



**University  
of Dayton  
Research  
Institute**

**AIR FORCE RESEARCH LABORATORY  
MATERIALS AND MANUFACTURING  
DIRECTORATE**

**SUPERSONIC RAIN EROSION (SuRE) TEST  
APPARATUS**

**Use Policies, Operating Procedures & Specimen Configurations**

March 2021

University of Dayton Research Institute  
300 College Park  
Dayton, OH 45469-0054

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## 1.0 GENERAL INFORMATION

The AFRL Supersonic Rain Erosion Test Facility (herein referred to as “SuRE facility”) is a government-owned facility operated by the University of Dayton Research Institute (UDRI) to serve the international aerospace community. Access is provided for both military and commercial testing. Priority of testing can usually be determined on a first-come, first-serve basis, but on occasion, this order must be broken for more immediate or emergency evaluations. Failure to comply with the direction of SuRE facility personnel can result in cancellation of testing. For more information about the AFRL/UDRI SuRE test apparatus, contact:

<b>Contractor Personnel University of Dayton Research Institute</b>	<b>AFRL Government Personnel</b>
UDRI Erosion Facilities ATTN: Ollie Scott 300 College Park Dayton, OH 45460-0054 Office: (937) 255-0197  <a href="mailto:Ollie.Scott.ctr@us.af.mil">Ollie.Scott.ctr@us.af.mil</a> <a href="mailto:Ollie.Scott@udri.udayton.edu">Ollie.Scott@udri.udayton.edu</a>	AFRL Rain Erosion Test Facility Coatings, Corrosion & Erosion Lab AFRL/RXSS (CCEL) ATTN: Matthew I. Hartshorne 2179 12th St, Building 652 Rm 59 Wright-Patterson AFB, Ohio 45433-7718 (937) 255-4108  <a href="mailto:matthew.hartshorne.1@us.af.mil">matthew.hartshorne.1@us.af.mil</a>

## **2.0 INTRODUCTION**

The phenomenon known as rain erosion, or the damage to materials caused by the impingement of raindrops at high speed, has long been a concern to the United States Air Force. The Air Force Research Laboratory (AFRL) at Wright-Patterson Air Force Base, Ohio, has conducted and sponsored research on rain erosion resistant materials since 1947. UDRI has been involved in rain erosion research and erosion-resistant material development since 1964.

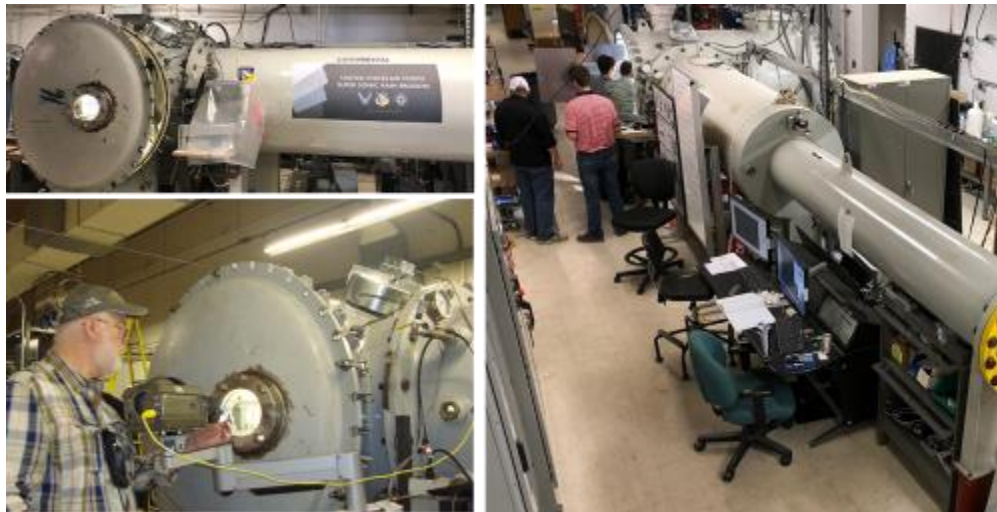
In the course of rain erosion research over the years, the rotating/whirling arm apparatus of which UDRI has participated in the design, development, construction, and calibration has provided the best laboratory simulation of the environment for evaluating materials and investigating rain erosion mechanisms at speeds up to 650 mph. However, as aircraft speeds have increased, the need to conduct rain erosion testing at higher speeds was required. As such, UDRI and AFRL, co-developed the Super Sonic Rain Erosion (SuRE) test facility that is capable of testing at speeds between 250 mph and 1750 mph (Mach 2.3).

