



**Federal Aviation  
Administration**

# International Aircraft Materials Fire Test Working Group Meeting

## Task Group Session on New Flammability Test for Magnesium-Alloy Seat Structure

Presented to: International Aircraft Materials Fire  
Test Working Group, Bremen

By: Tim Marker, FAA Technical Center

Date: June 22-23, 2011



# Summary of Program on Magnesium Alloy Flammability

## Initial Involvement

Informal discussions with magnesium suppliers, fact-finding

Oil burner testing of various mag alloys

Extinguisher testing using various agents against small magnesium fires

## Full-Scale Testing of Mag-Alloy Seats to Determine Postcrash Fire Threats

Baseline Tests

WE-43 and AZ-31 tests

Two all-mag tests

## Development of a Lab-Scale Test for Mag-Alloy Seats Structure

Test results of cone-shaped test samples

# Possible New Appendix F Structure

## Appendix F Part I: Requirements for In-Flight Fire Threats

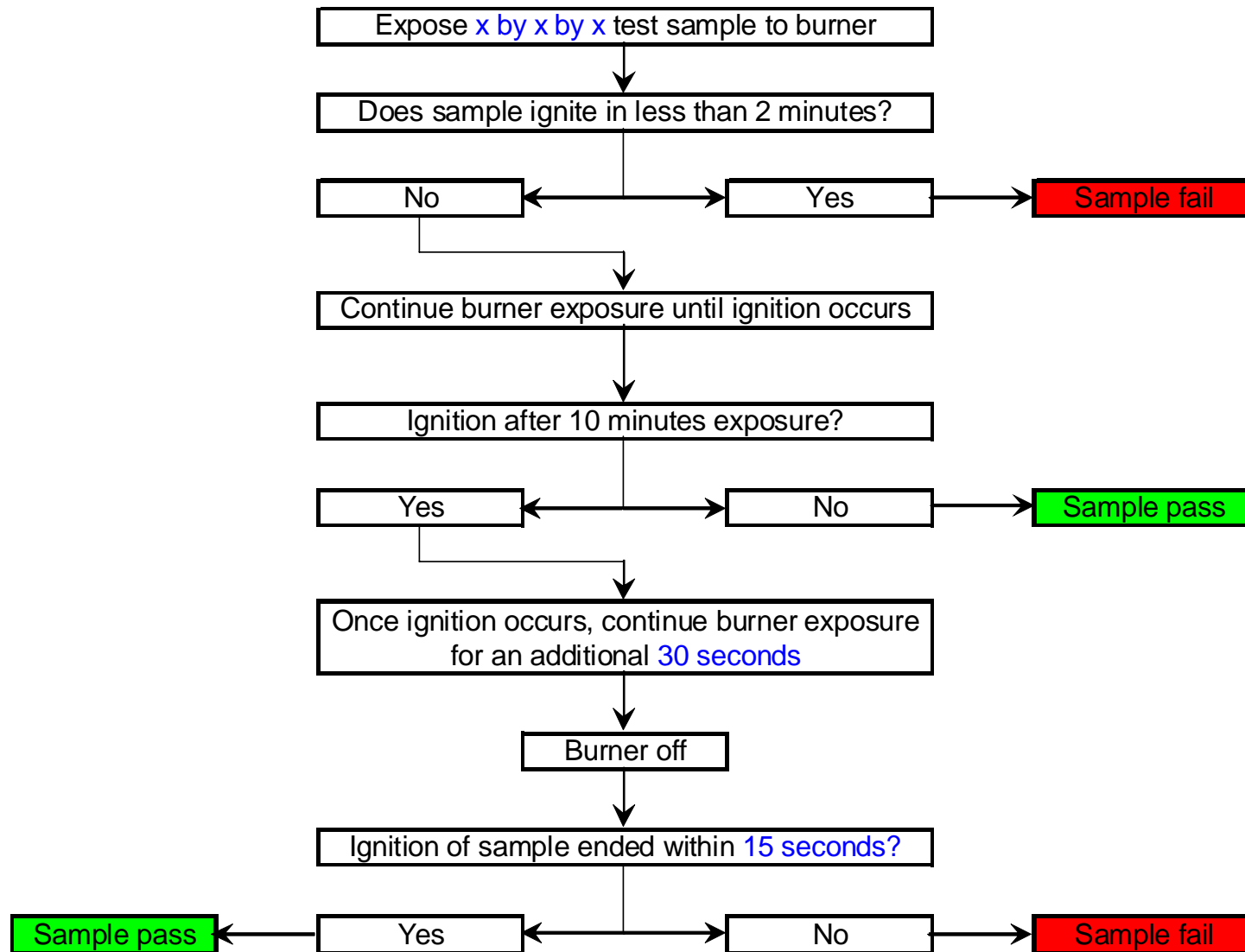
- A. Radiant Panel (insulation, ducting, wiring, composite fuselage)
- B. Oil Burner – cargo liner
- C. Fire Containment
- D. Bunsen burner

## Appendix F Part II: Requirements for Postcrash Fire Threats

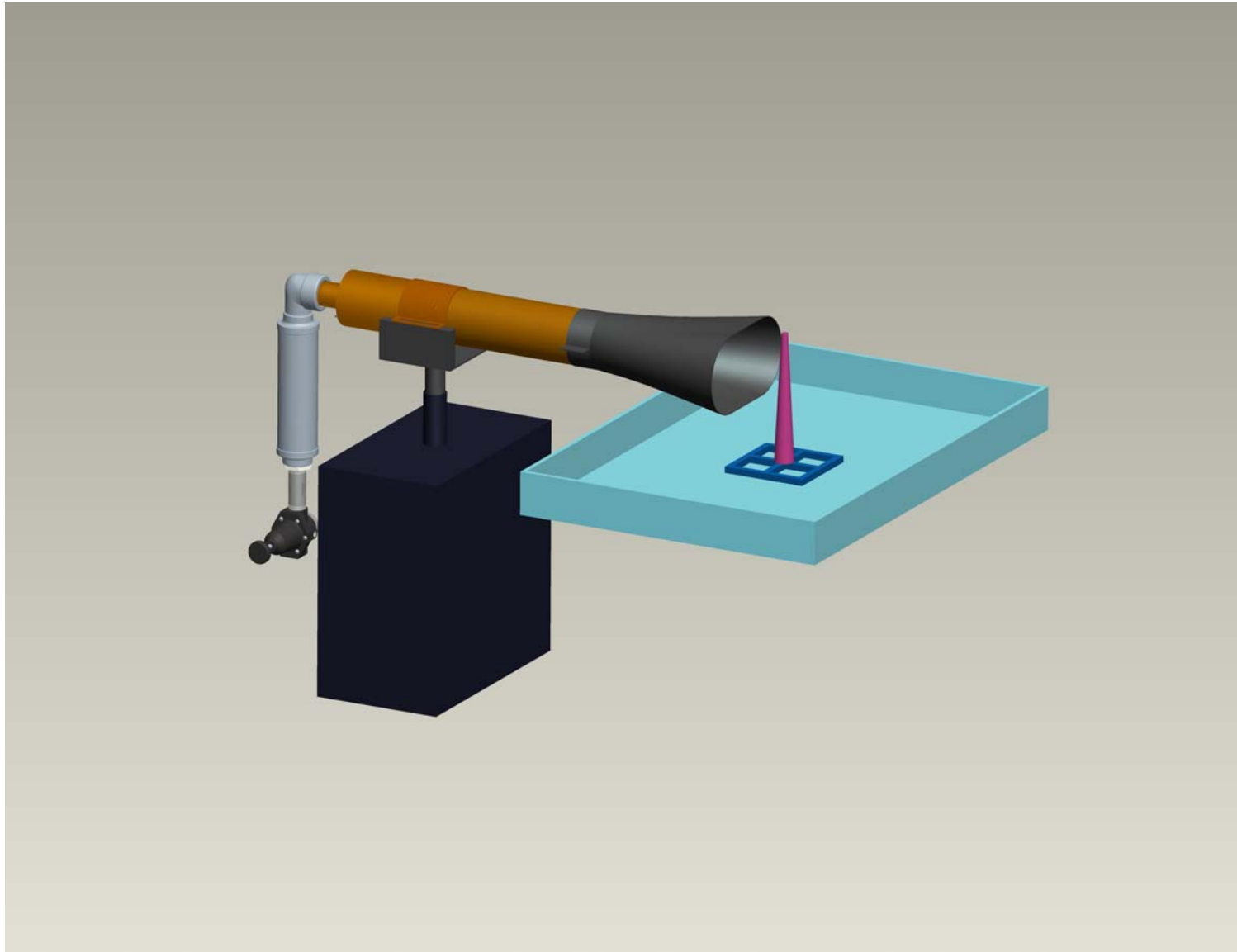
- A. OSU
- B. Oil Burner – seats
- C. Oil Burner - insulation
- D. Escape Slide radiant heat

E. Oil Burner – seat structure

# Possible Methodology for Testing Flammability of Magnesium Alloy



# Proposed Magnesium Alloy Flammability Test



# Review of Discussion from Previous Meeting

Why use a standard sample (cone) rather than shapes more representative of actual components?

