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, Indianapolis

By: Tim Marker, FAA Technical Center

Date: October 16-17, 2012

Federal Aviation Administration

Evolution of the Test Configuration

Horizontal Bar

Spring 2007

Vertical Cone

Spring 2011

Various Shapes

Shorter cones

Taller cones

Stepped cones

Rectangular stepped shape

Horizontal cylinders

Rectangular tubing horizontal

Rectangular tubing vertical

I-Webs horizontal

T-Webs horizontal

Inverted cones

Cylindrical tubes horizontal

Cylindrical tubes vertical

Hollow Cylinder

Summer 2011

Horizontal Bar

Spring 2012

Which Configuration?

Solid Cones (vertical)

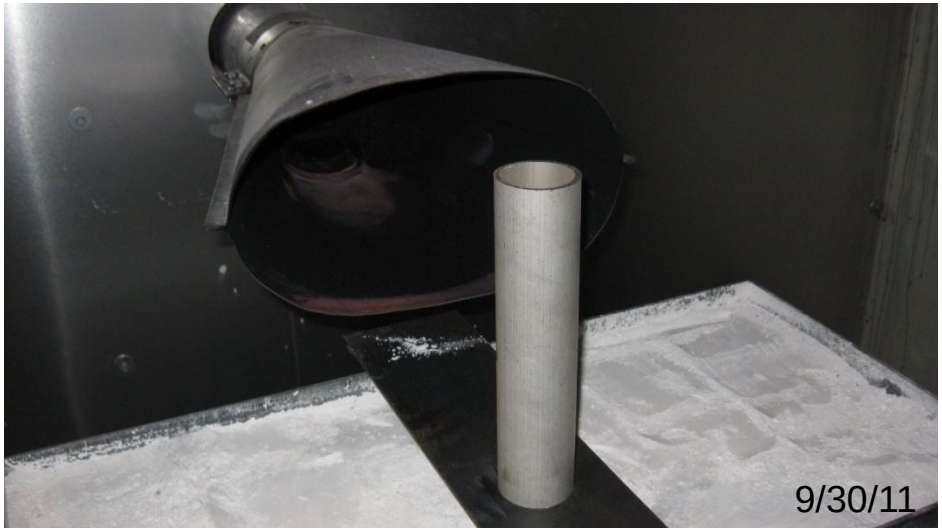
Hollow Cylinders (vertical)

Rectangular Bars (horizontal)

repeatability issues:

- Time of ignition dependent on resulting molten shape (random)
- Duration of burning following burner flame removal also dependent on resulting molten shape

Hollow Cylinder, Mounted Vertically



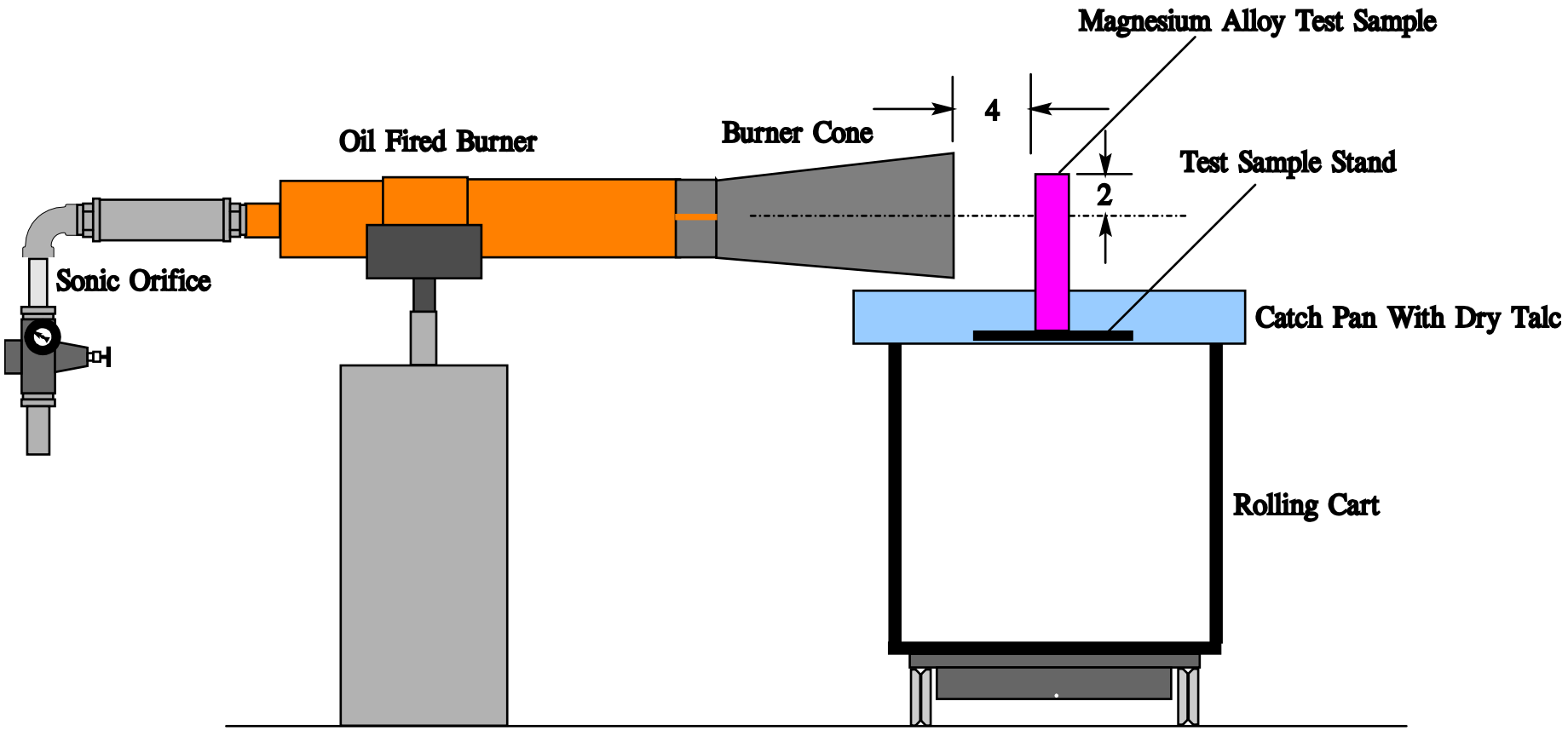
Hollow cross-sections demonstrated better ignitability than solid cross-sections

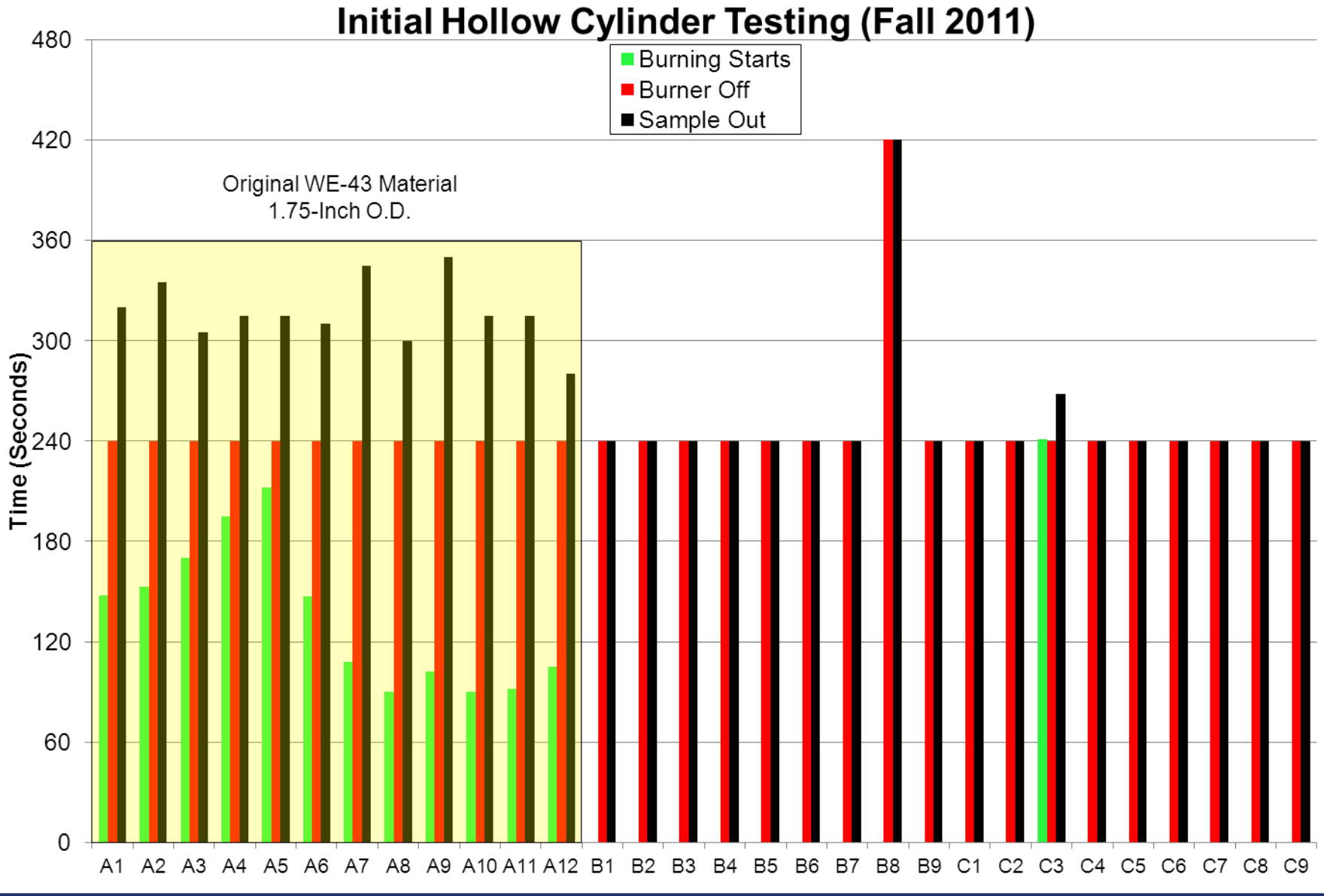
- Thinner wall has tendency to ignite simultaneous to melting

