Federal Aviation Administration

International Aircraft Materials Fire Test Working Group Meeting

Development of a New Flammability Test for Magnesium-Alloy Seat Structure

Presented to: International Aircraft Materials Fire Test Working Group, Savannah, GA

By: Tim Marker, FAA Technical Center

Date: March 4, 2014

What has been done since last meeting?

√ Additional tests conducted

Ran an additional 115 tests for grand total of 637 tests

√ Draft test method completed

-Sample thickness: 0.250 inches

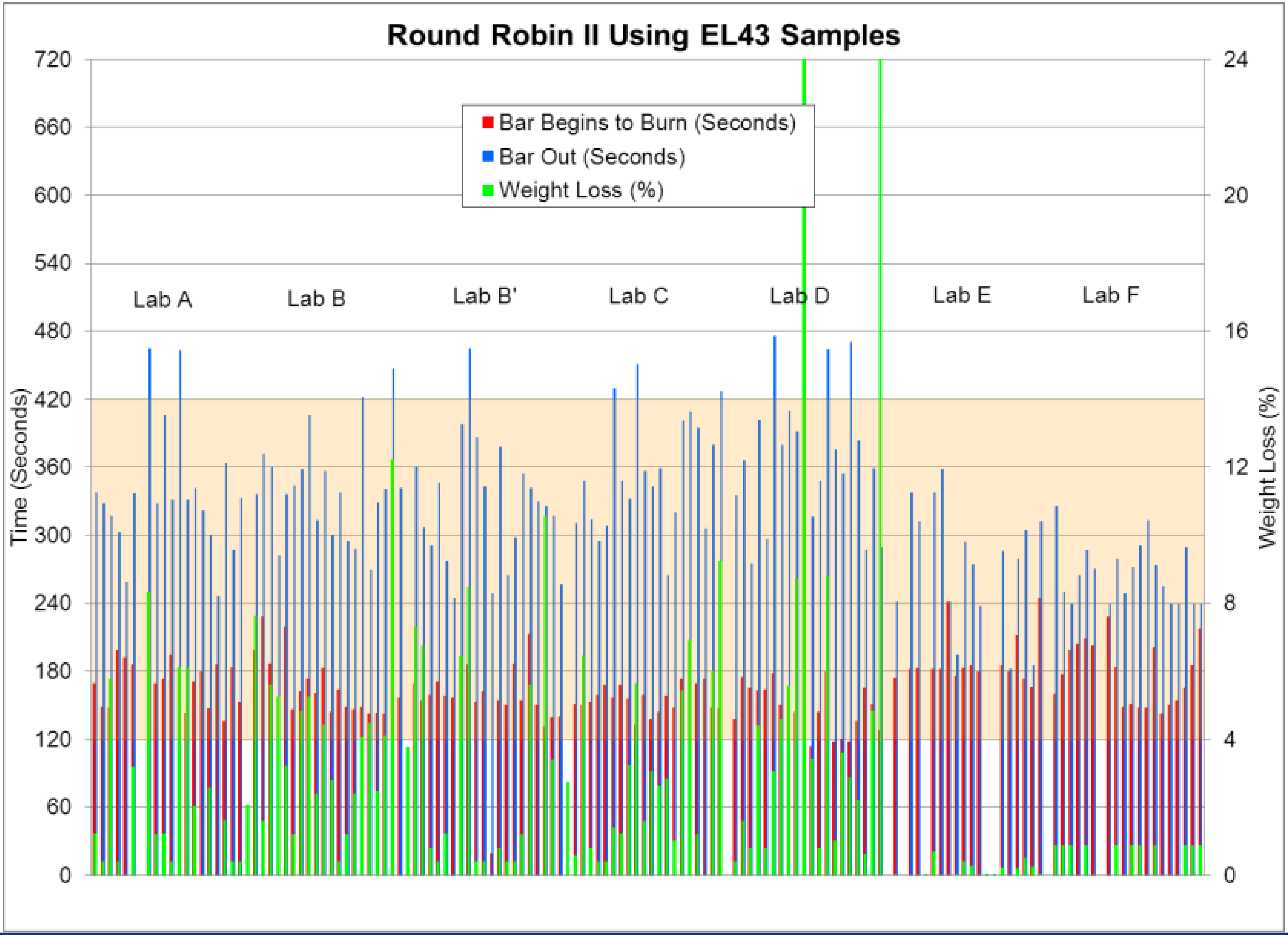
-Burner exposure time: 4 minutes

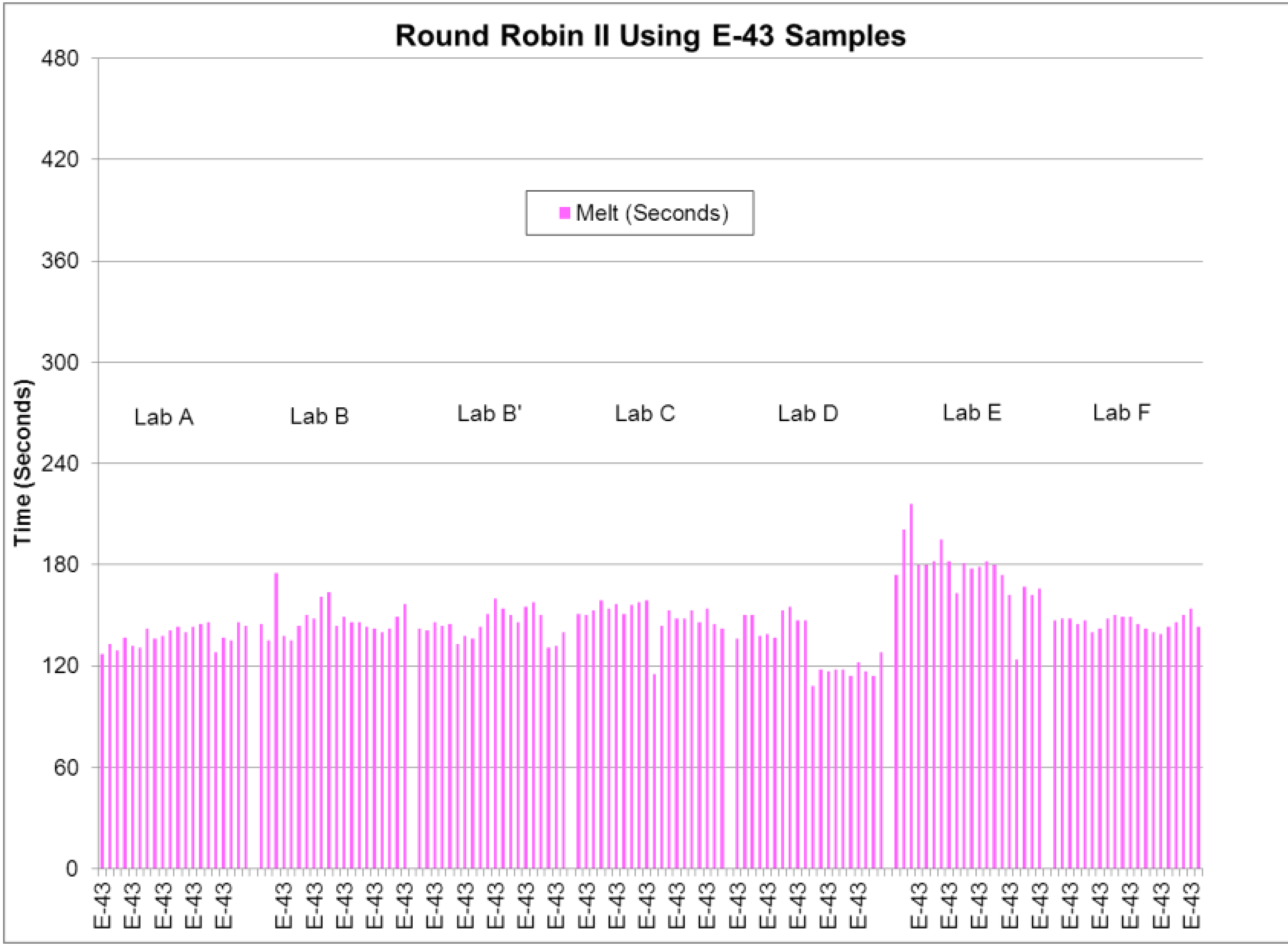
-Minimum time for sample to burn: 2 minutes

