Abstract – Energy Systems Test Area (ESTA) Battery Test Operations User Test Planning Guide

Test process, milestones and inputs are unknowns to first-time users of the ESTA Battery Test Operations. 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.

Energy Systems Test Area (ESTA)
Battery Test Operations

User Test Planning Guide

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Table of Contents

1.0 Introduction

The Johnson Space Center (JSC) has created and refined innovative analysis, design, development, and testing techniques that have been demonstrated in all phases of spaceflight. JSC is uniquely positioned to apply this expertise to components, systems, and vehicles that operate in remote or harsh environments. We offer a highly skilled workforce, unique facilities, flexible project management, and a proven management system.

1.1 Purpose

The purpose of this guide is to acquaint Test Requesters with the requirements for test, analysis, or simulation services at JSC. The guide includes facility services and capabilities, inputs required by the facility, major milestones, a roadmap of the facility's process, and roles and responsibilities of the facility and the requester. Samples of deliverables, facility interfaces, and inputs necessary to define the cost and schedule are included as appendices to the guide.

1.2 Facility Availability

JSC test facilities are available for the National Aeronautics and Space Administration (NASA), other government agencies, and commercial requesters. We have developed user-friendly agreements to streamline business relationships and are eager to share our unique facilities and expertise. We invite your inquiries regarding application or adaptation of our capabilities to satisfy your special requirements. Briefings on general or specific subjects of mutual interest can be arranged at JSC or at your business site.

1.3 Inquiries

General inquiries regarding the use of JSC facilities should be directed to:

JSC Engineering Directorate
Johnson Space Center
2101 NASA Parkway, Houston, TX 77058
Phone: 281-483-8991
Email: beth.a.fischer@nasa.gov

Inquiries regarding battery test operations at the Energy Systems Test Area (ESTA) should be directed to:

Martin McClean
Energy Systems Test Area Branch Chief
Johnson Space Center
2101 NASA Parkway, Houston, TX 77058
Phone: (281) 483-6478
Email: jsc-cal-ep6-esta@nasa.gov

Please refer to the Engineering Services website: http://jsceng.nasa.gov, for additional information and general inquiries about test, analysis, and simulation capabilities at JSC.

1.4 Battery Test Operations

ESTA has supported hundreds of abuse, performance, and flight tests of batteries and cells for applications ranging from such comfort devices for astronauts as satellite phones, portable digital assistants, and laptops to life-saving equipment used in the spacesuit and backup power supplies. Many of these batteries contain toxic materials and are high energy. Since batteries are so diverse, it is important to understand the specific dangers for each type of battery. ESTA houses test systems that provide various space environments appropriate for evaluating the performance and safety of batteries.

Services Provided

- Battery Performance Testing
  - Cell chemistry evaluation
  - Endurance cycling
  - Long-term storage testing
  - Operate to failure
  - Thermal environment cycling
  - Vacuum testing
  - Vibration testing
- Variety of Battery Chemistries
  - Li-Ion
  - NiMH
  - Alkaline
  - Pb-Acid
- Battery Abuse Testing
  - Crush testing
  - Destructive physical analysis
  - Drop testing
  - High temperature exposure and heat-to-vent testing
  - Overcharge and overdischarge characterization
  - Positive temperature coefficient failure testing
  - Short-circuit testing
  - Vent/burst pressure testing

1.5 Specifications

1.5.1 Battery Performance Testing

Voltage Range	Temperature Range	Capabilities
Ranges vary by test stand 0 – 80 V	–200 – 350 °F	• Multiple systems ranging from low current/voltage to high current/voltage • Data system that can record voltage, current, and temperature • Provision of constant voltage, current, and power modes • Long- and short-term cycling • Determination of optimal charge and discharge rates • Thermal capacities/vacuum tolerance • Cell calorimeter testing

1.5.2 Battery Abuse Chambers

Facility	Volume	Pressure Range	Temperature Range	Overcharge/Discharge Short Circuit
Abuse Chambers	24″ Dia 36″ L	0.1 – 150 psig	Ambient – 500 °F	Ranges up to 600 V and 7,500 A

Capabilities
• Texas Commission on Environmental Quality approved for controlled purge of battery vents • Overcharge and overdischarge • Thermal and heat-to-vent • Short circuit

1.5.3 Hazardous Vibration Testing

Frequency Range	Shaker Size Range	Load Direction	Displacement	Capabilities
20 – 2, 000 Hz	11,000 lb_f RMS Up to 16,000 lb_f sine Up to 15,500 lb_f random	x, y, or z	1″ stroke	• The test stand supports test articles (including fixture) up to 2,000 lb • Vibration capability includes sine, random, and classical shock

1.5.4 Drop/Crush Testing

Capabilities
• Simulation of internal short, causing deformation without penetration • Simulation of accidental drop (0 – 8 ft) • Temperature and voltage monitoring

1.5.5 Vent/Burst Testing

Capabilities
• Application of nitrogen pressure to battery and measurement of battery vent pressure • Vent block with measurement of battery burst pressure • MAWP – 2,500 psig

1.5.6 Analysis

Capabilities
• Destructive physical analysis • Gas chromatograph – mass spectrometry • Decomposition data for an abused cell

2.0 Facility Layout

JSC Building 354 Battery Systems Test Facility*

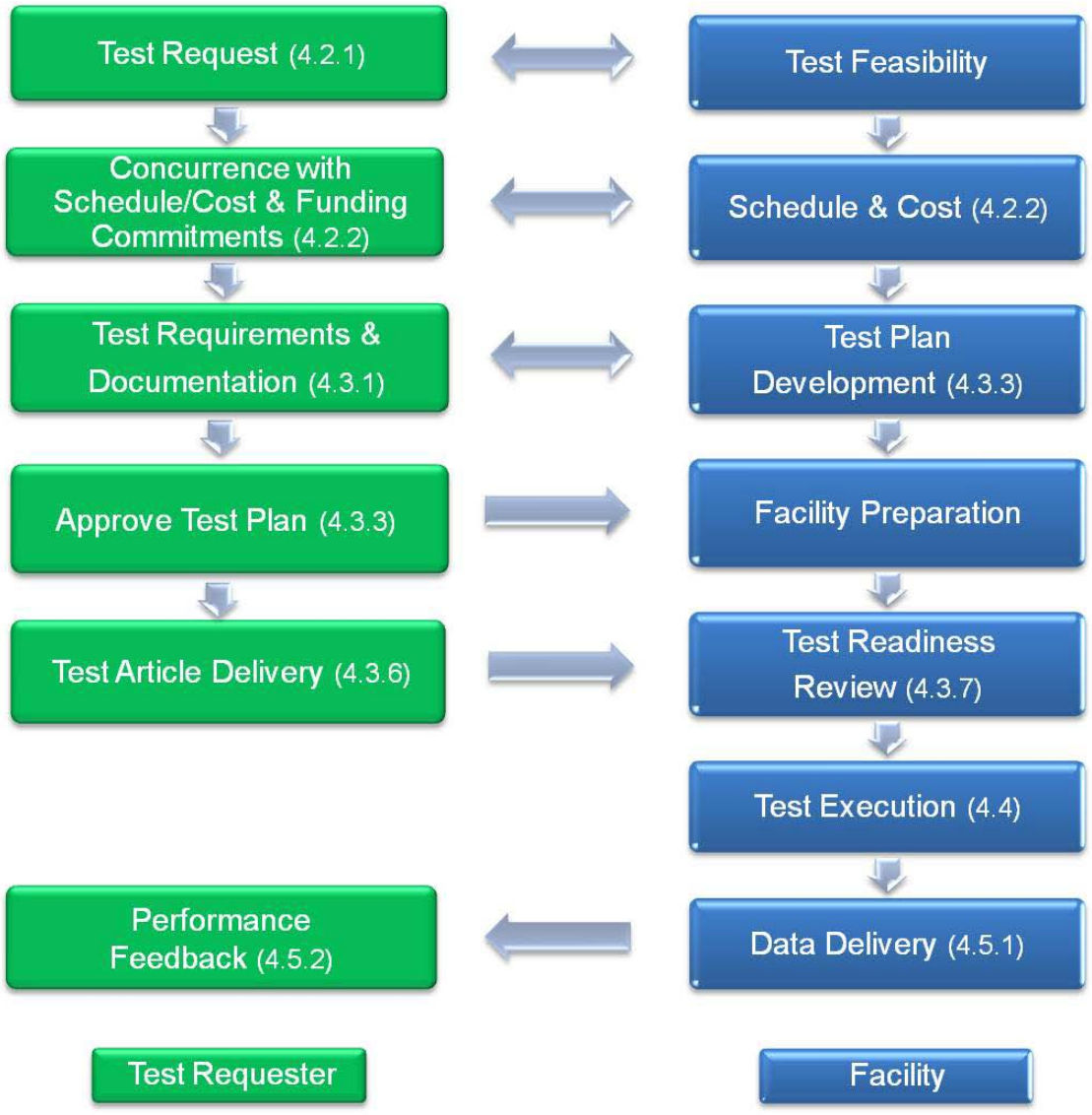
* See Appendix A for facility interfaces and the facility layout.

