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, Renton, WA

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Date: March 6-7, 2013

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

Which Configuration?

Hollow Cylinders (vertical): 59 Tests

Rectangular Bars (horizontal): 137 Tests

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

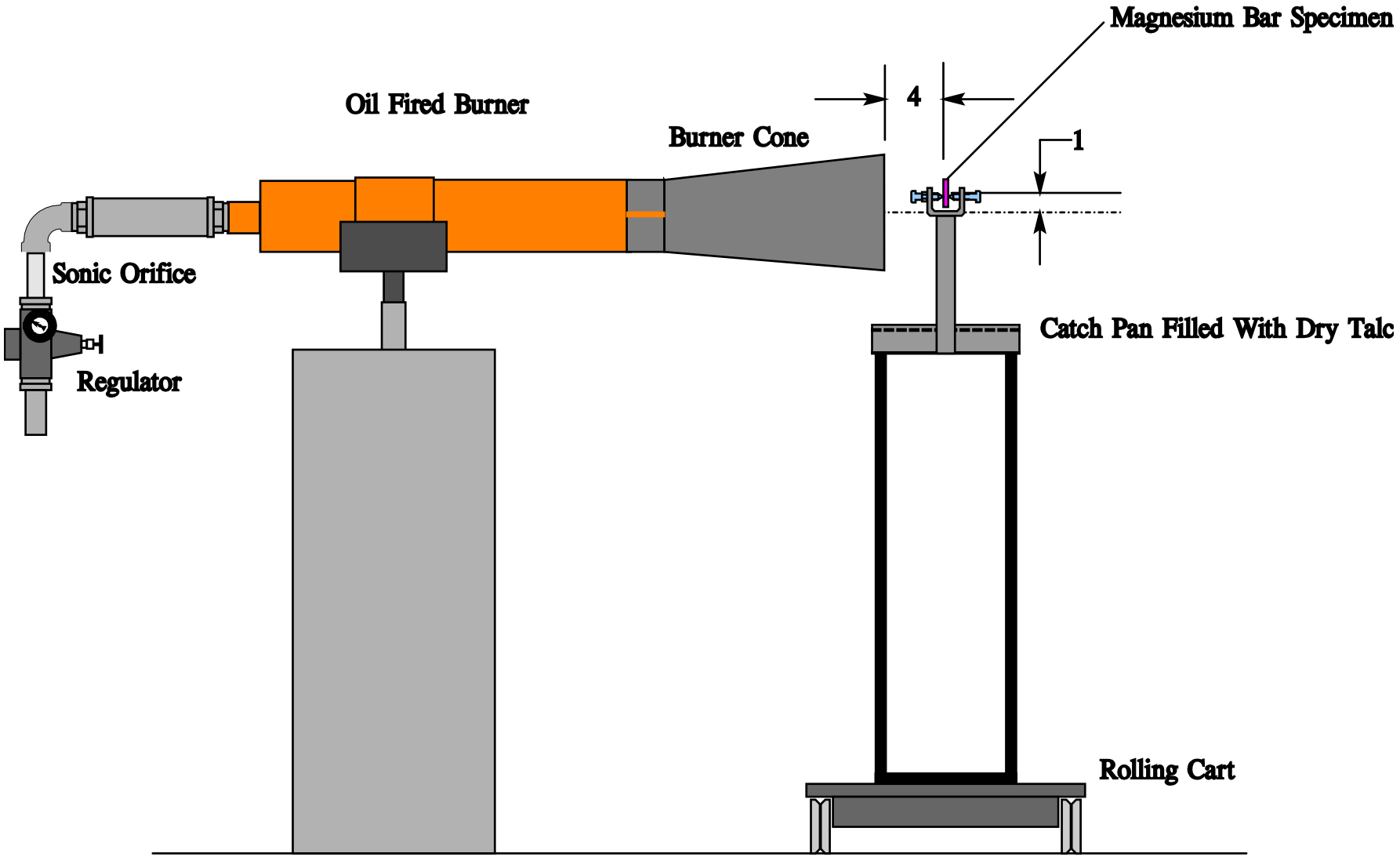
Data indicates horizontal bar configuration more repeatable

	Cylinder	
	Begin Burn	End Burn
	10[illegible]	[illegible].9
	97.2	13.7
	25[illegible]	[illegible].4
	[illegible]3	0[illegible]
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!

Updated Horizontal Bar Testing Rig



Continue with Horizontal Bar Test Refinement

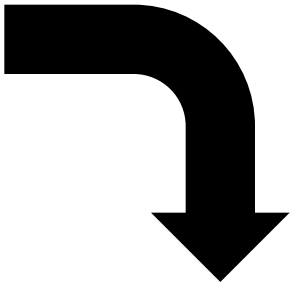
Improvements to test apparatus

-More precise mounting mechanism

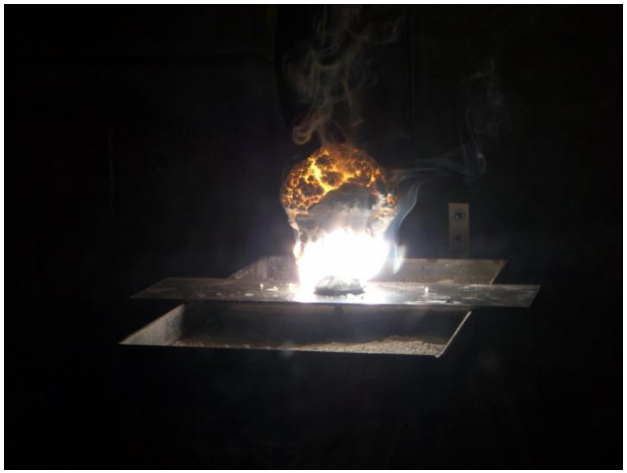
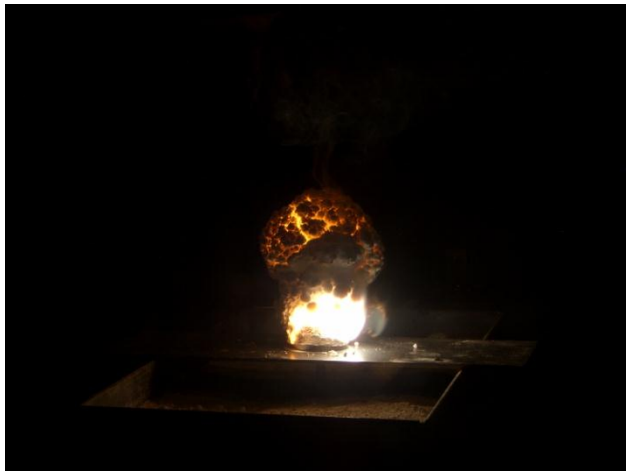
-Standardized depth of talc in catch pan

-Better control of ventilation in testing area

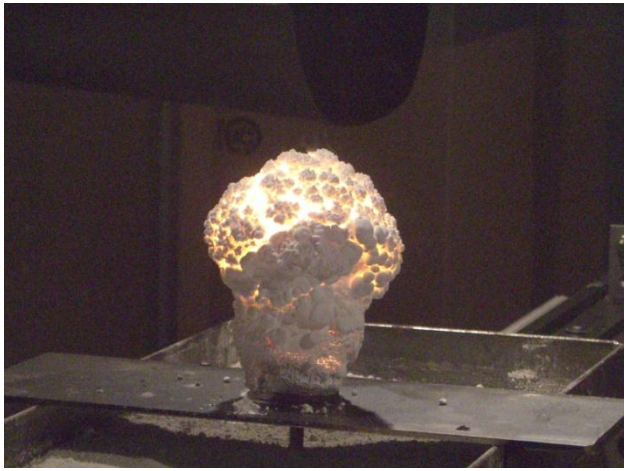
Better define test parameters



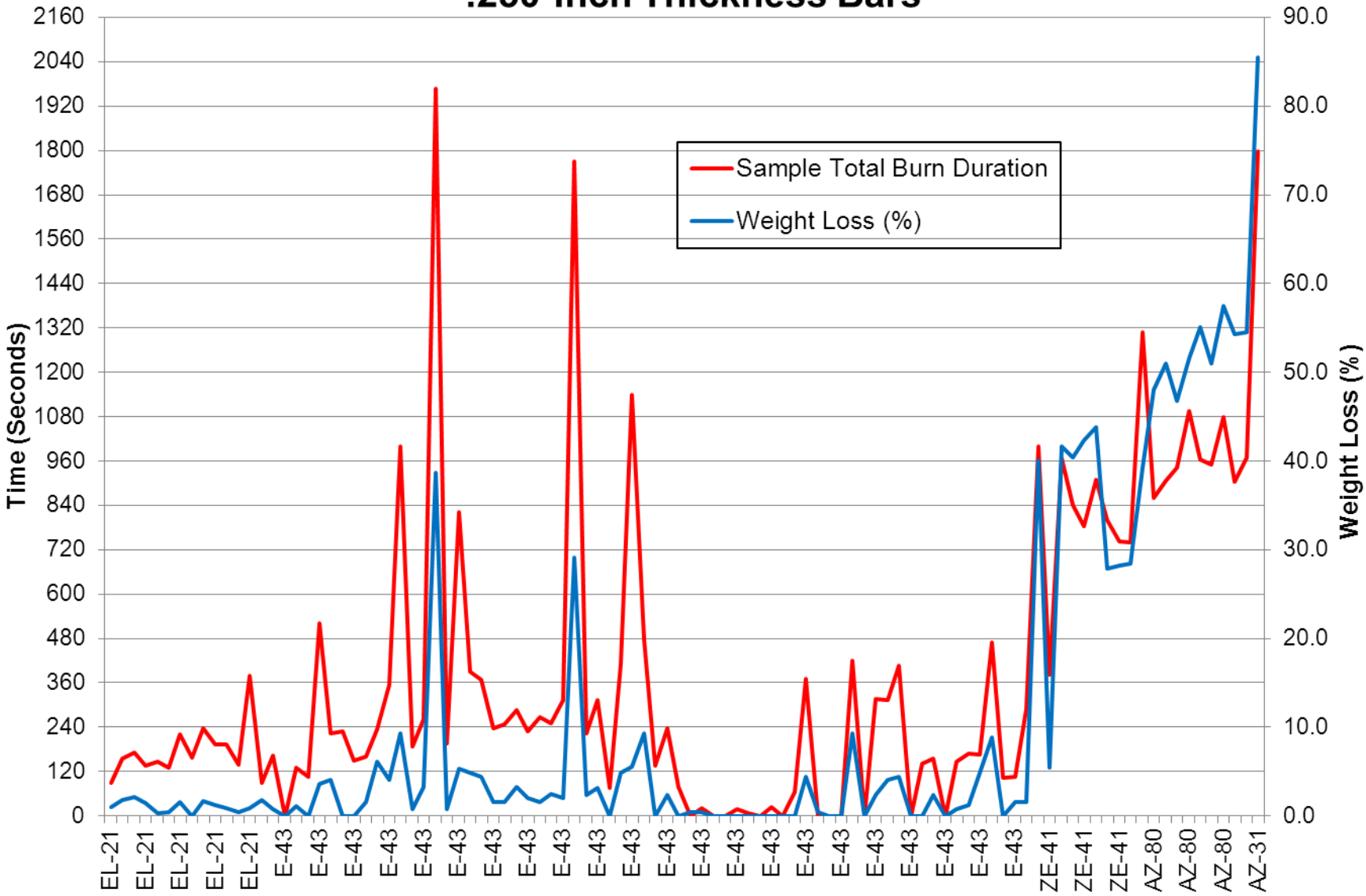
Eliminate measurement of residue ignition & extinguishment time

When is it “Out”?



