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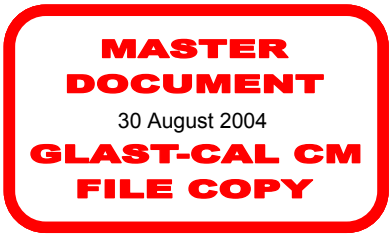
	Subsystem/Office Calorimeter Subsystem	
Document Title **CAL Flight Module Thermal-Vacuum Test Procedure**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter Flight Module Thermal-Vacuum Test Procedure



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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
01	12 August 2004	Initial Release

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1 INTRODUCTION

1.1 PURPOSE

The purpose of this test is to verify function and thermal design of the flight GLAST Calorimeter (CAL) Module in a thermal-vacuum environment. System functional testing, muon collection and thermal balance will be characterized at thermal extremes. This procedure details the sequence and methods to be followed in performing the module level thermal vacuum testing of the flight CAL Module in accordance with the LAT Calorimeter Verification & Environmental Test Plan, LAT-SS-01345. The test results for each CAL Module will be presented in separate test reports upon completion of the test.

1.2 OBJECTIVE

The qualification module (QM) and the flight modules (FM) of the CAL Module will be tested. The QM is defined as the first unit to be tested. Subsequent units are defined as FM

The four primary objectives of this test are:

- To verify the performance and thermal design of the QM over the qualification temperature range of –30 °C to +50 °C.
- To characterize the thermal balance of the QM over the qualification temperature range of –30 °C to +50 °C.
- To verify the performance of the FM over the flight acceptance temperature range of –20 °C to +35 °C.
- To characterize the functional performance of the QM and FM over the operating temperature range of –15 °C to +25 °C

Electrical functional testing and muon collection will occur during all tests.

1.3 VERIFICATION

This test satisfies the requirements for verification of the GLAST CAL Module as specified in the LAT Calorimeter Verification & Environmental Test Plan, LAT-SS-01345. This test will verify workmanship of the system and the functionality under temperature extremes.

2 APPLICABLE SPECIFICATIONS

Documents required to perform this test will accompany the test article, including the As-Built Configuration List (ABCL) and traveler control sheets. The applicable documents cited in this standard are listed in this section only for reference. The specified technical requirements listed in the body of this document takes precedence over the source document is listed in this section.

2.1 GOVERNMENT SPECIFICATIONS

The following specifications, standards and handbooks form a part of this document to extent specified herein.

Number	Title
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components

2.2 NON-GOVERNMENT SPECIFICATIONS

Number	Title
LAT-MD-00408	LAT Instrument Performance Verification Plan
LAT-MD-01370	CAL Comprehensive and Limited Performance Test Definition
LAT-MD-04187	CAL Electronic and Muon Calibration Definition
LAT-PS-04237	CAL Module Handling Procedure
LAT-SS-00788	LAT Environmental Specification
LAT-SS-01345	LAT CAL Verification & Environmental Test Plan
LAT-SS-00971	CAL Program Quality Assurance Plan
ANSI/ESD S20.20-1999	Standard for the Development of an ESD Control Program
N/A	Instrumentation Manuals

2.3 DRAWINGS

Number	Title
LAT-DS-00916	Calorimeter Module, GLAST

2.4 ORDER OF PREFERENCE

In the event of a conflict between this document and the technical guidelines cited in other documents referenced herein, the technical guidelines of this document would take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3 TEST DECRIPTION

3.1 TEST OBJECTIVE

The objective of this test is to verify the performance of the GLAST CAL Module over the qualification, flight acceptance, and operational temperature ranges, for the QM and FM, respectively. In addition, the thermal balance of the QM will also be characterized.

3.2 TEST METHODOLOGY

This test will be conducted in both cryo-pump thermal-vacuum test chambers of the Thermal-Vacuum Laboratory at the Payload Check-Out Facility, Building A-59, of the Naval Research Laboratory, Washington, D.C.

The CAL Module shall be subjected to a thermal-vacuum environment (1.0e-5 torr) with four thermal cycles to the following levels:

- QM –30 °C to +50 °C, qualification temperature ranges with the last cycle dedicated to thermal balance characterization
- FM -20 °C to +35 °C, acceptance temperature ranges

An additional cycle at –15 °C to +35 °C, will characterize the performance of the QM and FM at its operational temperature range.

The test fixture will provide the temperature control so that the temperature ramp of CAL Crystal Detector Elements (CDE) shall not exceed 10 °C per hour. At the hot and cold plateaus, the minimum 4-hour soak will be demonstrated at the qualification and acceptance levels.

Prior to initiating the test, initial functional testing will take place at ambient temperature and vacuum. At that point, the test will initiate the temperature ramp-up to the hot case. Thermal balance will be characterized during the last cycle at the qualification temperature levels.

Two cold plates cooled with liquid nitrogen will provide the TVAC test environment as shown in Figure 3-1. One cold plate (CAL Cold Plate) is attached to the CAL Base plate tabs. This attachment is the same as that used for the LAT Grid interface with the CAL. An additional cold plate (TPS Cold Plate) is attached to the –Z side of the TPS. Heaters attached to the cold plates control the temperature ramp and maintain constant test temperatures. The four 50 W heaters are installed on the CAL Cold Plate and four 25 W heaters on the TPS Cold Plate.

The entire CAL test unit will be completely thermally isolated from the walls of the thermal vacuum chamber by MLI blankets (Figure 3-1).

Tests that will occur in the thermal-vacuum environment are outlined below:

- Survival turn on sequence shall be performed once at the hot survival plateau and once at the cold survival plateau.
- Comprehensive Performance Tests (CPT) shall be conducted at each plateau of the first, fourth, and fifth test cycles.
- Limited Performance Tests (LPT) shall be conducted during thermal transitions, where system failures or intermittent problems are most likely to occur, and at each plateau of the intermediate test cycles (second and third cycles).

The thermal-vacuum test also fulfills the bakeout function for the QM and FM since the structure is above 40 °C during a majority of the transitions. A contamination plate is installed within the vacuum chamber during the test.

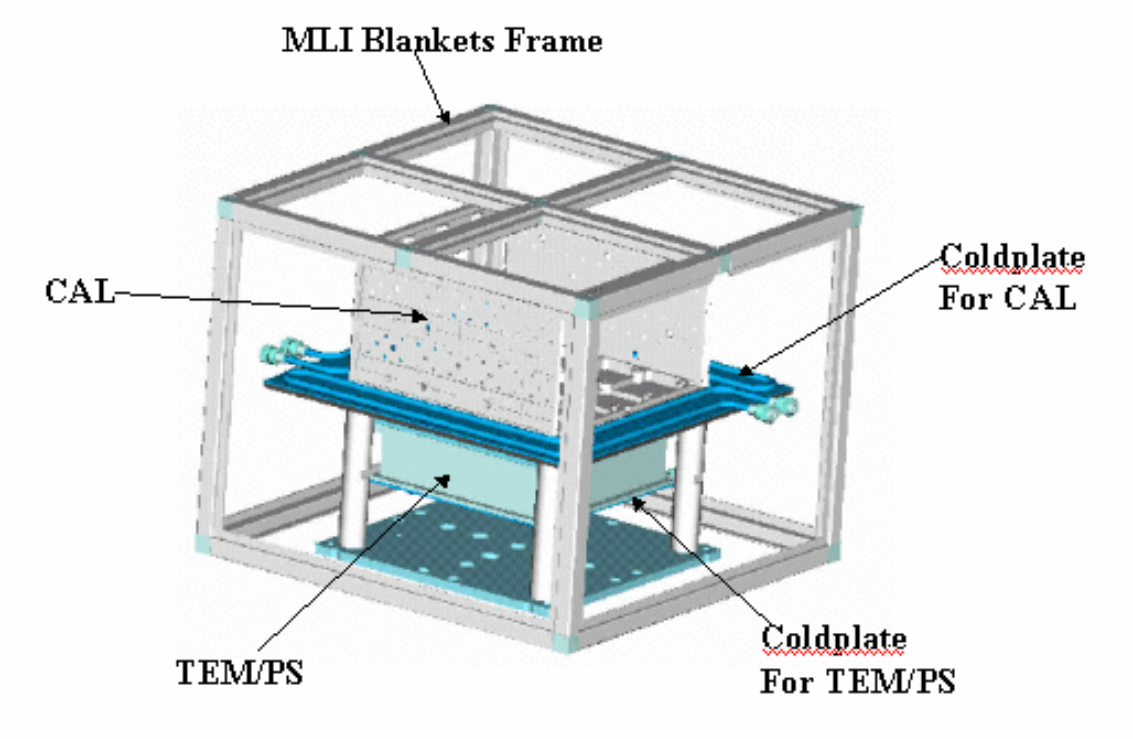


Figure 3-1: Test Fixture Set-up for Thermal Vacuum Test

(MLI Thermal Blankets Removed For Clarity)

3.3 TEST ARTICLE DESCRIPTION

The test article is the GLAST CAL Tower Module, as documented in the as-built configuration list (ABCL). The flight configuration is as follows:

- CAL Module (LAT-DS-00916)
- TEM is attached to the CAL Module Base Plate
- TPS is attached to the TEM

There are no deviations from the flight configuration, with the exception that the TEM and TPS are both version EM2, rather than Flight.
The GLAST CAL Tower Module in flight configuration is shown in Figure 3-2.

