BARREL Thermal Vacuum Test Procedure

BALLOON ARRAY FOR RBSP RELATIVISTIC ELECTRON LOSSES (BARREL)

BARREL THERMAL VACUUM TEST PROCEDURE

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National Aeronautics and Space Administration

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BARREL Thermal Vacuum Test Procedure

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1. OVERVIEW

This document defines the thermal vacuum test procedure for the Balloon Array for RBSP Relativistic Electron Losses (BARREL) science flights. Section 1 provides a general overview of objectives and procedure. The test set-up is described in Section 2. The step-by-step procedure (which should be followed during the actual test) can be found in Section 3. Data sheets for recording data during the test are in an excel spreadsheet.

1.1 Objectives

The objectives of the thermal vacuum testing are as follows:
1. Verify workmanship
2. Test hot and cold start-ups
3. Test functionality at thermal model temperature extremes

1.2 Test Article Description

Each test article consists of a BARREL payload core structure with the scintillator removed. The TVAC test is performed without the foam enclosure, solar panels, and flight train components. The terminate package is included with the flight terminate cable. The magnetometer is not mounted on its boom due to space available in the chamber. The flight GPS antenna is included, but the Iridium antenna and cable used will be test cables due to the length requirement to reach the building roof. The battery will be outside the chamber for three out of four cycles. An external bench power supply will be used in place of the solar panels.

Subsystems included
- Central Structure (DPU, DC-DC Converter Box, Charge Controller, Iridium Modem)
- Magnetometer & serial cable (not mounted to boom)
- GPS antenna
- Flight temperature sensors glued into place where applicable
- Terminate system with test bulbs & flight terminate cable
- Battery (outside chamber for three of four cycles)

Items excluded from test
- Scintillator
- Foam enclosure
- Outer structure (handle assembly, tic-tac-toe, solar panel mounts, mag boom)
- Flight Iridium antenna and cable
- Solar panels
- Flight train (ladder, parachute)
1.3 Test Requirements

1.3.1 Test Profile

The test will consist of a total of 4 cycles, including three cycles from -25°C to +55°C and one cycle from -20°C to 46°C. The transition rate is set by the chamber capabilities. There is no restriction on ramp rate. The temperature range is based on the BARREL thermal model and may, in some cases, be less extreme than the operating limits of an individual subsystem.

The payload will be on during vacuum pump-down. As vacuum is pulled, temperatures in the chamber may drop initially while component temperatures may increase to only cool back down as equilibrium is established. All yellow limits, defined when a component is within 10°C of its operating temperature limit, should be monitored closely. No red limit temperatures should be exceeded during this process with the payload powered on. The red limit is equal to the maximum operating temperature for each subsystem. If a yellow limit is exceeded and the test engineer determines that the red limit will inevitably be exceeded then measures should be taken to stop the test. The subsystem limits and model hot/cold extreme temperatures can be found in BARREL-ICD-104 (BARREL Thermal Interface Control Document).

At each temperature extreme, the system shall be thermally soaked. Soak will start when the payload temperature is within 2°C of the goal temperature. The cold soak temperature should be identified when the Iridium modem is not transmitting and the charge controller is operating at minimum heat dissipation. The hot soak temperature should be defined when the Iridium modem is transmitting and the charge controller is operating at maximum heat dissipation. Each cycle will include a hot start and cold start after the payload has reached equilibrium, defined when the temperature rate of change of all the subsystems is less than 0.5 degrees C per minute.

![Thermal Vacuum Test Profile](image)

Figure 1: Thermal Vacuum Test Profile.

1.3.2 Functional Tests

During the first three cycles, the bench power supplies should be powered on, except during a hot/cold restart. Data should be verified as nominal at regular intervals (recorded in the date sheet), and terminate tests are conducted at each temperature extreme. During the fourth cycle, the battery shall be placed inside the chamber, connected directly to the...
payload. The battery thermal cut-off switch will be exercised on hot cycle #4. The bench supply will be on during hot cycle #4 and off during cold cycle #4 (below 0°C).