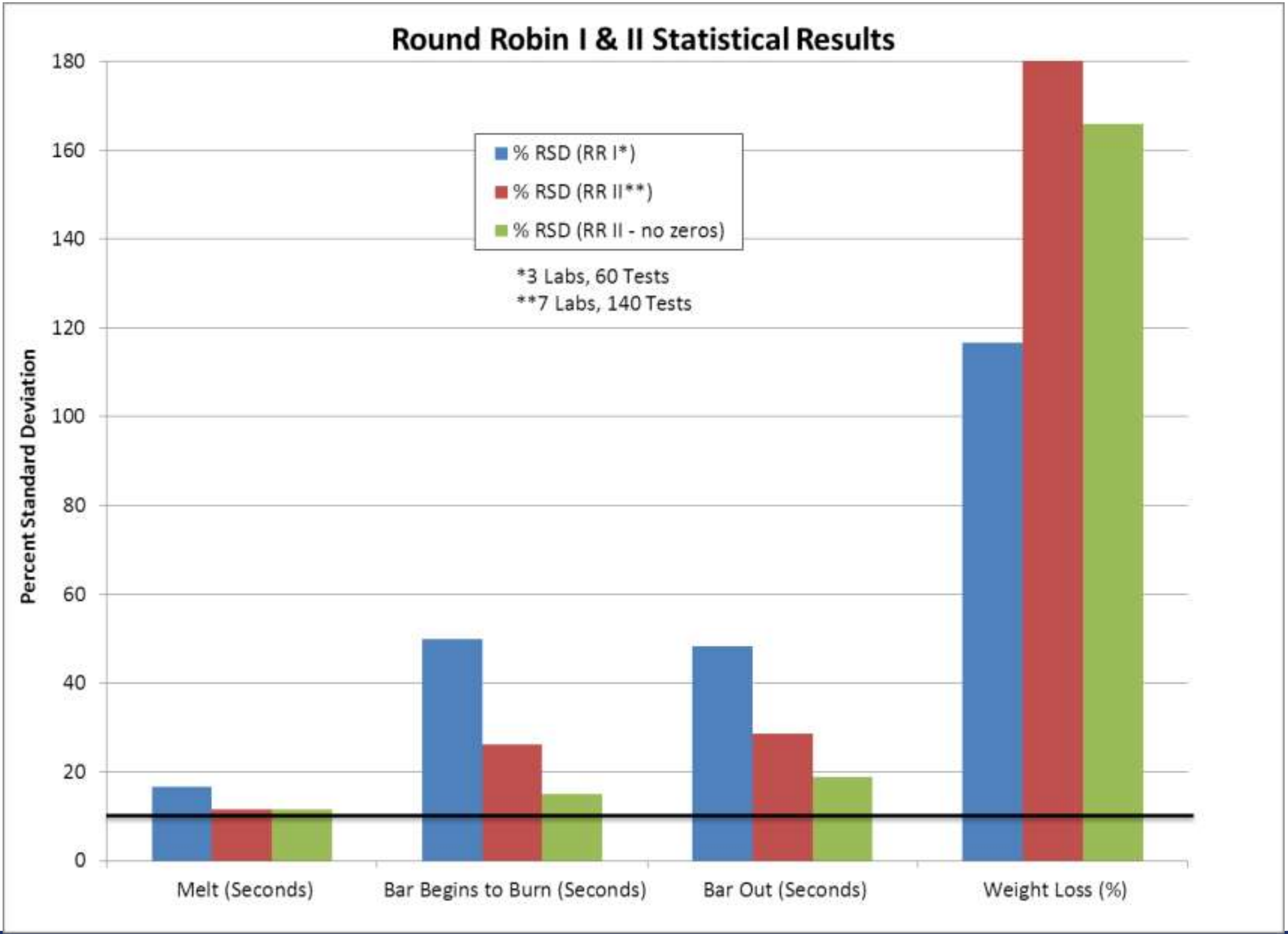
-Maximum time for sample to self extinguish: 3 minutes after burner off

-Maximum weight loss: 10% (replaces time measurement of residue burning)

√ Round Robin II completed


Round Robin II Using EL43 Samples
Bar Begins to Burn (Seconds)
Bar Out (Seconds)
Weight Loss (%)
Lab A
Lab B
Lab B'
Lab C
Lab D
Lab E
Lab F
Time (Seconds)
Weight Loss (%)
720
660
600
540
480
420
360
300
240
180
120
60
0
24
20
16
12
8
4
0


Round Robin II Using E-43 Samples
Time (Seconds)
480
420
360
300
240
180
120
60
0
Melt (Seconds)
Lab A
Lab B
Lab B'
Lab C
Lab D
Lab E
Lab F
E-43


Round Robin I & II Statistical Results
180
160
140
120
100
80
60
40
20
0
Percent Standard Deviation
% RSD (RR I*)
% RSD (RR II**)
% RSD (RR II - no zeros)
*3 Labs, 60 Tests
**7 Labs, 140 Tests
Melt (Seconds)
Bar Begins to Burn (Seconds)
Bar Out (Seconds)
Weight Loss (%)

Measuring Weight Loss of Bar Sample

1. Weigh the sample prior to test

Measuring Weight Loss of Bar Sample

2. After test, weigh the remaining bar sample pieces

Measuring Weight Loss of Bar Sample

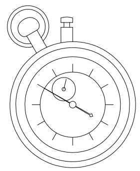
3. Remove and weigh re-solidified material from catch pan

*Use compressed air
to blow off oxidation and
talc from retrieved residue

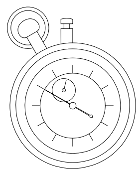
Measuring Weight Loss of Bar Sample

$$\text{Wt Loss \%} = \frac{\text{Initial Wt of Sample} - (\text{Final Wt of Sample} + \text{Residue})}{\text{Initial Wt of Sample}} \times 100$$

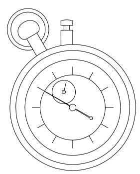
Measurement of Bar and Residue Weight



After 1 hour



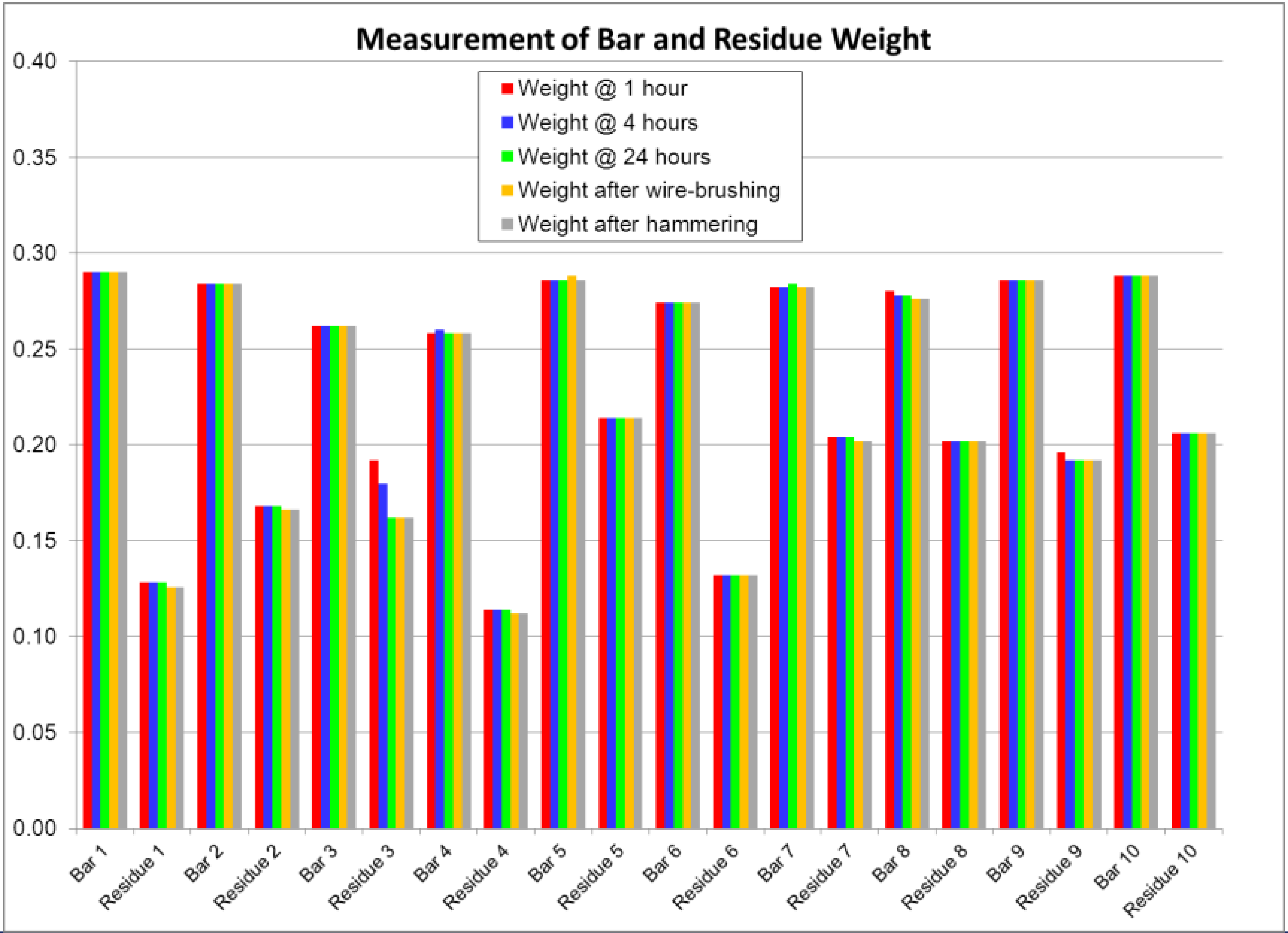
After 4 hours



After 24 hours

After wire-brushing

After hammering!


