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, Savannah

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Very Brief Recap 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

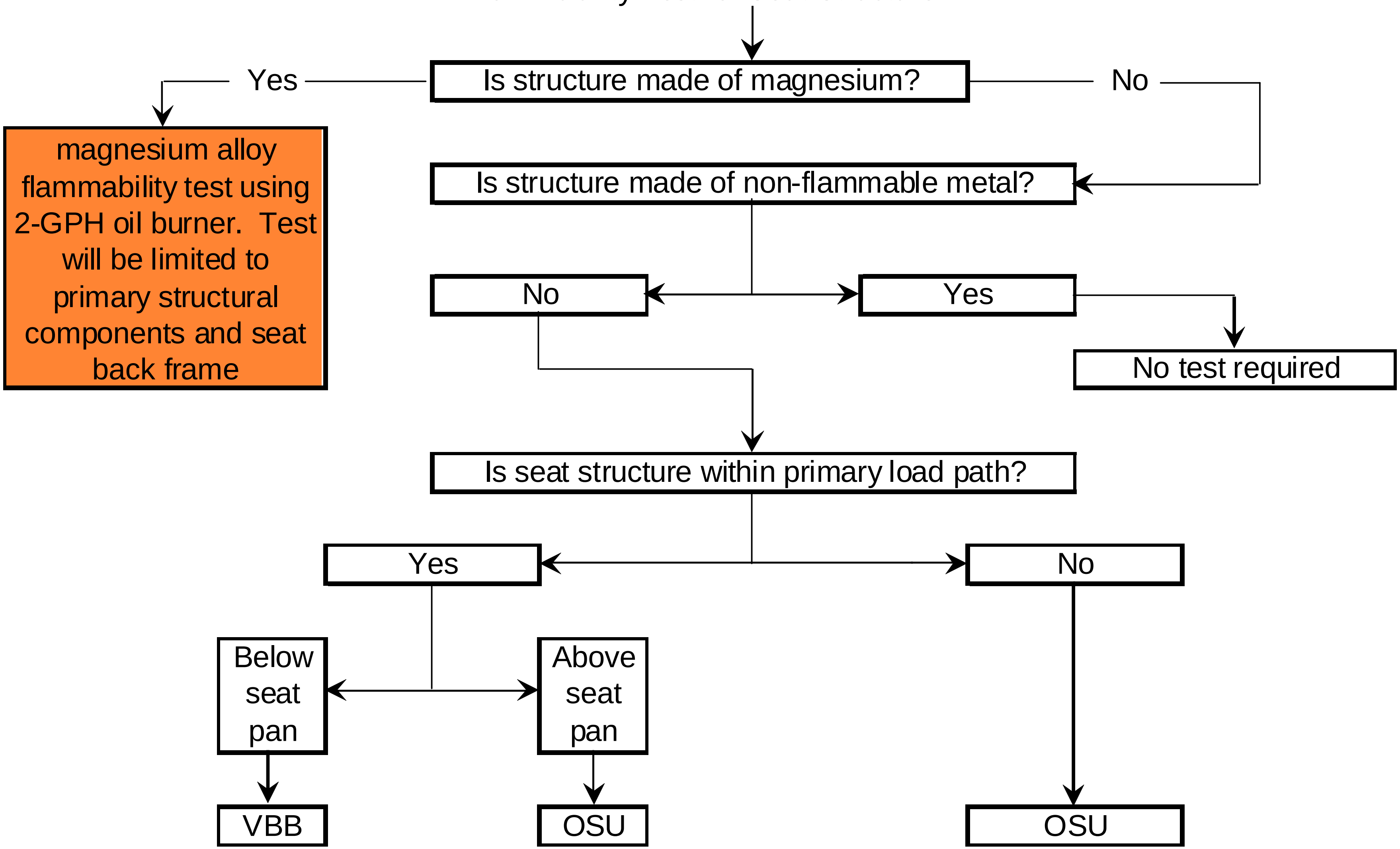
B. Oil Burner – seats

C. Oil Burner - insulation

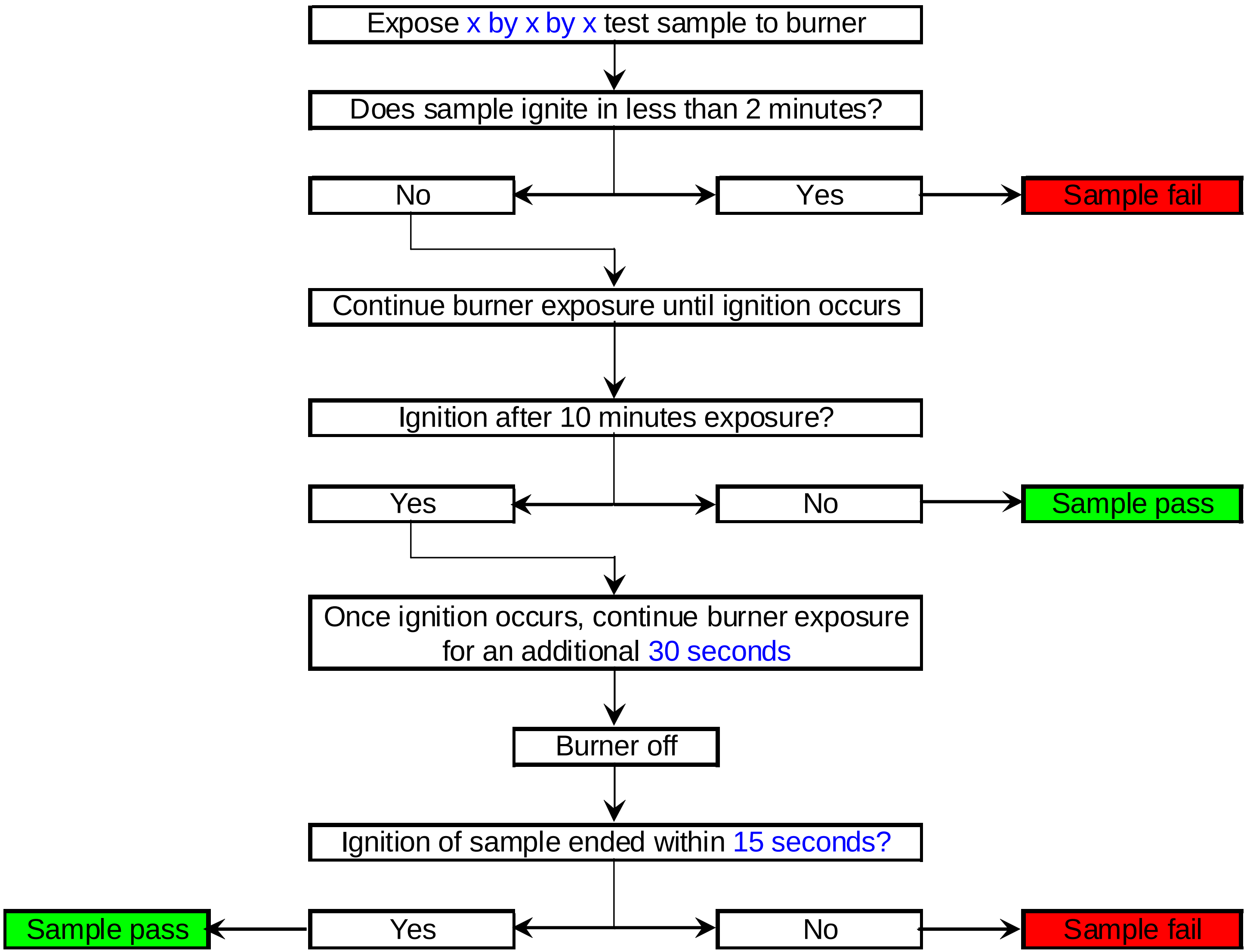
D. Escape Slide radiant heat

E. Oil Burner – seat structure

Flammability Test for Seat Structure



Possible Methodology for Testing Flammability of Magnesium Alloy, example 3



Chapter X (For New Appendix F)
Flammability Test for Magnesium Alloy Seat Structure

X.1 Scope

X.1.1 This test method evaluates the ignition resistance and flammability of magnesium alloy when used in the construction of aircraft seat structural components by utilizing a high-intensity open flame to show compliance to the requirements of part II B of Appendix F of CFR 25.853.

X.2 Definitions

X.2.1 Magnesium Alloy

A magnesium alloy is defined as any solid form of magnesium containing a variety of alloying materials, for example Zinc, or rare-earth elements. (should we include % to describe a magnesium component, ie, anything more than 5% is considered a magnesium part?)

X.2.2 Primary Load Path

The primary load path is the part of the seat structure that is structurally capable of carrying the passenger load according to the 16-g impact requirements.

X.2.3 Specimen Set

A specimen set consists of three or more replicate test samples of a particular magnesium-alloy used in the construction of an aircraft seat primary-load-path structural component.

X.3 Apparatus

X.3.1 Test Specimen Frame

The test specimen frame is shown in figures X-1 through X-3. The test specimen frame will be movable such that it can be positioned in front of the burner at the proper distance. The test specimen frame will be used for mounting the test specimen as shown in figure X-2.

X.3.1.1 Drip Pan

The test specimen frame will include a suitable drip pan lined with a layer of talc powder, capable of preventing back-splashing of molten magnesium. The drip pan should measure at least 16 inches wide by 16 inches long, and at least 6 inches deep. The sample holder can be mounted directly to the base of the drip pan.

X.3.1.2 Weight Scale (may not be necessary)

A weighing device will be provided to determine the pretest and posttest weights of each set of seat cushion specimens within 0.02 pound (9 g).