2. TEST SETUP

2.1 Chamber
The test will be performed at CSBF in the BEMCO thermal vacuum chamber.

2.2 Required Equipment

- Up to four payloads with test batteries
- Terminate system for each payload with internal batteries connected
- Non-conductive support structure (e.g. wood or foam)
- Extra temperature sensor (1) for each payload (to be attached to structure)
- TVAC test cables (for thermistors and power inside and outside, serial terminate)
- Bench power supply for each payload, 0-30V, 2 AMP
- 16-channel reader for extra temperature sensors
- GSE computer, modem, and modem power cord.
- External GPS repeater (already installed near the BEMCO)
- External Iridium antennas (installed on the roof or set up outside the building)

2.3 Setup

2.3.1 GSE

1. Connect GSE modem to exterior antenna.
2. Connect modem to GSE computer and AC power.
3. Start GSE software or Hyperterminal. Check modem (AT> OK) and signal strength (AT+CSQ) to verify modem is working.

2.3.2 Payloads

1. Glue one extra temperature sensor to each payload structure.
2. Place payloads in chamber on non-conductive support material
3. Attach GPS antenna to each payload and place antenna on top of payload.
4. Attach magnetometer to each payload using serial cable.
5. Attach terminate system to each payload using flight terminate cable. Make sure test bulbs face chamber window and are visible from outside.
6. Attach external Iridium cable to modems.

2.3.3 Power Harnessing

1. Inside chamber: Connect test harness to chamber feedthrough plate. Record feedthrough assignments in Table 1. **DO NOT CONNECT TO PAYLOADS!!**

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### Table 1: Chamber Feedthrough Assignments

<table>
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<tr>
<th>Wire Description</th>
<th>Signal Name</th>
<th>Feedthrough #</th>
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<tbody>
<tr>
<td>PWR 1 Black</td>
<td>PL1 SP1 -</td>
<td></td>
</tr>
<tr>
<td>PWR 1 Red</td>
<td>PL1 SP1 +</td>
<td></td>
</tr>
<tr>
<td>PWR 2 Black</td>
<td>PL1 Batt -</td>
<td></td>
</tr>
<tr>
<td>PWR 2 Red</td>
<td>PL1 Batt +</td>
<td></td>
</tr>
<tr>
<td>PWR 3 Black</td>
<td>PL2 SP1 -</td>
<td></td>
</tr>
<tr>
<td>PWR 3 Red</td>
<td>PL2 SP1 +</td>
<td></td>
</tr>
<tr>
<td>PWR 4 Black</td>
<td>PL2 Batt -</td>
<td></td>
</tr>
<tr>
<td>PWR 4 Red</td>
<td>PL2 Batt +</td>
<td></td>
</tr>
<tr>
<td>PWR 5 Black</td>
<td>PL3 SP1 -</td>
<td></td>
</tr>
<tr>
<td>PWR 5 Red</td>
<td>PL3 SP1 +</td>
<td></td>
</tr>
<tr>
<td>PWR 6 Black</td>
<td>PL3 Batt -</td>
<td></td>
</tr>
<tr>
<td>PWR 6 Red</td>
<td>PL3 Batt +</td>
<td></td>
</tr>
<tr>
<td>PWR 7 Black</td>
<td>PL4 SP1 -</td>
<td></td>
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<tr>
<td>PWR 7 Red</td>
<td>PL4 SP1 +</td>
<td></td>
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<tr>
<td>PWR 8 Black</td>
<td>PL4 Batt -</td>
<td></td>
</tr>
<tr>
<td>PWR 8 Red</td>
<td>PL4 Batt +</td>
<td></td>
</tr>
<tr>
<td>XT 0 Red</td>
<td>PL1 Extra Temp</td>
<td></td>
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<td>XT 4 Red</td>
<td>PL2 Extra Temp</td>
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<td>XT 8 Red</td>
<td>PL3 Extra Temp</td>
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<td>XT 12 Red</td>
<td>PL4 Extra Temp</td>
<td></td>
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<tr>
<td>XT COM</td>
<td>Temp COM (all)</td>
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2. **Outside chamber**: Connect battery test cable between battery and feedthroughs indicated in Table 1 above.

3. **Inside chamber**: Measure battery voltage on each 4-pin molex connector and record voltage. Take care to orient DVM leads correctly: Pin 4 (-), Pin 1 (+). It is critical that the voltage polarity be measured correctly! **DO NOT SHORT LEADS TOGETHER WHILE MEASURING. THIS WILL DAMAGE THE BATTERY!!**

VBatt_PL1: ___________

VBatt_PL2: ___________

VBatt_PL3: ___________

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4. *Outside chamber*: Disconnect the batteries from the test cables.

