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, Manchester, England

By: Tim Marker, FAA Technical Center

Date: June 19-20, 2013

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

Horizontal Bar

Spring 2012

Hollow Cylinder

Summer 2011

Which Configuration?

Hollow Cylinders (vertical): 59 Tests

Rectangular Bars (horizontal): 137 Tests

Comparison of %RSD of Cylinder and Bar 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

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

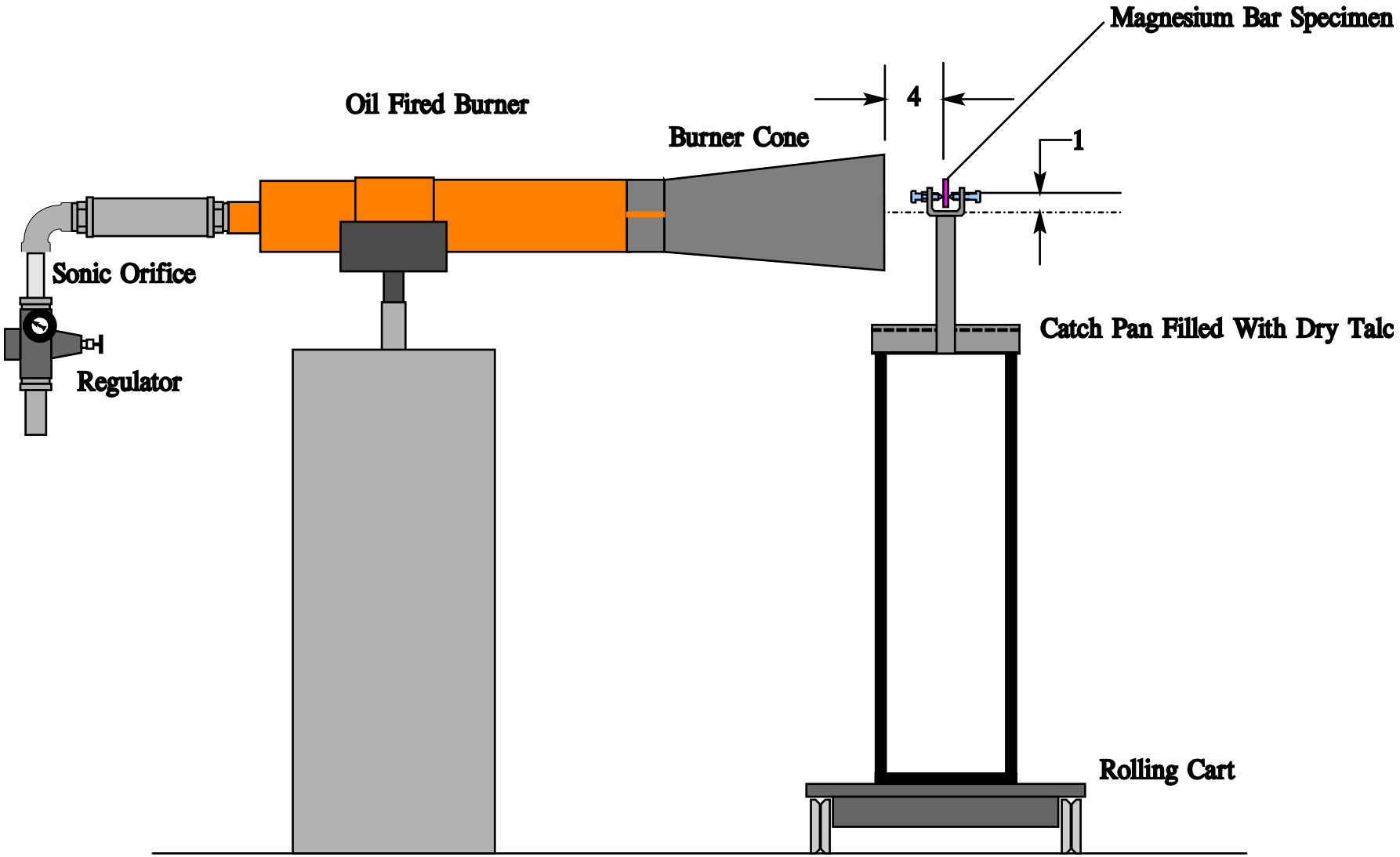
Data indicates horizontal bar configuration more repeatable

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

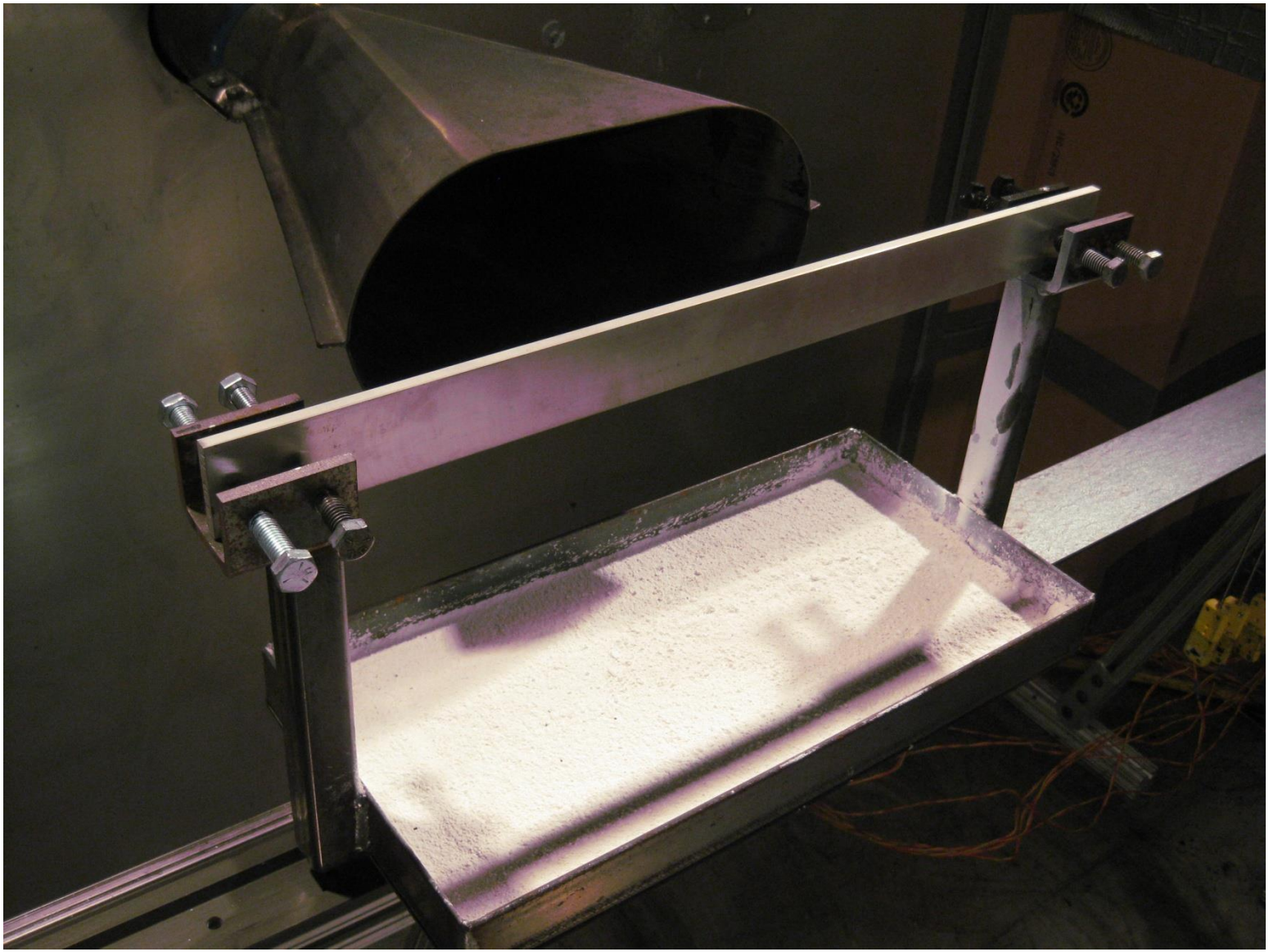
0.250-Inch Bar	
Begin Burn	End Burn
5.5	9.8
49.0	49.2
25.6	18.7
10.1	12.8
22.5	22.6

Bar samples easier/less expensive to produce!