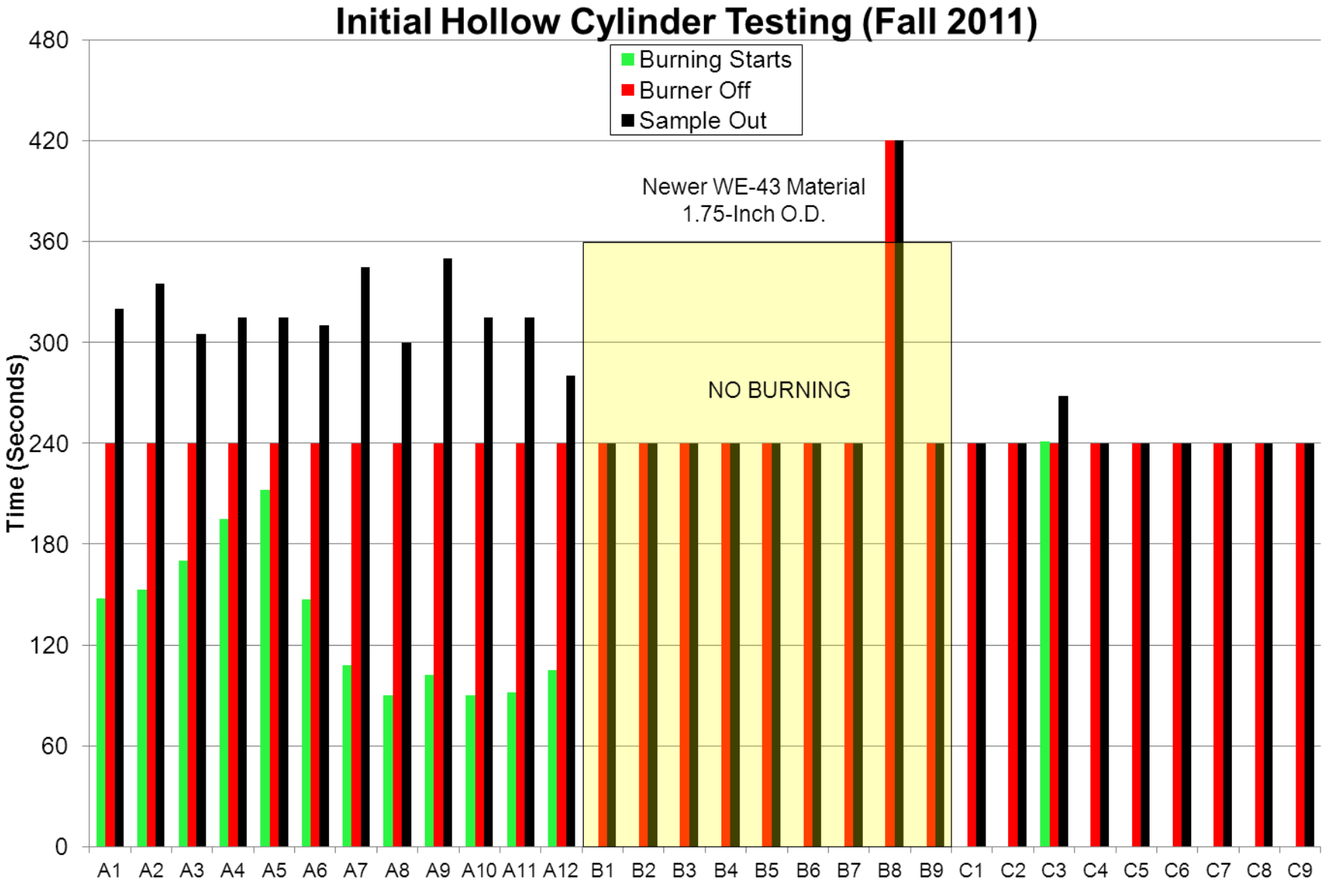
Hollow cylinder test sample demonstrates good repeatability

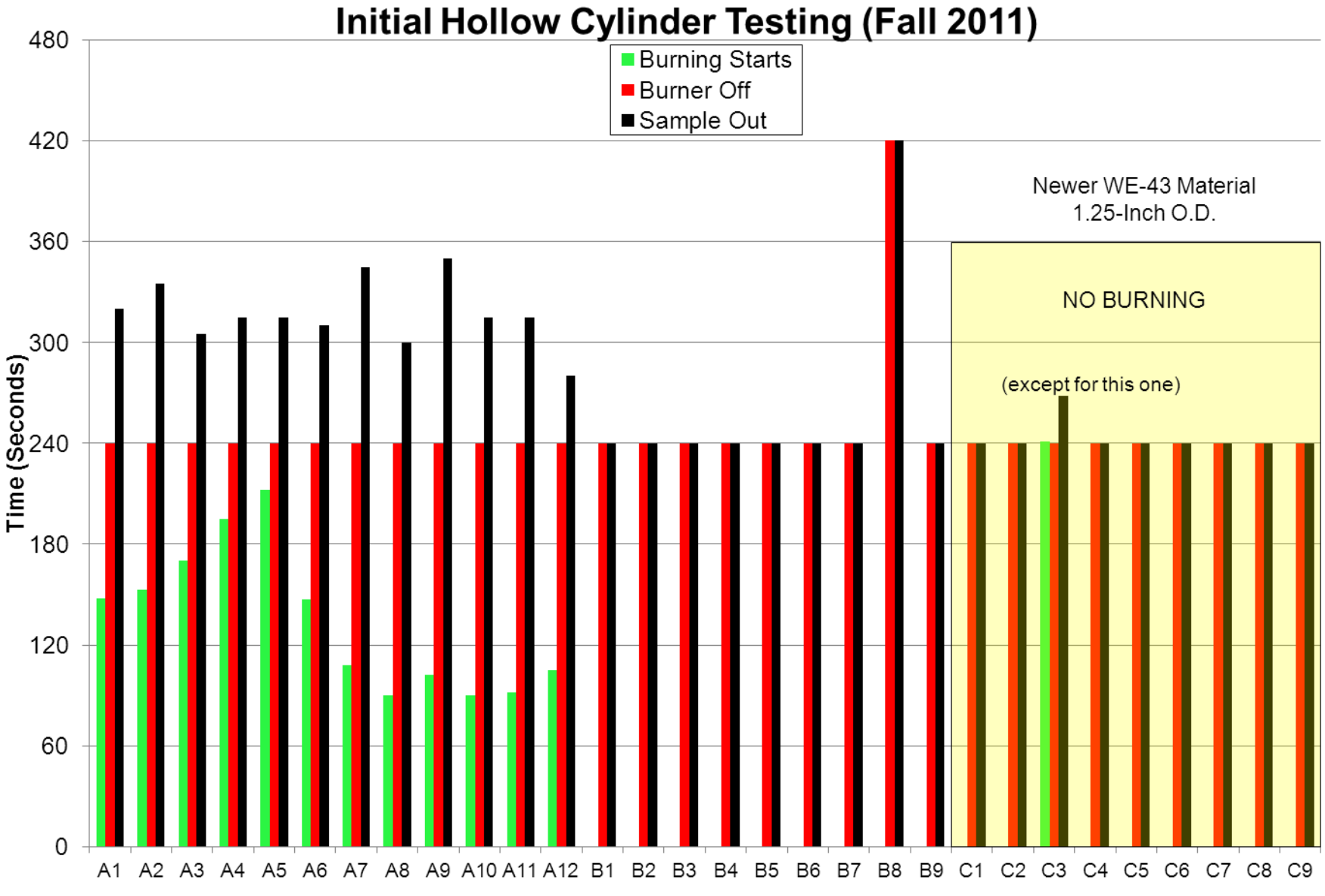
- Time of ignition and duration of after flame very consistent
- Resulting molten shape also very repeatable, demonstrating test robustness

(Gen III) Proposed Magnesium Alloy Flammability Test

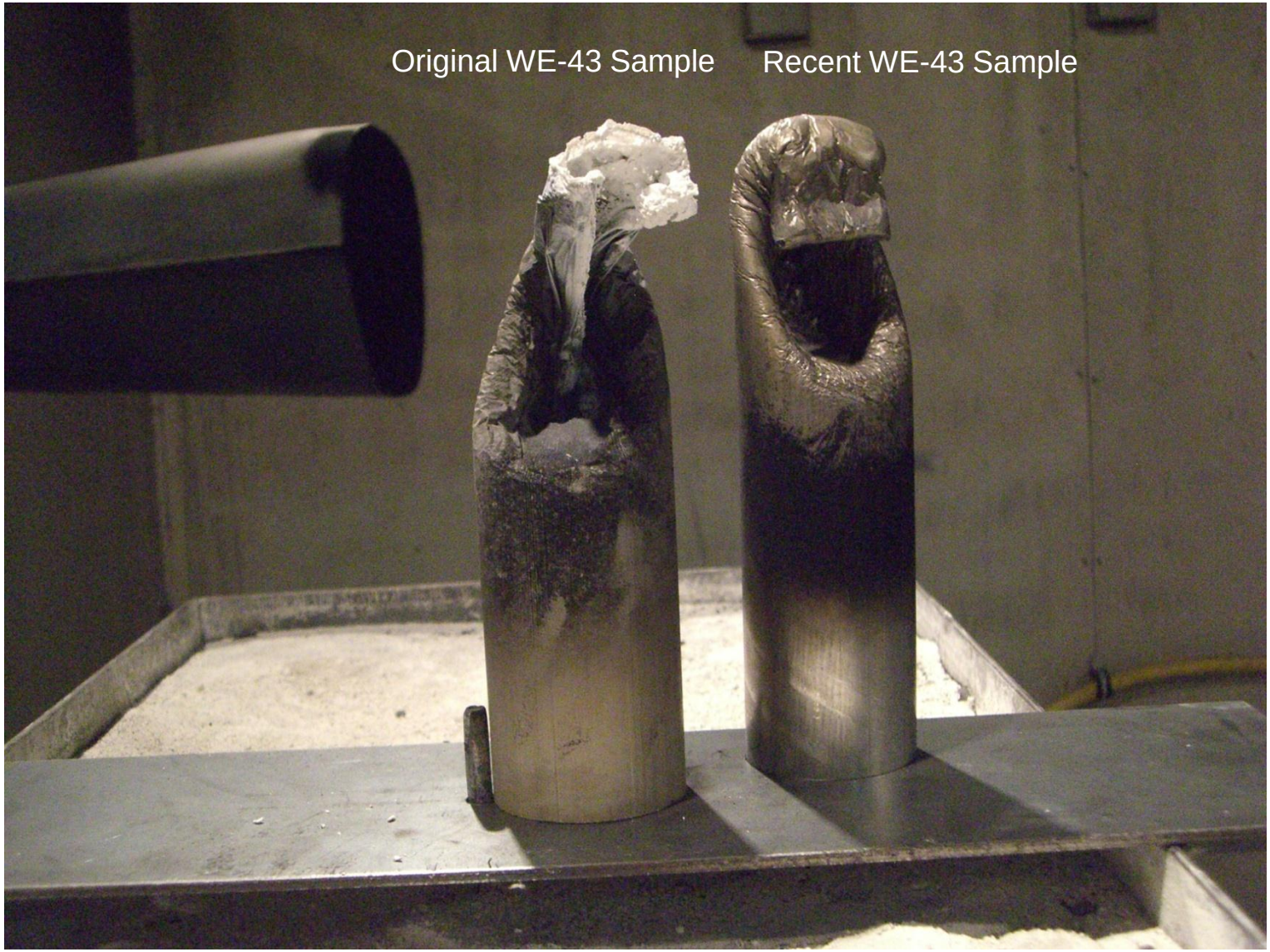



Initial Hollow Cylinder Testing (Fall 2011)
Burning Starts
Burner Off
Sample Out
Original WE-43 Material
1.75-Inch O.D.
Time (Seconds)
480
420
360
300
240
180
120
60
0
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 B1 B2 B3 B4 B5 B6 B7 B8 B9 C1 C2 C3 C4 C5 C6 C7 C8 C9


Initial Hollow Cylinder Testing (Fall 2011)
Burning Starts
Burner Off
Sample Out
Newer WE-43 Material
1.75-Inch O.D.
NO BURNING
Time (Seconds)
480
420
360
300
240
180
120
60
0
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 B1 B2 B3 B4 B5 B6 B7 B8 B9 C1 C2 C3 C4 C5 C6 C7 C8 C9


Initial Hollow Cylinder Testing (Fall 2011)
Burning Starts
Burner Off
Sample Out
Time (Seconds)
480
420
360
300
240
180
120
60
0
Newer WE-43 Material
1.25-Inch O.D.
NO BURNING
(except for this one)
A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 B1 B2 B3 B4 B5 B6 B7 B8 B9 C1 C2 C3 C4 C5 C6 C7 C8 C9

“Same” Material but Different Result



Which Configuration?

