7th Triennial Conference on Cabin and Fire Safety

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

Presented to: 7th Triennial Conference on Fire and Cabin Safety, Marriott Philadelphia

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Key Activities and Timeline

(2006) FAA approached by industry to discuss potential use of magnesium in aircraft

(2007) IAMFTWG Mag Task Group formed

(2007-2008) Initial Phase of Research

- Discuss Threats
- Potential Areas of Use
- Establish Need for Threat-Based Test
- Initial Lab-Scale Testing

(2008-2010) Full-Scale Testing

(2010-Present) Final Phase of Research

- Lab-Scale Test Development
- Finalize Lab-Scale Test
- Lab-Scale Test Into Fire Test Handbook
- Final FAA Policy

FAA Policy Statement

Use of Magnesium in Airplane Cabins—Updated 10/2007

The FAA has had several recent inquiries regarding the use of magnesium in airplane cabins. Specifically, magnesium alloys have been suggested as substitute for aluminum alloys in seat structure, as well as other applications, due to the potential for weight savings.

The FAA's central concern regarding the use of magnesium in the cabin is flammability. The current regulations do not address the potential for a flammable metal to be used in large quantities in the cabin. Therefore, if such a material were introduced to the cabin, the FAA would have to be convinced that the level of safety was not reduced. Special conditions may be required to establish appropriate criteria. Different magnesium alloys have different susceptibility to ignition, however, magnesium remains a material that, once ignited, is very challenging to cope with using fire extinguishers currently available on aircraft.

The use of magnesium is currently the subject of a task group of the International Aircraft Materials Fire Test Working Group. Depending on the outcome of the task group's work, the FAA may support additional research in this area, to the extent industry can supply materials. This would likely include full-scale testing should the initial assessments suggest there is some potential for acceptable installations. Both the post crash, as well as in-flight, fire scenarios need to be addressed.

FAA Policy Statement

Use of Magnesium in Airplane Cabins—Updated 8/2012

Based on requests from industry, and considering the absence of recent research data, the FAA has worked extensively with industry to evaluate the potential use of magnesium alloys in airplane cabins. Specifically, magnesium alloys have been evaluated as seat structure.

The FAA's central concern regarding the use of magnesium in the cabin is flammability. The current regulations do not address the potential for a flammable metal to be used in large quantities in the cabin. Therefore, the FAA and industry research has focused on identifying the large scale performance of different magnesium alloys under realistic fire threats, and characterizing that behavior in a laboratory scale test method.

The work has progressed to the point where it appears that certain magnesium alloys may have flammability properties acceptable to be used in aircraft seat structure. Special conditions will likely be required to establish appropriate criteria. The development of a laboratory-scale test method is progressing and could be defined near the end of the year.

The use of magnesium is still the subject of a task group of the International Aircraft Materials Fire Test Working Group. Depending on the outcome of the task group's work, the FAA may entertain requests for approval using the special condition process.

International Aircraft Materials Fire Test Working Group

Meets three times per year…

- One meeting held in Atlantic City, New Jersey
- One meeting held at host organization in North America
- One meeting held at host organization outside the US

Issues and concerns in the area of aircraft materials fire safety testing are discussed with emphasis on the current test methods.

The WG is open to anyone in the international community, including industry, government, and academia with an interest in aircraft materials fire safety and testing

Magnesium Alloy Use in Commercial Aircraft

Industry Question: Why can't we use Magnesium-Alloy in the construction of an aircraft seat frame?

Regulatory Response: Current FAA TSO C-127 "Rotorcraft and Transport Airplane Seating Systems" makes reference to an SAE specification (AS8049), which bans the use of magnesium in seats.

Initial Laboratory-Scale Testing (2007-2008)

Full-Scale Testing (2008-2010)

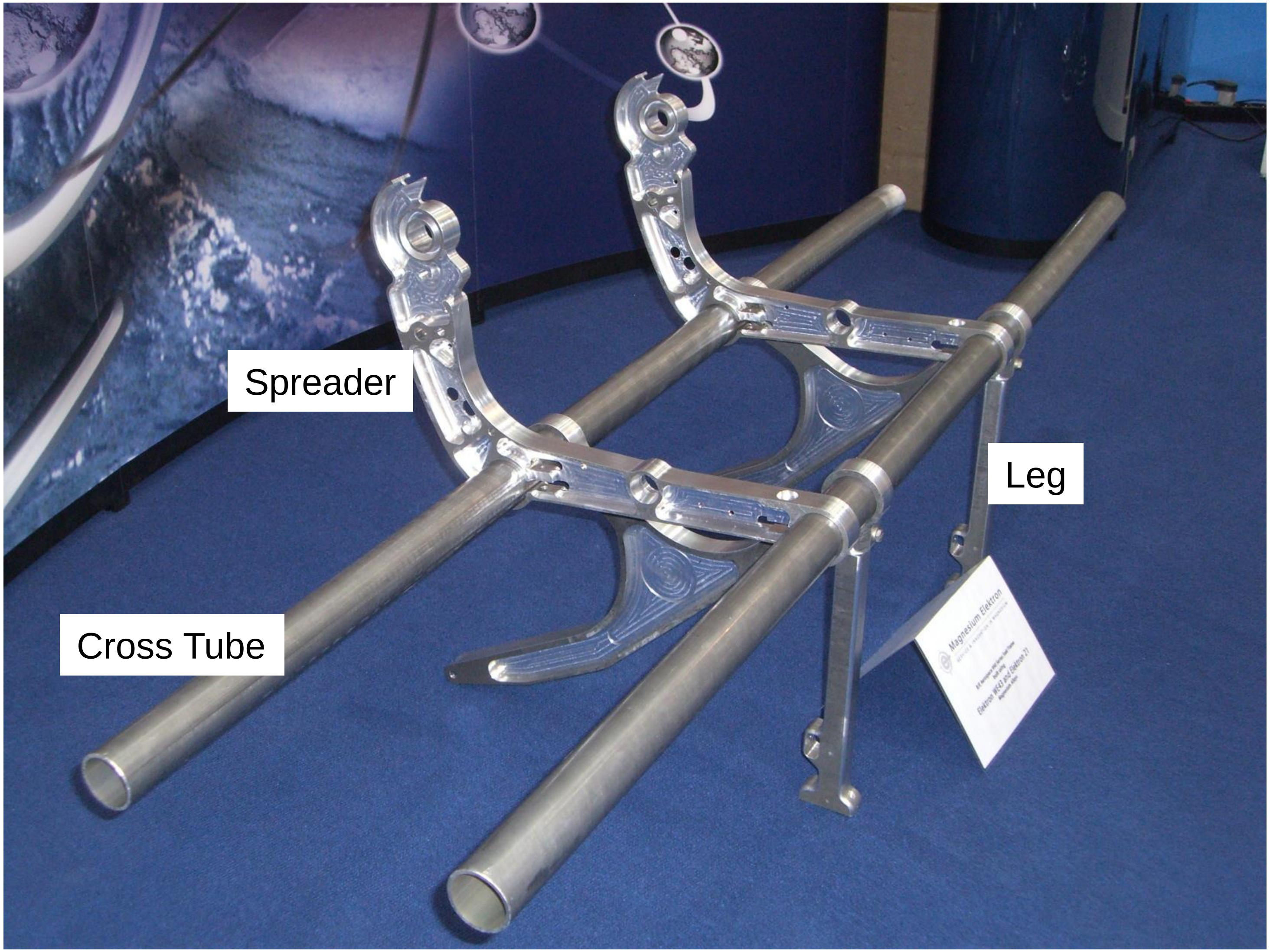
Method: Conduct baseline tests using OEM aluminum-framed triple seats. Tests will simulate a post-crash fire with fuselage rupture, allowing external fire to directly impact the cabin materials.