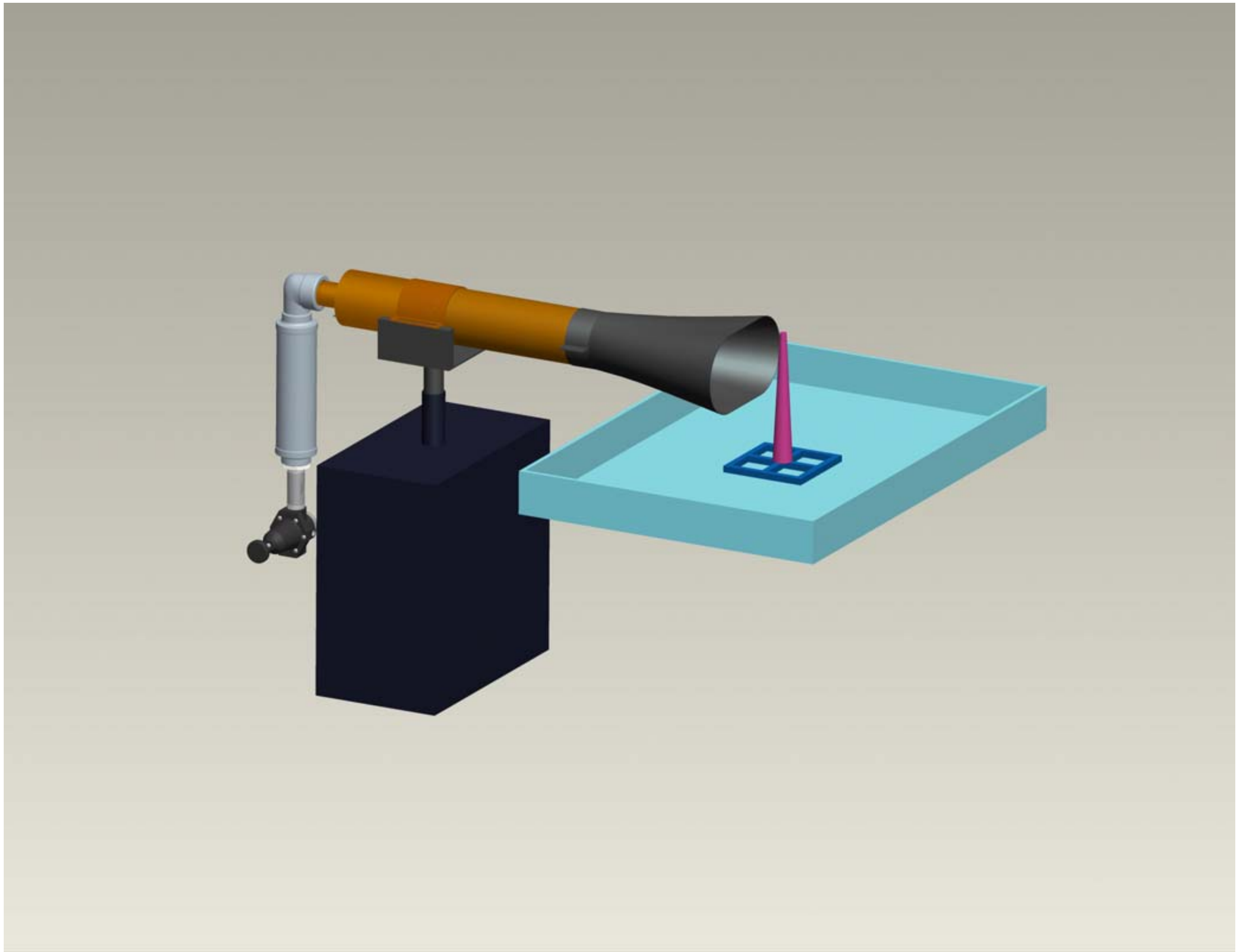


Figure X-1. Magnesium Alloy Testing Apparatus

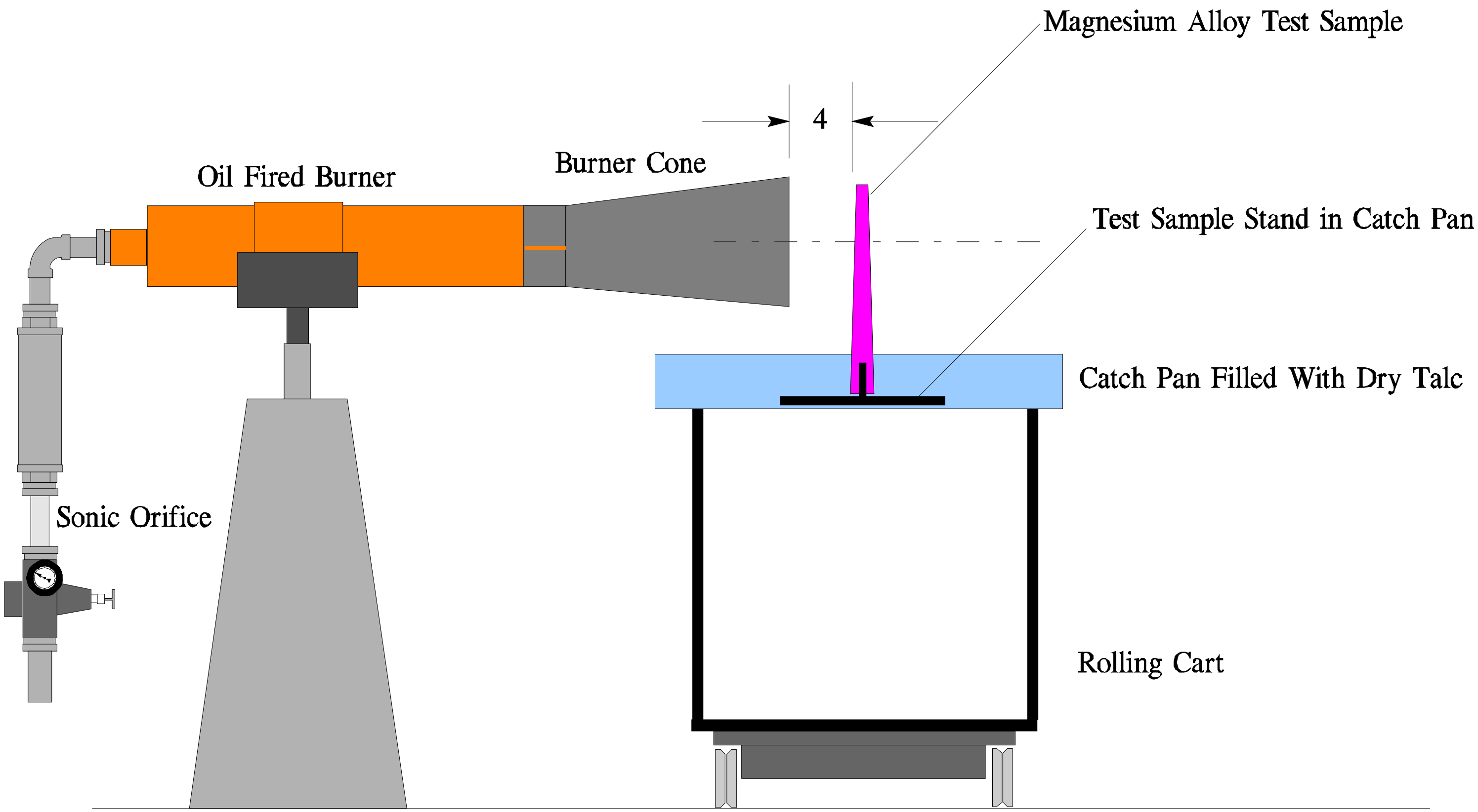


Figure X-2. Magnesium Alloy Testing Apparatus

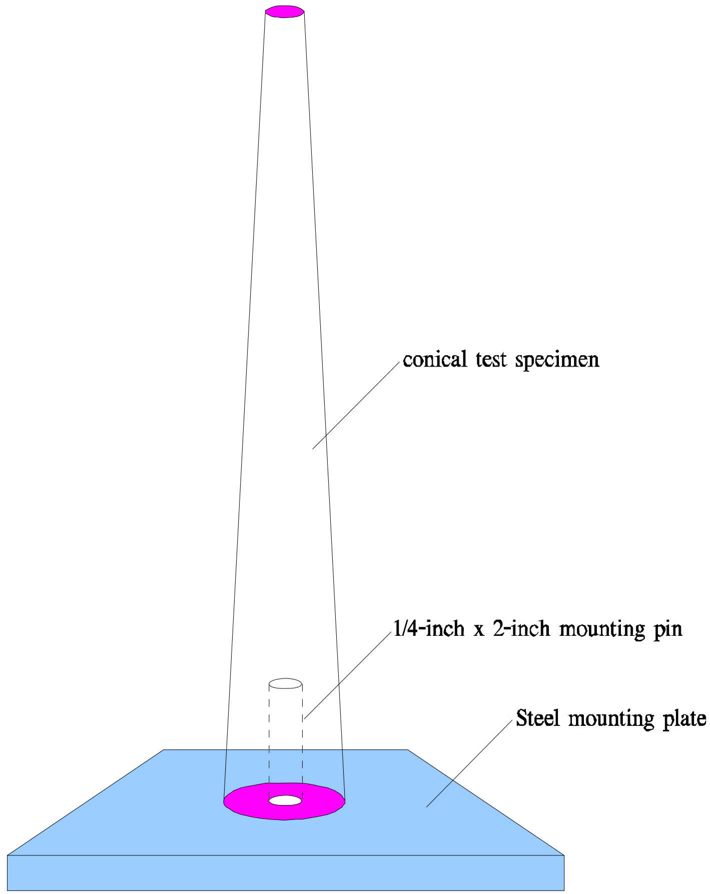


Figure X-3. Magnesium Alloy Test Specimen Mounting Frame

X.3.2 Test Burner

The test burner shall be a gun-type, using a pressurized, sprayed fuel charge in conjunction with a ducted air source to produce the burner flames. An interchangeable, screw-in fuel nozzle will be used to produce the conically-shaped fuel charge from a pressurized fuel source. A pressurized air source controlled via a regulated sonic orifice will supply the combustion air. The combustion air will be ducted through a cylindrical draft tube containing a series of diffusing vanes. The diffused combustion air will mix with the sprayed fuel charge in a bell-shaped combustion cone. The fuel/air charge will be ignited by a high-voltage spark electrode pair positioned in the vicinity of the fuel spray nozzle. Flame characteristics can be adjusted by varying the pressure of the regulated air into the sonic orifice (refer to more detailed section NG of the "report on new Appendix F" for details on the components and construction of this burner).