Hollow Cylinders (vertical)

Rectangular Bars (horizontal)

Cylinder vs. Bar Testing (Spring 2012)

Hollow Cylinders (vertical): 59 Tests

WE-43: (15)
EL-21: (18)
ZE-41: (18)
AZ-80: (3)
AZ-31: (1)
EXP: (4)

1 cylinder configuration tested

VS.

Rectangular Bars (horizontal): 137 Tests

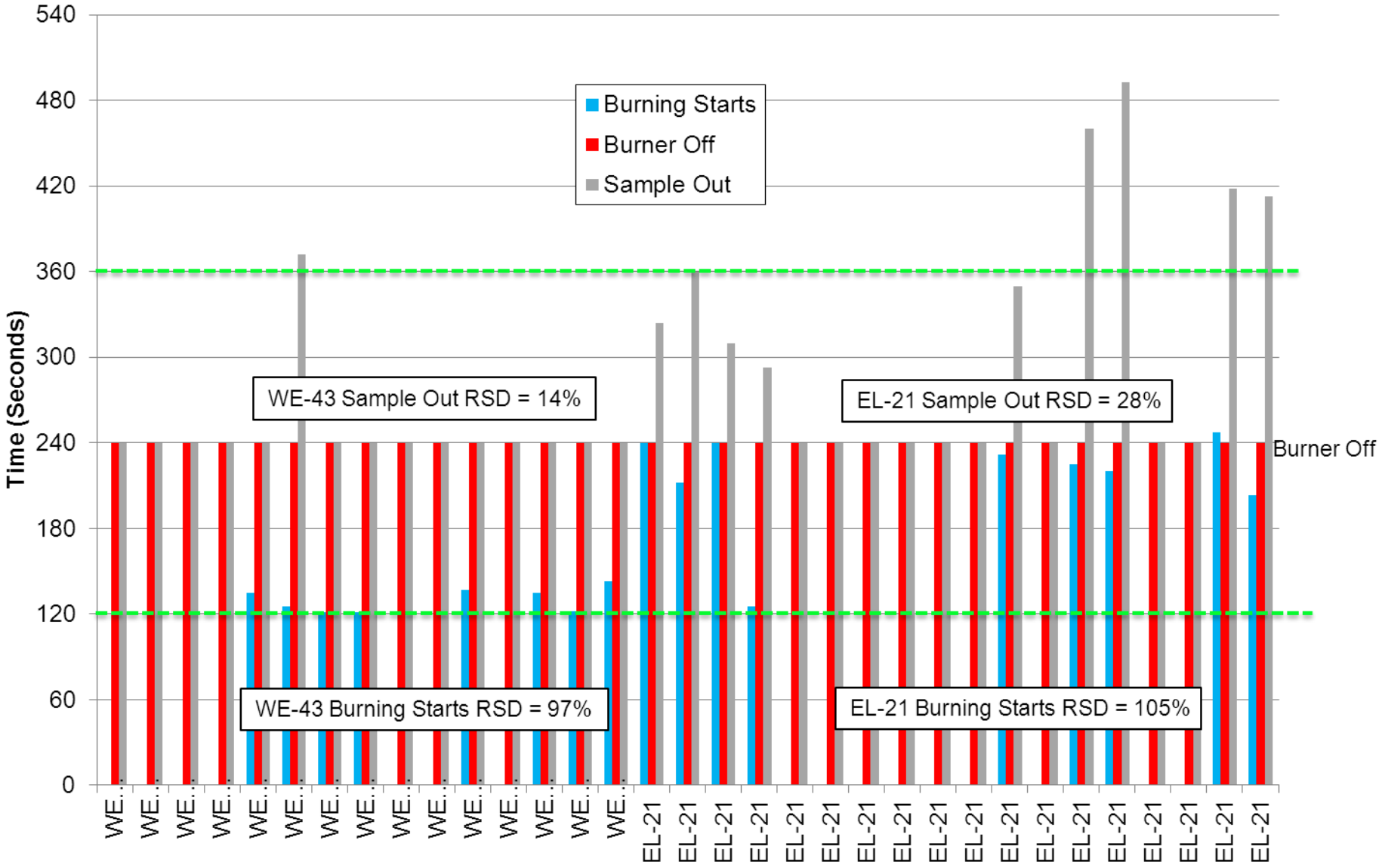
WE-43: (18)
E-43: (25)
EL-21: (34)
EXP-2: (2)
ZE-41: (24)
AZ-80: (27)
AZ-31: (7)

4 different bar thicknesses tested

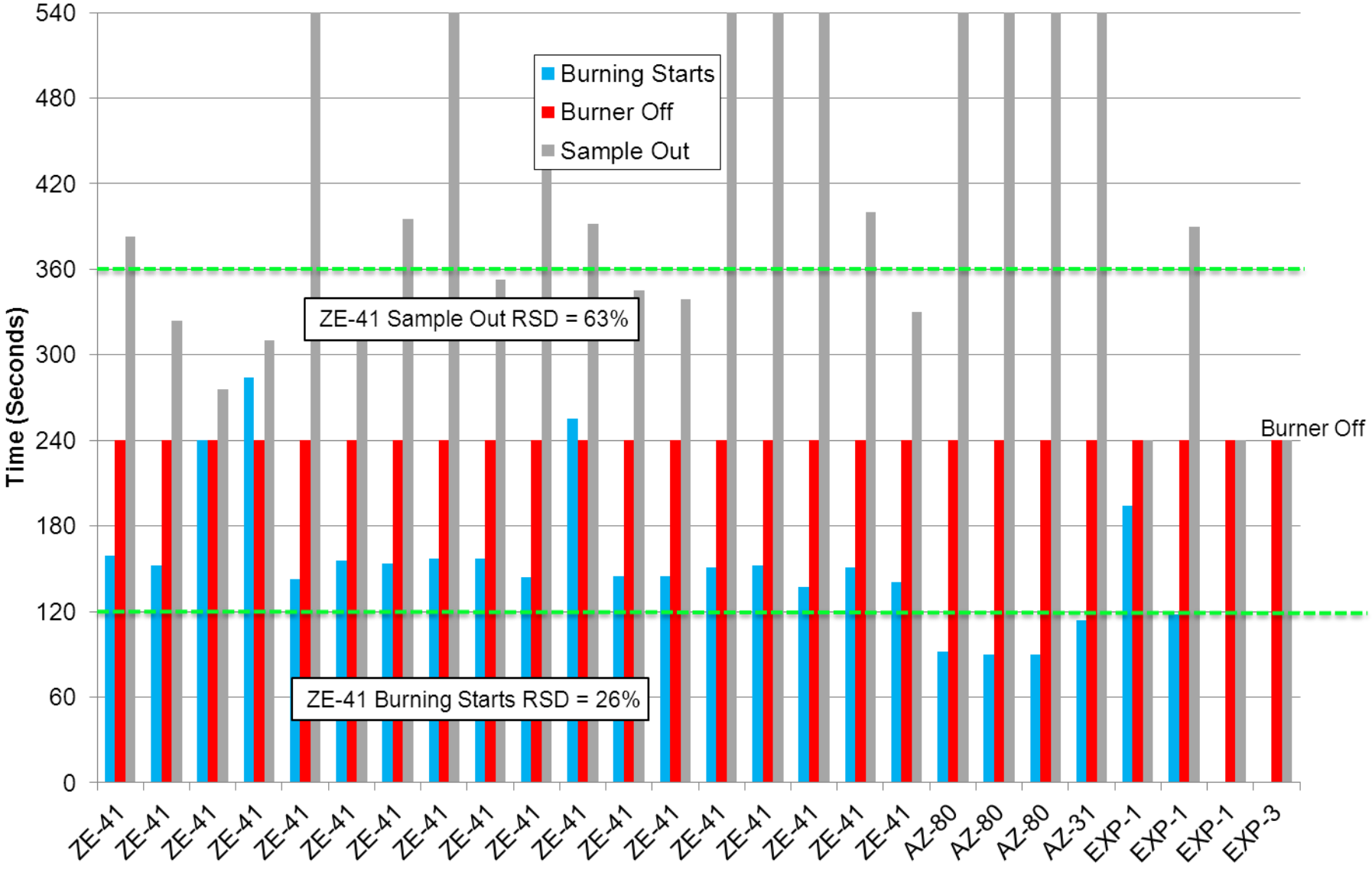
Cylinder Test Results

Tests Run on 5/9 – 5/10/2012

WE-43 and EL-21 Cylinder Test Results 1.625-Inch O.D. (4/2012)