Then…

Conduct additional tests in an identical fashion using mag-alloy in the construction of the primary seat components. External fuel fire permitted to burn for 5 minutes, then internal fire permitted to burn for 5 additional minutes before applying water.

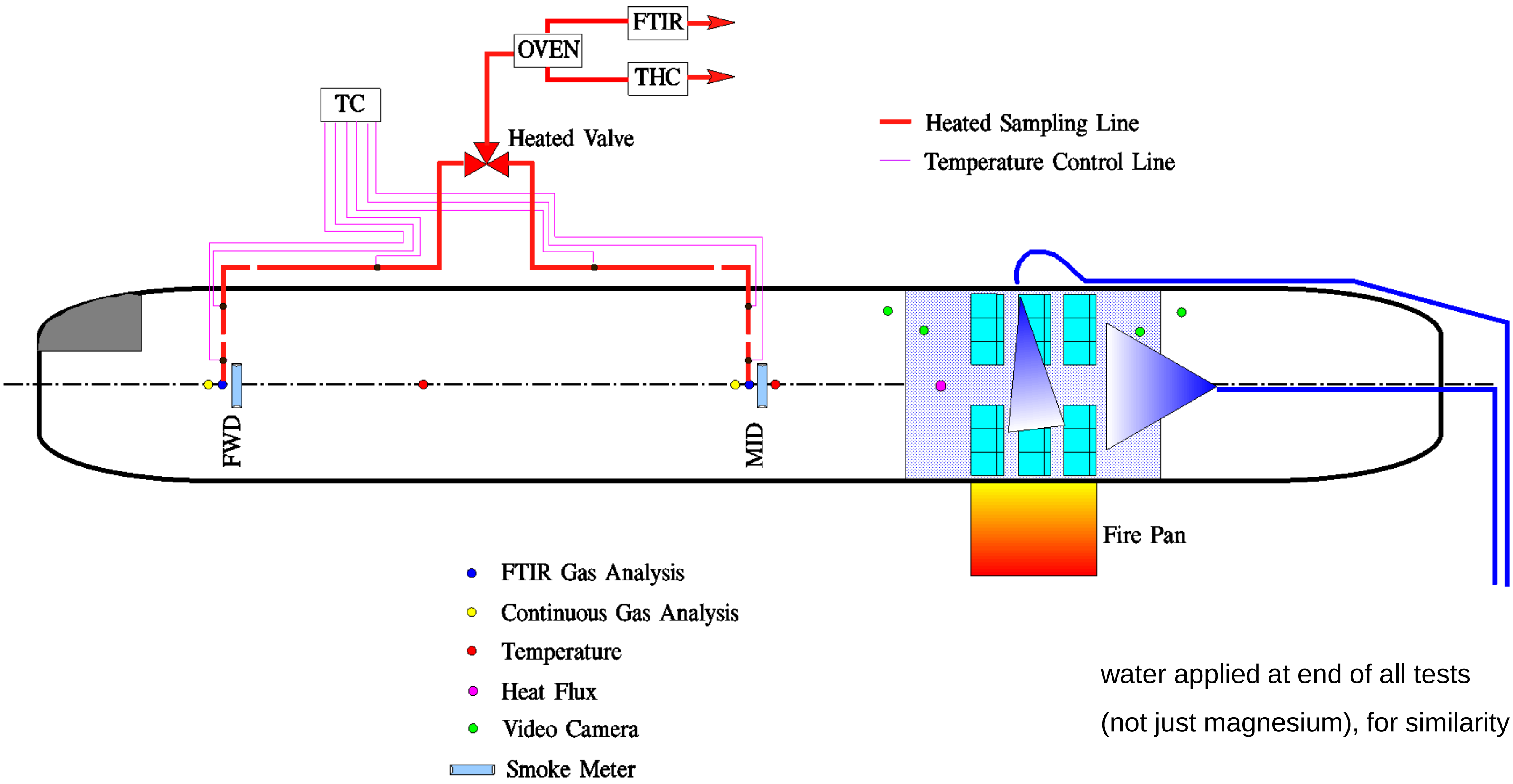
Outcome: Determine if the use of mag-alloy poses additional hazard during the 10-minute event