This highly-specialized apparatus allows scientists to evaluate materials and coatings durability by directing a spray of water at test specimens, subjecting them to conditions simulating real-world rain and weather events. Rain drop impact is randomly distributed over the exposed surfaces of the test specimens. The test duration can be designated in specific increments (e.g., seconds, minutes or hours) or terminated at the operator's discretion when erosion damage is observed. UDRI Erosion specialists can offer expert consultation and recommendations in the development of test plans to optimize and determine the effects of the high-force spray on the materials and components.

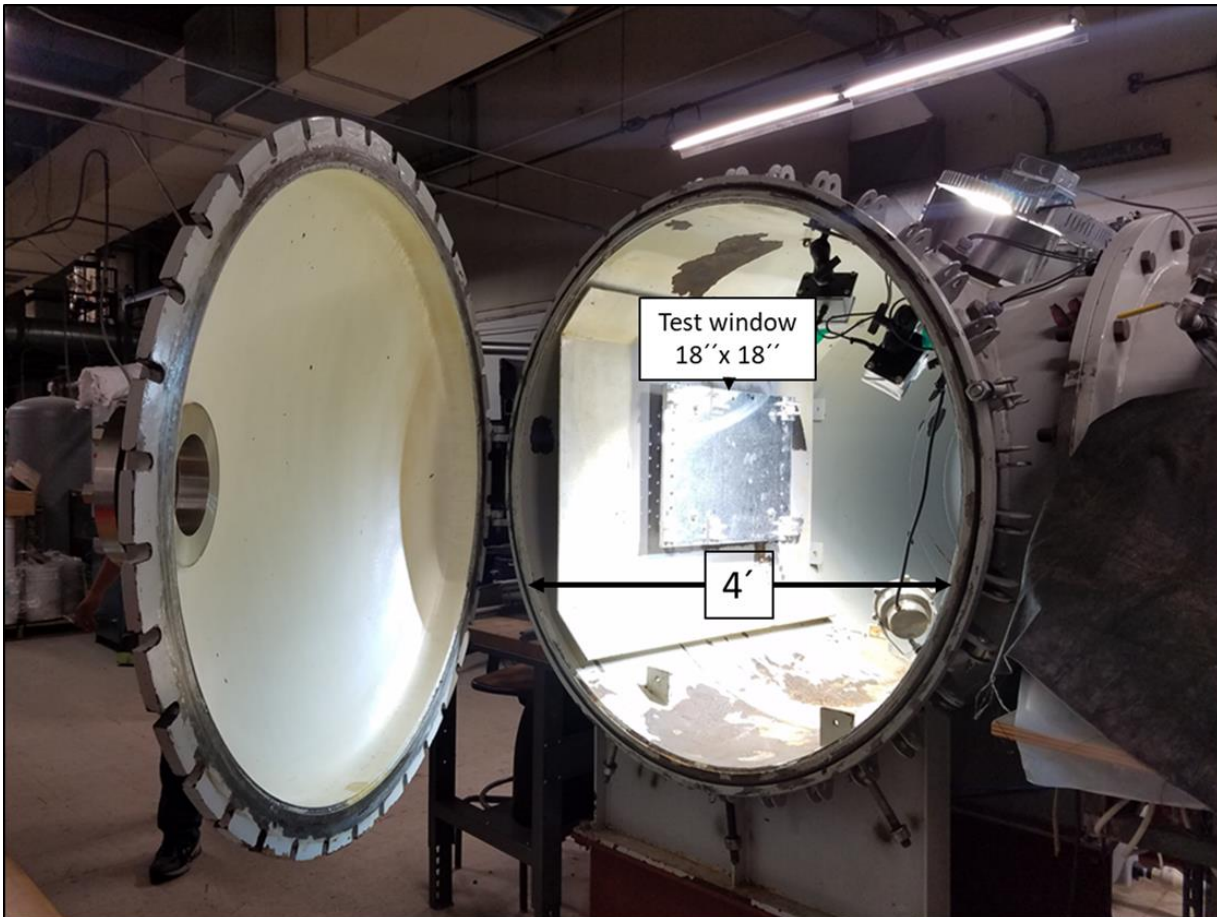
### 3.0 SURE TEST APPARATUS

The SuRE test apparatus is a unique, one-of a-kind capability that simulates the impact effects of high speed flight through rain for transonic and supersonic speeds up to Mach 2.3 for a range of water drop sizes between 1.0 to 2.0 mm. Larger water drop sizes of 3.0 mm can be achieved but rain speeds will inevitably decrease.

**Figure 1** shows the SuRE test apparatus. The SuRE test apparatus utilizes a combination of technologies to project and distribute water droplets at a variety of velocities to simulate flight conditions. A computer controlled targeting system is utilized to ensure proper water droplet location and accuracy. A variable-sized rotating water jet nozzle allows for water droplet size selection as requested; the rotating feature effectively eliminates potential “hammer-effects” of projected water droplets. A high-speed camera is utilized to accurately measure/confirm water droplet size and to measure the speed of the water droplets. High pressure water pumps are utilized to deliver the necessary deionized water during the test event.



*Figure 1: AFRL/UDRI SuRE Test Facility*



*Figure 2: SuRE Test Chamber Target Section*

The SuRE test chamber is configured to provide flexibility in the target (sample) size and mounting arrangement. The target section is a four foot diameter vacuum cylinder. The maximum test window is 18 x 18 inch (x, y) with capabilities of up to 4-foot (z) for sample projection. This freedom of target allows for a variety of sample configurations ranging from specimens to full size components. The entire end of the chamber swings open to accommodate test hardware, test specimens and lighting. A water drop train travels down a 24-foot flight tube oriented radially to the side of the test chamber. Those drops strike the test specimen(s) held in test fixtures in an XY raster path.