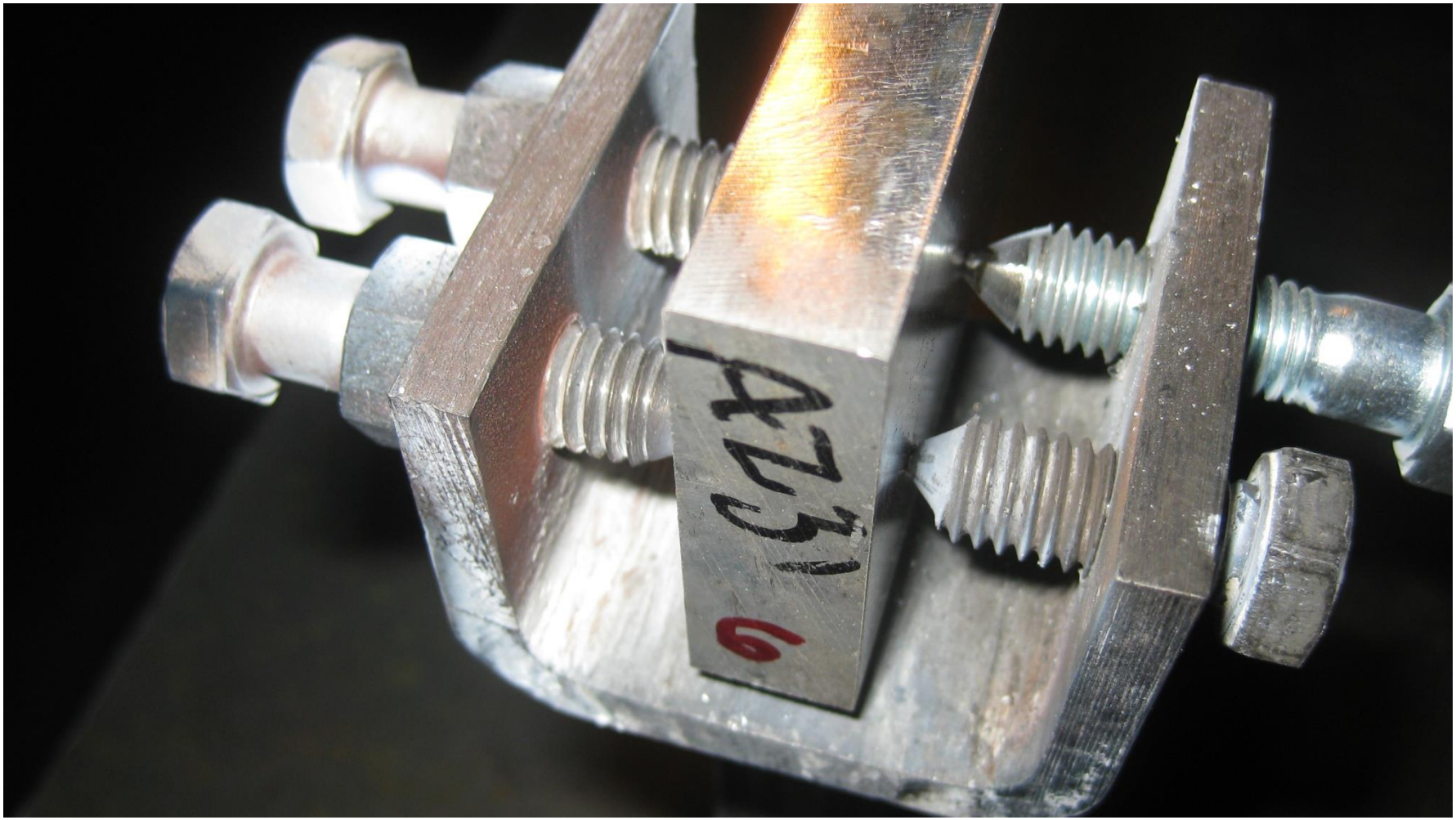
Updated Horizontal Bar Testing Rig



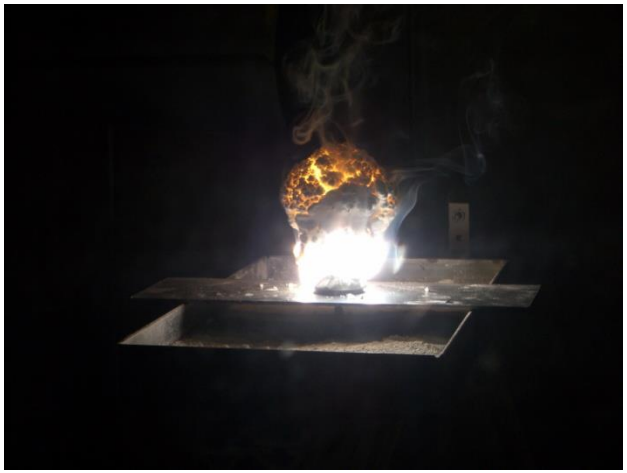
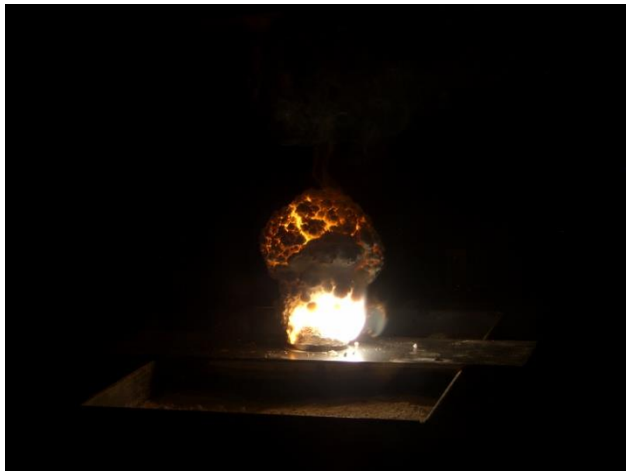
Updated Horizontal Bar Testing Rig



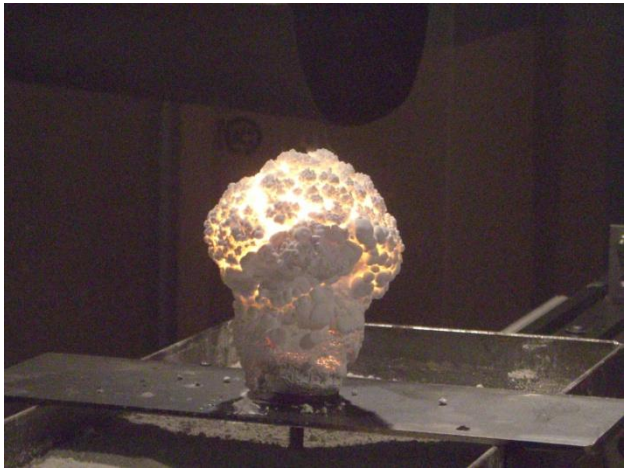
Updated Horizontal Bar Testing Rig



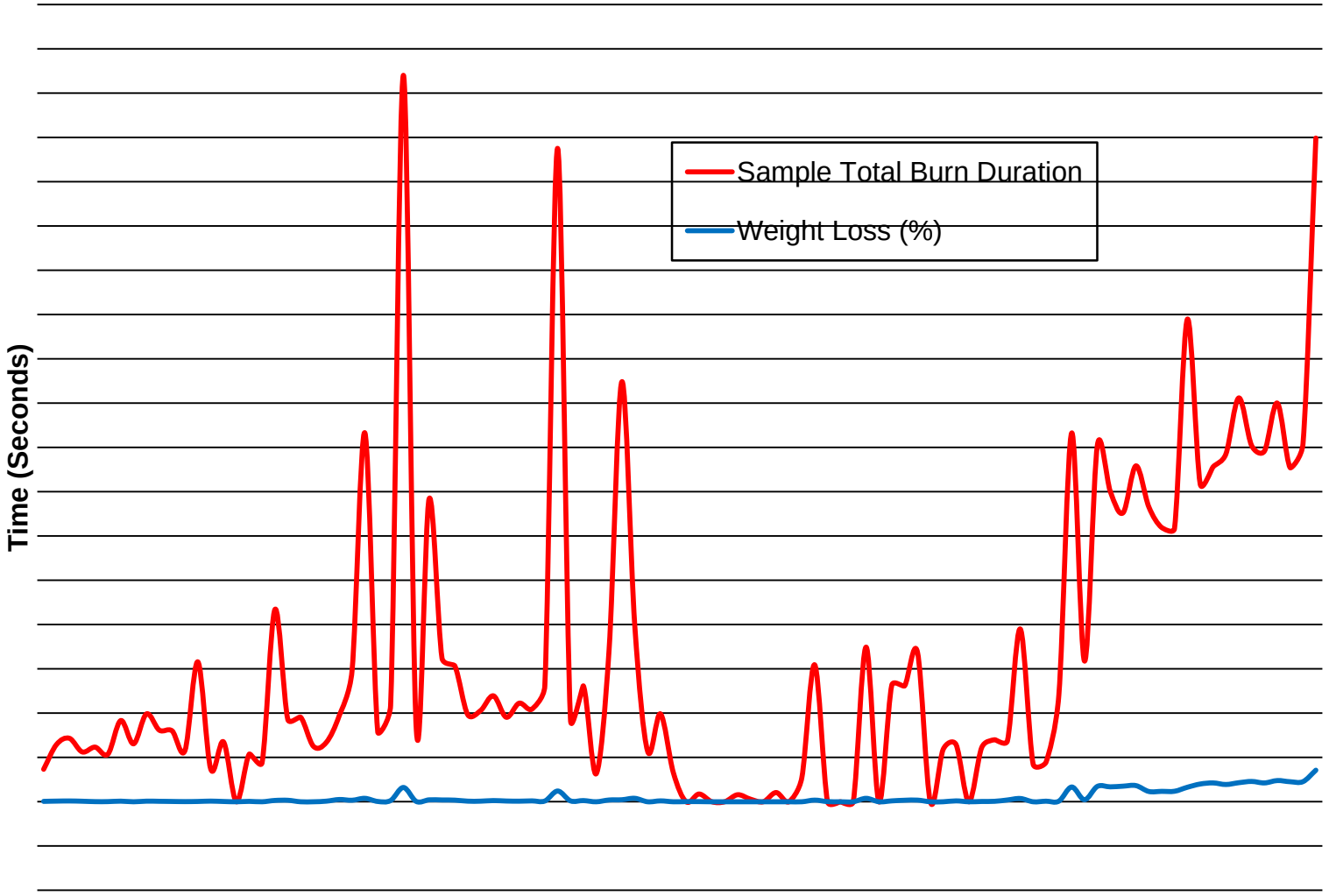
Eliminate measurement of residue ignition & extinguishment time

When is it “Out”?



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



What has been done since last meeting?

√ Additional tests conducted

Ran an additional 99 tests for grand total of 521 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: 6% to 10% (replaces time measurement of residue burning)

√ Round Robin II completed

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	38.7	0.8	5.3	4.9	4.4
Bar Out (Sec)	248	305	0	320	323	455	340	380	305	360	390	365	340	365	315	470	350	330	395	410
Bar Begins to Burn (Sec)	159	143	0	191	234	180	142	151	155	199	157	155	146	176	149	146	154	143	181	154
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	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	8/17/2012	8/17/2012	8/17/2012	8/17/2012	8/17/2012

Weight Loss (%)	1.6	1.6	3.2	2.0	1.6	2.4	2.0	29.1	2.4	3.2	0.0	4.8	5.5	9.3	0.0	2.4	0.0	0.4	0.4	0.0
Bar Out (Sec)	390	306	330	375	420	405	295	380	385	375	240	387	360	435	320	327	240	0	174	0
Bar Begins to Burn (Sec)	154	149	148	146	153	154	151	155	163	156	164	146	151	176	183	179	161	0	153	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	E-43	E-43	E-43	E-43	E-43
Date	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	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

Weight Loss (%)	0.0	0.0	0.0	0.0	0.0	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	175	163	0	176	0	235	385	0	0	0	386	0	310	351	388	0	172	375	0
Bar Begins to Burn (Sec)	0	156	156	0	151	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	E-43	E-43	E-43	E-43	E-43
Date	9/11/2012	9/12/2012	9/12/2012	9/12/2012	9/12/2012	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)

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 self-extinguishes, time residue self-extinguishes, 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 Robins