Primary Seat Components



Full-Scale Testing

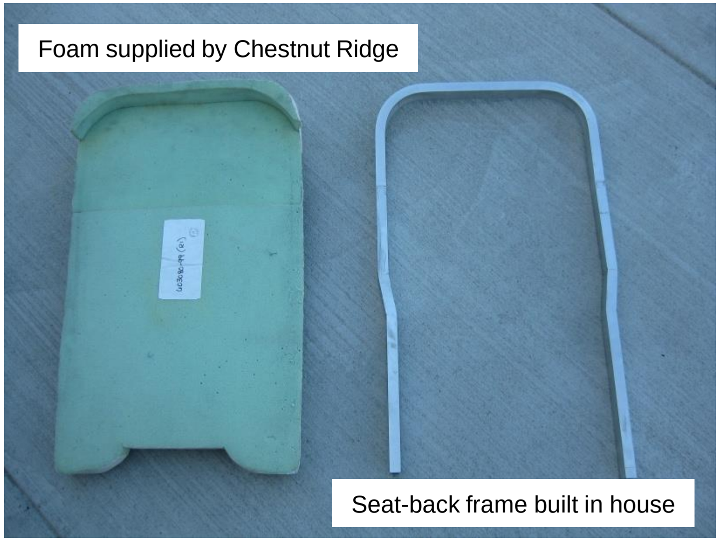
Full-Scale Test Apparatus



water applied at end of all tests

(not just magnesium), for similarity

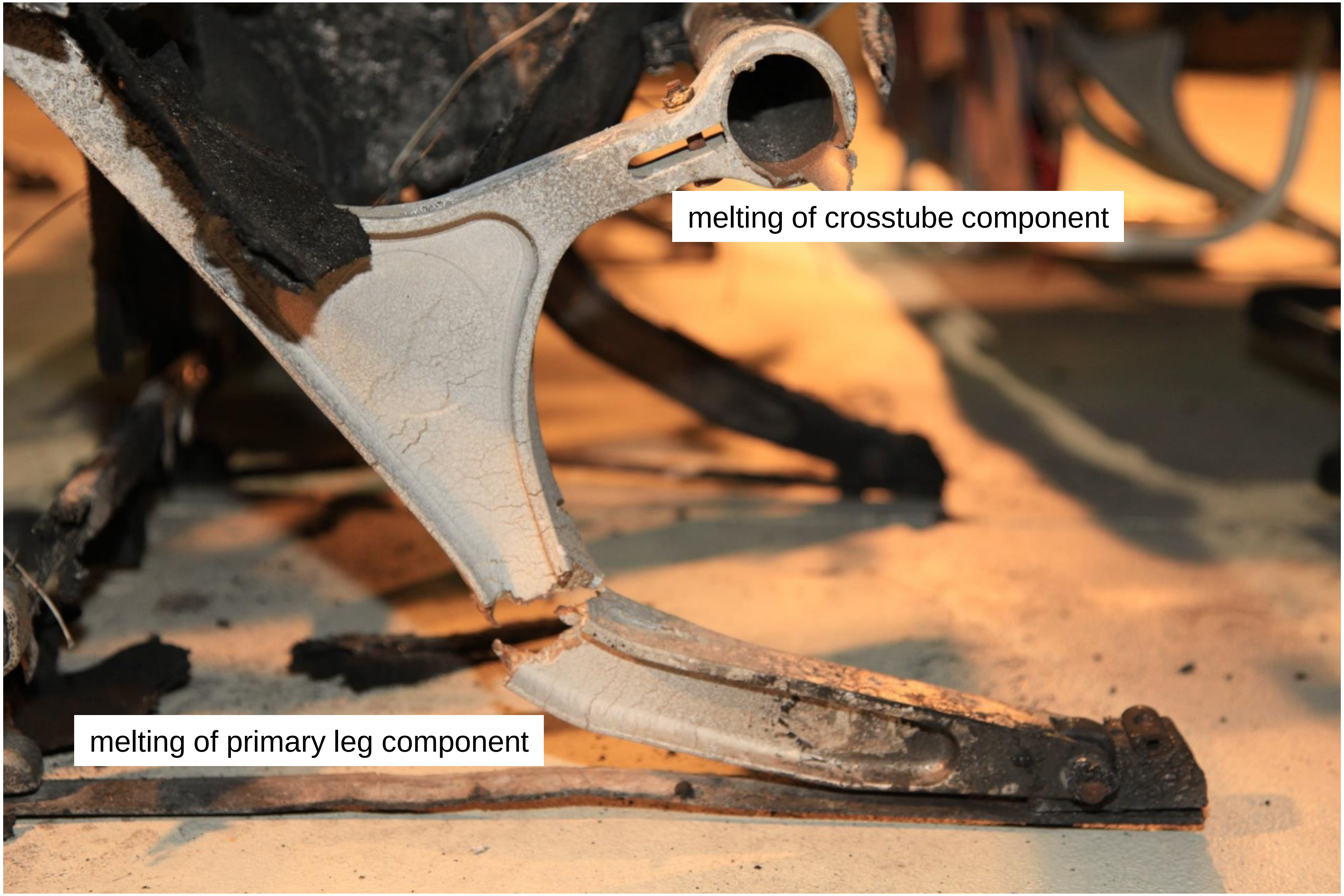
OEM Coach Style Seats w/Modified Back Frame



Full-Scale Test Configuration

Typical Test Result

Baseline Test Result



Full-Scale Testing Summary

Baseline, aluminum frames

WE43 in primary frame members

AZ31 in primary frame members

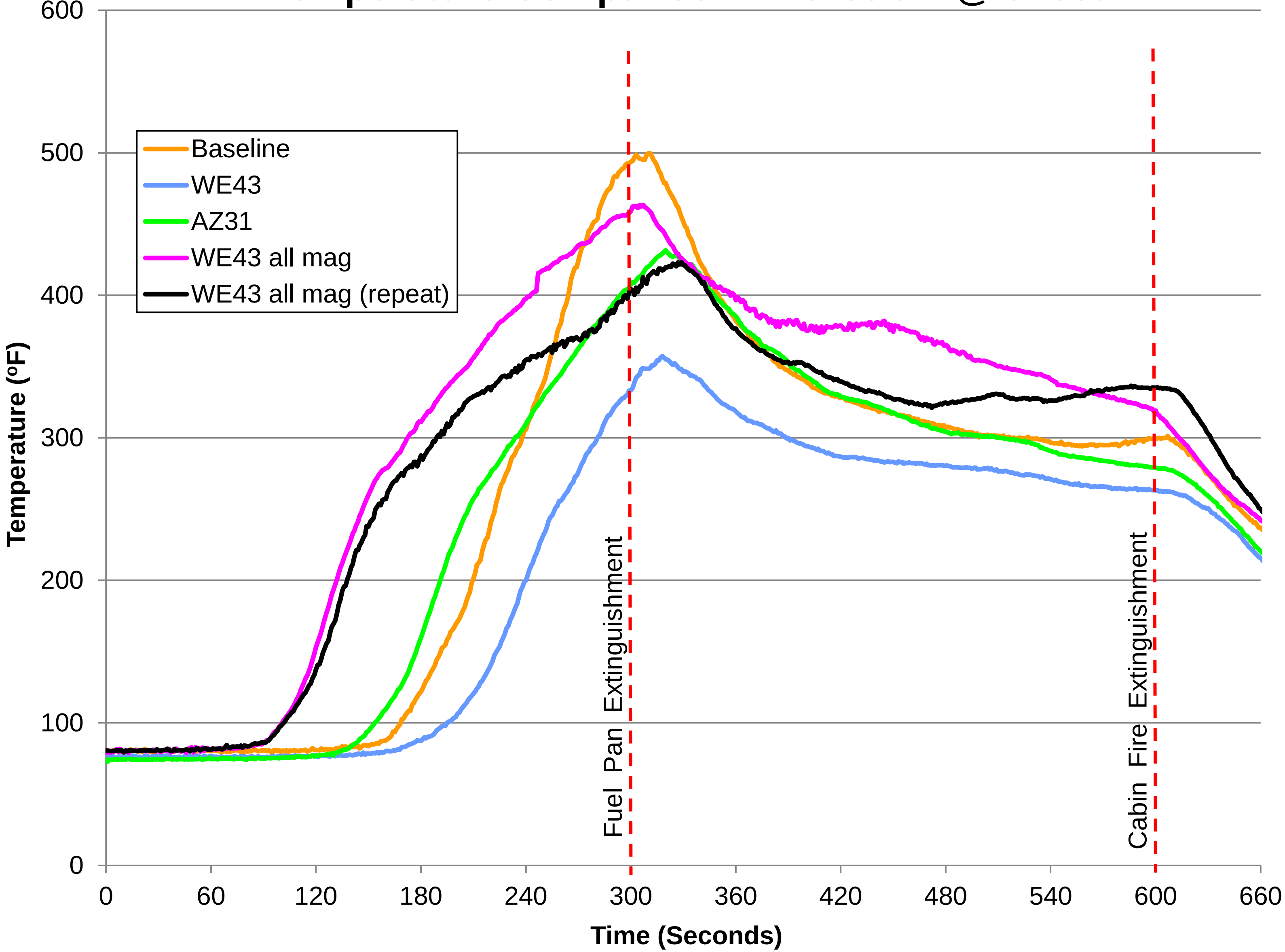
WE43 in primary and secondary frame members