3.0 Safety and Health

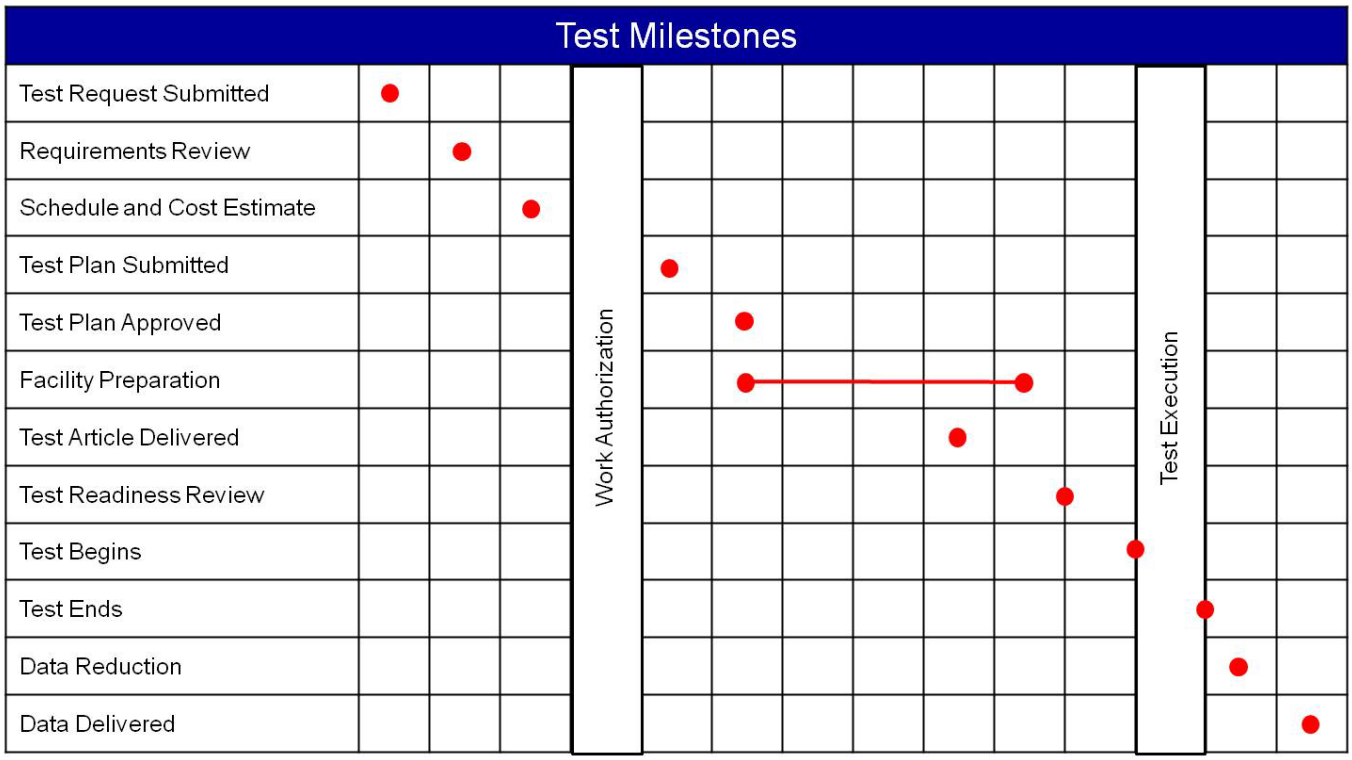
Safety is an integral part of the culture at NASA. Management, leadership, and employee involvement from all organizations are critical to the success of NASA's safety program. In order to ensure personal safety and a safe test environment throughout the process, the requester shall furnish the facility with the information necessary to perform a hazard assessment of the test article. Additionally, while visiting 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 ESTA safety rules, potential hazards, and emergency procedures.

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, highlighting interactions and inputs between the Test Requester and the facility Test Director.



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



4.1 Export Controlled and Proprietary Information

ESTA 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. 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:	Test Director reviews test request to determine test feasibility
Outputs:	Facility delivers preliminary test plan and estimated cost and schedule to Test Requester
	Test Requester concurs with estimated cost and schedule and provides necessary funding commitment to pay for test

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 B. This worksheet addresses the basic requirements for testing in the Battery Systems Test Facility at ESTA. 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. Internal Test Requesters should also submit a JSC Form 90, Test Request Form, to the Test Director. This form is used by JSC as a formal means of requesting a test within JSC. It is the work authorizing document for the test team to provide support. JSC personnel will complete the Test Request Form (Form 90) for external Test Requesters.

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 (vibration, battery performance, battery abuse)
- Proposed test approach
- Test data requirements

Test Article Description

A brief description of the 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 interface requirements (provided by Test Requester/facility)
- Orientation (x, y, z)
- 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. Test preparation will not begin until the Test Requester concurs with the estimated cost and schedule. The Test Requester must also provide the necessary funding commitment to pay for the test.

4.3 Test Preparation Phase

The detailed test plan, test schedule, and Interface Control Document (ICD) 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 Schedule and Cost Estimate

Following review of the test requirements, the Test Director will provide a cost and schedule estimate, including major milestones, to the Test Requester. The cost estimate is highly dependent on the level of detail provided for the test requirements.

4.3.3 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 the supplied batteries with an assessment of expected byproducts produced during the test. The MSDS shall be delivered prior to delivery of the test article. The Test Director will review the MSDS for compatibility with the test environment and 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. It is highly recommended that the Test Requester provide a test article hazard analysis or complete the Test Article Hazard Checklist included in Appendix B. The analysis should consider test article handling, support equipment, potential failure modes during the test, hazardous materials, batteries, high voltage/current devices, pressurized components, dangerous mechanical devices, sharp edges, and any other potential hazards.

4.3.4 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. A sample test plan is included in Appendix D.

4.3.5 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.

4.3.6 Interface Control Document

The ICD defines the interface between the test article and facility test equipment. An ICD will be prepared by the Test Director and approved by the Test Readiness Review Board (TRRB) with concurrence from the Test Requester. The ICD will include test fixture assembly requirements, a list and plot of specifications for the test, and test article interface drawings.

4.3.7 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. 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.

4.3.8 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 Article 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 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
Facility Manager/Engineer	

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.

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 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.

4.4.3 Facility Equipment

The facility equipment is meant for use by JSC personnel. Prior arrangements shall be made with the Test Director for potential use of this equipment by the Test Requester. The duration and type of use will be identified prior to authorization for use. JSC workstations are not available for use by Test Requester personnel. This is necessary to protect the integrity of the

facility. The Test Requester shall make prior arrangements with the Test Director if a dedicated workstation is required during testing. The Test Requester is encouraged to bring a laptop for use during the test. Wireless Internet access is available in the facility.

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 Data Package

A data package is an assembly of test results. The format of the data package is normally specified by the Test Requester. The standard data package format includes a description of the test and objectives, test observations, test results, and data plots.