The typical test exposure is composed of one continuous pass of drops starting from the bottom right of the target area to the top left of the target area and then back down across the specimen again to then be parked at the lower right. This motion makes up one full loop that covers the 18 x 18 inch target area in 2 minutes and 6 seconds. Overall sample exposure time can be varied depending on customer request by iterating the loop exposure to reach the desired total exposure time.

#### 4.0 TYPES OF MATERIALS EVALUATED

The following is a list of typical materials submitted for rain erosion evaluation.

Composites	Coated metals
Coated composites	Ceramics
Plastics	Honeycomb constructions
Coated plastics	Bulk material constructions
Reinforced plastics	Glass materials
Metals	Optical materials
Radomes	Leading Edges

#### 4.1 Failure Analysis

Materials evaluated for rain erosion resistance are normally either bulk type or coated. Damage is evidenced by material loss (erosion) or coating adhesion failure. Such terms as pitting, cratering, cracking, material loss or fracture, core-crushing, and delamination are used to describe the progressive performance of the materials.

#### 5.0 USE POLICIES

##### 5.1 Scheduling

Due to the frequent usage of the SuRE apparatus, prospective users are urged to schedule test dates well in advance. Scheduling is normally accomplished by calling UDRI at Wright-Patterson Air Force Base; Office: (937) 255-0197, FAX: (937) 255-0954 or e-mail (see below).

Address US Postal correspondence to:

UDRI Erosion Facilities  
ATTN: Ollie Scott  
300 College Park  
Dayton, OH 45460-0054  
Office: (937) 255-0197

[Ollie.Scott.ctr@us.af.mil](mailto:Ollie.Scott.ctr@us.af.mil)  
[Ollie.Scott@udri.udayton.edu](mailto:Ollie.Scott@udri.udayton.edu)

**Note: Do not use this address to ship samples. See Section 5.4.1 for sample shipment requirements.**



**IMPORTANT!! SPECIAL ARRANGEMENTS MUST BE MADE FOR DOD CLASSIFIED TEST SPECIMENS. NOTIFY EROSION FACILITY PERSONNEL WHEN SCHEDULING TEST DATES IF SPECIMENS ARE CLASSIFIED.**

## 5.2 Payment Scheduling

Payment arrangements are substantially different for users with a U.S. Government sponsor than those without a sponsor. To avoid delays or cancellation of testing, it is recommended that payment scheduling be arranged as soon as possible after test scheduling.

