Abstract – Atmospheric Reentry Materials and Structures Evaluation Facility (ARMSEF) User Test Planning Guide

Test process, milestones and inputs are unknowns to first-time users of the ARMSEF. The User Test Planning Guide aids in establishing expectations for both NASA and non-NASA facility customers. The potential audience for this guide includes both internal and commercial spaceflight hardware/software developers. It is intended to assist their test engineering personnel in test planning and execution. Material covered includes a roadmap of the test process, roles and responsibilities of facility and user, major milestones, facility capabilities, and inputs required by the facility. Samples of deliverables, test article interfaces, and inputs necessary to define test scope, cost, and schedule are included as an appendix to the guide.

Atmospheric Reentry Materials and Structures Evaluation Facility (ARMSEF)

User Test Planning Guide

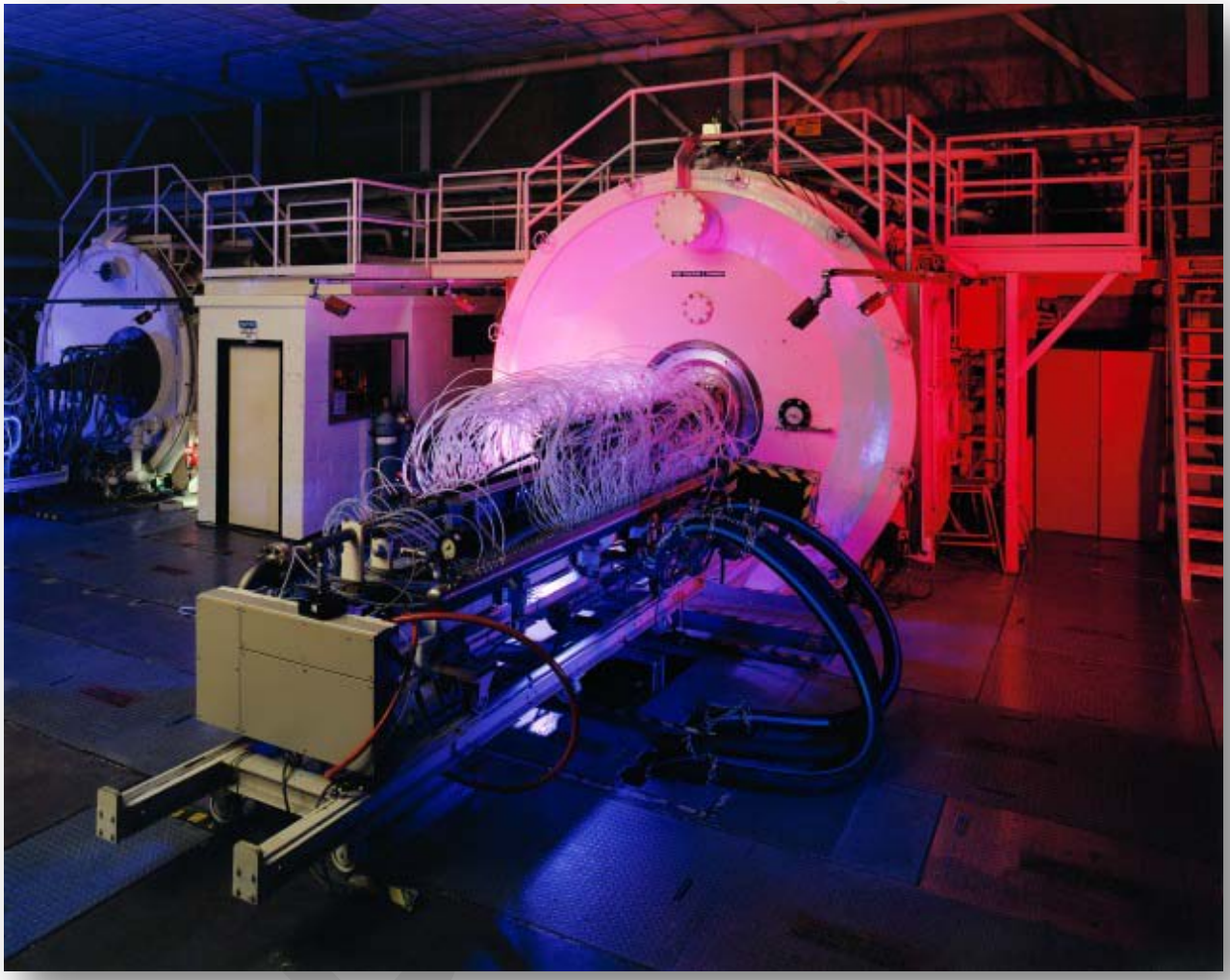

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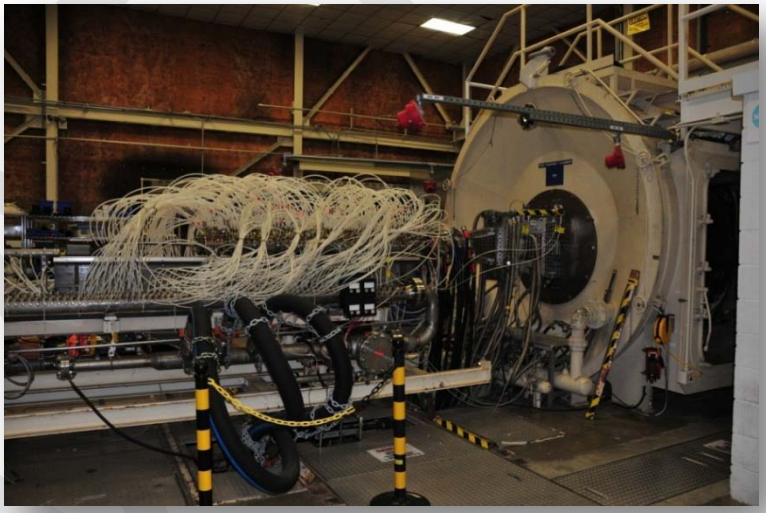
Table of Contents

1.0 Atmospheric Reentry Materials and Structures Evaluation Facility (ARMSEF)

The Arc Jet provides the capability to perform aerothermal heating environment tests representative of the convective heating conditions experienced by spacecraft during reentry that is required for the screening, development, and certification of manned/unmanned spacecraft Thermal Protection Systems (TPSs). This ARMSEF is a high altitude, hypersonic wind tunnel facility that uses electric power to heat and accelerate air to simulate reentry heating. The heated gas is accelerated through water-cooled nozzles into a vacuum chamber that is pumped by the facility four-stage steam ejection vacuum system. Flow fields created in the vacuum chambers are tailored to simulate specific reentry heating conditions for a given test article. Either of the two test positions can be configured for conical or channel nozzle testing. The following reflect the normally preferred configurations.

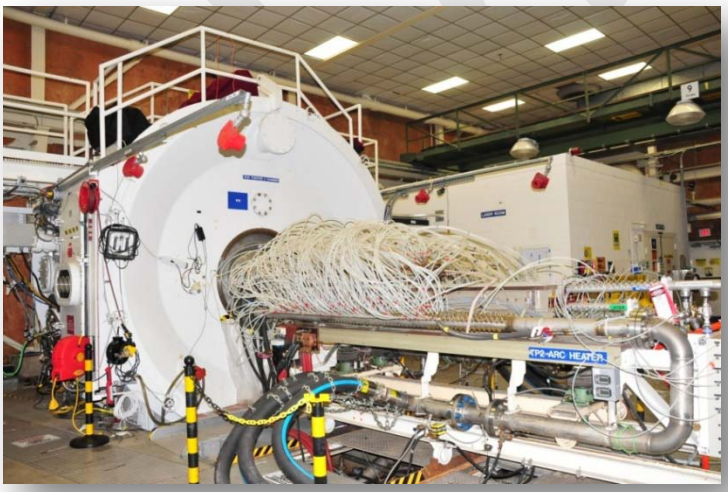
Channel Nozzle

The Channel Nozzle Test position is currently configured with a hypersonic duct for testing acreage-style test articles (e.g., tile arrays) in an environment where flow is parallel to the test article surface, such as the orbiter belly. The channel nozzle can accommodate 4″ x 4″, 8″ x 10 ″, 12″ x 12 ″, and 24″ x 24″ sized panels.



Conical Nozzle

The Conical Nozzle Test position is used to perform stagnation tests and other angle of attack testing configurations to simulate wing-leading-edge and nose cap conditions. The diameter of the flow field of this test position can be varied by selecting any one of ten nozzles sizes, ranging from 3.5″ to 40″. This test position is capable of containing two test articles at a time. The instruments used in this test position consist of optical pyrometers, a near infrared (IR) camera for temperature measurements, a spectral scanner for emissivity determinations, and a high definition camera for test article views.