Measurement of Bar and Residue Weight
Weight @ 1 hour
Weight @ 4 hours
Weight @ 24 hours
Weight after wire-brushing
Weight after hammering
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Bar 1
Residue 1
Bar 2
Residue 2
Bar 3
Residue 3
Bar 4
Residue 4
Bar 5
Residue 5
Bar 6
Residue 6
Bar 7
Residue 7
Bar 8
Residue 8
Bar 9
Residue 9
Bar 10
Residue 10

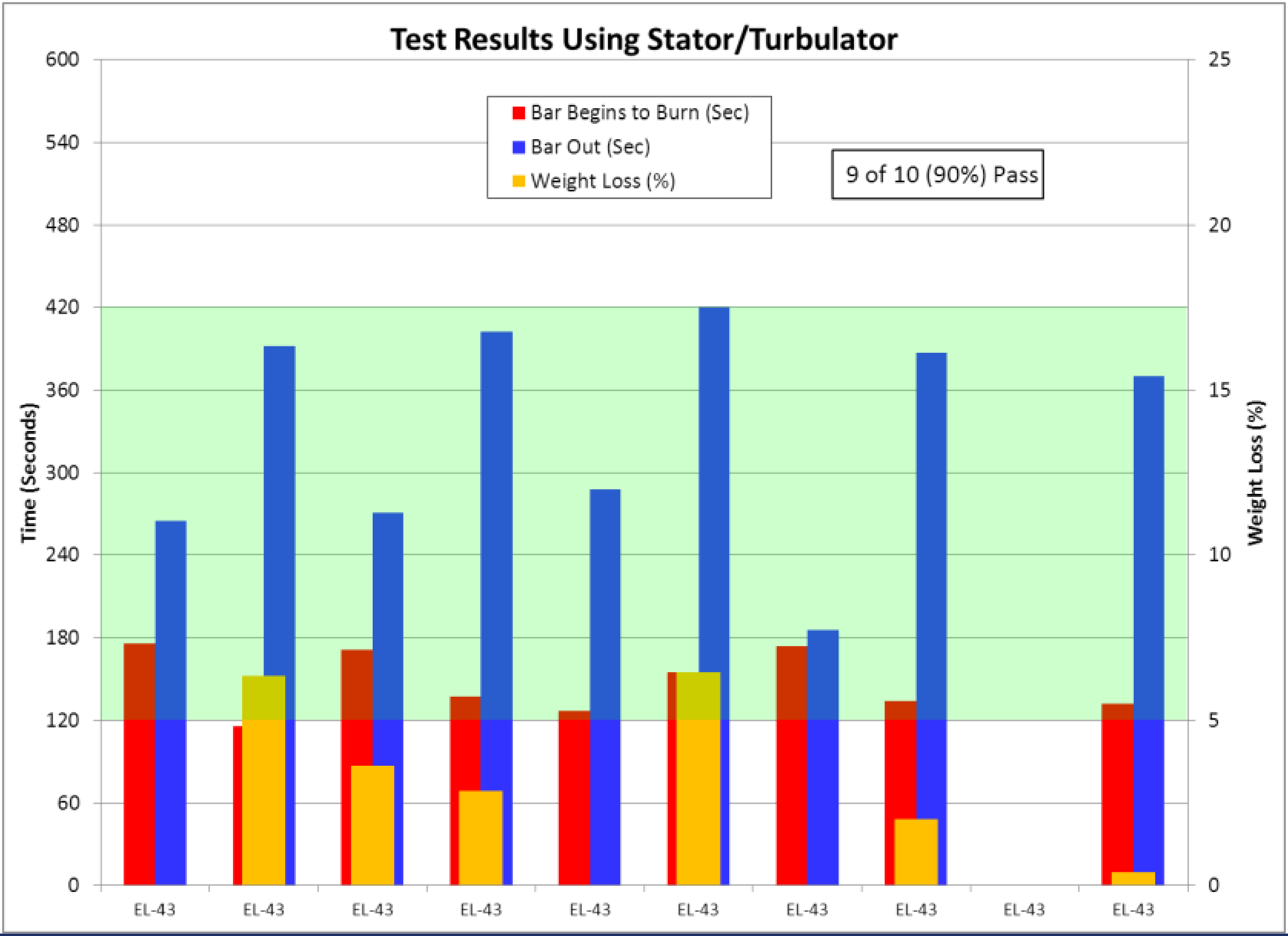
Refinement of Burner Flame for Increased Repeatability

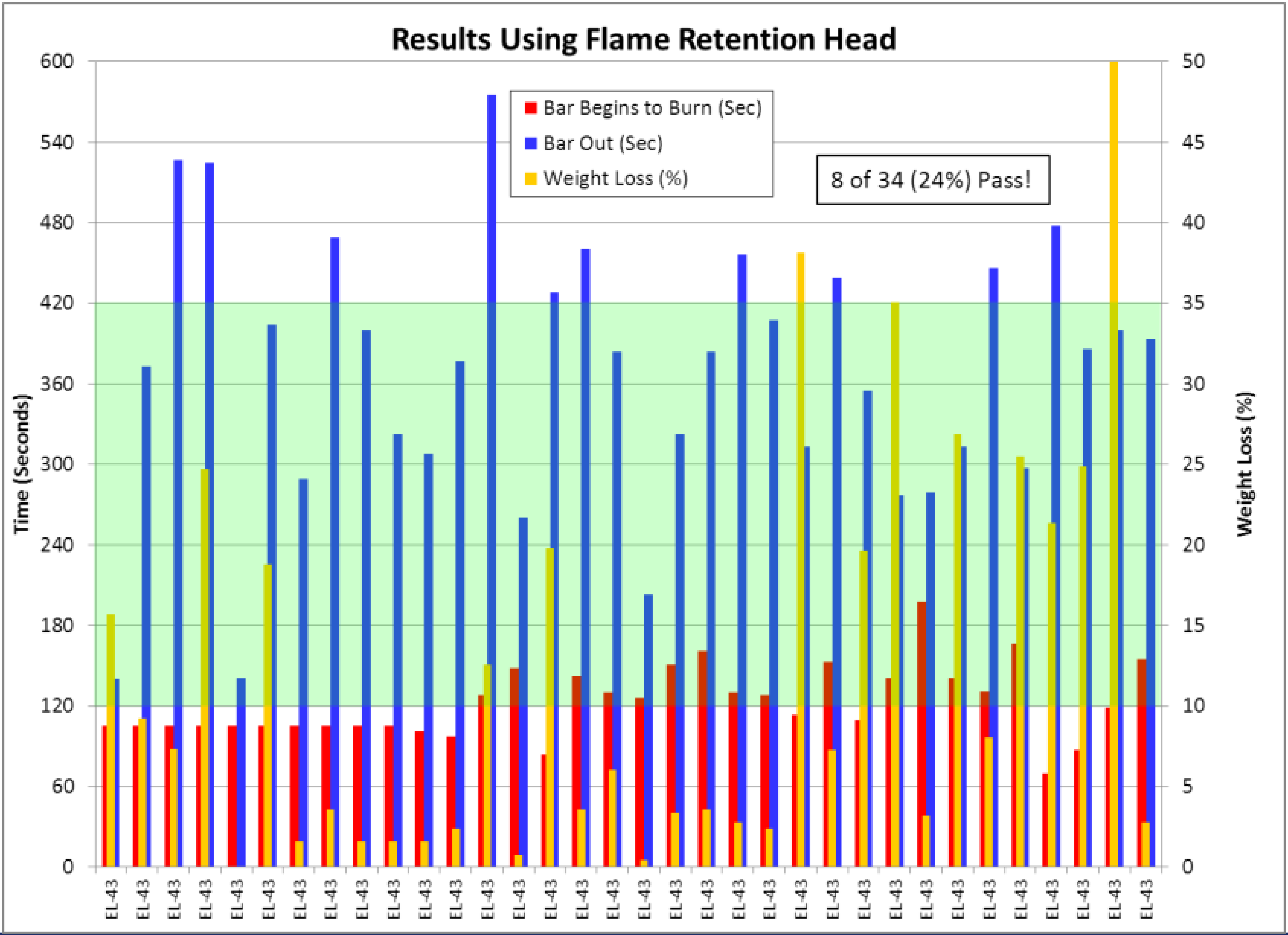
Use of Stator/Turbulator (baseline)