Complex shapes typical of components would make testing difficult, costly, time-consuming.



# Review of Discussion from Previous Meeting

Why use a standard sample (cone) rather than shapes more representative of actual components?

Mag-alloy must melt before it burns. Melting process results in somewhat random shape



## Review of Discussion from Previous Meeting

Why use a standard sample (cone) rather than shapes more representative of actual components?

Conical sample adds stability. Other shapes result in separation from threat.



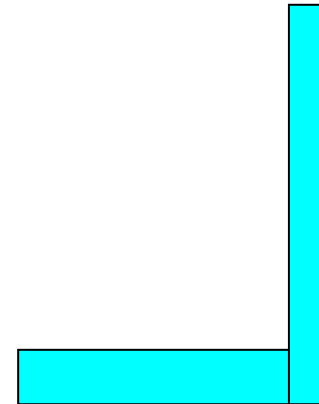
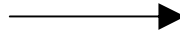


# Review of Discussion from Previous Meeting

Argument: standard sample (cone) not representative of actual components



represented by



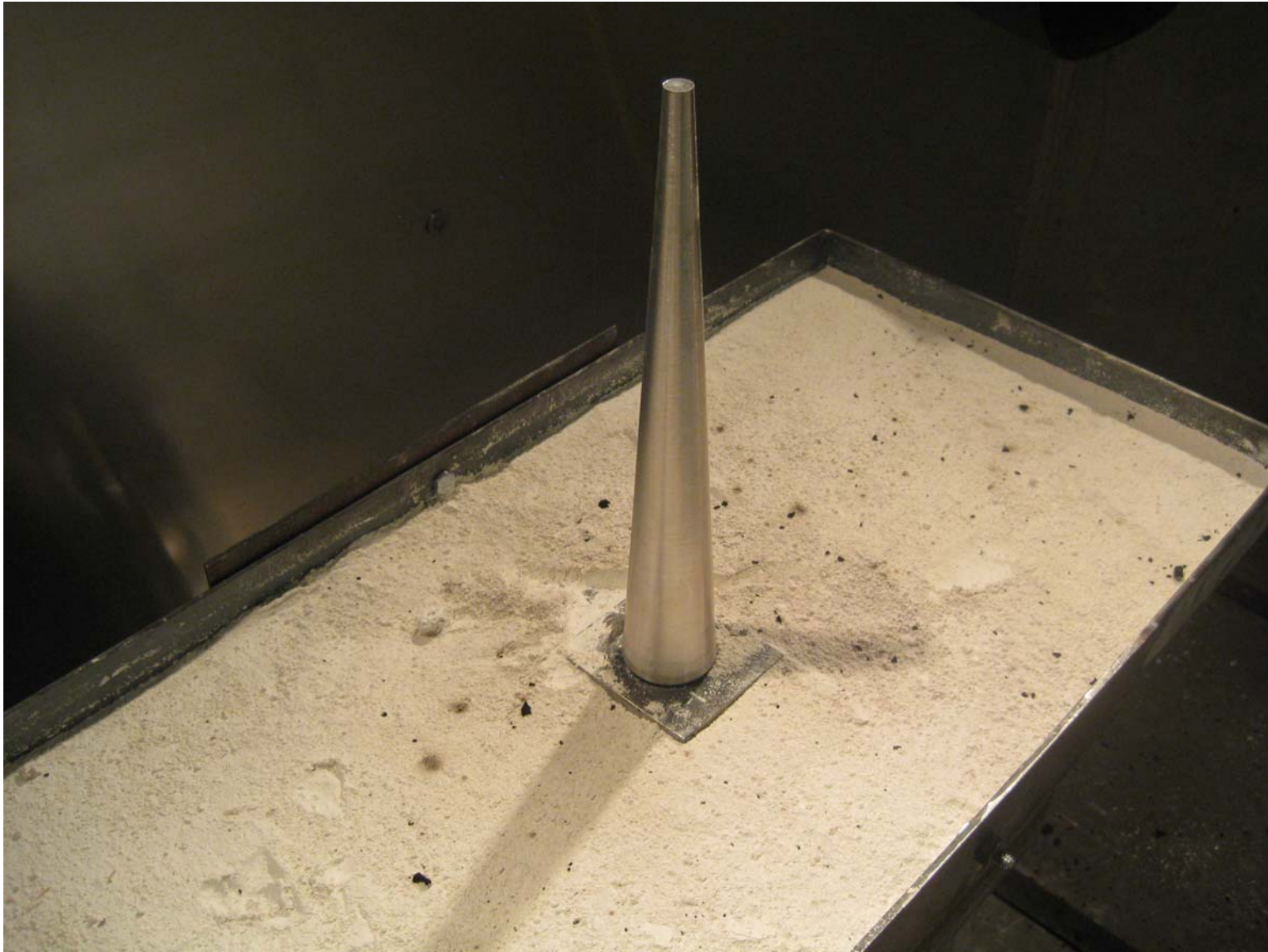
# Review of Discussion from Previous Meeting

Testing has revealed 2 key elements:

1. Ease of ignition (how quickly will a sample ignite?)
2. Duration of burning once ignited (will material self-extinguish?)

*Proceed with testing of truncated cone samples*

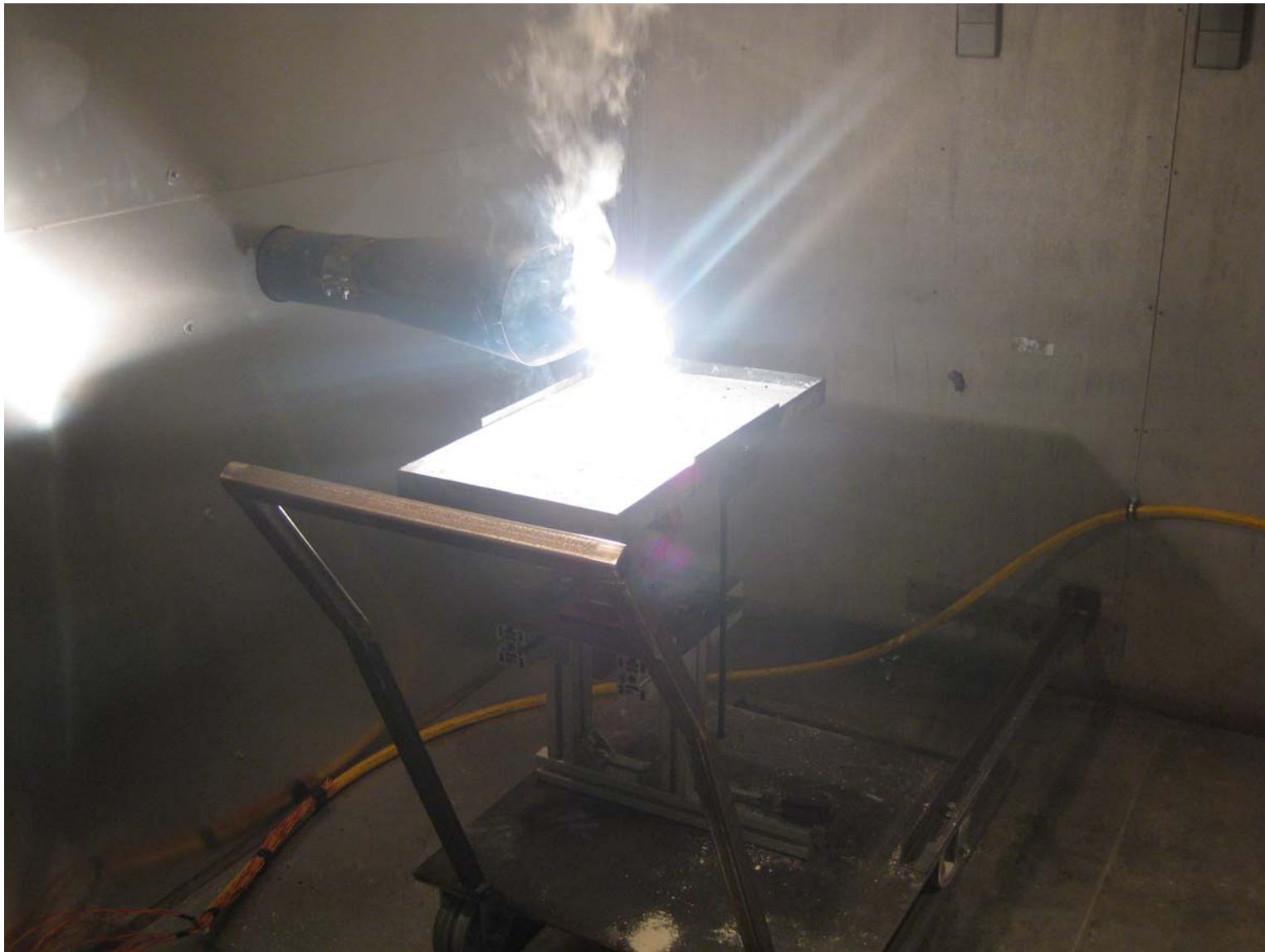
# Truncated Cone Test Sample of AZ-31 Magnesium Alloy