Specifications

Parameter	Conical Nozzle		Channel Nozzle
Gas	N_2 + O_2 (0 – 50% O_2), CO_2 (~90%)		N_2 + O_2 (0 – 50% O_2), CO_2 (~90%)
Input Power	0.5 – 13MW		0.5 – 13MW
Nozzle Exit (Inches)	3.5, 5, 7.5, 10, 12, 15, 18, 20, 25, 30, 35 & 40		2 x 10, 2 x 18, 2 x 30 Height x Width @ Test Article Center
Bulk Enthalpy (BTU/lbm)	1,500 – 20,000		1,500 – 20,000
Type of Test Article	Stagnation	Wedge	Flat Panel
Sample Size (Inches)	Max. 27 Dia.	3 x 3, 4.5 x 5, 6 x 6, 12 x 12, 24.5 x 24.5	4 x 4, 12 x 12, 24 x 24, 8 x 10
Convective Heating Rate (BTU/ft^2 –Sec)	0.5 – 1300	0.5 – 234	12″ x 12″: 2 – 78 24″ x 24″: 2 – 45
Surface Pressure (psf)	2 – 1000		4 – 110
Surface Temperature	400 – 5,500F+*		1, 000 – 3,100F+*

* Material dependent

Services Provided

- Earth (air test gas) and CO_2 atmospheric entry testing
- Basic material testing and screening
- Development testing
  - Gaps, seals and attachments
- “Clipped” hardware
  - RCS nozzles, antennas, instrument penetration, windows, and hatches
- Sustaining engineering
  - Orbital debris
  - Design changes
  - Recertification of materials

Unique Capabilities

- 4 direct current (DC) rectifiers capable of continuously producing 10 MW or a peak of 13 MW of electrical power to heat test gases that typically consist of 23% O_2 and 77% N_2 by mass
- Variable O_2 test gas concentration for material characterization
- Variable CO_2 test gas concentration (~90%)
- Range of nozzles: 3.5- to 40-inch diameter
- Variety of wedges/holders: 4.5 x 5.0 to 24 x 24 inches, or custom built to customer needs
- Rapid scanning spectroradiometer
  - 0.68 to 8.0-µm wavelength range
  - 432 spectral intensity measurements at discrete wavelengths
- Heater configuration is highly flexible for adjustment of test envelope capability

Point of Contact

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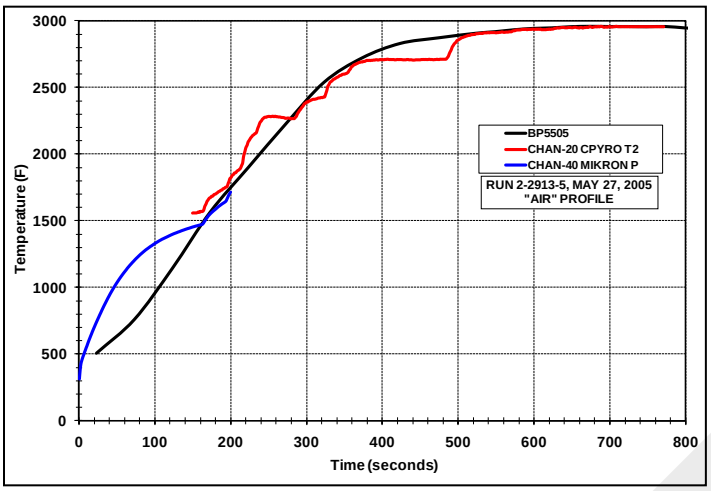
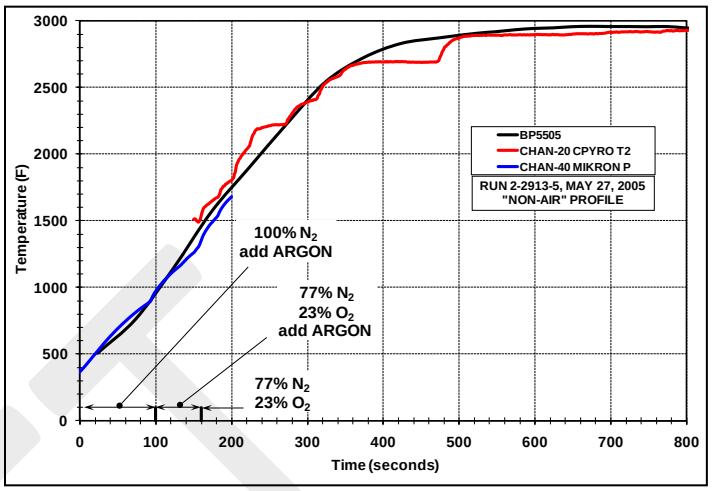
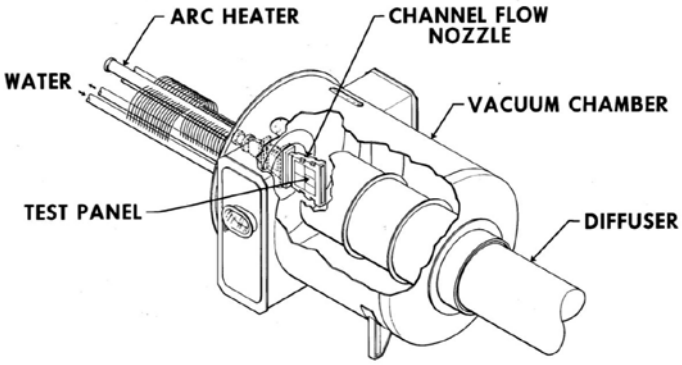
Typical Pressure and Thermal Environments Simulated



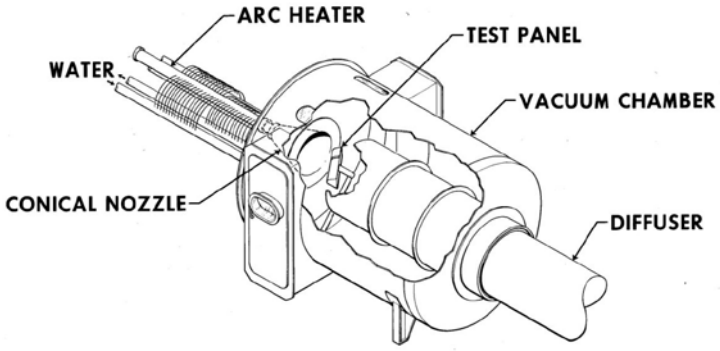


Transient temperature profile matching is achievable through real-time adjustment of the test gas mass flow rate and the applied power. If required, the low temperature portion of the profile may be more accurately traced with the inclusion of argon in the test gas and/or adjustment of the O_2/N_2 ratio.

2.0 Facility Layout

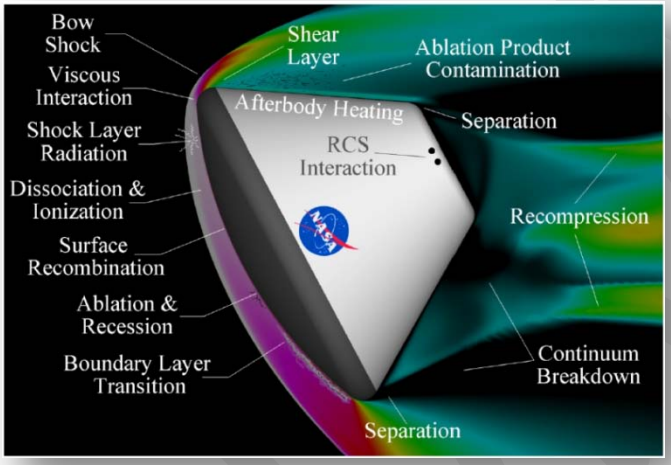


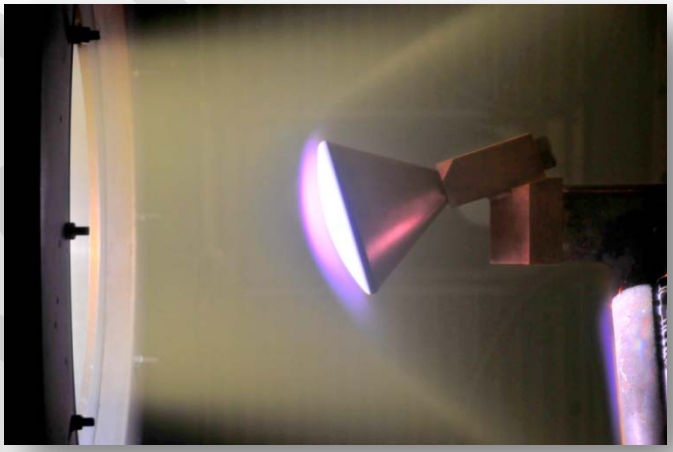
Chamber Cutaway – Channel Nozzle



Chamber Cutaway – Conical Nozzle

Entry Simulation Testing *





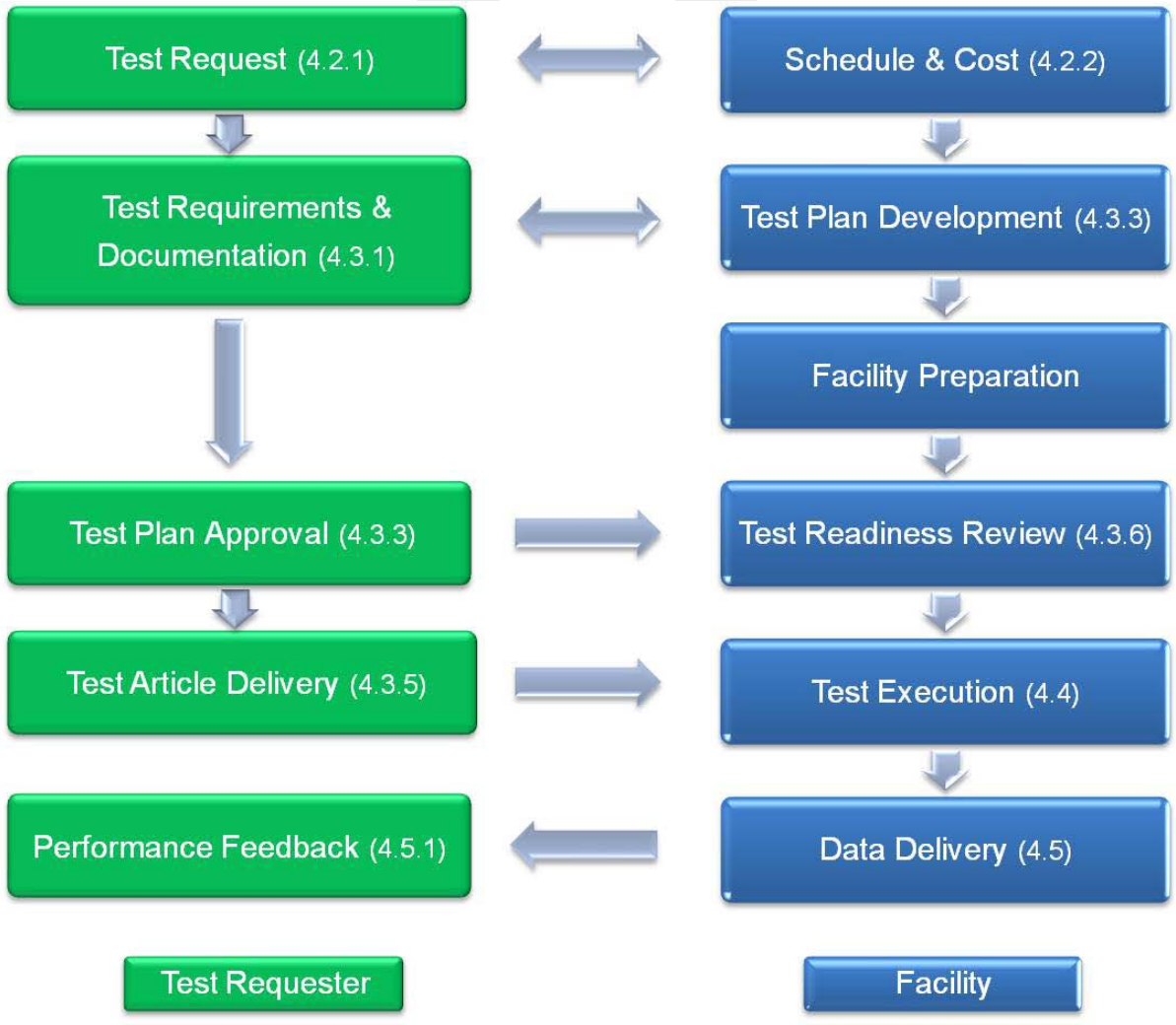
*See Appendix A for a sample facility interface and sample test configurations.