WE43 in primary and secondary frame members (repeat)

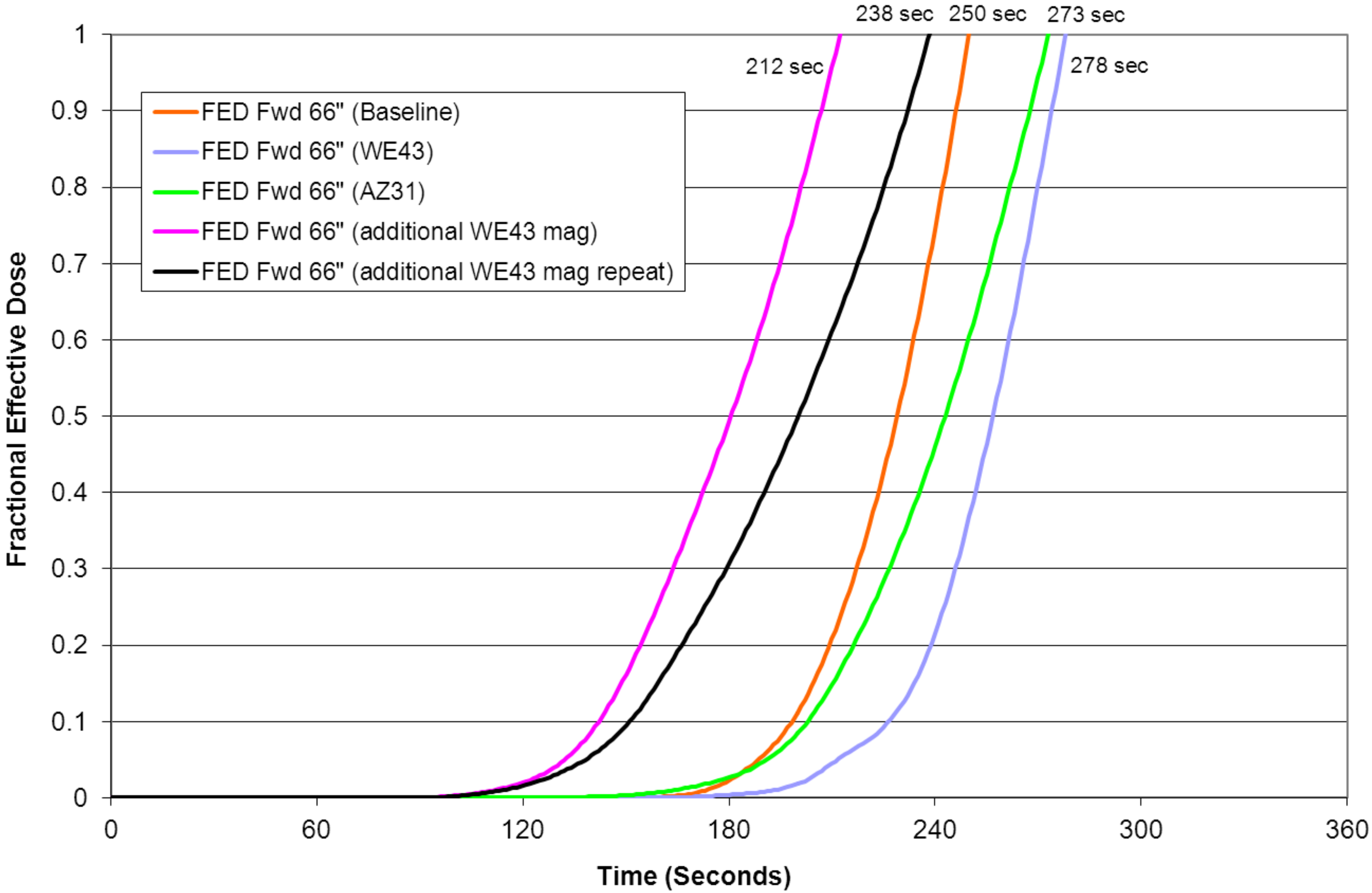
Pan fire extinguished at 5 minutes using AFFF