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



Sample Thickness Determination

	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	197.8	326.8	1.1	38.8	65.0	0.4	5.6	67.5	
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		186.7	

	0.250-Inch WE-43			0.375-Inch WE-43			500-WE		
	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	Weight oss (%)
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					
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Ba Be to	ar (Sec	eight (%)
Average	191.2	321.1	33.7	158.3	202.1	27.7		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)	W L	Bar egins to Burn (Sec)	Bar Out (Sec)	Weig Loss (%
Average	152.9	394.3	51.6	209.6	467.3		194.3	439.0	33.9
Std Dev	15.4	50.3	3.7	13.7	174.7		104.9	315.9	11.0
% RSD	10.1	12.8	7.2	6.5	37.4	12	54.0	72.0	32.4

No advantage to thicker sample; extended exposure time required

Sample Thickness Determination

	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

	0.375-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

	0.250-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	146.0	264.0	2.4
Std Dev	83.8	150.5	5.0
% RSD	57.4	57.0	204.8

VS.

	0.375-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
	181.2	268.7	1.2
	101.2	159.3	3.5
	55.9	59.3	295.6

	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

	0.375-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

	0.250-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

	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

Sample thickness was left unresolved

What has been done since last meeting?

√ Additional tests conducted

Ran an additional 138 tests for grand total of 422 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

~~-Time for residue to burn~~

~~-Time for residue to self extinguish~~ % weight loss

-Maximum weight loss: 6% to 10%

What has been done since last meeting?

- √ First round robin completed
- √ Report on test method development underway
- √ Final report on full-scale testing of mag alloys published

Testing Completed to Date

0.250-Inch Samples	0.375-Inch Samples	0.5 & 0.66-Inch Samples
Elektron 21 (13 tests)	Elektron 21 (12 tests)	Elektron 21 (19 tests)
WE/E-43 (107 tests)	WE/E-43 (100 tests)	WE/E-43 (27 tests)
ZE-41 (10 tests)	ZE-41 (7 tests)	ZE-41 (11 tests)
AZ-80 / AZ-31 (10 tests)	AZ-80 / AZ-31 (7 tests)	AZ-80 / AZ-31 (17 tests)
Experimental (20 tests)	Experimental (20 tests)	Experimental (2 tests)
(160 tests)	(146 tests)	(76 tests)

WE/E-43 for Round Robin (40 tests)

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422 tests

How Repeatable is the Data?

Example of some of the data recorded during tests

Weight Loss (%)	1.8	0.7	0.0	1.1	0.0	3.6	4.0	0.0	0.0	1.6	6.1	4.1	9.3	0.8	3.3
Bar Out (Sec)	248	305	0	320	323	455	340	380	305	360	390	365	340	365	315
Bar Begins to Burn (Sec)	159	143	0	191	234	180	142	151	155	199	157	155	146	176	149
Alloy	WE-43	WE-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	E-43
Date	5/16/2012	5/16/2012	5/16/2012	5/16/2012	6/6/2012	6/6/2012	6/6/2012	8/14/2012	8/14/2012	8/14/2012	8/14/2012	8/16/2012	8/16/2012	8/16/2012	8/16/2012

Weight Loss (%)	38.7	0.8	5.3	4.9	4.4	1.6	1.6	3.2	2.0	1.6	2.4	2.0	29.1	2.4	3.2
Bar Out (Sec)	470	350	330	395	410	390	306	330	375	420	405	295	380	385	375
Bar Begins to Burn (Sec)	146	154	143	181	154	154	149	148	146	153	154	151	155	163	156
Alloy	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	E-43	E-43
Date	8/17/2012	8/17/2012	8/17/2012	8/17/2012	8/17/2012	8/20/2012	8/20/2012	8/21/2012	8/21/2012	8/21/2012	8/21/2012	8/21/2012	8/21/2012	8/22/2012	8/22/2012

Weight Loss (%)	0.0	4.8	5.5	9.3	0.0	2.4	0.0	0.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Bar Out (Sec)	240	387	360	435	320	327	240	0	174	0	0	175	163	0	176
Bar Begins to Burn (Sec)	164	146	151	176	183	179	161	0	153	0	0	156	156	0	151
Alloy	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	E-43	E-43
Date	8/22/2012	8/22/2012	8/22/2012	8/29/2012	8/29/2012	8/29/2012	9/11/2012	9/11/2012	9/11/2012	9/11/2012	9/11/2012	9/12/2012	9/12/2012	9/12/2012	9/12/2012

Weight Loss (%)	0.0	0.0	4.4	0.4	0.0	0.0	9.3	0.0	2.4	4.1	4.4	0.0	0.0	2.4	0.0
Bar Out (Sec)	0	235	385	0	0	0	386	0	310	351	388	0	172	375	0
Bar Begins to Burn (Sec)	0	170	167	0	0	0	186	0	211	161	180	0	161	220	0
Alloy	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	E-43	E-43
Date	9/12/2012	9/12/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/24/2012	9/26/2012	9/26/2012	9/26/2012

Zeros inserted when sample does not burn

How Repeatable is the Data?

	0.250-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	146.0	264.0	2.4
Std Dev	83.8	150.5	5.0
% RSD	57.4	57.0	204.8

Original Data with Zeros when bar doesn't burn (107 Tests)

	0.250-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	184.4	353.6	3.9
Std Dev	37.5	53.4	5.9
% RSD	20.3	15.1	151.4

Modified Data with Zeros removed (67 Tests)

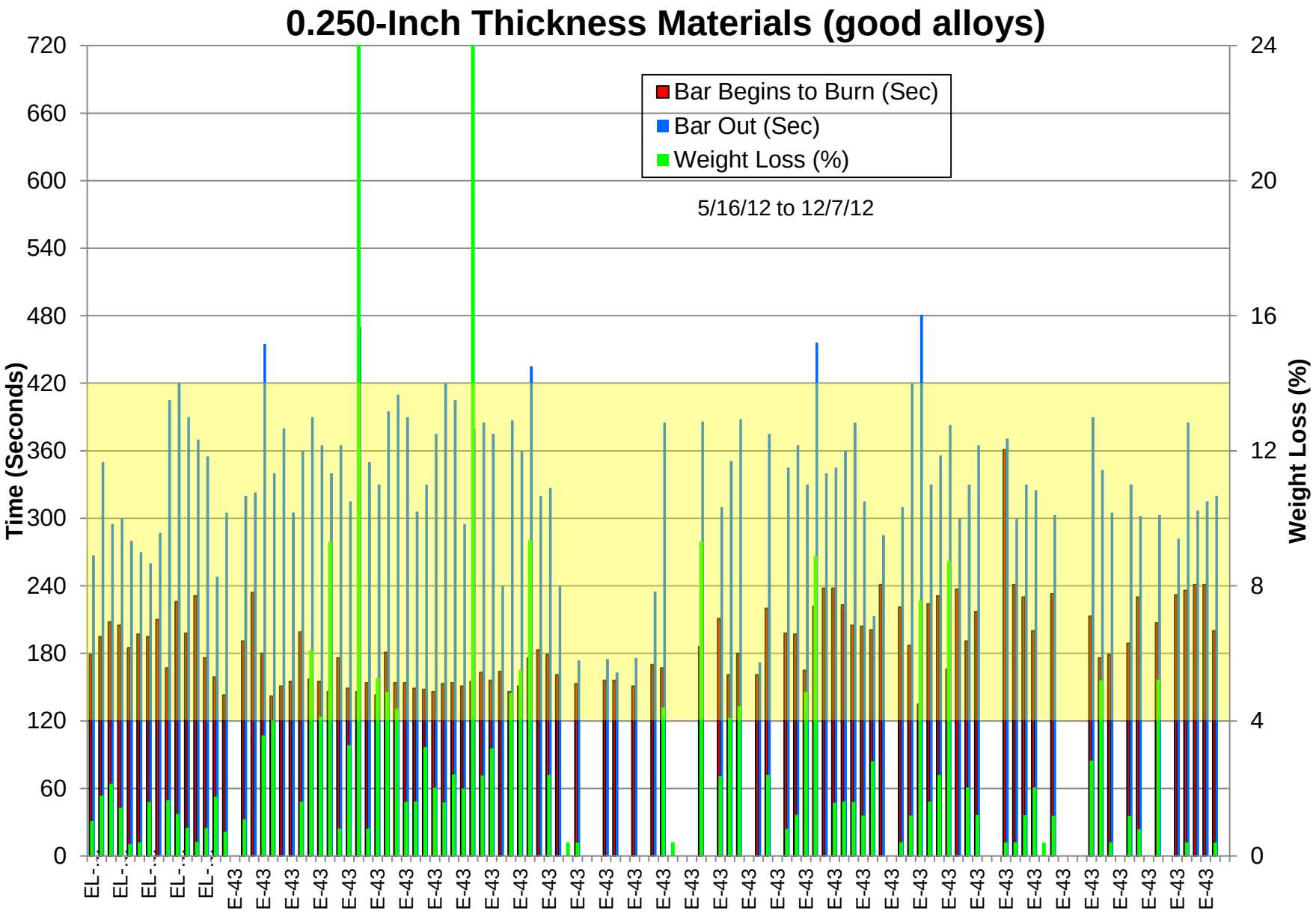
How Repeatable is the Data?