Use of Flame Retention Head

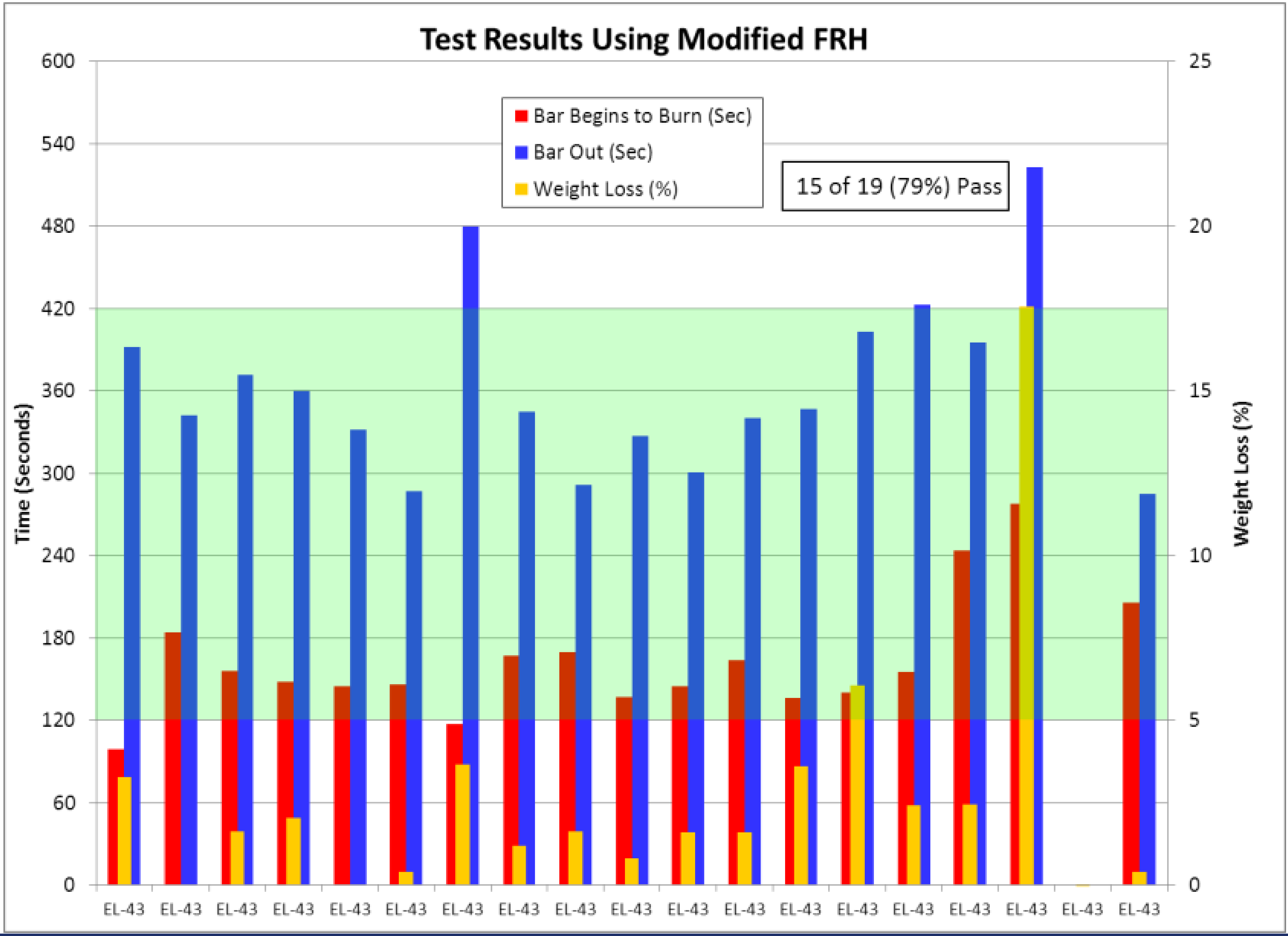
Use of Modified “Dutton” Flame Retention Head

Igniterless Stator


Test Results Using Stator/Turbulator
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
9 of 10 (90%) Pass
Time (Seconds)
Weight Loss (%)
600
540
480
420
360
300
240
180
120
60
0
25
20
15
10
5
0
EL-43
EL-43
EL-43
EL-43
EL-43
EL-43
EL-43
EL-43
EL-43
EL-43

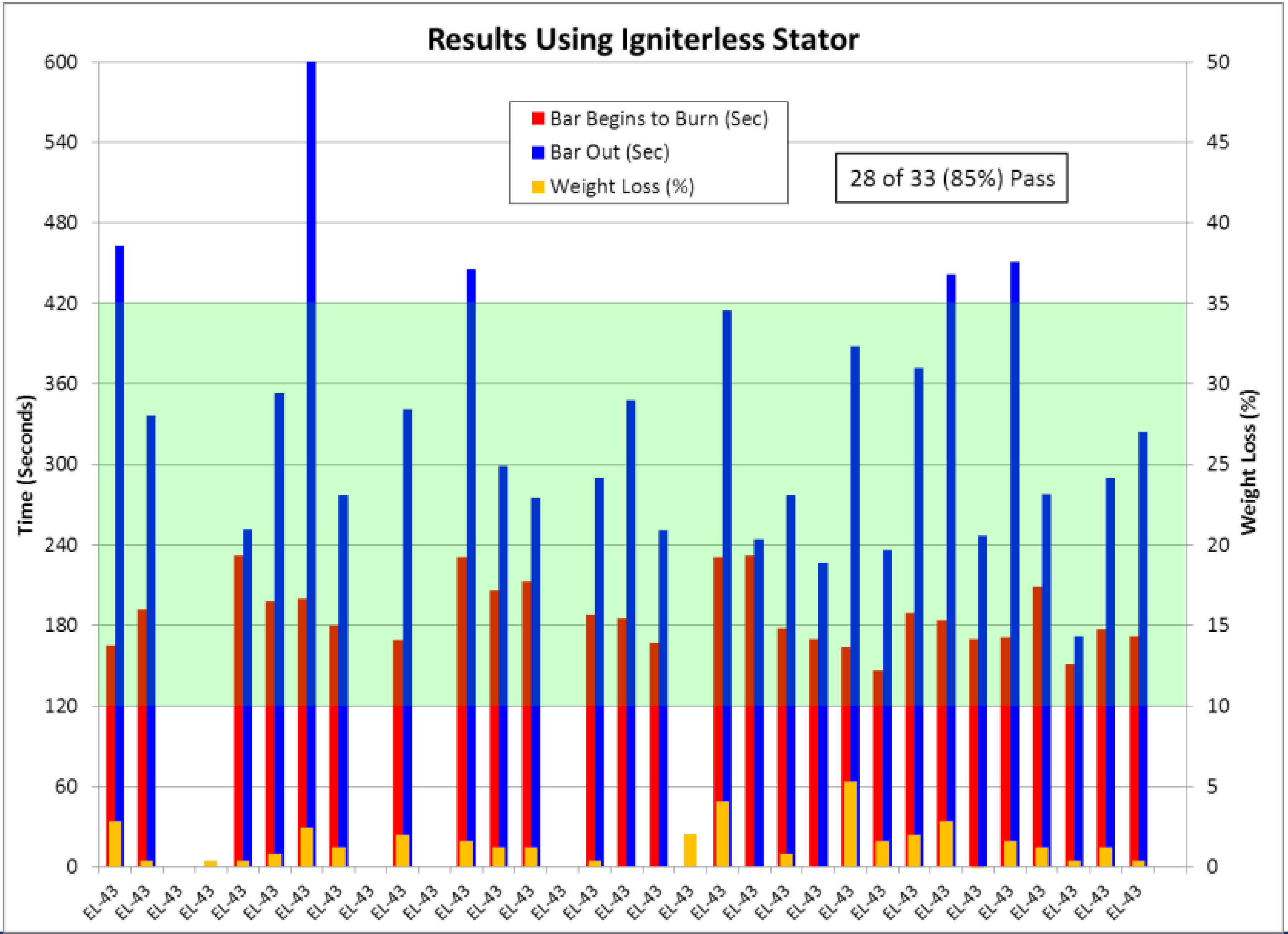

Results Using Flame Retention Head
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
8 of 34 (24%) Pass!
Time (Seconds)
Weight Loss (%)
600
540
480
420
360
300
240
180
120
60
0
50
45
40
35
30
25
20
15
10
5
0
EL-43

Modified Flame Retention Head


Test Results Using Modified FRH
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
15 of 19 (79%) Pass
Time (Seconds)
Weight Loss (%)
0
60
120
180
240
300
360
420
480
540
600
0
5
10
15
20
25
EL-43

Igniterless Stator Testing

Igniterless Stator Testing


Results Using Igniterless Stator
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
28 of 33 (85%) Pass
Time (Seconds)
Weight Loss (%)
600
540
480
420
360
300
240
180
120
60
0
50
45
40
35
30
25
20
15
10
5
EL-43

Planned Activities and Next Steps?

Refine method of determining when sample begins to burn

Refine method of determining when sample self-extinguishes

Refine method of measuring post-test weights

Finalize test method details

Insert new test method into Handbook

Discuss other potential areas of mag alloy use in cabin

DOT/FAA/AR-11/3

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
New Jersey 08405

Evaluating the Flammability of Various Magnesium Alloys During Laboratory- and Full-Scale Aircraft Fire Tests

Timothy R. Marker

January 2013

Final Report

This document is available to the U.S. public through the National Technical Information Services (NTIS), Springfield, Virginia 22161.