Interior fire extinguished at 10 minutes using water

Temperature Comparison Fwd Cabin @ 5 feet



Cabin Survivability at Forward Station



Full-Scale Testing Summary

Magnesium alloy components had little/no effect on survivability

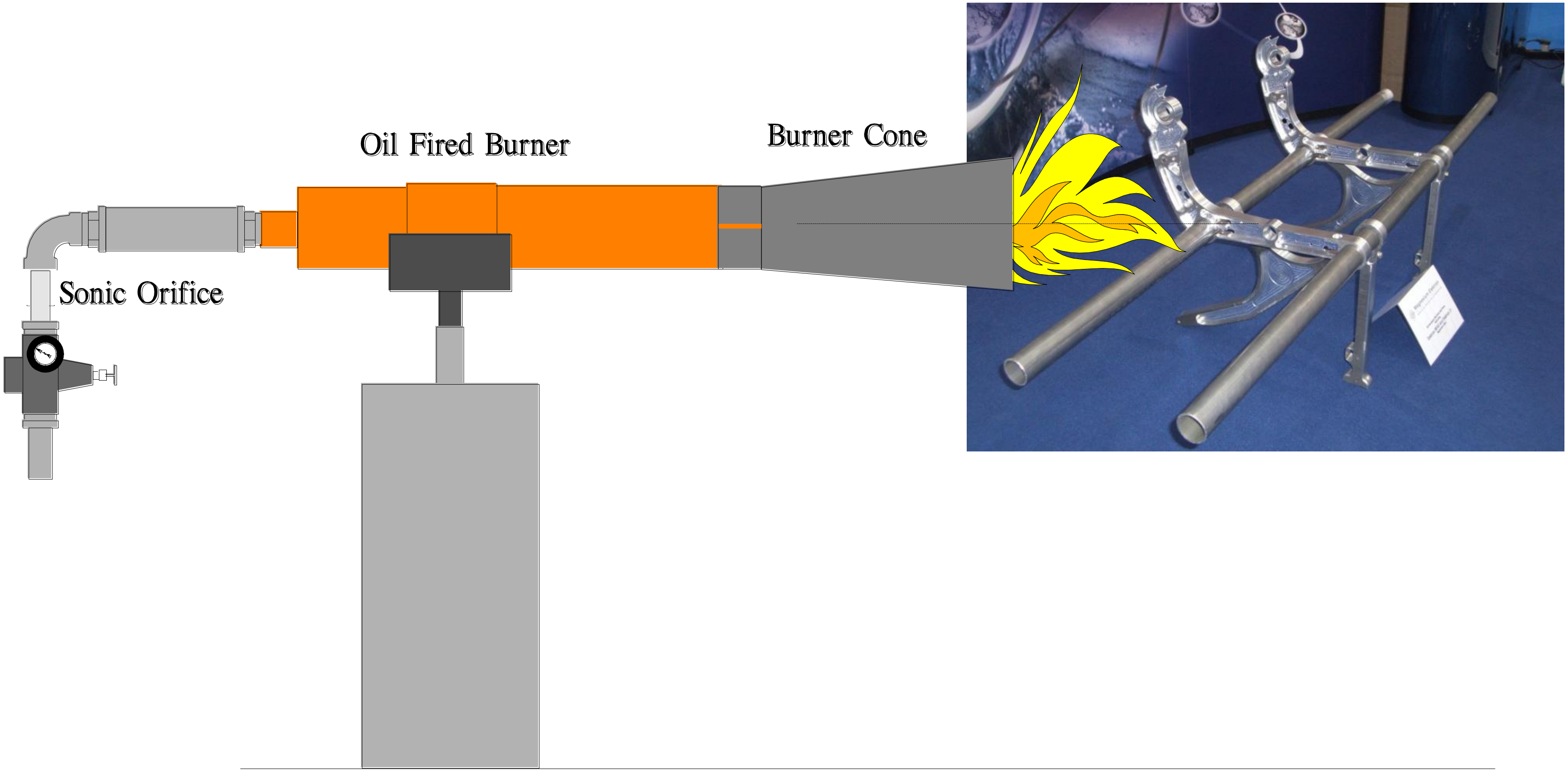
Slight flashing of burning mag-alloy during water application for WE43 test

Noticeable difficulty extinguishing burning mag-alloy during AZ31 test

Incapacitation results very similar for baseline and mag-alloy tests

- slightly better for mag-alloys at forward location
- slightly worse for mag-alloys at mid location
- More severe fire condition caused more rapid incapacitation during "all-mag" tests

Development of a Lab-Scale Test



Evolution of the Lab-Scale Test

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

Cylinder vs. Bar Testing (Spring 2012)

Hollow Cylinders (vertical): 59 Tests

WE43: (15)
EL21: (18)
ZE41: (18)
AZ80: (3)
AZ31: (1)
EXP: (4)

Rectangular Bars (horizontal): 137 Tests

WE43: (18)
E43: (25)
EL21: (34)
EXP2: (2)
ZE41: (24)
AZ80: (27)
AZ31: (7)

VS.

1 cylinder configuration tested

4 different bar thicknesses tested

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

Cylinder vs. Bar Summary

Data indicates horizontal bar configuration more repeatable

	Cylinder		0.250-Inch Bar	
	Begin Burn	End Burn	Begin Burn	End Burn
	10[illegible]	[illegible].9	5.5	9.8
	97.2	13.7	49.0	49.2
	2[illegible]	[illegible].4	25.6	18.7
	[illegible]8	0[illegible]	10.1	12.8
AVG %RSD	57.5	26.3	22.5	22.6

Bar samples easier/less expensive to produce!

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)	[illegible]	Bar Begins to Burn (Sec)	Bar Out (Sec)	[illegible]
Average	197.8	326.8	1.1	38.8	65.0	[illegible]	[illegible]	67.5	[illegible]
Std Dev	18.6	56.8	0.7	90.5	151.9	0.6	[illegible]	126.0	[illegible]
% RSD	9.4	17.4	61.6	233.6	233.8	157.7	[illegible]	186.7	[illegible]

	0.250-Inch WE-43			0.375-Inch WE-43			[illegible]		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	[illegible]	[illegible]	[illegible]
Average	139.7	277.1	3.1	173.4	242.3	1.3	[illegible]	[illegible]	5.5
Std Dev	69.9	146.1	6.0	104.4	156.3	4.4	98.1	[illegible]	8.6
% RSD	50.1	52.7	194.0	60.2	64.5	339.1	41.7	[illegible]	155.5

