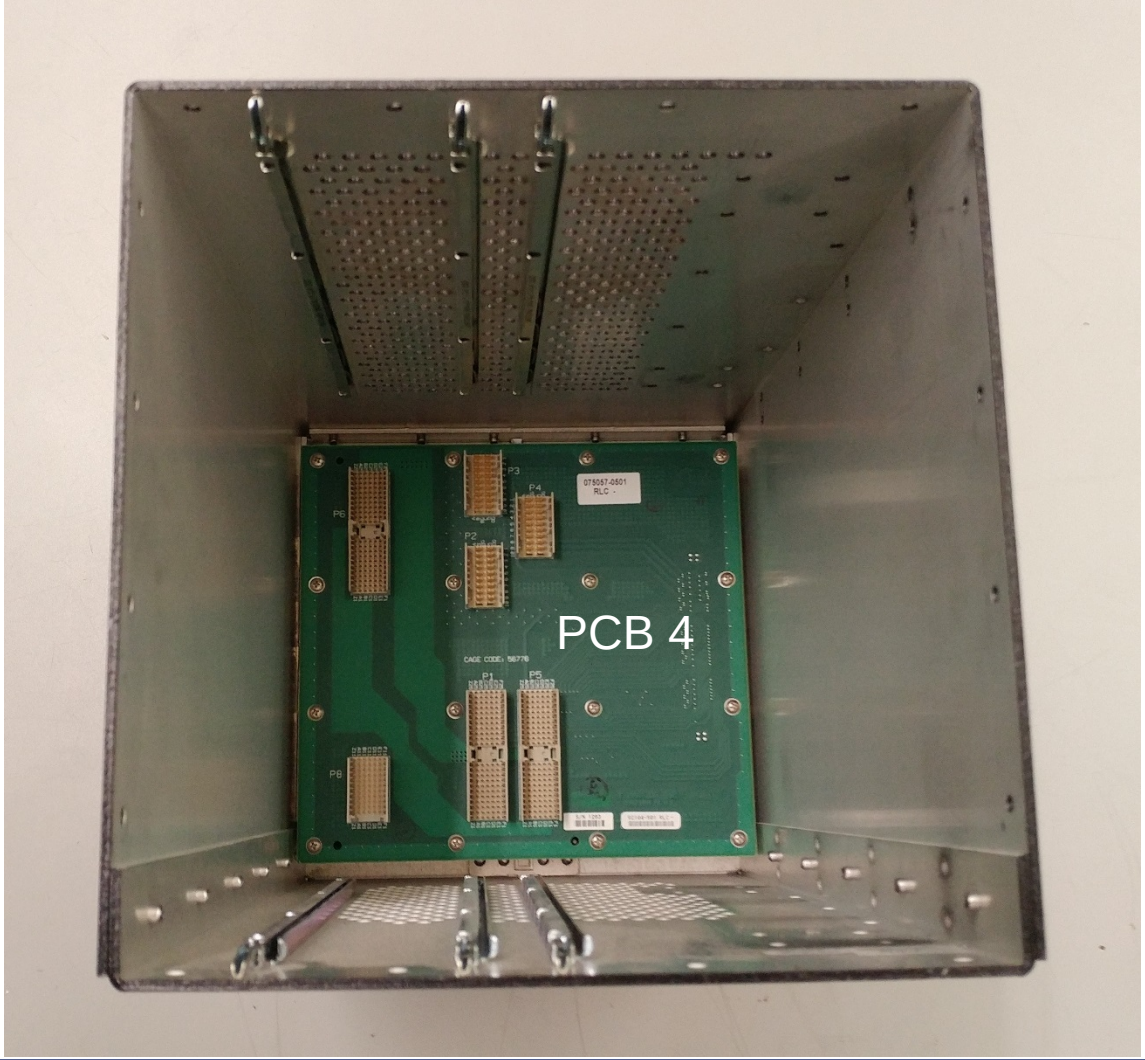
Round Robin



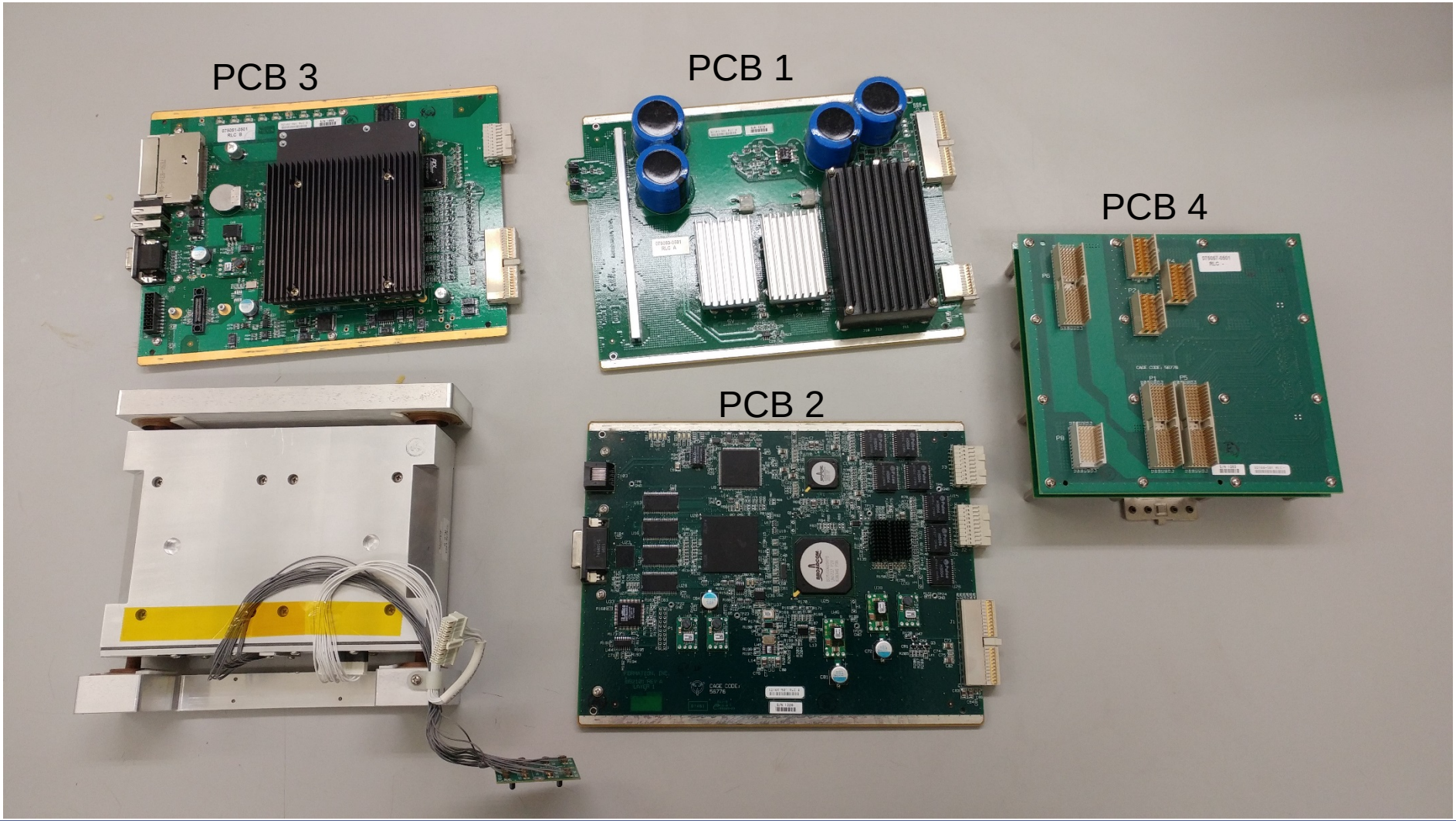
Round Robin



Round Robin



Round Robin

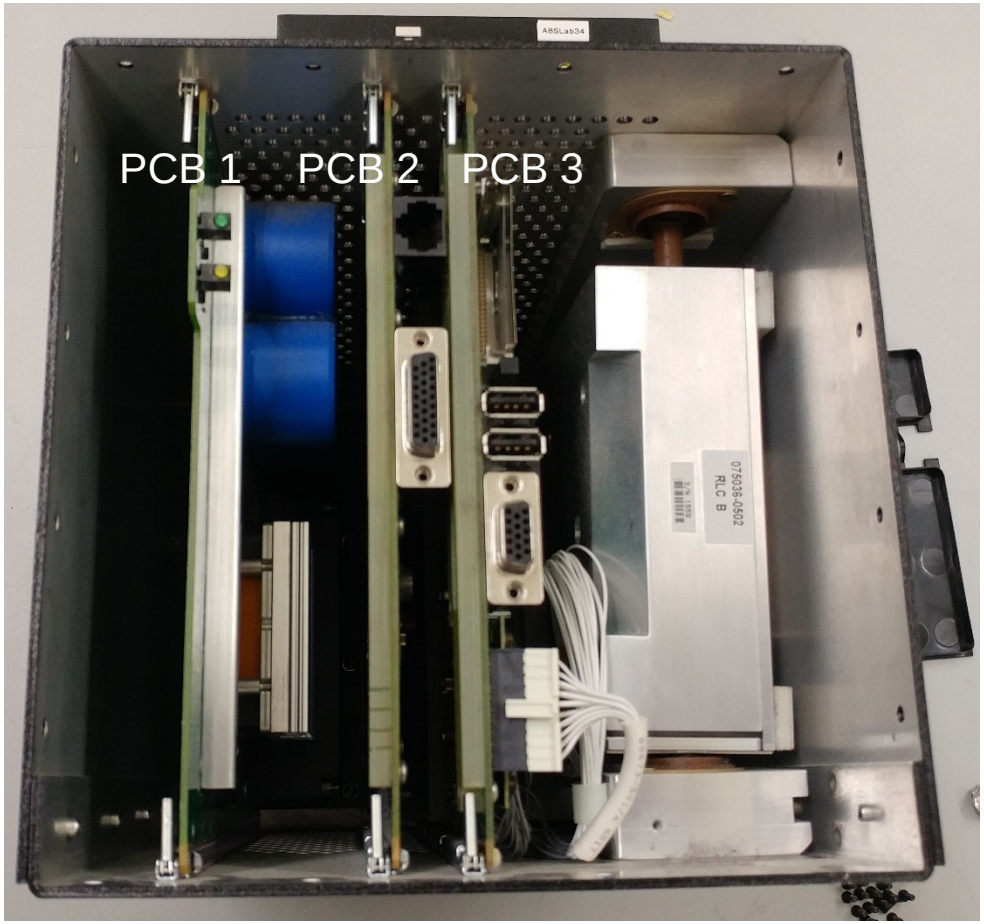


Burner Placement

- **Since this test method will be used for a variety of different boxes, burner placement is somewhat subjective**
- **Each lab determined burner placement and number of burns independently based on draft test method**
- **Then discussed placement with each other to determine number of burns and where the burner will be placed for testing**
- **Each lab will test with the same placement**