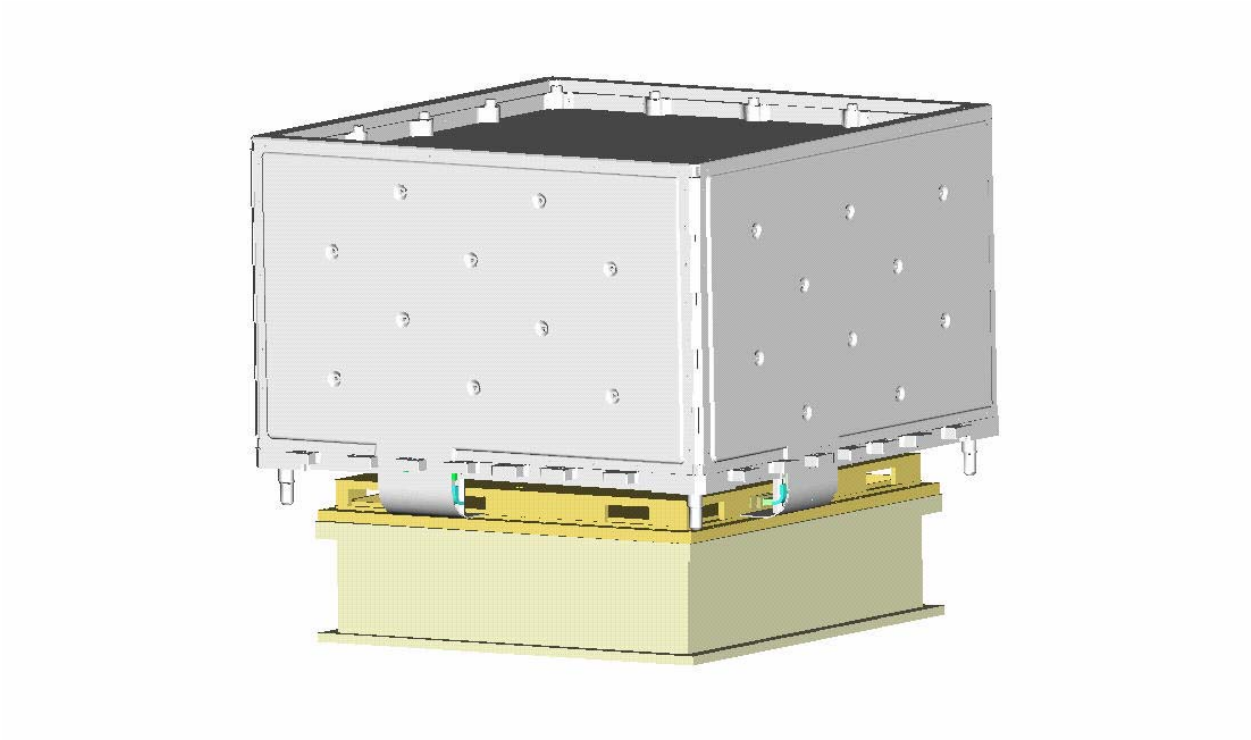


Figure 3-2: CAL in Flight Configuration with TEM/TPS

4 TEST RESPONSIBILITIES

4.1 TEST PERSONNEL

Test personnel are defined below. Responsible points of contact for this test procedure are listed in Table 4-1.

Table 4-1: Test Personnel

Role	Name	Telephone Number
Project Representative	Eric Grove	202-767-3112
Test Director	Paul Dizon	202-404-7193
Test Conductor, Primary	Mike Van Herpe	202-767-3944
Test Conductor, Electrical Subsystem	Jim Ampe	202-404-1464
Test Conductor, Science Subsystem	Eric Grove	202-767-3112
Instrumentation/Data Support	Mike Van Herpe	202-767-3944
Analysis Support	Peck Sohn	301-902-4098
Quality Assurance Support	Nick Virmani	301-902-4344

4.1.1 Project Representative

The Project Representative represents the GLAST project and will have the responsibility to ensure that no violations of project procedures or CAL handling procedures take place.

4.1.2 Test Director

The Test Director (TD) will have primary responsibility for directing test activities, maintaining the log, documenting the test schedules, coordination of resources, and preparation and close-out of all Problem Reports (PRs). The TD will also have the primary responsibility for all data collection and evaluation during the test for the final test report. The TD will be responsible for coordinating the inputs from the Test Conductors and Quality Assurance representatives, developing the as-run test file, and for executing the as-run test approval sheet. This includes assuring that all PRs have been properly prepared and correctly executed.

4.1.3 Test Conductor

The Test Conductor(s) will be responsible for a specific activity being conducted. The Primary Test Conductor will also be responsible for the entire laboratory, installation and check-out of instrumentation, data acquisition, and data reduction. The other TC(s) will be responsible for executing their specified test procedures. The TC(s) is also responsible for the preparation, operation of test equipment, and the scheduling of daily activities mentioned in the test procedure.

4.1.4 Support Personnel

Support Personnel are responsible for specific activities supporting installation of instrumentation, managing data, and providing real-time data analysis support.

4.2 CONFIGURATION VERIFICATION

Upon completion of the test setup, the Test Director, Test Conductor and Quality Assurance representative must inspect and approve the test configuration and test conditions, prior to the start of the testing and at any key phases of the test.

4.3 TEST DISCREPANCY RESOLUTION

In event of a test discrepancy, which indicates the potential of damage to equipment, a failure of the test article, or a failure of test equipment, testing will be stopped and the condition of the hardware and test setup preserved.

If a test discrepancy occurs, the test will be interrupted and the discrepancy will be noted and verified. The TC and TD will ensure that all discrepancies are recorded in a PR and resolved prior to continuing the test. If a discrepancy is verified, a PR will be opened and dispositioned by the TD in accordance with LAT-SS-00971, CAL Program Quality Assurance Plan.

In conducting the failure analysis, the TD can select and re-run in any sequence, any portion of the full functional test within this procedure. Any test steps, conditions, or procedures that are not a portion of this approved test procedure that needs to be included must first be approved by the TD and QA and a PR generated before they are performed. The results are to be included or referenced in the PR and included in the as-run appendix.

If the discrepancy is dispositioned as a failure of the test article, then a MRB will be opened and dispositioned in accordance with LAT-SS-00971, CAL Program Quality Assurance Plan.

5 GENERAL TEST PROGRAM REQUIREMENTS

5.1 TEST SETUP

5.1.1 Test Location

The thermal-vacuum test will be conducted in the Thermal-Vacuum Test Laboratory (cyro-pump TVAC test chambers: North Chamber and Big Blue) of the Payload Check-Out Facility, Building A-59, of the Naval Research Laboratory, Washington, D.C.

5.1.2 Test Article Configuration

The test article is the GLAST CAL Tower Module, which consists of the Flight CAL Module (LAT-DS-00916) and the EM2 Tower Electronics Module (TEM)/TEM Power Supply (TPS) assembly, as documented in the as-built configuration list (ABCL). There are no deviations from the flight configuration.

The CAL Tower Module in its test configuration is shown in Figure 3-2. An As-Built Configuration List (ABCL) will be generated for the test article in its test configuration.

The test article will be mounted in the upright position in the TVAC test fixture. Attached to the CAL Tower Module is one liquid nitrogen-cooled cold plate (CAL Cold Plate), using the flight interface as attachment points. The TVAC test fixture is isolated from the test chamber by G-10 spacers. Heaters on the cold plate will control temperature ramp up and maintain the test temperature. In addition, a liquid nitrogen cold plate (TPS Cold Plate) will be attached to the TEM/TPS, with heaters to control temperature. Four 50 W heaters are installed on the CAL Cold Plate and four 25 W heaters on the TPS Cold Plate.

MLI Thermal blankets will be mounted to the exterior box frame, which is also isolated from the test chamber by G-10 spacers. The blanket frame will surround the entire TVAC test fixture.

5.1.3 Test Equipment

The following test equipment and systems will be used in the execution of this test:

- Test Chamber: North Chamber and “Big Blue” TVAC Chamber Facilities
- Test Article: QM or FM CAL Module with EM2 TEM/TPS
- Test Article Support: CAL TVAC Test Fixture with two Cold Plates/MLI Blankets
  CAL Lift Fixture and Accessories
- Thermocouples: 14 (QM), 10 (FM)
- Temperature Control System: Four 50 W (CAL Cold Plate) Heaters
  Four 25 W (TPS Cold Plate) Heaters
- Data Acquisition and Control PC Computer and HP 34970A Data Acquisition/Switch Unit running the CDACS data acquisition software
- Electrical Test Equipment Calorimeter Test Stand Data Acquisition Unit/GASU

Any substitution of the designated test equipment will require the approval of the TD and/or the TC, and QA. Such substitutions will be noted as part of the test data and submitted with the test report.