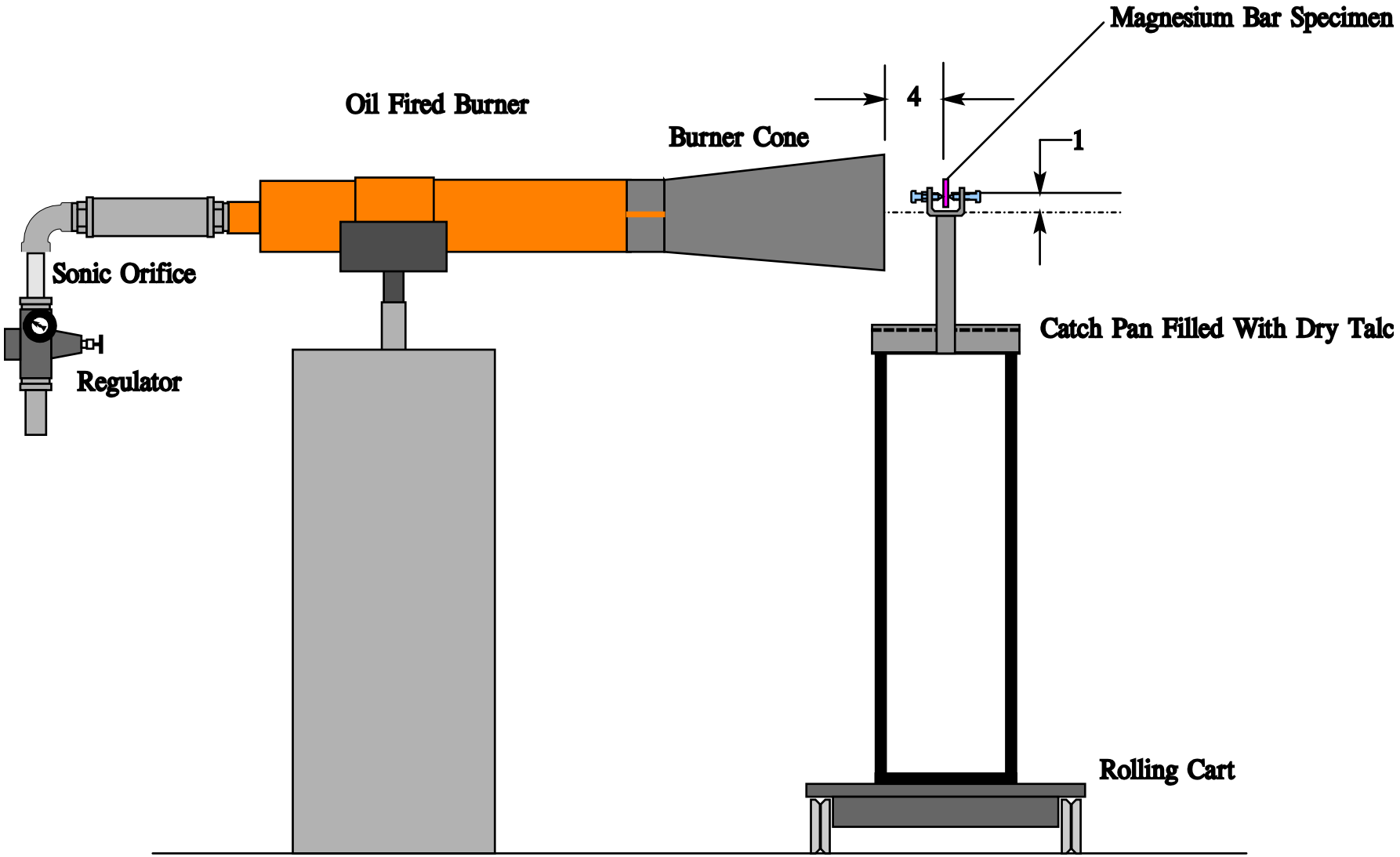


ZE-41 and AZ Cylinder Test Results 1.625-Inch O.D. (4/2012)