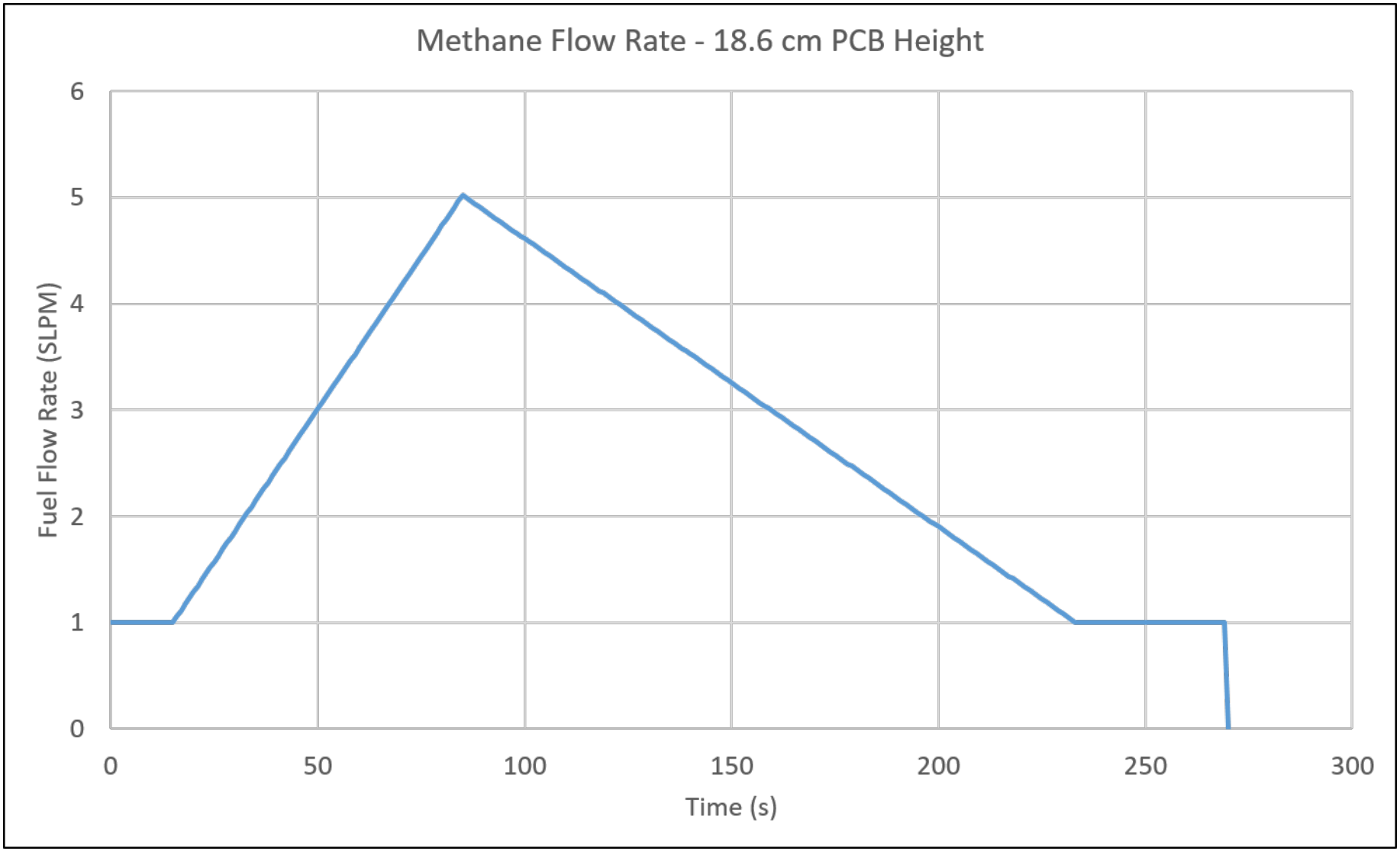
Burner Placement

- Labs A and B suggested 2 burns, Lab C suggested 3 burns, and Lab D suggested 5 burns
- Labs A and B suggested to burn PCBs 1 and 3 in order to test the large capacitors and lithium battery
- Labs C and D suggested additional burns to be more conservative



Burner Placement

- **After discussions, we agreed to 4 burns, one for each PCB**
- **Do not have bill of materials**
- **Assume boards are not all the same material**
- **Different threats on each board – capacitors, battery, plastic plugs, etc.**



- Same flow rate for all tests
- If flames escape box for >12 sec it is considered a failure (for this RR only)