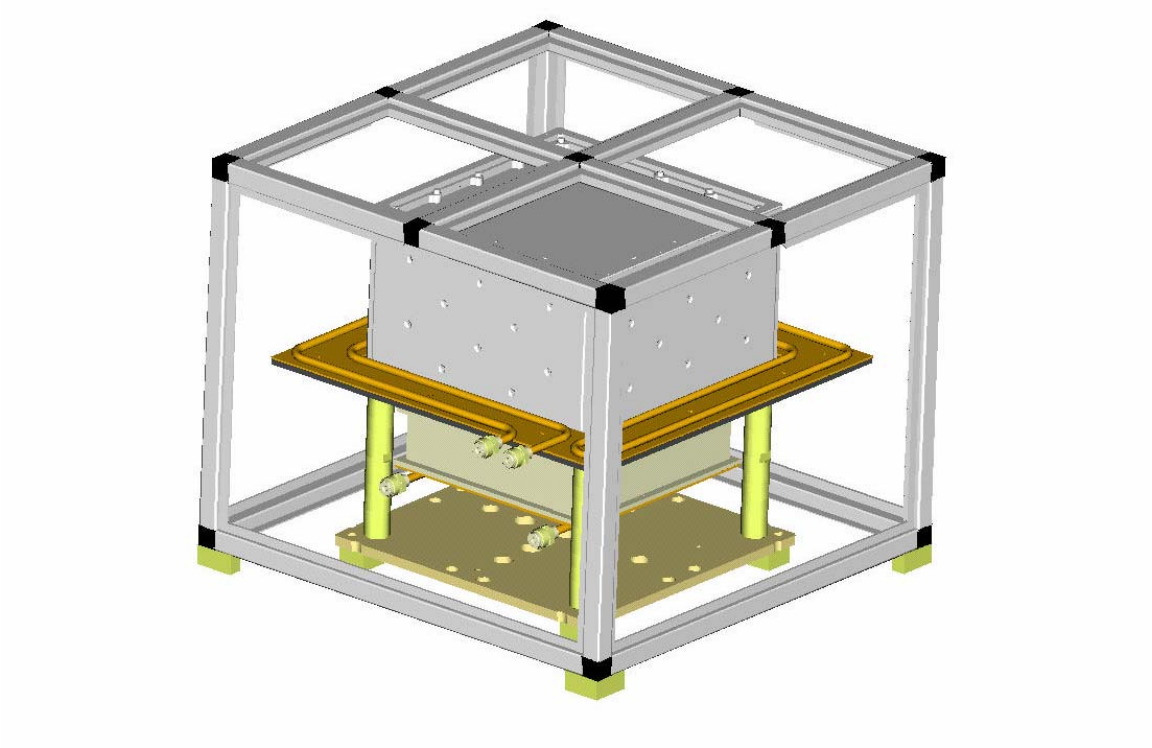


Figure 5-1: Test Fixture with CAL Module
(MLI Thermal Blankets Removed for Clarity)

5.1.4 Handling and Control of Equipment

Handling of the CAL Tower Module will be under the direction of the TD and/or TC. The following equipment must be used for the proper and safe handling:

- Proper CAL Grounding Strap for Electrostatic Discharge (ESD) Control
- Grounding Wrist Straps for ESD Control
- Gloves

Whenever the GASU is disconnected, the CAL Tower Module must be connected to a certified ground strap at all times. All personnel must wear gloves and ground straps when in contact with the Flight CAL.

The following equipment must be used for the proper and safe transportation of the CAL Tower Module as well as movement of the Tower Module within the Vibration Facility:

- Shipping Container (LAT-DS-03395)
- Hoist Plate (LAT-DS-02795)
- Lifting Fixture Assembly (LAT-DS-04138)

The CAL Tower Module is transported to and within the Thermal-Vacuum Test Laboratory inside its shipping container. The shipping container is wheeled and is also used as a transportation dolly. The CAL Module will be moved and positioned on the TVAC chamber platform via the facility crane. Interface between the CAL Module and the crane is the Lift Fixture Assembly.

5.2 INSTRUMENTATION AND DATA ACQUISITION

5.2.1 Instrumentation

Test article instrumentation consists of external thermocouples as well as thermistors integral to the AFEE cards (one per card).

The QM CAL Tower Module is instrumented with 10 thermocouples. The Flight CAL Tower Module is instrumented with 6 thermocouples. 4 additional thermocouples will be used for both of the QM and FM tests, 2 mounted on the CAL cold plate, and 2 on the TPS cold plate. These additional thermocouple channels will be monitored during the test in order to control the temperature environment. Since two FM units will be installed side-by-side in the chamber and cycled thermally together for the FM test, the maximum number of thermocouples for each FM unit is restricted to 10. All thermocouple locations are listed in Table 5-1 & Table 5-2. The locations of these thermocouples are illustrated in Figure 5.2 and Figure 5.3.

Test chamber instrumentation will consist of the normal thermal-vacuum chamber control instrumentation, including, but not limited to, additional thermocouples located on the cold plates and the contamination plate.

5.2.2 Calibration

Prior to testing, the thermocouples will be calibrated by comparison against a standard temperature (0 °C).

5.2.3 Data Acquisition

There will be two data acquisition systems used for this test:

- Dedicated PC computer and HP 34970A Data Acquisition/Switch Unit for the TVAC chamber and test article
- Calorimeter Test Stand Data Acquisition Unit for the test article electronics

A PC computer and data acquisition/switch unit running the CDACS data acquisition software will be used to collect temperature data from thermocouples on the Flight CAL Tower Module, the test fixture (CAL cold plate and TPS cold plate), and the TVAC chamber. Data will be acquired at a sampling rate of 1 sample every 5 minutes. All acquired data will be stored on the computer in ASCII format.

The Calorimeter Test Stand Data Acquisition Unit/GASU will be used to collect science and housekeeping telemetry from the TEM of the Flight CAL Module. Temperature data from the AFEE card thermistors is imbedded in the housekeeping data stream and can be correlated with the thermal model of Flight CAL Tower Module.

Table 5-1: Thermocouple Locations for the QM Protoflight Test

TC ID	Location	TC ID	Location
1	Top of Structure – Center	8	CAL Cold Plate Assembly
2	Top of Structure – Center	9	TPS Cold Plate Assembly
3	+X Base Plate – Bottom Center	10	TPS Cold Plate Assembly
4	+Y Base Plate – Bottom Center	11	+X Side Panel – Middle
5	TEM	12	+Y Side Panel – Middle
6	TPS	13	+X Base Plate – Tab
7	CAL Cold Plate Assembly	14	+Y Base Plate – Tab

Table 5-2: Thermocouple Locations for the FM Acceptance Test

TC ID	Location	TC ID	Location
1	Top of Structure – Center	6	TPS
2	Top of Structure – Center	7	CAL Cold Plate Assembly
3	+X Base Plate – Bottom Center	8	CAL Cold Plate Assembly
4	+Y Base Plate – Bottom Center	9	TPS Cold Plate Assembly
5	TEM	10	TPS Cold Plate Assembly

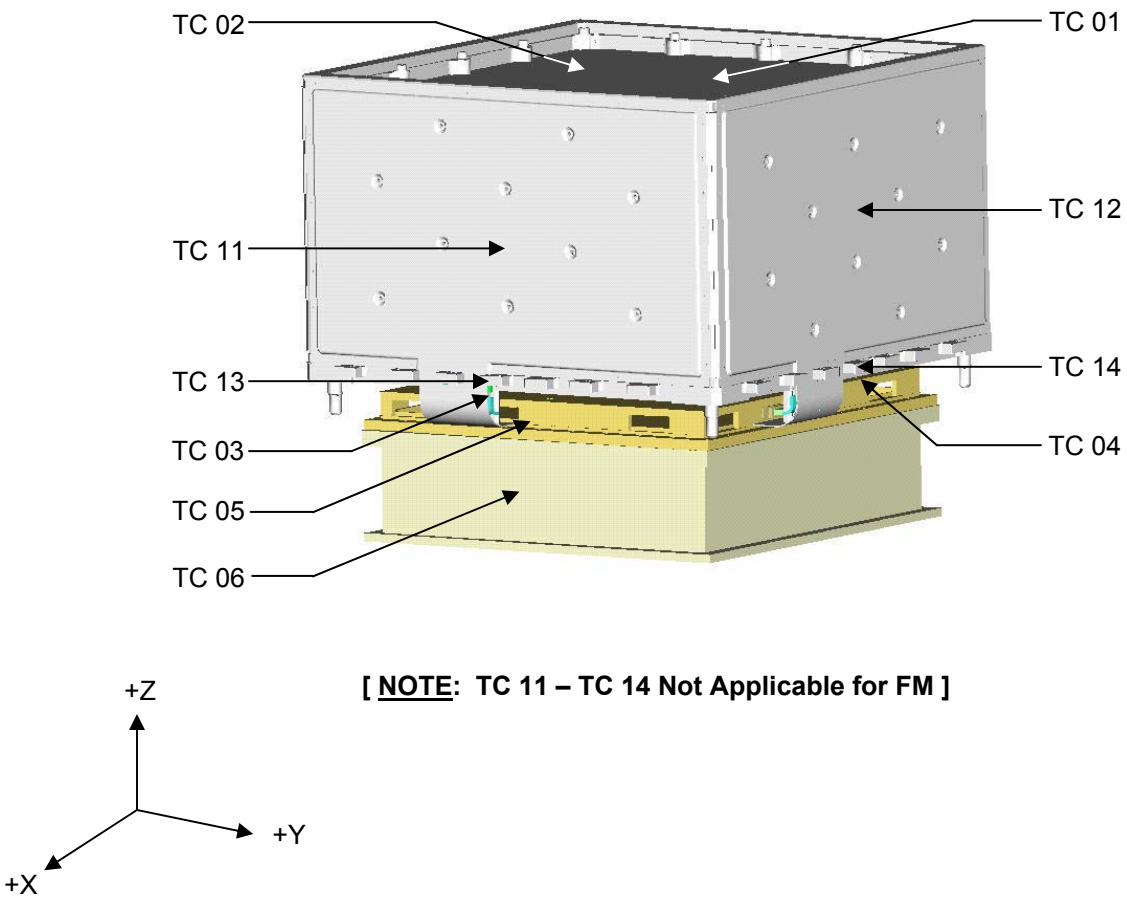


Figure 5-2 : Thermocouple Locations for CAL Module Tower (QM and FM)