Determine influence of exhaust ventilation on test results

Determine other sources of error and correct

Finalize all test parameters and details

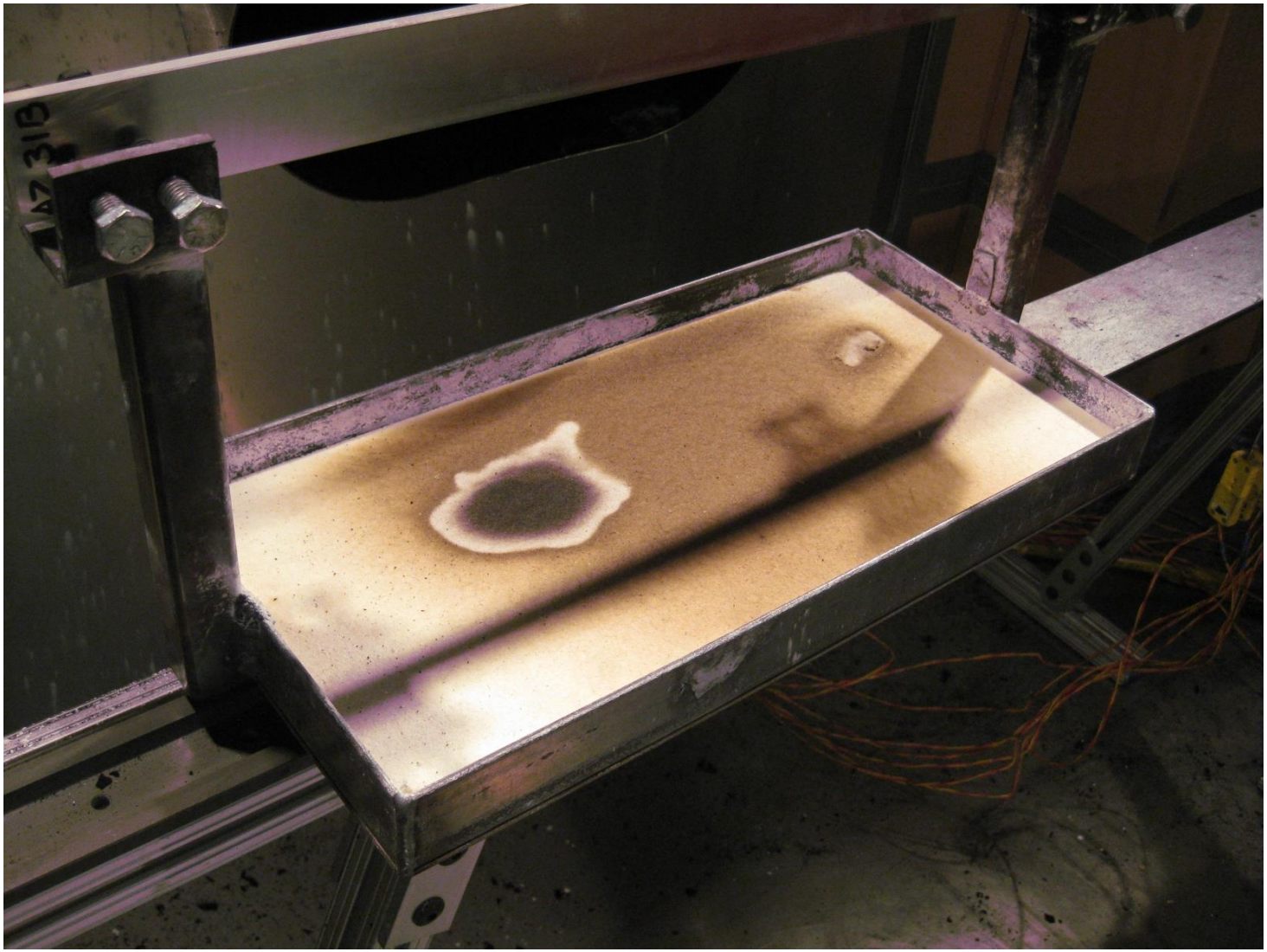
What is Left to Do??

Determine Influence of Catch Pan Material on Residue Burn Duration

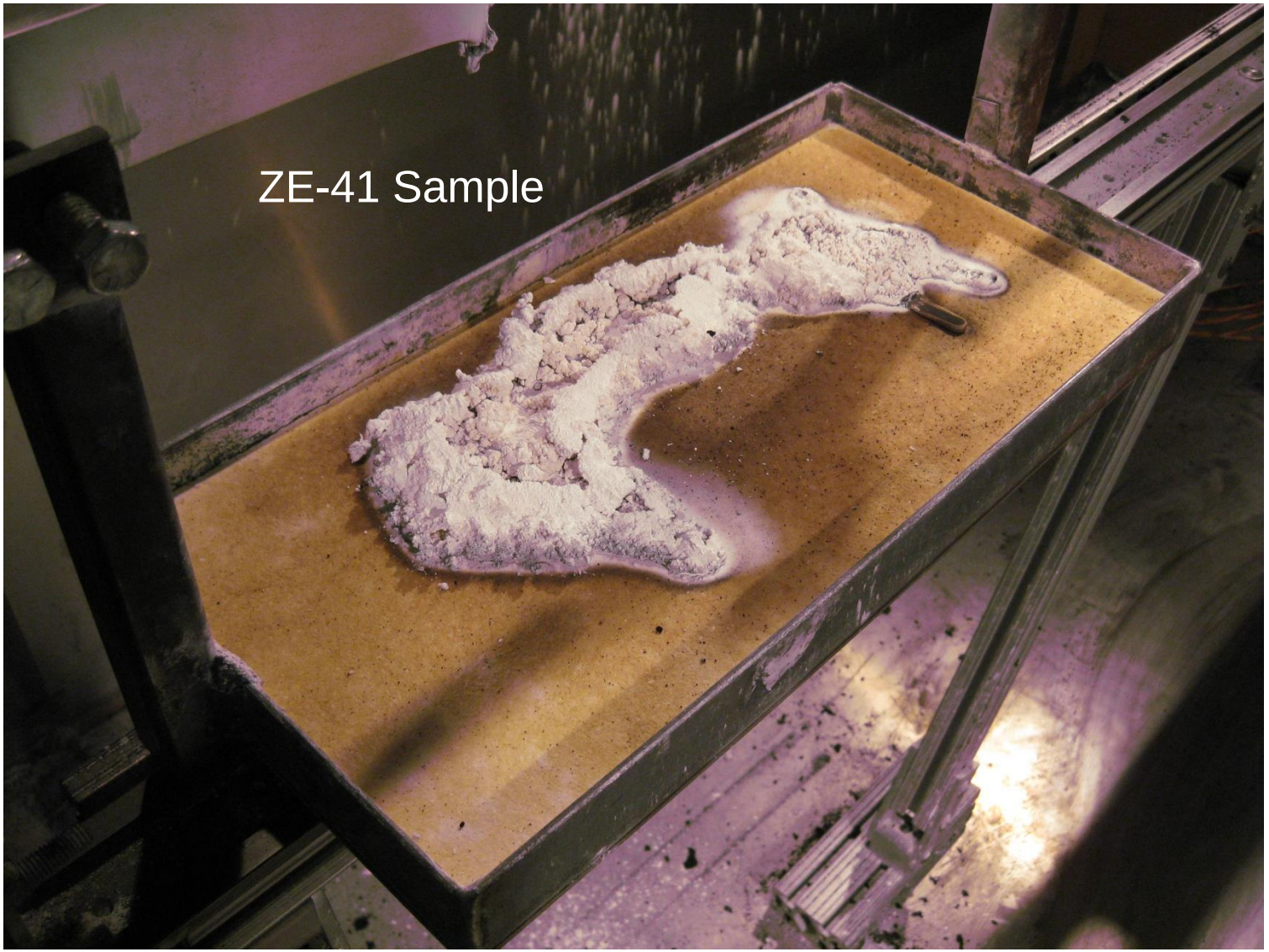
Impact of Pre-loading a Curved Sample on Test Results

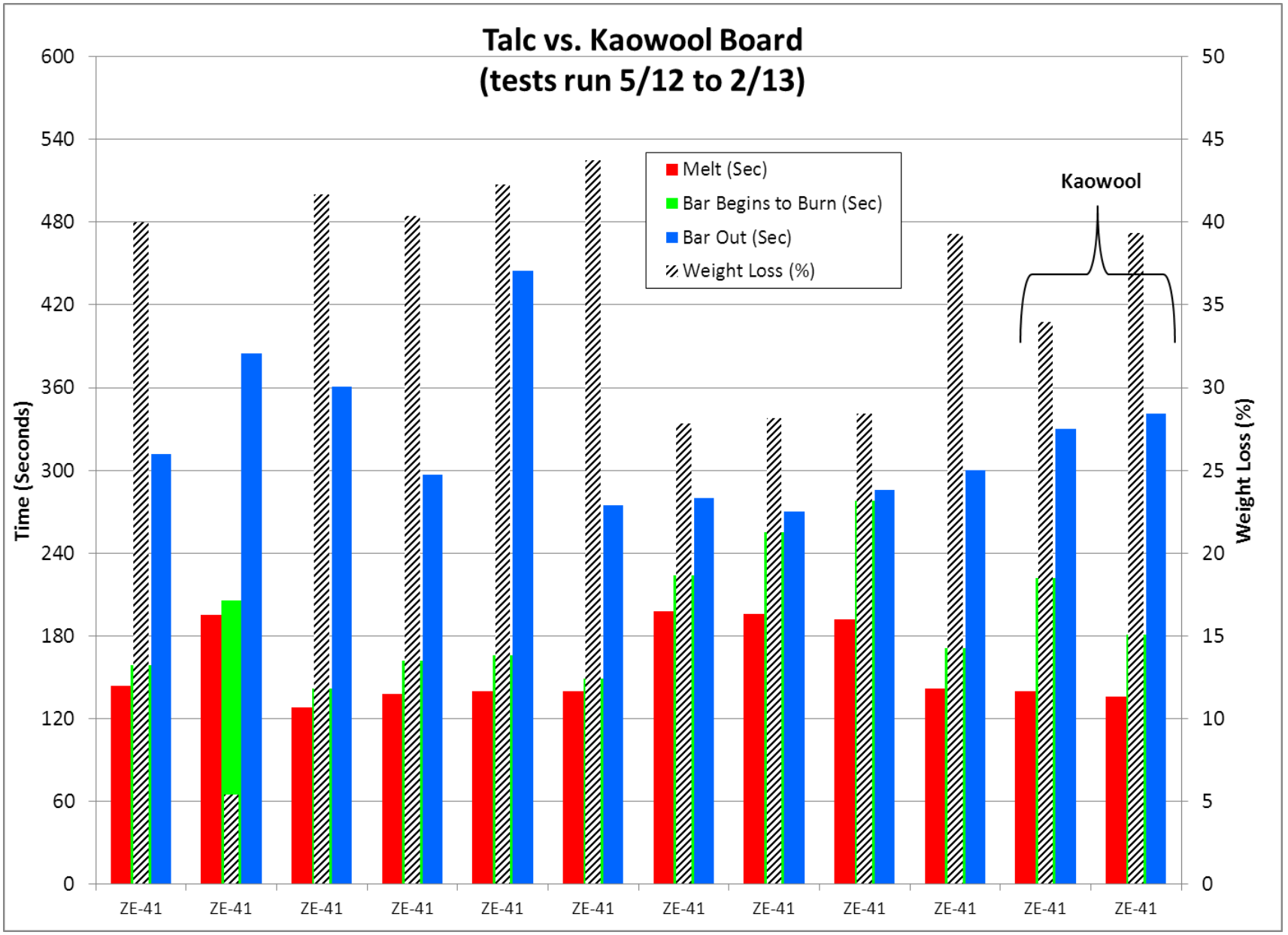
What is the Impact of Ventilation in the Testing Area?