PCB 1



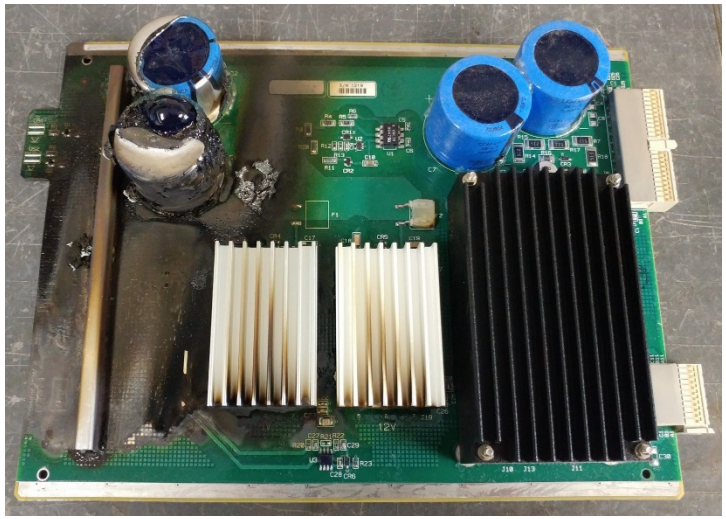
Burner



PCB 1

*No flames escaped box for any lab

FAA Results



Element Results



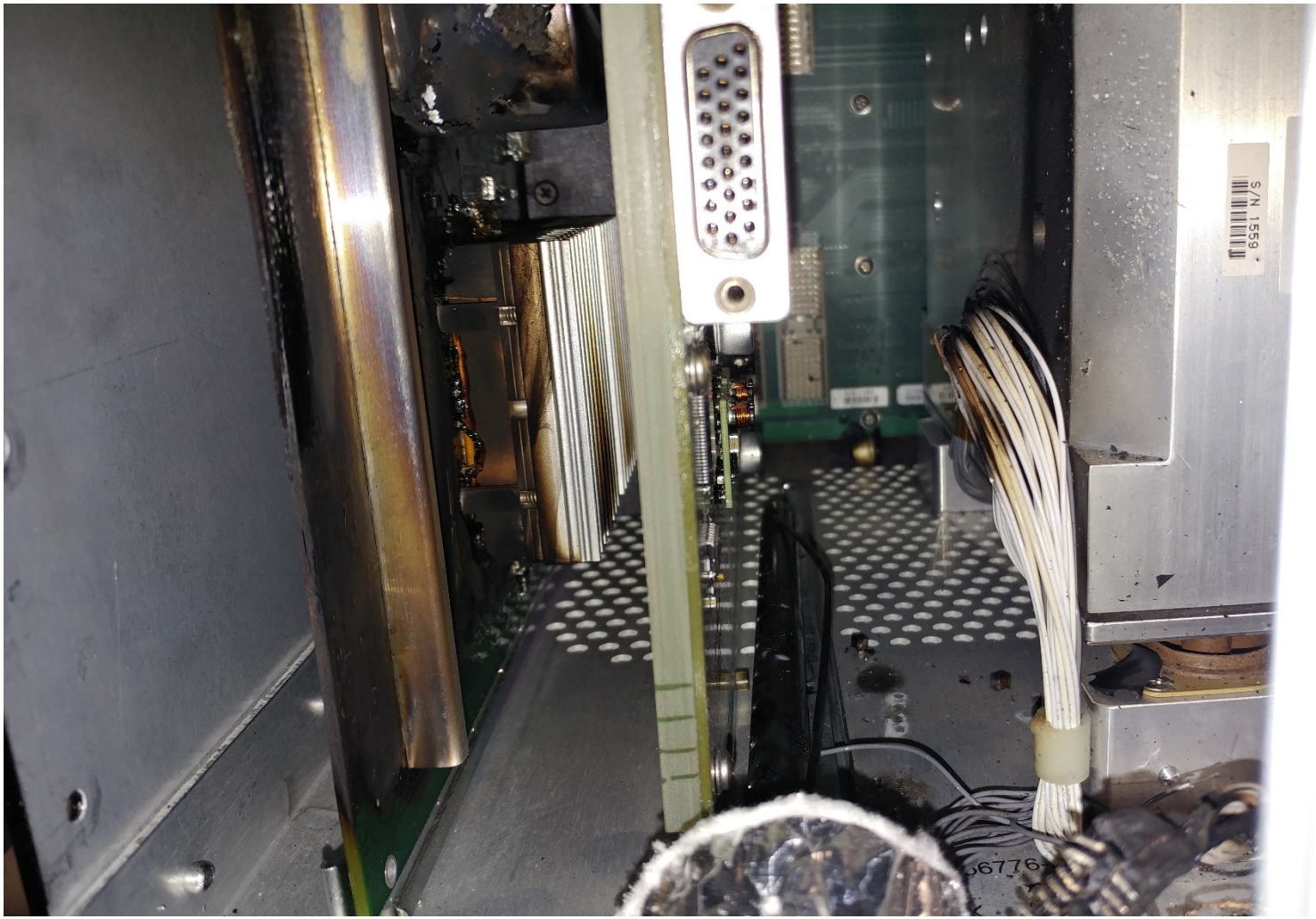
WSU Results



Airbus Results