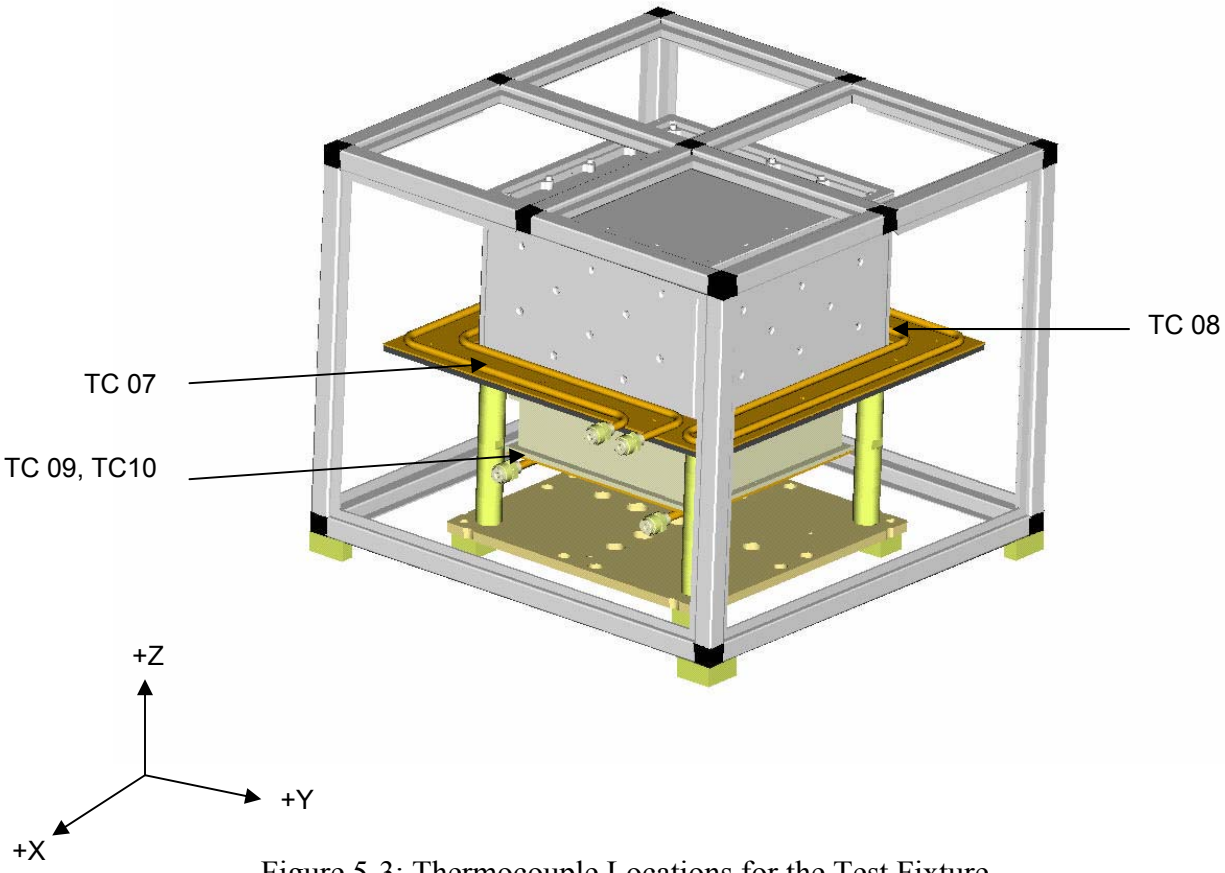


Figure 5-3: Thermocouple Locations for the Test Fixture
(MLI Thermal Blankets Removed for Clarity)

5.3 VACUUM CHAMBER TEST CONDITIONS AND TOLERANCES

Prior to installation of the Flight CAL , the thermal-vacuum chamber will be cleaned, by wiping all accessible surfaces of the chamber with isopropyl alcohol. Access to the chamber will then be controlled and will require suitable clothing to maintain a clean environment.

5.3.1 Environmental Conditions and Tolerances

The qualification temperature levels of the CAL Module are –30 °C to +50 °C. Thermal balance shall be conducted at the qualification temperature levels. The acceptance and operational temperature levels of the CAL Module are –20 °C to +35 °C and –15 °C to +25 °C, respectively.

Hot soak and cold soak temperatures of the AFEE and CDEs shall be maintained within $\pm$ 3 °C. The TVAC test fixture and cold plate temperatures shall be capable of maintaining any temperature within $\pm$ 2 °C. Throughout the test, the CAL Module and AFEE temperatures cannot exceed +60 °C during hot soak and –40 °C during cold soak. Vacuum shall be maintained at 1.0 e-5 torr or better.

5.3.2 Thermal Balance Stabilization Criteria

Thermal balance conditions shall be satisfied once the average temperature of the control points are stable within 0.1 °C/hour. These control points are defined in Table 6-2.

5.3.3 Outgassing

The test article and other test equipment used inside the vacuum chamber should only contain materials that are in compliance with the outgassing requirements

- Maximum Total Mass Loss (TML) of 1%
- Maximum Collected Volatile Condensible Material (CVCM) of 0.1%

5.3.4 Temperature Limits

Alarms will be set in the data acquisition to notify the Test Conductor with a warning message displayed on the terminal screen when temperatures read from the thermocouples exceed their allowable high and low limits (+60 °C during hot soak and –40 °C during cold soak).

5.4 DOCUMENTATION

5.4.1 Test Report

The results of the test will be documented in a separate test report after completion of the test. The report shall contain the as-run procedure, work order, all test data, photographs, a complete description of the test and a description of any deviation from this procedure.

5.4.2 Test/Data Log

The Test Conductor will maintain a test log of the daily activities during the test. The test log shall contain at a minimum the date and time of each test activity, a brief description of the activity, a description of any deviation from the planned procedure, and any other information known to be significant to the test, such as photographs. Furthermore, the Test Director shall maintain a master copy of the procedure. All deviations from the procedure shall be noted as "red lines" in this master copy.

5.4.3 Photographic Coverage

Photographs will be taken of the test article, the overall test set-up, and test equipment prior to the test. Photographs will be required of any failures and items deemed significant by the Test Director or Test Conductor.

5.4.4 Test Report Records

The following is a description of the test records required at the completion of the TVAC test. These records are included as part of the report and will be compiled with the As-Built records.

5.4.4.1 Data Reduction

Temperature and time history data, which is stored on the PC hard drive ~~and printed out~~ can easily be transferred into a spreadsheet for analysis. Similarly, the thermistor data can be extracted from housekeeping data stream stored on the GASU DVD.

The temperature data will be plotted to determine the steady state conditions and transients. This data will be used to correlate the thermal models.

5.4.4.2 Test Failure Reporting

If a test discrepancy occurs, the test shall be interrupted, the condition of the test specimen and set-up preserved, and the discrepancy verified. Any anomalies and /or failures shall be evaluated and documented in accordance to the Calorimeter Quality Assurance Plan.

5.4.4.3 Test Related Problem Reports (PR)

Any PRs that are opened during the test will be contained in the as-run test results. These will be ordered as they occur and will be sequentially numbered on the discrepancy log.

5.4.5 As Run Procedure

The test director will verify that the steps of this procedure are complete during the test. The procedural steps will be outlined in a Work Order form, which will be labeled to reflect the date and time of each activity and a description of any and all failures. Signatures within the procedure will be required from either the Test Director, Test Conductor, and/or Quality Assurance to verify that specific test activities have been completed. The As-Run Work Order forms will be included in the final test report.

5.5 HAZARDOUS CONDITIONS

5.5.1 Hazardous Environments

The hazardous environments associated with this test have been identified:

- Electrostatic Discharge (ESD)
- Electrical Power
- Gaseous Nitrogen (GN_2)
- Liquid Nitrogen (LN_2)

All personnel having access to the chamber shall be required to wear nominal clean-room attire while working inside the chamber. In addition, proper safety equipment shall be worn.

The CAL Tower Module must be connected to a certified ground wire whenever the GASU is disconnected.

5.5.2 Safety Requirements

This procedure involves the use of LN_2. Therefore, proper garments, including gloves, face shield, and non-absorbent footwear shall be worn during handling of LN_2.