### 5.2.1 Users with a U.S. Government Sponsor

Users with a sponsor must contact the Financial Division of the Air Force Research Laboratory (AFRL/RXFM) at (937) 255-9765 to arrange payment conditions as soon as possible after scheduling test dates. This is often a time-consuming process, but payment conditions must be arranged before testing can take place. **Testing will be delayed or cancelled if payment conditions are not arranged.**

### 5.2.2 Users Without a U.S. Government Sponsor

Users without a U.S. Government sponsor operate on a purchase order basis with the University of Dayton Research Institute (UDRI). The user company must submit the signed “Test Description and Approval Form” (Appendix A) enclosed in the Formal Proposal from the UDRI office of Contracts and Grants; [937-229-2919] In addition to the signatures of the UDRI collaborator and an official from the user company, the form will lastly be signed by AFRL/RXS for completion.

The purpose of this form is to provide mutual assurance of safety, responsibility, and confidentiality of testing and test results. Suitable time must be allowed to obtain the signatures on this form, especially with the users’ company. **Any discussion or questions regarding this form should be raised as soon as possible after test scheduling. Testing may be delayed or cancelled if payment conditions are not arranged at least two weeks prior to the test date(s).**

### 5.2.3 Cancellation Policy

Users who cancel or postpone a scheduled test must contact UDRI **at least two weeks prior to the scheduled test date(s)**. Users who fail to make timely notification will be charged 20% of the scheduled test cost. Exceptions to this charge will be made in the event of inclement weather, personal emergency, or in the event that UDRI can schedule another user in the testing dates that had been reserved for the original user. In the event that UDRI must cancel testing because payment conditions have not been arranged or necessary documents have not been received, the same cancellation policy will apply.



### 5.3 Test Plan

All users must submit a detailed test plan to fully document, guide, and direct specific test needs. Before scheduling testing, the user should know the number of specimens, geometry, configuration, maximum run time(s), intermediate inspections (if required), and if the specimens are DOD classified or unclassified. See **Section 8.0** for various specimen and configuration options. See **Section 7.0** for Angle of Impact/Incidence definition.

Prospective users are encouraged to discuss their test plans thoroughly with erosion facility personnel well before the scheduled test date. In addition to technical matters, guidance can often be provided regarding the necessary paperwork.

The test plan must include an adequate specimen material description, required velocity and angular modes, order of testing, and a definition of test duration, e.g., to initial failure, to complete failure (substrate exposed), length of time, etc. See **Section 6.0** for a velocity conversion chart.

**The final test plan must be submitted to erosion facility personnel at least 3 days prior to the scheduled test date to allow sufficient time for review and clarification. The test plan serves as a basis for the evaluation sheet used by the erosion facility operator at the time of testing. If the test plan is late or not submitted, the testing may be delayed or cancelled.**

**Safety Data Sheets (SDS) or other statements of material non-toxicity must be supplied with the Test Plan.**

### 5.4 Test Specimens

It is the policy of AFRL (Air Force Research Laboratory) to maintain a complete database of all rain erosion test results from the erosion facility. This data constitutes the history and progress of rain erosion resistant material development and is accessed only under a strict USAF need basis. Specimens to be tested must be accompanied by a description sufficient to allow the inclusion of the material and the results into the database. This description can be generic, but it must include at least the class of material(s) being evaluated, with some indication as to material treatment, coating thickness, etc. Specimen description is listed from the top down (face of sample exposed to droplets).

#### **Example:**

Polyurethane topcoat, light gray, 0.006” thickness / Polyurethane rain erosion coating, dark gray, 0.020” thickness / Epoxy primer, light green, 0.004” thickness / Chromate-free pretreatment / Aluminum Airfoil.

### 5.4.1 Specimen Shipment

Specimens must be shipped no less than 7 days in advance of the scheduled test date to allow for dimensional checking. Because rain erosion test specimens range from the fragile to the rugged, packaging and shipping should be guided accordingly. Every effort will be made to maintain the integrity of test specimens, although rain erosion test conditions can compromise this goal. If there is any concern about specimen configurations, contact erosion facility personnel.