Determine Influence of Catch Pan on Residue Burn Duration



Burned Sample Residue on Rigid Kaowool Board




Talc vs. Kaowool Board
(tests run 5/12 to 2/13)
Melt (Sec)
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
Kaowool
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
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41
ZE-41

Impact of Talc Versus Rigid Kaowool in Catch Pan

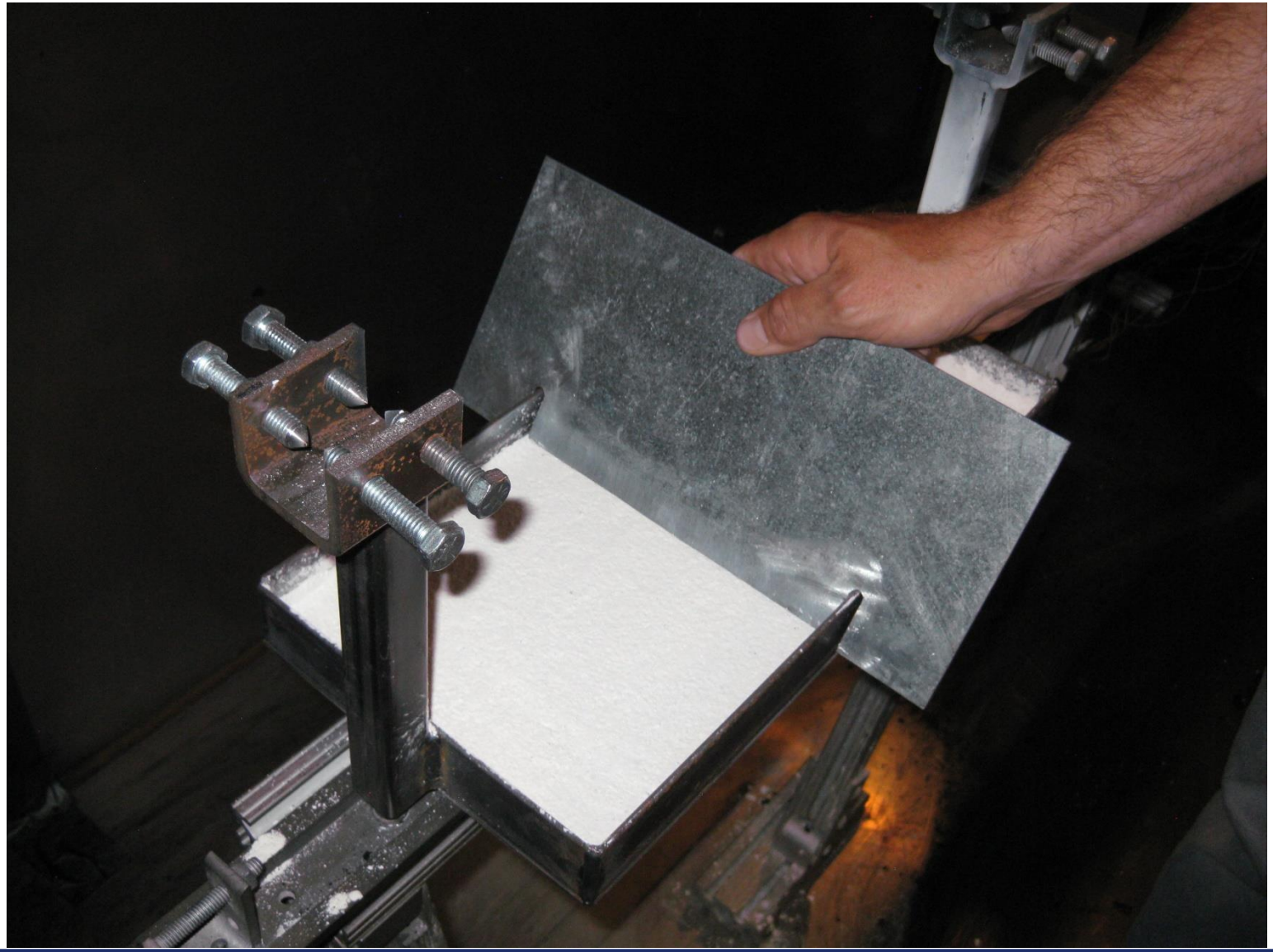
The use of rigid Kaowool board had no apparent impact on test results compared to a 0.25-inch layer of talc in catch pan.

During test method development, a 1-inch layer of talc was used. This depth allowed molten residue to bury below the surface and continue to burn (insulated).

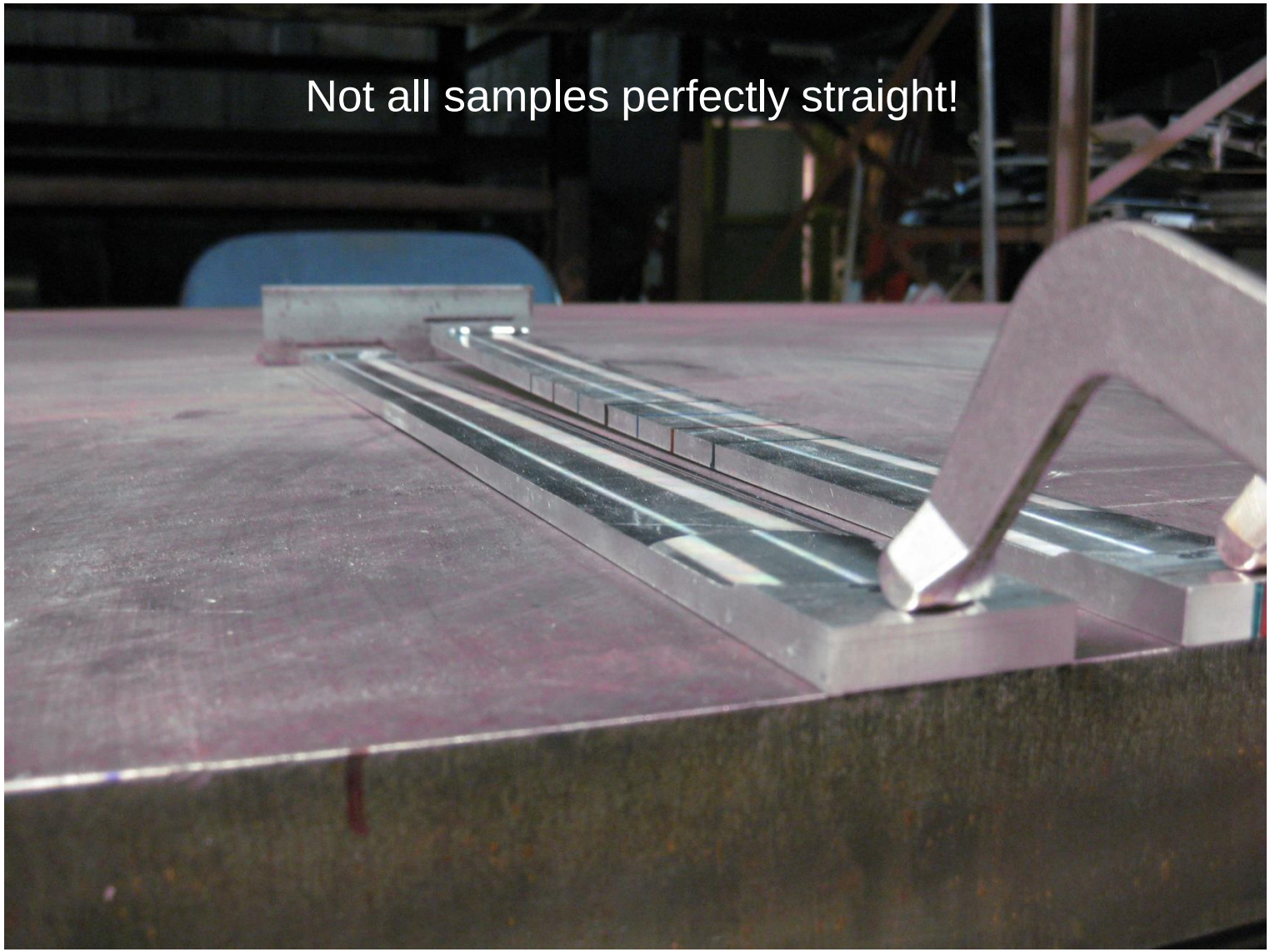
If the 0.25-inch talc depth is adhered to, results will not be impacted.

Recommend using a “screed” device to set proper talc depth.

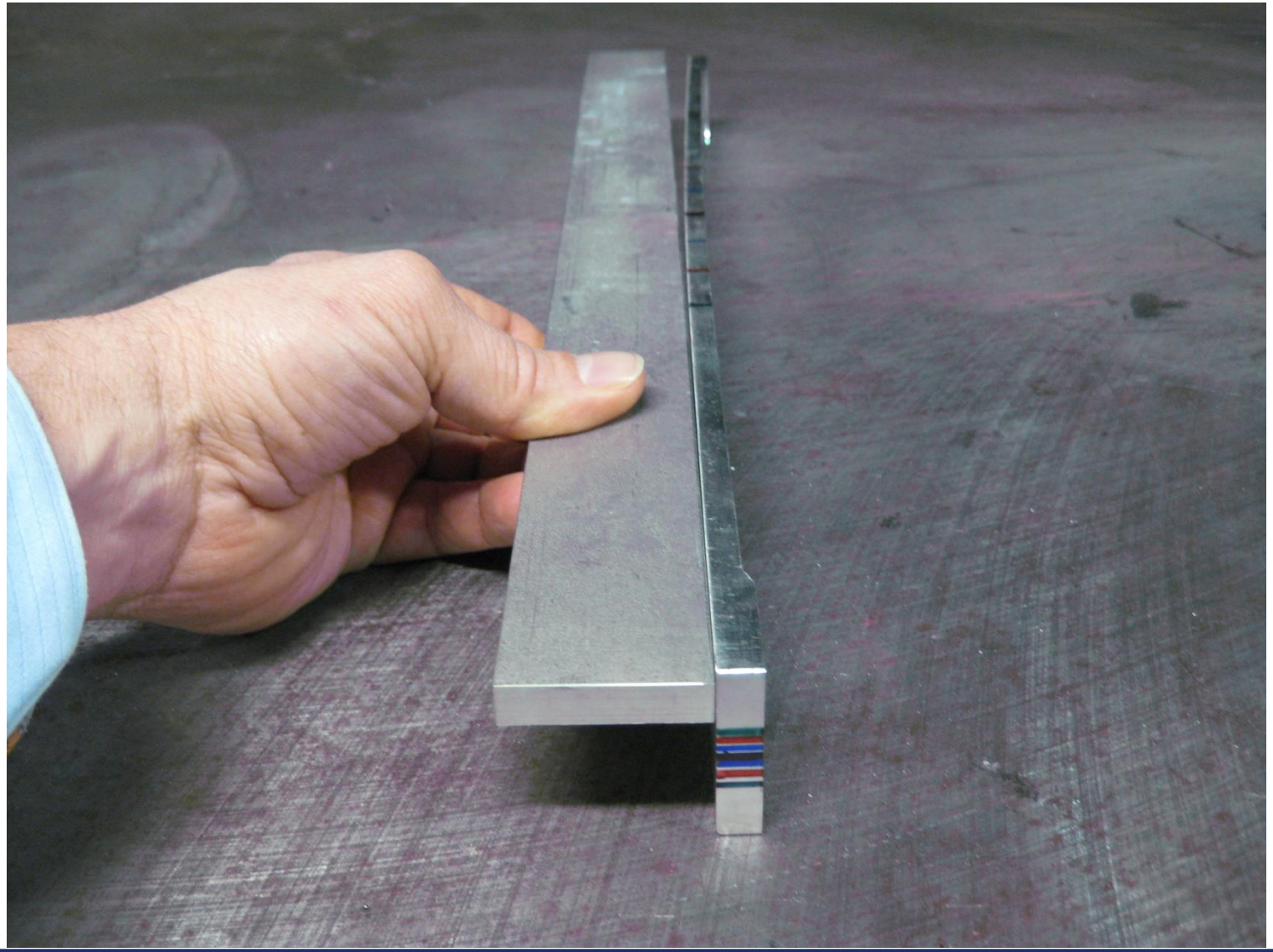
Screed Device for Leveling Talc and Setting Depth