5. *Inside chamber*: Connect the test harness 4 pin molex connectors to each payload CC_BATT cable.

6. Set each bench supply to 18V and current limit to between 0.5 and 1.0 Amps.

7. *Outside chamber*: Connect test cable between bench supplies and SP1 feedthroughs (indicated in Table 1 above).

8. *Inside chamber*: Measure voltage on each SP1 power cable at the 2 pin molex (that connects to the payload). Voltage polarity is critical here. Pin 1 (+), Pin 2 (-).

   - VSP1_PL1: ___________
   - VSP1_PL2: ___________
   - VSP1_PL3: ___________
   - VSP1_PL4: ___________

9. Turn bench supplies **OFF**!

10. *Inside chamber*: Connect each SP1 connector (CC_SOLAR) to test cable 2 pin molex connectors.

2.3.4 Extra Temperature Sensors

   1. *Inside chamber*: Connect each extra temperature sensor to test cable harness.
   
   2. *Outside chamber*: Connect 16-channel reader between outside feedthroughs and computer using the feedthrough assignments in Table 1 above.

   3. Start software for 16-channel reader and configure settings.

   4. Verify extra temperature sensor readings.

2.4 Pre-test Checkout

2.4.1 Payload Test (do for each payload)

   1. Connect battery outside the chamber.
   
   2. Turn on bench supply.
   
   3. Verify red and green lights on payload Iridium modem.
   
   4. Using local GSE, place a call.
   
   5. After connection is established, record filename and pre-test data sample on data sheet for each payload (excel spreadsheet).
   
   6. Verify all values are nominal.
   
   7. Connect terminate PWR_PLUG to each terminate box. Record housekeeping on data sheet and test terminate (ARM, FIRE, DISARM, and verify bulbs flashed).

2.4.2 MOC/SOC Test

   1. Instruct UCSC to place a call to each payload. Record time on data sheet.
2. Verify data coming through SOC.

3. STEP-BY-STEP TEST PROCEDURE

3.1 Main Test Procedure
Data and test conditions should be recorded on a data sheet (excel spreadsheet) throughout the test. Make sure to indicate times of each event.

1. Verify all steps in Section 2, “Set-up” were completed and all systems are nominal. Payloads should be powered on and connected to the MOC.
2. Start logging extra temperature values.
3. Close chamber door.
4. Pump down chamber and backfill with nitrogen.
5. Cold Cycle #1: Cool chamber to -25°C.
6. When set point reached, pump down to pressure of a few mbar.
7. Verify all values nominal for each payload.
8. Conduct primary terminate test for each payload (Section 3.2).
9. Conduct secondary terminate test for each payload (Section 3.3).
10. Soak for 1 hour.
11. Cold Restart – After payload reaches equilibrium, turn off bench supply and disconnect battery. Wait at least 30 seconds. Reconnect battery. Turn on bench supply. Verify Iridium connection and data nominal.
12. Conduct primary terminate test for each payload (Section 3.2).
13. Conduct secondary terminate test for each payload (Section 3.3).
14. End Cycle: Return chamber to room temperature if finished for the day or proceed to next step.
15. Hot Cycle #1: Set chamber temperature set point to +55°C.
16. When set point reached, pump down to a pressure of a few mbar.
17. Verify all values nominal for each payload.
18. Conduct primary terminate test for each payload.
19. Conduct secondary terminate test for each payload.
20. Soak for 30 minutes.
21. Hot Restart – After payload reaches equilibrium, turn off bench supply and disconnect battery. Wait at least 30 seconds. Reconnect battery. Turn on bench supply. Verify Iridium connection and data nominal.
22. Conduct primary terminate test for each payload.
23. Conduct secondary terminate test for each payload.
24. End Cycle: Return chamber to room temperature if finished for the day or proceed to next step.
25. Cold Cycle #2: Repeat Steps 5-14.
27. Cold Cycle #3: Repeat Steps 5-14.
28. Hot Cycle #3: Repeat Steps 15-24
29. Power down payloads. Return chamber to room temperature and pressure and open door, backfilling with nitrogen as needed (CSBF will handle this).
30. Move batteries to inside of chamber and connect directly to payload CC_BATT
31. Attach BATT temperature sensor (on battery) to payload harness.
32. Establish Iridium connection and verify all data nominal before proceeding.
33. Close chamber door.
34. Pump down chamber and backfill with nitrogen.
35. Cold Cycle #4:
36. Turn off bench supplies (can be done at any temperature above 0°C).
37. Cool chamber until it reaches -15°C.
38. When set point reached, pump down to pressure of a few mbar.
39. Verify all values nominal for each payload.
40. Conduct primary terminate test for each payload.
41. Conduct secondary terminate test for each payload.
42. Soak for 1 hour.
43. Conduct primary terminate test for each payload.
44. Conduct secondary terminate test for each payload.
45. Hot Cycle #4: Set chamber temperature set point to +40°C
46. Turn bench supplies on when battery temperatures are above 0°C.
47. When set point reached, pump down to a pressure of a few mbar.
48. Adjust chamber temperature set point to raise battery temperature to 46°C.
49. Verify bench supply current drops to zero or battery voltage begins to decrease when temperature reaches around 46°C (indicating thermal cutoff is functional). If battery is still being charged, increase temperature set point by a few degrees until charging cutoff is noted. Battery temperature should NOT exceed 60°C. Record in “Notes” section of data sheet: actions (set points), and cutoff time, filename, & temperature for each payload. DO NOT TURN OFF BENCH SUPPLY.
50. Verify all values nominal for each payload.
51. Conduct primary terminate test for each payload (Section 3.2)
52. Conduct secondary terminate test for each payload (Section 3.3)
53. Soak for 30 minutes.
54. Conduct primary terminate test for each payload (Section 3.2)
55. Conduct secondary terminate test for each payload (Section 3.3)
56. Begin cooling. Battery should begin charging again below about 42°C. Verify this by observing the battery voltage and/or bench supply current. Record time, filename, and temperature on data sheet when charging resumes for each payload.
57. Return chamber to room temperature and pressure, backfilling with nitrogen as needed (CSBF will handle this).
58. Disconnect Iridium and quit GSE.
59. Disconnect batteries to turn off payloads.