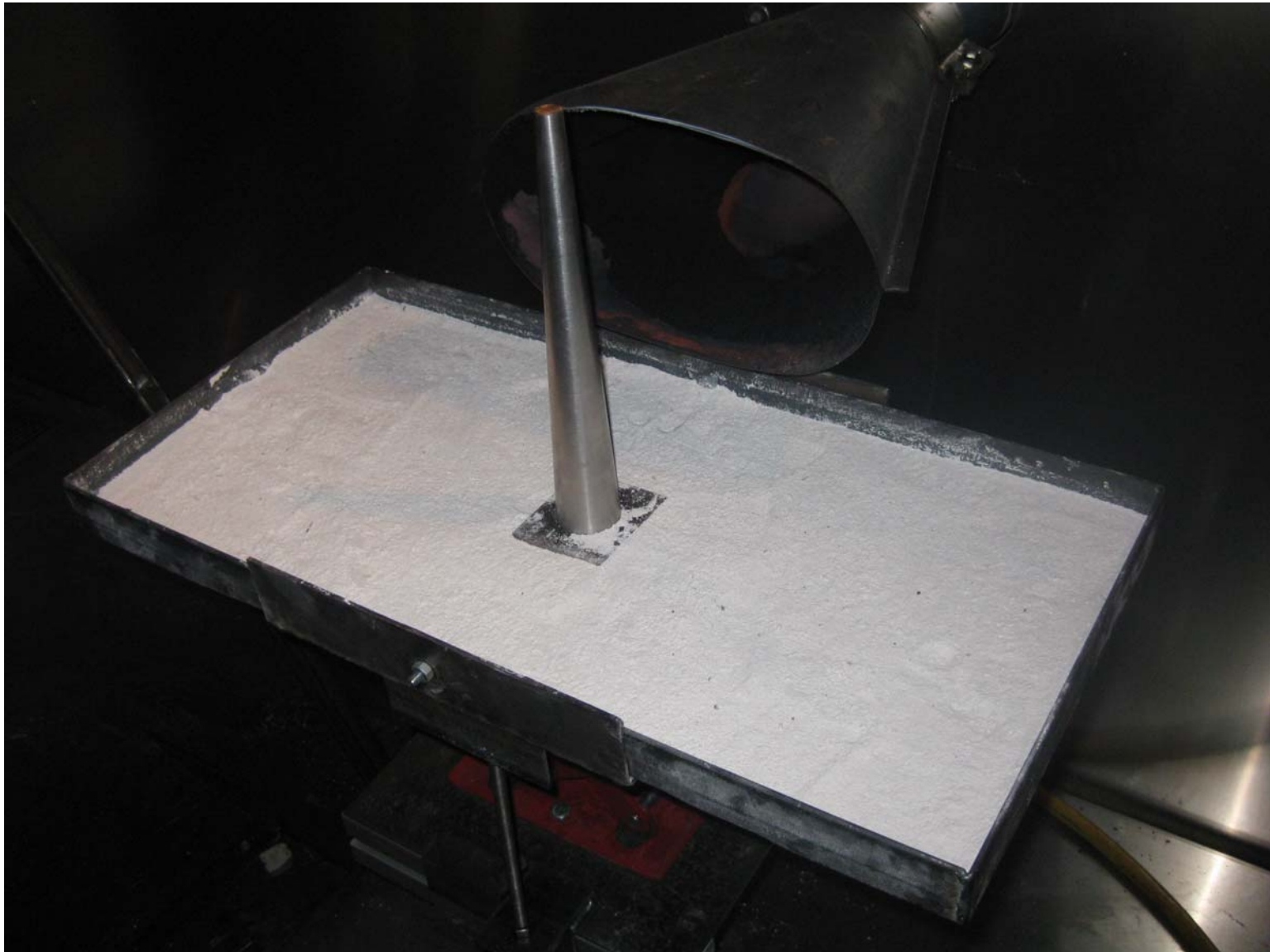
# Truncated Cone Test Sample of AZ-31 Magnesium Alloy



# Truncated Cone Test Sample of AZ-31 Magnesium Alloy



# Truncated Cone Test Sample of WE-43 Magnesium Alloy



# Truncated Cone Test Sample of WE-43 Magnesium Alloy



# Truncated Cone Test Sample of WE-43 Magnesium Alloy





# Truncated Cone Test Sample of WE-43 Magnesium Alloy



# Preliminary Test Results (8 Test Samples)

Date Tested	#	Material Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in <sup>2</sup> )	Volume (in <sup>3</sup> )	Surface to Volume Ratio	Time to Melt (Min:Sec)	Time to Melt (Sec)	Melting Rate (in <sup>3</sup> /min)	2nd Melt	Time to Ignition (Min:Sec)	Burner Exposure (Min:Sec)	Time Ignition Ends (Min:Sec)	Duration of Ignition (Min:Sec)
2/8/2011	1	WE-43	1.58	0.59	10.1875	36.9784	10.0575	3.68	02:30	150	4.02		03:40	04:00	05:40	01:40
2/8/2011	2	AZ-31	1.58	0.40	10.1563	33.7190	8.7498	3.85	01:38	98	5.36		01:50	03:00	30:00	27:00
2/8/2011	4	WE-43	1.57	0.39	10.0000	32.8965	8.4543	3.89	01:42	102	4.97		02:30	03:00	04:20	01:20
2/8/2011	14	WE-43	1.58	0.60	10.2500	37.3829	10.2089	3.66	02:22	142	4.31		02:54	03:30	04:35	01:05
2/8/2011	15	WE-43	1.57	0.39	9.8125	32.3203	8.2958	3.90	02:05	125	3.98		02:25	03:10	03:10	00:00
2/16/2011	17	WE-43	1.58	0.59	10.1875	37.0004	10.0728	3.67	05:00	300	2.01		06:45	07:15	09:45	02:30
2/24/2011	24	WE-43	0.60	0.60	10.1875	19.7685	2.8804	6.86	01:40	100	1.73		02:40	03:10	03:10	00:00
2/24/2011	25	AZ-31	1.57	0.40	10.0000	33.0592	8.5161	3.88	02:00	120	4.26		02:00	04:00	30:00	26:00

# Truncated Cone: Problems Encountered During Preliminary Tests

Problem 1: Upper portion of cone sometimes falls off, away from bulk of sample

*Possible solution 1: stepped cone could decrease the likelihood of upper portion falling away*

*Possible solution 2: thinner cone could decrease the likelihood of upper portion falling away*

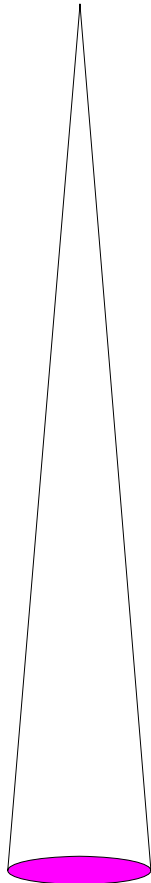
*Possible solution 3: adjust exposure of sample, to induce slower melting*

Problem 2: Costly to manufacture truncated cone samples?

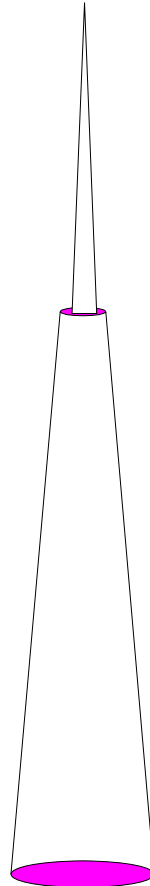
*Possible solution 1: stepped, rectangular cross-section sample*