#### Ship specimens via Fed Ex or UPS to:

ATTN: Ollie Scott, UDRI  
AFRL/RXSS (CCEL), Erosion Facilities  
2700 D Street, Building 1661, Room C110  
Wright-Patterson AFB, OH 45433



**IMPORTANT: The address above cannot be used for shipment of classified materials.**



**IMPORTANT: If test specimens are hand-carried to the erosion facility on the day of testing and do not fit the testing assembly, the test time will be abbreviated or canceled.**

### 5.4.2 Specimen Evaluation

Due to the design of the SuRE apparatus, specimen evaluation is typically conducted after the test specimens have been removed from the apparatus. Digital photography is typically used to capture images of tested specimens. High speed camera footage can be captured during the test event, but the duration is limited to only a few seconds due to mist and moisture build-up on the SuRE viewing windows. If required, additional post-test analysis services are available at an additional cost.

### 5.4.3 Specimen Return

After testing, all specimens and DVD's containing the files digitally recorded after testing will be returned via domestic UPS ground service. If a different shipper or expedited shipping service is required, the user must provide a UPS or FedEx shipping account number. International shipments are the responsibility of the user.

### 5.4.4 Data Submission

Following the test and evaluation sequence, an electronic copy (PDF) of the detailed test report is emailed to the user; a hard copy of the report is available upon request. All test results and all test specimens are handled on a strict proprietary basis. No endorsement of materials is intended either by the USAF or UDRI.

## **5.5 On-Site Visitors**

Users are welcome to witness the testing of their specimens. Due to facility size and safety restrictions, no more than three visitors at one time are allowed inside the laboratory. Prior notification is required and the visitors must contact the government personnel or contractor (see Section 1.0 General Information) a minimum of 5 business days prior to the test date to gain access to Wright-Patterson Air Force Base: The visitor access process and requirements change periodically, you will be advised of the current requirements at the time you contact government personnel.

**NOTE: Foreign National visitors may witness the testing of their specimens; however, the visit access process is different and requires a minimum of 4-8 weeks advance notice.**

**6.0 VELOCITY CONVERSION TABLE***Table 2: Velocity Conversion Table*

<b>METER/SEC</b>	<b>FT/SEC</b>	<b>MPH</b>	<b>MACH<sup>1</sup></b>	<b>KNOTS</b>	<b>KM/HR</b>
100	328	224	0.29	194	360
110	361	246	0.32	214	396
120	394	268	0.35	233	432
130	427	291	0.38	253	468
140	459	313	0.41	272	504
150	492	336	0.44	292	540
160	525	358	0.47	311	576
170	558	380	0.50	330	612
180	591	403	0.53	350	648
190	623	425	0.56	369	684
200	656	447	0.59	389	720
210	689	470	0.62	408	756
220	722	492	0.65	428	792
230	755	514	0.68	447	828
240	787	537	0.71	467	864
250	820	559	0.73	486	900
260	853	582	0.76	505	936
270	886	604	0.79	525	972
280	919	626	0.82	544	1008
290	951	649	0.85	564	1044
300	984	671	0.88	583	1080
310	1017	693	0.91	603	1116
320	1050	716	0.94	622	1152
330	1083	738	0.97	641	1188
340	1115	761	1.00	661	1224
350	1148	783	1.03	680	1260
360	1181	805	1.06	700	1296
370	1214	828	1.09	719	1332
380	1247	850	1.12	739	1368
390	1280	872	1.15	758	1404
400	1312	895	1.18	778	1440
410	1345	917	1.20	797	1476
420	1378	940	1.23	816	1512
430	1411	962	1.26	836	1548
440	1444	984	1.29	855	1584
450	1476	1007	1.32	875	1620
460	1509	1029	1.35	894	1656
470	1542	1051	1.38	914	1692
480	1575	1074	1.41	933	1728
490	1608	1096	1.44	952	1764
500	1640	1118	1.47	972	1800