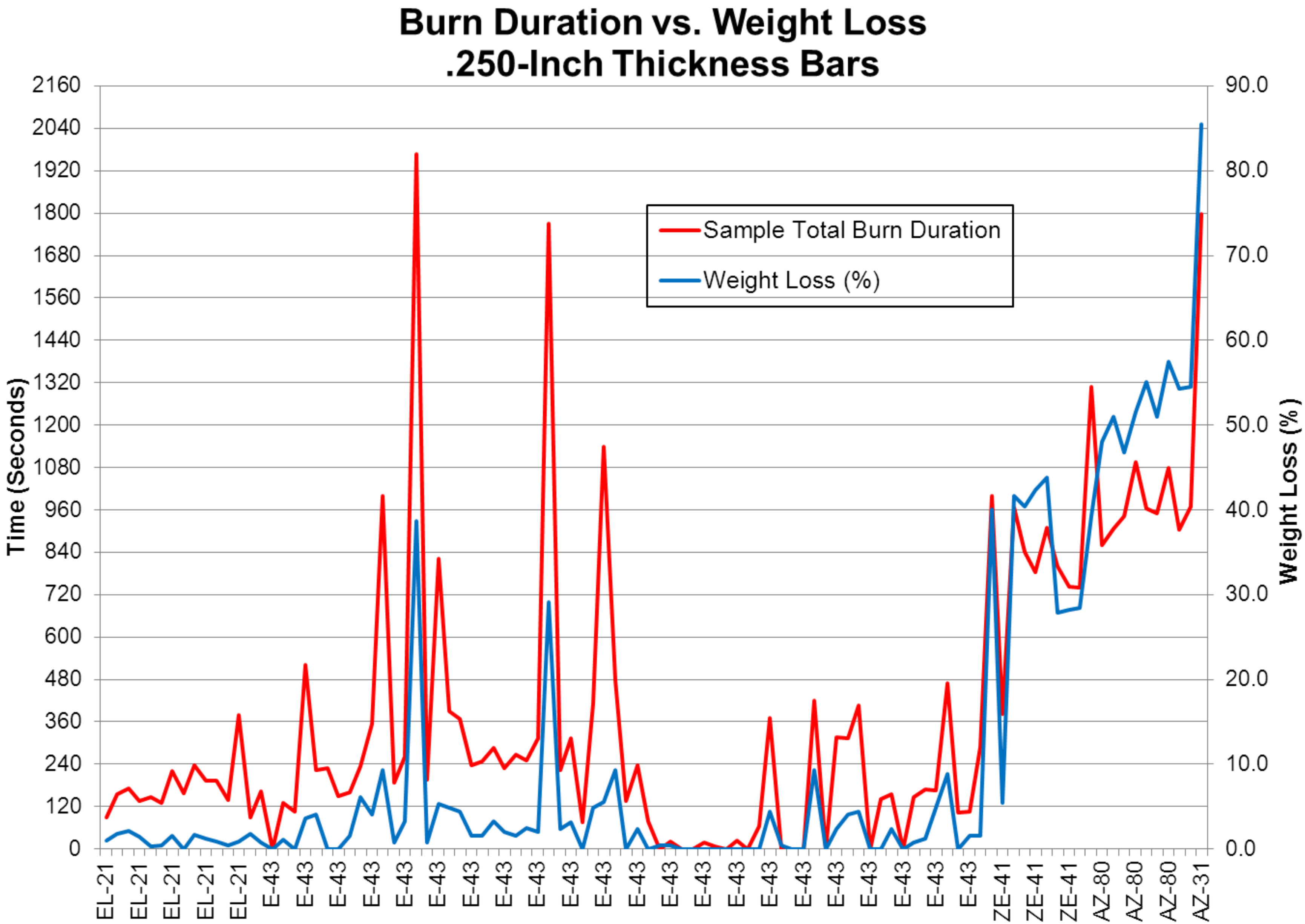
	0.250-Inch ZE-41			0.375-Inch ZE-41			[illegible]		
	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	Bar Begins to Burn (Sec)	Bar Out (Sec)	Weight Loss (%)	[illegible]	[illegible]	[illegible]
Average	191.2	321.1	33.7	158.3	202.1	27.7	[illegible]	[illegible]	[illegible]
Std Dev	47.2	145.9	27.0	151.8	193.0	1.5	[illegible]	207.5	[illegible]
% RSD	24.7	45.4	80.0	95.9	95.5	5.3	[illegible]	56.9	[illegible]

	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)	[illegible]	[illegible]	Bar Out (Sec)	[illegible]
Average	152.9	394.3	51.6	209.6	467.3	[illegible]	194.3	439.0	33.9
Std Dev	15.4	50.3	3.7	13.7	174.7	[illegible]	104.9	315.9	11.0
% RSD	10.1	12.8	7.2	6.5	37.4	[illegible]	54.0	72.0	32.4

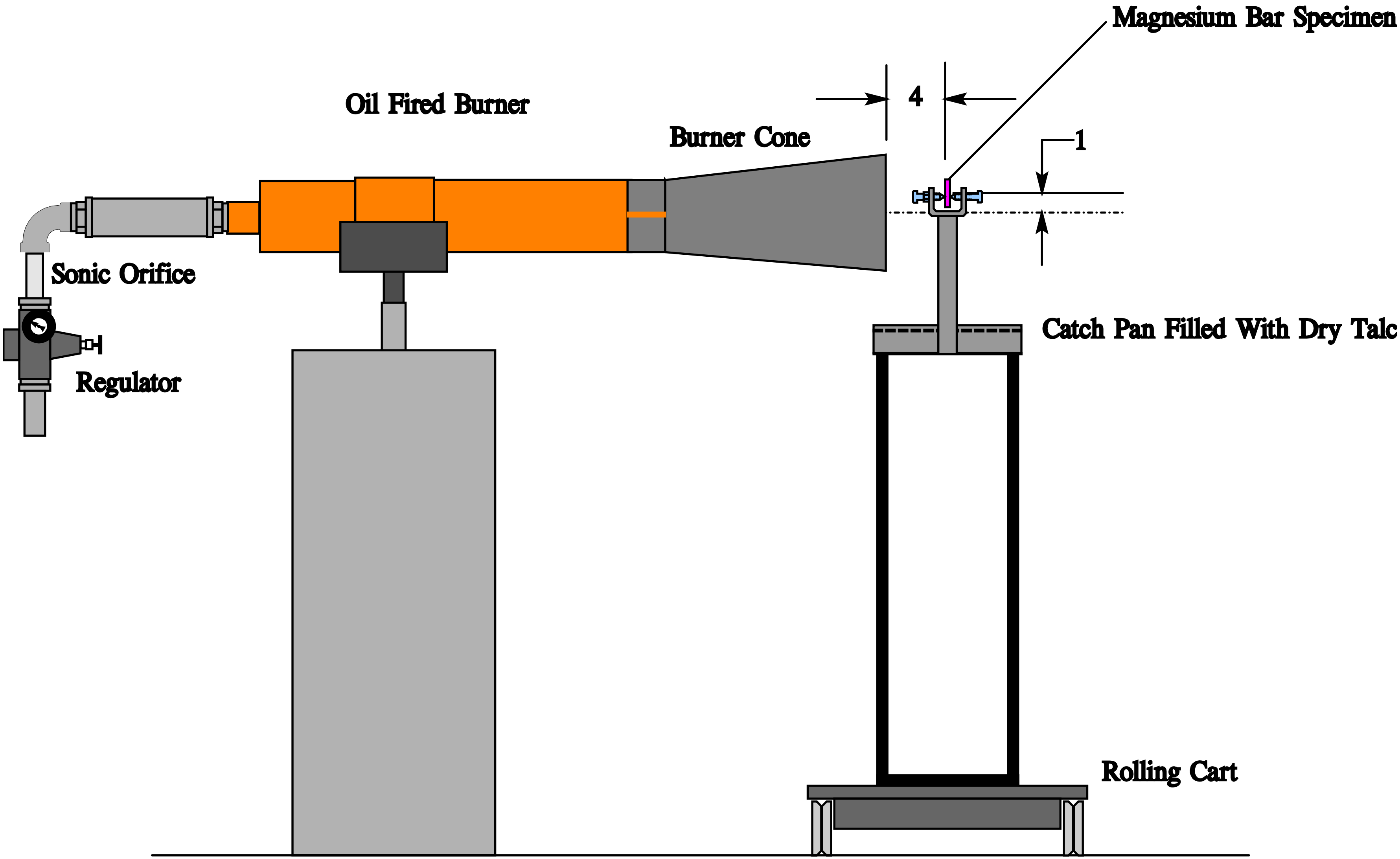
No advantage to thicker sample; extended exposure time required