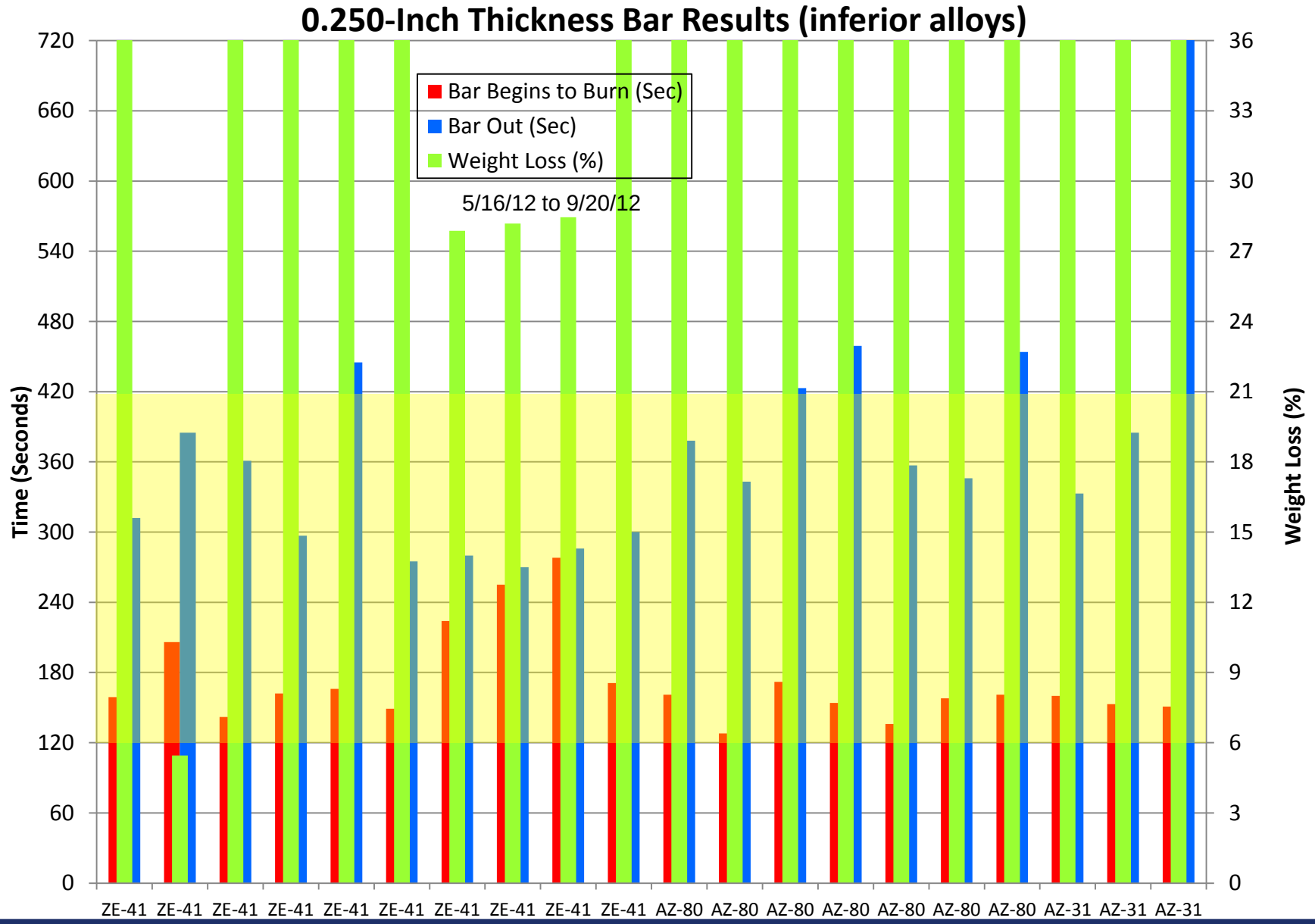
	0.375-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	181.2	268.7	1.2
Std Dev	101.2	159.3	3.5
% RSD	55.9	59.3	295.6

Original Data with Zeros when bar doesn't burn (100 Tests)

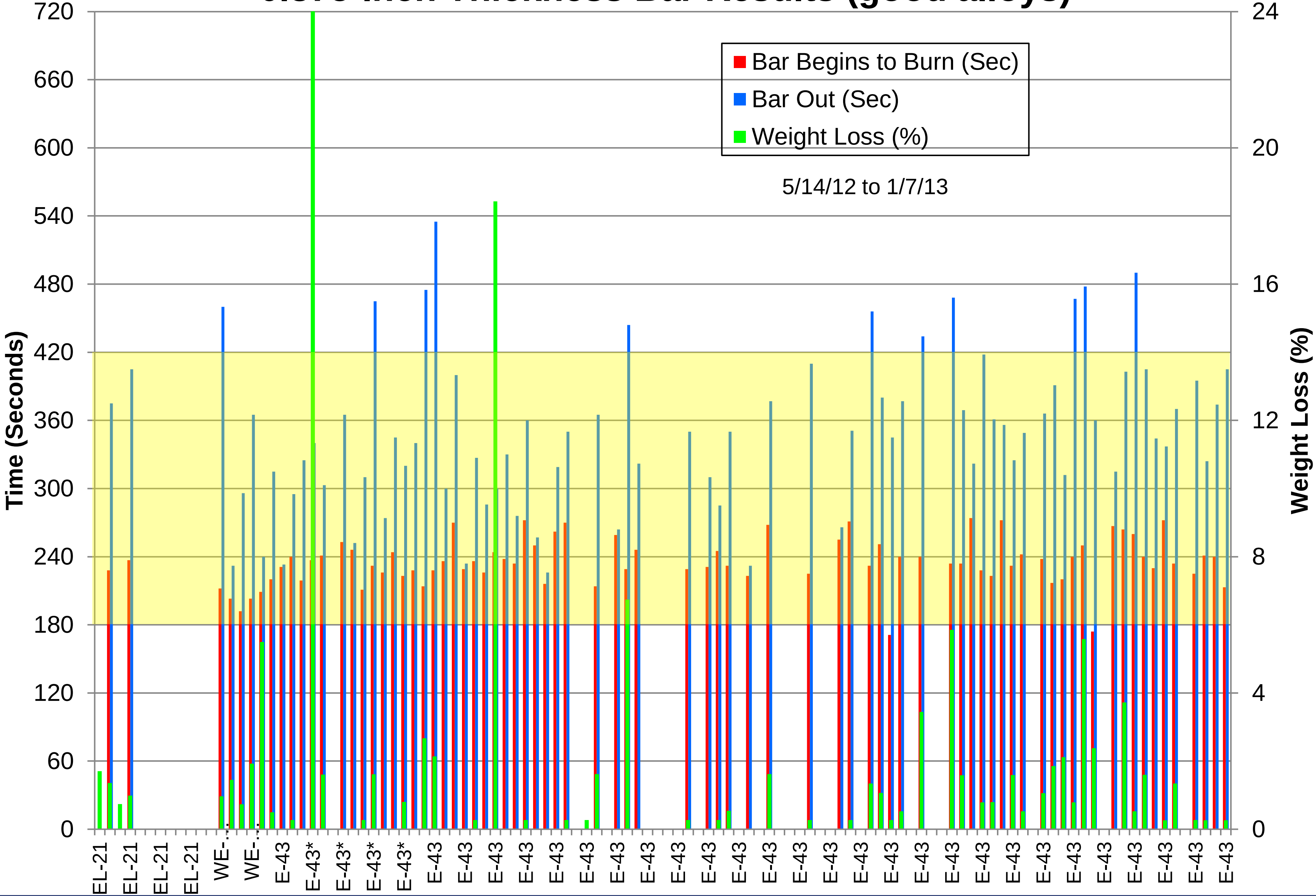
	0.375-Inch WE-43		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)
Average	231.6	371.0	2.3
Std Dev	21.9	65.7	4.7
% RSD	9.5	17.7	203.0

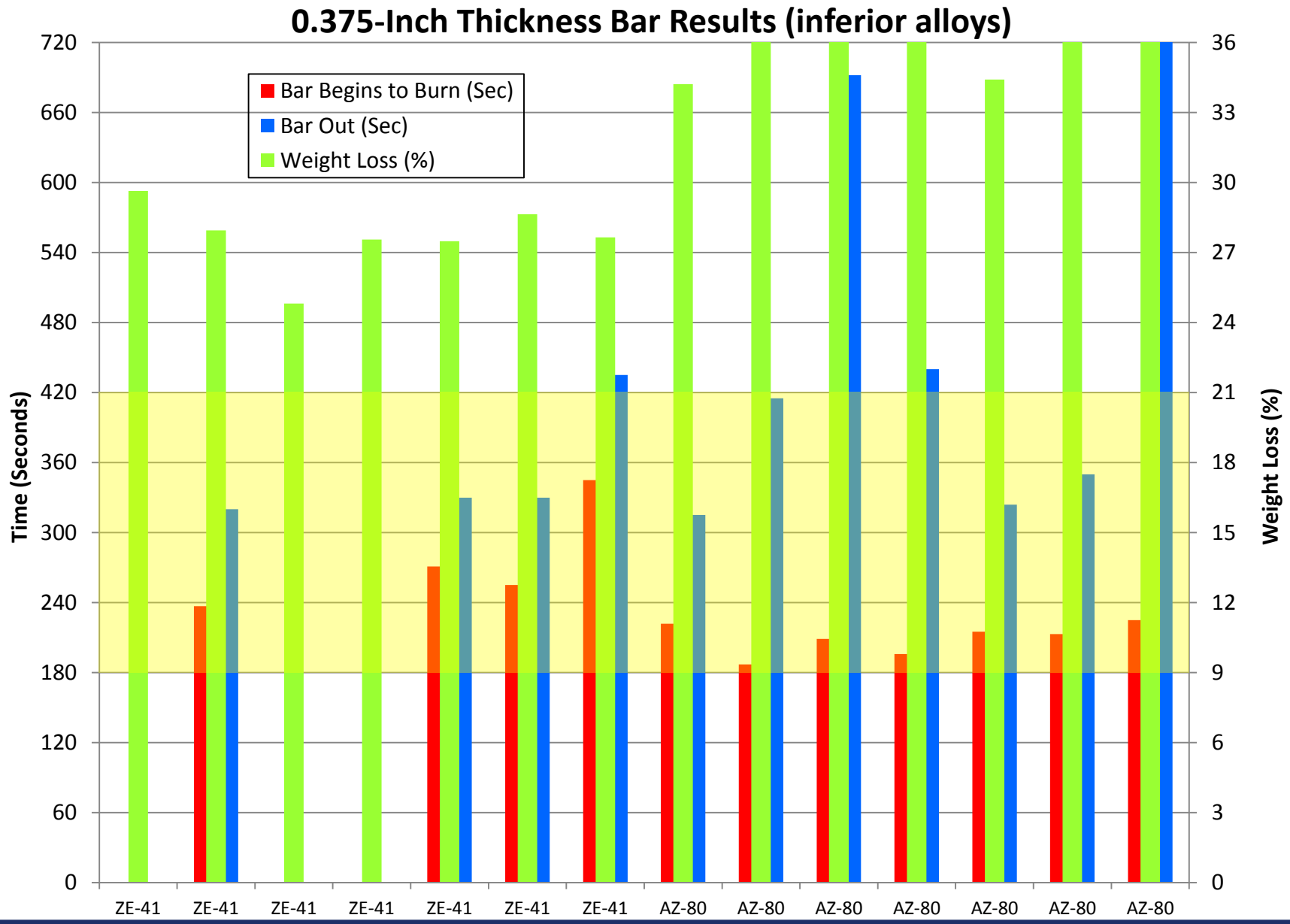
Modified Data with Zeros removed (52 Tests)