*Table 3 continued: Velocity Conversion Table*

<b>METER/SEC</b>	<b>FT/SEC</b>	<b>MPH</b>	<b>MACH</b>	<b>KNOTS</b>	<b>KM/HR</b>
510	1673	1141	1.50	991	1836
520	1706	1163	1.53	1011	1872
530	1739	1186	1.56	1030	1908
540	1772	1208	1.59	1050	1944
550	1804	1230	1.62	1069	1980
560	1837	1253	1.65	1089	2016
570	1870	1275	1.68	1108	2052
580	1903	1297	1.70	1127	2088
590	1936	1320	1.73	1147	2124
600	1969	1342	1.76	1166	2160
610	2001	1365	1.79	1186	2196
620	2034	1387	1.82	1205	2232
630	2067	1409	1.85	1225	2268
640	2100	1432	1.88	1244	2304
650	2133	1454	1.91	1263	2340
660	2165	1476	1.94	1283	2376
670	2198	1499	1.97	1302	2412
680	2231	1521	2.00	1322	2448
690	2264	1543	2.03	1341	2484
700	2297	1566	2.06	1361	2520
710	2329	1588	2.09	1380	2556
720	2362	1611	2.12	1400	2592
730	2395	1633	2.15	1419	2628
740	2428	1655	2.17	1438	2664
750	2461	1678	2.20	1458	2700
760	2493	1700	2.23	1477	2736
770	2526	1722	2.26	1497	2772
780	2559	1745	2.29	1516	2808
790	2592	1767	2.32	1536	2844

<sup>1</sup>Mach number based on standard conditions, not actual conditions used for the SuRE facility