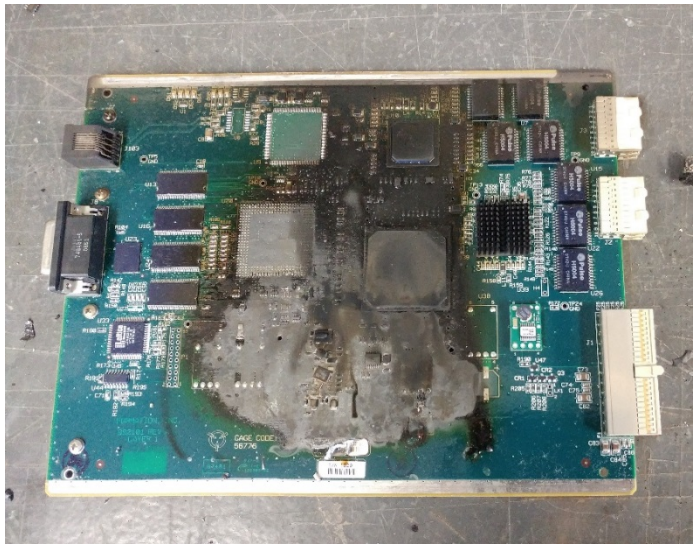
PCB 2



PCB 2

*No flames escaped box for any lab

FAA Results



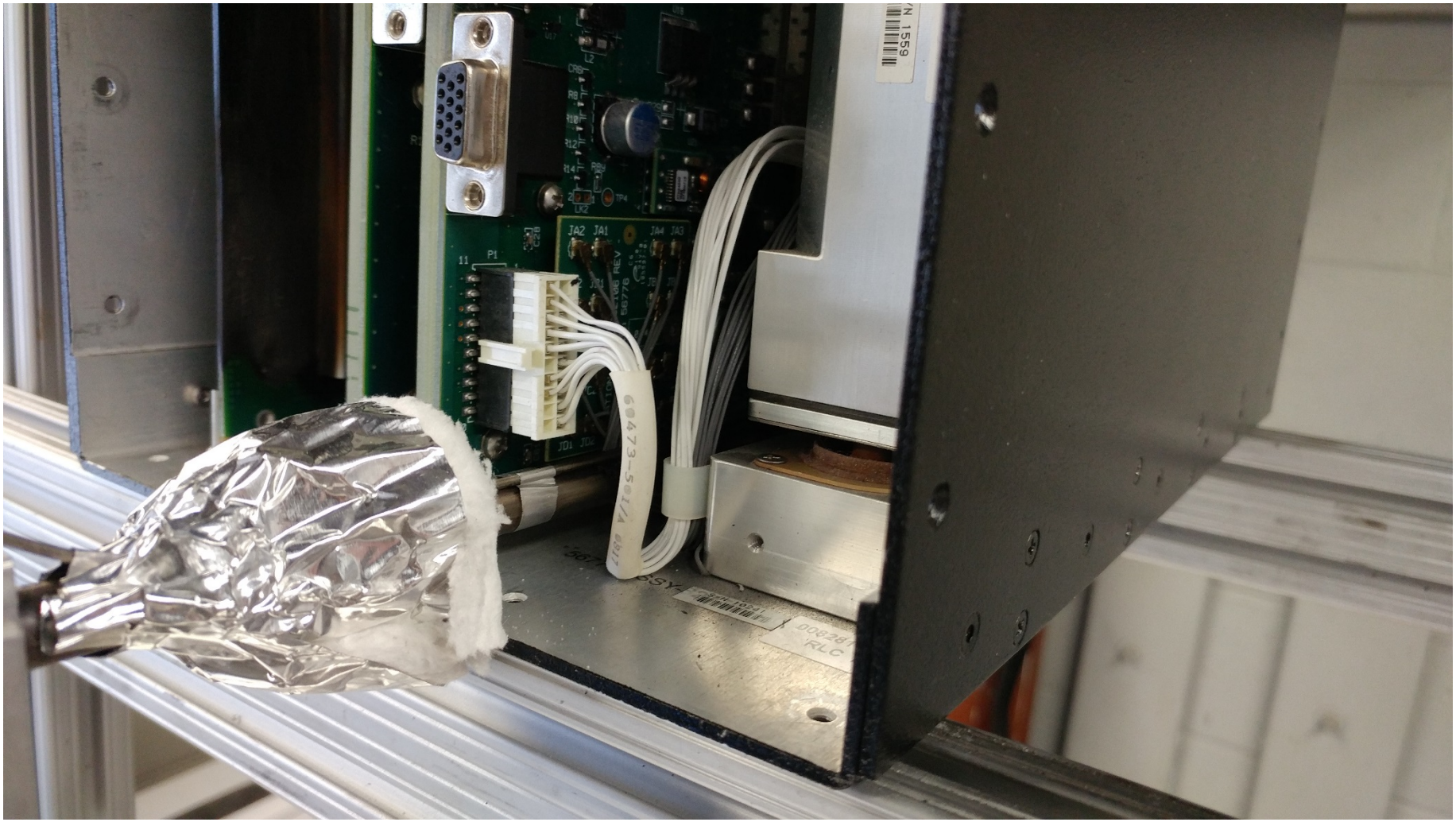
Element Results



WSU Results



PCB 3



PCB 3: Battery exploded 41 seconds