0.250-Inch Thickness Materials (good alloys)
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
5/16/12 to 12/7/12
Time (Seconds)
Weight Loss (%)
720
660
600
540
480
420
360
300
240
180
120
60
0
24
20
16
12
8
4
0
EL-...
E-43


0.250-Inch Thickness Bar Results (inferior alloys)
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
5/16/12 to 9/20/12
Time (Seconds)
Weight Loss (%)
720
660
600
540
480
420
360
300
240
180
120
60
0
36
33
30
27
24
21
18
15
12
9
6
3
0
ZE-41 ZE-41 ZE-41 ZE-41 ZE-41 ZE-41 ZE-41 ZE-41 ZE-41 ZE-41 AZ-80 AZ-80 AZ-80 AZ-80 AZ-80 AZ-80 AZ-80 AZ-31 AZ-31 AZ-31

0.375-Inch Thickness Bar Results (good alloys)




0.375-Inch Thickness Bar Results (inferior alloys)
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
Time (Seconds)
Weight Loss (%)
720
660
600
540
480
420
360
300
240
180
120
60
0
36
33
30
27
24
21
18
15
12
9
6
3
0
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
AZ-80
AZ-80
AZ-80
AZ-80
AZ-80
AZ-80
AZ-80

Test Results Using New (draft) Standard

When Testing “Good” Mag Alloys:

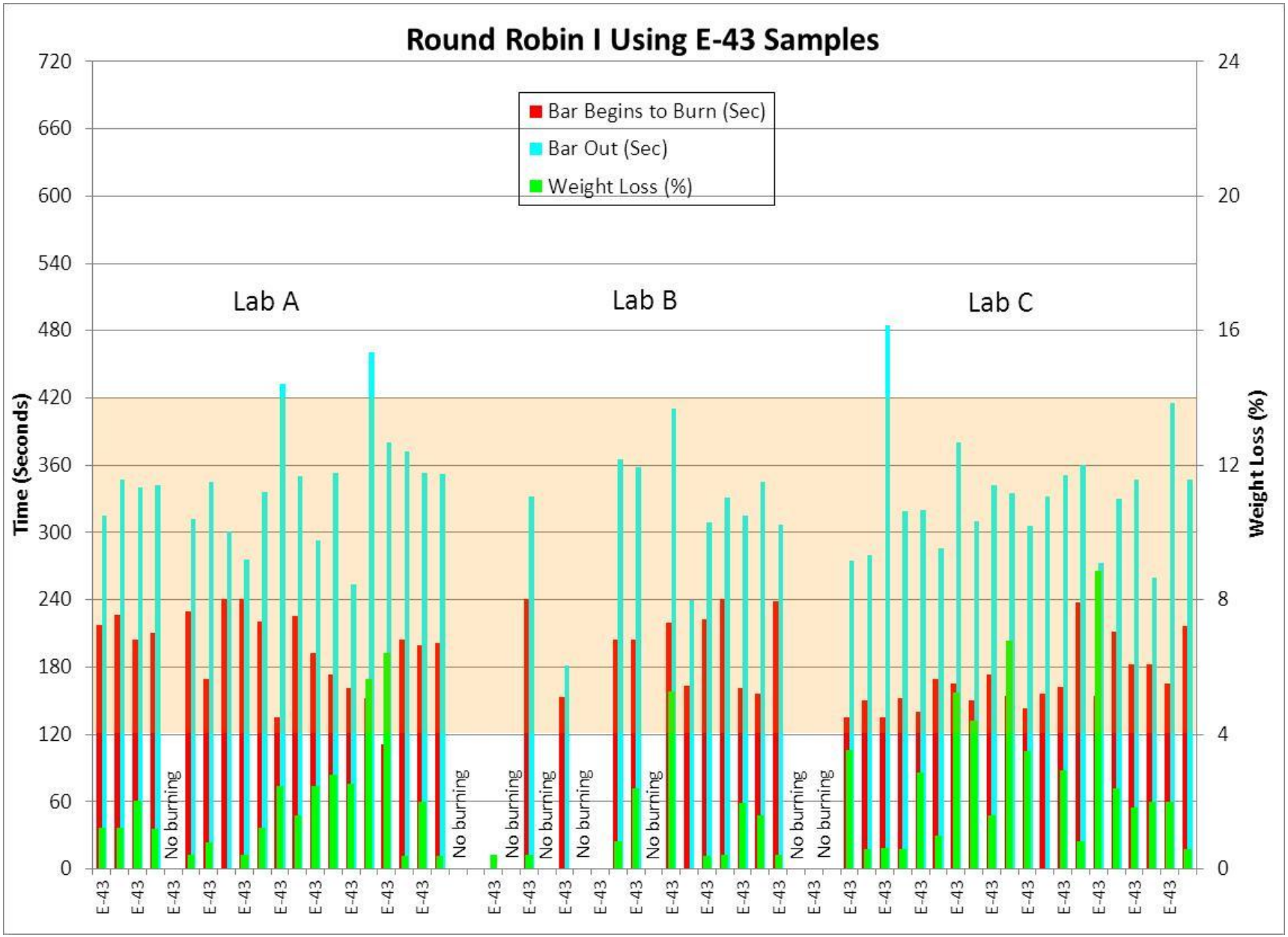
0.250-Inch Thick Bars: 172/180 Passed (95.6% Passing Rate)

0.375-Inch Thick Bars: 119/132 Passed (90.2% Passing Rate)

When Testing “Poor” Mag Alloys:

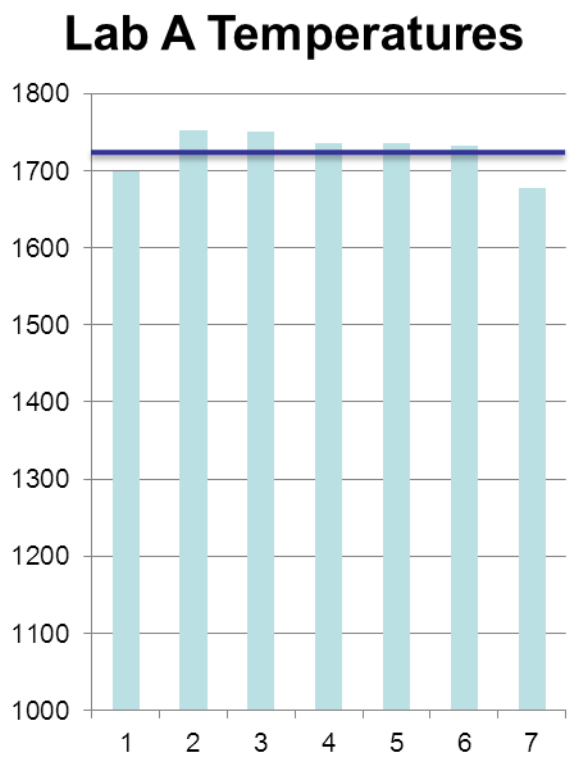
0.250-Inch Thick Bars: 1/20 Passed (5% Passing Rate)

0.375-Inch Thick Bars: 0/14 Passed (0% Passing Rate)

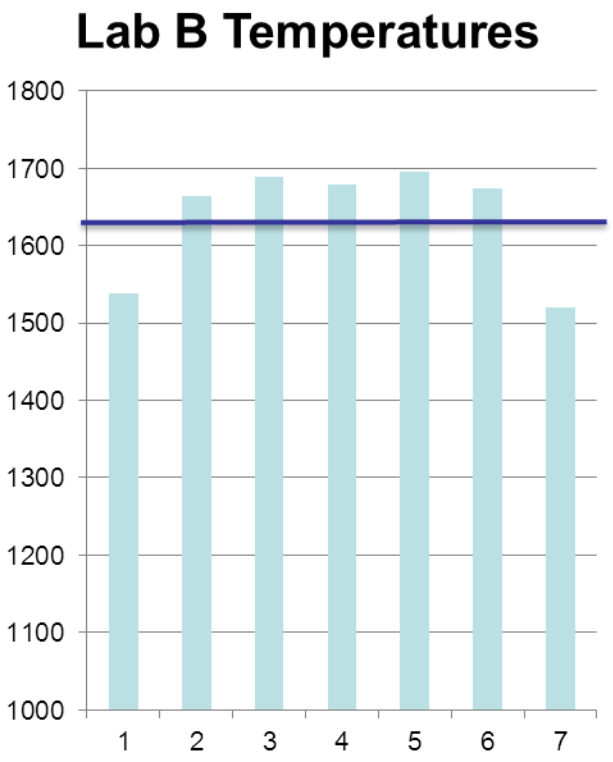

Round Robin I Using E-43 Samples
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
Lab A
Lab B
Lab C
Time (Seconds)
Weight Loss (%)
720
660
600
540
480
420
360
300
240
180
120
60
0
24
20
16
12
8
4
0
No burning
E-43