# Other Possible Test Sample Shapes

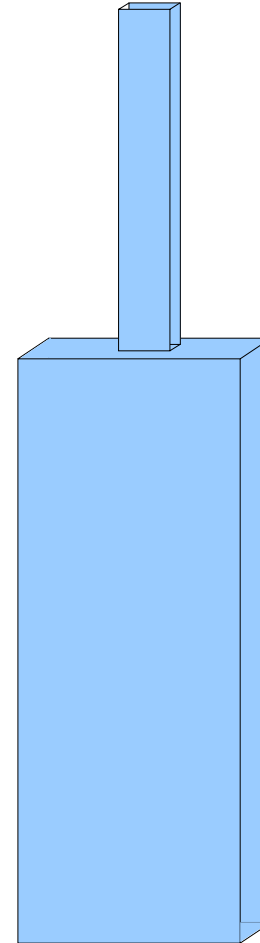
Thinner Cone



Stepped Cone



Rectangular Cross-section



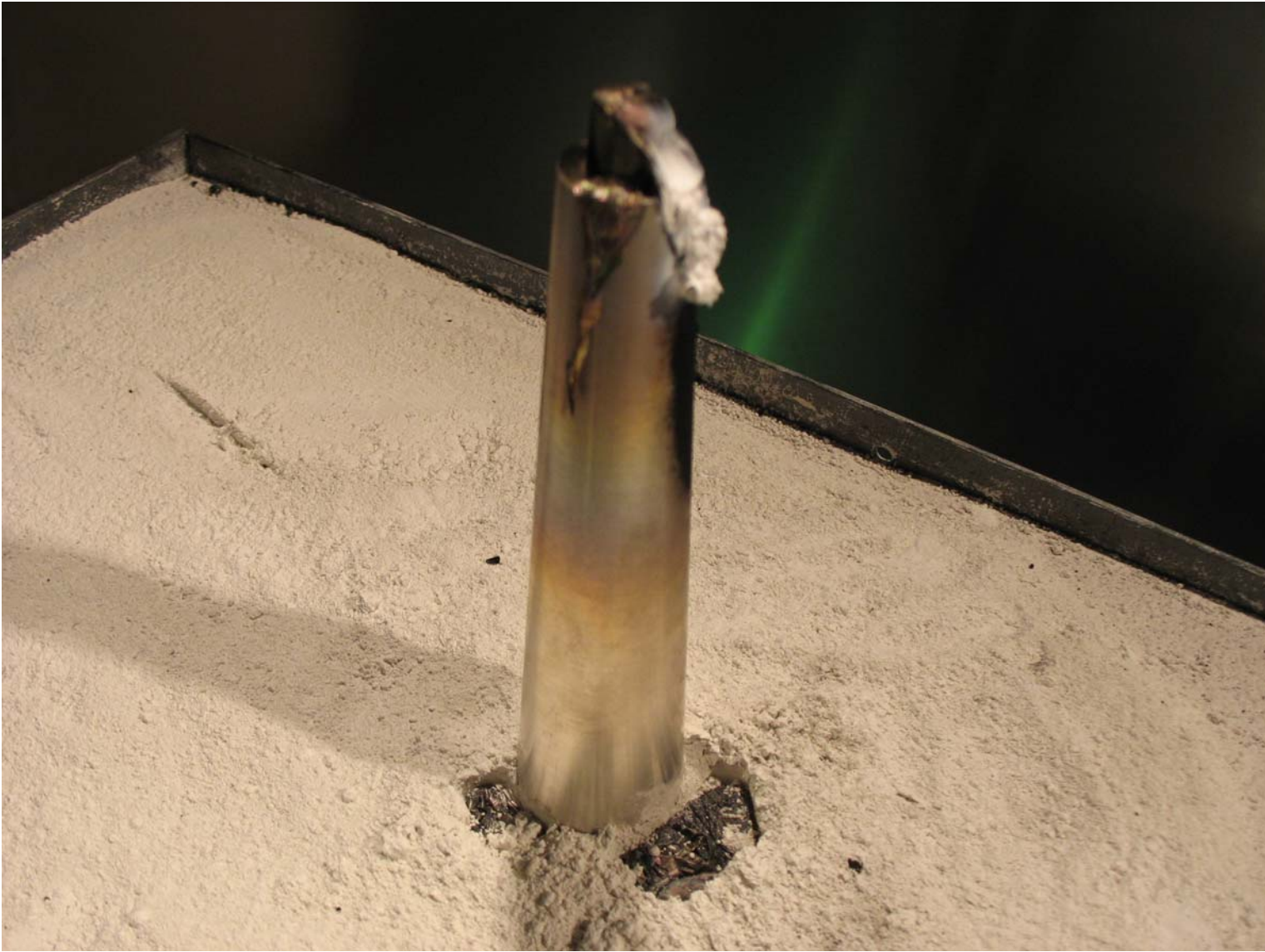
# Stepped Cone Sample



# Stepped Cone Sample

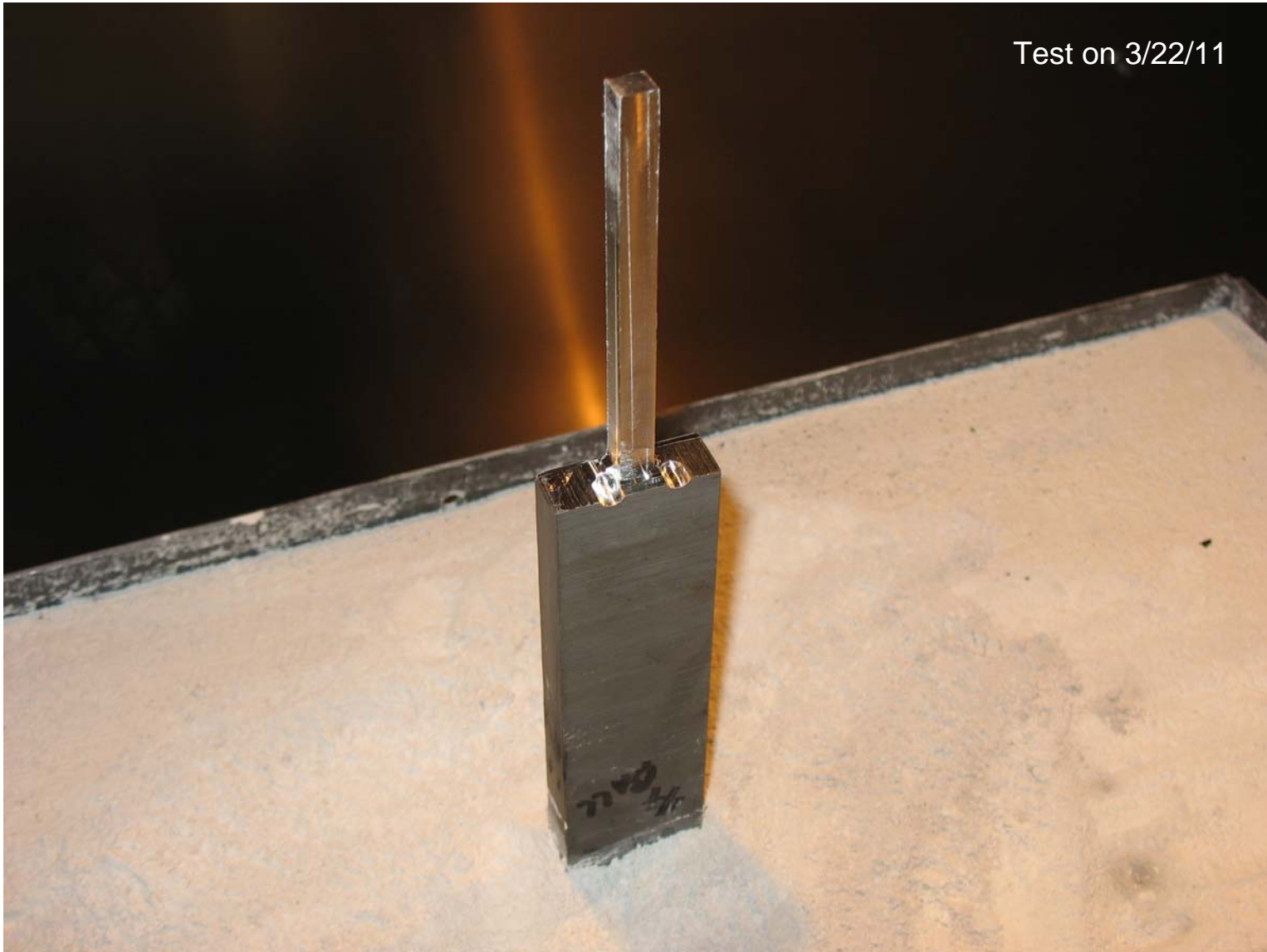


# Stepped Cone Sample



# Rectangular Cross-Section Sample

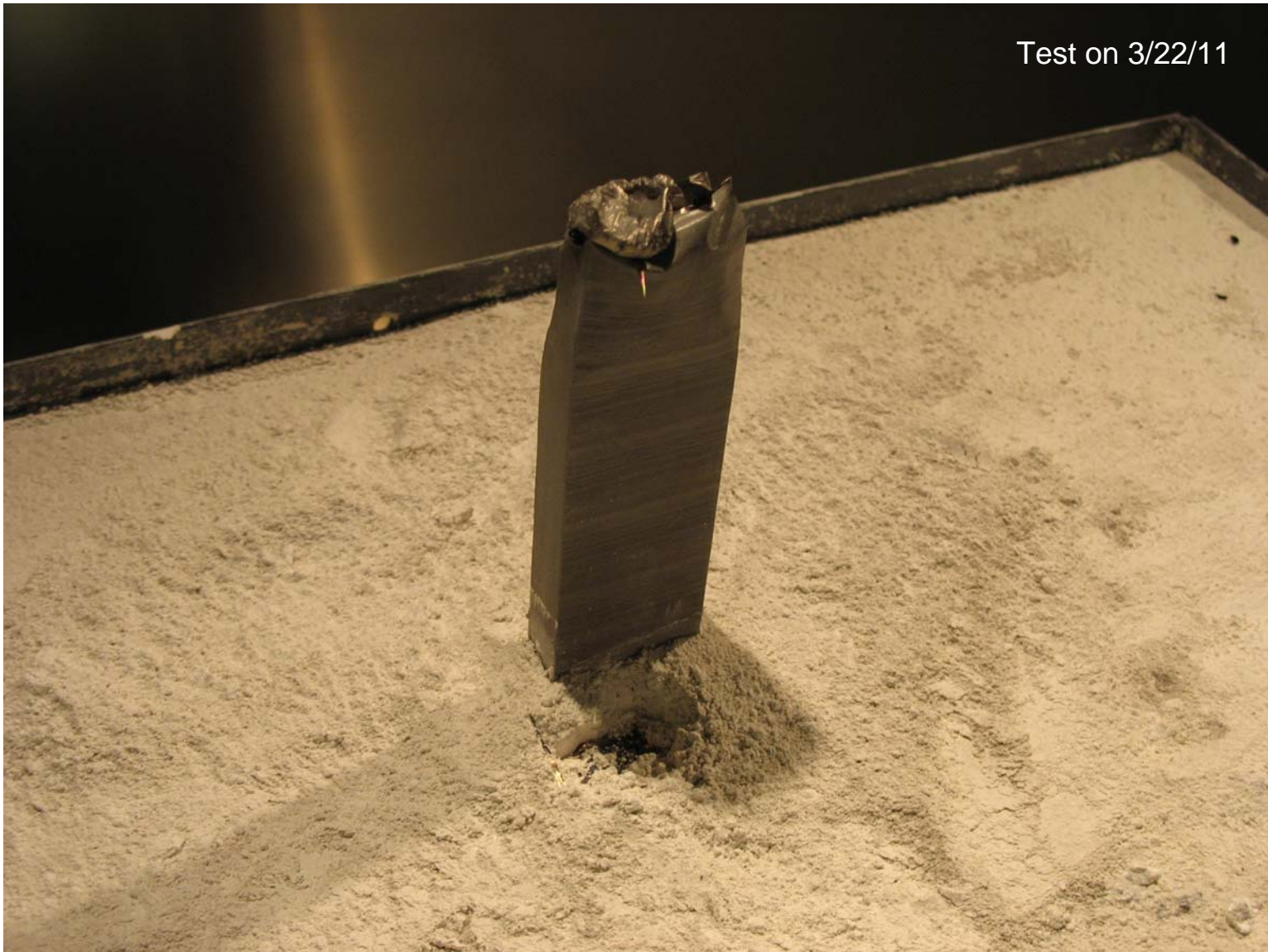
Test on 3/22/11