3.0 Safety and Health

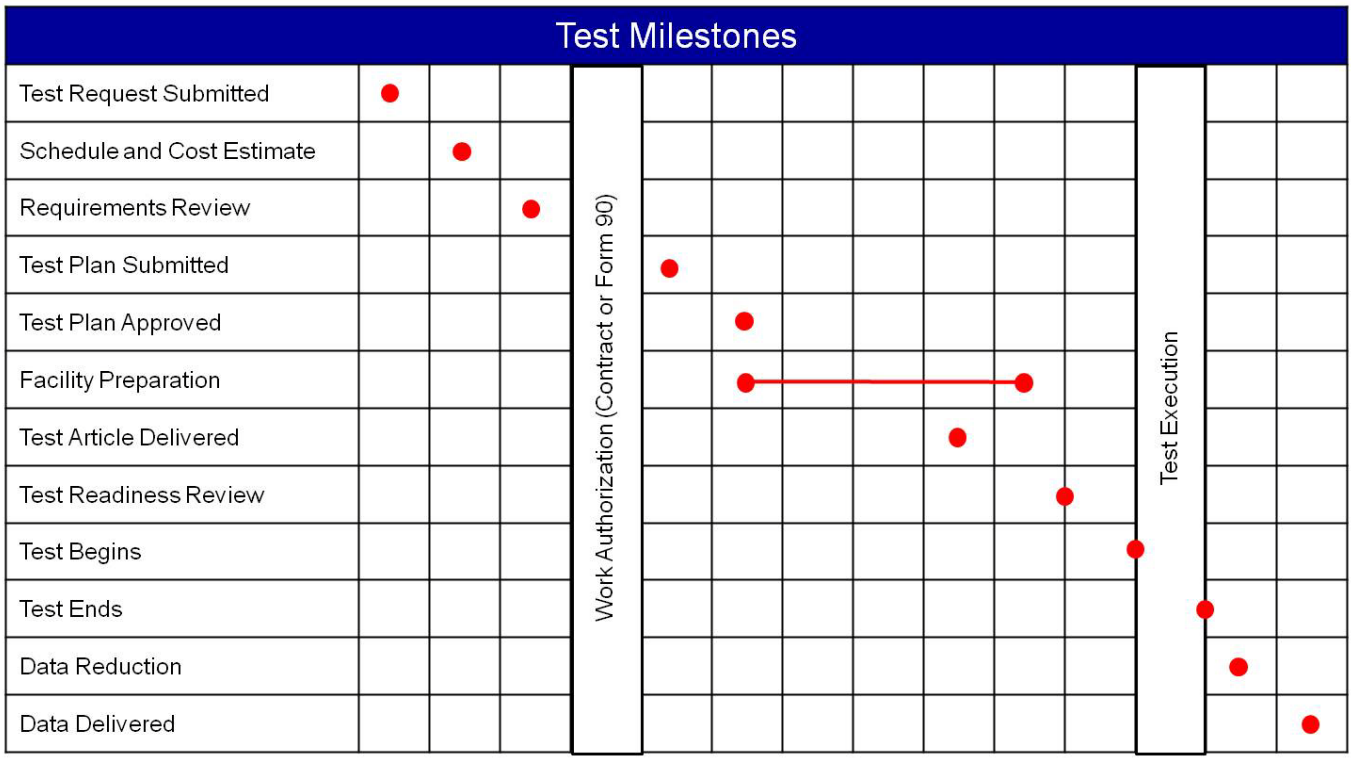
Safety is an integral part of the culture at the National Aeronautics and Space Administration (NASA). Management, leadership, and employee involvement from all organizations are critical to the success of NASA's safety program. In order to ensure personal safety and a safe test environment throughout the process, the requester shall furnish the facility with the information necessary to perform a hazard assessment of the test article. Additionally, while visiting the Johnson Space Center (JSC), the requester shall follow all facility-specific safety and health requirements. A facility safety briefing shall be provided to all personnel prior to the start of the test. The safety briefing will include a review of the STL safety rules, potential hazards, and emergency procedures. An outline of the material covered is included in Appendix E.

4.0 Test Process Flow

The flowchart presented below outlines the basic roadmap and significant milestones between the initial test request and delivery of test data. The flow is separated between Test Requester actions and Facility actions. Interactions and inputs between the Test Requester and the facility Test Director also are highlighted.



The test schedule is highly dependent on the complexity of the test, facility availability, and sequence of runs. For time-critical testing, this schedule may be accelerated. A detailed schedule shall be developed following a review of the test objectives and requirements. Major milestones are presented below:



4.1 Export Controlled and Proprietary Information

All TPS data is restricted by the International Traffic in Arms Regulation (ITAR) and Export Administration Regulations (EAR). The ARMSEF provides for protection of export controlled and proprietary information and hardware throughout the test process. The Test Requester shall clearly mark all export controlled or proprietary hardware items and data provided with a notice of restriction on disclosure or usage. The Test Director shall safeguard export controlled or proprietary items from unauthorized use and disclosure and ensure that test articles remain secure within the facility and are properly sequestered. Access to the facility is restricted to facility personnel and escorted visitors. Hardware items shall be returned to the Test Requester or disposed of in accordance with the Test Requester's instructions at the completion of the test activity.

4.2 Test Initiation Phase

The test initiation phase establishes the relationship between the Test Requester and the Test Director. The Test Requester shall provide a test request to the Test Director, which will be used to determine test feasibility and to develop an estimated cost and a preliminary test schedule. An initial requirements review shall define the characteristics of the test article, test objectives, and special considerations for the test. An onsite tour of the facility is highly recommended for familiarization and to provide an opportunity for an exchange of technical information.

Inputs:	Test Requester provides test request, identifies Test Article Expert
Activities:	Facility Test Director reviews test request to determine test feasibility
Outputs:	Facility delivers preliminary test plan, estimated cost and schedule to Test Requester

4.2.1 Test Request

The test request outlines the test objectives, test article description, and schedule. A Test Request Worksheet is provided in Appendix D. This worksheet addresses the basic requirements for testing in the ARMSEF. It is suggested that the Test Requester complete this worksheet to facilitate the development of a preliminary test plan. Contact the Test Director if you have questions about completing the Test Request Worksheet. At a minimum, the test request should include the following information:

Test Objective

A brief description of the test requirements, including, but not limited to, the following:

- Desired test conditions (pressure, enthalpy, temperature)
- Proposed test approach
- Test data requirements

Test Article Description

A brief description of test article, including, but not limited to, the following:

- Size (provide drawings, sketches, photos)
- Weight
- Test article interface (load points, method of suspension or test article support)
- Test article fluid interface requirements (type, pressure, flow)
- Orientation (fixed or moveable)

- Special considerations [e.g., hazards, cleanliness, compatibility, material safety data sheets (MSDS)]
- Handling and storage requirements

Schedule

Identify the required start date and proposed date for test completion.

4.2.2 Schedule and Cost Estimate

A cost and schedule estimate, including major milestones, will be delivered following receipt of the Test Request Worksheet.

4.3 Test Preparation Phase

The detailed test plan and test schedule are finalized during the test preparation phase. The Test Requester shall provide detailed test requirements and test article documentation to the Test Director. A Test Readiness Review (TRR) will be held following approval of the test plan.

Inputs:	Test Requester provides test requirements and test article documentation
Activities:	Facility develops test plan, begins assembly of facility interface/support structure(s)
	Test Requester ships/transports test article to JSC
Outputs:	Test Requester approves test plan and test schedule
	Facility holds TRR

4.3.1 Test Requirements

A complete understanding of test requirements is mandatory for a successful test. Test requirements must be defined and reviewed so that the test team understands the effect of the requirements on test facility preparation. The Test Requester shall provide a detailed list of test requirements, including, but not limited to, the following:

- Specific test conditions
- Interface requirements (e.g., fluid, structural, electrical, mechanical)
- Data/instrumentation requirements (provided by Test Requester and facility)

4.3.2 Test Article Documentation

Test Article Drawings

The Test Requester shall provide detailed test article drawings as requested by the facility. Test article drawings are used to prepare the facility interfaces, test article support structures, and instrumentation connection points.