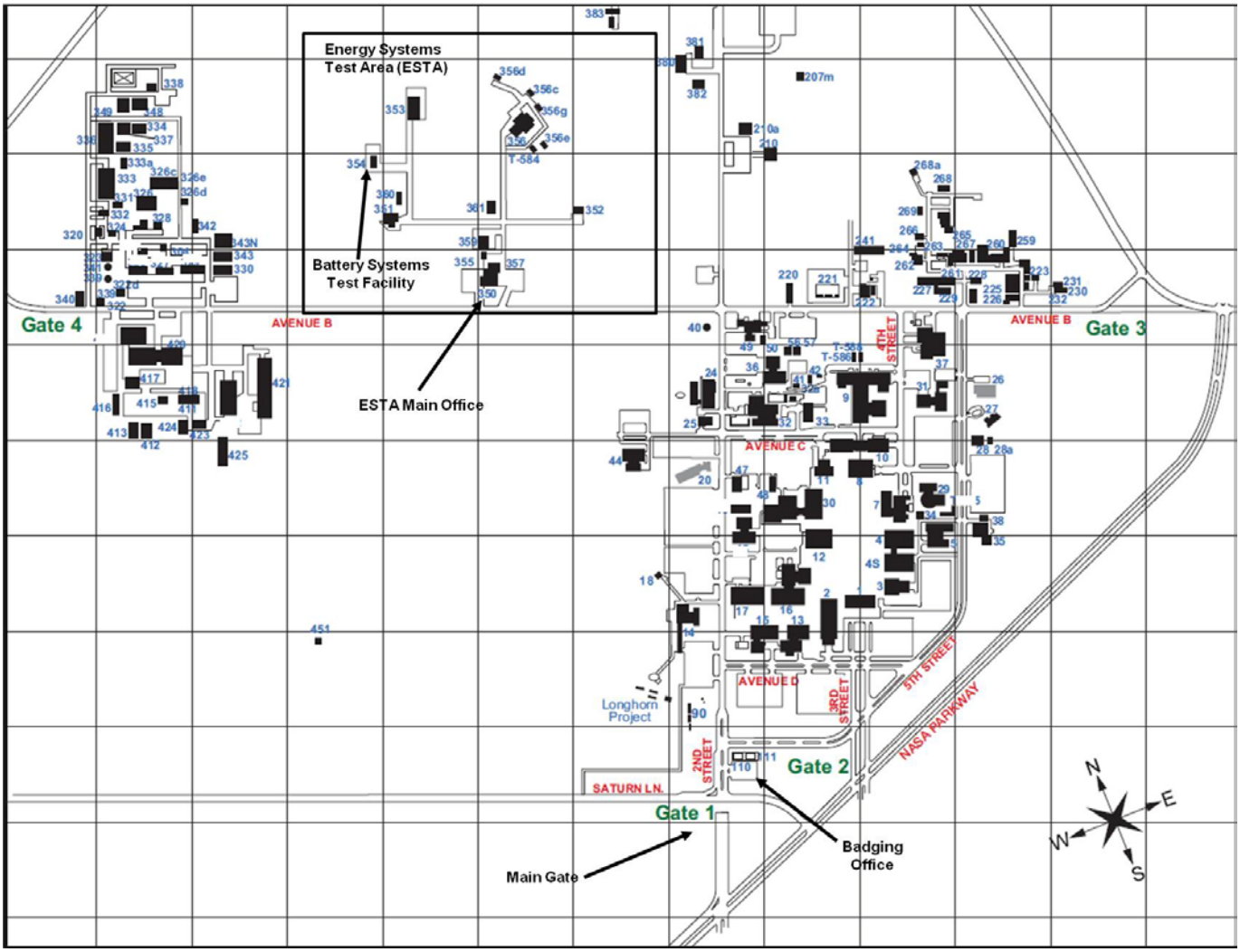
4.5.2 Customer Feedback

ESTA 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 E. You are encouraged to complete the Customer Feedback form and return it 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 Battery Systems Test Facility is located in JSC Building 354. The facility is part of the Energy Systems Test Area identified on the map below. Test Requester personnel shall go to JSC Building 350, ESTA Main Office, to complete a facility access briefing prior to arriving at JSC Building 354.



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.

Facility Manager/Engineer – Responsible for designing and fabricating any required test article interfaces, including structures, fluids, and power. The Facility Manager/Engineer also provides support for external test article instrumentation and data acquisition.

Safety Engineer – Reviews the test article hazard assessment and prepares an integrated hazard analysis for the test facility to identify any additional hazards that could result from mating the test article to the test facility.

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 and provide assistance as needed
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

°C	degrees Celsius
°F	degrees Fahrenheit
A	ampere(s)
Ah	ampere-hour
ASCII	American Standard Code for Information Interchange
dB	decibel(s)
dBA	decibel A-weighting
e.g.	for example
ESTA	Energy Systems Test Area
ft	feet
FTP	File Transfer Protocol
g^2	square grams
GN_2	Gaseous Nitrogen
H	Height
hr	hour(s)
Hz	Hertz
ICD	Interface Control Document
ID	Identification
IR	Infrared
JSC	Johnson Space Center
L	Length
lb	pound(s)
lb_f	pound-force
Li-ion	Lithium-Ion
mΩ	milli-ohm(s)
mAh	milliampere-hour
MAWP	Maximum Allowable Working Pressure
mg	milligram(s)
MSDS	Material Safety Data Sheets
mW	milliwatt(s)

N/A	Not Applicable
NASA	National Aeronautics and Space Administration
Ni-Cd	Nickel Cadmium
NiMH	Nickel-Metal Hydride
No.	Number
OCV	Open-Circuit Voltage
Pb	Lead
psi	pounds per square inch
psia	pounds per square absolute
psig	pounds per square inch gauge
PTC	Positive Temperature Coefficient (type of thermistor)
RF	Radio Frequency
RMS	Root Mean Square
sccs	standard cubic centimeters per second
sec	second(s)
SPS	Samples per Second
TRR	Test Readiness Review
TRRB	Test Readiness Review Board
UV	Ultraviolet
V	volt(s)
W	Width
Wh	Watthour