X.3.2.1 Fuel Nozzle

A fuel nozzle will be provided to maintain the fuel pressure to yield a nominal 2 ± 0.1 gal/hr (0.126 ± 0.0063 liter/min) fuel flow (see Chapter 8 Supplement).

X.3.2.2 Fuel

Either number 2 Grade kerosene or American Society for Testing and Materials (ASTM) D2 fuel (number 2 Grade fuel oil) will be used.

X.3.3 Thermocouples

The seven thermocouples to be used for calibration will be 1/16-inch (1.6-mm) ceramic packed, metal sheathed, type K (Chromel-Alumel), grounded junction thermocouples with a nominal 30 AWG size conductor. The seven thermocouples will be attached to a steel angle bracket to form a thermocouple rake for placement in the test stand during burner calibration, as shown in figure X-4 (update drawing). Possibility of using 1/8 inch thermocouples

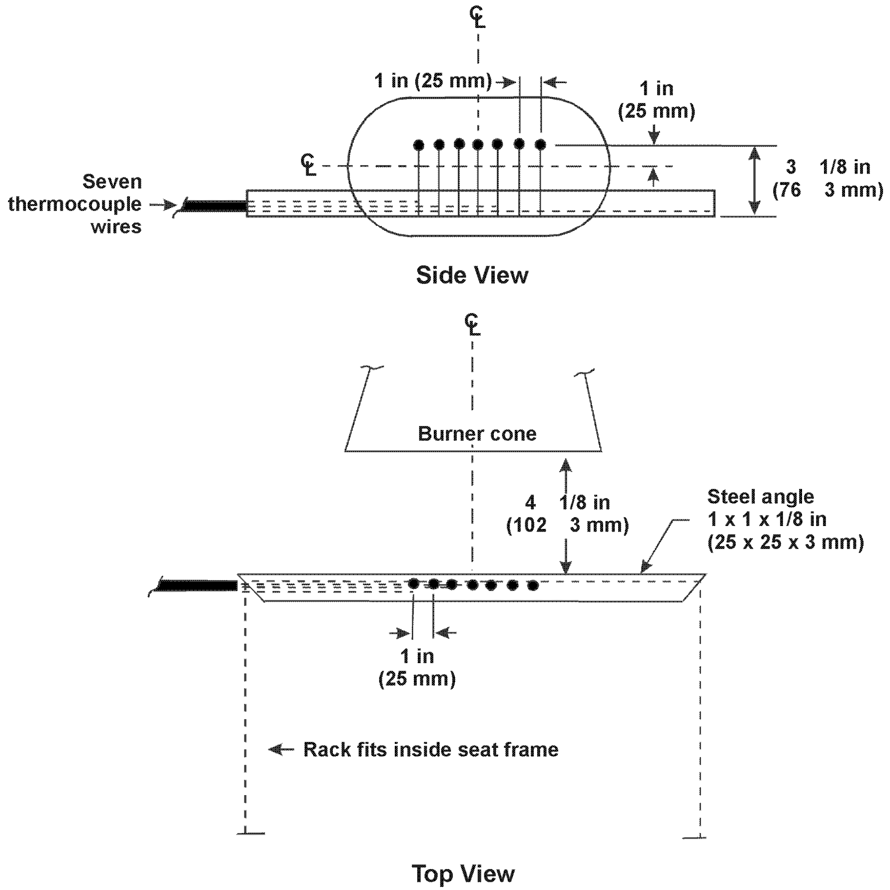


Figure X-4. Top and Side View of Thermocouple Rake Bracket

X.3.4 Instrumentation

A calibrated recording device or a computerized data acquisition system with an appropriate range will be provided to measure and record the outputs of the calorimeter and the thermocouples.

X.3.4.1 Timing Device

A stopwatch or other device, accurate to within 1 second/hour, will be provided to measure the time of application of the burner flame, the material flaming time, and the burnthrough time.

X.3.4.2 Anemometer

A vane-type air velocity sensing unit will be used to monitor the flow of air inside the test chamber when the ventilation hood is operating.

X.4 Test Specimen(s)

X.4.1 Specimen Configuration

Each magnesium alloy primary seat frame component such as the legs, spreaders, cross-tube assemblies, seat back frames, and lower baggage bars will be tested. Test samples representing these seat components shall be constructed of the identical magnesium-alloy material to be used in service. Test samples shall be constructed according to drawing xx.

X.4.2 Specimen Number

A minimum of three specimens for each magnesium alloy type or design configuration will be prepared for testing.

X.4.3 Specimen Size

The specimens to be tested will measure xx ± 1/8 inches (xxx ± 3 mm) wide by xx ± 1/8 inches (xxx ± 3 mm) thick by xx ± 1/8 inches (xxx ± 3 mm) in length.

X.4.3 Specimen Orientation

The specimens will be mounted vertically, with the face of the sample located 4 inches from the vertical plane of the burner cone. The top of the xx inch long sample will be located 2 inches above the horizontal centerline of the burner cone.

X.5 Specimen Conditioning

X.5.1 The specimens will be conditioned at 70° ± 5°F (21° ± 2°C) and 55% ± 10 % relative humidity for a minimum of 24 hours prior to testing.

X.6 Preparation of Apparatus

X.6.1 Level and center the sample holder frame assembly to ensure alignment with respect to the burner cone.

X.6.2 Turn on the ventilation hood for the test chamber. Do not turn on the pressurized burner air (or alternatively the burner motor-driven blower). Measure the airflow in the test chamber using a hot wire anemometer or equivalent measuring device. The vertical air velocity within a 12-inch radius from the center of the vertically-positioned specimen will be less than 50 ft/min (25.4 cm/second). The horizontal air velocity within a 12-inch radius of this point will be less than 25 ft/min (12.7 cm/second).

X.6.3 Sonic Burner

X.6.3.1 Volumetric Air Flow

The combustion make-up air for the burner is controlled via the regulated sonic orifice. Specifically, the air flow rate is controlled by adjusting the upstream pressure using a regulator (i.e., higher pressure = higher flow rate). Historical data and practice using traditional motor-driven blower-style gun burners have determined the air velocities exiting the burner draft tube into the combustion cone to be in the range of 1460 to 1720 ft/min. These measurements were found using a vane-style anemometer, housed within a 27.5-inch long test pipe with an inside diameter of 2.75 inches. The anemometer was positioned at the end of the test pipe, which was secured to the draft tube exit (figure in report?). This 1460 to 1720 ft/min measurement range was obtained when the intake air velocity was adjusted to the prescribed range of 1550 to 1800 ft/min. When using the sonic burner, an inlet pressure range of 39 to 48 lbs/in^2 was found to yield the identical 1460 to 1720 ft/min air velocity range exiting the draft tube.

X.6.3.2 Fuel Flow Calibration

If a calibrated flow meter is not available, measure the fuel flow using a graduated cylinder of appropriate size. Turn on the fuel pump and the burner motor, making sure the igniter system is off. Collect the fuel by placing a plastic or rubber tube over the fuel nozzle and into the graduated cylinder for a 2-minute period. Ensure that the flow rate is 2 ± 0.1 gal/hr (0.126 ± 0.0063 L/min).

X.7 Flame Calibration

X.7.1 Sonic Burner

X.7.1.1 Examine and clean the burner cone of any evidence of buildup of productions of combustion, soot, etc. Soot build-up inside the cone may affect the flame characteristics and cause calibration difficulties. Since the burner cone may distort with time, dimensions should be checked periodically.

X.7.1.2 Mount the thermocouple rake on a rolling stand that is capable of being quickly moved into position in front of the burner. Move the rake into calibration position and check the distance of each of the seven thermocouples to ensure that they are located 4 ± 1/8 inches (203 ± 3 mm) from the vertical plane of the burner exit. Ensure that the horizontal centerline of the thermocouples are offset 1 ± 1/16 inch (25.4 ± 1.6 mm) above the horizontal centerline of the burner cone (see figure X-5). Place the center thermocouple (thermocouple number 4) in front of the center of the burner cone exit (Note: The thermocouple rake rolling stand must incorporate "detents" that ensure proper centering of the thermocouple rake with respect to the burner cone, so that rapid positioning of the rake can be achieved during the calibration procedure). Once the proper position is established, move the thermocouple rake away, and then move back into calibration position to re-check distances. When all distances and positions are confirmed, move thermocouple rake away from burner.

X.7.1.3 While the thermocouple rake is away from the burner, turn on the pressurized air, fuel flow and light the burner. Allow it to warm up for a period of 2 minutes. After warm-up, move the thermocouple rake into calibration position and allow 1 minute for thermocouple stabilization, then record the temperature of each of the 7 thermocouples once every second for a period of 30 seconds. Remove thermocouple rake from calibration position and turn off burner. Calculate the average temperature of each thermocouple over this period and record. The average temperature of each of the 7 thermocouples must be 1800°F (982°C) ± 100°F.

X.7.1.4 If the temperature of each of the 7 thermocouples is not within the specified range, repeat sections X.7.1.1 through X.7.1.3 until all temperatures are within the calibration range. A slight adjustment of the internal stator orientation and distance from the end of the draft tube may be necessary to achieve the required temperatures.

X.7.1.5 Calibrate prior to each test until consistency has been demonstrated. After consistency has been confirmed, several tests can be performed with calibration conducted before and after the tests. See this chapter's supplement for recommendations on achieving calibration.

X.8 Procedure

X.8.1 Examine and clean the cone of soot deposits and debris.

X.8.2 Mount the magnesium alloy test specimen on the test frame and secure using the retaining frame bolts. Verify that the vertical test sample is perpendicular to level.

X.8.3 Move the test frame away from the burner so that the flame does not impinge on the test specimen during the warmup period. Turn on the burner and allow it to stabilize for at least 2 minutes.

X.8.4 Move the test frame into the test position, and start the timing device when the test frame is fully in the test position.

X.8.5 If sample ignites in less than (2 minutes?), turn off burner and terminate test. Test sample fails.