Material Safety Data Sheets

NASA must ensure that all materials exposed to test environments do not present a hazard to personnel or the test facility. The Test Requester shall deliver to the facility MSDS for materials used in the construction of the test article with an assessment of expected byproducts produced during the thermal test. The MSDS shall be delivered prior to delivery of the test article. The Test Director will review the materials list for compatibility with the test environment and to determine protective measures for personnel, if required.

Test Article Hazard Identification

The safety of facility personnel, facility equipment and the test article is imperative to NASA. Potential hazards, material compatibility, and facility interfaces will be reviewed with the facility prior to testing. In certain instances, special precautions must be taken, due to the severity level of these potential hazards. The Test Requester may be asked to provide further information to clarify or mitigate a potential hazard.

4.3.3 Test Plan

A test plan will be prepared by the Test Director, unless one is submitted by the Test Requester. The final test plan shall be approved by the Test Requester with concurrence from the Test Director. The test plan will be the controlling document, with respect to scope and approach for the test program. The test plan will include, at a minimum, the test objectives, scope, test article description, safety considerations, and data requirements. Changes to the test plan that occur after the TRR that result in a major change to the scope of the test or that present new hazards may require a delta TRR.

4.3.4 Test Schedule

A detailed schedule shall be developed by the Test Director and approved by the Test Requester. The schedule shall allow adequate time for review and approval of test requirements, assembly of facility interfaces/structures and delivery of the test article. The schedule of other tests and maintenance activities will be reviewed and potential conflicts shall be addressed by the Test Director.

4.3.5 Test Article Delivery

The test article delivery date will be determined on a case-by-case basis. An agreed-upon delivery date shall be captured as a milestone in the test schedule. The Test Requester shall provide detailed handling instructions prior to delivery of the test article, including handling hazards, cleanliness, and storage requirements. The test article shall be secured within the test facility, unless directed to provide another means of storage. An inspection of the test article shall be performed by the Test Director and the Test Article Expert prior to the start of testing. NASA encourages Test Article Expert participation in the test article integration phase to provide immediate feedback on test article handling and on any integration issues that arise.

4.3.6 Test Readiness Review

A TRR will be held to ensure the completion of all necessary facility and test article activities prior to test execution. The TRR will include the following:

- Review of the test plan, test procedures, and other required test documentation
- Confirmation of facility and test article readiness
- Review of configuration records, including facility interface control documents, pressure system certification, instrumentation calibration, and materials compatibility
- Assurance that controls are in place to mitigate risks or hazards identified in the Test Hazard Analysis
- Verification that data acquisition and processing functions are in place to adequately capture all critical data
- Confirmation that multimedia coverage is adequate to provide recognition and assessment of potential test anomalies

Approval to proceed with test operations is granted by the Test Readiness Review Board (TRRB). The Test Director shall ensure that all TRR actions have been accomplished prior to the start of the test. The TRRB shall convene 1 to 5 business days prior to the start of the test. TRRB participants shall include the following:

NASA TRRB Chairman	Test Article Expert (Appointed by Test Requester)
Test Director	Safety Engineer
NASA Test Safety Officer	Quality Engineer – if required by facility

4.4 Test Execution Phase

NASA encourages Test Requester participation in the testing activity. The Test Requester shall provide a Test Article Expert to verify that test setup and execution meet the stated objectives. The Test Article Expert also shall verify test article performance and approve requested test deviations during test operations. In some cases, the Test Director may be designated as the Test Article Expert. The ARMSEF control room has limited space available; therefore, the Test Requester is allowed to have no more than three observers in the control room during the test activity.

Inputs:	Approval to begin testing received from TRRB
Activities:	Facility completes facility buildup, Detailed Test Procedure
	Facility conducts testing activity
Outputs:	Test completed

4.4.1 Test Authority

The Test Director has the authority and responsibility to direct the test in accordance with the approved test plan and to terminate test activities per test rules when danger is imminent or test control cannot be maintained. The Test Director will ensure that positive actions are taken to halt any steps in the test procedure whenever unsafe or hazardous test conditions arise. The Test Director, with the concurrence of the Test Article Expert, has the authority to terminate the test when sufficient data has been obtained to meet objectives or when objectives cannot be met. Test team personnel will only accept directions only from the Test Director.

4.4.2 Test Deviations

Changes to the test procedure shall be approved by the Test Article Expert with concurrence from the Test Director. Deviations that result in a major change to the scope of the test or that present new hazards may require a delta TRR.

4.5 Test Closeout Phase

Data shall be delivered to the Test Requester within 10 business days following completion of testing. The Test Requester shall notify the Test Director upon receipt of the data. Acceptance of the test data concludes the test activity.

Inputs:	Test completed
Activities:	Facility ships/transports test article to Test Requester
	Test Director delivers data to Test Requester
Outputs:	Test Requester accepts data
	Test Requester completes Customer Feedback form

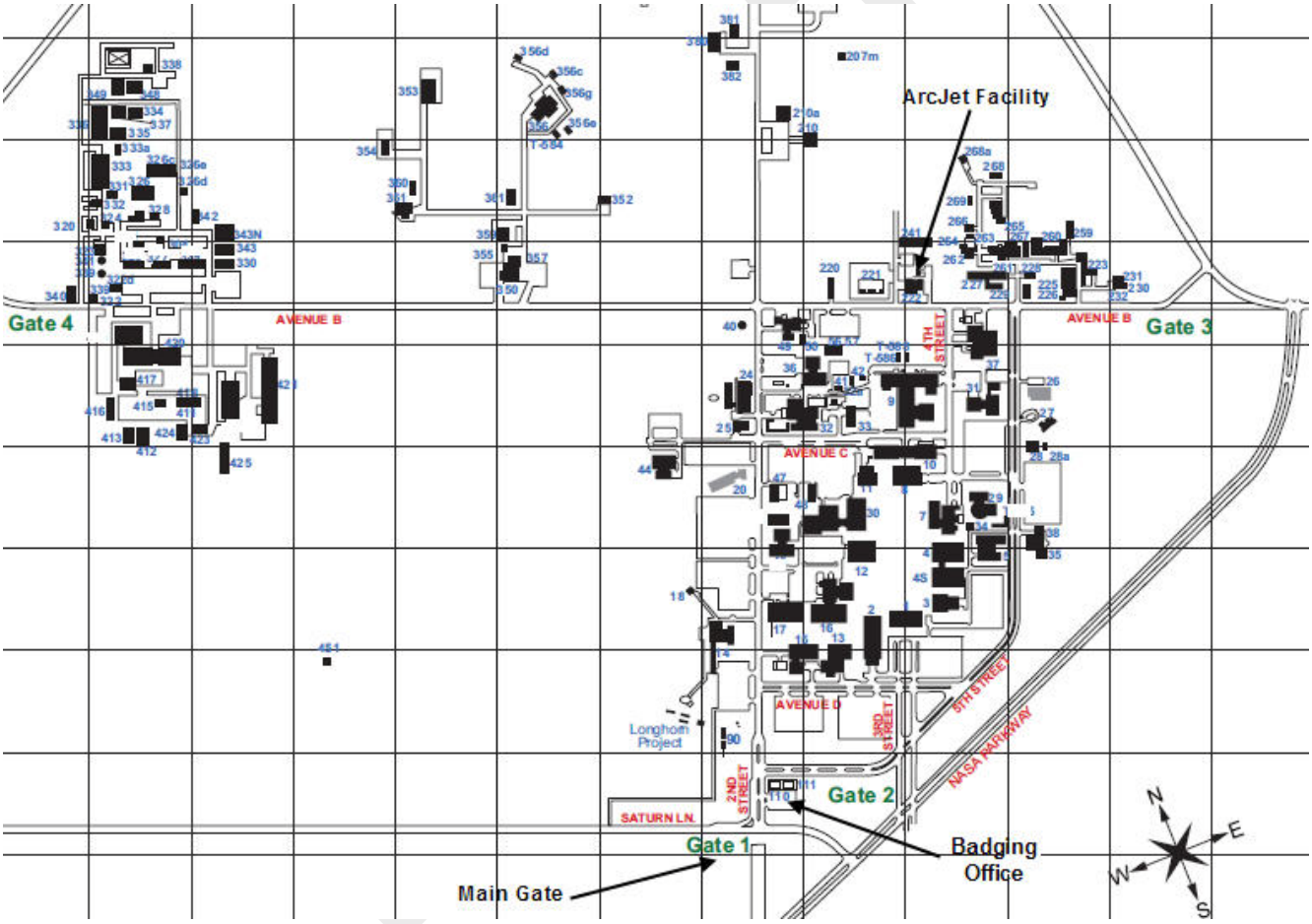
4.5.1 Customer Feedback

The ARMSEF requests feedback from our customers. Evaluation of the services we provide enables continued improvement to our process. A Customer Feedback form is included in Appendix F. You are encouraged to complete the Customer Feedback form and return to the Test Director, following receipt of the test data. Your participation is greatly appreciated.

5.0 Facility Access

Identification badges are required for all persons requiring access to JSC. The Test Director or designee will initiate a badge request for all Test Requester personnel who will be participating in the test activity. Badge requests must be submitted at least 4 days prior to the visit to prevent badge processing delays. Badge requests for non-U.S. citizens may require a minimum of 30 business days to process. Test Requester personnel shall arrive at JSC Building 110 to pick up temporary identification badges. Visitors to JSC must show a current picture identification (valid driver's license, U.S. passport, government ID card).

The ARMSEF is located in JSC Building 222. A facility access briefing shall be provided to all personnel requiring access to the facility prior to the start of the test.