Bar Test Results

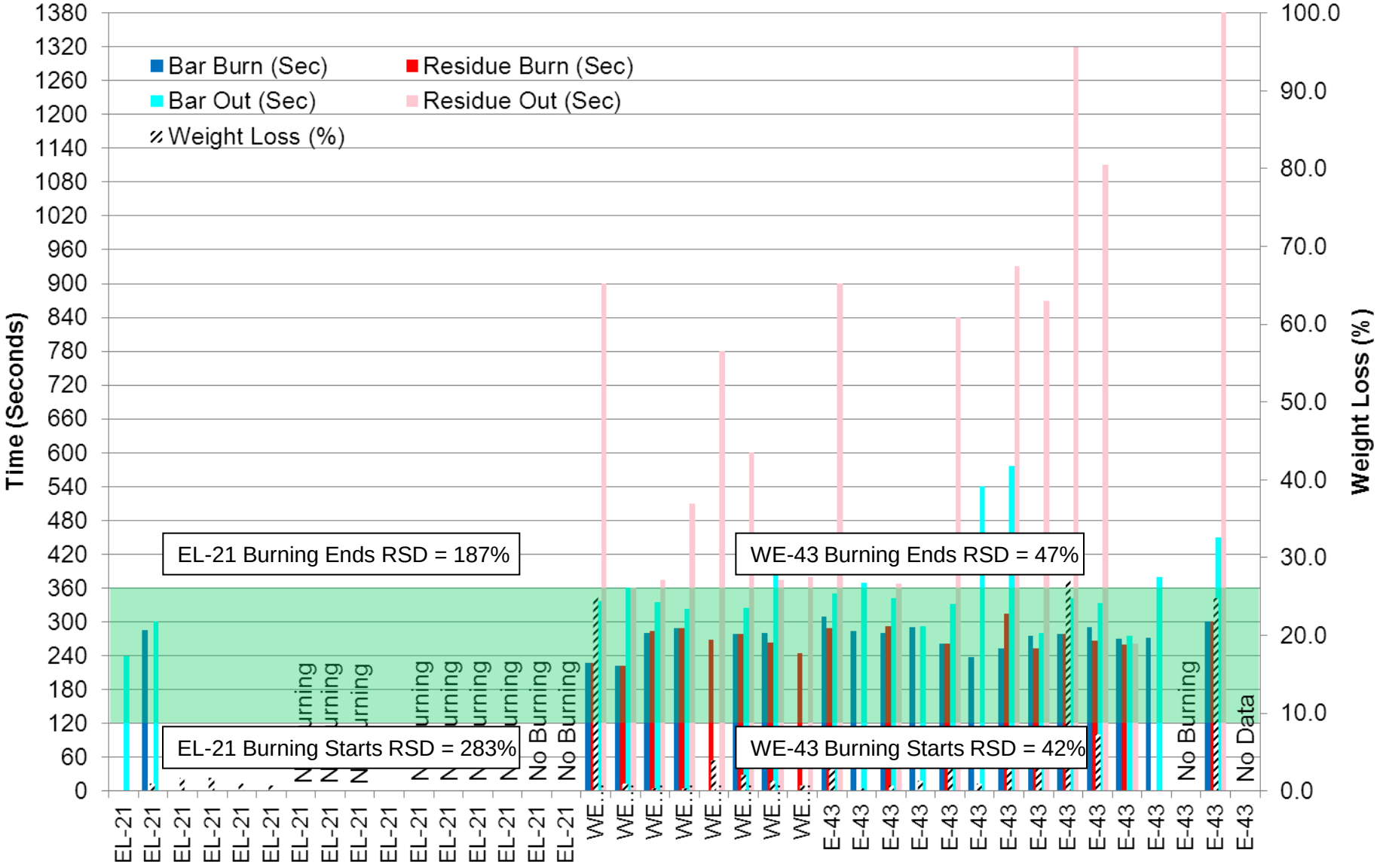
Updated Horizontal Bar Testing Rig 2012



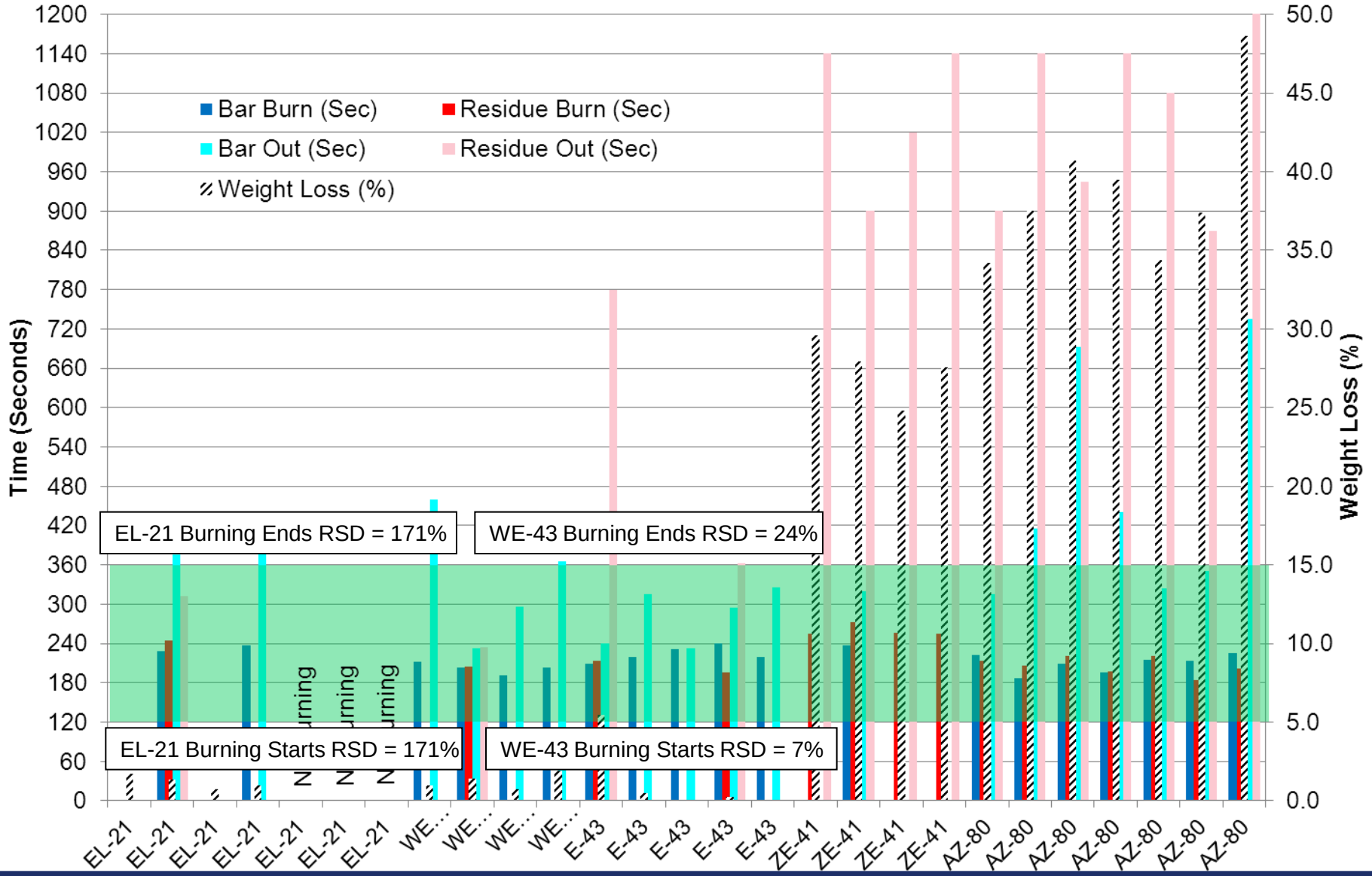
Parameters Measured During Bar Tests

Test No.	Lab	Date	Alloy	Bev	Fin	Thick-ness (inches)	Height (inches)	Length (inches)	Melt (Sec)	Ignition (Sec)	Bar Begins to Burn (Sec)	Residue Begins to Burn (Sec)	Burner Off (Sec)	Bar Out (Sec)	Residue Out (Sec)	Initial Weight (lbs)	Final Weight Bar (lbs)	Final Weight Residue (lbs)	Weight Loss (%)	Total Bar Burn Duration	Total Residue Burn Duration	Sample Total Burn Duration
5	A	4/24/2012	EL-21		S	0.669	1.57	19.69	339	0	0	0	360	0	0	1.320	1.050	0.270	0.0	0.0	0.0	0
6	A	4/24/2012	EL-21		S	0.669	1.57	19.69	308	0	0	0	360	0	0	1.320	1.030	0.290	0.0	0.0	0.0	0
11	A	4/24/2012	EL-21		S	0.669	1.57	19.69	324	0	0	0	360	0	0	1.320	1.030	0.290	0.0	0.0	0.0	0
2	A	4/23/2012	WE-43		S	0.669	1.57	19.69	290	290	290	0	360	403	0	1.350	0.980	0.370	0.0	113.0	0.0	113
3	A	4/23/2012	WE-43		S	0.669	1.57	19.69	298	298	330	0	360	415	0	1.350	1.000	0.350	0.0	85.0	0.0	85
12	A	4/24/2012	WE-43		S	0.669	1.57	19.69	300	300	330	300	360	477	820	1.350	0.960	0.290	7.4	147.0	520.0	667
1	A	4/23/2012	ZE-41		S	0.669	1.57	19.69	344	0	0	0	360	0	0	1.350	1.160	0.000	14.1	0.0	0.0	0
10	A	4/24/2012	ZE-41		S	0.669	1.57	19.69	343	350	0	343	360	0	960	1.350	1.070	0.000	20.7	0.0	617.0	617
13	A	4/25/2012	ZE-41		S	0.669	1.57	19.69	346	420	0	346	360	0	960	1.350	1.180	0.000	12.6	0.0	614.0	614
16	A	4/25/2012	EXP-2		S	0.669	1.57	19.69	304	302	302	302	360	420	304	1.410	1.010	0.400	0.0	118.0	2.0	120
17	A	4/25/2012	EXP-2		S	0.669	1.57	19.69	309	305	305	309	360	445	600	1.400	0.990	0.390	1.4	140.0	291.0	431
9	A	4/24/2012	AZ-80		S	0.669	1.57	19.69	247	286	286	247	360	470	960	1.340	0.840	0.000	37.3	184.0	713.0	897
4	A	4/23/2012	AZ-31		S	0.669	1.57	19.69	332	294	294	332	360	960	960	1.310	0.250	0.000	80.9	666.0	628.0	1294
61	A	5/22/2012	WE-43		S	0.575	1.57	19.69	N/A	0	0	0	300	0	0	1.200	1.194	0.000	0.5	0.0	0.0	0
14	A	4/25/2012	EL-21		S	0.500	1.57	19.69	231	0	0	0	240	240	0	1.040	0.820	0.220	0.0	240.0	0.0	0
15	A	4/25/2012	EL-21		S	0.500	1.57	19.69	225	274	285	0	300	300	0	1.030	0.730	0.290	1.0	15.0	0.0	15

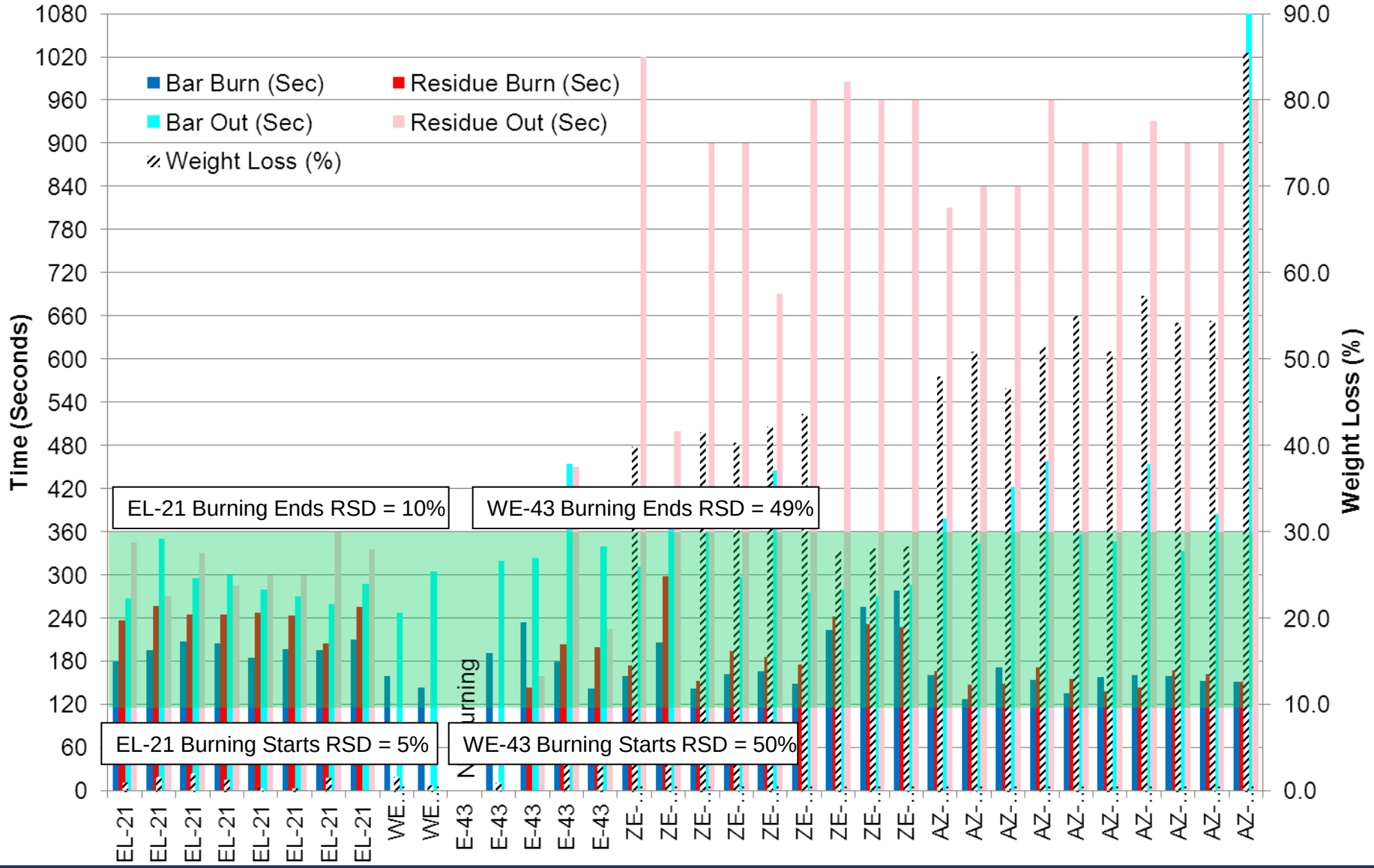
.5-Inch Thickness Bar Results (5-Minute Test)



.375-Inch Thickness Bar Results (4-Minute Test)



.250-Inch Thickness Bar Results (4-Minute Test)



Cylinders

	EL-21	
	Cylinder Begins to Burn (Sec)	Cylinder Out
Average	108.0	310.1
Std Dev	114.0	86.4
% RSD	105.5	27.9

	WE-43	
	Cylinder Begins to Burn (Sec)	Cylinder Out
Average	69.3	248.8
Std Dev	67.3	34.1
% RSD	97.2	13.7

	ZE-41	
	Cylinder Begins to Burn (Sec)	Cylinder Out
Average	167.9	573.7
Std Dev	43.3	363.9
% RSD	25.8	63.4

	AZ-80	
	Cylinder Begins to Burn (Sec)	Cylinder Out
Average	90.7	1140.0
Std Dev	1.2	0.0
% RSD	1.3	0.0

VS.

Bars

	0.250-Inch EL-21			0.375-Inch EL-21			0.500-Inch EL-21		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	196.8	288.6	1.1	66.4	111.4	0.7	35.6	67.5	0.8
Std Dev	10.9	28.4	0.8	113.5	190.5	0.7	100.8	126.0	0.7
% RSD	5.5	9.8	70.5	170.8	171.0	103.3	282.8	186.7	94.2

	0.250-Inch WE-43			0.375-Inch WE-43			0.500-WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	149.9	284.4	1.6	214.3	306.8	1.3	235.4	317.6	5.5
Std Dev	73.4	140.0	1.6	14.9	73.3	1.7	98.1	149.4	8.6
% RSD	49.0	49.2	102.3	7.0	23.9	136.2	41.7	47.0	155.5

	0.250-Inch ZE-41			0.375-Inch ZE-41			0.500-ZE-41		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	193.4	323.4	33.1	59.3	80.0	27.5	250.3	364.8	17.6
Std Dev	49.5	60.5	12.3	118.5	160.0	2.0	201.3	207.5	8.7
% RSD	25.6	18.7	37.1	200.0	200.0	7.3	80.4	56.9	49.7

	0.250-Inch AZ-80			0.375-Inch AZ-80			0.500-AZ-80		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	152.9	394.3	51.6	209.6	467.3	38.9	194.3	439.0	33.9
Std Dev	15.4	50.3	3.7	13.7	174.7	4.9	104.9	315.9	11.0
% RSD	10.1	12.8	7.2	6.5	37.4	12.6	54.0	72.0	32.4

Vertical Cylinder vs. Horizontal Bar Summary

Data indicates horizontal bar configuration more repeatable

	Cylinder	
	Begin Burn	End Burn
	10	.9
	97.2	13.7
	25	.4
	3	0
AVG %RSD	57.5	26.3

0.250-Inch Bar	
Begin Burn	End Burn
5.5	9.8
49.0	49.2
25.6	18.7
10.1	12.8
22.5	22.6

Bar samples easier/less expensive to produce!

…as a comparison to recent seat cushion round robin…

	Weight Loss		
	Cushion 1	Cushion 2	Cushion 3
	10.17	4.39	8.23
	12.51	6.12	8.65
	10.38	7.05	8.69
	4.27	6.38	6.51
	4.30	7.20	7.40
	5.49	6.23	6.06
	10.03	7.94	5.77
	8.84	6.46	6.67
	8.05	8.24	5.37
	6.05	8.38	8.97
	7.30	9.30	8.37
	6.15	9.23	6.44
	7.01	5.92	6.14
	6.85	6.85	7.81
	6.35	7.75	9.09
	7.67	7.21	7.82
	10.38	7.30	8.03
	7.05	6.99	6.40
% RSD	29.4	16.9	16.2

0.250-Inch Bar	
Begin Burn	End Burn
5.5	9.8
49.0	49.2
25.6	18.7
10.1	12.8
22.5	22.6

…Continue with Horizontal Bar Testing

What has been done?