# Rectangular Cross-Section Sample

Test on 3/22/11

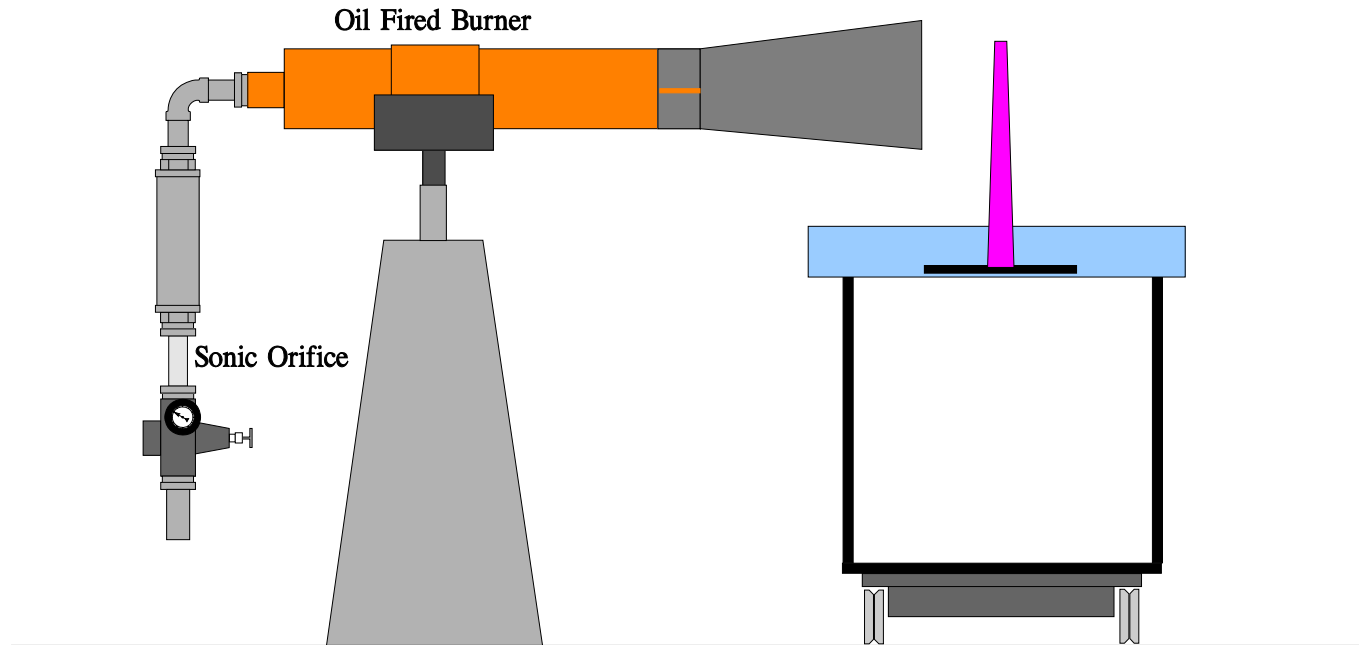


# Rectangular Cross-Section Sample

Test on 3/22/11



# Experimentation With Exposure

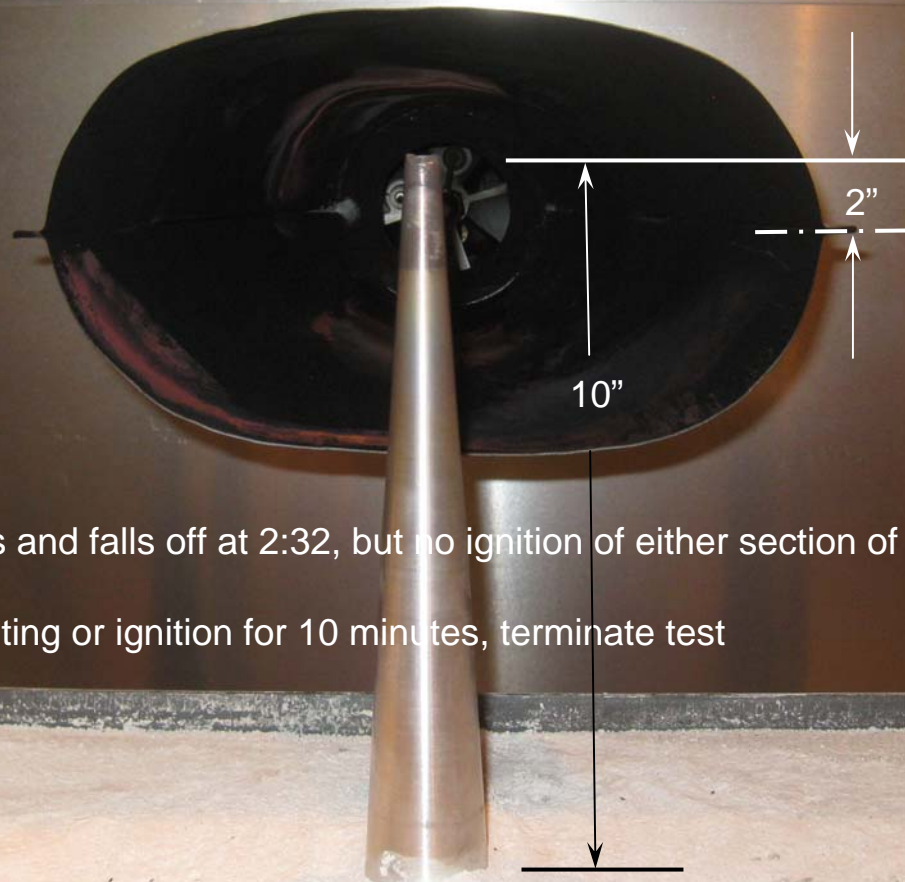


Objective: reproduce results shown in full-scale tests

*WE-43: After several minutes of exposure, remove burner, sample burns for approx 1 minute*