6.0 Roles and Responsibilities

Test Director – Has overall responsibility for all phases of the test process.

Test Requester – The client requesting performance of a test activity. The Test Requester is responsible for the test article and for providing a Test Article Expert.

Test Article Expert – A representative of the Test Requester with thorough knowledge of the test article and how it is to be operated in the test environment. The Test Article Expert also is responsible for approving the test plan and verifying that test objectives are met.

Test Conductor – Assigned under the authority of the Test Director to execute the test in accordance with the approved test plan.

Safety Engineer – Reviews the test article hazard assessment and the integrated hazard analysis for the test facility to identify any additional hazards that could result in injury to personnel.

Quality Engineer – Responsible for verifying that the test facility is ready for the test by ensuring that all constraints to the test have been closed.

Responsibilities Matrix

Item	Test Requester	Facility
Test Request Worksheet	Create	Review
Cost and schedule	Approve	Create and sign off
Hazards	Identify test article hazards	Create test article/facility integrated hazard analysis
Test plan	Review and approve	Create and sign off
Test Readiness Review	Approve	Conduct and approve
Test execution	Verify test article performance Verify that test setup and execution meet objectives Approve requested deviations	Execute test
Provide test data/results	Notify Test Director of data receipt	Deliver to Test Requester
Review test data/results	Approve	
Shipping	Provide instruction	Execute per request

Acronyms

ARMSEF	Atmospheric Reentry Materials and Structures Evaluation Facility
CEV	Crew Exploration Vehicle
DC	Direct Current
EAR	Export Administration Regulation
FRSI	Felt Reusable Surface Insulation
HRSI	High Temperature Reusable Surface Insulation
IR	Infrared
ITAR	International Traffic in Arms Regulation
JSC	Johnson Space Center
MSDS	Material Safety Data Sheets
NASA	National Aeronautics and Space Administration
RCC	Reinforced Carbon-Carbon
TPS	Thermal Protection System
TRR	Test Readiness Review
TRRB	Test Readiness Review Board

Appendices

A. Facility Interface and Test Configurations

B. Channel Nozzle Test Data Envelope

C. Instrumentation Provided by Facility

D. Test Request Worksheet

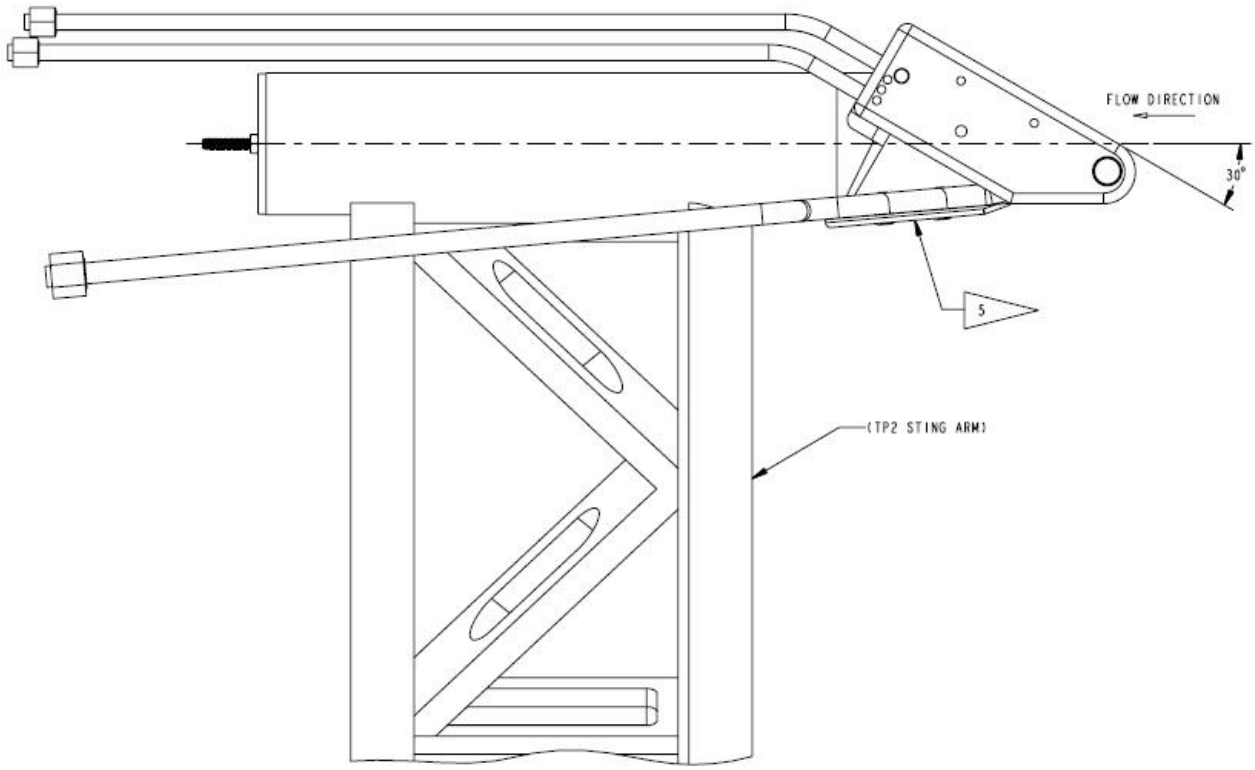
E. ARMSEF Visitor Orientation

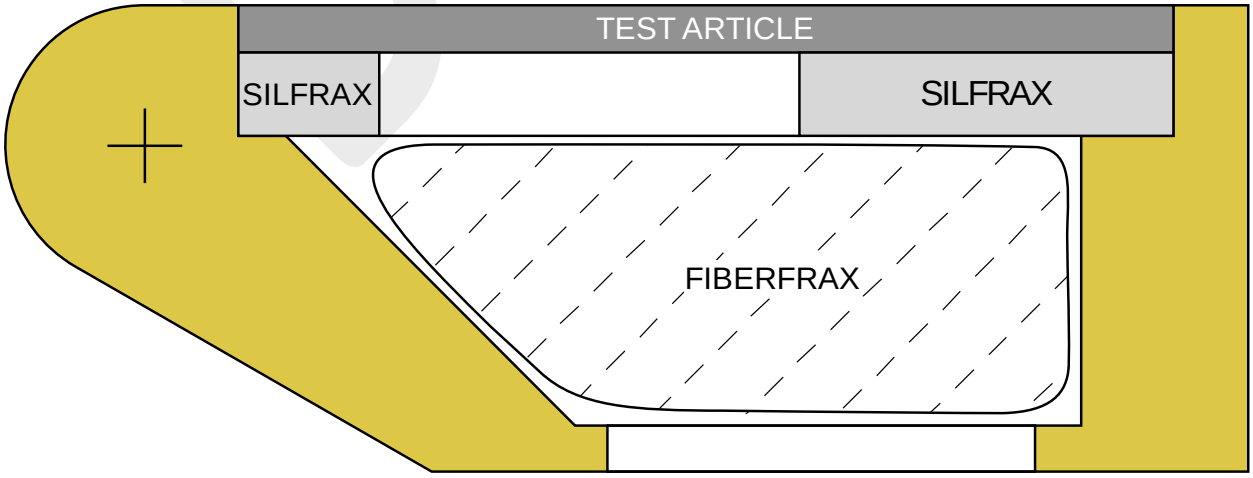
F. Customer Feedback

Appendix A Facility Interface and Test Configurations

The test fixture drawings included in this guide are a sampling of the capabilities within the ARMSEF. The facility maintains a variety of fixtures to support general and requester-specific testing. Additional test fixture drawings are available upon request. The facility also can manufacture test fixtures to requester specifications. Contact the Test Director to discuss test article interface requirements.

Sting Arm Integration



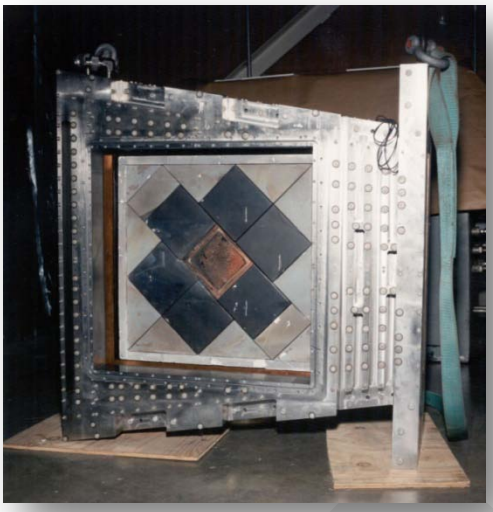


Sample Test Configurations

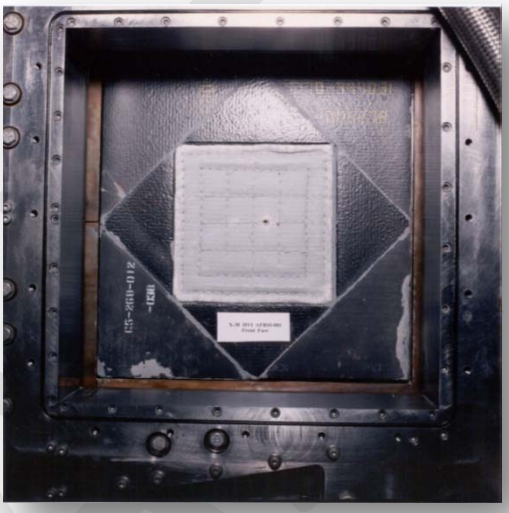
Channel Nozzle

- 2″ wide, 10° half angle duct
- Parallel flow field
- Panels, TPS tile arrays
- Laminar or turbulent flow