into test, flames escaped for 0.33 seconds, explosion extinguished burner flame



Wichita State University Test – PCB 3

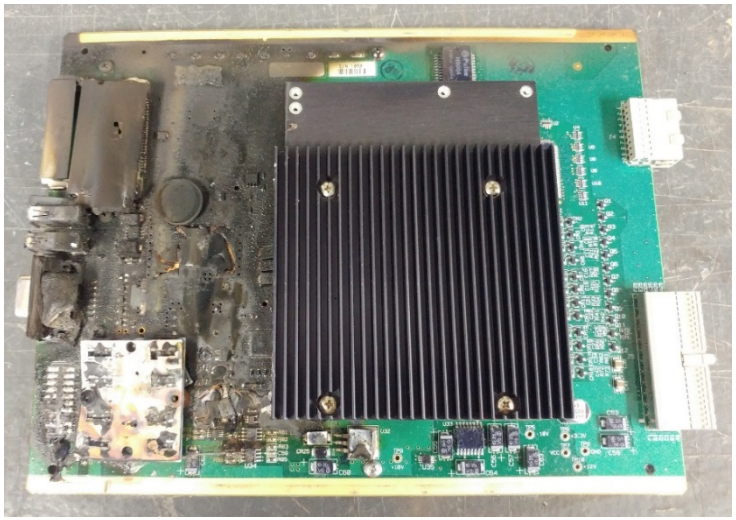
- Battery exploded 50 seconds after start of test