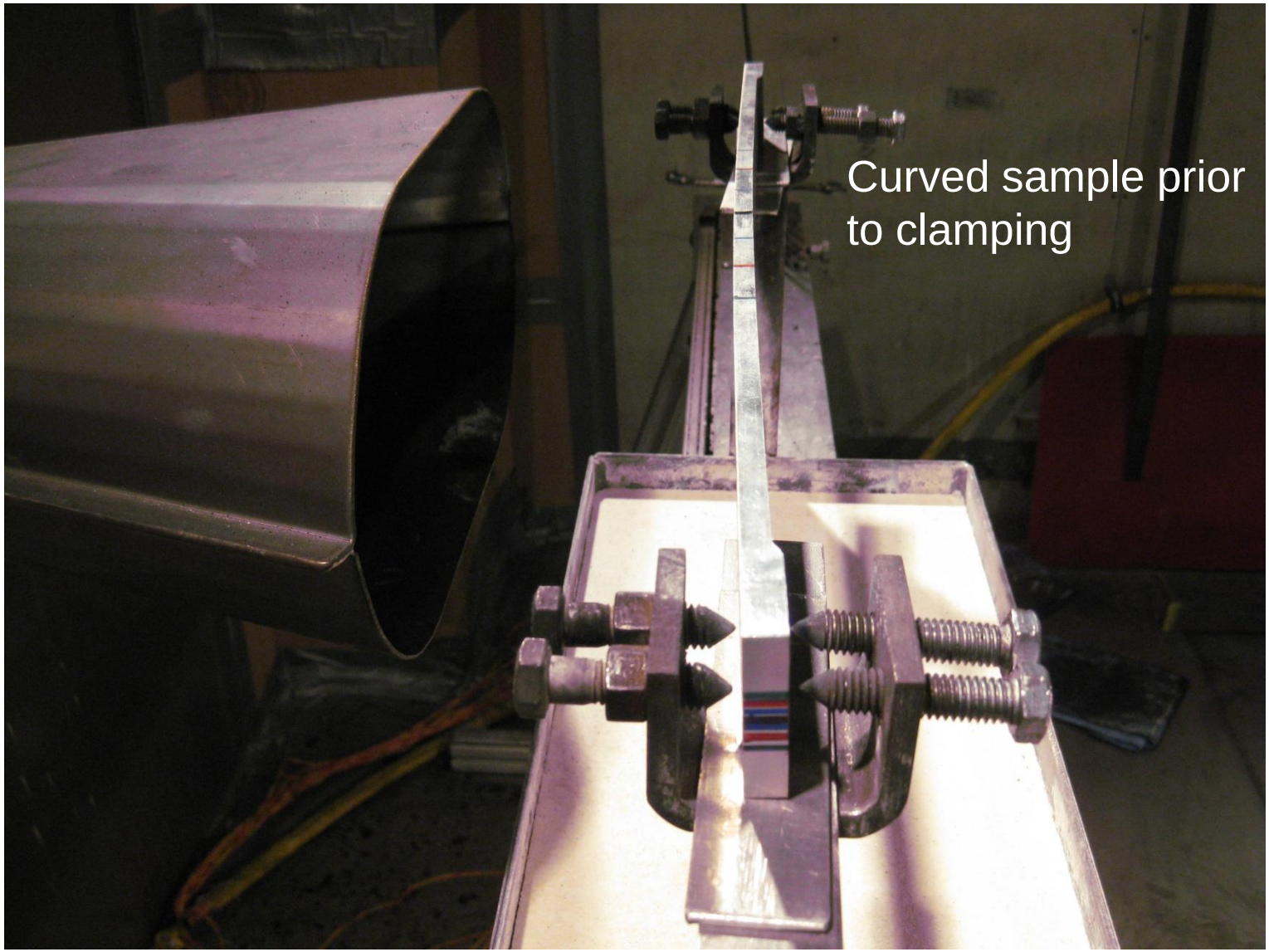
Impact of Curved Sample on Test Results



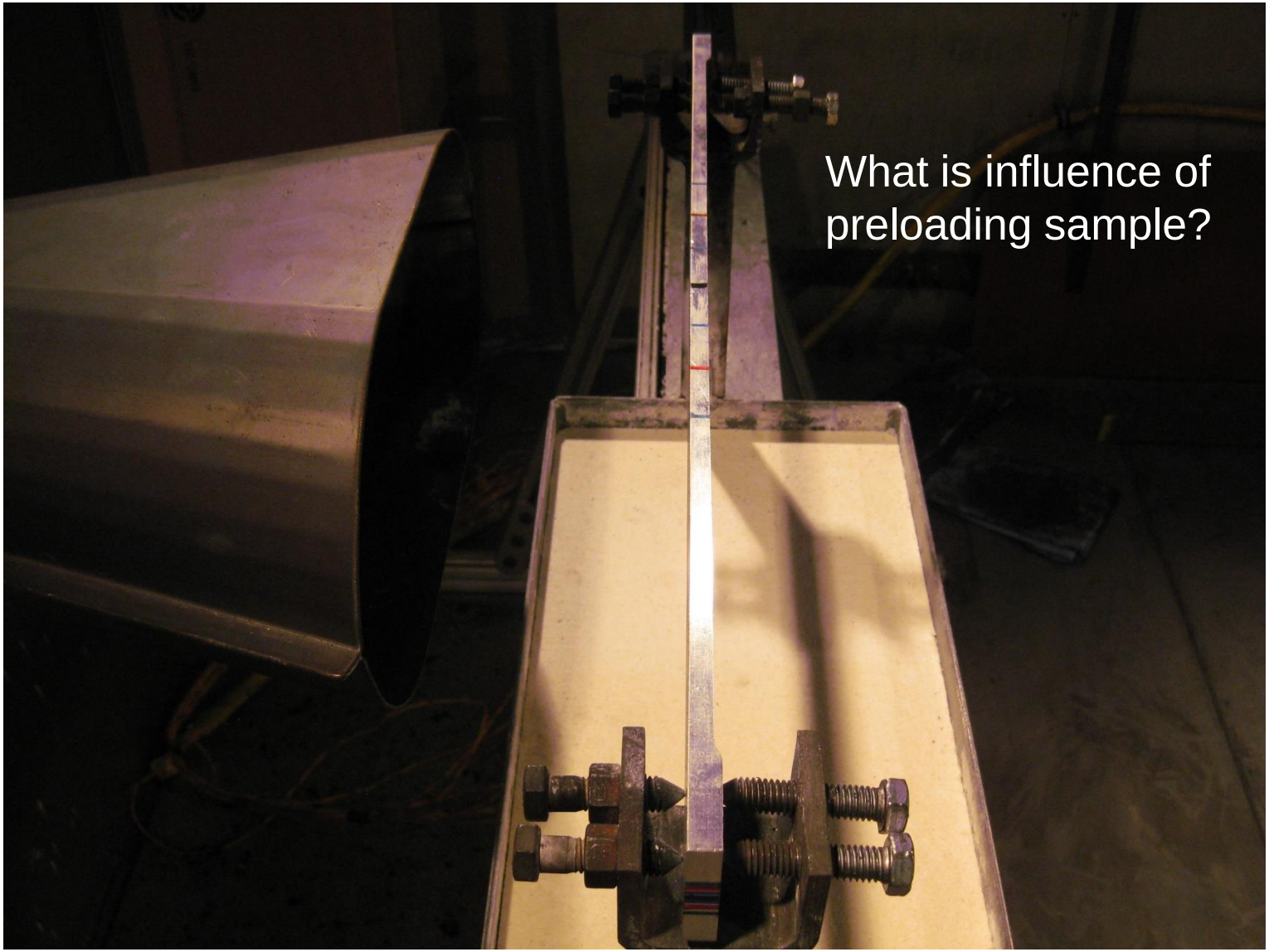
Impact of Curved Sample on Test Results

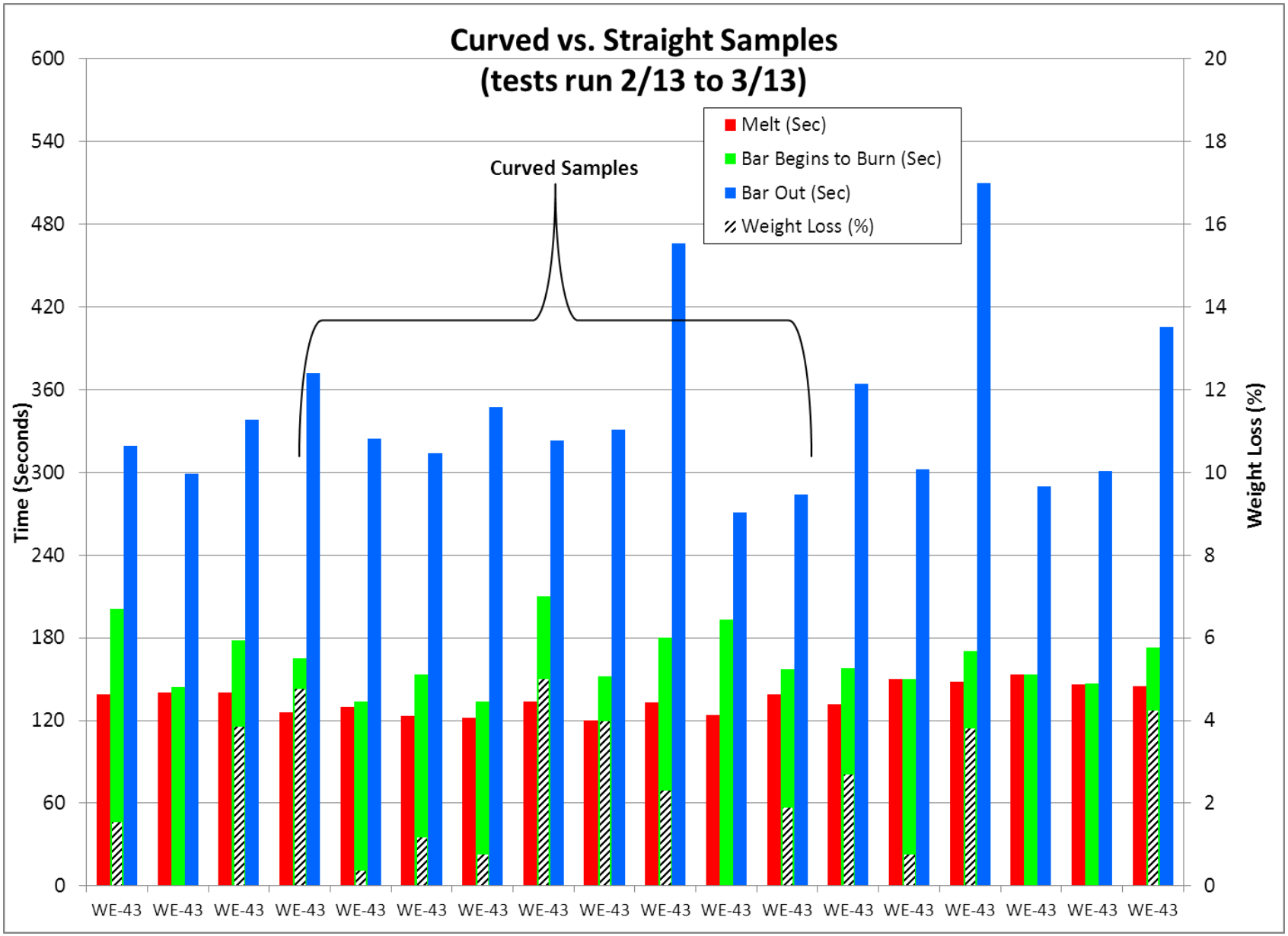


Impact of Curved Sample on Test Results



Pre-Loaded Sample




Curved vs. Straight Samples
(tests run 2/13 to 3/13)
Curved Samples
Melt (Sec)
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
Time (Seconds)
Weight Loss (%)
600
540
480
420
360
300
240
180
120
60
0
20