Test Section	Surface Temp Range	Surface Pressure
8″ x 10″	1,500 – 3,000 F	15 – 130 psf
12″ x 12″	1,000 – 2,500 F	10 – 110 psf
24″ x 24″	700 – 2,200 F	5 – 60 psf



Shuttle Lost Tile
24″ x 24″ test section



X-38 Hypervelocity Impacted
Blanket Test – 12″ x 12″ test section

X-33 Metallic TPS Panel Seal Test
24″ x 24″ test section

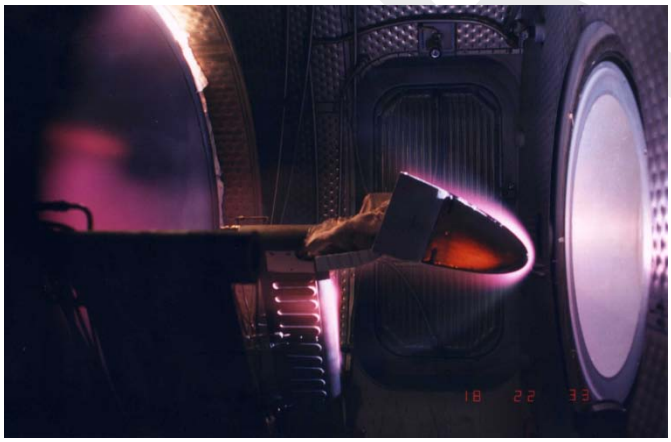
24″ x 24″ HRSI Damage Tolerance

Conical Nozzle

- Two hydraulically-controlled sting arms
  - Support capability – up to 500 lb
  - Dynamic loading during insertion and retraction is a limiting factor; however, the hydraulic pressure can be tailored to accommodate large models at the expense of increasing the insertion and retraction times
- 500-psi coolant water supplied to model holders
- Wedge configuration (4.5″ x 5″, 6″ x 6″, 12″ x 12″, 24″ x 24″)

FRSI in a 12″ x 12″ Wedge

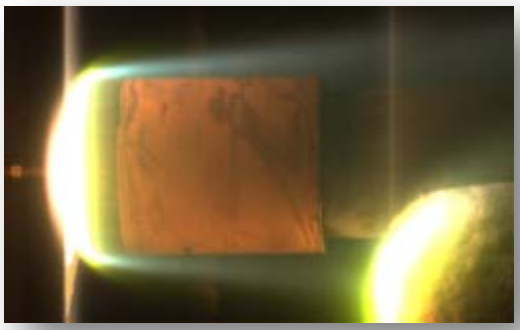
RCC Plate in a 4.5″ x 5 ″ Wedge



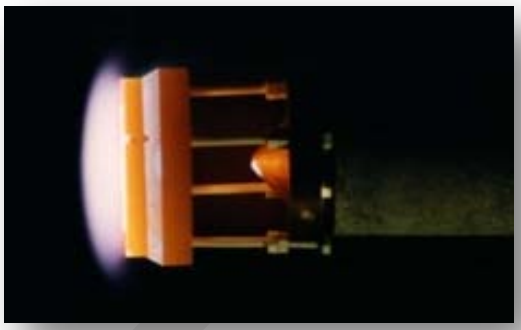
X-33 Wing Leading Edge

Bullnose Wedge

Stagnation Configuration



4″ CEV Ablator Model

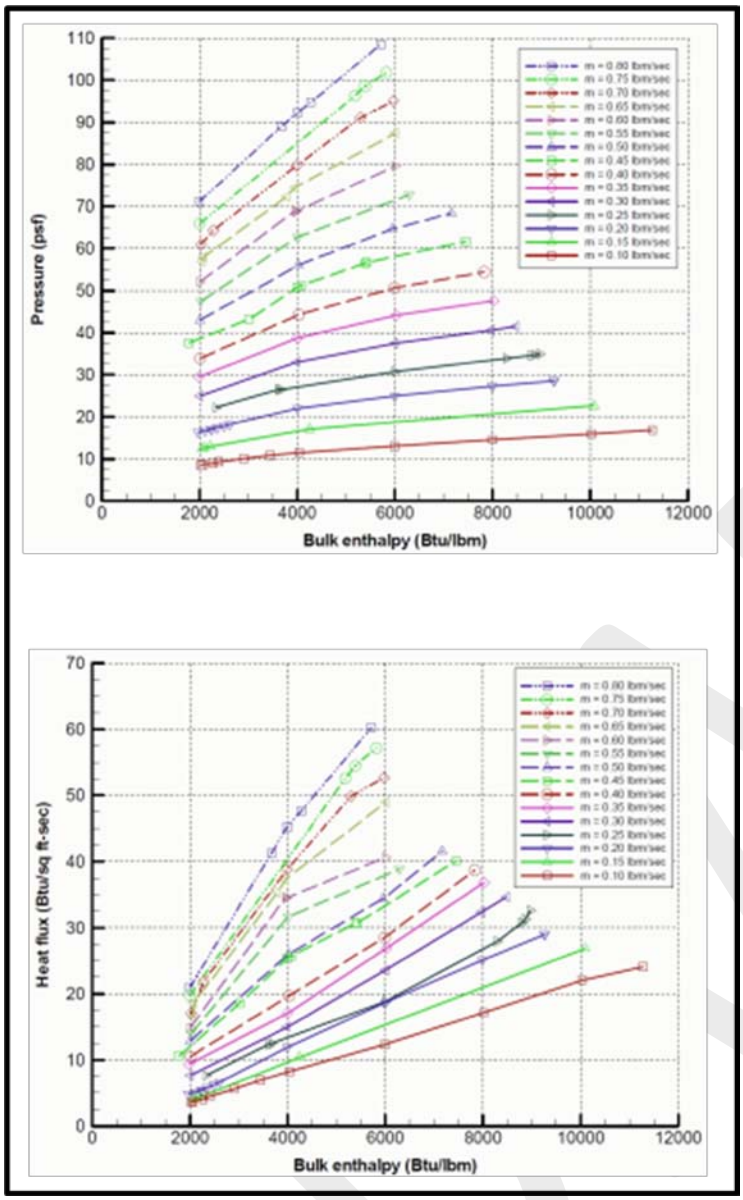


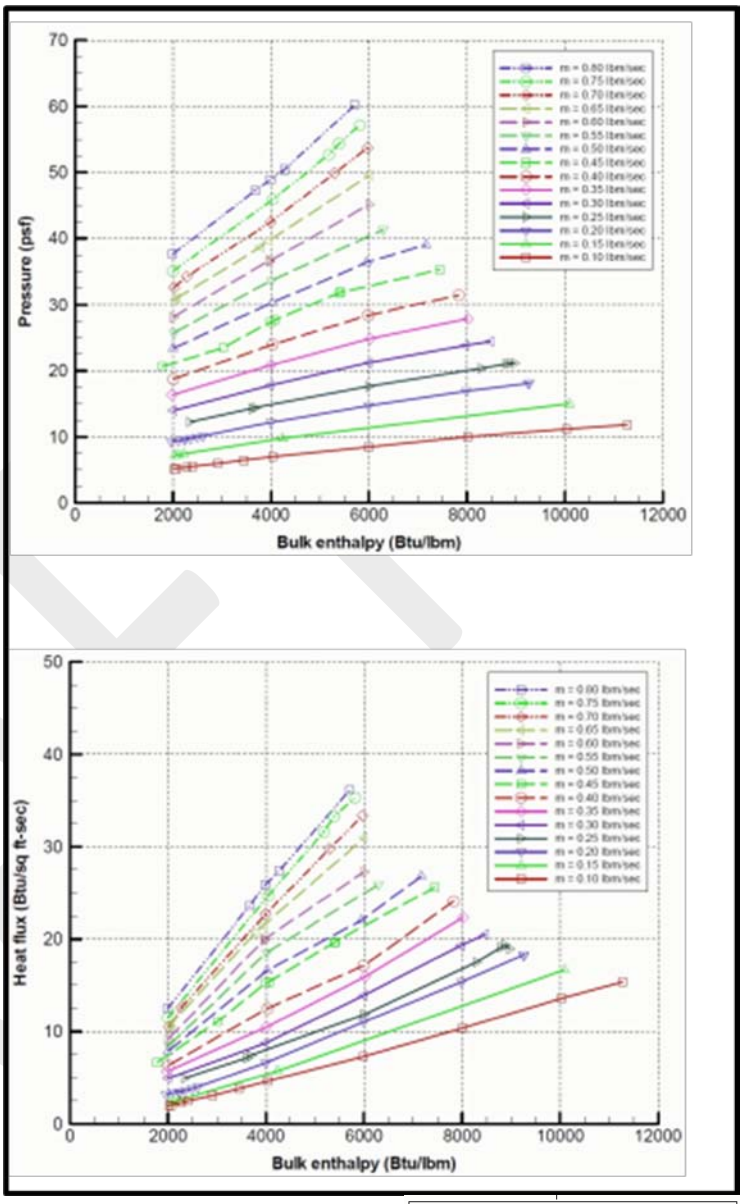
Open-Back Graphite Holder

4″ Puck, 5″ Holder (preinstallation)

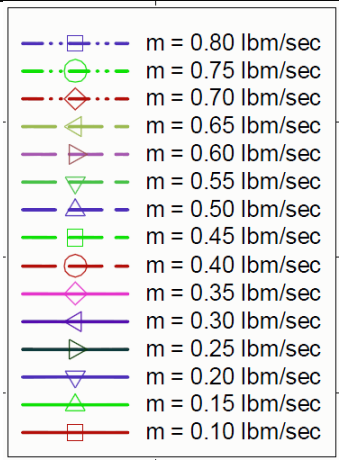
4″ Puck, 5″ Holder (installed)

Appendix B Channel Nozzle Test Data Envelope





* Heat flux measurements made with gardon gage
* Measurements taken using a 10 pack heater