This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

U.S. Department of Transportation
Federal Aviation Administration

http://www.fire.tc.faa.gov/pdf/AR11-13.pdf

DOT/FAA/TC-13/52

Federal Aviation Administration
William J. Hughes Technical Center
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Development of a Laboratory-Scale Flammability Test for Magnesium Alloys Used in Aircraft Seat Construction

Timothy R. Marker

February 2014

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U.S. Department of Transportation
Federal Aviation Administration

Magnesium Usage in Aircraft Cabins - Certification

SAE AS8049 - Aircraft Seat Standard

Evil Para 3.3.3 “Magnesium alloys shall not b

- AS8049 up for regular five year review
- How long will this take, end 2014?
- FAA issue Magnesium Lab-Scale Test rep specification (March 2014)
- AIR6160 issue Q1, 2014 - technical backup for AS8049 change
- AIR6160 28 day ballot results 17 of 22 voting members responded, all approved
- AS8049 Para 3.3.3 re-worded to allow magnesium in seat structure

Magnesium Usage in Aircraft Cabins - Certification

SAE Aircraft Seat Committee

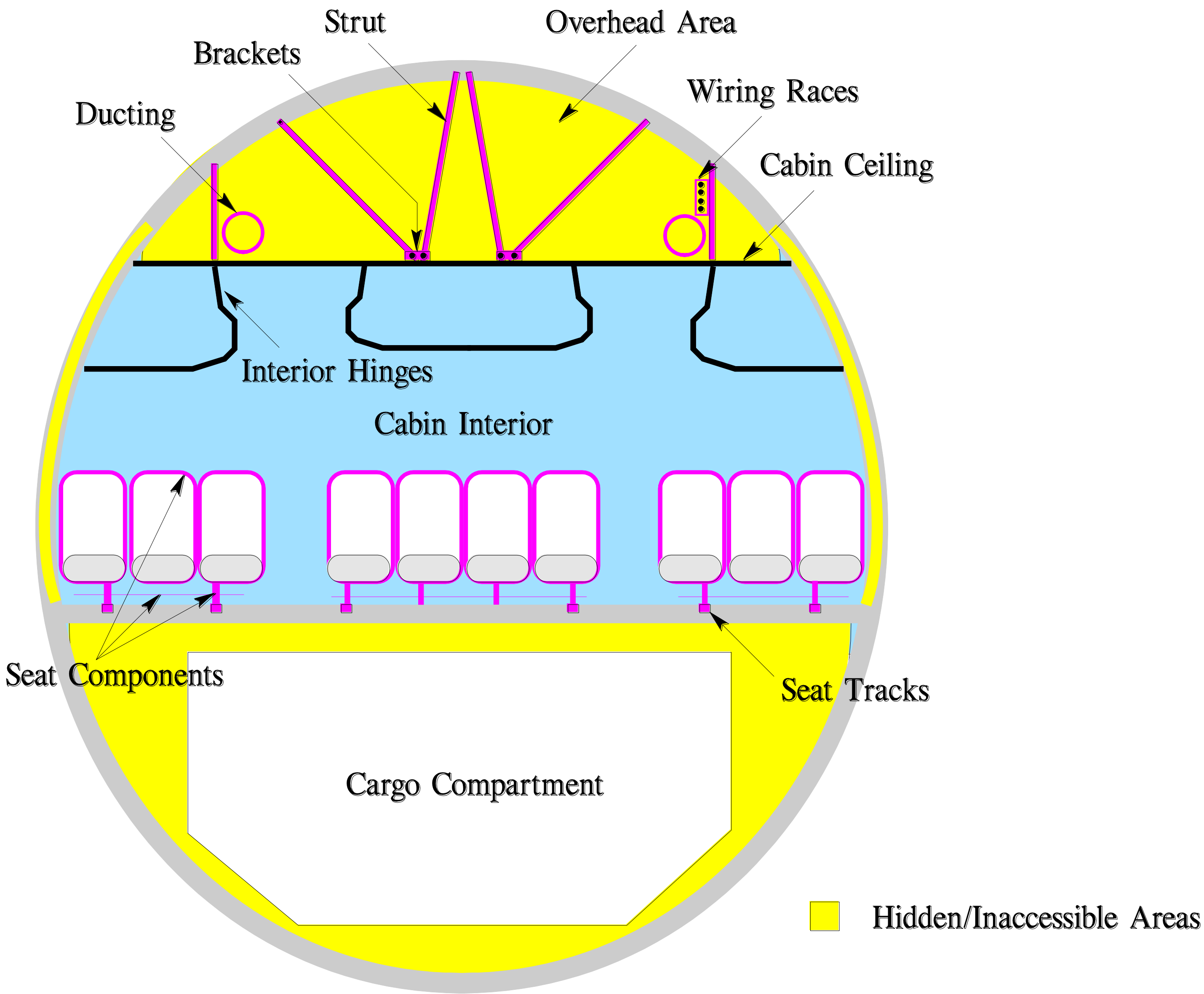
Magnesium Working Group – February 20, 2014

AS8049 Para 3.3.3 – Magnesium alloys shall not be used.

Agreed re-wording:

3.3.3 Magnesium alloys ~~shall not be used~~ may be used in aircraft seat construction provided they are tested to and meet the flammability performance ~~requirements~~ in the FAA Fire Safety Branch document: Aircraft Materials Fire Test Handbook – DOT/FAA/AR-00/12.

Other Areas of Use?


Strut
Overhead Area
Brackets
Wiring Races
Ducting
Cabin Ceiling
Interior Hinges
Cabin Interior
Seat Components
Seat Tracks
Cargo Compartment
Hidden/Inaccessible Areas

Possible Areas of Mag-Alloy Use

Possible Areas of Mag-Alloy Use

How Can We Certify?

Surface Area to Volume Ratio

For <u>truncated cone</u> test sample: (l = 10, D_b = 1.57, D_h = 0.40)

Surface Area = $\pi(((D_b \div 2)^2 + (D_h \div 2)^2 + \sqrt{(((D_b \div 2)^2 - (D_h \div 2)^2)^2 + \left(l\, x\, ((D_b \div 2) + (D_h \div 2))\right)^2)})$

Surface Area = 33.0592 in^2

Volume = $\left((\pi\, x\, l) \div 3\right) x \left(((D_b \div 2)^2\right) + \left((D_h \div 2)^2 + (D_b \div 2) x (D_h \div 2)\right))$

Volume = 8.5161 in^3

SAV Ratio = 33.0592 ÷ 8.5161 = 3.88 in^{-1}

SAV Ratio = 3.88

Surface Area to Volume Ratio

For <u>rectangular bar</u> test sample:

Surface Area = (2 x 0.25 x 20) + (2 x 1.5 x 20) + (2 x 0.25 x 1.5)

Surface Area = (10) + (60) + (0.75) = 70.75 in^2

Volume = (0.25 x 1.5 x 20) = 7.5 in^3

SAV Ratio = 70.75 ÷ 7.5 = 9.42 in^{-1}

SAV Ratio = 9.42

Surface Area to Volume Ratio

For <u>hollow cylinder</u> test sample (1.75 OD, wall thickness = 0.094):

Surface Area = $(\pi\ x\ OD\ x\ l) + (\pi\ x\ ID\ x\ l) + 2(\pi\ x\ (OD^2 \div 4) - \pi\ x(ID^2 \div 4))$

Surface Area = $(\pi\ x\ 1.75\ x\ 8) + (\pi\ x\ 1.5625\ x\ 8) + 2(\pi\ x\ 0.765625 - \pi\ x\ 0.61035)$

Surface Area = $(43.9823) + (39.2699) + 2(2.40528 - 1.91747)$

Surface Area = 84.22782 in^2

Volume = $\left(\pi\ x\ (OD^2 \div 4) - \pi\ x(ID^2 \div 4)\right)\ x\ l$

Volume = $\left(\pi\ x\ (0.765625) - \pi\ x(0.61035)\right)\ x\ l$ = 3.90248 in^3

SAV Ratio = 84.22782 ÷ 3.90248 = 21.58 in^{-1}

SAV Ratio = 21.58

Surface Area to Volume Ratio

For thin sheet test sample: (10 inch square, thickness = 0.0625)

Surface Area = (2 x 10 x 10) + (4 x 0.0625 x 10)

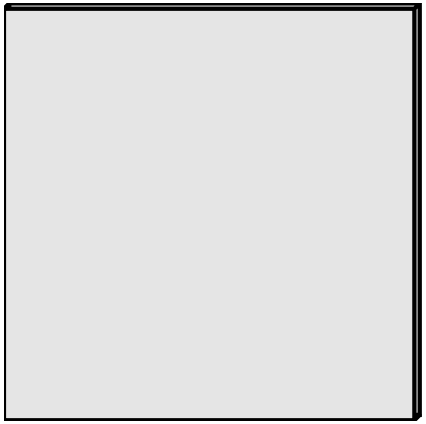
Surface Area = (200) + (2.5) = 202.5 in^2

Volume = (l x w x t)

Volume = (10 x 10 x .0625) = 6.25 in^3

SAV Ratio = 202.5 ÷ 6.25 = 32.4 in^{-1}

SAV Ratio = 32.4



Surface Area to Volume Ratio

For solid basketball-sized test sample: (9.5-inch diameter)