Appendices

A. Facility Interfaces/Sample Text Configurations

B. Test Request Worksheet

C. Sample Test Plan

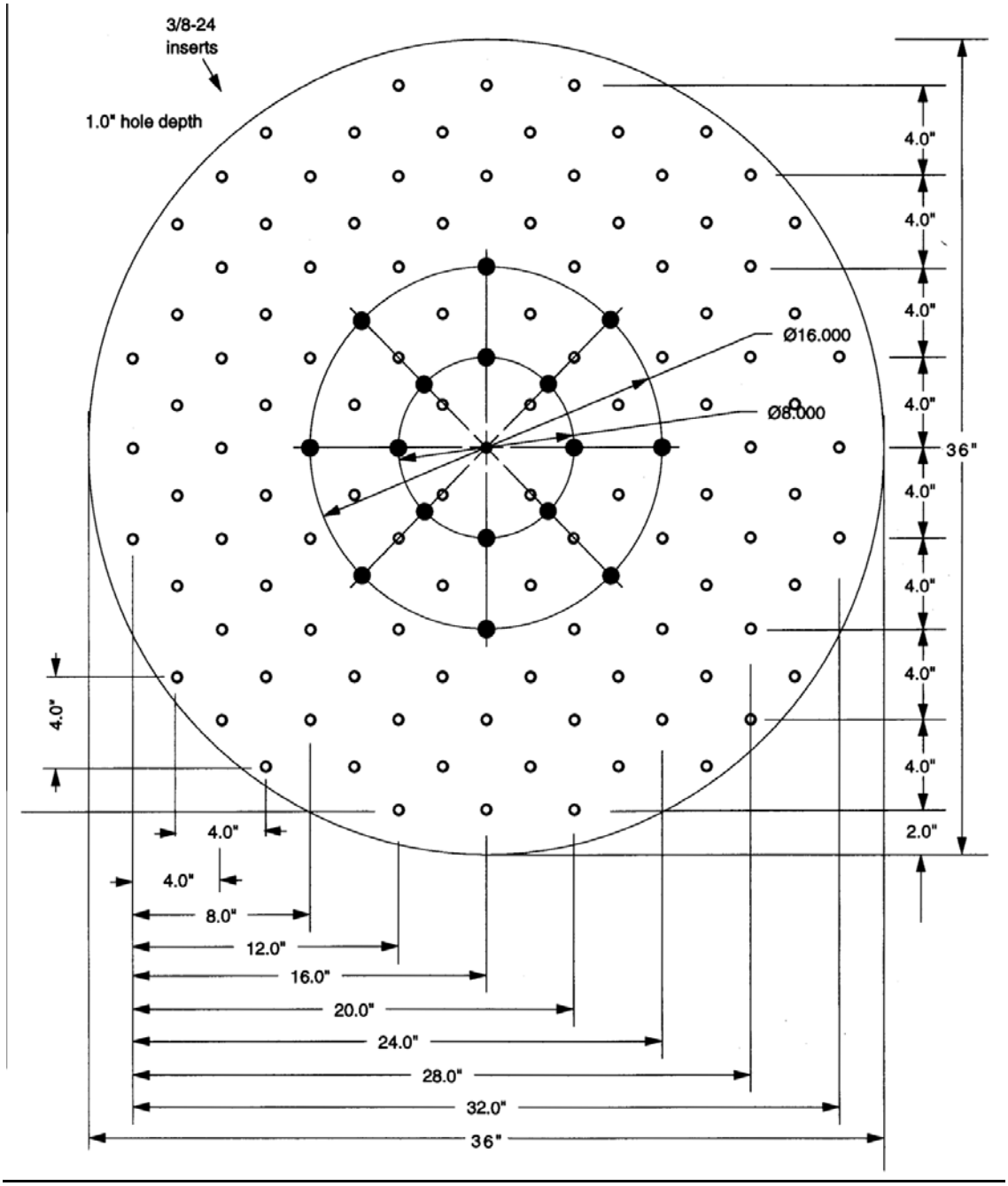
D. Customer Feedback

Appendix A Facility Interfaces/Sample Test Configurations

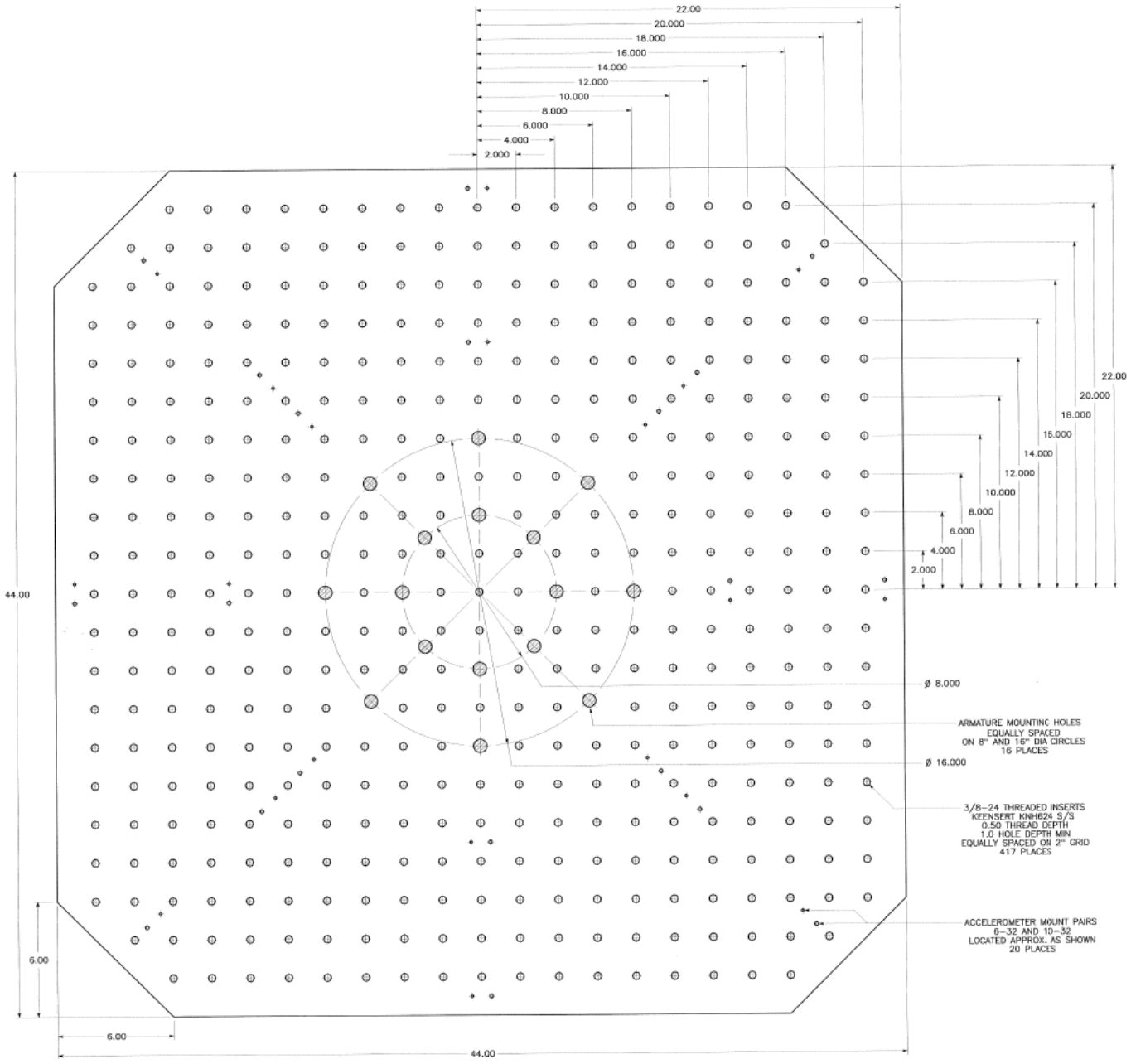
The test fixture drawings included in this guide are a sampling of the capabilities within ESTA. The facility maintains a variety of fixtures to support general and requester-specific testing. Additional test fixtures are available upon request. The facility also can manufacture test fixtures to requester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