# Truncated Cone Test Sample of WE-43 Magnesium Alloy

Test on 3/23/11  
Sample 42



Top section melts and falls off at 2:32, but no ignition of either section of material  
No additional melting or ignition for 10 minutes, terminate test

# Truncated Cone of WE-43, 6 Inches High

Test on 3/28/11

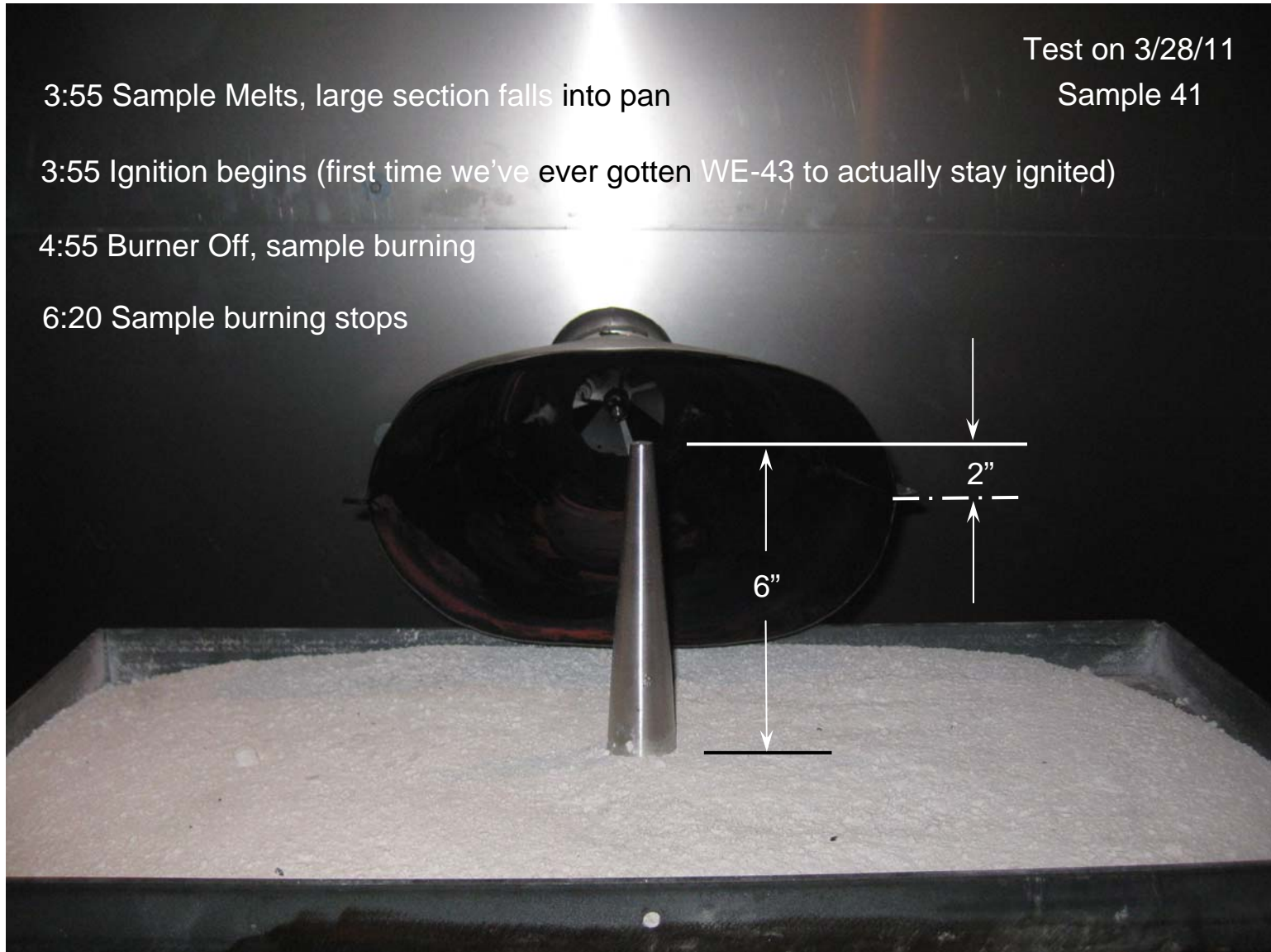
3:55 Sample Melts, large section falls into pan

Sample 41

3:55 Ignition begins (first time we've ever gotten WE-43 to actually stay ignited)

4:55 Burner Off, sample burning

6:20 Sample burning stops



# Truncated Cone of WE-43, 6 Inches High (Post test)



# Truncated Cone of WE-43, 6 Inches High (repeat)

Test on 3/28/11

Sample 26

2:15 Small section of sample top melts, falls into pan

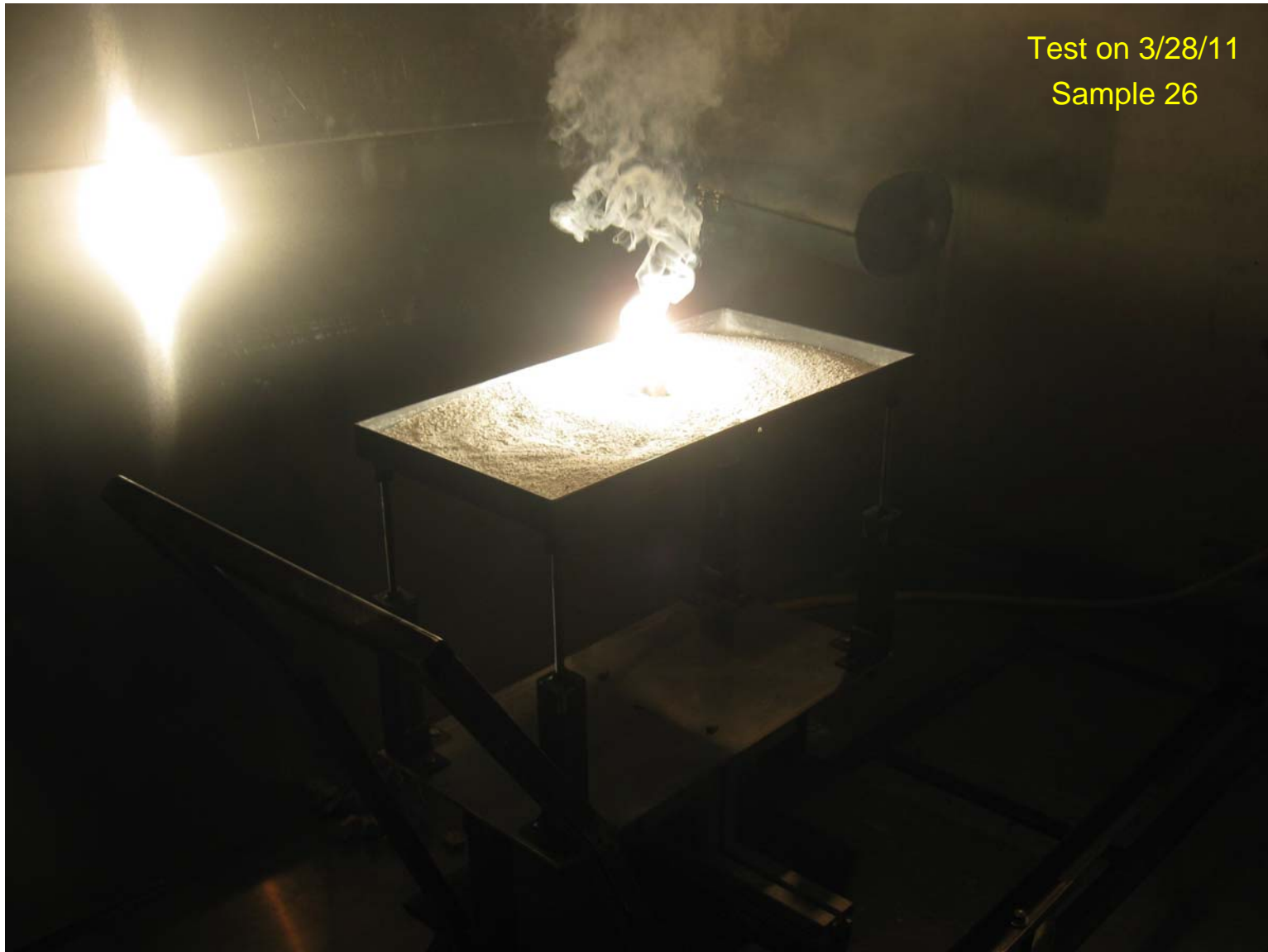
2:15-3:30 top of sample slumping downward

3:30 Slumped section falls into pan, ignition begins

4:00 Burner off

13:30 Sample burning stops

# Truncated Cone of WE-43, 6 Inches High (repeat)





# Truncated Cone of WE-43, 6 Inches High (Sample 35)

3/29/2011  
Sample 35

2:30 Small section of sample top melts, falls into pan

2:30-3:30 top of sample slumping downward

3:30 Slumped section falls into pan

3:42 Ignition begins

4:00 Burner off

5:30 Sample burning stops

# Truncated Cone of AZ-31, 6 Inches High (Sample 11)

*...to determine if there is a difference between AZ and WE under this configuration*