Eliminate measurement of residue ignition & 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
E-43
ZE-41
AZ-80
AZ-31

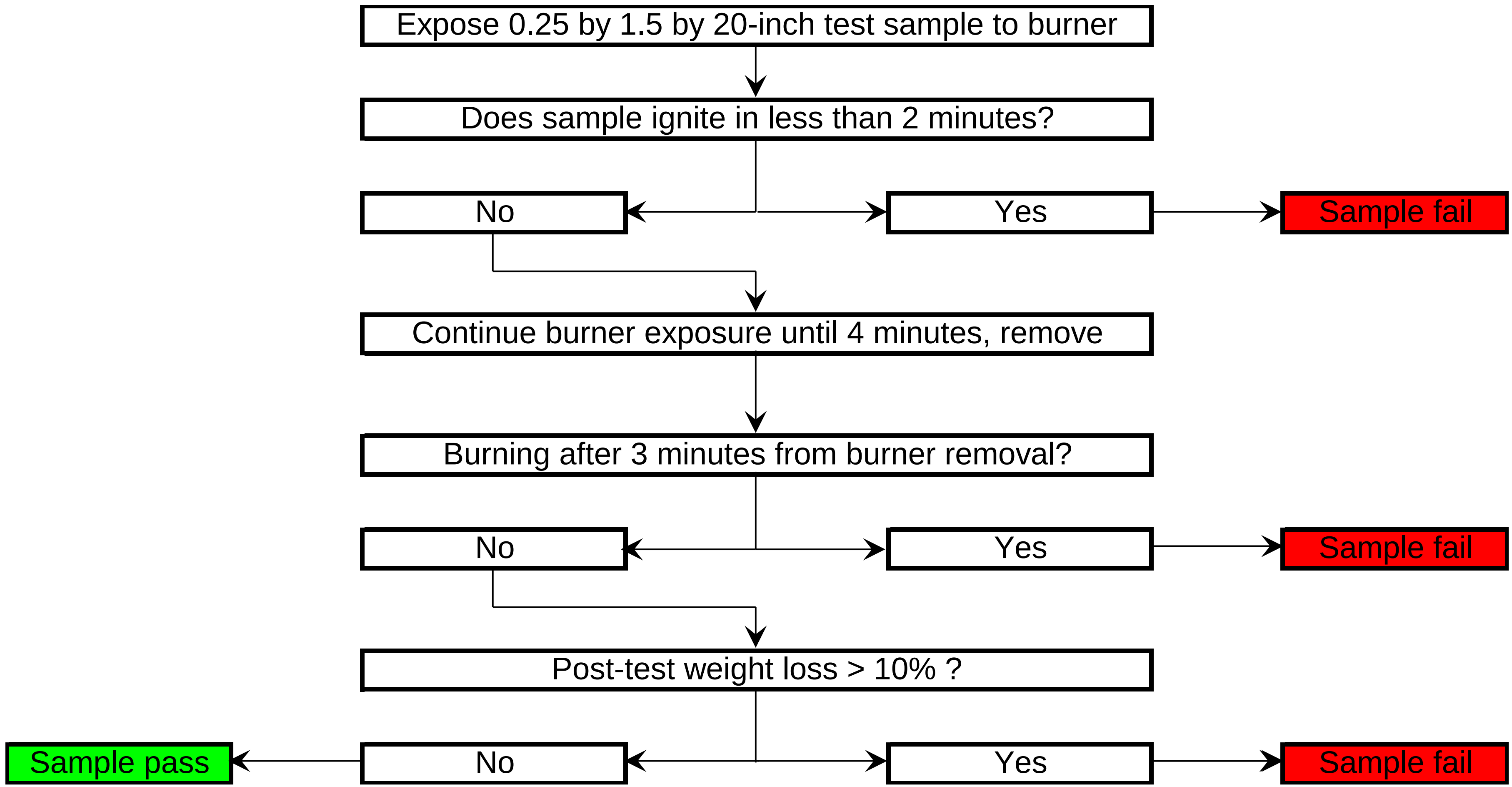
Updated Horizontal Bar Testing Rig 2012

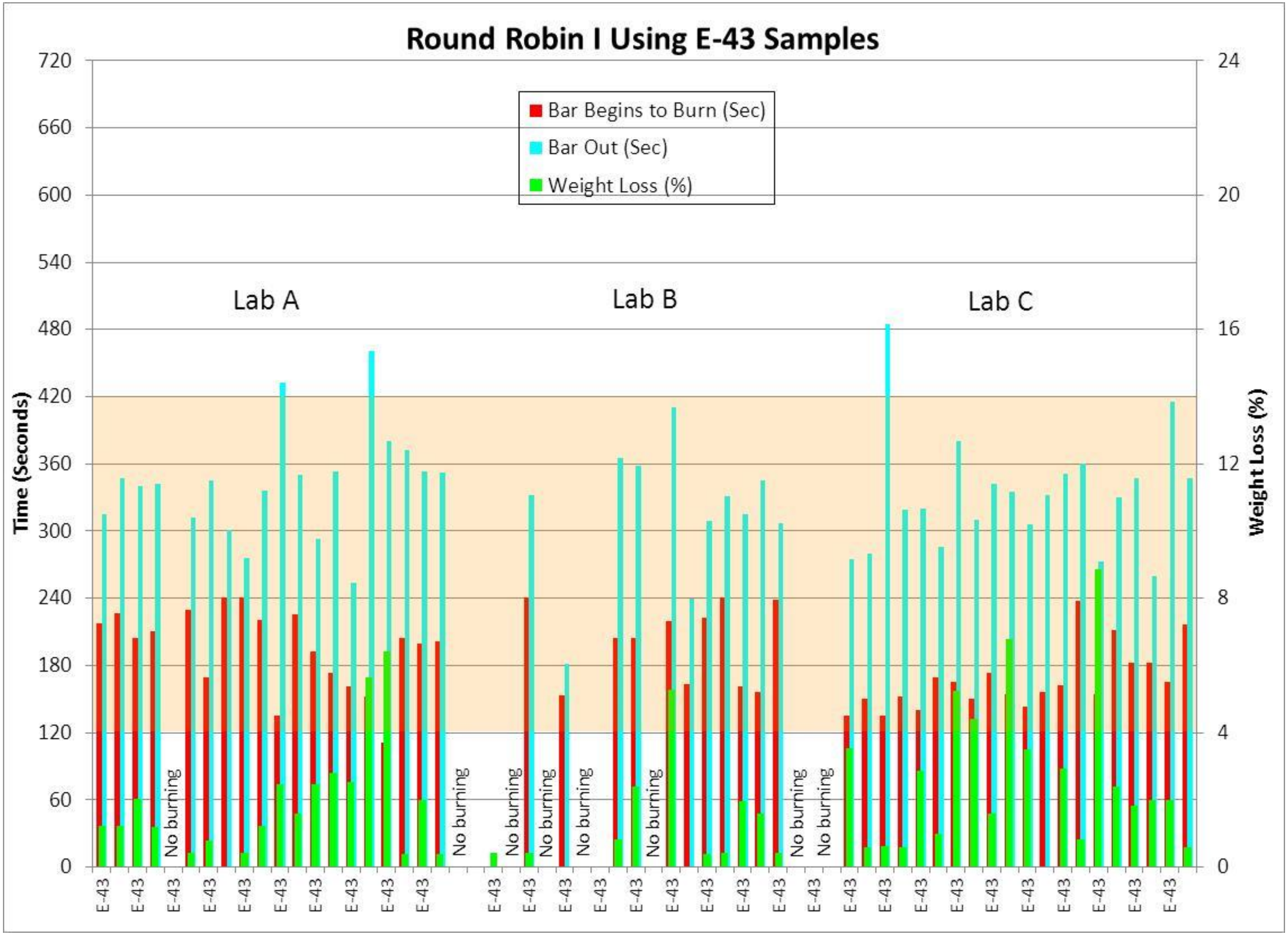


Systematic Development of Lab-Scale Test

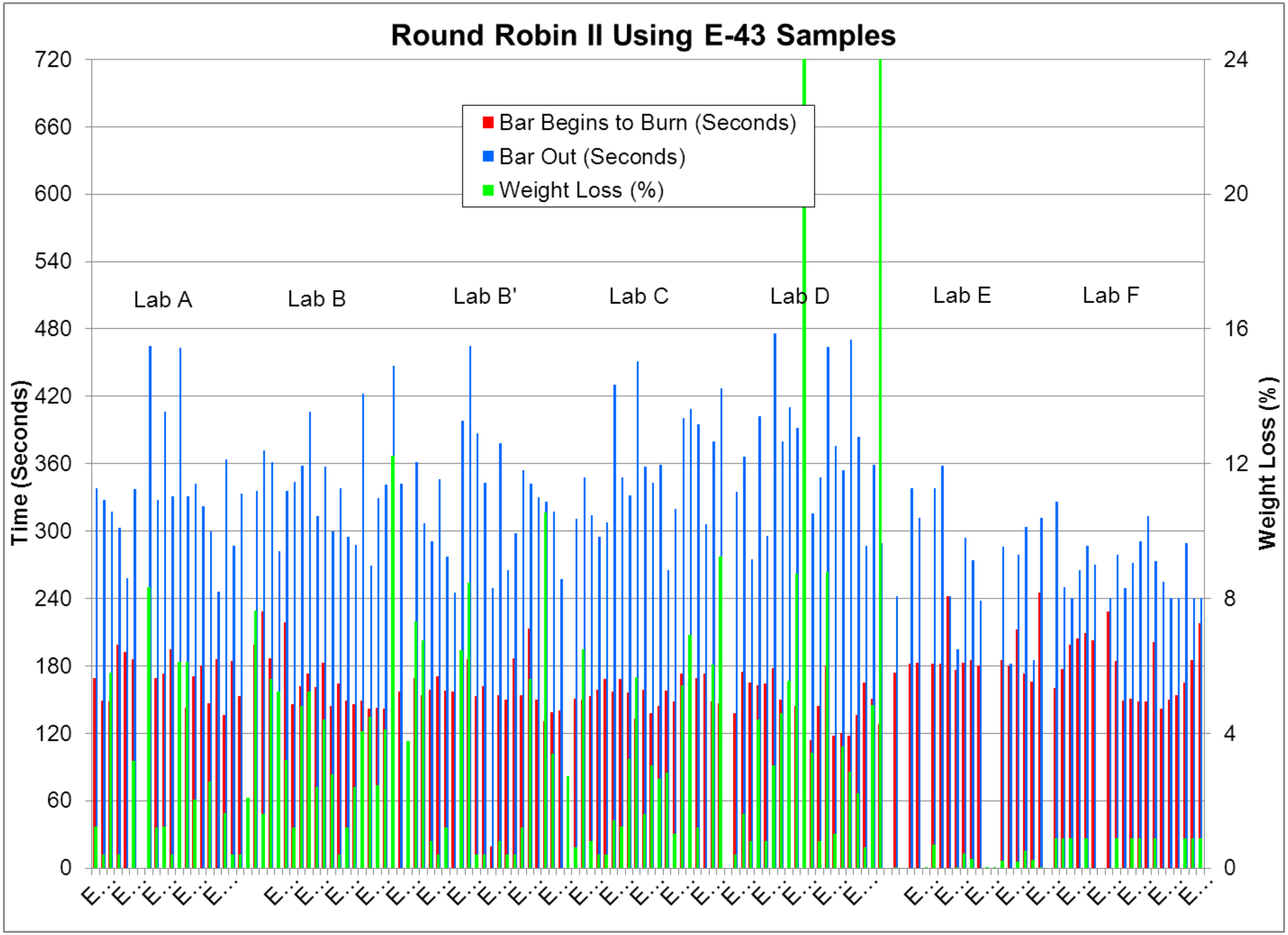
- Determine basic configuration: solid cone, vertical cylinder, horizontal bar ✓
- Make improvements to test apparatus: mounting mechanism, depth of talc ✓
- Determine which parameters to measure: e.g., time to melt, time to ignite sample, time residue burns, time sample extinguished, time residue extinguished, 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 ✓
- Finalize all test parameters and details ✓
- Determine other sources of error and correct

Lab-Scale Test Logic





Round Robin I Using E-43 Samples
Bar Begins to Burn (Sec)
Bar Out (Sec)
Weight Loss (%)
Time (Seconds)
Weight Loss (%)
Lab A
Lab B
Lab C
No burning
E-43



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

RRI & II Statistics

	Melt (Seconds)	Bar Begins to Burn (Seconds)	Bar Out (Seconds)	Initial Weight (lbs)	Final Weight Bar (lbs)	Final Weight Residue (lbs)	Weight Loss (%)
% RSD (RR I*)	16.5	49.8	48.4	1.5	9.4	17.2	116.7
% RSD (RR II**)	11.6	26.1	28.7	1.1	10.8	21.5	186.8
% RSD (RR II - no zeros)	11.6	14.9	18.8	1.1	10.8	21.5	166.0

*3 Labs, 60 Tests

**7 Labs, 140 Tests

Planned Activities and Next Steps?

Complete analysis of Round Robin II ✔

Complete final report on test method development ✔

Finalize draft test method ✔

Refine method of determining when sample begins to burn

Refine method of determining when sample self-extinguishes

Refine method of measuring post-test weights

Insert new test method into Aircraft Materials Fire Test 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

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

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November 2013

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