18
16
14
12
10
8
6
4
2
0
WE-43

Impact of Pre-Loading Curved Samples vs. Straight Samples

Slight impact on melt time?

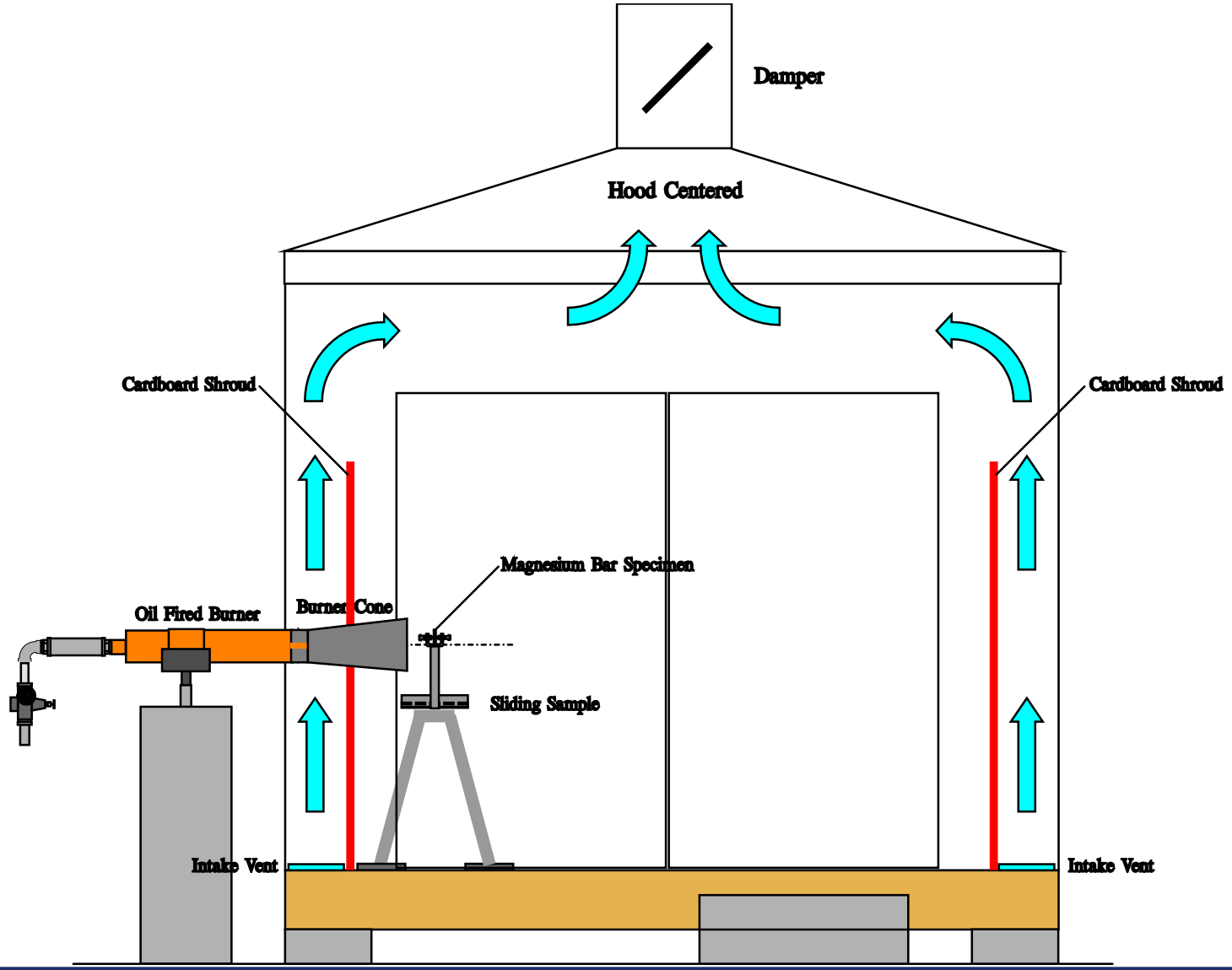
- Average melt time for straight sample: 143.7 seconds
- Average melt time for curved sample: 127.9 seconds

No impact on time to begin burning

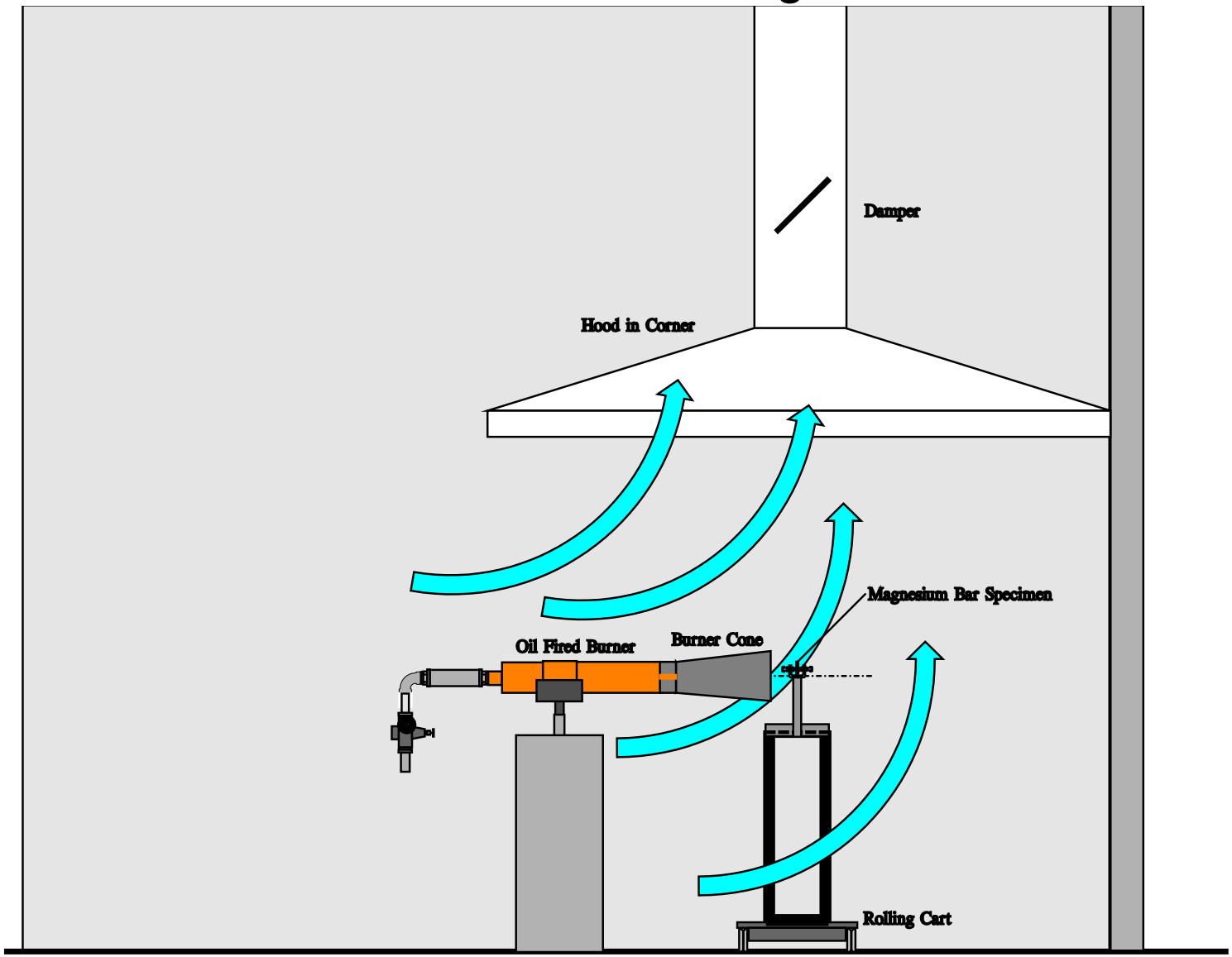
- Average time to begin burning for straight sample: 163.8 seconds
- Average time to begin burning for curved sample: 164.2 seconds