# Summary of Truncated Cone Testing (8 Samples)

Date Tested	#	Mat'l Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in <sup>2</sup> )	Vol (in <sup>3</sup> )	Surface to Volume Ratio	Time to Melt	Time to Melt (Sec)	Melting Rate (in <sup>3</sup> /min)	Secondary Melting	Time to Ignition	Burner Exposure	Time Ignition Ends	Duration of Ignition
3/23/2011	7	WE-43	1.567	0.3915	9.1875	30.371	7.750	3.92	x	x	x	x	x	10:00	10:00	00:00
3/23/2011	7A	WE-43	1.567	0.3915	9.1875	30.371	7.750	3.92	x	x	x	x	x	10:30	10:30	00:00
3/23/2011	7B	WE-43	1.567	0.3915	9.1875	30.371	7.750	3.92	08:00	480	0.97	x	x	12:00	12:00	00:00
3/23/2011	42	WE-43	1.572	0.3935	10.0625	33.183	8.547	3.88	02:32	152	3.37	x	x	10:00	10:00	00:00
3/28/2011	41	WE-43	1.298	0.3965	6.0000	17.456	3.700	4.72	03:55	235	0.94	no	03:55	04:55	06:20	01:25
3/28/2011	26	WE-43	1.075	0.3960	6.0000	14.911	2.728	5.47	02:15	135	1.21	03:30	03:30	04:00	13:30	09:30
3/29/2011	35	WE-43	1.096	0.3915	6.0000	15.102	2.800	5.39	02:30	150	1.12	03:30	03:42	04:00	05:30	01:30
3/29/2011	11	AZ-31	1.088	0.3915	6.0000	15.018	2.769	5.42	02:20	140	1.19	no	02:20	03:00	20:00	17:00



# Summary of Additional Truncated Cone Testing (9 Samples)

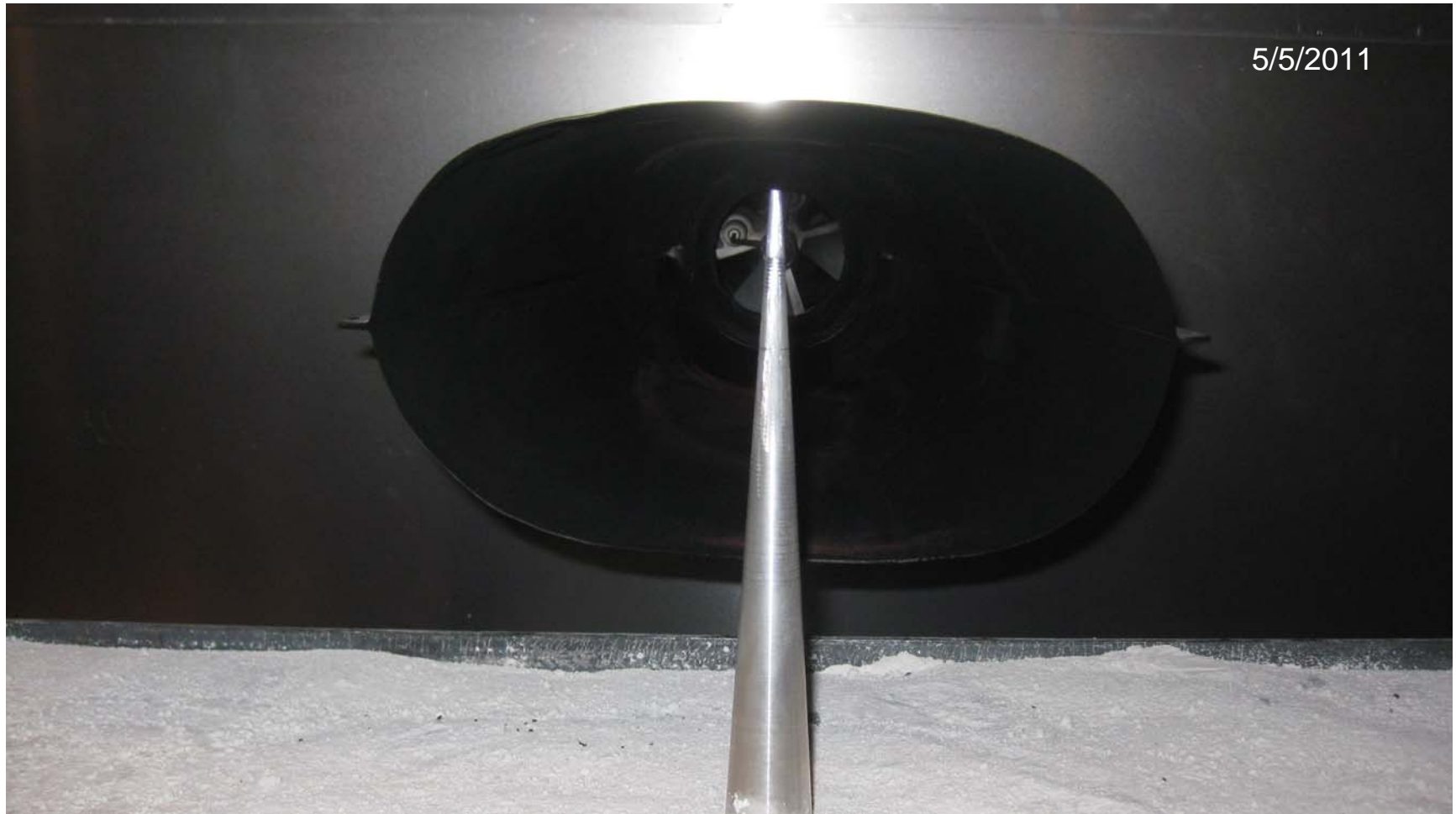
...continue using 6-inch high samples...

Date Tested	#	Mat'l Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in <sup>2</sup> )	Vol (in <sup>3</sup> )	Surface to Volume Ratio	Time to Melt	Time to Melt (Sec)	Melting Rate (in <sup>3</sup> /min)	Secondary Melting	Time to Ignition	Burner Exposure	Time Ignition Ends	Duration of Ignition
4/1/2011	31	WE-43	1.176	0.5935	6.0000	18.060	3.822	4.73	03:52	232	0.99	04:47	04:57	06:52	08:05	01:13
4/1/2011	36	WE-43	1.100	0.3950	6.0000	15.187	2.828	5.37	03:08	188	0.90	04:23	05:15	06:15	06:40	00:25
4/1/2011	37	WE-43	1.120	0.3940	6.0000	15.402	2.907	5.30	02:37	157	1.11	03:53	04:50	05:50	07:00	01:10
4/1/2011	16	AZ-31	1.120	0.400	6.0000	15.462	2.925	5.29	02:15	135	1.30	no	02:15	03:00	20:00	17:00

...use larger head diameter, smaller base diameter, maintain surface-to-volume ratio...

4/14/2011	32	WE-43	0.875	0.5850	6.0000	14.629	2.542	5.75	02:51	171	0.89	03:20	03:50	05:05	18:05	13:00
4/14/2011	28	WE-43	0.938	0.5750	6.0000	15.211	2.747	5.54	02:46	166	0.99	no	03:54	04:54	20:00	15:06
4/14/2011	29	WE-43	0.936	0.5895	6.0000	15.345	2.789	5.50	02:38	158	1.06	03:21	04:00	05:00	18:00	13:00
4/14/2011	1	EL-21	1.101	0.3915	8.1250	20.132	3.819	5.27	01:52	112	2.05	03:20	03:30	04:30	20:00	15:30
4/14/2011	2	EL-21	1.098	0.3915	8.0625	19.942	3.773	5.29	01:55	115	1.97	02:27	04:14	05:14	14:00	08:46

# Thinner Cone Sample



# Summary of Additional Truncated Cone Testing (6 Samples)

...increase sample length to 8-inches, reduce head diameter...

Date Tested	#	Mat'l Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in <sup>2</sup> )	Vol (in <sup>3</sup> )	Surface to Volume Ratio	Time to Melt	Time to Melt (Sec)	Melting Rate (in <sup>3</sup> /min)	Secondary Melting	Time to Ignition	Burner Exposure	Time Ignition Ends	Duration of Ignition
5/5/2011	x	AZ-31	1.093	0.113	7.8750	15.895	2.744	5.79	00:35	35	4.70	no	00:45	01:15	03:15	02:00
5/5/2011	x	AZ-31	1.090	0.118	8.1250	16.383	2.829	5.79	00:43	43	3.95	no	01:34	02:34	05:34	03:00
5/5/2011	x	WE-43	1.090	0.115	7.9375	15.990	2.756	5.80	01:33	93	1.78	06:20	NA	07:00	07:00	00:00
5/5/2011	x	WE-43	1.093	0.120	8.0000	16.214	2.806	5.78	01:12	72	2.34	02:38	02:45	03:45	07:30	03:45
5/5/2011	25	AZ-31	1.570	0.400	10.0000	33.059	8.516	3.88	2:00	120	4.26	no	02:00	04:00	20:00	16:00
5/25/2011	x	WE-43	1.090	0.115	8.0000	16.114	2.779	5.80	01:05	65	2.56	03:45	01:30	04:00	05:35	01:35

# Summary of Additional Truncated Cone Testing (8 Samples)

...increase sample length back to 10-inch high samples...