5.5.3 Safety Equipment

- Oxygen Monitor (for use inside the test chamber, as required)
- Ground Strap
- Gloves
- Gloves, Face Shield, and Non-Absorbent Footwear (for handling of LN_2)

5.6 PASS-FAIL CRITERIA

The GLAST CAL Module will have passed this series of testing if the following criteria are met:

- The environmental conditions and tolerances are applied in accordance to those described in Section 5.3.1 and Section 5.3.2.
- The GLAST CAL Module incurs no detrimental damage.
- Acquisition of data is recorded and suitable for correlation with the thermal models.
- Functional test data for the AFEE and TEM electronics are collected in accordance with, LAT-MD-01370, CAL Comprehensive and Limited Performance Test Definition.
- Muon test data are collected in accordance with, LAT-MD-01370, CAL Comprehensive and Limited Performance Test Definition.
- At the conclusion of the thermal vacuum test, no change in the electrical functional pass/fail status of the CAL Module has occurred.

6 TEST PROCEDURE

The thermal-vacuum test is divided into three phases: 1) thermal-vacuum cycling (QM and FM), 2) thermal balance (for QM only), and 3) operational temperature function test (QM and FM). The thermal-vacuum test shall follow the temperature profile and test timeline as described in Section 6.1 and Section 6.4, respectively. Limited and comprehensive electrical functional testing as well as muon performance testing occurs throughout the TVAC test cycle, as described in Section 6.2. All test preparation and set-up procedures are described in Section 6.3.

Typical Test Sequence is summarized as follows:

1. Installation of CAL Tower Module into the Test Fixture
2. Installation of the Test Article into the TVAC Test Chamber
   - Limited Performance Test
3. Thermal-Vacuum Cycle 1 (QM and FM)
   - Bake-Out
   - Hot Turn-On
   - Cold Turn-On
   - 4 Hour Cold Soak - Comprehensive Performance Test and Muon Collection
4. Thermal-Vacuum Cycle 2 (QM and FM)
   - 4 Hour Cold Soak - Limited Performance Test and Muon Collection
5. Thermal-Vacuum Cycle 3 (QM and FM)
   - 4 Hour Cold Soak - Limited Performance Test and Muon Collection
6. Thermal-Vacuum Cycle 4 (QM and FM)
   - 4 Hour Cold Soak - Comprehensive Performance Test and Muon Collection
7. Thermal-Vacuum Cycle 5 - Operational Temperature
   - Thermal Balance Test (QM)
   - Comprehensive Performance Test and Muon Collection (QM and FM)
8. Removal of the Test Article from the TVAC Test Chamber

6.1 TEMPERATURE PROFILE

The thermal cycling of the CAL Tower Module shall be conducted at the qualification temperature range, –30 °C through +50 °C for the QM and the acceptance temperature range, -20 °C through +35 °C for the FM. A performance characterization test at the operational temperatures of –15 °C to +25 °C shall also be conducted as a separate cycle. Thermal balance will also be conducted at the operational temperature levels. The thermal balance shall only be conducted with the QM, defined as the first flight CAL Module. All tests on subsequent units shall be only thermal cycle tests. Operational temperature performance characterization tests shall be conducted on all units.

The thermal-vacuum test requires 4 cycles, with the last cycle dedicated to the thermal balance characterization on the QM only. Remaining Flight CAL modules shall be tested with 4 thermal-

vacuum cycles. The profile is shown in Figure 6-1 and Figure 6-2. For both tests, Cycle 1 will also fulfill the bake-out function of the structure.

Two cold plates cooled with liquid nitrogen will provide the TVAC test environment. One cold plate (CAL Cold Plate) is attached to the CAL Baseplate tabs. This attachment is the same as that used for the LAT Grid interface with the CAL. An additional cold plate (TPS Cold Plate) is attached to the –Z side of the TPS. Heaters attached to the cold plates control the temperature ramp and maintain constant test temperatures. The four 50 W heaters are installed on the CAL Cold Plate and four 25 W heaters on the TPS Cold Plate.

During the cold or hot soak period of each TVAC cycle, the CAL and TPS Cold Plates will be set according to the temperatures in Table 6-1. The CAL and TPS Cold Plates shall be capable of maintaining their temperatures within $\pm$ 2 °C. To expedite the hot and cold transition from plateau to plateau, the CAL cold plate will ramp up or down by the rate of 30 °C per hour and be set to maximum +60 °C for hot transition and –40 °C for cold transition before setting to the qualification or acceptance temperature ranges at the final stage of transition. According to analysis predictions, as shown in Appendix A, the CAL Module and AFEE temperatures shall not exceed +60 °C (for hot tests) and –40 °C (for cold tests); and the CDE shall not exceed the transition rate requirement of 10 °C per hour throughout the test.

There are no thermocouples installed on the CDE at the inside of CAL module. As shown in the analysis figures (Appendix A), the top of CAL Module (Node 10) and CDE (Node 11) are merging closely together to each plateau temperature at the final stage of transition and plateaus. Therefore, the thermocouples attached to the top of the CAL Module (TC 1 and 2) are monitored as control points for tests.

Per SLAC direction due to the functional performance problem at the cold temperature, the thermal cycling of the EM2 TEM/TPS shall be conducted only at the temperature range of +15 °C through +35 °C. Thus, the TPS Cold Plate will be set at +15 °C for cold tests and +35 °C for hot tests.

During thermal balance test activities, the test fixture temperature is set in accordance with the temperatures listed in Table 6-1. Thermal balance conditions shall be satisfied once the average temperature of the control points, as defined in Table 6-2, are stable within 0.1 °C/hour.