Surface Area = $4\ p r^2$

Surface Area = (4 x 3.14 x 22.5625) = 283.53 in^2

Volume = $4/3 p r^3$

Volume = (4 ÷ 3 x 3.14 x 107.17) = 448.92 in^3

SAV Ratio = 283.53 ÷ 448.92 = 0.632 in^{-1}

SAV Ratio = 0.632

Surface Area to Volume Ratio

Solid Basketball SAV Ratio = 0.632 in^{-1}

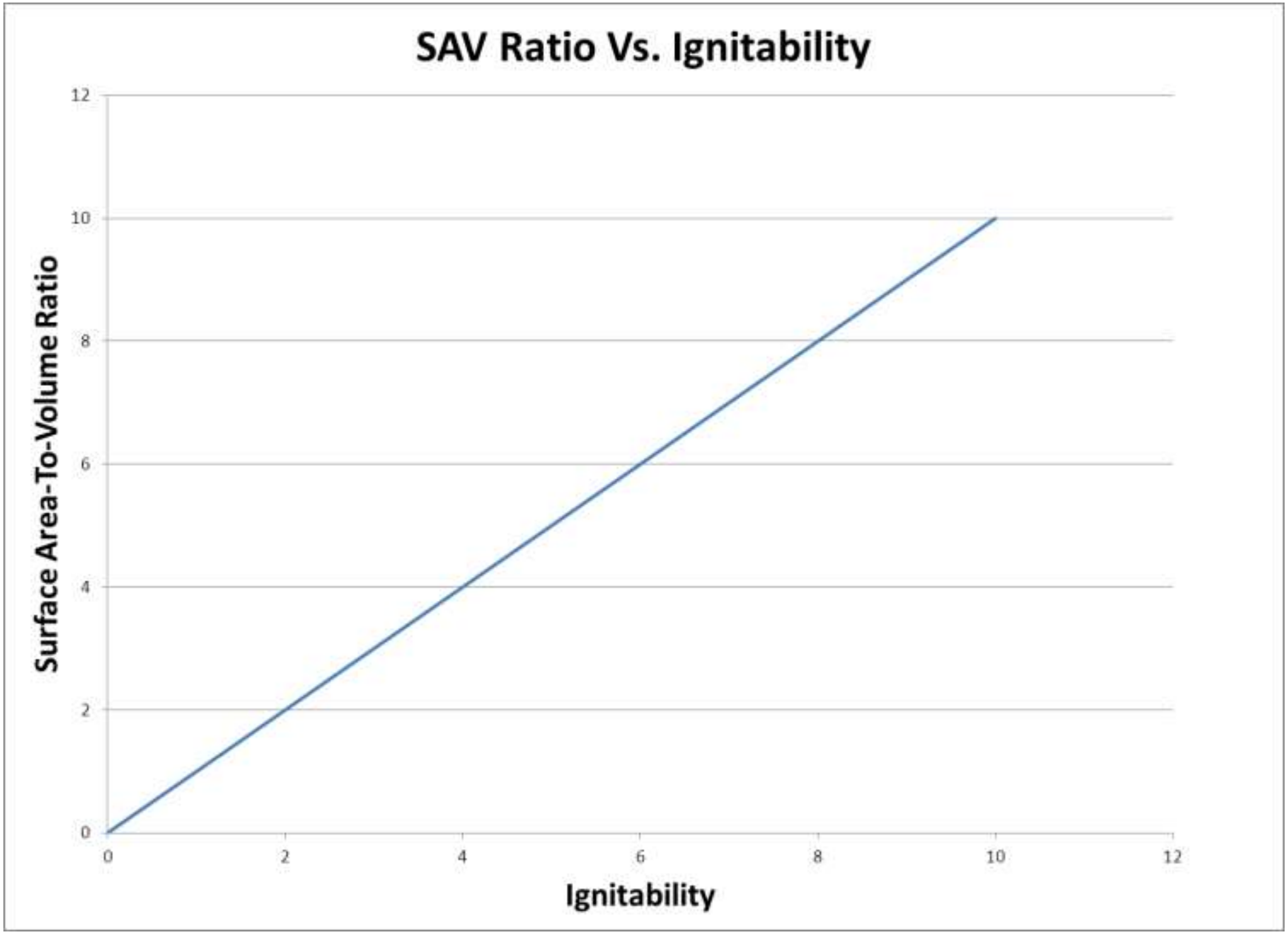
Solid Truncated Cone SAV Ratio = 3.88 in^{-1}

Solid Rectangular Bar SAV Ratio = 9.42 in^{-1}

Thin-Walled Cylinder SAV Ratio = 21.58 in^{-1}

Thin Sheet SAV Ratio = 32.40 in^{-1}

Surface Area to Volume Ratio



Considerations for Qualifying Other Mag-Alloy Components

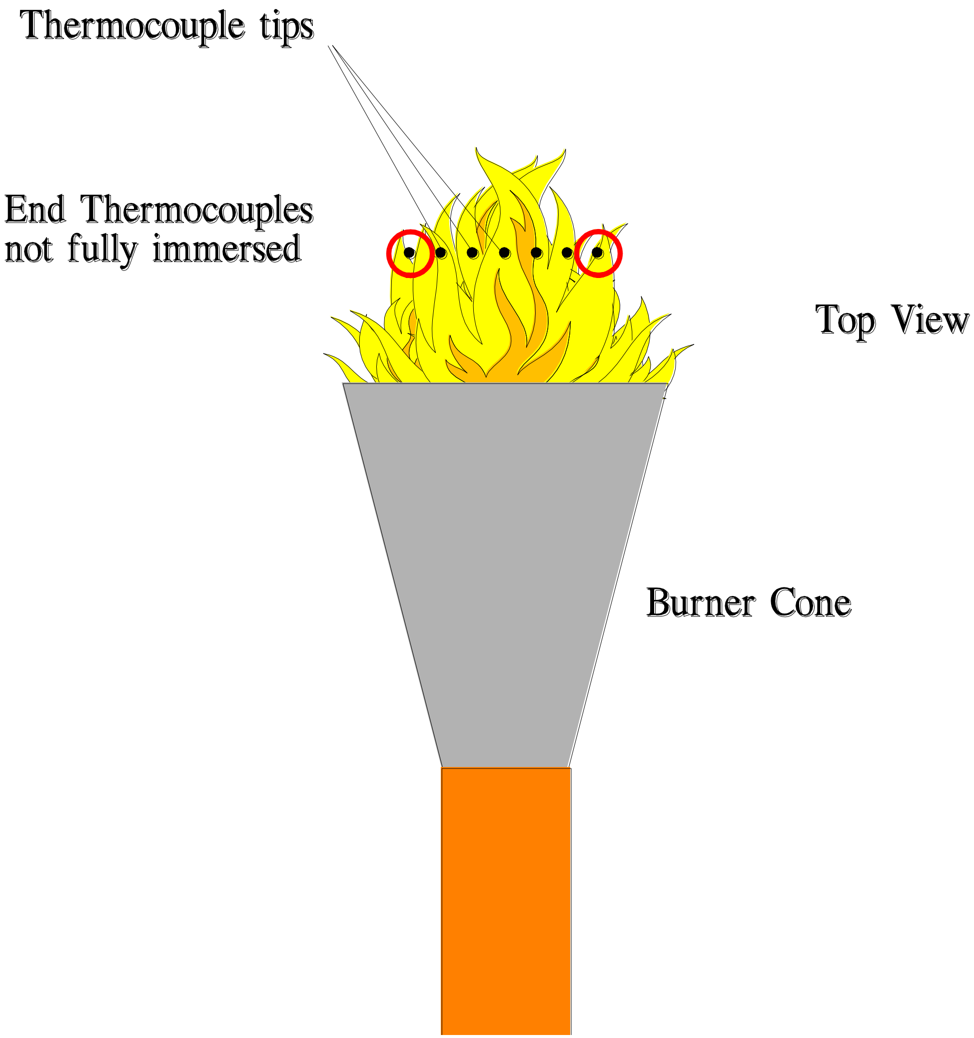
Define a maximum SAV ratio + use oil burner test

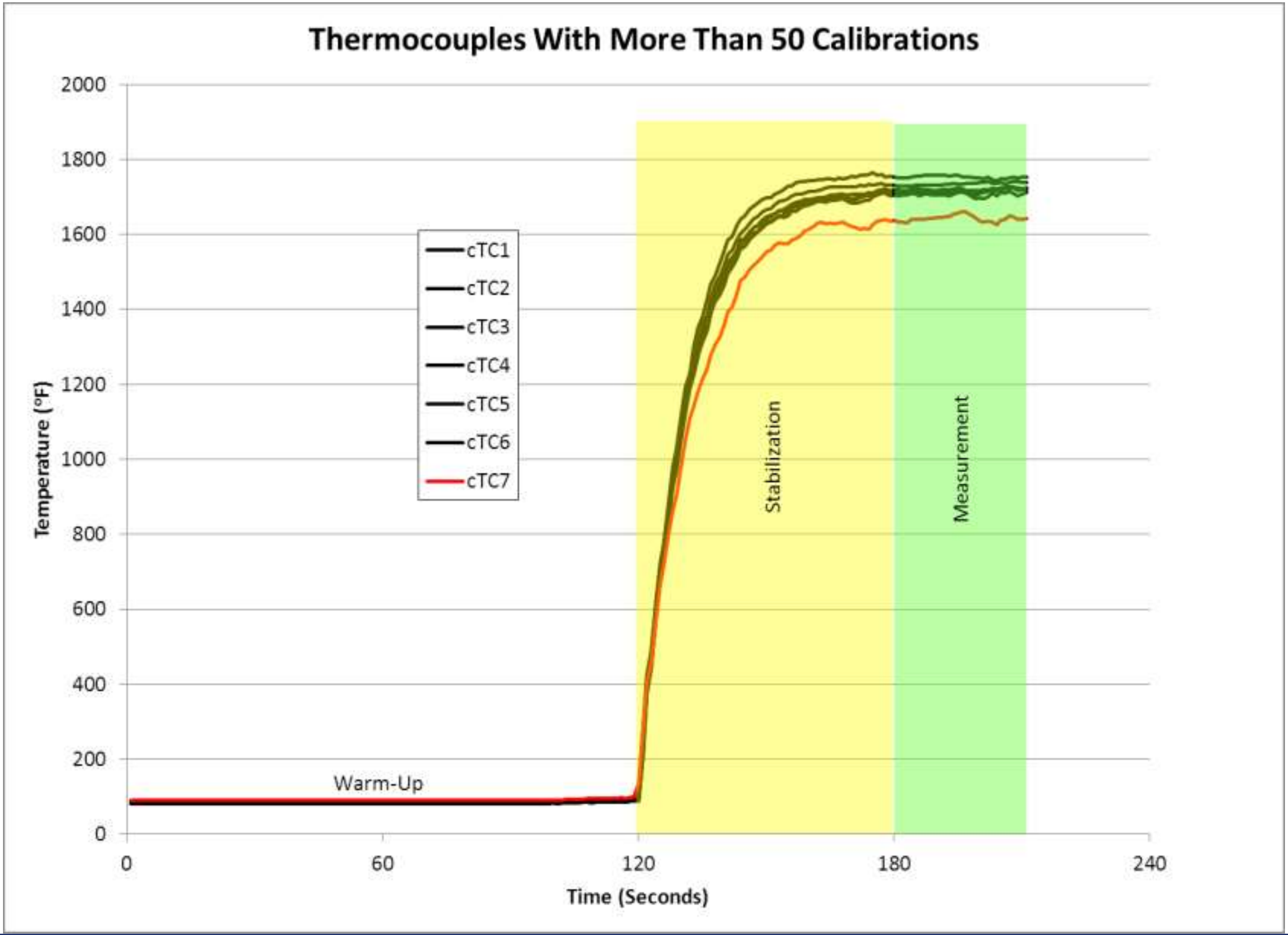
If SAV ratio is less than xx, use oil burner test