Appendix C Instrumentation Provided by Facility

Optical Instruments

Instrument	Wavelength (Microns)	Quantity	Range	Target Area
Rapid Scanning Spectroradiometer	.68 – 8.0 432 Discrete Wave Lengths	1		Adjustable ¼″ to 1″
Near Infrared Camera	0.9	1		Approx. 12″ x 12″ at chamber center line
Reference Standard Pyrometer	0.65	1	1050 – 3000C	.12″
Reference Standard Pyrometer	0.9	1	600 – 1800C	.05″
Laser Pyrometer	0.9	2	500 – 2500C and 600 – 3000C	0.9″
Fiber Optic Pyrometers	1.3	22	*	0.2″
Fiber Optic Pyrometers	1.0 – 2.5	9	* 370 – 1650C	0.1″, adjustable down to .01″
Disappearing Filament Pyrometer	0.65	1	590 – 3320C	0.05″
Long Wavelength Pyrometer	5.1	3	* 250 – 2500C	0.25″
Total Radiometers	.2 – 6.1	5	* 100 BTU/ft^2-sec	1.5 deg. view angle

* Can be re-ranged and certified for higher temperatures and/or a target area modified by facility personnel

Gardon Gage Sensor Inventory (634 + Sensors of various configurations)

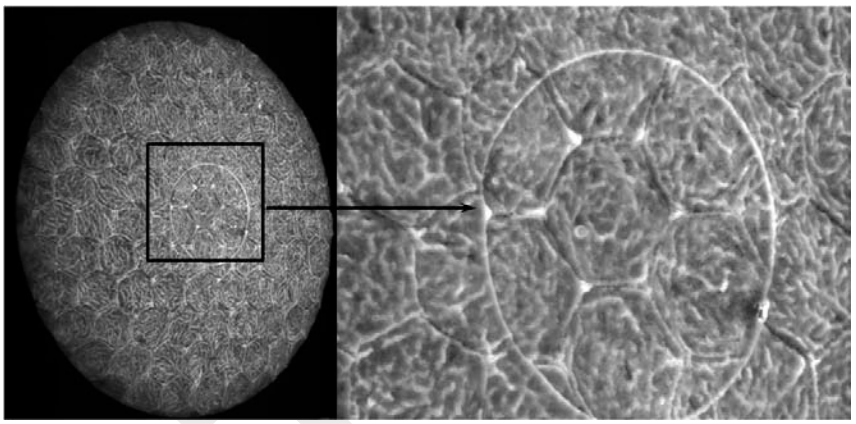
Heating Rate Range	Non-Cooled		Cooled		
BTU/Ft^2-Sec	1/8″ Dia.	¼″ Dia.	3/8″ Dia.	½″ Dia.	1″ Dia.
5					15
10		37			39
15		33			16
25		7			
30	13	117			15
50	12				11
60	24	23	2		19
100		10			1
120	36	7			7
200					1
250	1				
300		12			27
500	23			1	18 flat, 3 with 3″ r, 2 with 4″ r
1000	38				19 flat, 1 with 4″ r, 4 with 2″ r
2000	20				20

* A large variety of slug calorimeters are available and custom calorimeters can be fabricated in-house as required.

Ultra-High Definition Video

Capabilities

- 2048 x 2048 resolution
- Monochrome and color options
- 15 fps at full resolution
- Large quantity of raw data
  - 20 min is approx. 22 GB
  - Each image is indexed, time-stamped, and archived
- Video is produced and provided to the customer
  - Greatly-reduced file size (1:1000) for usability at the cost of reduced fidelity and resolution
  - Time-lapse or real-time
  - Standard *.mpg format



Appendix D Test Request Worksheet

Test Requester Information

Test Article Expert:	Contact Information (Phone, E-mail, Address):

Test Objectives

Purpose of Test:	
Proposed Start Date:	Critical Start Date:

Test Article

Test Article Description:	
Physical Dimensions (L/W/H):	Weight:
Test Article Surface Chemistry:	Number of Specimens:
Number of Test Conditions (conditions per test article/total conditions):	Type of Test (Steady State/Continuous):

Test Article Interface

Support Structure/Interface Points:
Orientation:

Test Environment

Complete the Test Environment table below for steady state conditions or provide a plot of the test environment to be simulated for a continuous environment.

Test Condition	Surface Temperature(F)		Surface Pressure (psf)		Cold Wall Heat Flux (BTU/ft^2-s)	Bulk Enthalpy (BTU/lbm)	Exposure Time (secs)
	Parameter	Tolerance	Parameter	Tolerance			
1							
2							
3							

* Data is only required in each column where the parameter is significant to your desired test environment.

Test Article Handling Requirements

Cleanliness Level:	Controlled Access:
Special Moving/Handling:	

Instrumentation

Instrumentation Provided by Test Requester:
List the primary measurements to be made (e.g., surface temperature, pressure, heatflux, duration in flow, flow velocity):

Data Acquisition and Recording

Number of Channels:	Audio/Video Recording (Yes/No):
Sampling Rates:	Photographic Film (Yes/No):
Real-Time Data Processing (Yes/No):	High Speed/Low Speed:
Data Handling Requirements (storage, delivery, format):	

Other Information

List any other information pertinent to the test:

Appendix E ARMSEF Visitor Orientation

Orientation for New Employees & Visitors at the ARMSEF

The ARMSEF, Building 222, has a number of potential hazards, safety rules, and emergency procedures to which all visitors to the ARMSEF must be made aware. The potential hazards include high voltage or current, hydraulic insertion systems, high-pressure water, Class 3 and 4 laser system, high pressure/temperature steam, nitrogen, oxygen, argon, cryogenic LN2, hazardous materials, compressed gas cylinders, machine tools silica fibers, vacuum chamber windows, and crane and forklift operations. For more information about the hazards within this facility, please review the facility hazard analysis, system hazard analyses and job hazard analyses.

1. ARMSEF SAFETY RULES

1.1 Rectifier / 10MW Power System & 2.5MW Load Bank System:

a. High voltage or current may be present in the Rectifier / 10 Megawatt Power Supply (located in the Rectifier Building) and the 2.5 Megawatt Load Bank System (located northwest of the main building within fenced area) or on the arc columns (located in front of each test chamber in the test cell).
b. Observe all electrical hazard warning signs posted at the entrance to work areas or equipment containing high voltage and electrical hazards.
c. Do not leave tools or equipment on the arc column or carriage platform as this could cause thousands of dollars worth of damage to test equipment and hardware.
d. Only certified facility personnel shall operate the Rectifier / 10 Megawatt Power Supply System and 2.5 Megawatt Load Bank System.
e. Only authorized personnel are permitted in the Rectifier Building, the 2.5 Megawatt Load Bank System, and in the transformer yard (adjacent to the Rectifier House) during maintenance, pre-test and post test system operations.
f. No one is permitted in either area during test system operations.
g. Hearing protection is required around the 2.5 Megawatt Load Bank System when the system is operation which has hearing protection warning signs posted around the area.

1.2 Hydraulic Insertion Systems:

a. The hydraulic insertion systems can be installed in both test chambers and may present a crush hazard both inside and in back of both test chamber. These systems exert thousands of pounds of force and have unguarded moving parts.
b. Only certified facility operators shall operate the Hydraulic Insertion Systems.
c. Personnel are not permitted in the test chambers when a hydraulic insertion system is operating.

1.3 Coolant Water System:

a. The Coolant Water System has operating pressures up to 580 psig and flows up to 1300 gallons per minute.
b. The test cell is off-limits to all when the Coolant Water System pump (P301) is operated above 150 psig. The Test Conductor will announce over the facility intercom system that the Coolant Water System is operational, clear all personnel from the test cell and activate the “Test In Progress” warning signs.

c. Only certified facility operators shall operate the Coolant Water System.
d. Flex hoses supplying water to the test chamber arc column are restrained to prevent whipping. Any flex hose that ruptures due to high-pressure water flowing is a hazard that can cause severe injury**.**

1.4 Test Gas Area:

a. The Test Gas Area contains both the LN2 Storage & Intensifier System and Test Gas System.
b. The Test Gas System consists of Department of Transportation certified GN2 and GO2 tube trailers and an Argon k-bottle rack which are used to supply gases for the test cell.
c. The LN2 Storage & Intensifier System consists of a 3,185 gal. LN2 storage tank and cryogenic reciprocal pump which is used to convert LN2 into GN2 for recharging GN2 tube trailers.
d. Only certified facility operators shall operate the Test Gas System and the LN2 Storage & Intensifier System.
e. Only authorized personnel are permitted in the fenced area during maintenance, pre-test and post test system setup.
f. Always observe hazard operation / authorized personnel warning signs posted at the entrances to the Test Gas System Area.
g. Post test residual gas or leaking valves may leave high or low oxygen levels in the test chamber. A calibrated O2 gas detection monitor must be used to verify proper atmospheric conditions prior to personnel entry into the test chamber.
h. A full-time calibrated O2 stationary gas detection monitor is located next to the gas tree section of the Test Gas System in the test cell. Personnel are required to exit the building immediately and assemble at the evacuation assembly point upon hearing the warning alarm.

1.5 Boiler System:

a. An 80,000 lbs/hr. boiler system is located in the Nebraska Boiler House (located northwest of the main facility building).
b. Only authorized personnel are permitted in the Nebraska Boiler House when the boiler is operating and safety glasses and hearing protection is required in the Nebraska Boiler House when the system is operating.
c. All personnel are to exercise caution with respect to hot surfaces and potential steam leaks when in the Boiler House whether the boiler is operating or not.