X.8.6 Continue burner exposure until ignition occurs. If sample does not ignite after (10 minutes?) exposure, terminate test (sample passes).

X.8.7 Record the time that ignition first occurs. Continue burner exposure for an additional (30 seconds?) exposure, then turn off burner. Observe sample if still burning, and measure the time ignition ends. Record this ignition duration.

X.9 Report

X.9.1 Report a complete description of the material(s) being tested, including manufacturer, alloy content, trade name, etc.

X.9.2 Report the time to ignition, and ignition duration after burner is turned off for the three test specimens.

X.9.3 Record any observations regarding the behavior of the test specimen during flame exposure, such as popping, explosions, smoke, etc., and the time each event occurred.

X.9.4 Provide a record of calibration.

X.10 Requirements

X.10.1 None of the three specimens tested will ignite within (2 minutes?) of burner exposure.

X.10.2 If no ignition occurs for (10 minutes?) after exposure, the sample is a pass.

X.10.3 If ignition occurs in less than (10 minutes) but greater than (2 minutes), the sample must be exposed for an additional (30 seconds) and then burner is switched off.

X.10.4 If ignition occurs in less than (10 minutes) but greater than (2 minutes), the sample must self-extinguish within (2 minutes) of burner being turned off.

Chapter X Supplement

This supplement contains advisory material pertinent to referenced paragraphs.

X.3.2 The basic burner, including description of components, assembly, and recommended settings is described in detail in Section NG of the (report on new Appendix F), dated (insert date of report) report number xxxx.

X.3.2.1 A Monarch 80-degree AR or 80°R nozzle, nominally rated at 2.25 gal/hr (0.142 L/min) at 100 lb/in^2 (0.69 MPa) and operated at 85 lb/in^2 (0.59 MPa) gauge, has been found satisfactory to maintain a fuel flow of 2 gal/hr (0.126 L/min) and produce a proper spray pattern. A Monarch 80-degree CC nozzle, nominally rated at 2 gal/hr at 100 lb/in^2 and operated between 95 and 105 lb/in^2 gauge, is also acceptable. Minor deviations to the fuel nozzle spray angle, fuel pressure, or other parameters of the nozzle are acceptable if the fuel flow rate and flame temperature conform to the requirements of section X.7 of the this document.

X.3.2.2 Number 2 Grade diesel fuel, Jet A, or the international equivalent is the recommended fuel because it has been found to produce satisfactory results if the flow rate and inlet airflow conform to the requirements of Section NG of the (report on new appendix F) document.

X.3.3 The thermocouples are subjected to high temperatures durations during calibration. Because of this type of cycling, the thermocouples may degrade with time. Small but continuing decreases or extreme variations in temperature or “no” temperature reading at all are signs that the thermocouple or thermocouples are degrading or open circuits have occurred. In this case, the thermocouple or thermocouples should be replaced in order to maintain accuracy in calibrating the burner. It is recommended that a record be kept for the amount of time the thermocouples are exposed to the oil burner’s flame (consideration should be given to change thermocouples to 1/8-nch diameter units).

X.6.3.1 The Omega microprocessor-based portable air velocity kit, model HHF142B, is a recommended unit. The kit includes a vane-type air velocity sensor, hand-held digital readout displaying air velocity and volumetric airflow, extension rods, and a 9-volt lithium battery. If an air velocity sensor other than the Omega model HHF142B is being used, the volumetric airflow can be obtained using the following equation:

$$\text{Airflow} = \text{Air Velocity} \times \text{Area of Opening (Air Velocity Sensor)}$$

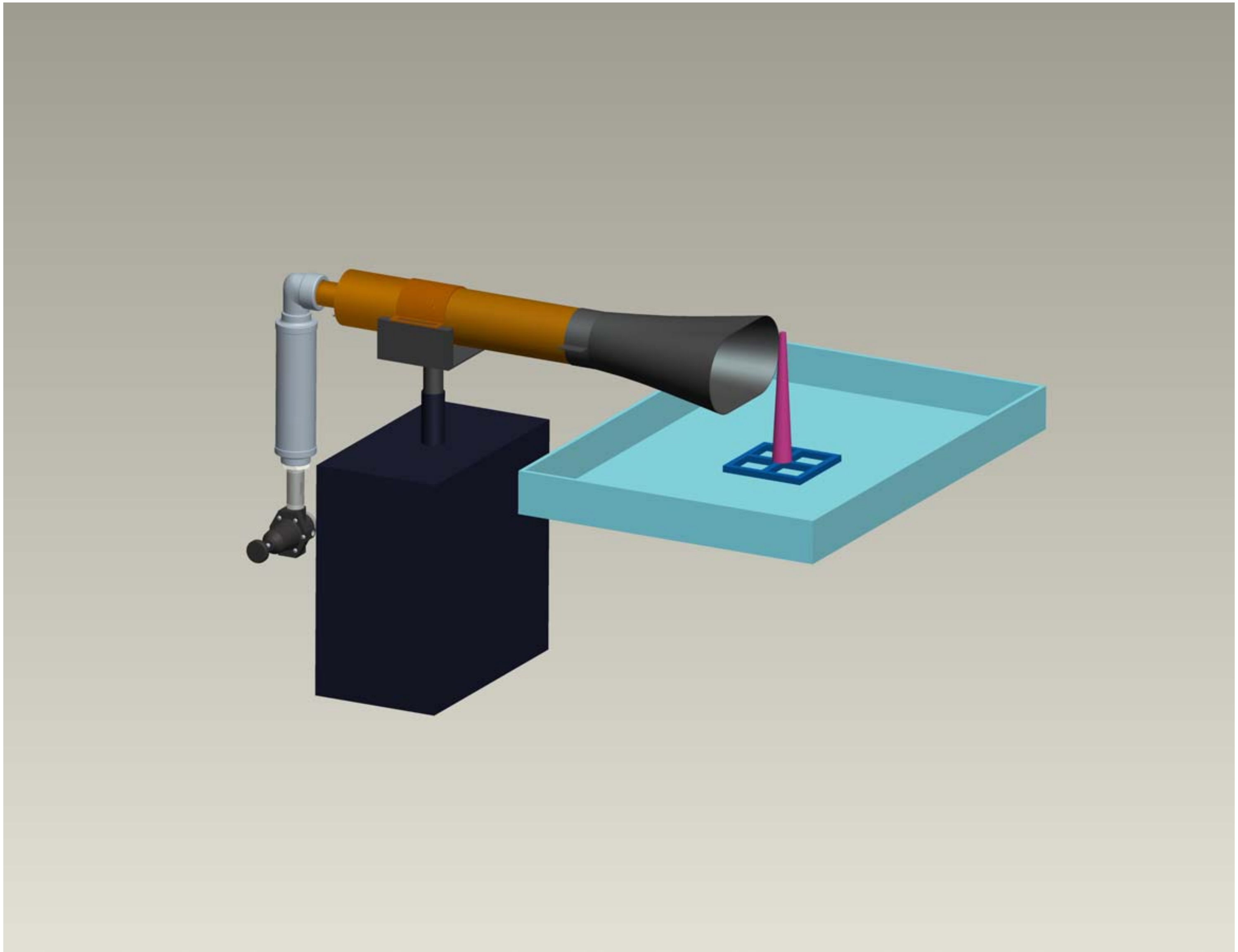
X.7.1.1 A stainless steel wire brush is one possible cleaning tool. Soot buildup inside the burner cone can affect the flame characteristics and cause calibration difficulties. Since the burner cone may distort with time, dimensions will need to be checked periodically.

X.7.1.5 Following are recommendations for achieving calibration temperatures:

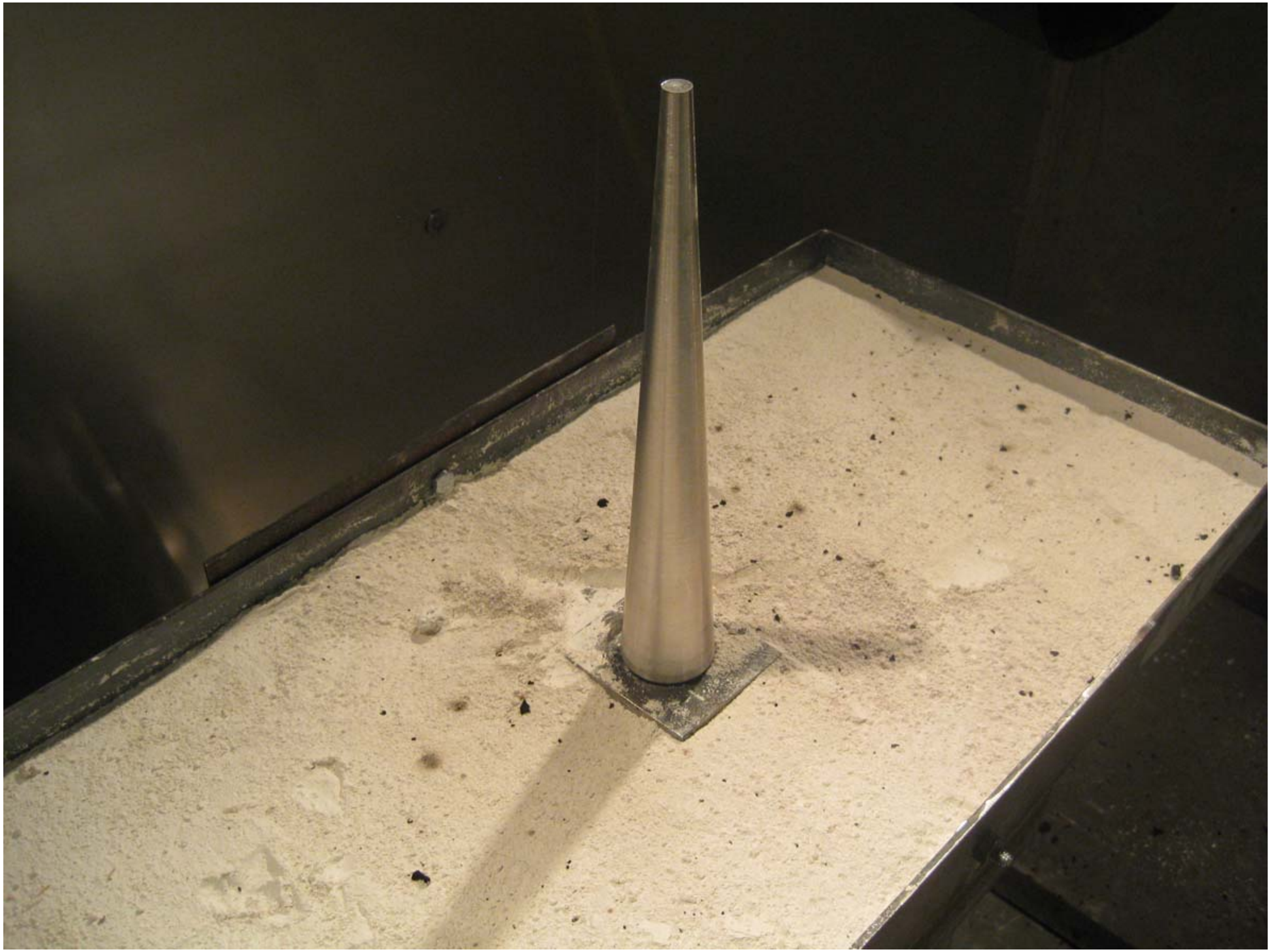
1. Set the stabilizer 3.25 ± 0.25 inches from the end of the draft tube.
2. Rotate the ignitor to the 6 o'clock and 9 o'clock position (viewpoint: looking toward the stabilizer from the end of the draft tube).
3. Set the air pressure to 41 to 49 lbs/in^2.
4. Seal all possible air leaks around the burner cone and draft tube area.
5. Replace thermocouples after 50 hours of use.