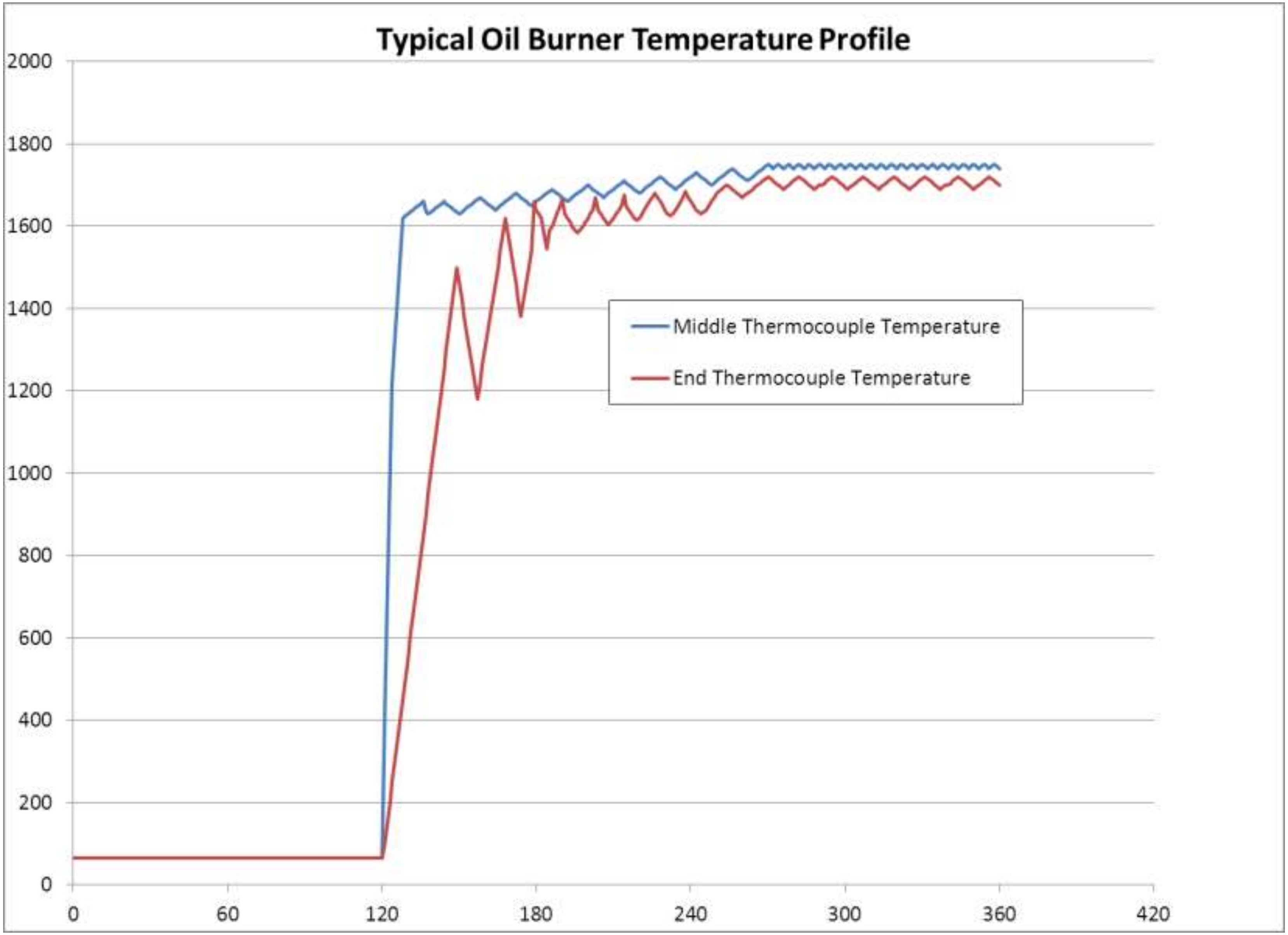
If SAV ratio is greater than xx, use suitable electrical arc test

Questions?