Vibration Test Fixtures

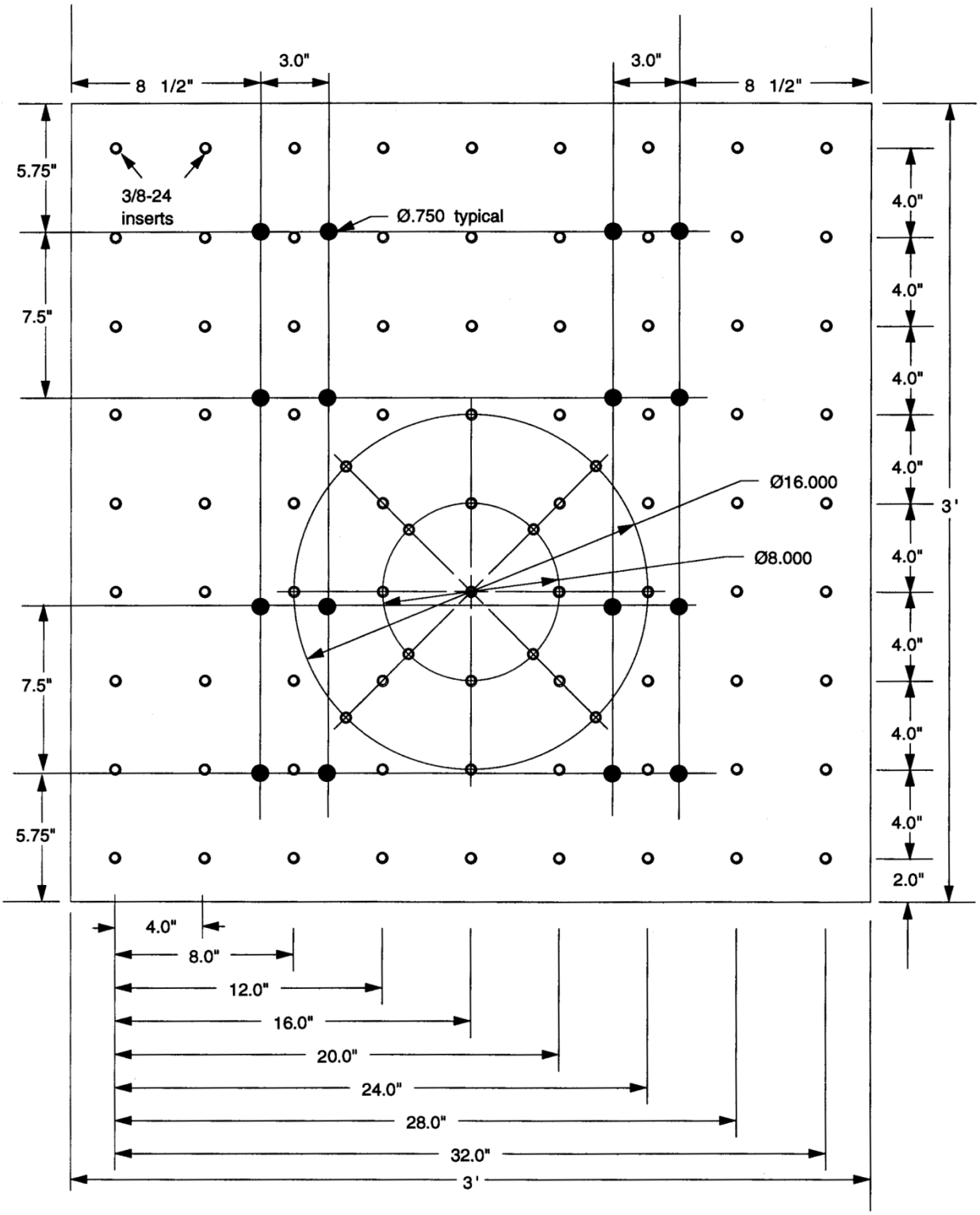
Vibration Bolt Pattern



Expander Head – 44-inch Bolt Pattern

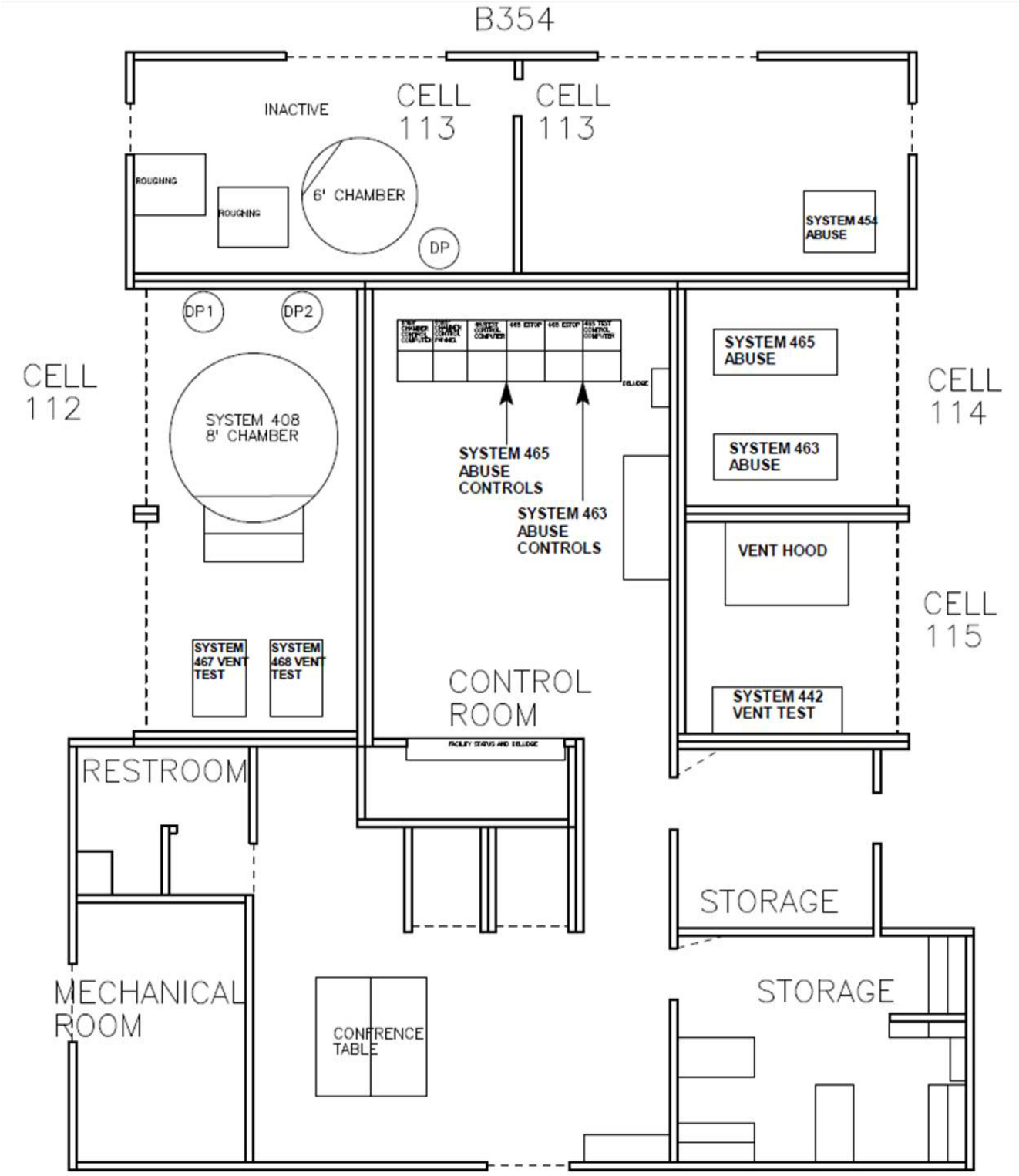


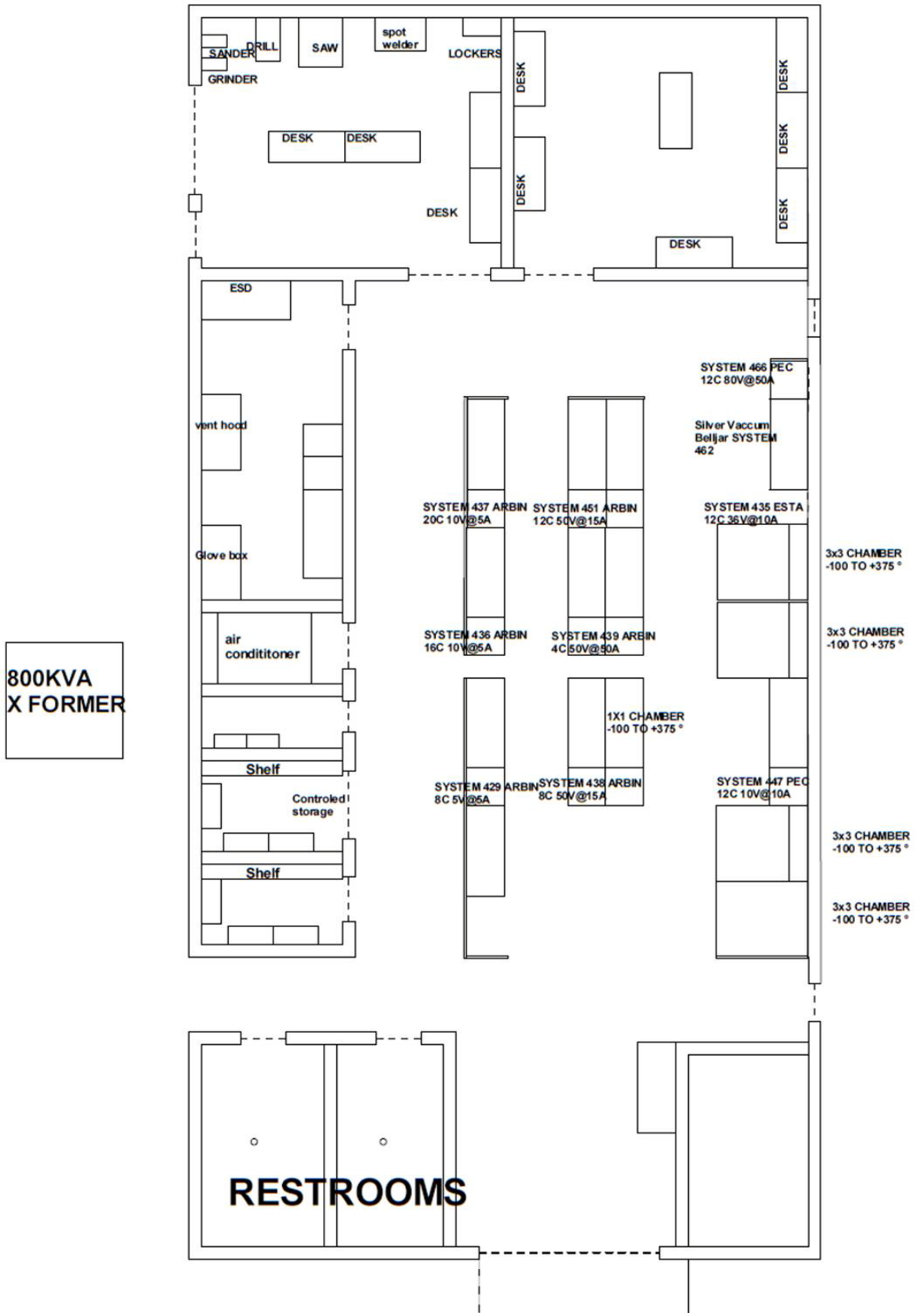
Slip Table Bolt Pattern



Facility Layout

The facility is broken up into five main areas. The high bay houses the battery test systems and thermal chambers. The area provides for multiple cycling channels with ranges up to 600 V and 7,500 A. The thermal chambers are capable of temperature ranges from ambient to 500 °F.




SANDER
DRILL
SAW
spot welder
LOCKERS
GRINDER
DESK
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DESK
ESD
vent hood
Glove box
air condititoner
Shelf
Controled storage
Shelf
800KVA X FORMER
SYSTEM 466 PEC 12C 80V@50A
Silver Vaccum Belljar SYSTEM 462
SYSTEM 437 ARBIN 20C 10V@5A
SYSTEM 451 ARBIN 12C 50V@15A
SYSTEM 435 ESTA 12C 36V@10A
3x3 CHAMBER -100 TO +375 °
SYSTEM 436 ARBIN 16C 10V@5A
SYSTEM 439 ARBIN 4C 50V@50A
3x3 CHAMBER -100 TO +375 °
1X1 CHAMBER -100 TO +375 °
SYSTEM 429 ARBIN 8C 5V@5A
SYSTEM 438 ARBIN 8C 50V@15A
SYSTEM 447 PEC 12C 10V@10A
3x3 CHAMBER -100 TO +375 °
3x3 CHAMBER -100 TO +375 °
RESTROOMS
RECEIVING ENTRANCE

Sample Test Configurations

Battery Performance Testing

Circuit Board Testing

Circuit board testing involves determining the cutoff voltage and current for smart circuit batteries. Overcharge, overdischarge, and overcurrent scenarios are covered.

Electrochemical Characteristics

This test determines the open circuit voltage and closed circuit voltage of the test articles. This can be performed with a voltmeter and resistor or an automated battery test stand.

Automated Battery Test Stand

Battery Abuse Testing

Crush/Drop Testing

Crush testing consists of crushing a test article to simulate the internal short caused by the electrodes coming into contact with each other. The battery voltage and performance is observed. Drop testing consists of dropping a test article onto a concrete surface and comparing precycling and postcycling data.

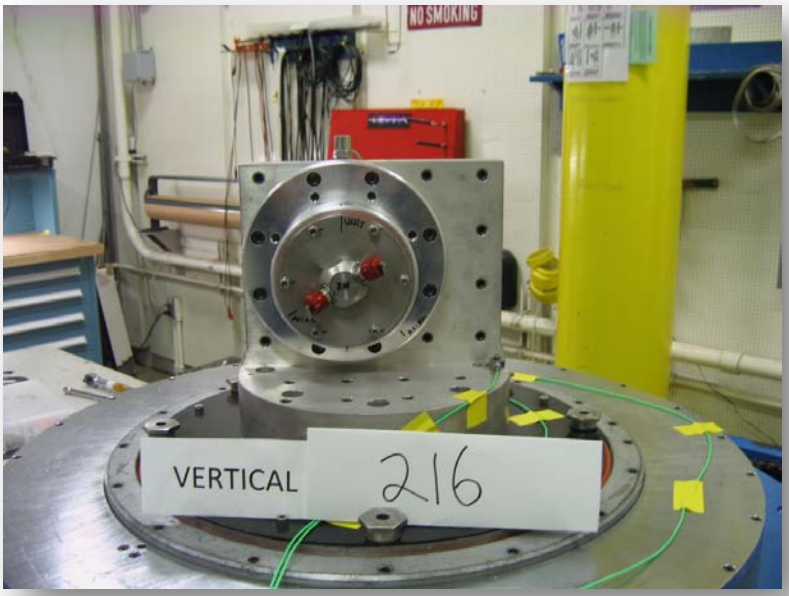
Vibration:

Test articles are subjected to routine vibration spectrums for up to 15 minutes on each of three mutually-perpendicular axes. Previbration and postvibration functional testing will determine the quality of the workmanship of the test articles.