X.8.2 In order to expedite the specimen mounting and testing process, several sample holders can be incorporated. The catch pan can utilize pins for mounting the sample holder, to facilitate quick removal following each test. Once the test is complete, the entire sample holder, including sample remnants, can be removed from the catch pan, and a new sample holder and test sample replaced. Ensure that the new test sample is properly aligned with respect to the burner.

Magnesium Alloy Flammability Test, Concept Diagram



Conical Test Sample of AZ-31 Magnesium Alloy



Conical Test Sample of AZ-31 Magnesium Alloy

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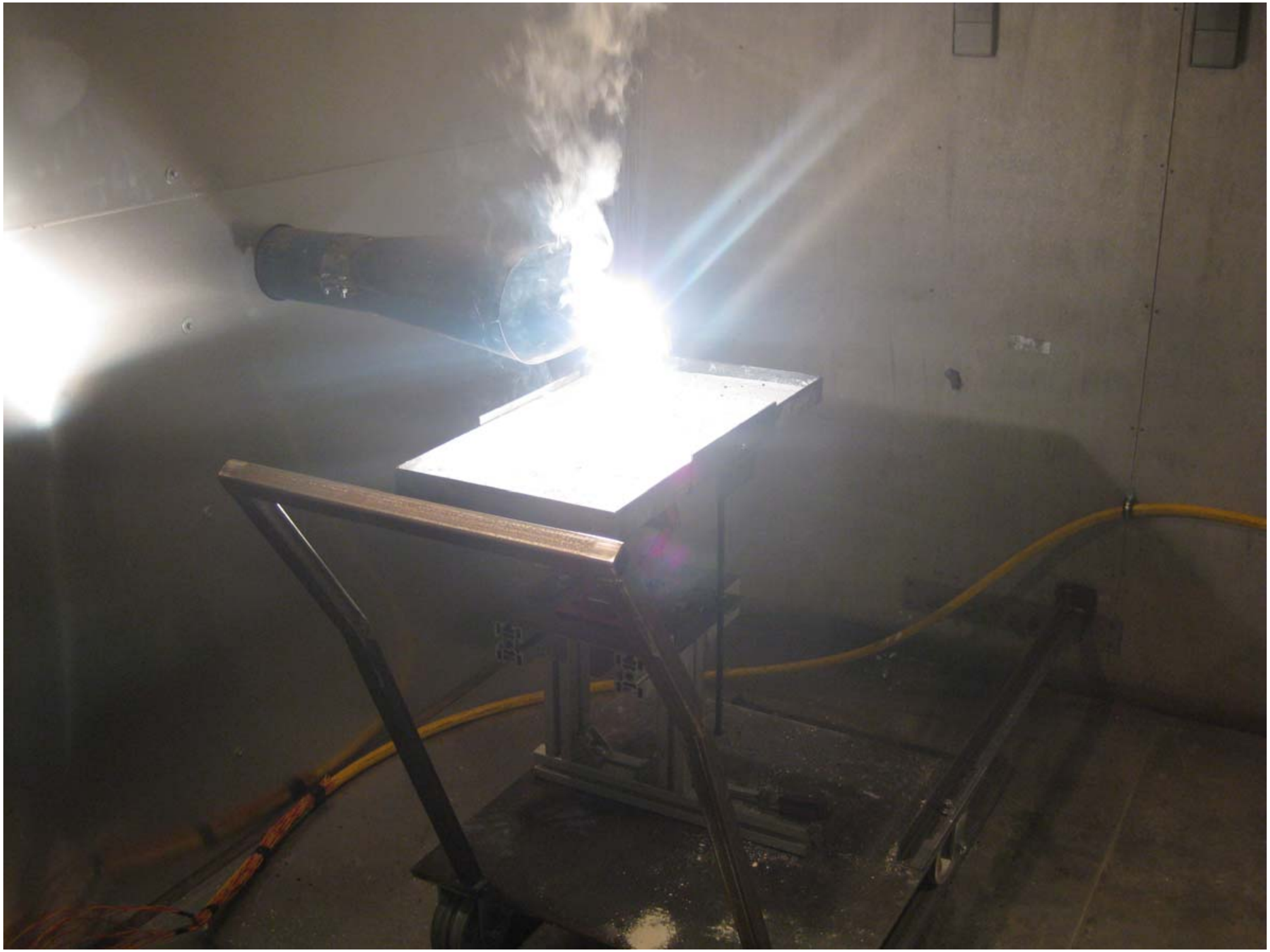
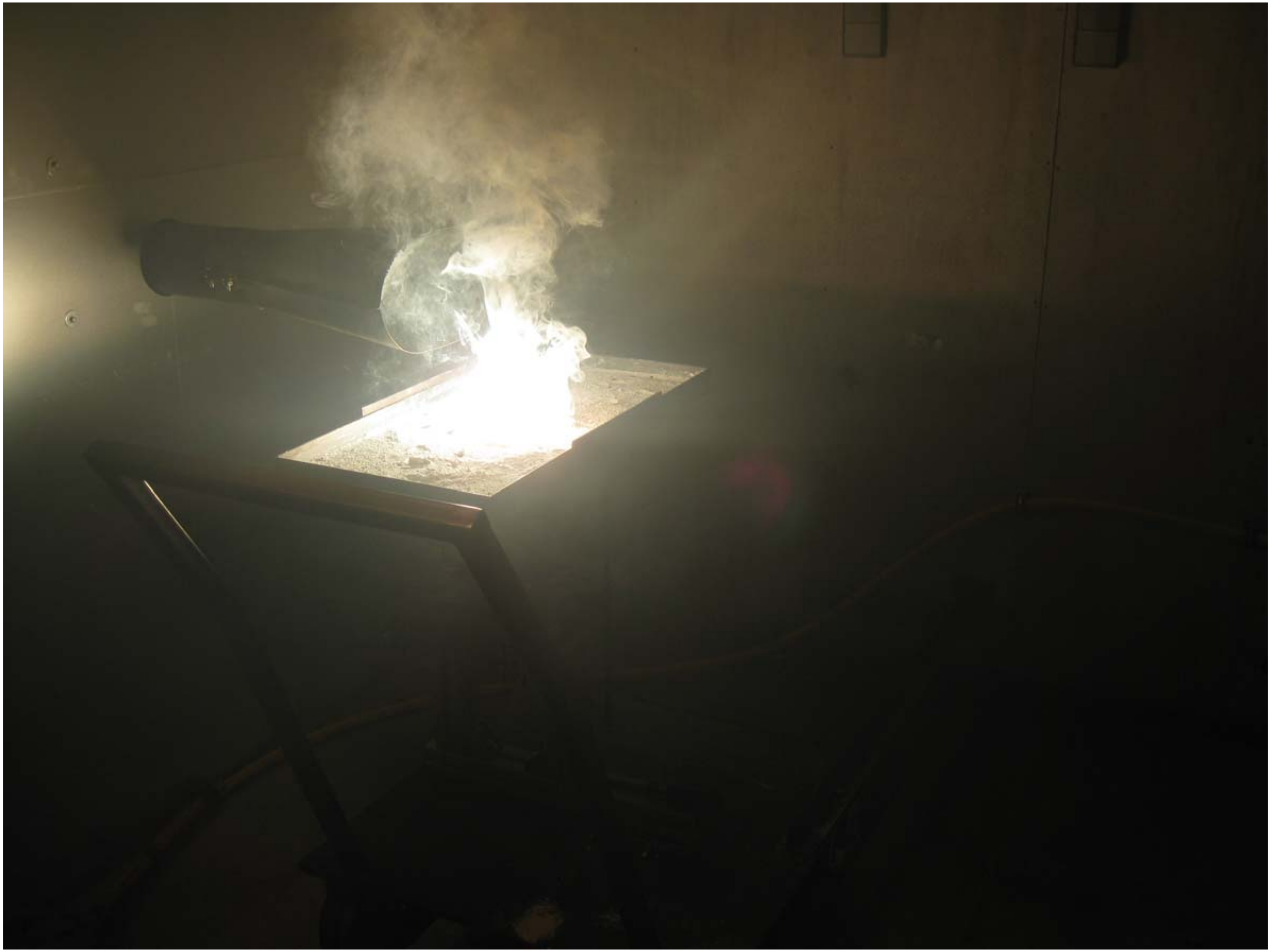
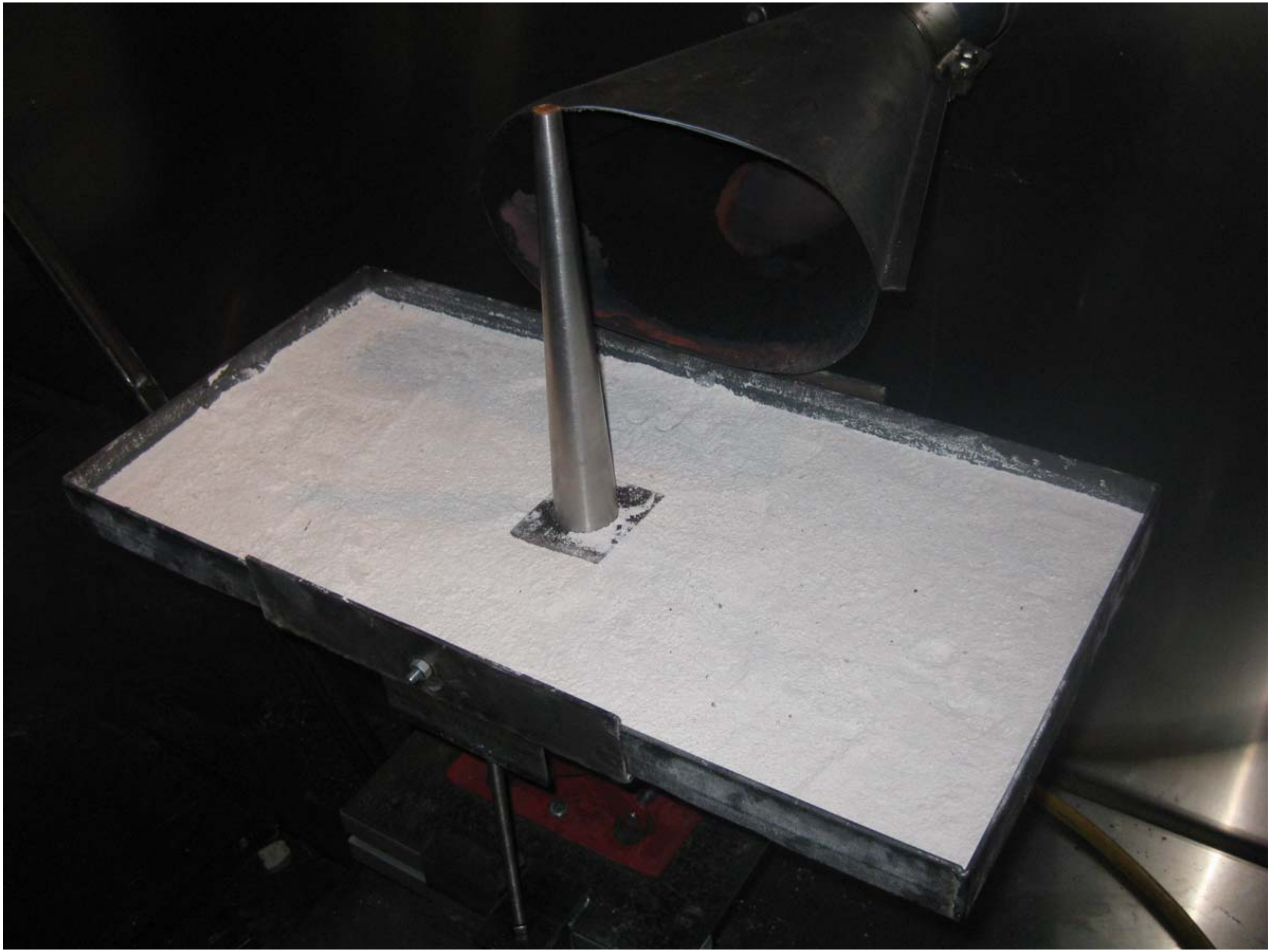