PCB 3

WSU did a shortened second burn after flame went out during first burn

FAA Results



Element Results



WSU Results



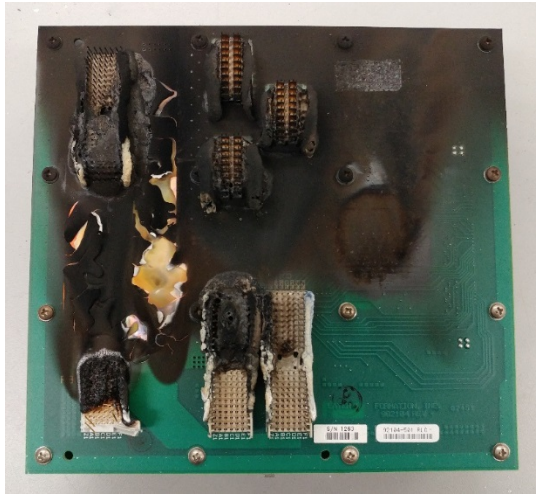
Airbus Results



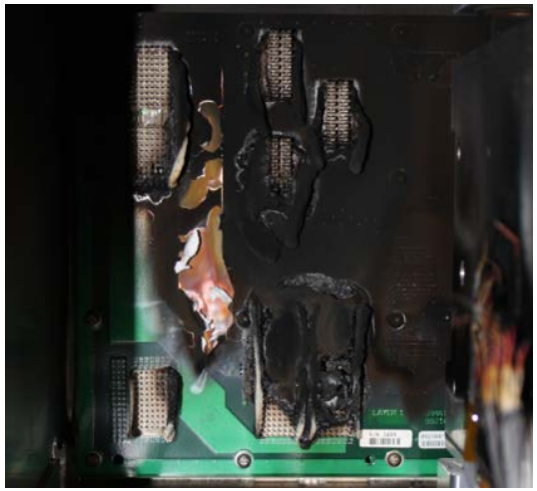
PCB 4

*No flames escaped box for any lab

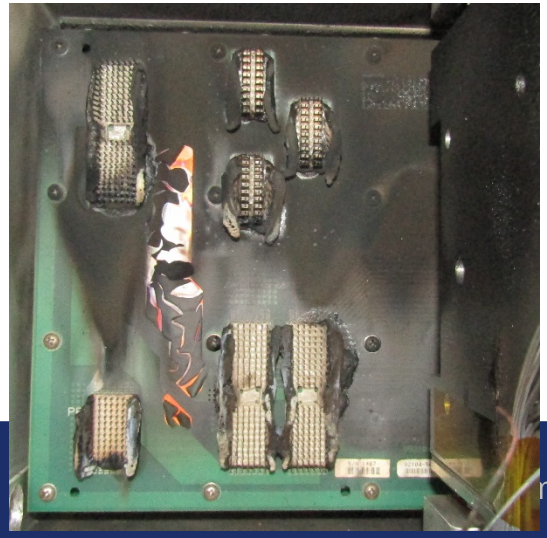
FAA Results



Element Results



WSU Results



Additional Testing

- **Test 3 samples each**
- **Test one at a time placed inside empty box**
- **Test for repeatability and reproducibility**



1/16” FR-4 Glass Epoxy UL94-V0 Certified



1/16” Flammable Garolite

FAA: FR4 Glass epoxy material

- Flames did not escape for any of the 3 samples



Element: Material Sample Burns FR4 Glass Epoxy



Burn 2 with room light



Burn 2 without room light

Results: All three FR4 samples were burned. Room lighting had a large impact of the ability to detect if flames exited the UUT enclosure. With room lighting on they would likely all have passed. Without room lighting they may have failed.

FAA: Garolite material test (23 sec flame time)

- No flames escaped box for any Garolite sample for the three labs except this one



Results Summary

Flame time (s)

	PCB 1	PCB 2	PCB 3	PCB 4
FAA	0	0	0.33	0
WSU	0	0	0.5	0
Element	0	0	<1	0
Airbus	0	-	<1	-

	PCB 3 Time to Explosion (s)
FAA	41
WSU	50
Element	49
Airbus	55

	FR4 1	FR4 2	FR4 3
FAA	0	0	0
WSU	0	0	0
Element	0	0	0
Airbus	-	-	-

	Garolite 1	Garolite 2	Garolite 3
FAA	0	23	0
WSU	0	0	0
Element	0	0	0
Airbus	-	-	-

Element FR4 glass epoxy test

- Flames appear to be escaping when the lights are off

Repeated test at FAA with same FR4 glass epoxy material w/ lights off



- Test repeated, 1/16” flammable garolite material placed above
  - Material typically ignites within 5 seconds if burned



Pass/Fail Criteria

- ~~**Flames visible above box for >12 seconds**~~
- **Material placed above box as indicator of flames escaping**
  - Which material to use?
  - Can a similar material be acquired into the future?
- **Temperature measurement above box**
  - Response time of thermocouples?
  - Temperature threshold?

Conclusion

- **Test is typically more severe than Bunsen Burner**
  - More realistic scenario
  - Less total testing required
- **Methane line burner is very repeatable and reproducible**
- **Need more work on adequate pass/fail criteria**

Questions?

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