Hazardous Vibration Test Stand Y-Axis

Hazardous Vibration Test Stand Z-Axis

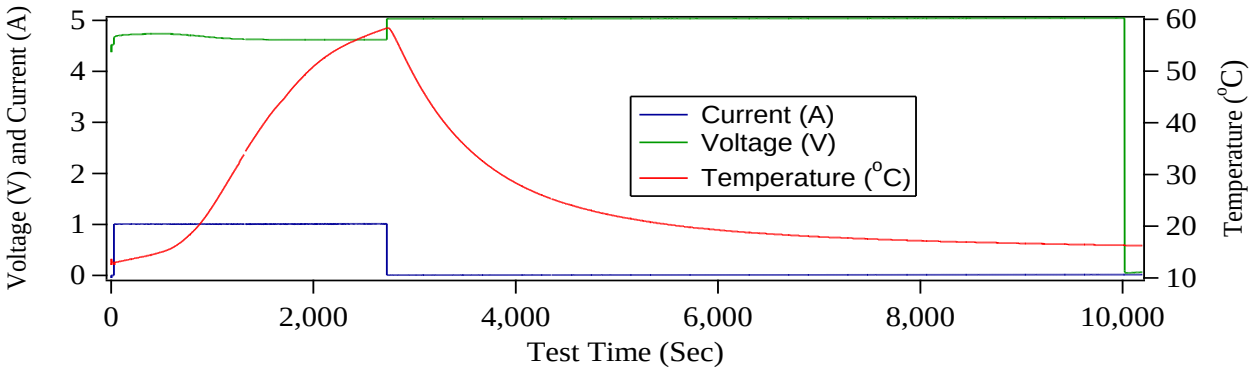
Vertical Mount Adapter



Cell Overcharge

Overcharging a test article includes charging for a period that is more than its recommended charge time, and/or with a high rate of charge, and/or with no voltage limit. The test is performed to determine the tolerance to overcharge and to devise safety features that will prevent this condition.

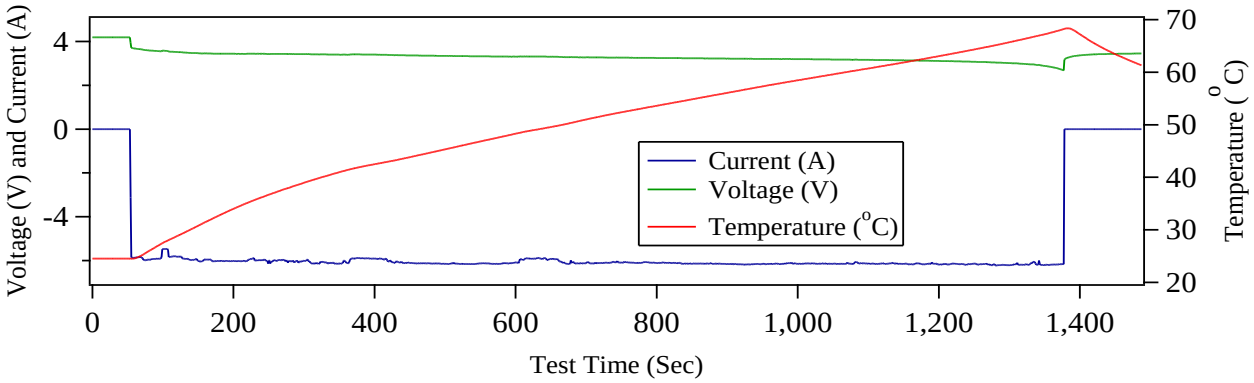
Sample Data



Cell Over Discharge

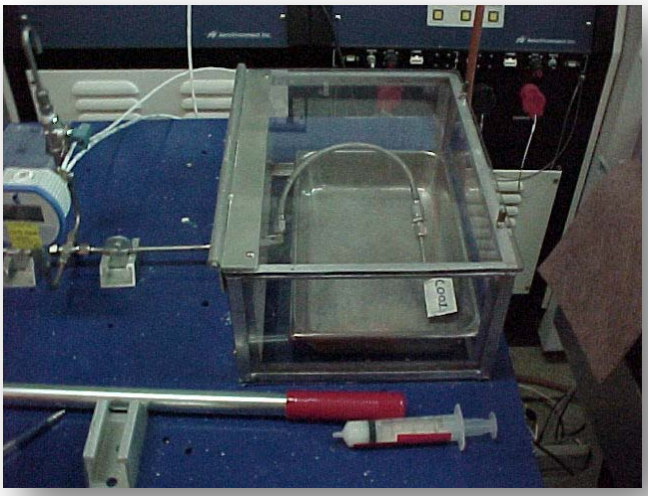
Over discharging a test article includes discharging below the cutoff voltage for either a certain time period and/or until a specific amp hour rating is reached. Over discharge also includes discharging into reversal (negative voltages). This test determines the safety features required for protection in an over-discharged condition.

Sample Data



Vent/Burst Testing

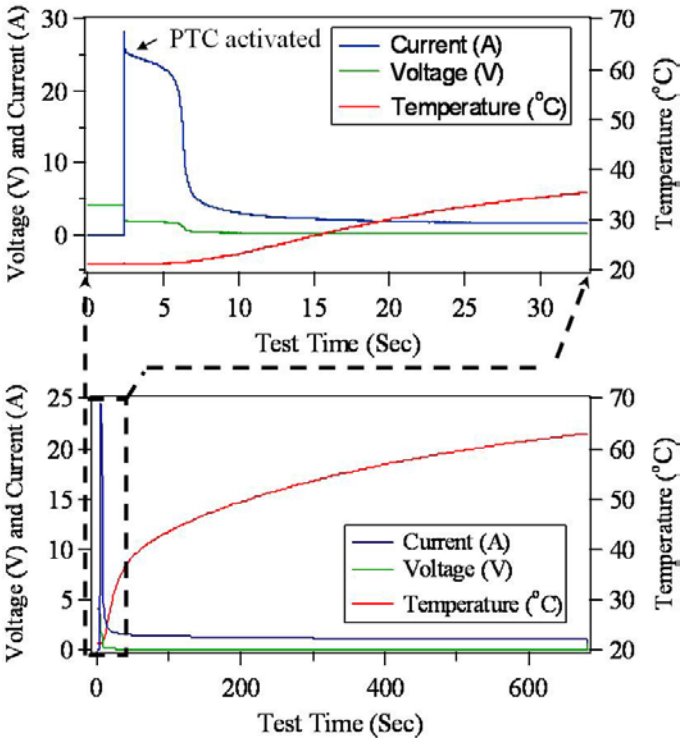
Vent and burst testing involves completely discharging a test article, removing the electrolyte, and pressurizing the case until it ruptures. This test determines the maximum internal pressure of the test article.



Short Circuit

Short-circuit testing consists of placing a short of approximately 10 to 200 mΩ across a test article with a relay until the temperature decreases monotonically for 20 to 60 minutes or a certain time or current is reached. Test can be performed at ambient or in a hot thermal environment.

Sample Data

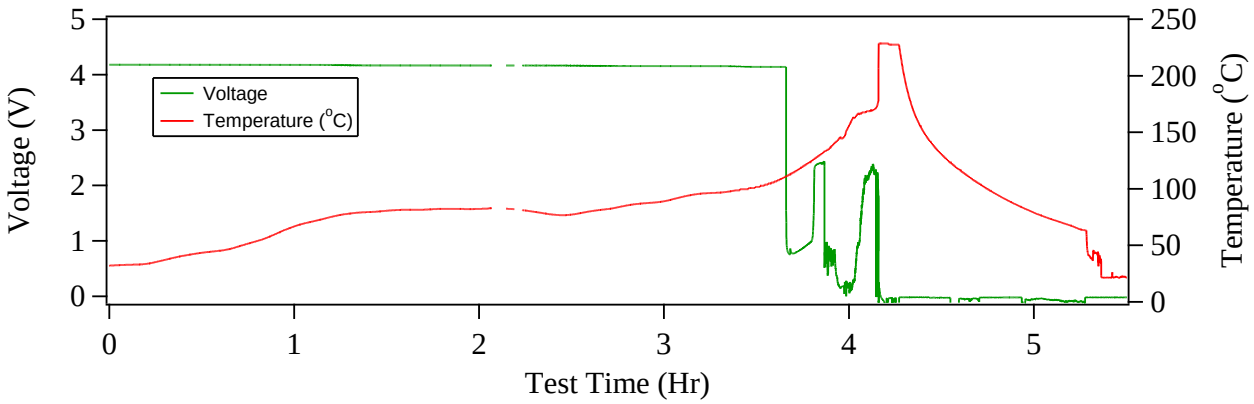


- Apply 10 – 50 mW load across terminals
- Data acquisition at fast and slow speed
- Load maintained until temperature increase levels off

Thermal and Heat-to-Vent

Test articles are subjected to thermal environments that are within the operating range as specified by the manufacturer. Open-Circuit Voltage (OCV) measurements will be made to monitor the health of the battery.