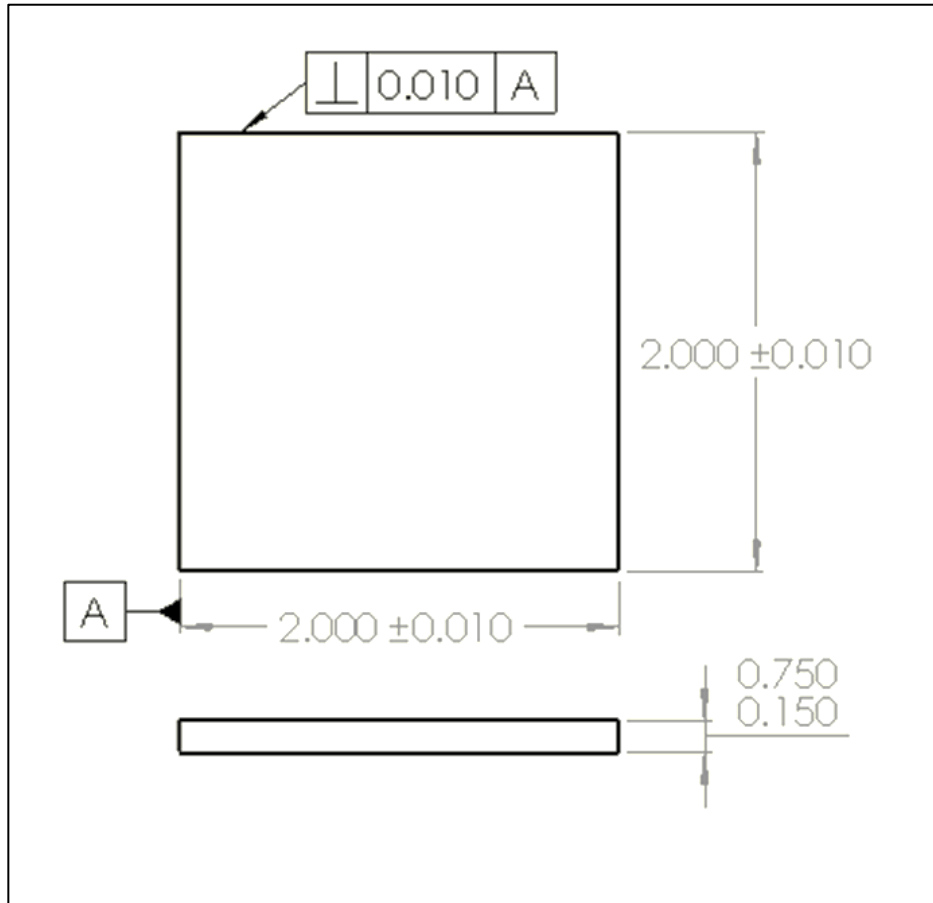
## **7.0 ANGLE OF IMPACT DEFINITION**

For the SuRE test apparatus, the angle of impact is defined as the angle that the plane of the specimen surface makes with the plane containing the droplet stream of the SuRE. Therefore, when the specimen surface is perpendicular to the plane of the droplet stream, the impact angle is 90 degrees. Conversely, when the specimen surface is parallel to the plane of the droplet stream, the impact angle is 0 degree. Specimens tested at low/shallow impact angles will exhibit little or no erosion. The lowest impact angle tested to date on the SuRE is 7 degrees. Specimens tested at the maximum impact angle of 90 degrees typically exhibit the greatest erosion.

Fixtures can be constructed to accommodate the impact angle needed for testing. Current impact angles available are 7, 16, 30, 45, 60 and 90 degrees.

## 8.0 SPECIMEN CONFIGURATIONS

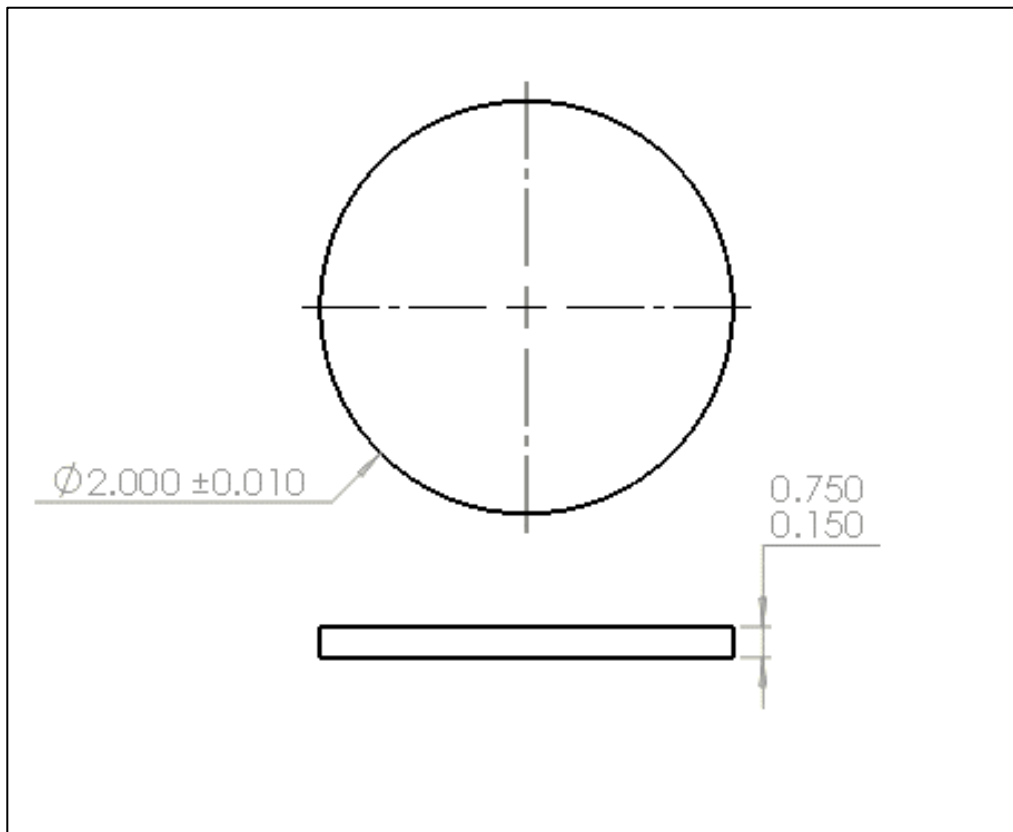
### 8.1 Square Specimen: 30, 45, 60, and 90°



*Figure 3: Square Specimen 2 x 2 inches*

- All dimensions in inches
- The effective specimen exposure area is 1.5 x 1.5 inches
- Maximum specimen thickness is 1.0 inch
- Specimen holder can accommodate 8 test specimens