284 Bar Tests Completed!

(14) 0.668-Inch Samples Tested

(62) 0.500-Inch Samples Tested

(88) 0.375-Inch Samples Tested

(120) 0.250-Inch Samples Tested

Improvements to test apparatus

-More precise mounting mechanism

-Standardized depth of talc in catch pan

Test parameters more well-defined

Time for sample to burn

Time for residue to burn

Time for sample to self extinguish

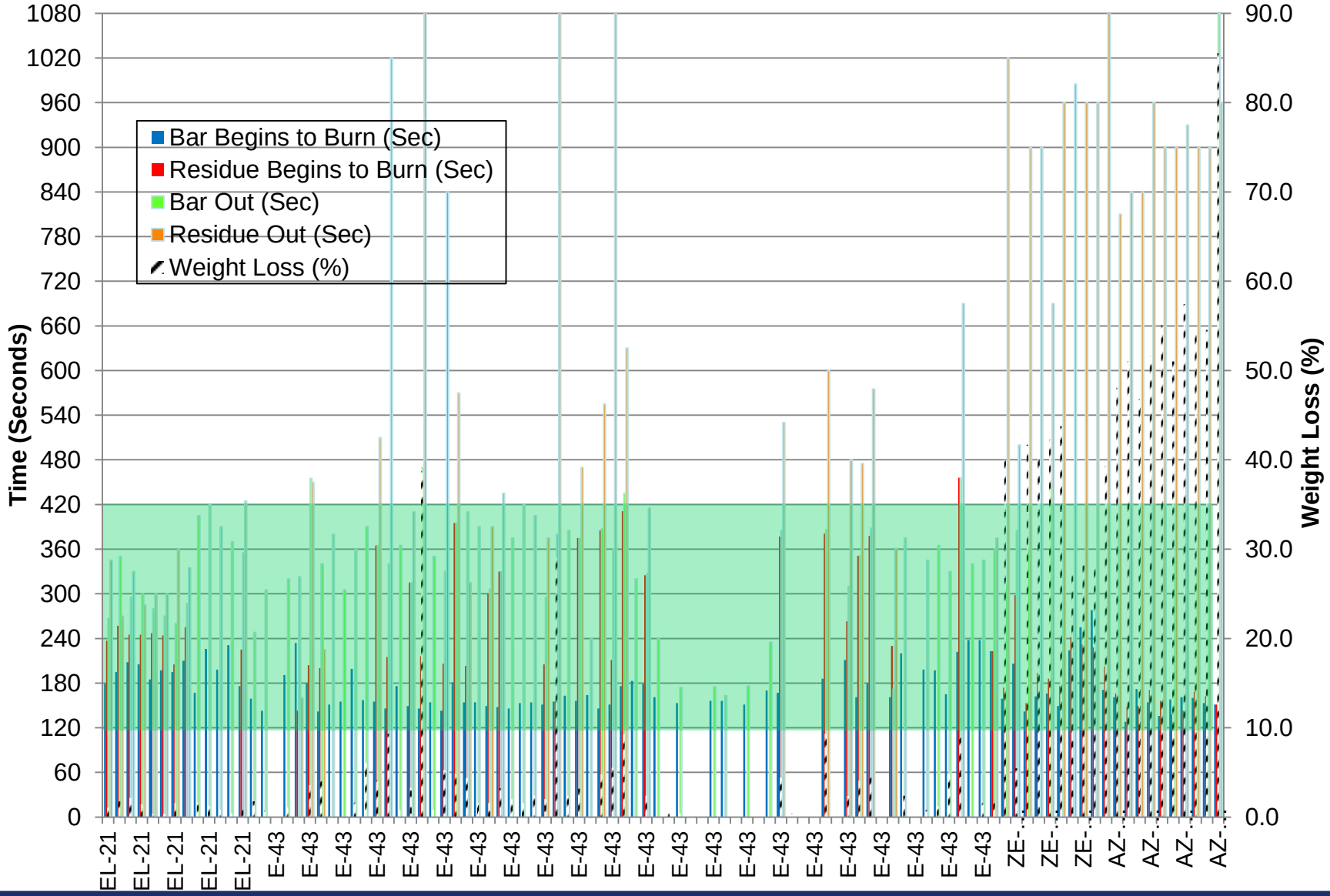
~~Time for residue to self extinguish~~

% weight loss

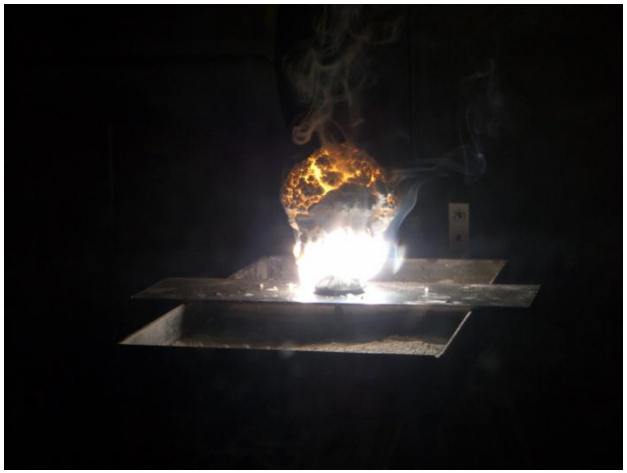
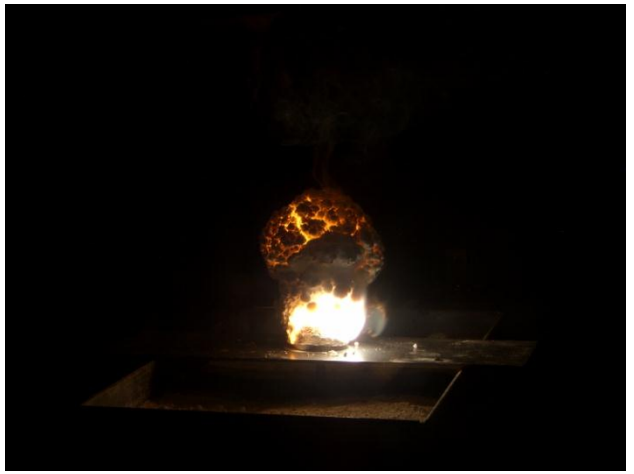
Internal “micro” round robin

Determine repeatability, test robustness

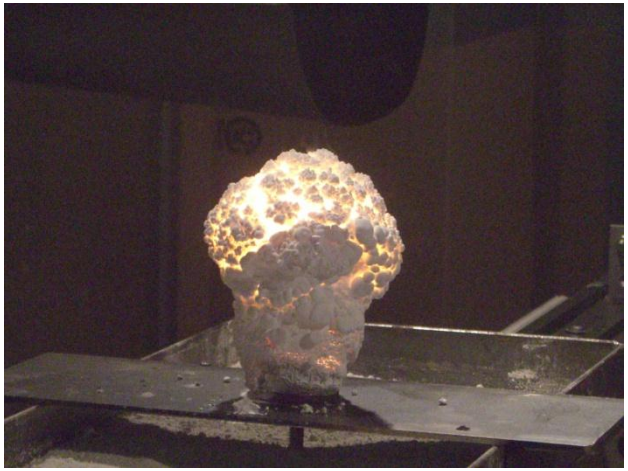
.250-Inch Thickness Bar Results (4-Minute Test)

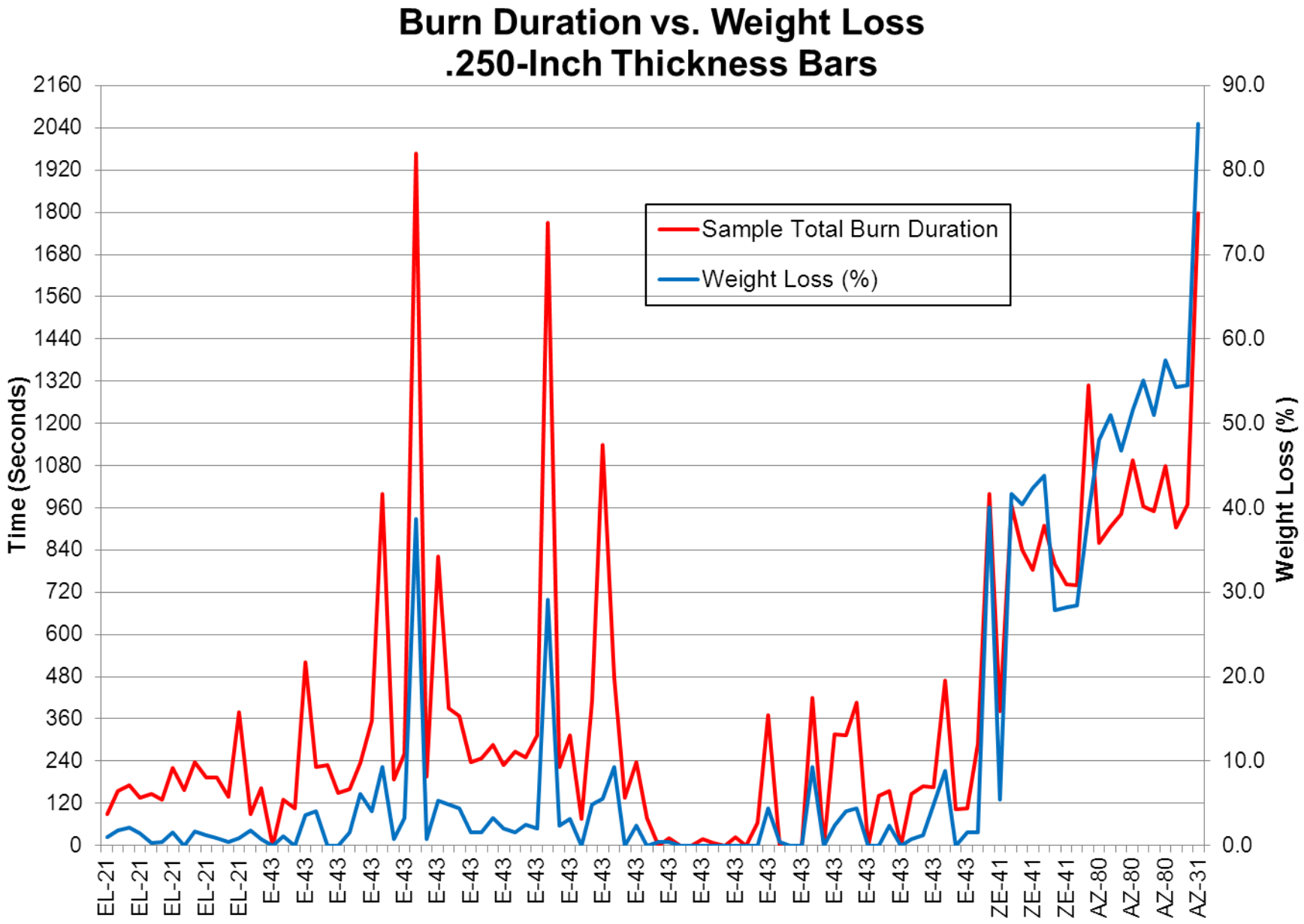


Eliminate measurement of residue extinguishment time

When is it “Out”?