Sample Data



- Chamber is purged with nitrogen and a baseline gas sample is obtained.
- Chamber temperature is increased to 80 °C and maintained for 2 hours.
- Temperature is increased until venting occurs.
- A contaminated gas sample is obtained.
- Chamber is purged with Gaseous Nitrogen (GN_2) for 12 hours.
- Weight before and after temperature treatments is recorded.

Appendix B Test Request Worksheet

Test Requester Information

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

Test Objectives

Vibration Testing	☐	Sine	☐	Random	☐	Shock	☐
Battery Performance	☐	Cell Chemistry	☐	Endurance Cycling	☐	Storage	☐
		Operate-to-Failure	☐	Thermal Testing	☐	Vacuum Testing	☐
Battery Abuse	☐	Crush Testing	☐	Destructive Analysis	☐	Drop Testing	☐
		Heat-to-Vent	☐	Overcharge/overdischarge	☐	PTC Failure	☐
		Short Circuit	☐	Vent/Burst Testing	☐		

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

Test Article

Test Article Description:	
Physical Dimensions (L/W/H):	Weight:

Batteries

Model Number:	Capacity:	Nominal Voltage:
Mass (entire assembly):	Watt Hours (entire assembly):	Number of Cells Delivered:
Volume (individual cells):		
Cell Configuration:		
Description of any smart circuitry:		
Chemistry (Alkaline, Ni-Cd, Ni-MH, Li-ion, Other):		
Charge Schedule (current, voltage, time)		
Discharge Schedule (current, voltage, time):		
Battery Safety Limits:		

Operational Requirements

Functional Checks (Describe any functional checks to be performed prior to, during, or after testing):	
Test Article Limitations (High/low cutoff temperature, ramp rate not to exceed):	
Continuous Operations (24 hr):	Authorized Shutdown Points:

Test Article Handling Requirements

Cleanliness Level:	Controlled Access:
Special Moving/Handling:	
Storage Requirements:	

Test Article Interface

Test Article Interface Design (Facility or Requester designed, drawings attached, instructions):
Test Fixture (facility stock, facility fabricated, or requester provided):
Power Supply (Describe power supply to test article; include voltage, current, and connections):
List materials and instruments supplied by Requester (connectors supplied):

Designs/Drawings

We can accept files through a File Transfer Protocol (FTP) site, by e-mail, or via standard mail.

1. E-mail drawings to jsc-cal-ep6-esta@nasa.gov.
2. The Test Director will send an invitation to the NASA FTP site to upload and send files.
3. Mail drawings to National Aeronautics and Space Administration, Attention Martin McClean, Mail Code EP6, Lyndon B. Johnson Space Center, Houston, TX 77058.

Test Environment (Vibration)

Complete the Test Environment table below or provide a plot of the test environment to be simulated.

Axis (x, y, z or all)	Frequency Range (Hz):	Amplitude (g^2/Hz)	Tolerance (dB)	Temperature (°F)	Tolerance (°F)	Duration

Test Environment (Performance Testing)

Describe the test environment for each environment to be simulated.

Cell Chemistry:
Long-Term Storage Testing:
Endurance Cycling:
Operate-to-Failure:

Test Environment (Thermal/Vacuum)

Complete the Test Environment table below or provide a plot of the test environment to be simulated.

Type	Minimum	Maximum	Ramp Rate	Tolerance	No. of Cycles
Pressure					
Temperature					
Describe any holds at temperature outside of thermal soaks:					
Termination Criteria (Temperature cutoff):					

Test Environment (Abuse)

Describe the test environment for each environment to be simulated

Crush Testing:
Drop Testing:
Destructive Analysis:
Vent/Burst Testing (Hydrostatic, Pneumatic, Pressure, Burst Expected, Pressure Rise Rate):
Heat-to-Vent:

Overcharge/pverdischarge (current, voltage, time, data rate)
PTC Failure:
Short Circuit:
Destructive Analysis:

Instrumentation

Instrumentation (type of instrumentation, number, attach diagram of planned sensor locations):
Instrumentation Provided by Test Requester:

Data Acquisition and Recording

Number of Channels:	Video Recording (Yes/No):
Sampling Rates:	Photographic Film (Yes/No):
Real-Time Data Processing (Yes/No):	High Speed/Low Speed (Video):
Data File (ASCII/Excel):	Plots (Yes/No):

Other Information

List any other information pertinent to the test:

Test Article Hazard Checklist

A hazard analysis statement is required for any of the following applicable attributes of any of your provided hardware (e.g., test article, support equipment).

Hazard	Y	N	Comments
Mechanical	☐	☐	
Handling (> 40 lb or > 4 ft in any dimension)	☐	☐	
Instability	☐	☐	
Sharp Edges	☐	☐	
Pinch Points	☐	☐	
Exposed Mechanisms (e.g., rotating, reciprocating)	☐	☐	
Pressure Systems	☐	☐	
Stored Energy (e.g., springs, weights, flywheels)	☐	☐	
Ejected Parts, Projectiles	☐	☐	
Electrical	☐	☐	
Voltage (> 50 volts)	☐	☐	
Batteries	☐	☐	
Generation/Storage (e.g., coils, magnets, capacitors)	☐	☐	
Electrostatic Sensitive Devices	☐	☐	
Thermal	☐	☐	
Hot Surfaces (> 113 °F, 45 °C)	☐	☐	
Heaters	☐	☐	
Cold Surfaces (< 39 °F, 4 °C)	☐	☐	
Cooling Devices	☐	☐	

Hazard	Y	N	Comments
Radiation	☐	☐	
Ionizing	☐	☐	
Non-Ionizing	☐	☐	
Laser	☐	☐	
Microwave	☐	☐	
Infrared (IR)	☐	☐	
Ultraviolet (UV)	☐	☐	
Radio Frequency (RF)	☐	☐	
Visible Light, High Intensity	☐	☐	
Material	☐	☐	
Uncontained Brittle Materials	☐	☐	
Test Environment Incompatibility	☐	☐	
Contained Fluids	☐	☐	
Toxic, Corrosive, Flammable Fluids	☐	☐	
Biohazards	☐	☐	
Miscellaneous	☐	☐	
Noise Level (> 85 dBA)	☐	☐	
Ultrasonic	☐	☐	
Pyrotechnics/Explosives	☐	☐	

Appendix C Sample Test Plan

Test Requester Information

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

Test Objectives

Vibration Testing	x	Sine	☐	Random	x	Shock	☐
Battery Performance	☐	Cell Chemistry	x	Endurance Cycling	x	Storage	☐
		Operate-to-Failure	☐	Thermal Testing	☐	Vacuum Testing	x
Battery Abuse	☐	Crush Testing	☐	Destructive Analysis	☐	Drop Testing	☐
		Heat-to-Vent	☐	Overcharge/overdischarge	x	PTC Failure	☐
		Short Circuit	x	Vent/Burst Testing	x		

Purpose of Test:

Provide stated primary and secondary objectives. Wherever possible, specific goals and/or limitations should be included. The primary objectives are to be interpreted as minimum achievements for test success, and the secondary objectives are considered highly desirable options.

Sample Objective: The primary objective of this program is to perform an engineering evaluation on TA1 by performing the following tests: random vibration, cell chemistry, endurance cycling, vacuum, overcharge and overdischarge, short circuit, and vent/burst testing.

Proposed Test Start Date:	Critical Test Start Date:
Proposed Start Date	*Need Date*

Test Article

Test Article Description:

Technical description of the test article, defining method of operation, and theoretical considerations, referring to drawings and/or schematics if necessary. Operational characteristics, including normal and off-limit performance parameters, such as temperature, thrust, voltage, current, and flow rate. Operational constraints of the test article that cannot be violated without harming the test article (for example, pressure limits, environmental temperature limits, vibration levels, system cleanliness, and fluid purity).

Sample Description: TA1 is an individual cell battery with a voltage of 50 Vdc and 10 Ah with Lithium-ion chemistry.