Charts showing burner calibration temps during RR

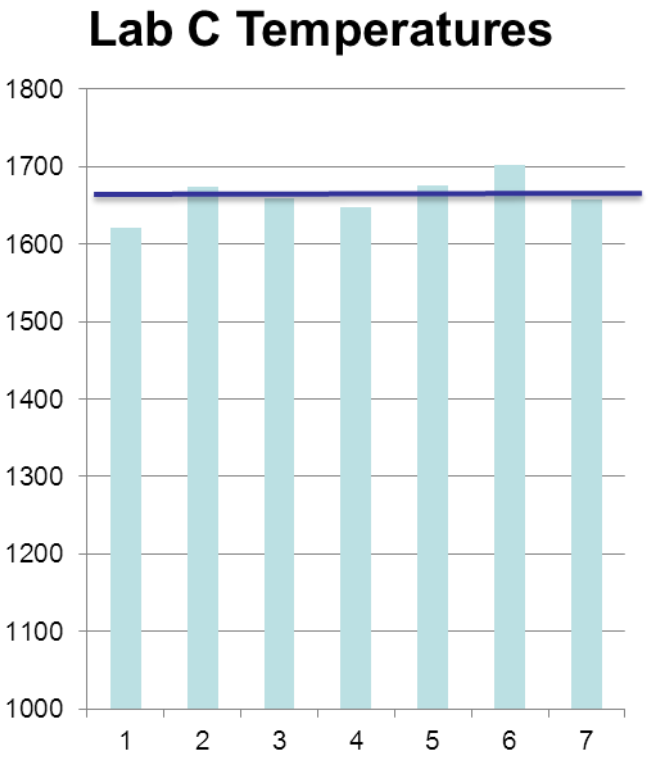
1726 F



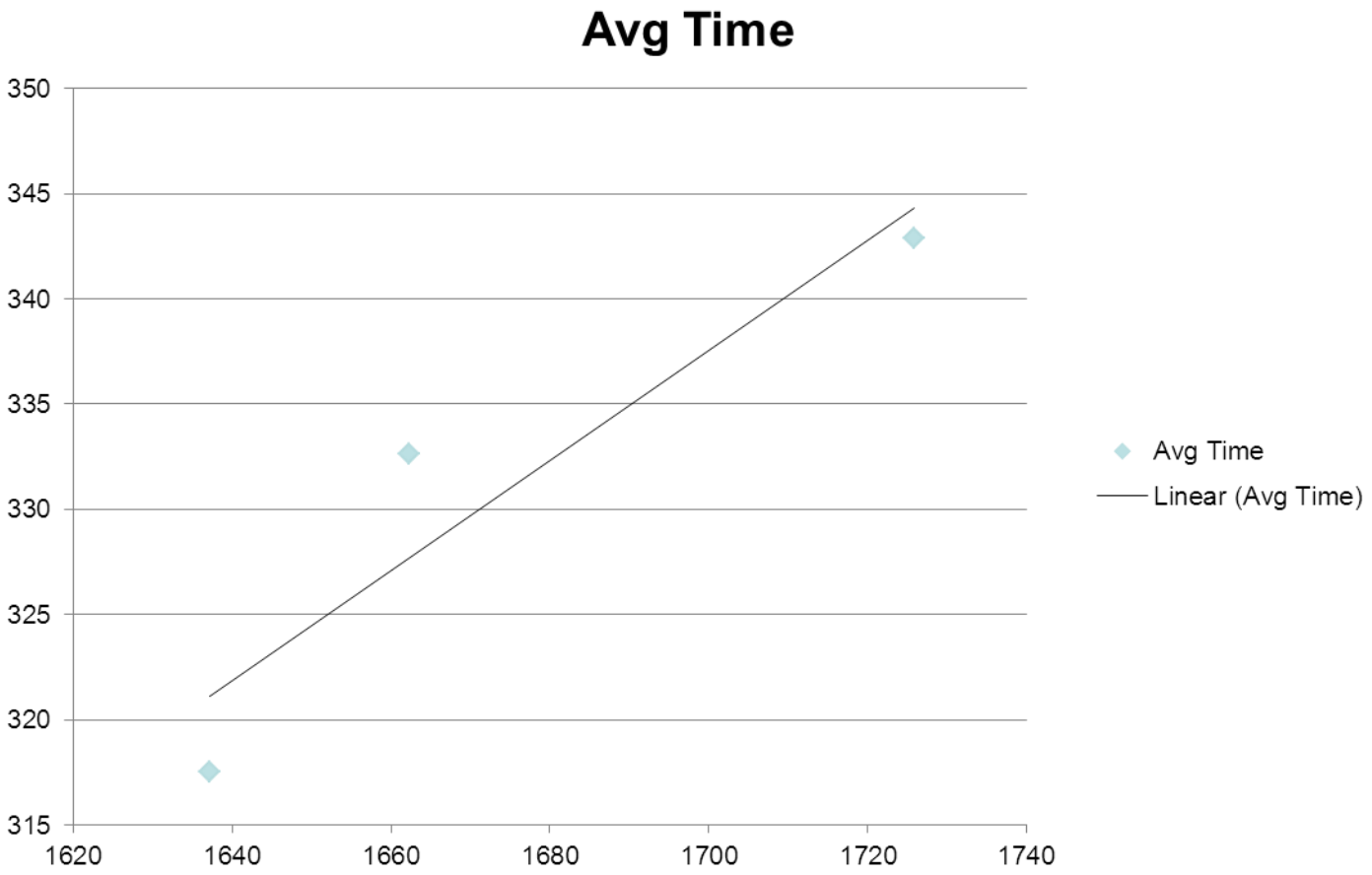
1637 F



1662 F



Relationship of burner calibration temps and extinguishment time



Systematic Development of Lab-Scale Test

Determine basic configuration: solid cone, vertical cylinder, horizontal bar

Make improvements to test apparatus: mounting mechanism, depth of talc

Determine which parameters to measure: e.g., time to melt, time to ignite sample, time residue burns, time sample extinguished, time residue extinguished, weight loss

Determine if weight loss is good predictor of residue burn duration

Select appropriate test parameters

Select appropriate thickness of sample

Determine interlab repeatability via Round Robin

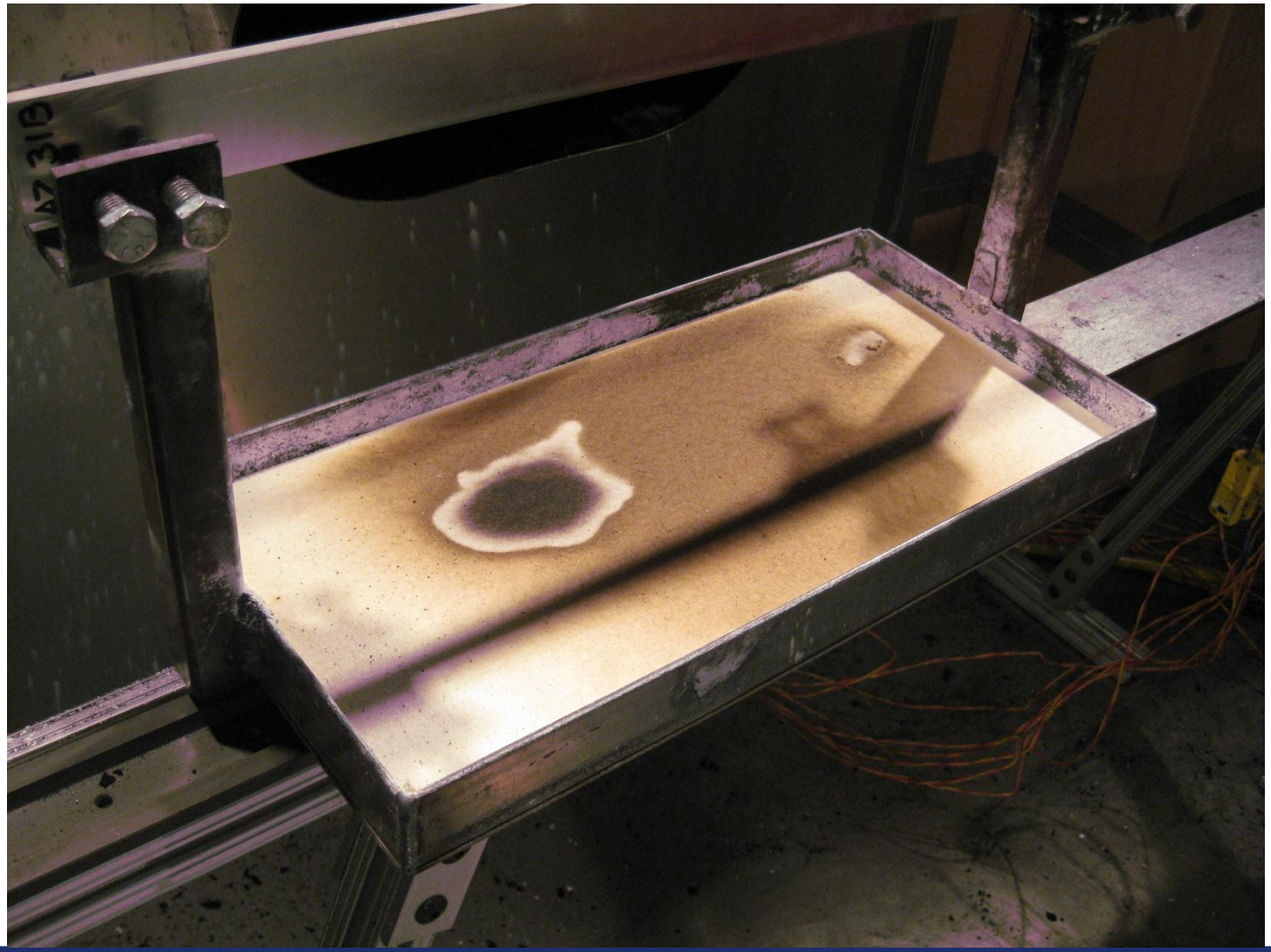
Determine influence of exhaust ventilation on test results