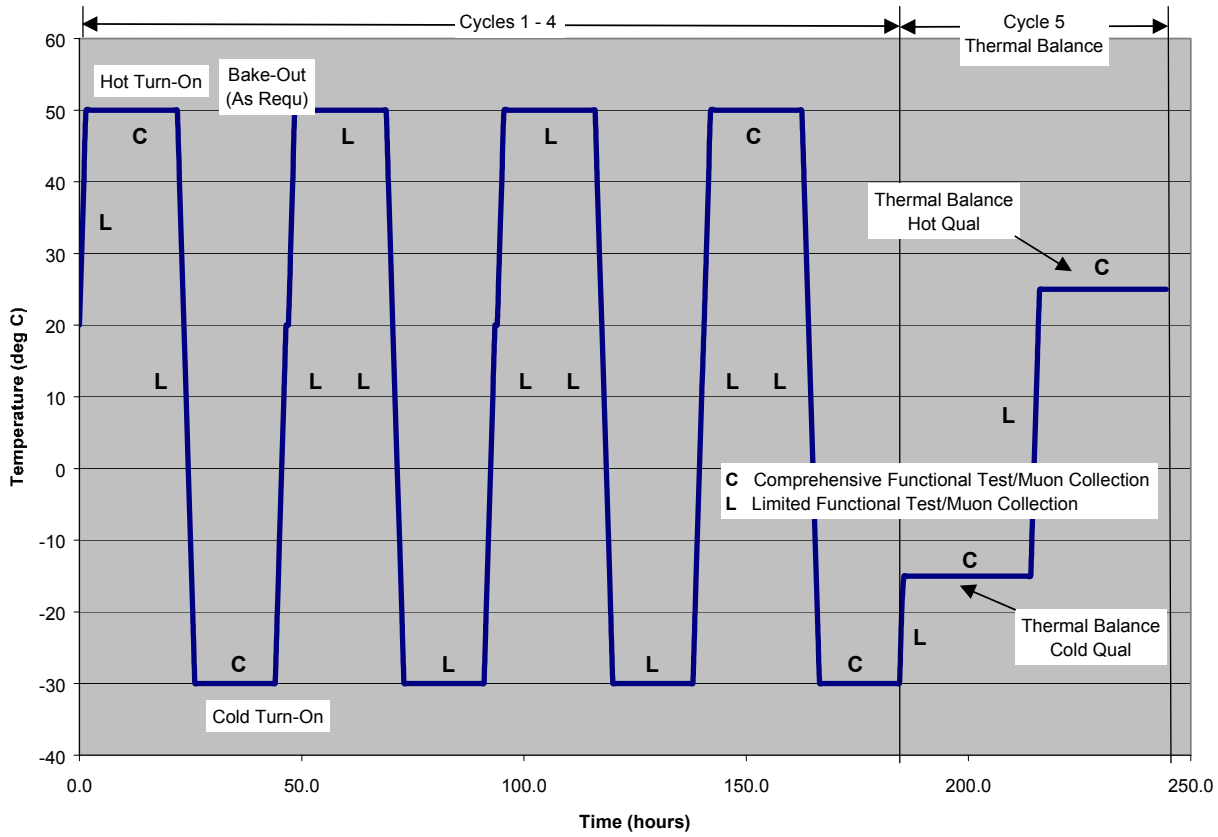


Figure 6-1: CAL Module Qualification Levels for Thermal Vacuum Testing of QM

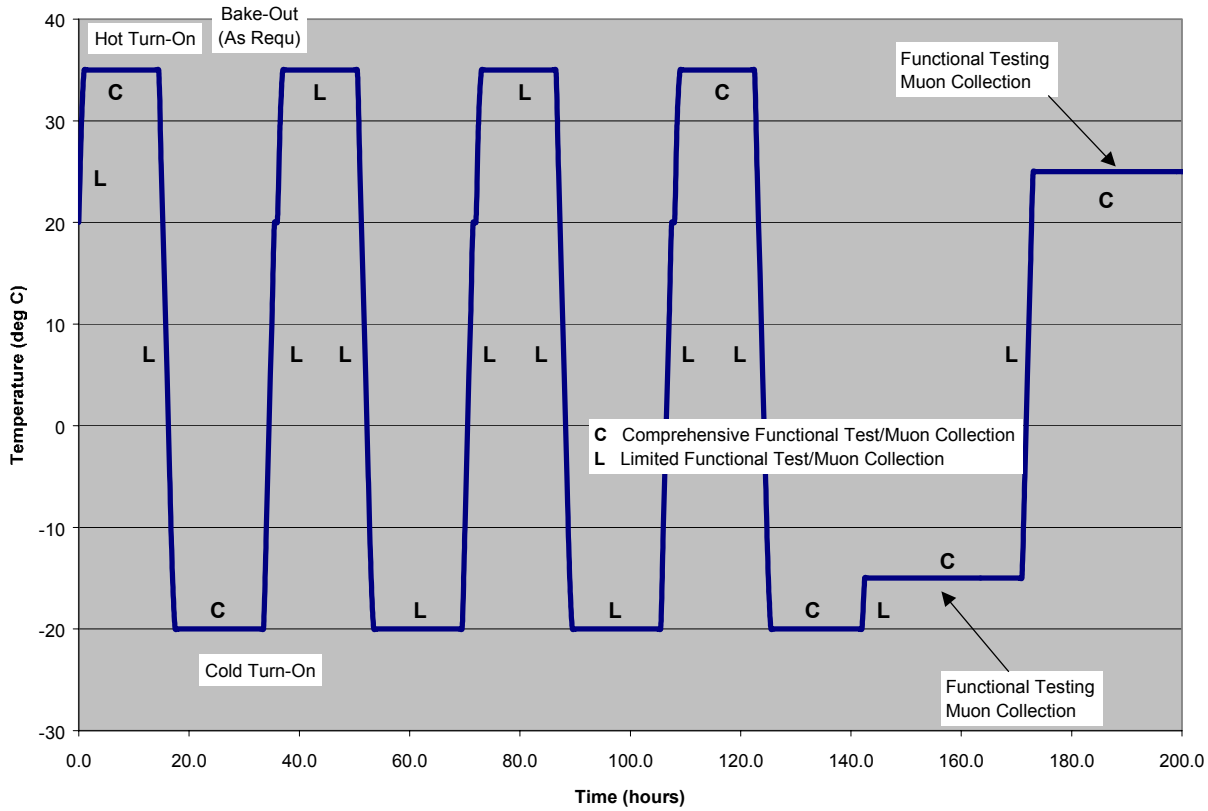


Figure 6-2: CAL Module Acceptance Levels for Thermal Vacuum Testing of FM

Table 6-1: CAL Module Temperature Levels for Thermal Vacuum Testing

TEST COMPONENT	QUALIFICATION LIMITS		ACCEPTANCE LIMITS	
	COLD (deg C)	HOT (deg C)	COLD (deg C)	HOT (deg C)
CAL Module	-30	+50	-20	+35
TEM-TPS	+15	+35	+15	+35
CAL Cold Plate Assembly	-33	+50	-23	+35
TPS Cold Plate Assembly	+15	+35	+15	+35

Table 6-2: CAL Module Thermal Balance Control Points

Thermocouple	Component
TC 01 and 02	Top of Structure – Center of EMI shield
Thermal Balance Conditions Satisfied when Average Temperature of the Components are Stable within 0.1 °C per Hour	

6.2 FUNCTIONAL AND MUON TESTING DEFINITIONS

During the Thermal Vacuum Test, the CAL Tower Module shall undergo both limited and comprehensive electrical functional testing as well as muon performance testing in accordance with LAT-MD-01370, CAL Comprehensive and Limited Performance Test Definition.

These tests, as described below, are conducted by the Electrical and Science Subsystem Test Conductors via a test scripts.

6.2.1 Survival Turn-On Sequence

Survival turn on sequence shall be performed once at the hot survival plateau and once at the cold survival plateau of Cycle 1.

6.2.2 Limited Functional Performance Testing of AFEE and TEM

Limited Electrical Functional Performance Testing (LPT) shall provide verification of selected elements of the electrical function of the AFEE and TEM electronics. This test is conducted during thermal transitions, where system failures or intermittent problems are most likely to occur, and at each plateau of Cycle 2 and Cycle 3.

6.2.3 Comprehensive Functional Testing of AFEE and TEM

Comprehensive Electrical Functional Performance Testing (CPT) shall provide verification of the full electrical function of the AFEE and TEM electronics. This test is conducted at each plateau of the first and last test cycles.

6.2.4 Cosmic Muon Test

Cosmic ray muons provide patterns of energy deposition in the CAL that are analogous to the flight science data. The muon test provides a limited end-to-end functional test of science data acquisition and science performance. The LPT and CPT contain brief muon data accumulations. Longer, dedicated muon accumulations are performed at the conclusion of the LPT or CPT while the CAL remains in each temperature plateau. This test is conducted throughout the test flow.

6.3 TEST PREPARATION AND SET-UP PROCEDURES

The following handling procedures will be used when moving the test article to and from the test fixture or the TVAC test chamber.

CAUTION – ESD PRECAUTION - CAUTION

Ensure that certified ground strap is connected to the test article at all times.

Wrist-strap must be connected to certified ground during all handling operations involving the test article

6.3.1 Installation of the CAL Tower Module into the Test Fixture

1. Attach certified grounding strap to the CAL Tower Module.
2. Attach personal wrist strap to the CAL Tower Module
3. Remove the CAL Tower Module from the Shipping Container per LAT-PS-04237 and suspend it above the Container
4. Move the Shipping Container away from the suspended CAL Tower Module
5. Move a Work Table underneath the suspended CAL Tower Module
6. Lower the CAL Tower Module onto the table
7. Remove the protective covers from the tabs of the CAL Module base plate and wipe tabs with isopropyl alcohol.

   NOTE: Once the protective covers are removed from the tabs of the base plate, care must be take to prevent damage to the mating surfaces of the tabs
8. Wipe down CAL Module and TEM/TPS with isopropyl alcohol.
9. Attach Thermocouples to CAL Module in accordance to their location described in Section 5.2.1
10. Wipe down the TVAC Base Plates (LAT-DS-03805) with isopropyl alcohol.
11. Attach the TVAC Base Plates to the tabs of the CAL Module base plate using 6-32 and 8-32 socket-head cap screws. Tighten fasteners to specified torque values:
    - 6-32 Socket-Head Cap Screw 15-17 in-lb
    - 8-32 Socket-Head Cap Screw 28-31 in-lb
12. Lift the CAL Tower Module Assembly from the work table and suspend it high enough to remove the CAL Handling Fixture
13. Remove the four 5/16-18 socket-head cap screws which secure the Handling Fixture Base Plate (LAT-DS-01524) to the Handling Fixture Posts (LAT-DS-05952)
14. Remove the Handling Fixture Posts from the shear pins of the CAL Module base plate.

15. Install a TVAC Handling Fixture Post (LAT-DS-03810) to each shear pin and tighten to 28-31 in-lb
16. Re-install the Handling Fixture Base Plate onto the TVAC Handling Fixture Posts using the 5/16-18 socket-head cap screws. Tighten fasteners to 28-31 in-lb.
17. Wipe down the CAL Cooling Tube Assemblies (LAT-DS-03845) and TPS Cooling Tube Assembly (LAT-DS-03846) with isopropyl alcohol.
18. Attach both CAL Cooling Tube Assemblies to the TVAC Base Plates using 8-32 socket-head cap screws. Be sure that the Co-Therm sheet is installed between the Cooling Tube Assembly and the TVAC Base Plates. Tighten fasteners to 28-31 in-lb.
19. Attach the TPS Cooling Tube Assembly onto the bottom of the TEM-TPS using 8-32 socket-head cap screws. Tighten fasteners to 28-31 in-lb.

This final assembly (CAL Tower Module with TVAC support and cooling tube assemblies) becomes the test article.