Burn Duration vs. Weight Loss
.250-Inch Thickness Bars
Time (Seconds)
Weight Loss (%)
Sample Total Burn Duration
Weight Loss (%)
2160
2040
1920
1800
1680
1560
1440
1320
1200
1080
960
840
720
600
480
360
240
120
0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
EL-21
EL-21
EL-21
EL-21
EL-21
E-43
E-43
E-43
E-43
E-43
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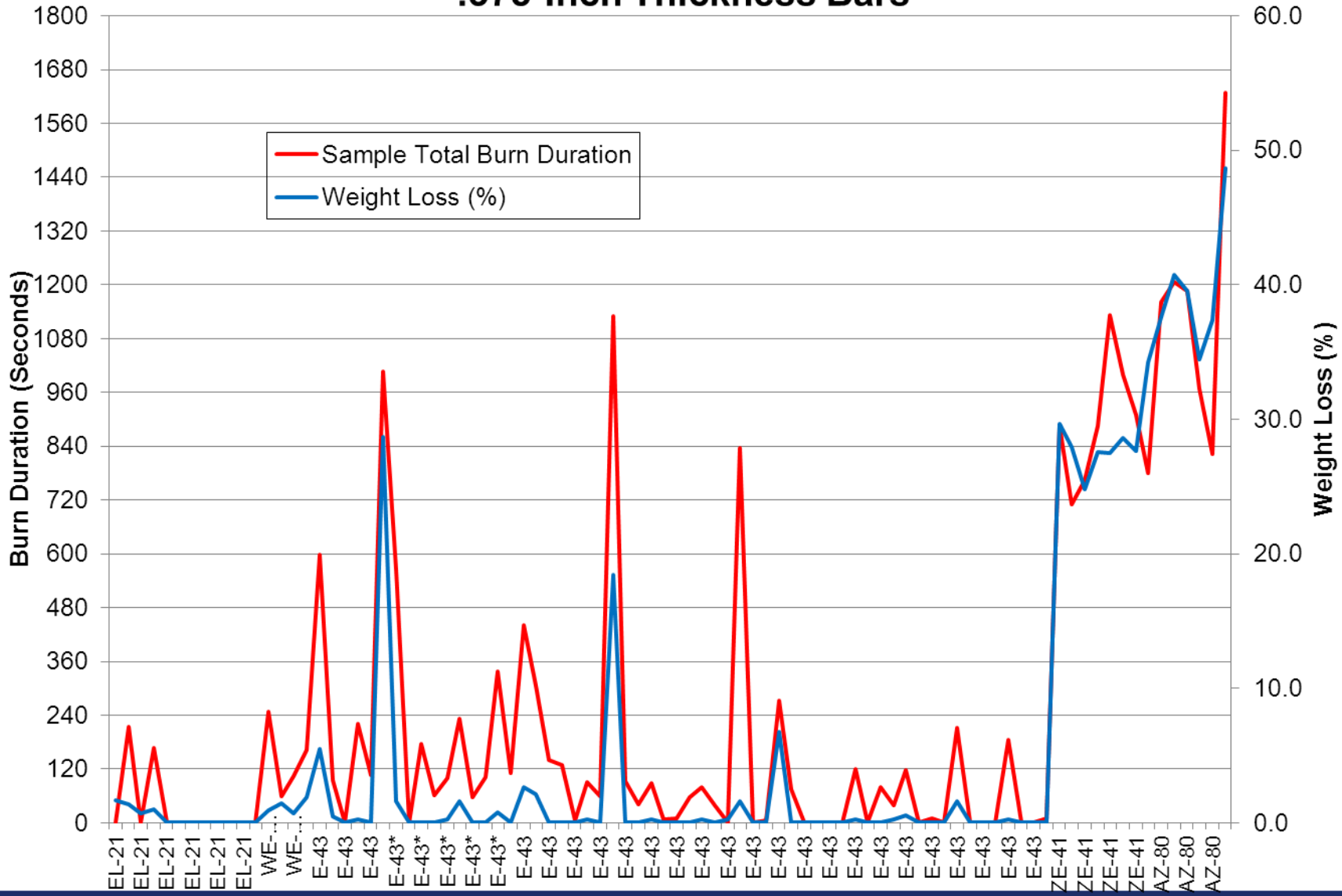
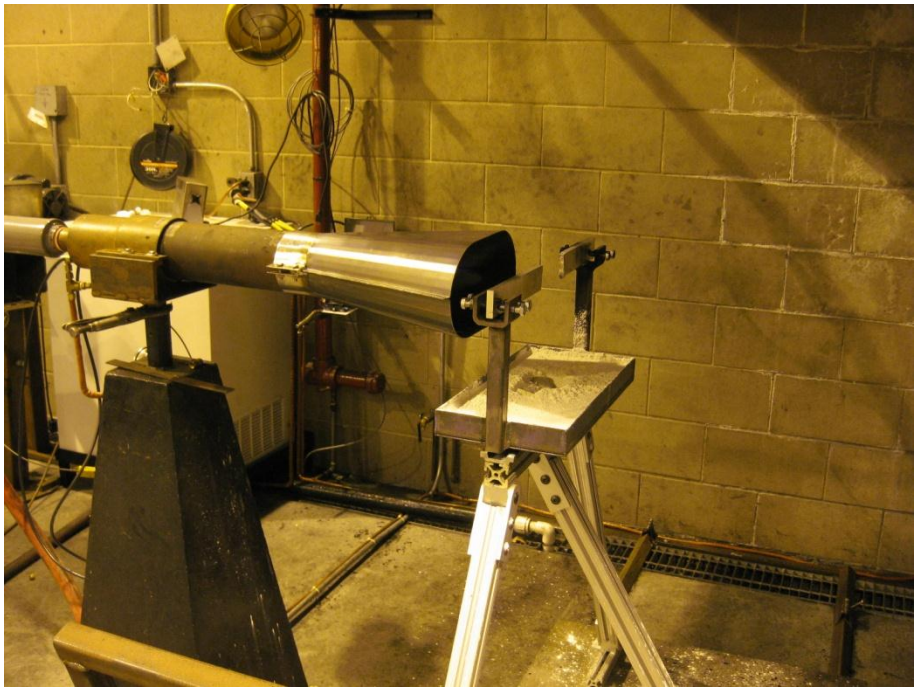
E-43
E-43
E-43
E-43
E-43
E-43
E-43
E-43
E-43
E-43
E-43
E-43
E-43
ZE-41
ZE-41
ZE-41
AZ-80
AZ-80
AZ-80
AZ-31