Determine other sources of error and correct

Finalize all test parameters and details

Potential Sources of Error

Talc in Pan vs. Kaowool Board

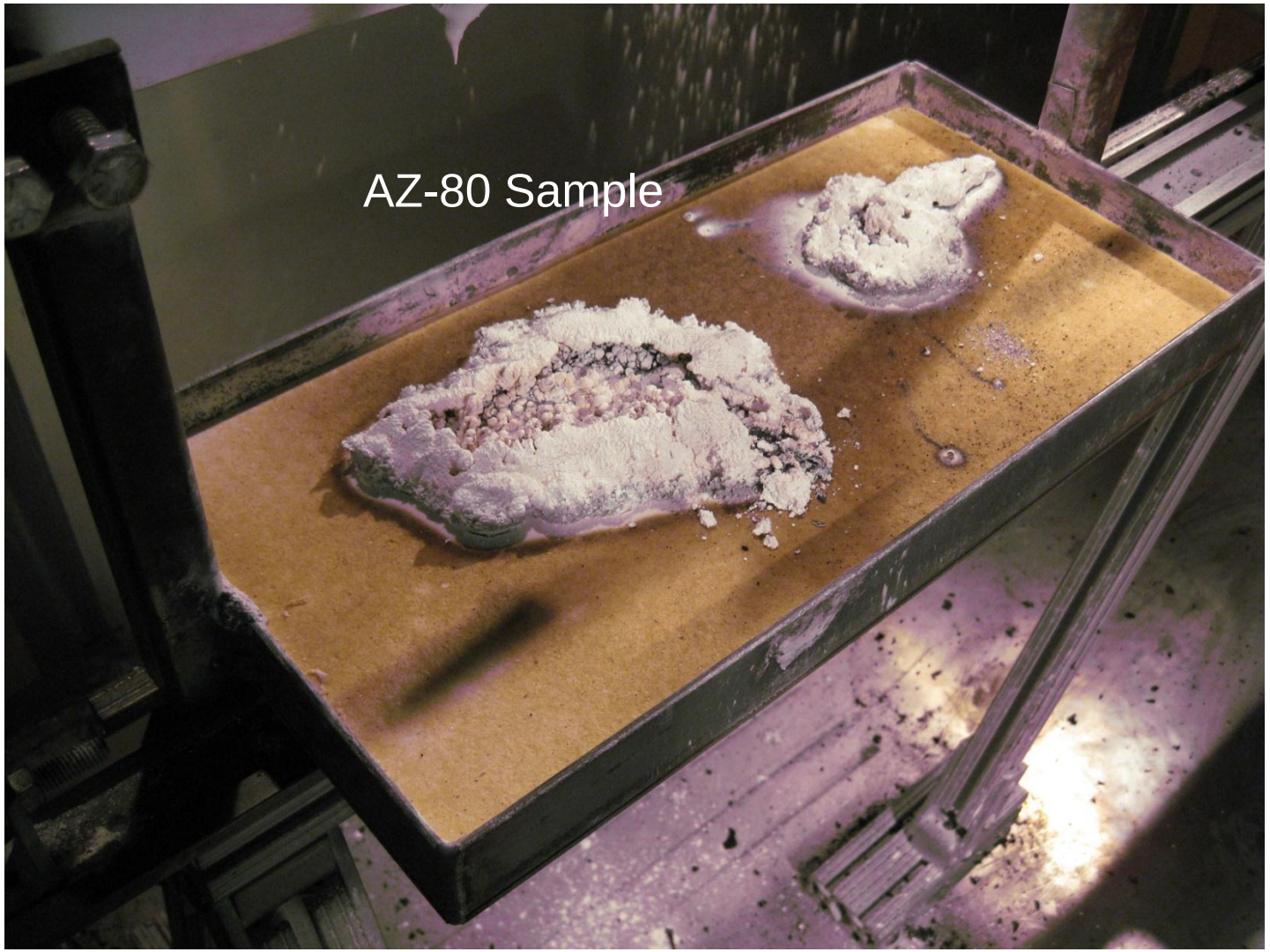


Potential Sources of Error

AZ-31 Sample on Kaowool Board

Potential Sources of Error

AZ-80 Sample on Kaowool Board



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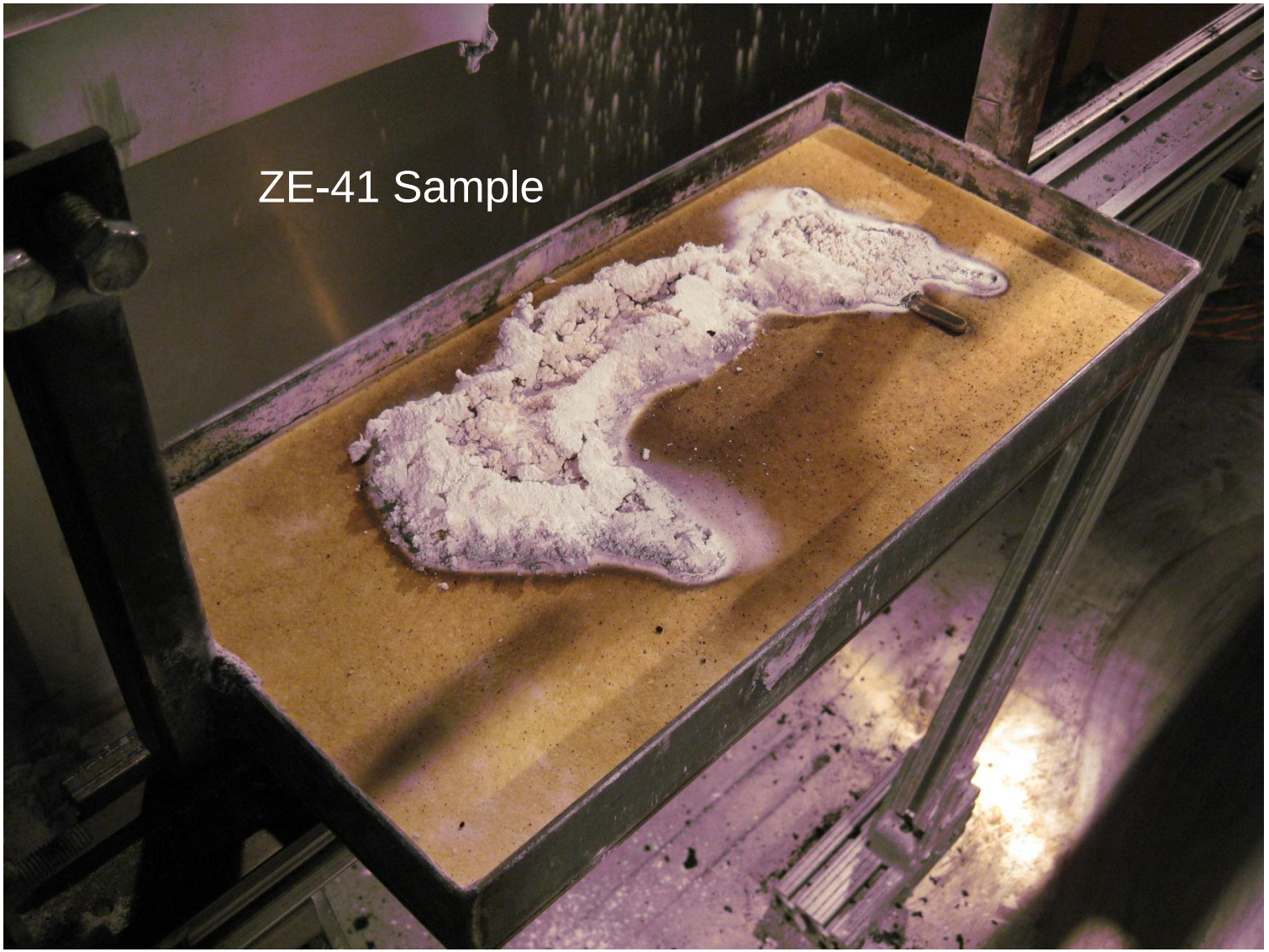

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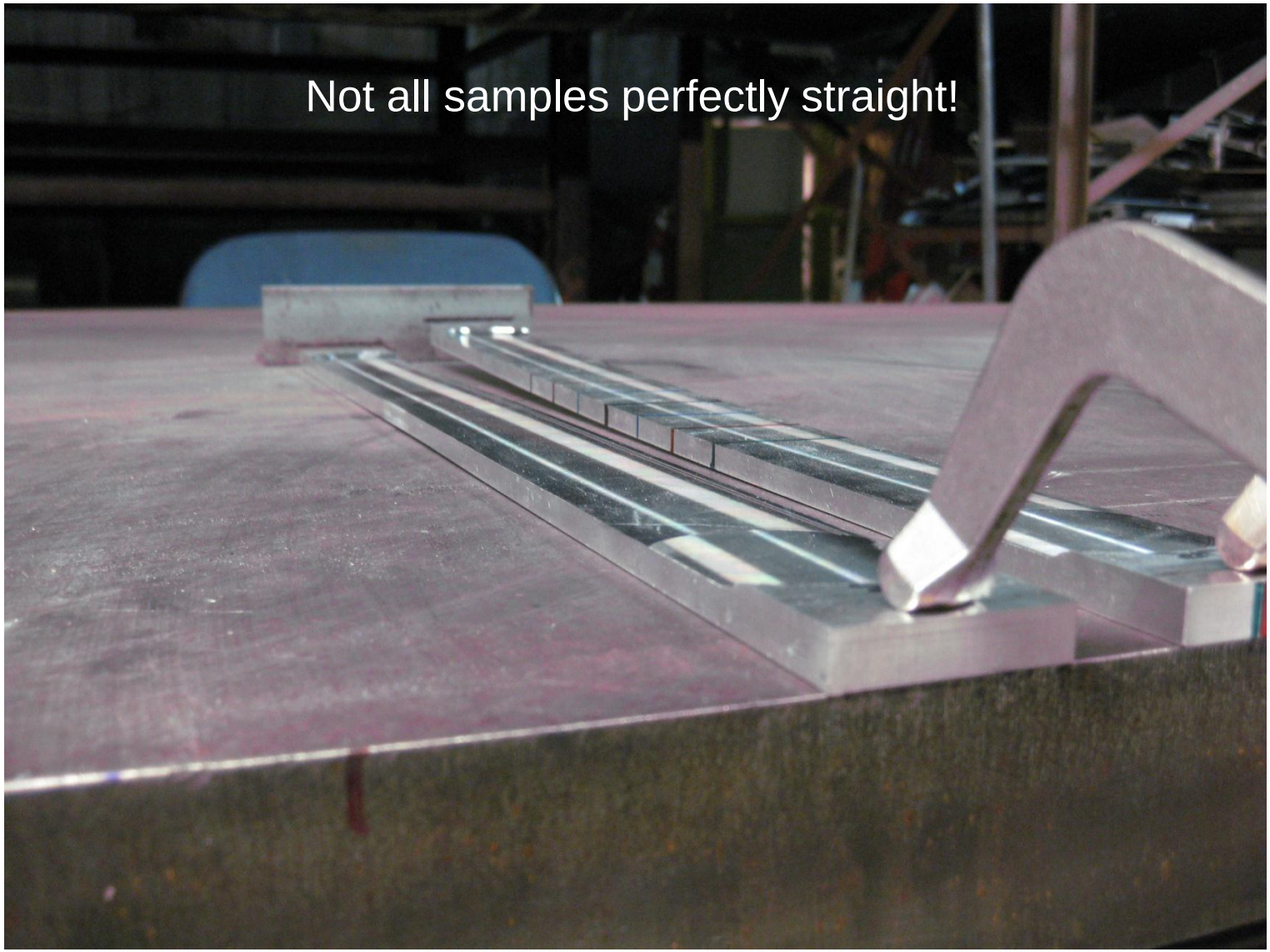