3.2 Primary Terminate Test Procedure
(Carried out at times noted in main test procedure above)
1. Verify Iridium connection
2. Open terminate window (enter password)
3. Send ARM command, verify armed by checking TERM CAP voltage and verifying “Armed” LED lit on MOC screen.

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5. Send DISARM command. Verify not armed by checking TERM CAP voltage and verifying “Armed” LED not lit on MOC screen.

3.3 Secondary Terminate Test Procedure

Carried out at times noted in main test procedure above. This test should be carried out twice for each cycle – once below 55 mbar nominal and once above 55 mbar nominal (the actual pressure threshold will be 55 ± 0.2 mbar).

1. Start the RealTerm program if needed. Check scrollback under “Display” menu and change baud rate to 1200 (Port -> 1200 -> click “Change”).

2. Connect the serial cable for the payload to the netbook and click on the Realterm terminate window. Press ‘r’ to reset the timer.

3. Before each test, press ‘r’ to reset the controller. To test at room pressure (greater than 525 mbar), also press ‘o’ to override the low-altitude lock-out.

4. If pressure is low (first test), advance the timer by 16 cycles by pressing ‘t’ a total of 16 times, making sure to wait for board to respond between each command (this will take about 8 seconds). After the 16th time, the board should report:
   \[
   \text{t } 0\text{FFF } 0\text{B }\text{xxxxx} \\
   0\text{FFF } 0\text{B (after 8 seconds)} \\
   1000 \text{ BB }\text{xxxxx}
   \]
   Press ‘q’. The board should report:
   \[
   \text{q } 1000 \text{ AB }\text{xxxxx} \\
   1000 \text{ 7B (after 8 seconds)}. \]
   Verify the secondary test bulb flashes.

5. If pressure is high (second test), advance the timer by 2 cycles by pressing ‘t’ twice, making sure to wait for the board to respond between each command. After the 2nd time, the board should report:
   \[
   \text{t } 0\text{1FF } 0\text{1 }\text{xxxxx} \\
   0\text{1FF } 0\text{1 (after 8 seconds)} \\
   0200 \text{ B1 }\text{xxxxx}
   \]
   Press ‘q’. The board should report:
   \[
   \text{q } 0200 \text{ A1 }\text{xxxxx} \\
   0200 \text{ 71 (after 8 seconds)}. \]
   Verify the secondary test bulb flashes.

For more information on the secondary terminate system commands, please refer to the BARREL Terminate System Specification Document, BARREL SSD-107 and the BARREL Terminate System Test Procedure, BARREL FTP-106.
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