Physical Dimensions (L/W/H): *X" in length and X" in diameter*	Weight: *X mg*

Batteries

Model Number: *XXX-000*	Capacity: *4200 mAh*	Nominal Voltage: *3.9 V*
Mass (entire assembly): *170 lb*	Watt Hours (entire assembly): *at 4.2 V, 1,700 Wh, 400 Ah*	Number of Cells Delivered: *20*
Volume (individual cells): *Volume is less than 777 in3 for a cylindrical can cell expected to burst at less than 1800 psig (normal vent is less than 400 psig).*		
Cell Configuration: Provide description or attach schematic.		
Description of any smart circuitry: *N/A*		
Chemistry (Alkaline, Ni-Cd, Ni-MH, Li-ion, Other): *Li-ion*		
Charge Schedule (current, voltage, time)		
Discharge Schedule (current, voltage, time):		
Battery Safety Limits: Describe any safety features of the battery		

Operational Requirements

Functional Checks (Describe any functional checks to be performed prior to, during, or after testing): *Test Requester will verify nominal performance of VA1 prior to each test series.*	
Test Article Limitations (High/low cutoff temperature, ramp rate not to exceed): All tests are to be stopped after the temperature drops to less than 50 °C after any event.	
Continuous Operations (24 hr): *No*	Authorized Shutdown Points: *At completed test point or defined termination criteria*

Test Article Handling Requirements

Cleanliness Level:	Controlled Access:
N/A	*N/A*
Special Moving/Handling:	
N/A	
Storage Requirements:	
N/A	

Test Article Interface

Test Article Interface Design (Facility or Requester designed, drawings attached, instructions):
Facility designed; test article drawing attached.
Test Fixture (facility stock, facility fabricated, or requester provided):
Three-axis fixturing on slip table, 4" mounting holes, with one triaxial accelerometer (three channels) mounted on center of crossbar at top of unit. Special fixture with test article mounted with standard mounting bolts and interfacing to shaker tables with 3/8" countersunk bolts. Fixture will be defined per approved engineering drawings, including axes indication and mounting definition for triaxial accelerometer.
Power Supply (Describe power supply to test article; include voltage, current, and connections):
None
List materials and instruments supplied by Requester:
None

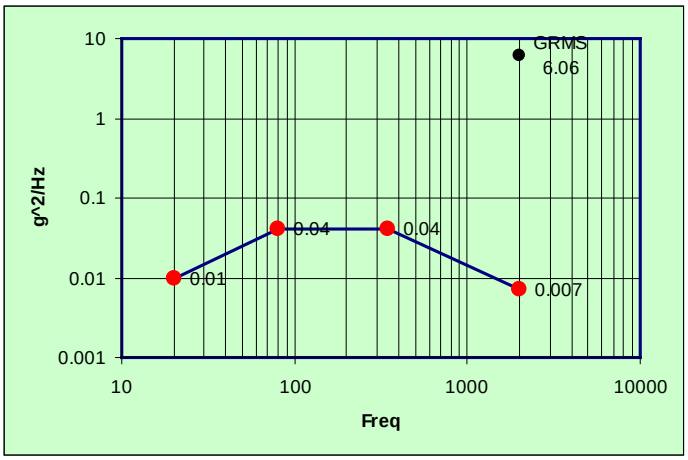
Provide a detailed explanation of the proposed test conditions and schedule of operations. Include a test matrix as appropriate.

Test Environment (Vibration)

Complete the Test Environment table below or provide a plot of the test environment to be simulated.

Axis (x, y, z or all)	Frequency Range (Hz)	Amplitude (g^2/Hz)	Tolerance (dB)	Temperature (°F)	Tolerance (°F)	Duration
X	*20*	*0.01*	*+1, –3*	*–240* °F	± *5.4* °F	*60 sec/axis*
X	*80*	*0.04*	*+1, –3*	*–240* °F	± *5.4* °F	*60 sec/axis*
X	*350*	*0.04*	*+1, –3*	*–240* °F	± *5.4* °F	*60 sec/axis*
X	*2000*	*0.007*	*+1, –3*	*–240* °F	± *5.4* °F	*60 sec/axis*

Sample Vibration Environment Plot



Test Environment (Performance Testing)

Describe the test environment for each environment to be simulated.

Cell Chemistry: *Determine the open circuit voltage and closed circuit voltage of TA1.*
Long-Term Storage Testing:
Endurance Cycling: *TA1 shall be subjected to thermal environments within the operating range between –80 to 80 °C for a period of x days.*
Operate-to-Failure:

Test Environment (Thermal/Vacuum)

Complete the Test Environment table below or provide a plot of the test environment to be simulated.

Type	Minimum	Maximum	Ramp Rate	Tolerance	No. of Cycles
Pressure	*0.1 psia*		*8 psi/minute*	*±1 psia*	*1*
Temperature					
Describe any holds at temperature outside of thermal soaks:					
Termination Criteria:					

Test Environment (Abuse)

Describe the test environment for each environment to be simulated

Crush Testing:
Drop Testing:
Destructive Analysis:
Vent/Burst Testing (Hydrostatic, Pneumatic, Pressure, Burst Expected, Pressure Rise Rate): *Pressurize the case for TA1 until it ruptures. Provide maximum internal pressure of TA1.*
Heat-to-Vent:
Overcharge/overdischarge (current, voltage, time, data rate): *Test is to be performed to determine the tolerance to overcharge. Charge time = x seconds with rate of charge = x and no voltage limit. Overdischarge will be performed for x seconds and until x amp/hour rating has been achieved.*
PTC Failure:
Short Circuit: *Place ~ 40 mΩ across TA1 with a relay unitl the temperature decreases monotonically for 30 minutes or x amps is reached.*
Destructive Analysis:

Instrumentation

Instrumentation (type of instrumentation, number, attach diagram of planned sensor locations): Identify requirements for instrumentation, data recording, displays, and data processing. *Instrumentation diagram attached.*
Instrumentation Provided by Test Requester: Identify instrumentation and data recording to be provided to the facility.

Data Acquisition and Recording

Number of Channels: *32*	Video Recording (Yes/No): *Yes*
Sampling Rates: *10 SPS*	Photographic Film (Yes/No): *Yes, pretest and posttest and test setup*
Real-Time Data Processing (Yes/No): *No*	High Speed/Low Speed (Video): *High Speed*
Data File (ASCII/Excel): *Excel*	Plots (Yes/No): *Yes, Vibration*

Other Information

List any other information pertinent to the test:

Test Article Hazard Checklist

A hazard analysis statement is required for any of the following applicable attributes of any of your provided hardware (e.g., test article, support equipment).

Hazard	Y	N	Comments
Mechanical	☐	☐	Identify the hazards and present the approach for mitigating each.
Handling (> 40 lb or > 4 ft in any dimension)	☐	☐	
Instability	☐	☐	
Sharp Edges	☐	☐	
Pinch Points	☐	☐	
Exposed Mechanisms (e.g., rotating, reciprocating)	☐	☐	
Pressure Systems	☐	☐	
Stored Energy (e.g., springs, weights, flywheels)	☐	☐	
Ejected Parts, Projectiles	☐	☐	
Electrical	☐	☐	
Voltage (> 50 volts)	☐	☐	
Batteries	☐	☐	
Generation/Storage (e.g., coils, magnets, capacitors)	☐	☐	
Electrostatic Sensitive Devices	☐	☐	
Thermal	☐	☐	
Hot Surfaces (> 113 °F, 45 °C)	☐	☐	
Heaters	☐	☐	
Cold Surfaces (< 39 °F, 4 °C)	☐	☐	
Cooling Devices	☐	☐	

Appendix D Customer Feedback

EP TEST REQUESTER FEEDBACK (ESTA & EPSL)	
Test Number/Title:	**Date:**
Test Requester/Org (Optional):	**Facility:**

	SCORE * 1= Poor, 5 = Excellent
SCHEDULE:	
1. Was the test initiated and completed to meet your requirements/test objectives?	_____
2. Was the test performed within the agreed to schedule?	_____
3. Was the Test data/report provided to you in a timely manner?	_____
COST:	
1. Was the test performed within the estimated cost?	_____
2. Was the test cost reasonable for the test performed?	_____
PRODUCT:	
1. Was the provided test data/report sufficient?	_____
2. Was the test data/report provided to you in an acceptable format?	_____
3. Were the objectives of the test satisfied?	_____
SAFETY:	
1. Was safety during test operations adequately addressed and controlled?	_____
2. Was test article handling and use safe while in the care of the test facility/personnel?	_____
FACILITY/TEST TEAM:	
1. Did the facility's capability meet the needs of the test requirements?	_____
2. Was the facility reliable during the test?	_____
3. Did you find the test team helpful and knowledgeable in meeting your objective	_____
4. Would you consider using this test facility for future tests?	_____

* If score is below 3, please provide comment below.

COMMENTS/Suggestions for Improvements or Future Capability Needs:

_____

_____

_____

Note: We are concerned and interested in your comments and would like an opportunity to improve our service.

RETURN TO: Mail code EP/Test Feedback (or e-mail to jsc-cal-ep6-esta@nasa.gov)