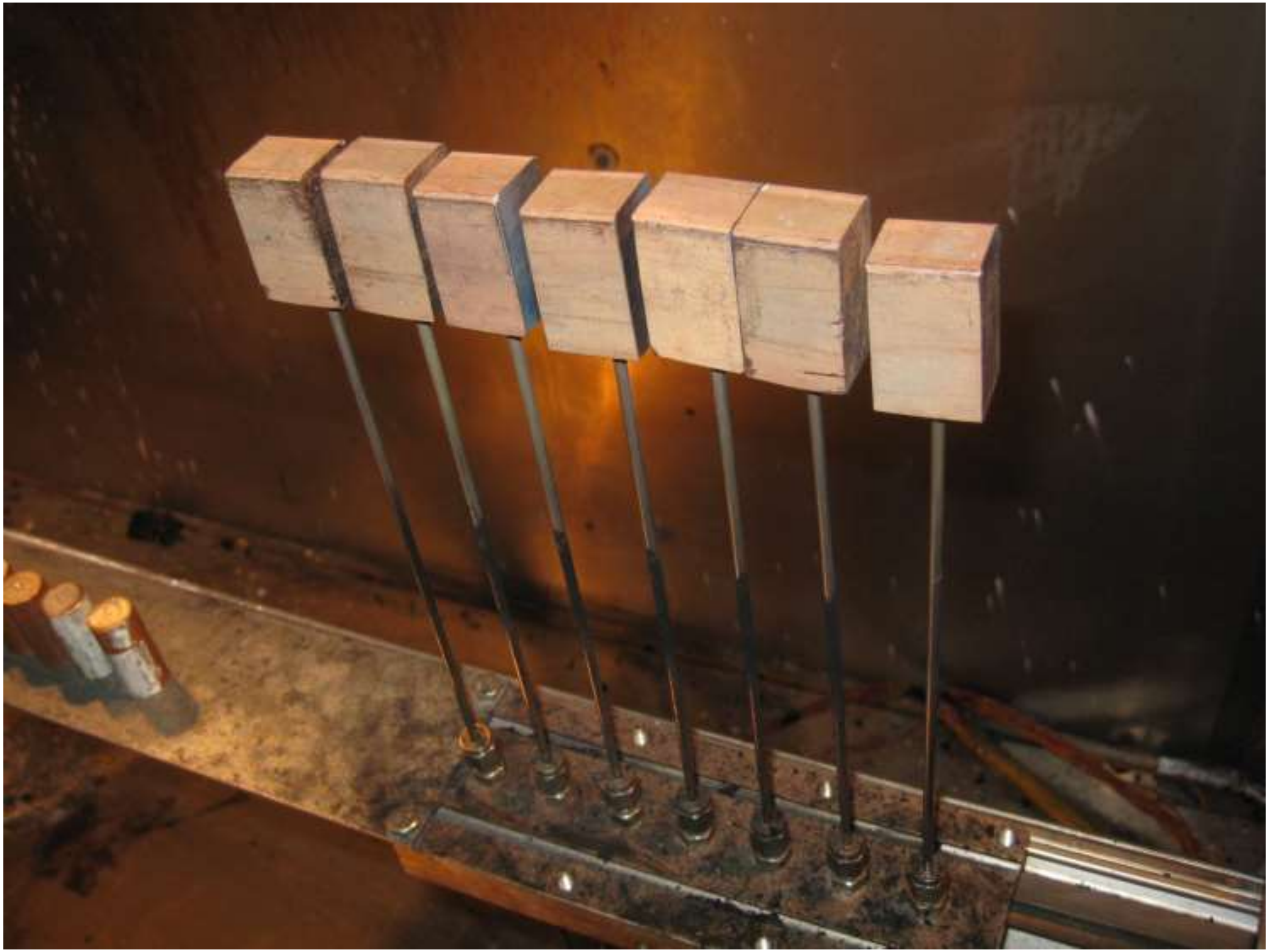
Thermocouple Degradation

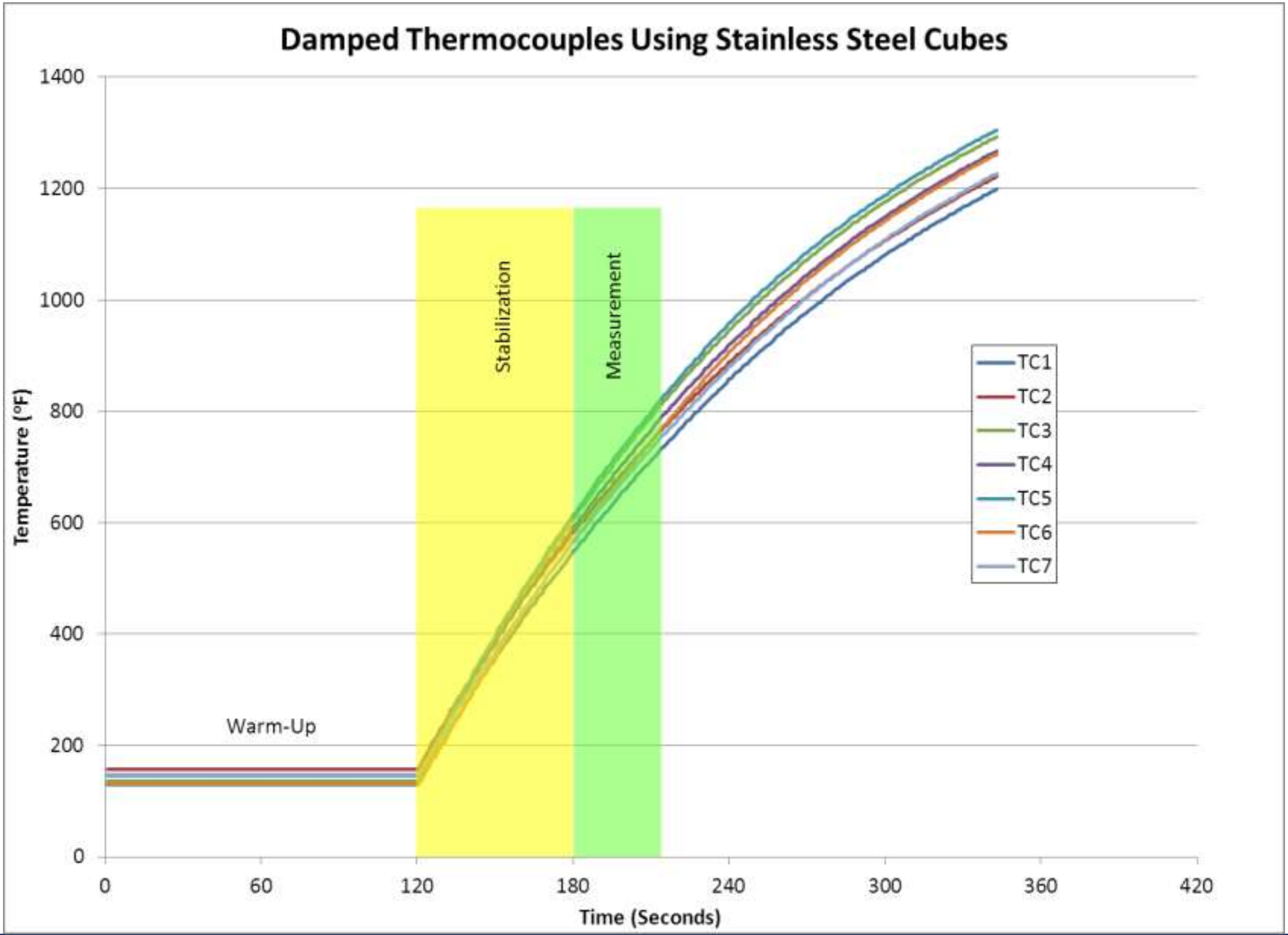



Thermocouples With More Than 50 Calibrations
Temperature (°F)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Time (Seconds)
0
60
120
180
240
cTC1
cTC2
cTC3
cTC4
cTC5
cTC6
cTC7
Warm-Up
Stabilization
Measurement

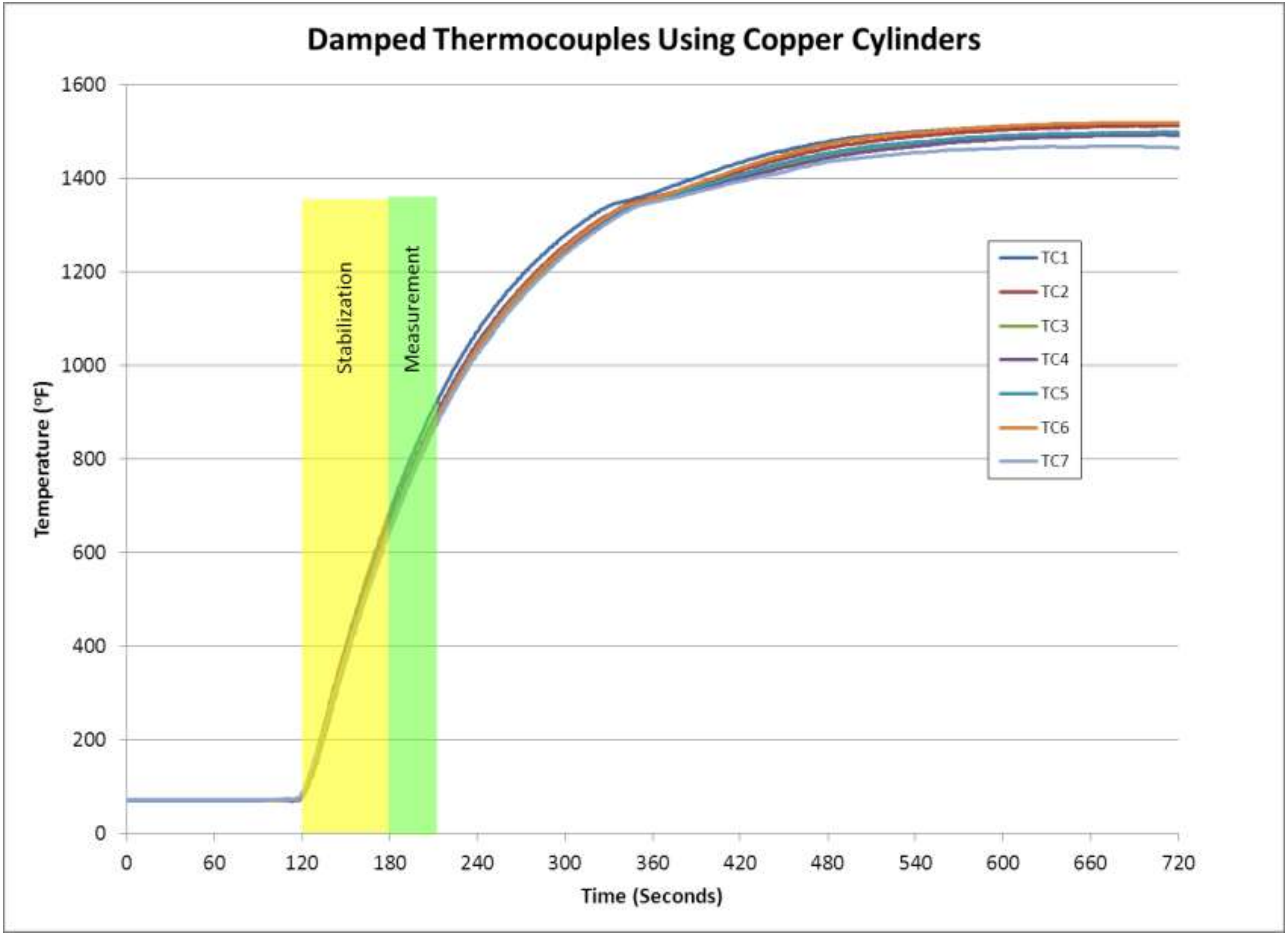

Typical Oil Burner Temperature Profile
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0
60
120
180
240
300
360
420
Middle Thermocouple Temperature
End Thermocouple Temperature

Thermocouple Damping




Damped Thermocouples Using Stainless Steel Cubes
Temperature (°F)
Time (Seconds)
0
200
400
600
800
1000
1200
1400
0
60
120
180
240
300
360
420
Warm-Up
Stabilization
Measurement
TC1
TC2
TC3
TC4
TC5
TC6
TC7

Thermocouple Damping


Damped Thermocouples Using Copper Cylinders
Temperature (°F)
Time (Seconds)
1600
1400
1200
1000
800
600
400
200
0
0
60
120
180
240
300
360
420
480
540
600
660
720
Stabilization
Measurement
TC1
TC2
TC3
TC4
TC5
TC6
TC7

Thermocouple Degradation

Objective is to reduce temperature fluctuations, to minimize thermal shock, and extend life (accuracy) of thermocouples.

The use of a flat plate will not allow monitoring of a flame "shape", just an average temperature.

Experimentation with lower mass dampers

Possible Solutions to Thermocouple Accuracy Issue

Damping of thermocouples using solid mass

Remove end thermocouples (5 point measurement)

Establish maximum exposure periods/cycles on thermocouples

Remove thermocouples from calibration procedure completely