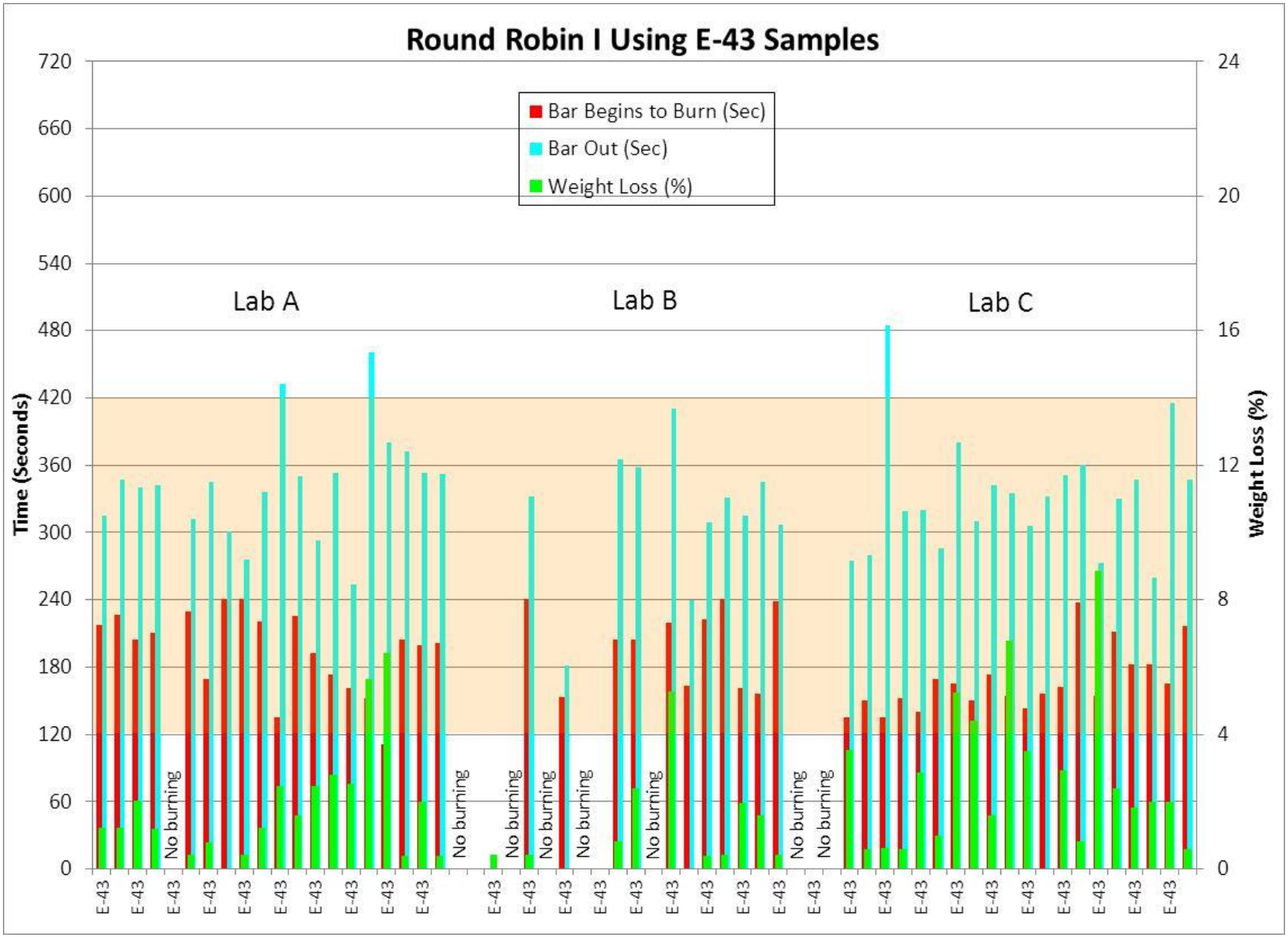
What is the Impact of Ventilation in the Testing Area?