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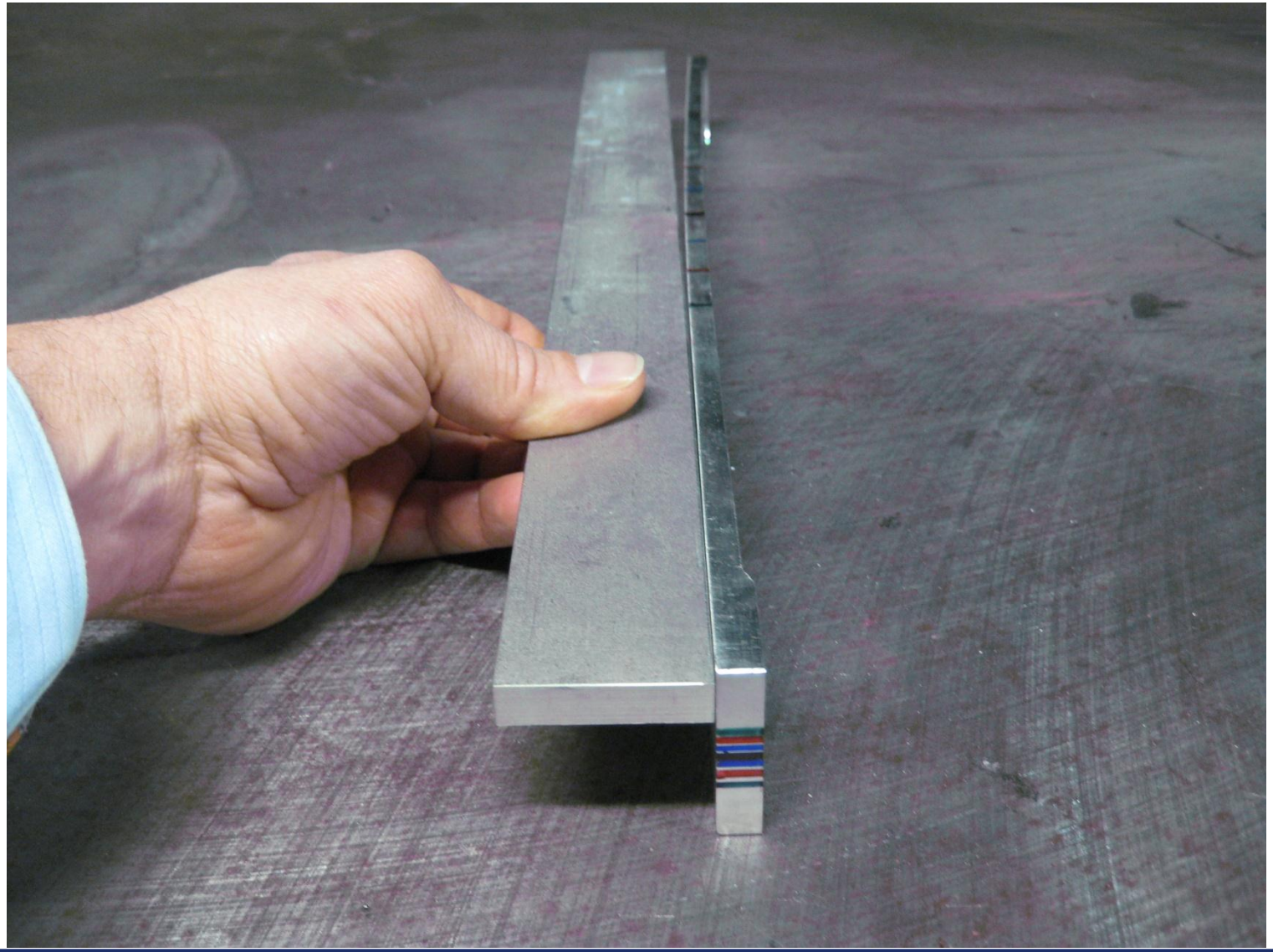
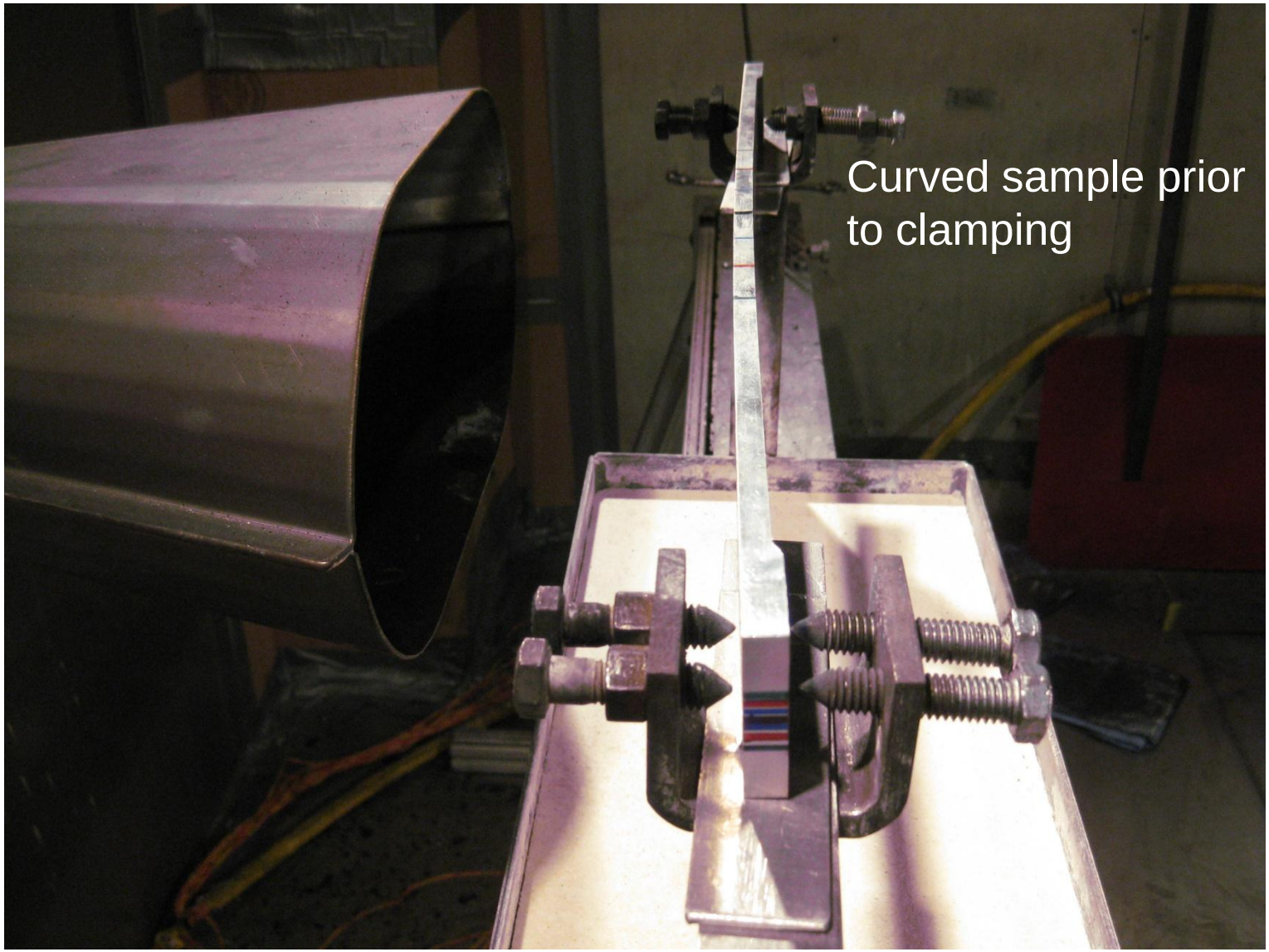
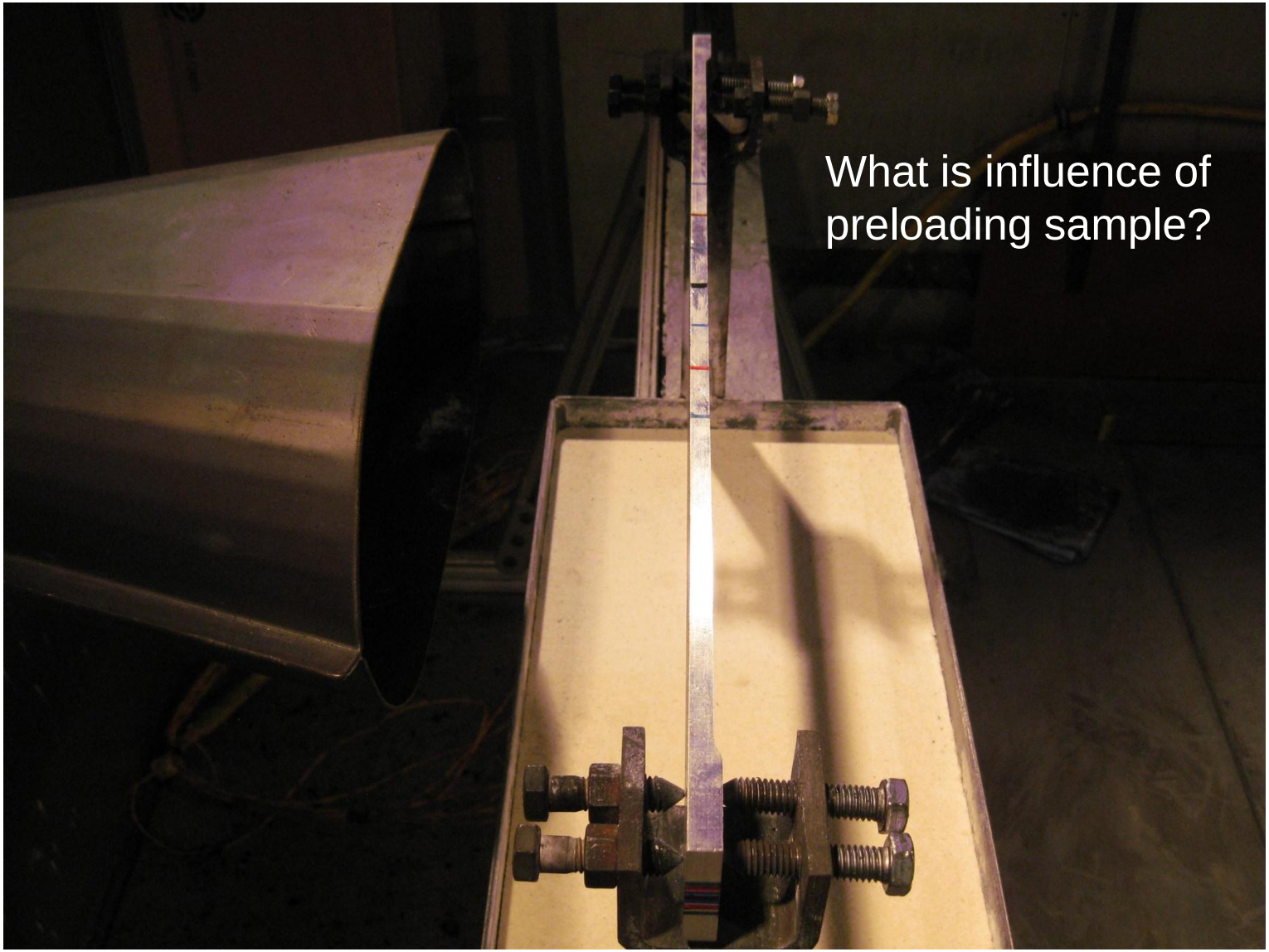