1.6 Ejector Yard (Cooling Water System, Cooling Tower and Steam Ejector System):

a. The Cooling Water System, Cooling Tower, and four-stage Steam Ejector System are located outside the north side of the test cell in an area known as the Ejector Yard. High pressure/temperature steam is used to create a vacuum in either test chamber.
b. Only authorized personnel are permitted within the Ejector Yard during operation.
c. Hearing protection is required within the Ejector Yard during test system operations which has hearing protection warning signs are posted around the areas.
d. All personnel in the vicinity of the Steam Ejector System, whether it is operating or not, are to exercise caution due to the presence of hot surfaces and possible steam leaks. Surface temperatures in the Ejector Yard can be in excess of 400 deg. F.
e. An implosion hazard from worn / corroded section of the Steam Ejector System vacuum jackets is present during system and test operations. During operation, personnel are to maintain a minimum 6' clearance between themselves and the vacuum jackets and hazard warnings are posted within the area.
f. High bacteria counts may exist in the retention pond which supplies cooling water to the Cooling Tower which feeds the Cooling Water System and parts of the Coolant Water System.
g. Cooling water associated with these systems circulate through the test cell, Rectifier Building, and Ejector Yard.
h. Anyone coming into physical contact with this cooling water is advised to wash the exposed area with soap and water.

1.7 Laser System:

a. Class 3 and 4 laser systems located inside the Laser Room, Rm. 120A and are used in conjunction with some test cell activities.
b. A laser status warning system is located outside the Laser Room which notifies personnel of operational status within the room.

c. Warning of their imminent use within the test cell is made on the facility intercom system and warning signs are posted at all test cell entrances.

d. Nitrogen gas from trailers located on the east side of Building 222 provides clean dry nitrogen gas for operations within the Laser Room. K-bottles of various gases are also used for operations within the Laser Room. A full-time O2 stationary gas detection monitor is located within the room to ensure that there is adequate supply of oxygen in the room.

e. Only authorized personnel are permitted in the test cell when lasers are being used for ARMSEF testing related applications. Only authorized personnel are permitted in the Laser Room when lasers are in use for any reason.

f. Laser safety eyewear is available both inside and outside Room 120A. Laser systems can burn tissue and cause severe eye damage.

1.8 Test Cells/Test Chambers:

a. All hazardous systems must be locked and tagged out and a calibrated O2 gas detection monitor must be used to verify proper atmospheric conditions prior to personnel entry into the test chamber.

b. Vacuum chamber windows present a hazard if a vacuum exists within the chamber. Only authorized personnel are permitted in the test cell when a vacuum exists within a test chamber and all activities during this time are to be coordinated with a test conductor.

c. High temperatures may be present around test articles and heaters even after a cool down period. Use caution around these items and wear thermal protective gloves when necessary.

d. During all tests, visitors are requested not to engage in conversation with the Test Conductor and other ARMSEF test team personnel. All questions and other discussion should be directed to the ARMSEF Test Director only.

e. During all testing, personnel are not allowed within the test cell without permission of the Test Conductor and/or Test Director.

1.9 Lifting Devices & Equipment:

a. Cranes, forklifts and lifting hardware shall only be operated by certified equipment operators and must have current load limit certification

b. Lifting operations require an approved lift plan (both critical and non-critical lifts).

c. A documented pre-use inspection must be completed for the cranes and forklifts prior to their first use of the shift

d. Prior to any lifting operation, a visual pre-use inspection of the crane, forklift and lifting hardware must be completed and the lifting zone shall be established with adequate barricades and warning signs.
e. During crane operations, only those directly involved in the lifting operation are permitted in the lifting zone and must wear the required Personal Protective Equipment which includes safety glasses, hard hats and safety toe shoes.

1.10 Machine Tools:

a. Several machine tools are located throughout the facility which includes the test cell as well as outlying buildings.
b. Only authorized personnel are permitted to operate these machine tools.
c. All machine tools must be inspected prior to use and all machine guards must be used during operation.
d. Personal Protective Equipment for machine tools must be used when machine tools are operated which includes at minimum safety glasses with side shields, safety toe shoes and work gloves (when handling machined materials).
e. Use of grinders requires the additional use of a face shield along with safety glasses with side shields.
f. Hearing protection, protective clothing and respirator protection may be required depending on the material being machined.

1.11 Confined Spaces:

a. Building 222 contains several designated JSC and OSHA confined spaces. These confined spaces have hazard warning signs posted outside the entrance of the designated confined space.
b. All entries into confined spaces must have an approved JF992 – Confined Space Procedure, all confined space entrants and attendants must be confined space trained and complete a JF1476 – Confined Space Permit during the entry into the confined space.

1.12 Hazardous Materials:

a. Several hazardous material storage cabinets are located throughout the facility.
b. Each hazardous material storage cabinet has an inventory list located outside the cabinet and all hazardous materials have MSDS sheets which are available in Room 106 of Building 222 as well as the JSC MSDS database located on the JSC Occupational Health website.
c. When ordering or bringing a hazardous material to the facility, the most current MSDS from the manufacturer must be submitted to the hazardous materials POC for registration with recordkeeping with the JSC Occupational Health Department.

d. Hazardous materials must be properly segregated and stored in their appropriate locations. When certain hazardous materials are stored or mixed together, violent reactions may occur because the materials are unsuitable for mixing, or are incompatible. Classes of incompatible materials should be segregated from each other during storage, according to their hazard class.
e. Once through using a hazardous material, it must be returned to the hazardous storage cabinet that it originated from.
f. All hazardous materials must be properly labeled. Containers provided by the hazardous material manufacturer must include the material name, manufacturer name and address, hazard properties and must be in English. All secondary containers must be labeled with the common material name, JSC MSDS number or manufacture's name and hazard properties and must be in English.

1.13 Compressed Gas Cylinders:

a. Compressed gas cylinders must be properly secured at all times to prevent tipping, falling or rolling. Compressed gas cylinders should be secured with straps or chains connected to a wall bracket or other fixed surface, or by use of a cylinder stand in a cool, dry, well-ventilated, fire-resistant area.
b. Full and empty compressed gas cylinders must have legible markings that identify the type of gas contained. All compressed gas cylinders must be marked as either empty or full and stored separately.
c. Never store compressed gas cylinders of flammable gases (empty or full) near compressed gas cylinders of oxygen or other oxidizers. A minimum separation of 20 feet or a noncombustible fire wall having a fire resistance rating of at least 0.5 hr which extends 5 feet must be maintained for separating oxidizers from incompatible materials.
d. When a compressed gas cylinder is empty or not being used, the valve must be closed, regulator removed and valve protector cap secured.
e. Compressed gas cylinders must be handled by trained personnel transported using hand trucks designed for the purpose of transporting compressed gas cylinders, and be secured so that they do not tip, fall or roll.

1.14 Silica Material

a. Silica fiber based insulation materials are used in the test chambers and some test articles which may cause irritation to eyes, skin and upper respiratory passages if exposure occurs.
b. Any request for test chamber entry involving non-routine interaction with silica material shall be evaluated by the Safety Engineer who will advise personnel of applicable respirator requirements.

c. Silica tile cutting equipment is located in the Old Nebraska Boiler house, shall be used by only authorized facility personnel using proper Personal Protective Equipment.

d. Respiratory protection is required by facility management to be used during silica tile cutting as a precautionary control to prevent silica inhalation exposure.

2. EMERGENCY PROCEDURES

Visitor Emergency Procedures

a. In the event you smell smoke, notify facility management who will contact the Emergency Operations Center at x33333.

b. If the smoke smell gets stronger, see flames, or see large amounts of smoke, activate a fire alarm pull box to notify facility personnel to evacuate the facility and contact the Emergency Operations Center at x33333 in safe location.

c. If you see a fire, pull a fire alarm pull box and contact the Emergency Operations Center at x33333 in safe location.

d. If you hear a fire alarm or a stationary O2 gas detection monitor alarm, exit the building immediately in a safe manner. Proceed at least 75 feet from the building to the designated emergency assembly point on the west side of Building 222.

e. During test operations, all personnel shall listen to and follow the approved emergency procedures and directions of the Test Conductor and/or Test Director.

f. In the event you hear the JSC Employee Alarm, you shall get/stay inside a building and warn others to stay inside, close all doors and windows, turn off the air handlers and stay inside until you get further instructions over the employee warning system.

Appendix F Customer Feedback

TEST CUSTOMER FEEDBACK							
Test Title:						**Facility:**	
Test Number:	**TD:**					**Test Date:**	
	SCORE (Check or Click on Box)						
	Poor					Excellent	
SCHEDULE:	**1**	**2**	**3**	**4**	**5**	**N/A**	
1. Was the test initiated and completed to meet your requirements?	☐	☐	☐	☐	☐	☐	
2. Were we able to accommodate your requested schedule changes?	☐	☐	☐	☐	☐	☐	
COST:							
3. Was the test performed within estimated budget?	☐	☐	☐	☐	☐	☐	
4. Was the test cost reasonable for the test performed?	☐	☐	☐	☐	☐	☐	
PRODUCT:							
5. Was the provided test data accurate?	☐	☐	☐	☐	☐	☐	
6. Was the test data provided to you in an acceptable format and a timely manner?	☐	☐	☐	☐	☐	☐	
FACILITY (Test Position and Support Hardware):							
7. Did the facility's capability meet the needs of the test requirements?	☐	☐	☐	☐	☐	☐	
8. Was the facility reliable during the test?	☐	☐	☐	☐	☐	☐	
TEST TEAM:							
9. Did you find the test team helpful and knowledgeable in meeting your objective?	☐	☐	☐	☐	☐	☐	
10. Would you consider using this test facility for future tests?	☐	☐	☐	☐	☐	☐	
Note: We are concerned and interested in your comments and would like an opportunity to improve our services.							
Comments/Suggestions for Improvement:							
Testimonial:							
Customer Name & Organization:							
Return to: Tien Nguyen, *tien.q.nguyen@.nasa.gov*							