Conical Test Sample of AZ-31 Magnesium Alloy

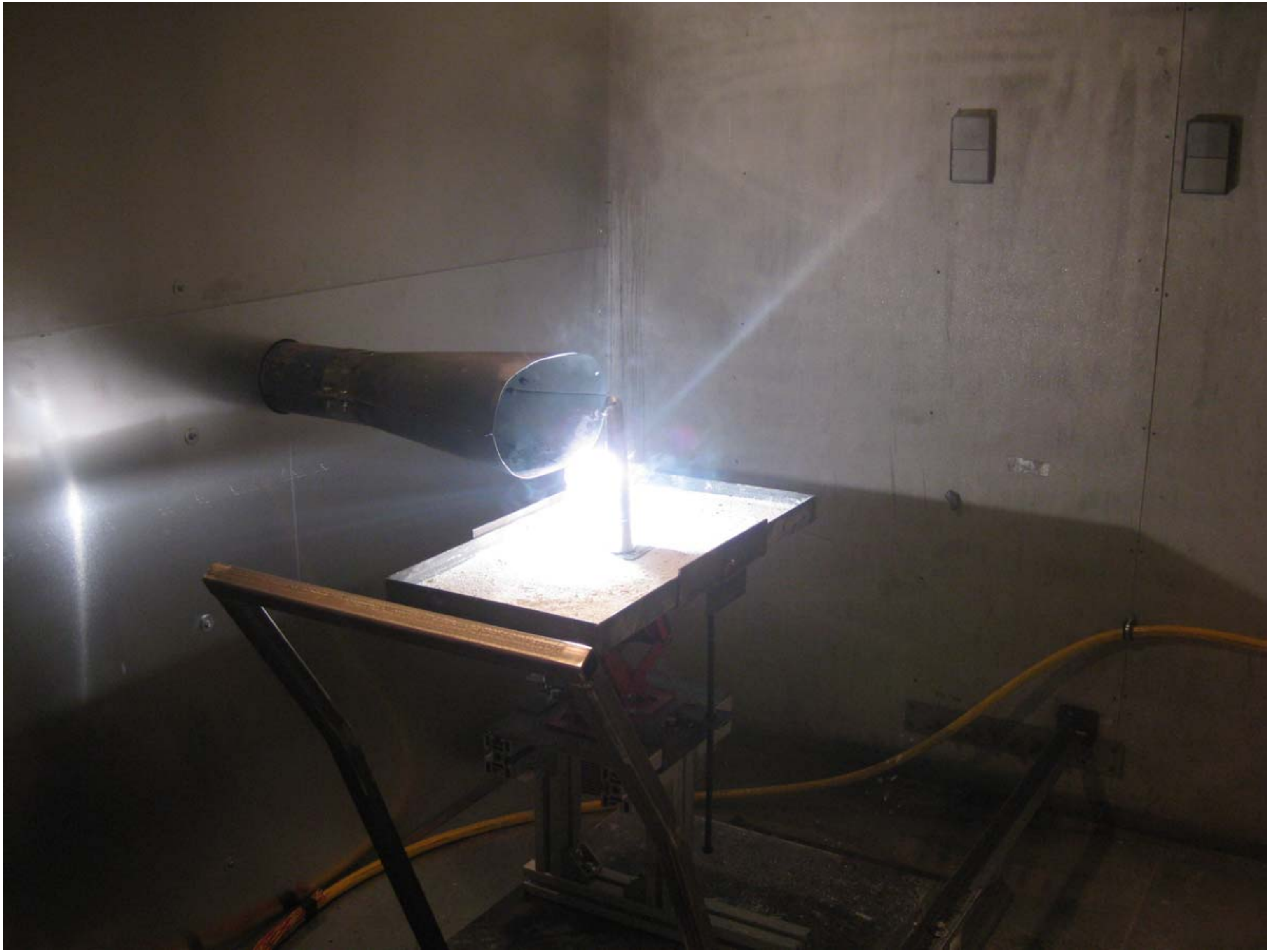


Conical Test Sample of WE-43 Magnesium Alloy



Conical Test Sample of WE-43 Magnesium Alloy

Conical Test Sample of WE-43 Magnesium Alloy