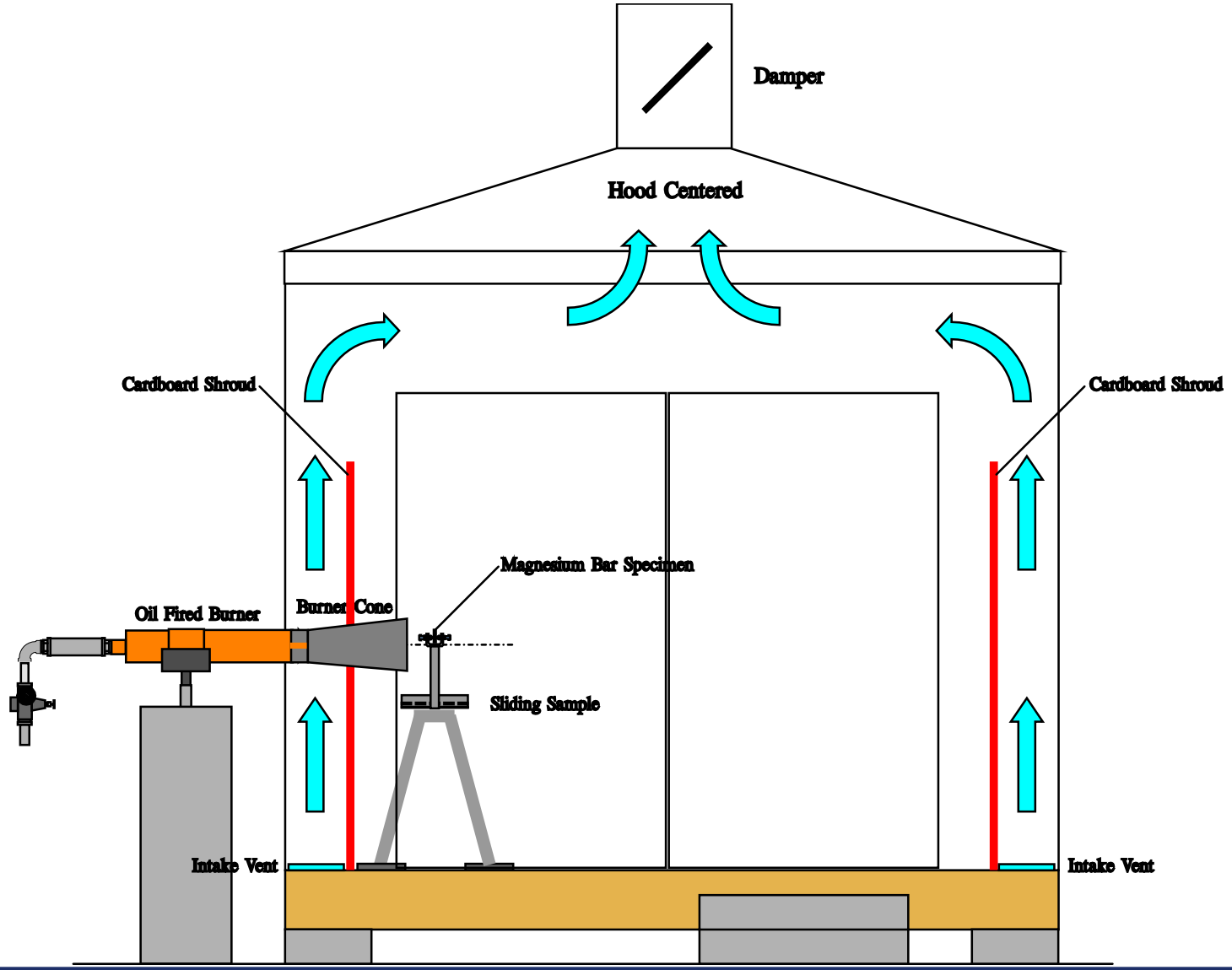
Potential Sources of Error



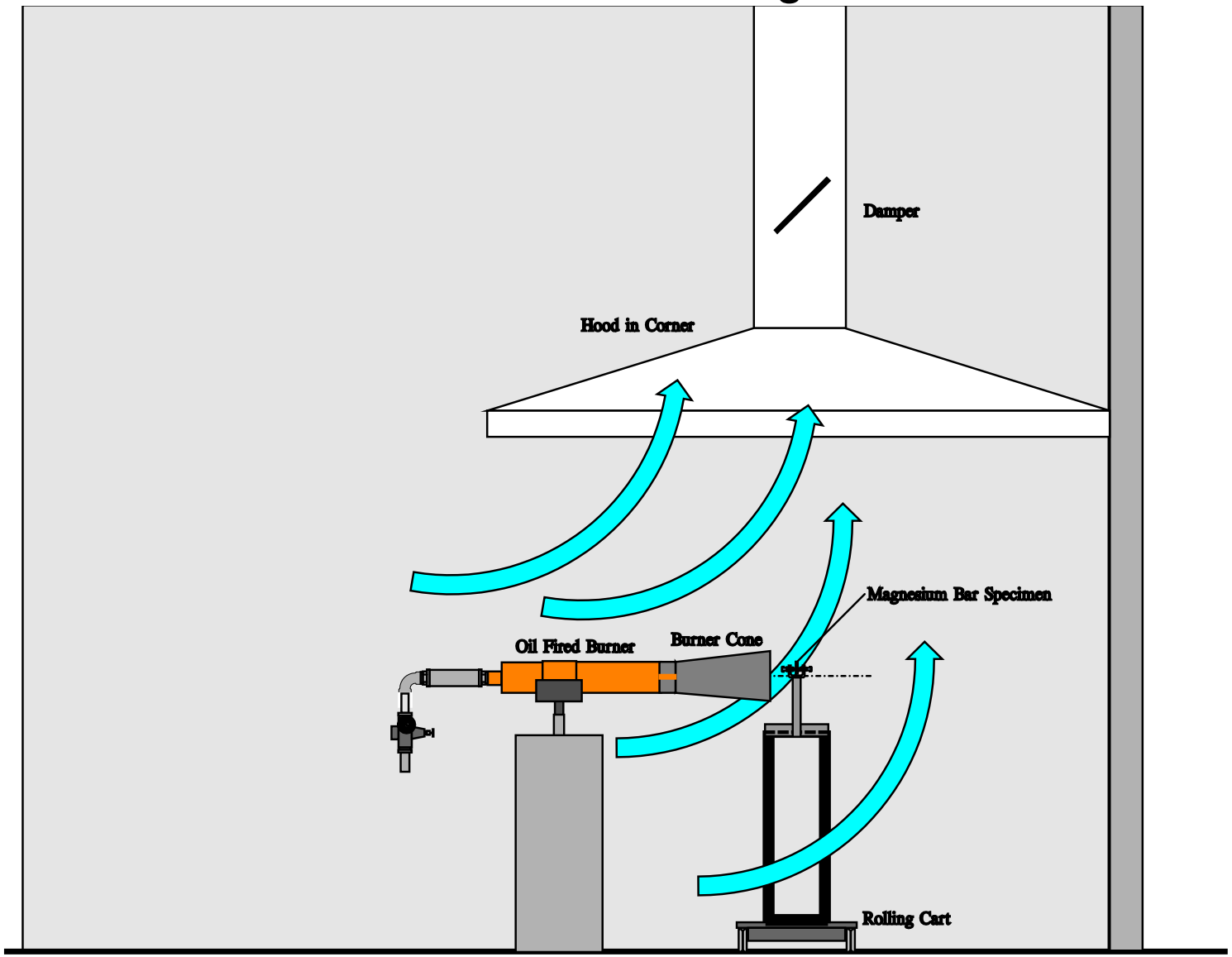
Potential Sources of Error



Lab A Ventilation Configuration



Lab B Ventilation Configuration



Planned Activities and Next Steps?

Determine sources of error, finalize draft test method

Complete report on test method development

Additional Round Robin with other labs participating?

Insert new test method into Handbook?

DOT/FAA/AR-11/3

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

Timothy R. Marker

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

January 2013

Final Report

U.S. Department of Transportation
Federal Aviation Administration

Questions?