...fix exposure time to 4:00 or 5:00...

Date Tested	#	Mat'l Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in <sup>2</sup> )	Vol (in <sup>3</sup> )	Surface to Volume Ratio	Time to Melt	Time to Melt (Sec)	Melting Rate (in <sup>3</sup> /min)	Secondary Melting	Time to Ignition	Burner Exposure	Time Ignition Ends	Duration of Ignition
5/12/2011	2	WE-43	1.567	0.391	10.1250	33.224	8.530	3.89	02:00	120	4.27	no	03:50	04:00	05:30	01:30
5/12/2011	3	WE-43	1.568	0.390	10.1250	33.244	8.541	3.89	01:52	112	4.58	02:36	02:58	04:00	04:50	00:50
5/12/2011	6	WE-43	1.567	0.390	10.1250	33.217	8.529	3.89	01:46	106	4.83	03:08	NA	04:00	04:00	00:00
5/12/2011	7	WE-43	1.570	0.390	10.1250	33.272	8.557	3.89	01:55	115	4.46	02:46	04:04	05:00	09:30	04:30
5/12/2011	1	WE-43	1.568	0.389	10.0625	33.035	8.482	3.89	02:02	122	4.17	03:40	04:40	05:00	05:08	00:08
5/12/2011	4	WE-43	1.573	0.390	9.7500	32.182	8.270	3.89	02:05	125	3.97	04:14	04:20	05:00	06:15	01:15
5/13/2011	5	WE-43	1.569	0.390	9.7500	32.110	8.234	3.90	02:22	142	3.48	04:19	NA	05:00	05:08	00:08
5/13/2011	8	WE-43	1.563	0.390	10.0625	32.951	8.438	3.91	02:01	121	4.18	04:05	02:15	05:00	05:10	00:10

# Summary of Final Truncated Cone Testing (10 Samples)

...maintain sample length at 10-inches high...

...fix exposure time to 4:00 or 5:00...

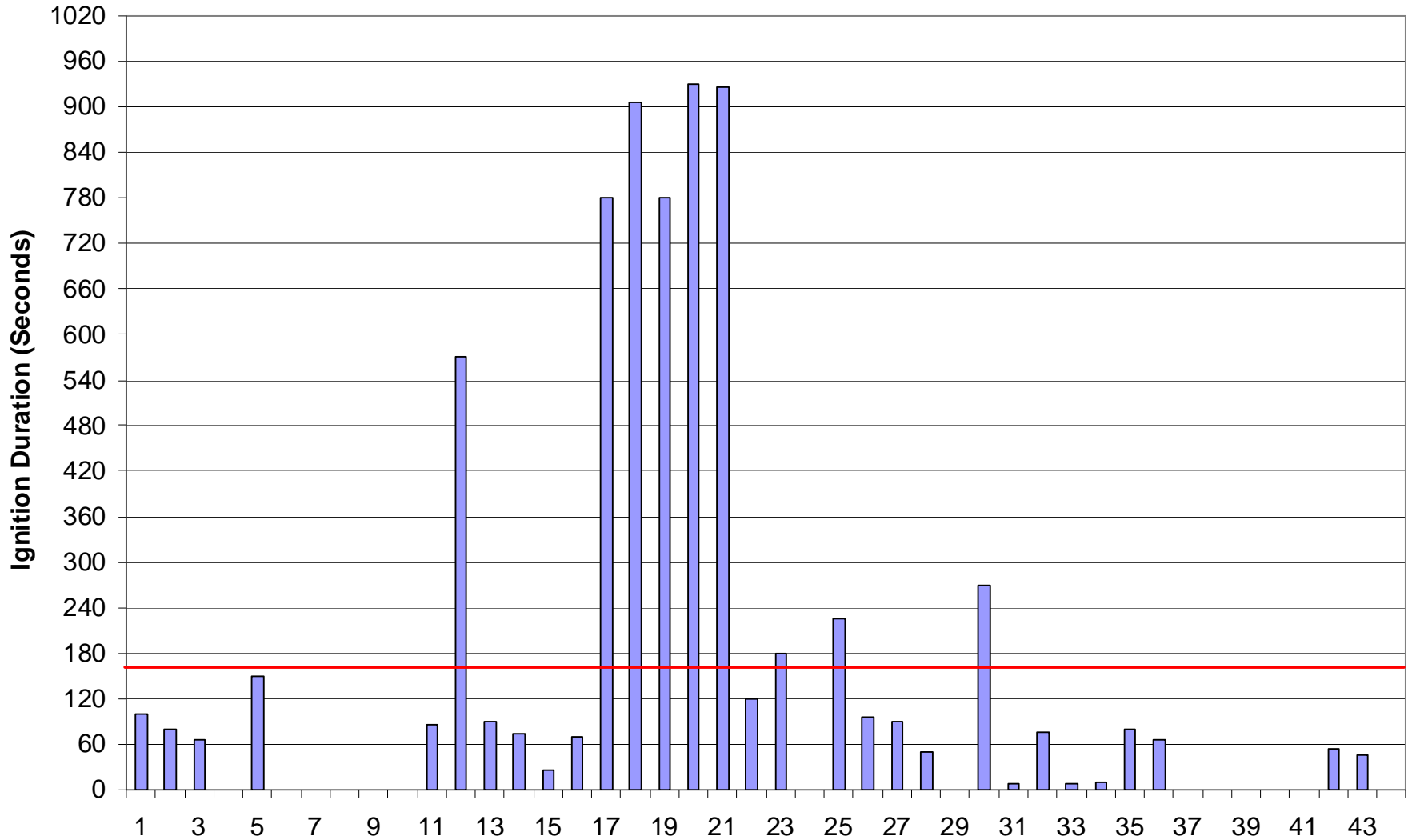
Date Tested	#	Mat'l Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in <sup>2</sup> )	Vol (in <sup>3</sup> )	Surface to Volume Ratio	Time to Melt	Time to Melt (Sec)	Melting Rate (in <sup>3</sup> /min)	Secondary Melting	Time to Ignition	Burner Exposure	Time Ignition Ends	Duration of Ignition
6/9/2011	1	WE-43	1.568	0.390	10.1875	33.436	8.594	3.89	02:01	121	4.26	03:27	02:10	05:00	06:20	01:20
6/9/2011	2	WE-43	1.571	0.391	10.1250	33.316	8.576	3.88	01:59	119	4.32	03:27	03:40	04:00	05:05	01:05
6/10/2011	3	WE-43	1.568	0.391	10.1875	33.452	8.600	3.89	02:21	141	3.66	NA	NA	04:00	04:00	00:00
6/10/2011	4	WE-43	1.569	0.390	10.1250	33.262	8.551	3.89	02:08	128	4.01	NA	NA	04:00	04:00	00:00
6/10/2011	5	WE-43	1.571	0.390	10.0625	33.107	8.516	3.89	02:46	166	3.08	NA	NA	05:00	05:00	00:00
6/10/2011	6	WE-43	1.572	0.391	10.1250	33.325	8.580	3.88	02:22	142	3.63	NA	NA	05:00	05:00	00:00
6/10/2011	1	WE-43	1.572	0.390	10.1250	33.308	8.574	3.88	02:18	138	3.73	04:00	NA	04:00	04:00	00:00
6/10/2011	2	WE-43	1.570	0.390	10.1875	33.473	8.613	3.89	01:51	111	4.66	02:52	02:10	04:00	04:54	00:54
6/10/2011	3	WE-43	1.575	0.390	10.0625	33.163	8.546	3.88	02:30	111	4.62	NA	02:55	04:00	04:45	00:45
6/10/2011	4	WE-43	1.570	0.392	10.1875	33.498	8.622	3.89	02:08	128	4.04	04:01	NA	04:00	04:00	00:00



# Summary of Final Truncated Cone Testing (10 Samples)



# Duration of Ignition WE-43 Samples



# Planned Activities for Summer 2011

Continue fine-tuning of test parameters (sample size, distance, exposure time)

Continue testing of various magnesium alloys, how do they react compared to WE-43 and AZ-31

- AZ91E
- AZ80
- ZK60
- ZE41
- Elektron 21
- Elektron 675

Continue to update sonic burner with set-up parameters obtained from seat burner trials

- Stator depth and angle
- Air pressure
- Location of muffler and elbow
- Updated fuel nozzle to increase calibration consistency

4/11/2011



4/14/2011