Burn Duration vs. Weight Loss
.375-Inch Thickness Bars

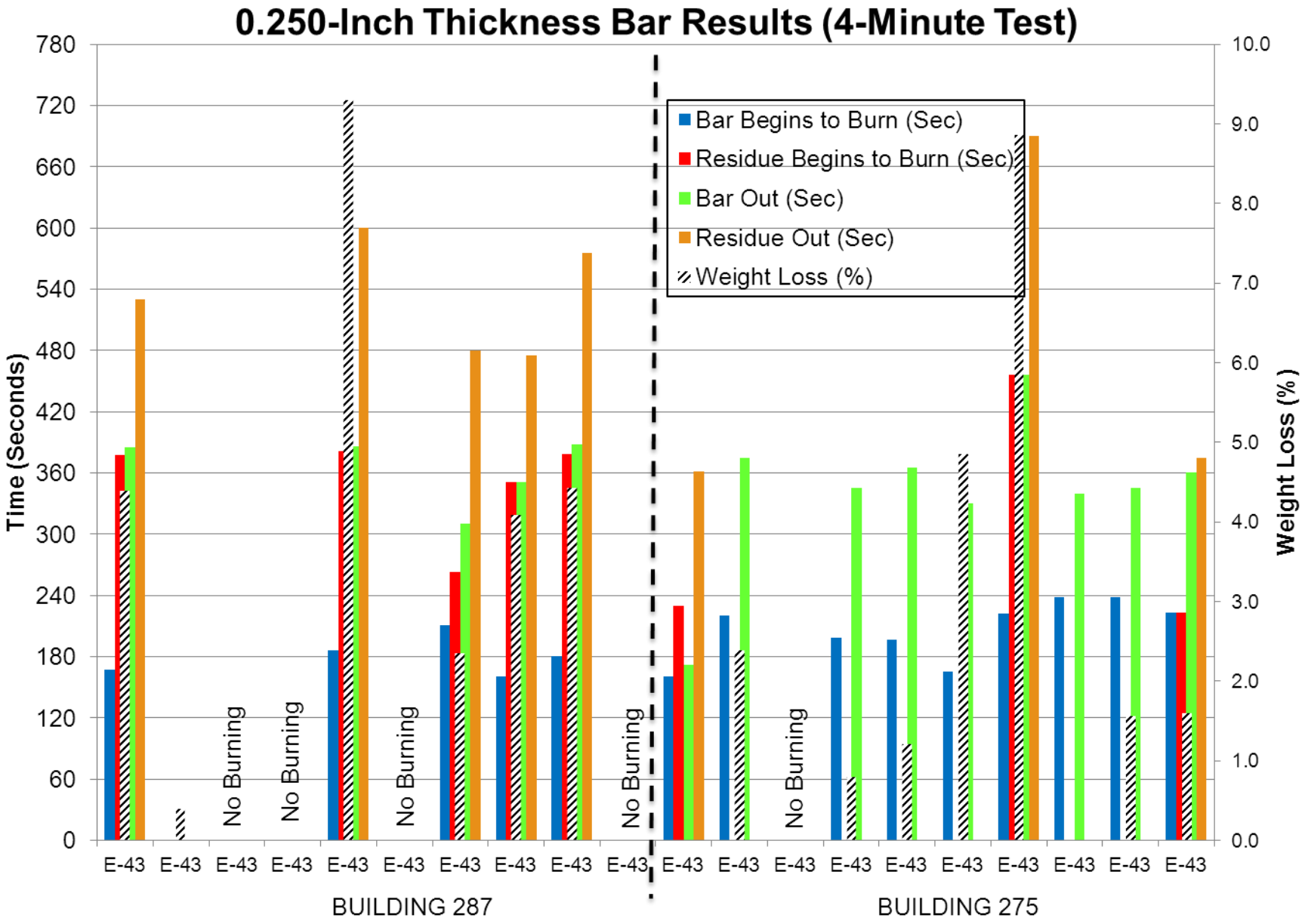


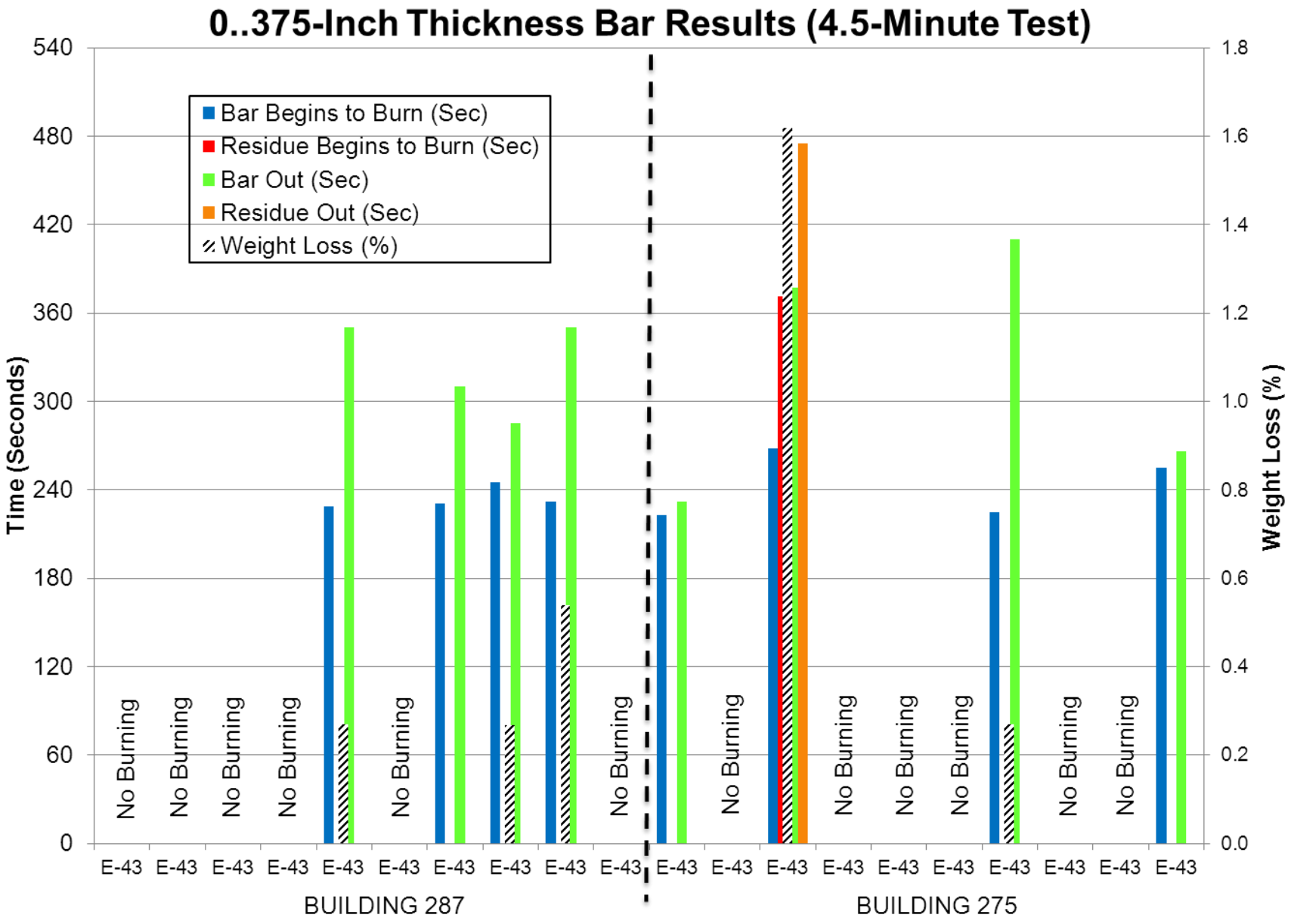
Micro Round Robin

Building 287 Apparatus



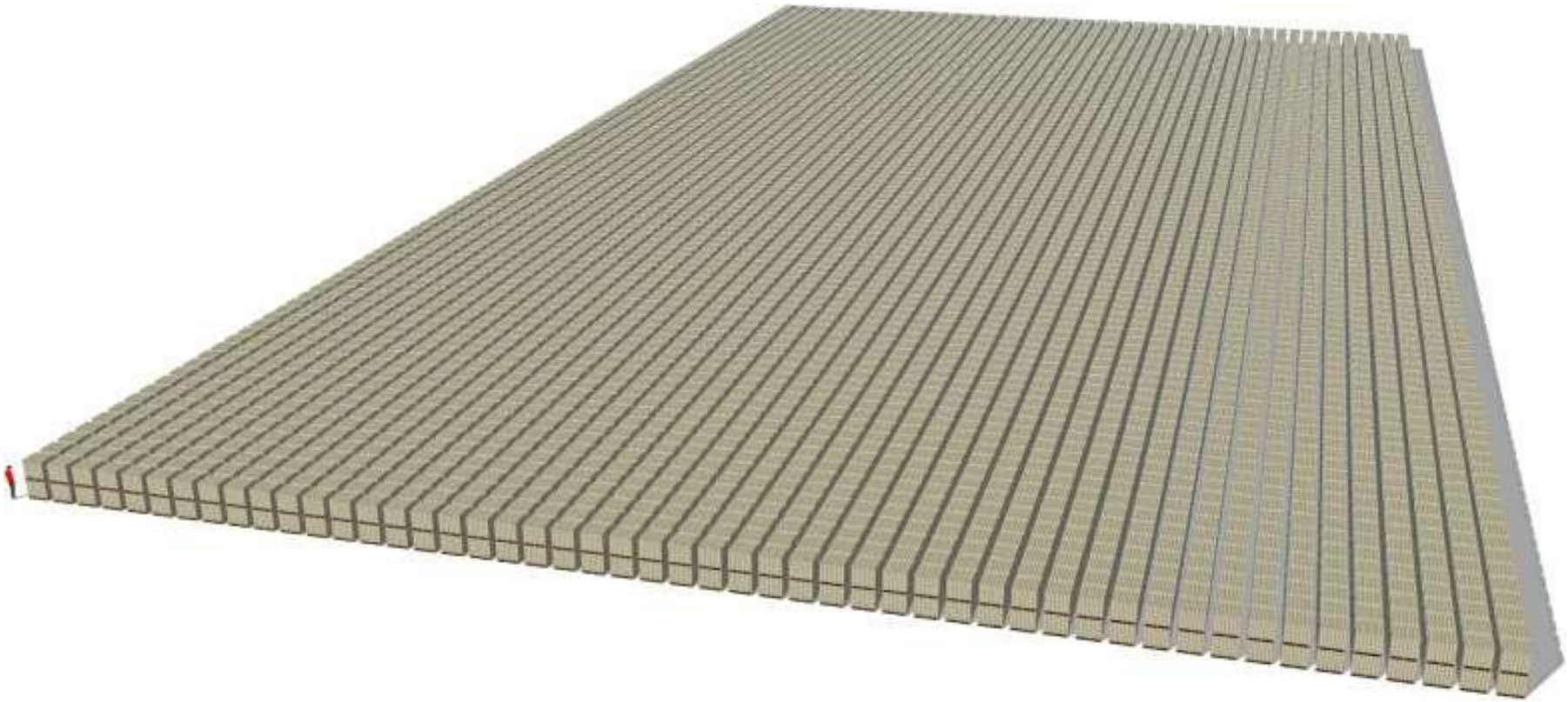
Building 275 Apparatus


0.250-Inch Thickness Bar Results (4-Minute Test)
Time (Seconds)
Weight Loss (%)
780
720
660
600
540
480
420
360
300
240
180
120
60
0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Bar Begins to Burn (Sec)
Residue Begins to Burn (Sec)
Bar Out (Sec)
Residue Out (Sec)
Weight Loss (%)
No Burning
E-43
BUILDING 287
BUILDING 275


0..375-Inch Thickness Bar Results (4.5-Minute Test)
Bar Begins to Burn (Sec)
Residue Begins to Burn (Sec)
Bar Out (Sec)
Residue Out (Sec)
Weight Loss (%)
Time (Seconds)
Weight Loss (%)
540
480
420
360
300
240
180
120
60
0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
No Burning
E-43
BUILDING 287
BUILDING 275

16.2 Trillion Dollar Question:

What should the thickness of the test sample be???



	0.250-Inch EL-21			0.375-Inch EL-21			0.500-Inch EL-21		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Wt Loss	Bar Begins o Burn Sec)	Bar Out (Sec)	Weigh Loss
Average	197.8	326.8	1.1	38.8	65.0	0.4	5.6	67.5	0
Std Dev	18.6	56.8	0.7	90.5	151.9	0.6	.8	126.0	
% RSD	9.4	17.4	61.6	233.6	233.8	157.7	3	186.7	

	0.250-Inch WE-43			0.375-Inch WE-43			500-WE-4		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Be to B (Se	ar O Se	eight ss (%)
Average	139.7	277.1	3.1	173.4	242.3	1.3	235.4		5.5
Std Dev	69.9	146.1	6.0	104.4	156.3	4.4	98.1		8.6
% RSD	50.1	52.7	194.0	60.2	64.5	339.1	41.7		155.5

	0.250-Inch ZE-41			0.375-Inch ZE-41			1		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begin to Bu (S	r Sec	eight s (%)
Average	191.2	321.1	33.7	158.3	202.1	27.7	2	364.8	6
Std Dev	47.2	145.9	27.0	151.8	193.0	1.5		207.5	
% RSD	24.7	45.4	80.0	95.9	95.5	5.3		56.9	

	0.250-Inch AZ-80			0.375-Inch AZ-80			0.500-AZ-80		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Wei Los	ar gins Burn (Sec)	Bar Out (Sec)	Weig Loss (
Average	152.9	394.3	51.6	209.6	467.3	3	194.3	439.0	33.9
Std Dev	15.4	50.3	3.7	13.7	174.7	4.	104.9	315.9	11.0
% RSD	10.1	12.8	7.2	6.5	37.4	12.6	54.0	72.0	32.4

	0.250-Inch EL-21		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	197.8	326.8	1.1
Std Dev	18.6	56.8	0.7
% RSD	9.4	17.4	61.6

	0.250-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	139.7	277.1	3.1
Std Dev	69.9	146.1	6.0
% RSD	50.1	52.7	194.0

	0.250-Inch ZE-41		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	191.2	321.1	33.7
Std Dev	47.2	145.9	27.0
% RSD	24.7	45.4	80.0

	0.250-Inch AZ-80		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	152.9	394.3	51.6
Std Dev	15.4	50.3	3.7
% RSD	10.1	12.8	7.2

VS.

0.375-Inch EL-21		
Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
38.8	65.0	0.4
90.5	151.9	0.6
233.6	233.8	157.7

0.375-Inch WE-43		
Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
173.4	242.3	1.3
104.4	156.3	4.4
60.2	64.5	339.1

0.375-Inch ZE-41		
Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
158.3	202.1	27.7
151.8	193.0	1.5
95.9	95.5	5.3

0.375-Inch AZ-80		
Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
209.6	467.3	38.9
13.7	174.7	4.9
6.5	37.4	12.6

	0.250-Inch EL-21		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	197.8	326.8	1.1
Std Dev	18.6	56.8	0.7
% RSD	9.4	17.4	61.6

	0.250-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	139.7	277.1	3.1
Std Dev	69.9	146	
% RSD	50.1	52.7	194.0

	0.250-Inch ZE-41		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	191.2	321.1	33.7
Std Dev	47.2	145.9	27.0
% RSD	24.7	45.4	80.0

	0.250-Inch AZ-80		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	152.9	394.3	51.6
Std Dev	15.4	50.3	3.7
% RSD	10.1	12.8	7.2

	159	159
	143	143
	0	191
	191	234
	234	180
	180	142
	142	151
	151	155
	155	199
	199	157
	157	155
	155	146
	146	176
	176	149
	149	146
	146	154
	154	143
	143	181
	181	154
	154	154
	154	149
	149	148
	148	156
	146	153
	153	154
	154	151
	151	155
	156	156
	156	164
	164	146
	146	151
	151	176
	176	183
	183	179
	179	161
	161	153
	0	156
	153	156
	0	151
	0	170
	156	167
	156	186
	0	211
	151	161
	0	180
	170	161
	167	220
	0	198
	0	197
	0	165
	186	222
	0	238
	211	238
	161	223
	180	
	0	
	161	
	220	
	0	
	198	
	197	
	165	
	222	
	238	
	238	
	223	
Average	139.657	170.127
Std Dev	69.9261	26.3889
% RSD	50.07	15.5113

REMOVE ZEROS

	Bar Begins to Burn (Sec)
Average	170.1
Std Dev	26.4
% RSD	15.5

Planned Activities

What is the reason for the scatter of data?

- Is it material-related or test-related?
- Determine influence of exhaust ventilation on sample extinguishment

Conduct additional tests on most appropriate thickness of bars

- How many tests is enough?

Finalize test parameters (i.e., sample thickness, exposure time)

- Establish appropriate minimum time until burning begins
- Establish appropriate maximum time for extinguishment of sample to occur
- Establish appropriate weight-loss criteria

Influence of Talc in Pan vs. No Talc

Questions?