Conical Test Sample of WE-43 Magnesium Alloy

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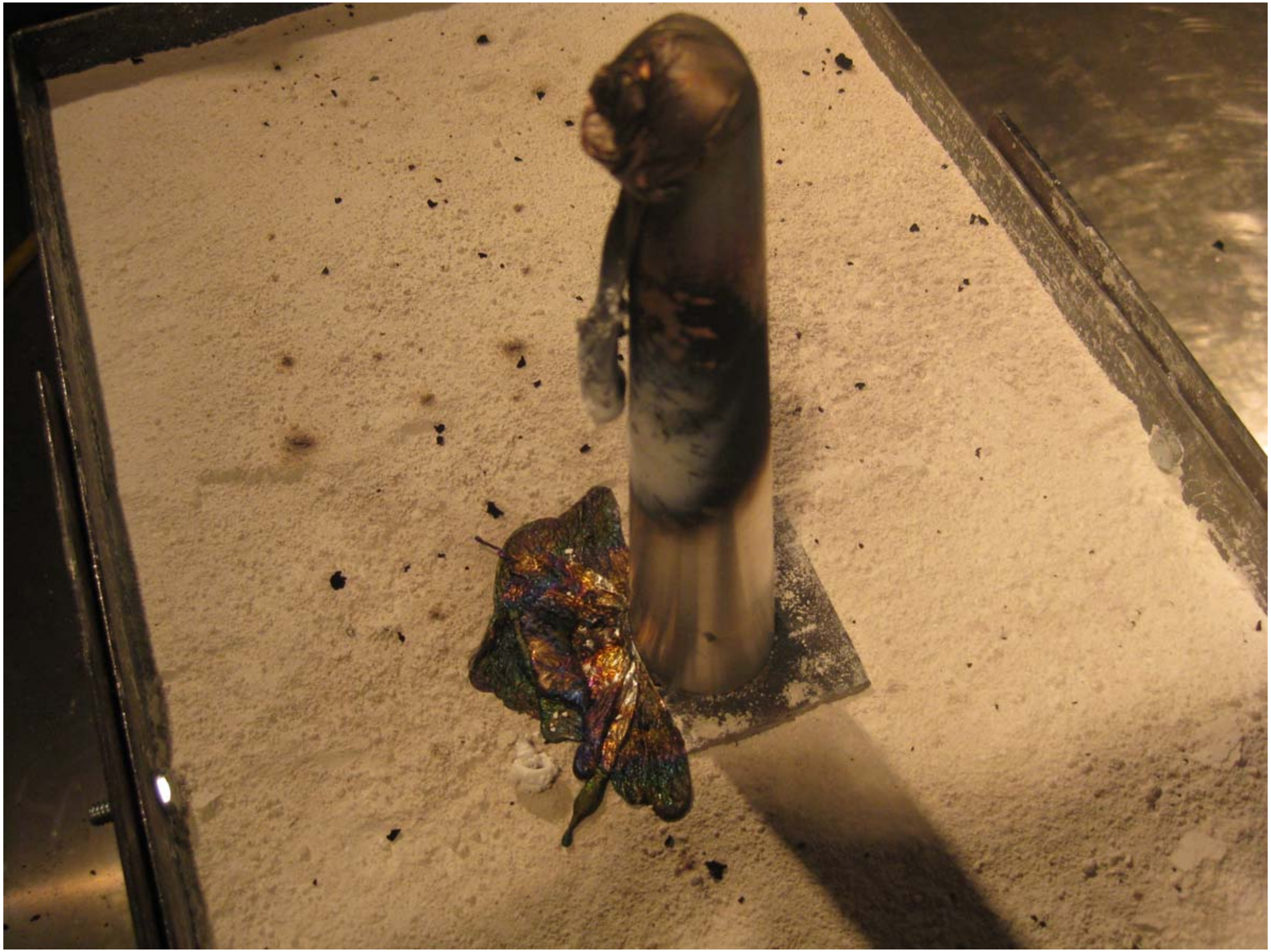
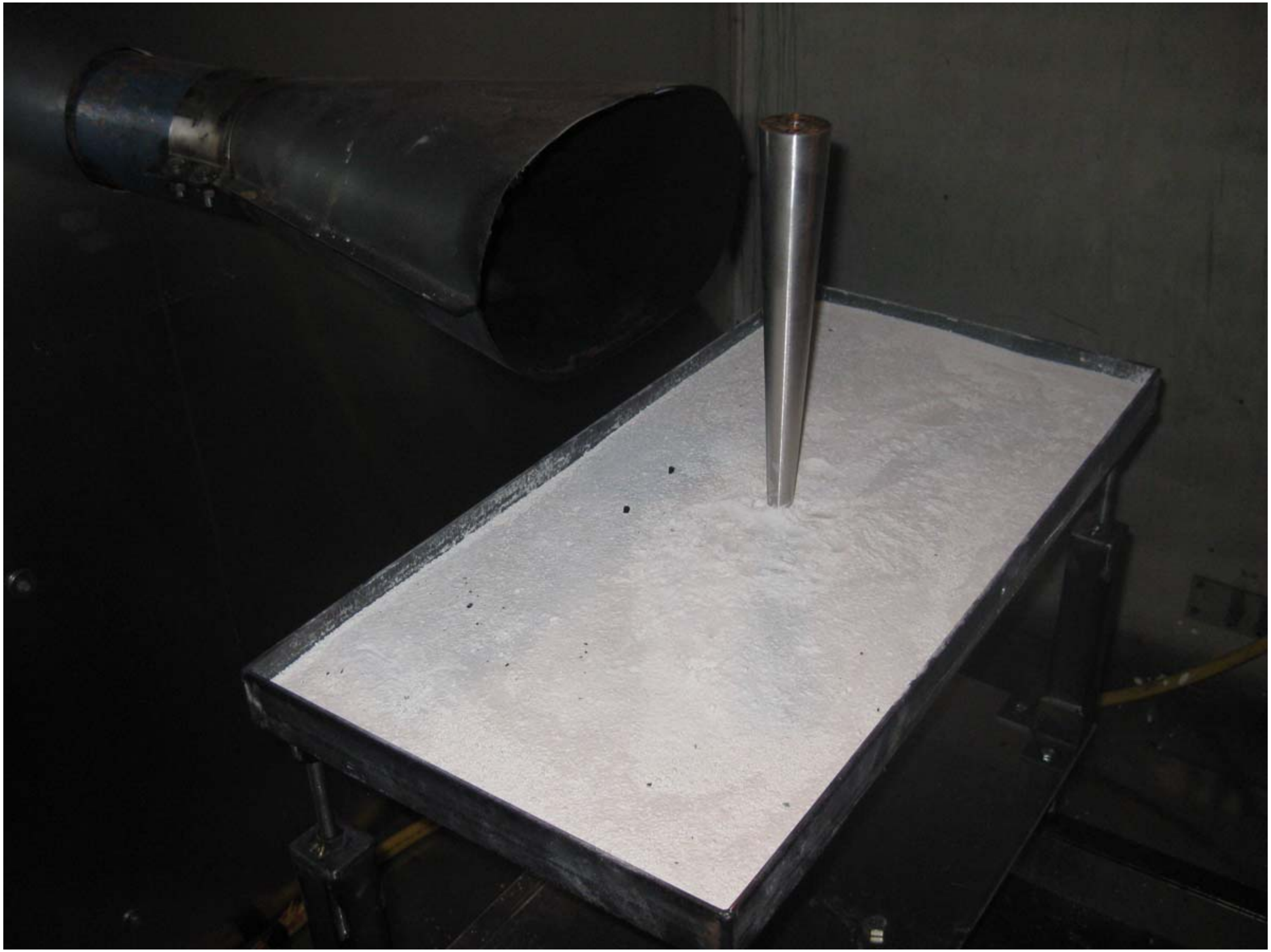
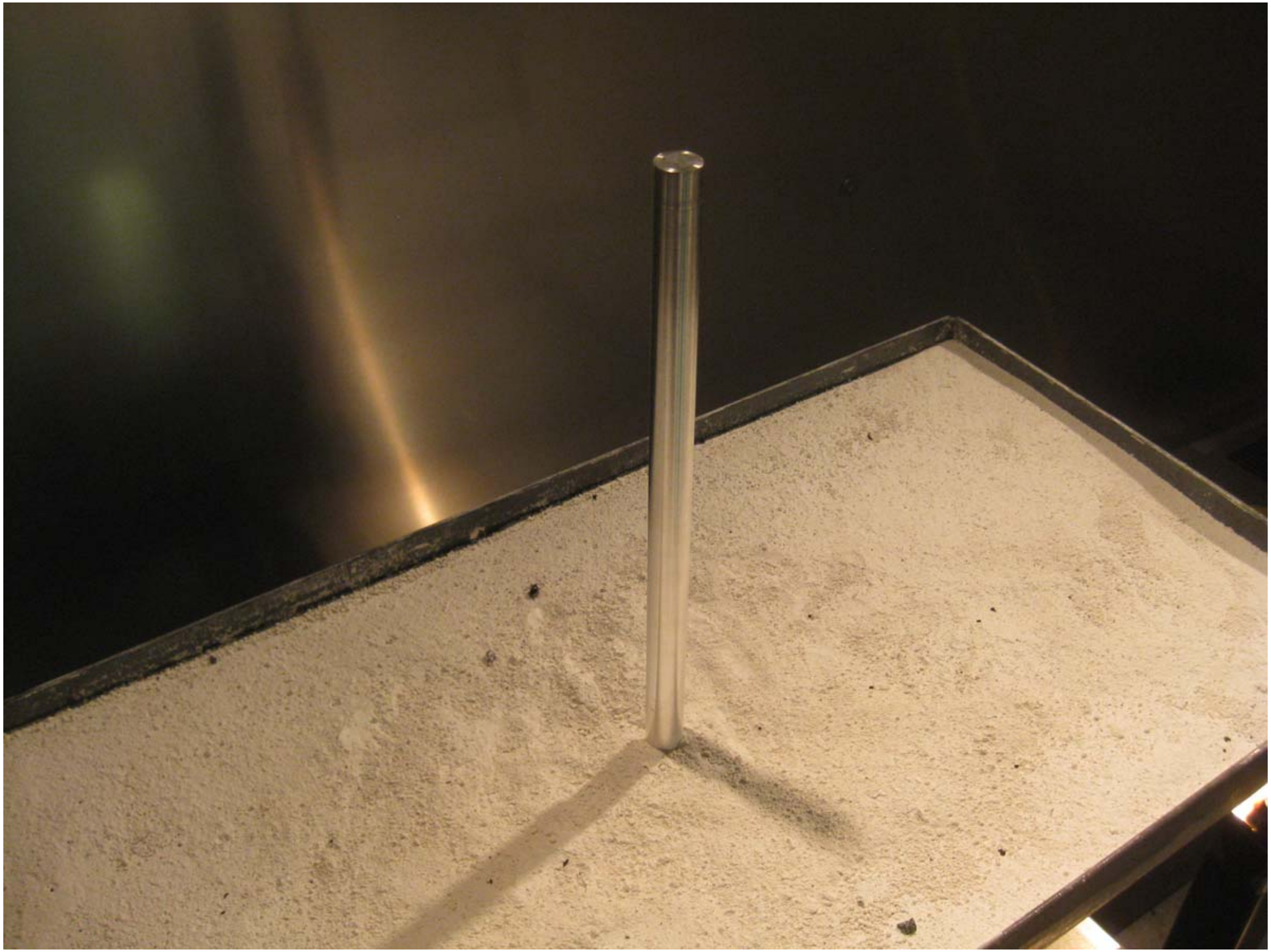
Conical Test Sample of WE-43 Magnesium Alloy