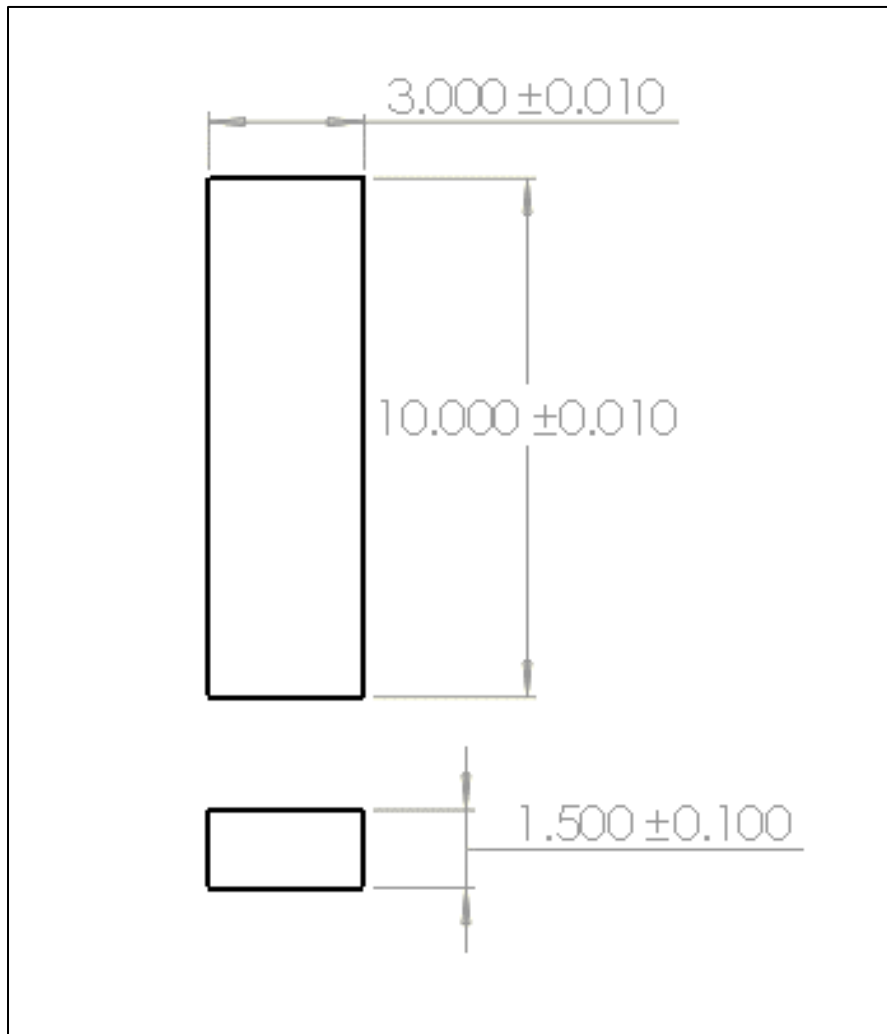
## 8.2 Disc Specimen: 30, 45, 60, and 90°



*Figure 4: Disc Specimen Size 2 x 2 inches*

- All dimensions in inches
- The effective specimen exposure area is 1.5 x 1.5 inches
- Maximum specimen thickness is 1.0 inch
- Specimen holder can accommodate 8 test specimen



**8.3 Rectangle Specimen: 7 and 16°**

*Figure 5: Rectangle Specimen Size 3 x 10 inches*

- All dimensions in inches
- Maximum specimen thickness of 1.25 inches
- Specimens must be mounted on a metal plate; the plate must have 2 standard screw holes for securing the specimen in the holder
- Pocket depth of the specimen holder is 1.5 inches
- Specimen holder screw holes are 2.5 inches from the top (short edge (3 inches)) and bottom edges and are 1.5 inches from the long edge.
- Specimen holder can accommodate 8 test specimen
- Shims are made available for height adjustment of the sample in the pocket

In the event standard specimen configurations and fixtures offered by AFRL/UDRI erosion facility do not meet the requirements of the user, it is possible to have custom specimen configuration fixtures designed and fabricated. The erosion facility personnel will work closely with the user in developing safe and effective specimen configuration tooling.

Materials used to manufacture specimen fixtures depend on the expected useful testing lifetime. Fixtures are typically made from stainless steel, titanium alloy, or 2XXX or 7XXX series tempered aluminum or combinations of these.

**End of Guide**