6.3.2 Installation of the Test Article into the Thermal-Vacuum Chamber

1. Verify that certified grounding strap is connected to the CAL Tower Module, and that a certified grounding strap is connected to the floor of the TVAC test chamber.
2. Attach personal wrist strap to the CAL Tower Module
3. Move the overhead crane to suspend the test article over the floor of the TVAC test chamber.
4. Place the Bottom Thermal Blanket onto the floor of the TVAC test chamber and position the four CAL Isolator Blocks (LAT-DS-03811) onto the center of the blanket to support the test article.
5. Lower the test article so that the Handling Fixtur Base Plate sits onto the CAL isolator blocks.
6. Remove MJ4 socket-head cap screws securing the CAL Lifting Fixture Hoist Plate (LAT-DS-02795) to the top frame of the CAL Module.
7. Using the overhead crane, lift the CAL Lifting Fixture Assembly (LAT-DS-04138) from the test article.
8. Place Thermal Blanket Frame (LAT-DS-03813) over the test article. Verify that the test article is in the center of the frame.
9. Attach the TVAC Test Fixture (CAL and TPS Cooling Tube Assemblies) thermocouple connectors to the thermocouple test harness
10. Attach the thermocouple test harness to the bulkhead connector
11. Attach Heater Connections of the CAL and TPS Cooling Tube Assemblies to the heater harness
12. Attach the heater harness to the bulkhead connector

13. Attach LN_2 Inlet and Outlet lines to the CAL and TPS Cooling Tube Assemblies, and the Contamination Plate.
14. Attach the LN2 lines to the bulkhead connectors
15. Attach the CAL Module Power and Telemetry test cables to the TEM and TEM Power Supply.
16. Attach CAL Module Power and Telemetry test cables to the bulkhead connectors
17. Attach Thermocouple External Cables from the PC/HP34970A Data Acquisition/Switch Unit to the outside bulkhead connectors
18. Attach Heater External Cables from the Power Supply rack to the outside bulkhead connectors
19. Attach CAL Module Power and Telemetry External Cables from the CAL Test Stand Data Acquisition Unit/GASU to the outside bulkhead connectors
20. Disconnect grounding strap from the CAL Tower Module and floor of the TVAC test chamber.
21. Test Thermocouple Connections
22. Test Heater Connections
23. Power up the CAL Tower Module
24. Verify function of CAL Tower Module.
    - Perform Limited Functional Test (LAT-MD-01370)
    - Begin Cosmic Muon Collection
25. Verify function of Test Set-up
    - Power up PC/HP 34970A Data Acquisition/Switch Unit
    - Initialize the CDACS Software
    - Turn on grid test fixture heaters
26. Attach personal wrist strap to the CAL Tower Module and complete close-out of the thermal blankets as required.
27. Perform final check of the TVAC test chamber for loose tools or supplies.
28. Close and secure the TVAC test chamber door
29. Complete CAL Module Tower performance check per LAT-MD-01370.
30. Initiate Vacuum Pump-Down and maintain at high vacuum (1e-5 torr or less)

6.3.3 Removal of the Test Article from the Thermal-Vacuum Chamber

1. Verify that the TVAC test chamber has reached ambient pressure and temperature
2. Open the TVAC test chamber door.
3. Remove the access blanket panel from the Thermal Blanket Frame
4. Attach certified grounding strap to the CAL Tower Module
5. Attach personal wrist strap to the CAL Tower Module
6. Disconnect Fixture Thermocouples to the TVAC Test Fixture (CAL and TPS Cooling Tube Assemblies).
7. Disconnect the thermocouples from the thermocouple test harness
8. Disconnect Heater Connections of the CAL and TPS Cooling Tube Assemblies from the heater harness
9. Disconnect LN_2 Inlet and Outlet lines from the CAL and TPS Cooling Tube Assemblies.
10. Disconnect the CAL Module Power and Telemetry test cables from the TEM and TEM Power Supply.
11. Remove the Thermal Blanket Frame from test article
12. Using the overhead crane, position the CAL Lifting Fixture Assembly (LAT-DS-04138) over the test article and lower into place.
13. Attach the Lifting Fixture Assembly to the top frame of the CAL Module per LAT-PS-04237. Tighten the MJ4 socket-head cap screws to 34-35 in-lb
14. Lift the CAL test article from the test fixture per LAT-PS-04237.

6.4 TEST TIMELINE

Test timelines for two different test cycles are given below. The first timeline represents the first cycle of the QM thermal cycle test activities. The second timeline represents the first cycle of the FM thermal cycle test activities. Bake-Out can take place during the first cycle when the structure temperature exceeds 40 deg C. Deviations from these timelines shall be permitted at the discretion of the Test Director. The time, activity, and purpose of each deviation shall be noted in the Test Log.

6.4.1 Typical Thermal-Vacuum Test Cycle for QM (-30 deg C to +50 deg C)

Day	Elapsed Time	Activity
Day 0	00:00 hr	Begin the Heating Cycle for Qualification Temperature Hot Soak. Gradually apply full power (using the constant voltage setting on the power supplies) to start the temperature of the CAL Cold Plates and TPS Cold Plate moving in the positive direction. Adjust the heater power and LN_2 flow of the TPS Cold Plate to gradually increase its temperature Adjust the heater power and LN_2 flow CAL Cold Plates, as required, to maintain temperature ramp of the CAL Cold Plates at +30 °C/hour.
	00:00 hr	Perform the Limited Performance Test (LAT-MD-01370) during the ramp
	00:00 hr	Perform the Cosmic Muon Collection after the completion of the Limited Performance Test
	03:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of +60 °C ▪ TPS Cold Plate at a stable temperature of +30 °C
	06:00 hr	Perform Hot Survival Turn-On Sequence when AFEE Temperature reaches +50°C
	14:00 hr – 15:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of +50 °C ▪ TPS Cold Plate at a stable temperature of +30 °C
	18:00 hr	Monitor AFEE Thermistors and thermocouples on the top of the CAL Module. Adjust LN_2 flow and the heater power to the CAL Cold Plates, as required, to maintain the CAL Module temperature at +50°C $\pm$ 3°C for the Qualification Temperature Hot Soak.
	19:00 hr	Perform the Comprehensive Performance Test (LAT-MD-01370) when AFEE reach +50°C $\pm$ 3°C
	21:00 hr	Perform the Cosmic Muon Collection after the completion of the Comprehensive Performance Test

Day	Elapsed Time	Activity
	22:00 hr	Begin the Cooling Cycle for Qualification Temperature Cold Soak. Reduce power (using the constant voltage setting on the power supplies) to start the temperature of the CAL Cold Plates and TPS Cold Plate moving in the negative direction. Adjust the heater power and LN_2 flow of the TPS Cold Plate to gradually increase its temperature Adjust the heater power and LN_2 flow CAL Cold Plates, as required, to maintain temperature ramp of the CAL Cold Plates at -30 °C/hour.
	22:00 hr	Perform the LPT (LAT-MD-01370)
	22:15 hr	Perform the Cosmic Muon Collection after the completion of the LPT
Day 1	25:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of –40 °C ▪ TPS Cold Plate at a stable temperature of +15 °C
	35:00 hr	Perform Cold Survival Turn-On Sequence when AFEE Temperature reaches –30°C
	37:00 hr – 38:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of –33 °C ▪ TPS Cold Plate at a stable temperature of +15 °C
	40:00 hr	Monitor AFEE Thermistors and thermocouples on the top of the CAL Module. Adjust LN_2 flow and the heater power to the CAL Cold Plates, as required, to maintain the CAL Module temperature at –30°C ± 2°C for the Qualification Temperature Cold Soak.
	41:00 hr	Perform the CPT (LAT-MD-01370) when CDEs reach –30°C ± 2°C
	43:00 hr	Perform the Cosmic Muon Collection after the completion of the CPT
	44:00 hr	Completion of Full Cycle

6.4.2 Typical Thermal-Vacuum Test Cycle for FM (-20 deg C to +35 deg C)

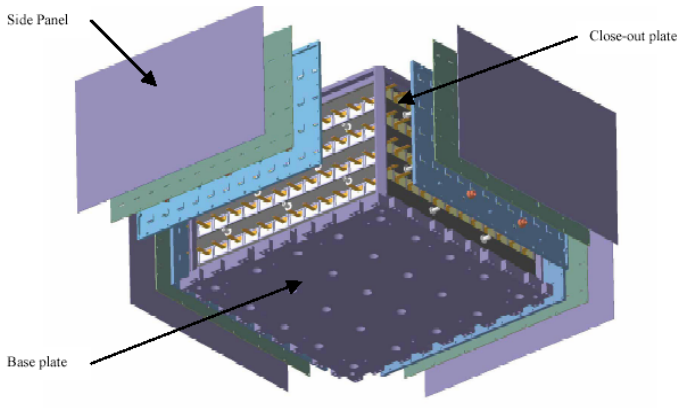
Day	Elapsed Time	Activity
Day 0	00:00 hr	Begin the Heating Cycle for Qualification Temperature Hot Soak. Gradually apply full power (using the constant voltage setting on the power supplies) to start the temperature of the CAL Cold Plates and TPS Cold Plate moving in the positive direction. Adjust the heater power and LN_2 flow of the TPS Cold Plate to gradually increase its temperature Adjust the heater power and LN_2 flow CAL Cold Plates, as required, to maintain temperature ramp of the CAL Cold Plates at +30 °C/hour.
	00:00 hr	Perform the LPT (LAT-MD-01370) during the ramp
	00:15 hr	Perform the Cosmic Muon Collection after the completion of the LPT
	02:30 hr	Perform Hot Survival Turn-On Sequence when AFEE Temperature reaches +35°C
	03:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of +60 °C ▪ TPS Cold Plate at a stable temperature of +30 °C
	08:00 hr – 09:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of +35 °C ▪ TPS Cold Plate at a stable temperature of +30 °C
	12:00 hr	Monitor AFEE Thermistors and thermocouples on the top of the CAL Module. Adjust LN_2 flow and the heater power to the CAL Cold Plates, as required, to maintain the CAL Module temperature at +35°C $\pm$ 3°C for the Qualification Temperature Hot Soak.
	12:00 hr	Perform the CPT (LAT-MD-01370) when CDEs reach +35°C $\pm$ 3°C
	12:00 hr	Perform the Cosmic Muon Collection after the completion of the CPT