Lab A Ventilation Configuration

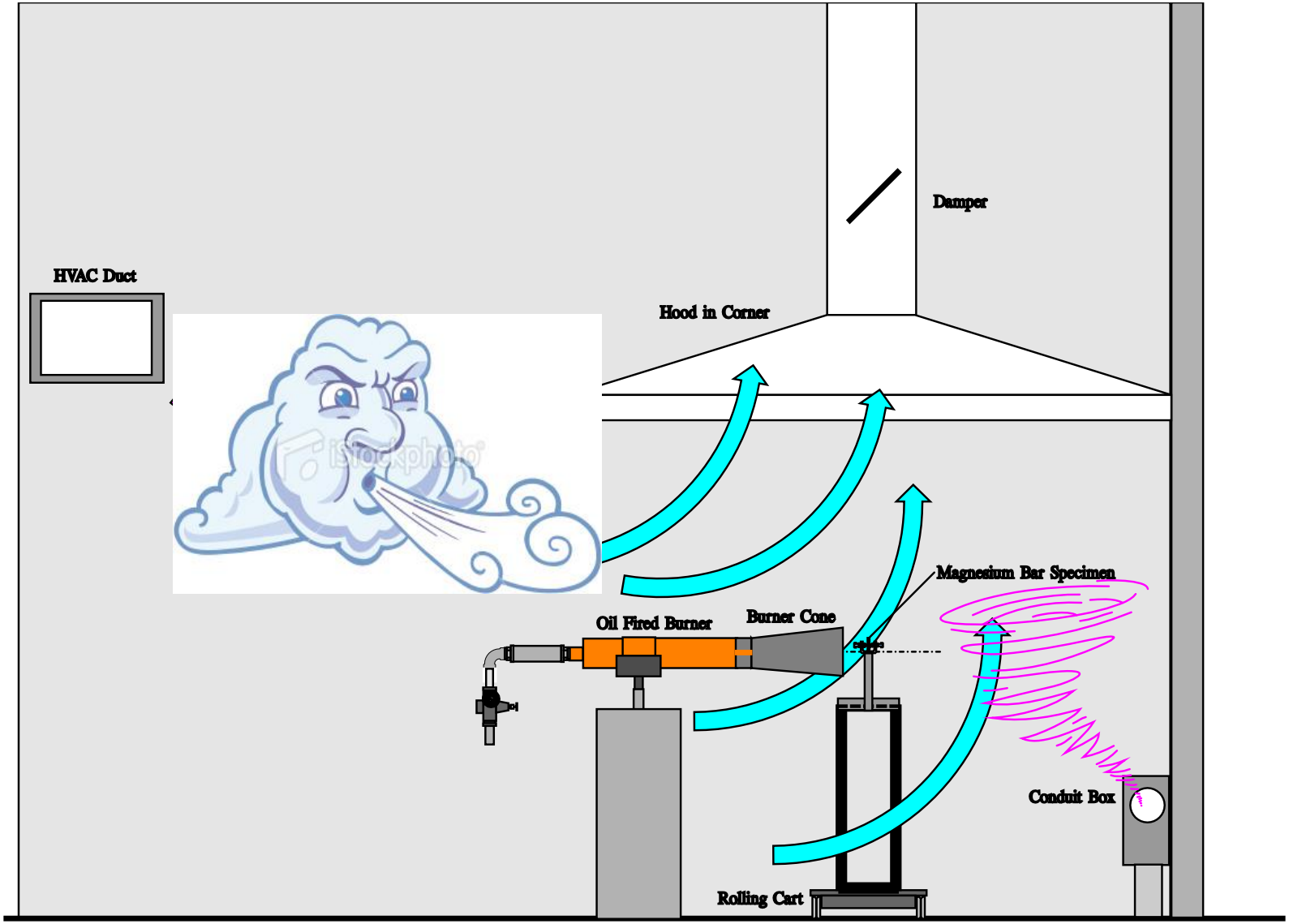


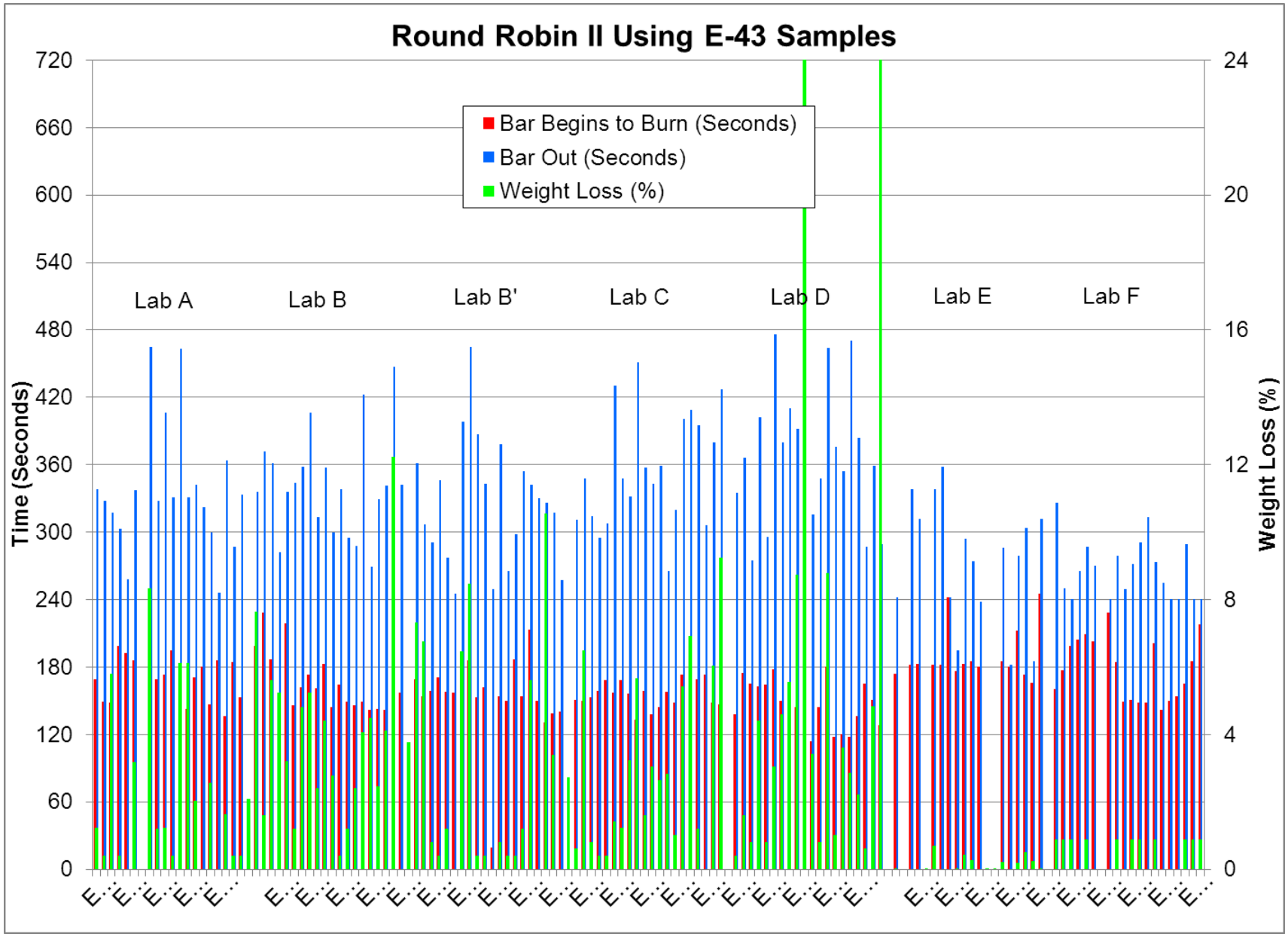
Lab B Ventilation Configuration

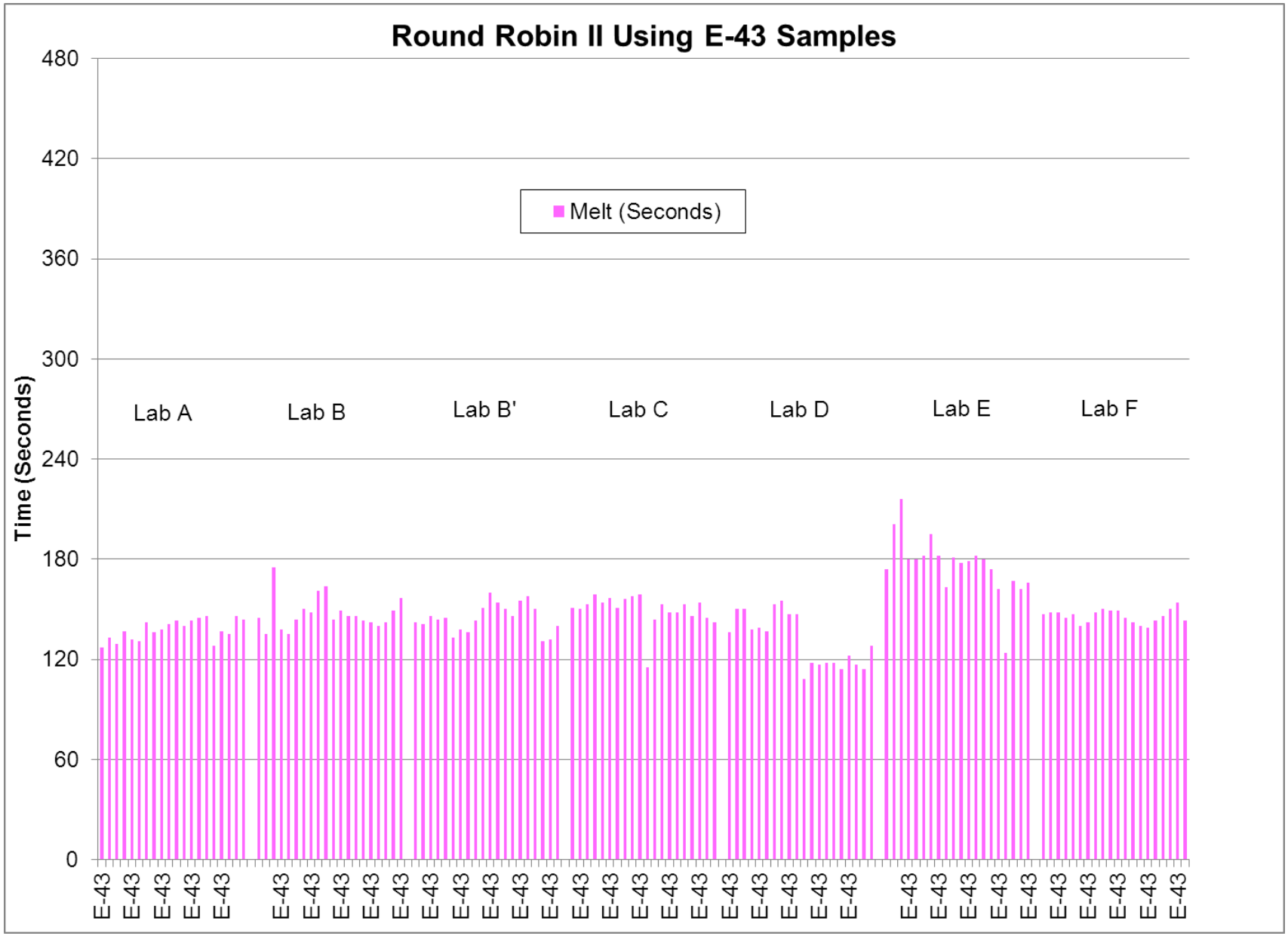



Round Robin I Using E-43 Samples
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
Lab A
Lab B
Lab C
Time (Seconds)
Weight Loss (%)
720
660
600
540
480
420
360
300
240
180
120
60
0
24
20
16
12
8
4
0
No burning
E-43

Lab B Ventilation Issue Resolved




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

RRII Statistics

7 Labs, 140 tests

	Melt (Seconds)	Bar Begins to Burn (Seconds)	Bar Out (Seconds)	Initial Weight (lbs)	Final Weight Bar (lbs)	Final Weight Residue (lbs)	Weight Loss (%)
Average	147.6	157.3	311.5	0.496	0.321	0.162	2.71
Standard Deviation	17.2	43.0	89.3	0.0	0.0	0.0	5.1
% RSD	11.6	27.3	28.7	1.1	10.8	21.5	186.8

RRI Statistics (for comparison…)

3 Labs, 60 tests

	Melt (Seconds)	Bar Begins to Burn (Seconds)	Bar Out (Seconds)	Initial Weight (lbs)	Final Weight Bar (lbs)	Final Weight Residue (lbs)	Weight Loss (%)
Average	138.9	154.2	277.7	0.494	0.321	0.165	1.68
Standard Deviation	23.0	76.8	134.3	0.0	0.0	0.0	2.0
% RSD	16.5	49.8	48.4	1.5	9.4	17.2	116.7

Comparison of RRI and RRII

Additional labs = more data = greater ability to determine problem areas

% RSD of time for sample to burn decreased

% RSD of time for sample to self-extinguish decreased

% RSD of weight loss increased

Measuring Weight Loss of Bar Sample

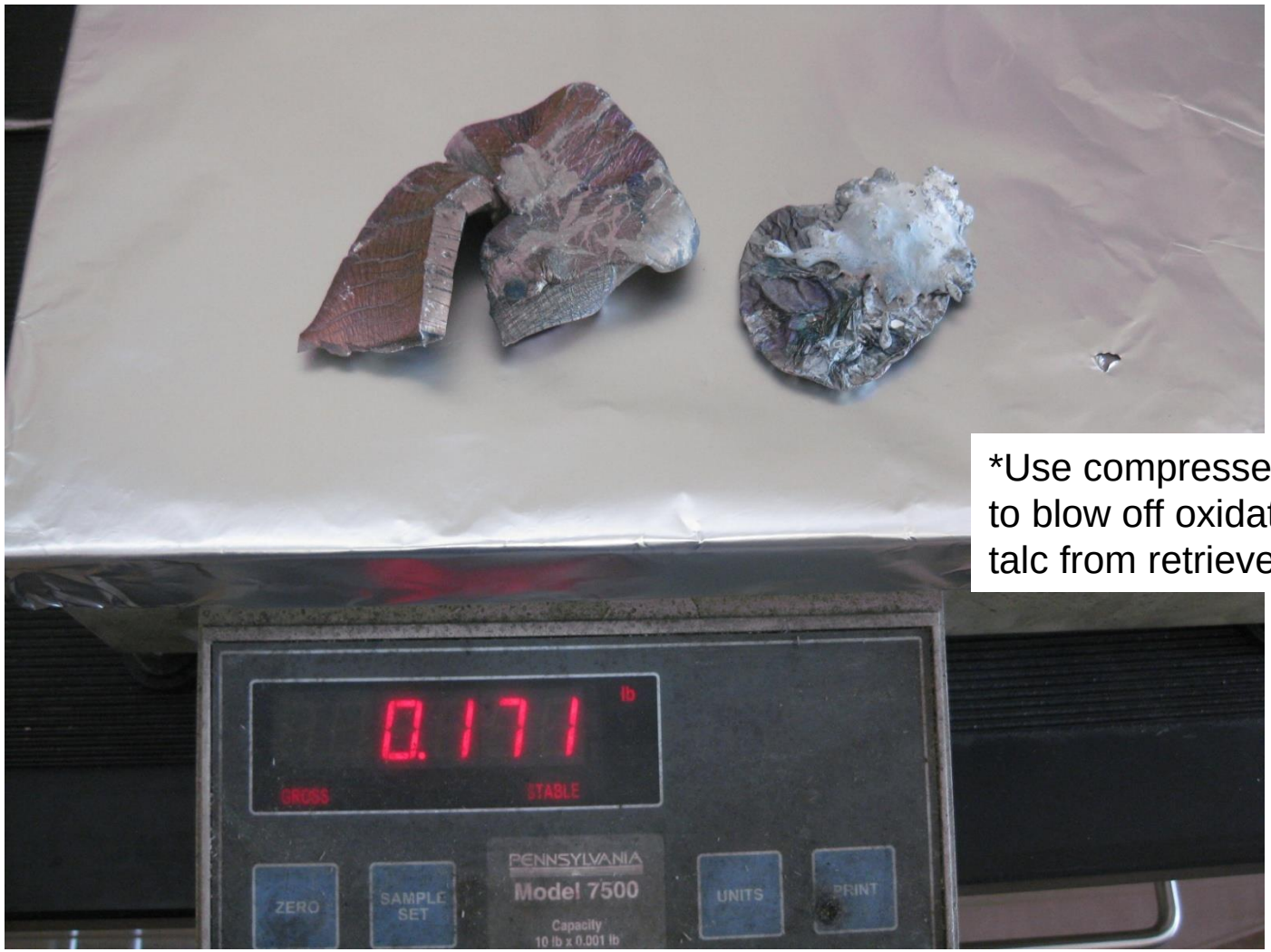
1. Weigh the sample prior to test

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

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

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

Complete analysis of Round Robin II

Complete report on test method development

Finalize draft test method

Insert new test method into Handbook?

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

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

January 2013

Final Report

U.S. Department of Transportation
Federal Aviation Administration

Questions?

Determining Time Sample Begins to Burn & Self Extinguishment