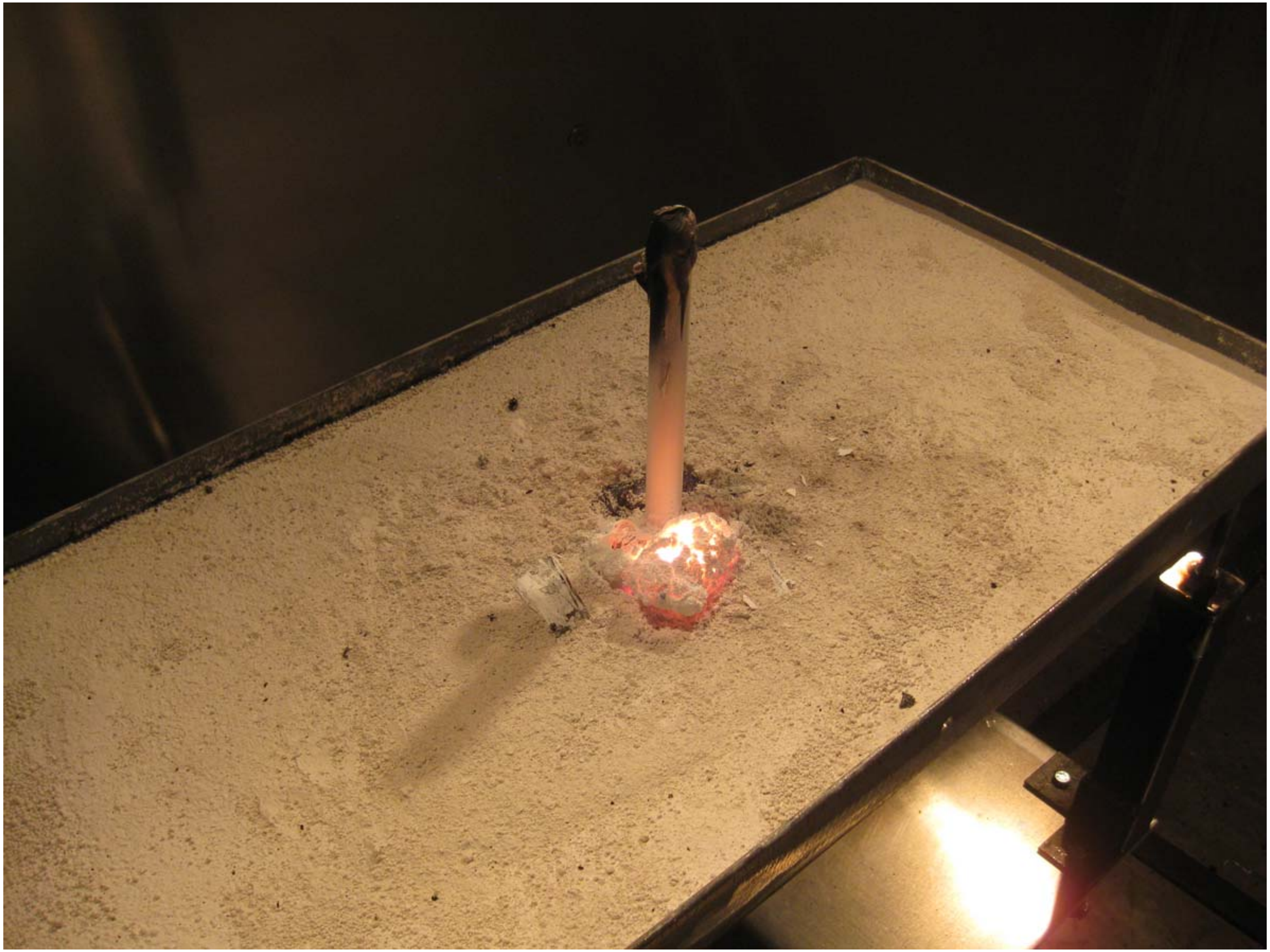
Inverted Conical Test Sample of WE-43 Magnesium Alloy



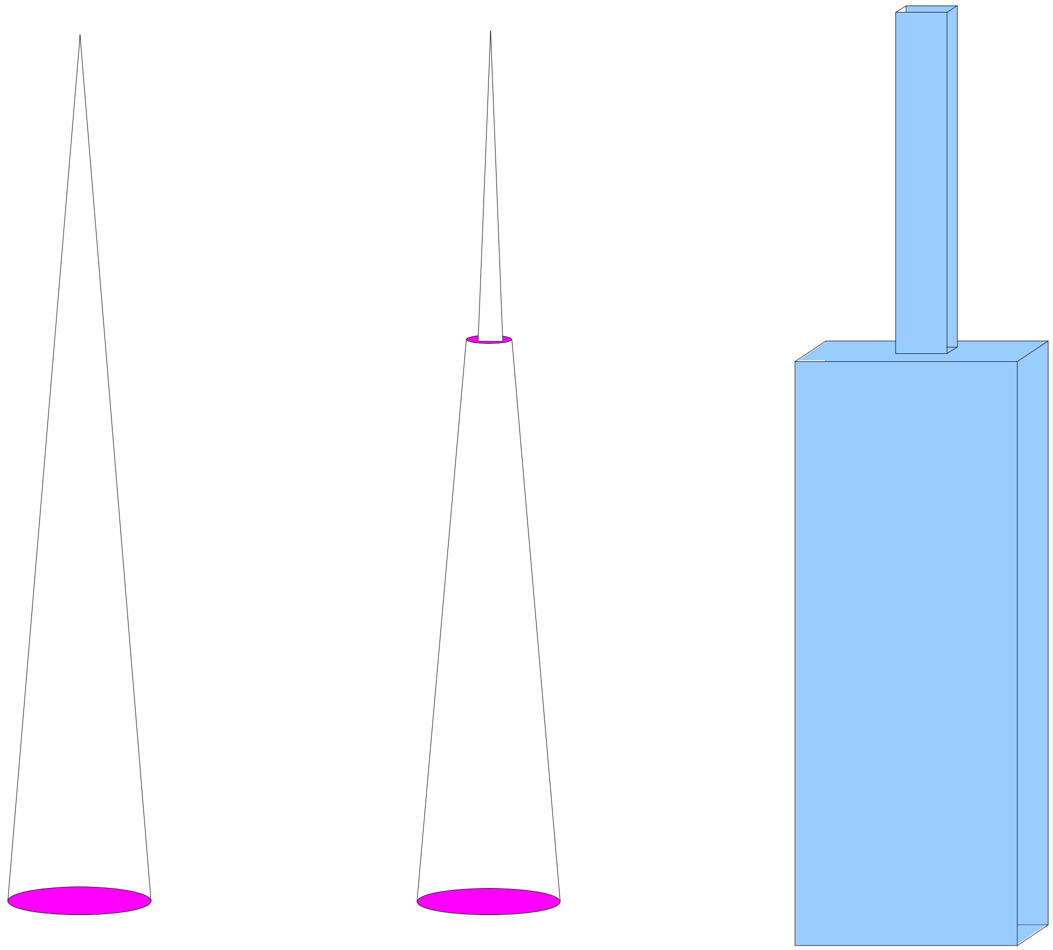
Cylindrical Test Sample of WE-43 Magnesium Alloy



Cylindrical Test Sample of WE-43 Magnesium Alloy



Other Possible Test Sample Shapes



Preliminary Test Results Using Conical Test Samples

#	Material Type	Base Dia (in)	Head Dia (in)	Length (in)	Surface Area (in^2)	Volume (in^3)	Surface to Volume Ratio	Time to Melt (Min:Sec)	Time to Melt (Sec)	Melting Rate (in^3/min)	Time to Ignition (Min:Sec)	Burner Exposure (Min:Sec)	Time Ignition Ends (Min:Sec)	Duration of Ignition (Min:Sec)	comments
1	WE-43	1.58	0.59	10.1875	36.9784	10.0575	3.68	2:30	150	4.02	3:40	4:00	5:40	1:40	
2	AZ-31	1.58	0.40	10.1563	33.7190	8.7498	3.85	1:38	98	5.36	1:50	3:00	30:00:00	27:00:00	cpl consumed
3	AZ-31	1.58	0.39	10.1250	33.4657	8.6538	3.87								
4	WE-43	1.57	0.39	10.0000	32.8965	8.4543	3.89	1:42	102	4.97	2:30	3:00	4:20	1:20	
5	AZ-31	1.58	0.59	9.8750	35.9365	9.7638	3.68								
6	AZ-31	1.58	0.59	9.7500	35.5110	9.6402	3.68								
7	WE-43	1.57	0.39	9.1875	30.3998	7.7674	3.91								
8	AZ-31	1.58	0.40	10.0000	33.2422	8.6090	3.86								
9	AZ-31	1.57	0.40	10.0000	33.0592	8.5161	3.88								
10	AZ-31	1.59	0.59	9.8750	36.1176	9.8610	3.66								
11	AZ-31	1.58	0.40	9.8750	32.8541	8.5014	3.86								
12	AZ-31	1.58	0.59	9.9375	36.1493	9.8256	3.68								
13	WE-43	1.58	0.39	10.1250	33.4657	8.6538	3.87								
14	WE-43	1.58	0.60	10.2500	37.3829	10.2089	3.66	2:22	142	4.31	2:54	3:30	4:35	1:05	
15	WE-43	1.57	0.39	9.8125	32.3203	8.2958	3.90	2:05	125	3.98	2:25	3:10	3:10	0:00	
16	AZ-31	1.58	0.40	10.0000	33.2422	8.6090	3.86								
17	WE-43	1.58	0.59	10.1875	37.0004	10.0728	3.67	5:00	300	2.01	6:45	7:15	9:45	2:30	inverted
18	AZ-31	1.58	0.40	9.8125	32.6601	8.4476	3.87								
19	AZ-31	1.58	0.59	10.1250	36.7876	10.0110	3.67								
20	AZ-31	1.58	0.39	10.1250	33.4657	8.6538	3.87								
21	AZ-31	1.57	0.59	9.6875	35.1203	9.4835	3.70								
22	AZ-31	1.58	0.59	9.9375	36.1493	9.8256	3.68								
23	AZ-31	1.58	0.60	10.1250	36.9554	10.0844	3.66								
24	WE-43	0.60	0.60	10.1875	19.7685	2.8804	6.86	1:40	100	1.73	2:40	3:10	3:10	0:00	cylinder

Planned Activities

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

- Stator Depth and angle
- Air pressure
- Elbow vs. Non-Elbow
- Fuel Nozzle, impact of rotating

Continue testing of various magnesium alloys, experimenting with different shapes

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