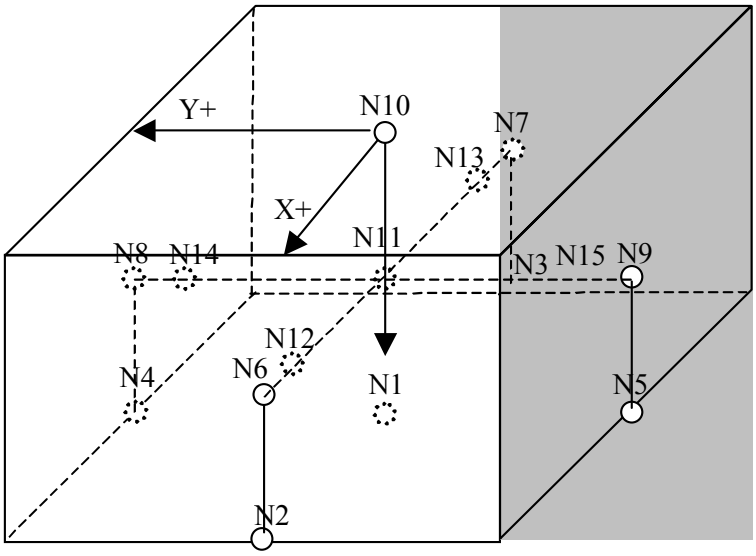
Day	Elapsed Time	Activity
	16:00 hr	Begin the Cooling Cycle for Qualification Temperature Cold Soak. Reduce power (using the constant voltage setting on the power supplies) to start the temperature of the CAL Cold Plates and TPS Cold Plate moving in the negative direction. Adjust the heater power and LN_2 flow of the TPS Cold Plate to gradually increase its temperature Adjust the heater power and LN_2 flow CAL Cold Plates, as required, to maintain temperature ramp of the CAL Cold Plates at -30 °C/hour.
	16:00 hr	Perform the LPT (LAT-MD-01370)
	16:15 hr	Perform the Cosmic Muon Collection after the completion of the LPT
	19:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of - 40 °C ▪ TPS Cold Plate at a stable temperature of +15 °C
	20:00 hr	Perform Cold Survival Turn-On Sequence when AFEE Temperature reaches -20°C
Day 1	25:00 hr – 26:00 hr	Adjust LN_2 and heater power, as required, to maintain: ▪ CAL Cold Plate at a stable temperature of -23 °C ▪ TPS Cold Plate at a stable temperature of +15 °C
	31:00 hr	Monitor AFEE Thermistors and thermocouples on the top of the CAL Module. Adjust LN_2 flow and the heater power to the CAL Cold Plates, as required, to maintain the CAL Module temperature at -20°C $\pm$ 2°C for the Qualification Temperature Cold Soak.
	32:00 hr	Perform the CPT (LAT-MD-01370) when CDEs reach -20°C $\pm$ 2°C
	34:00 hr	Perform the Cosmic Muon Collection after the completion of the CPT
	35:00 hr	Completion of Full Cycle

APPENDIX A

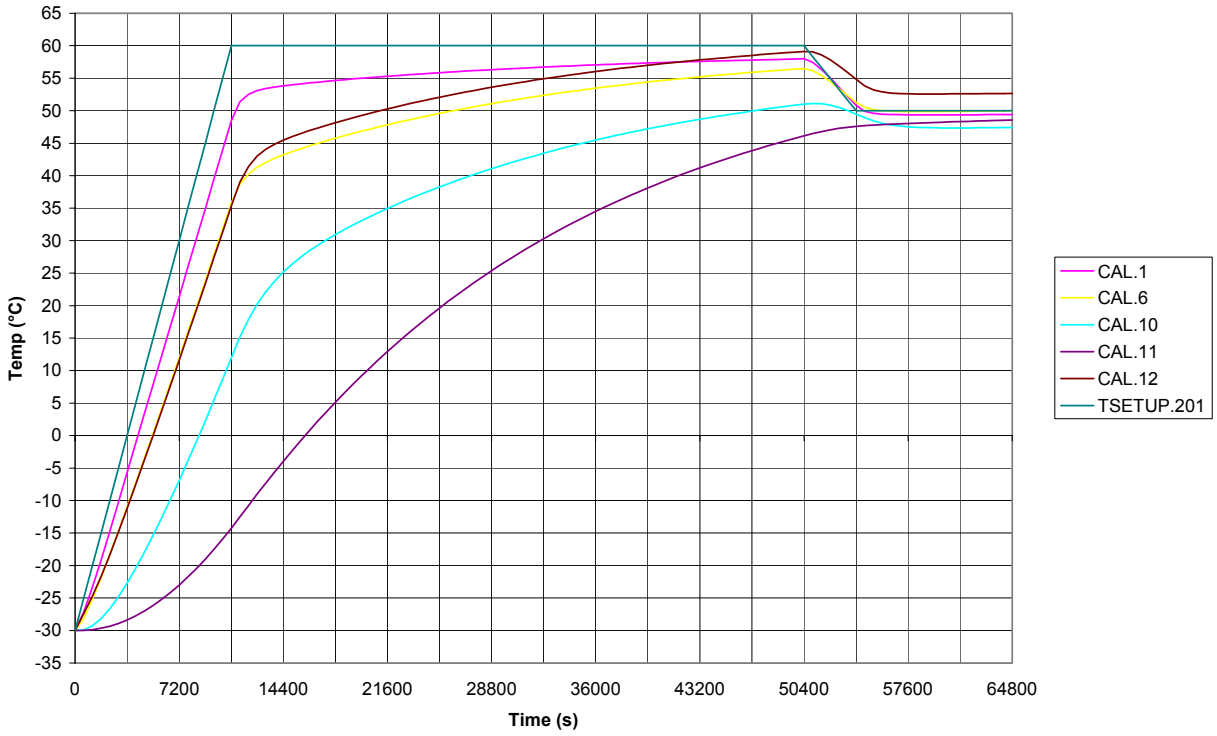
CAL Module Simplified Thermal Model Node List

Nodes	Description
1	Base Plate
2	Base Plate Tabs (+X)
3	Base Plate Tabs (-X)
4	Base Plate Tabs (-Y)
5	Base Plate Tabs (+Y)
6	Side Plate (+X)
7	Side Plate (-X)
8	Side Plate (-Y)
9	Side Plate (+Y)
10	Top Plate
11	CDE
12	AFEE Board (+X)
13	AFEE Board (-X)
14	AFEE Board (-Y)
15	AFEE Board (+Y)

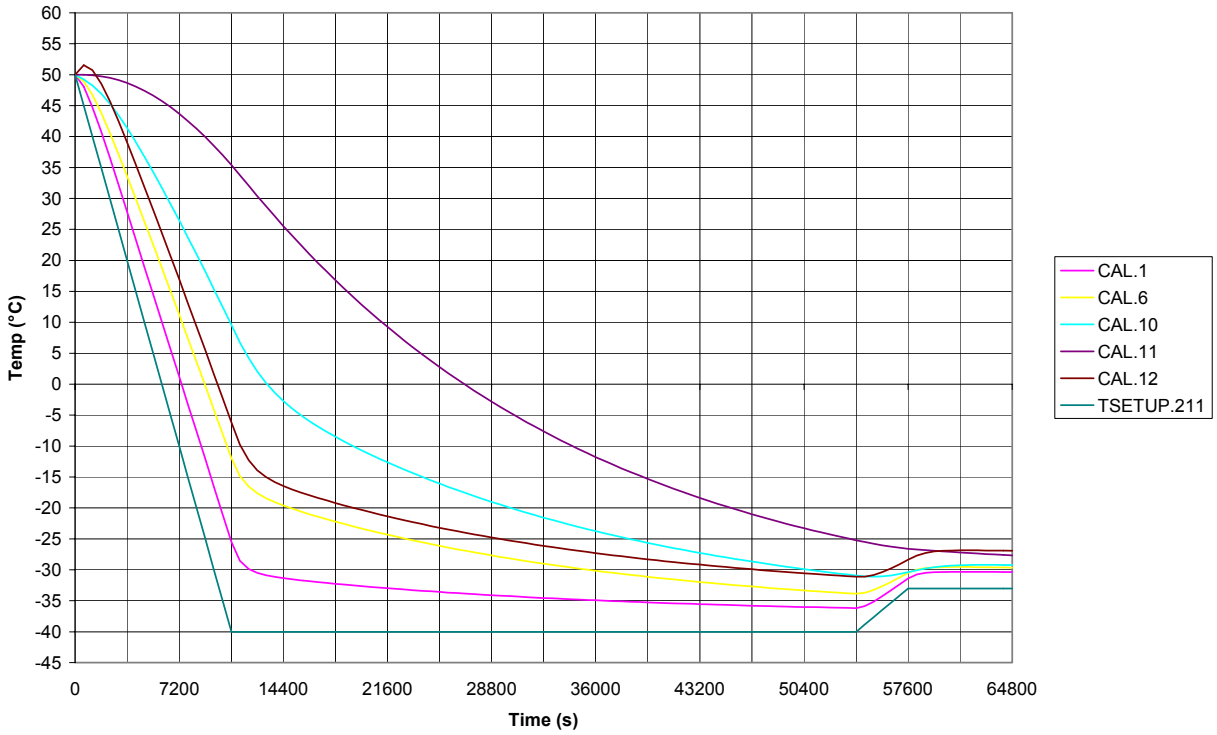




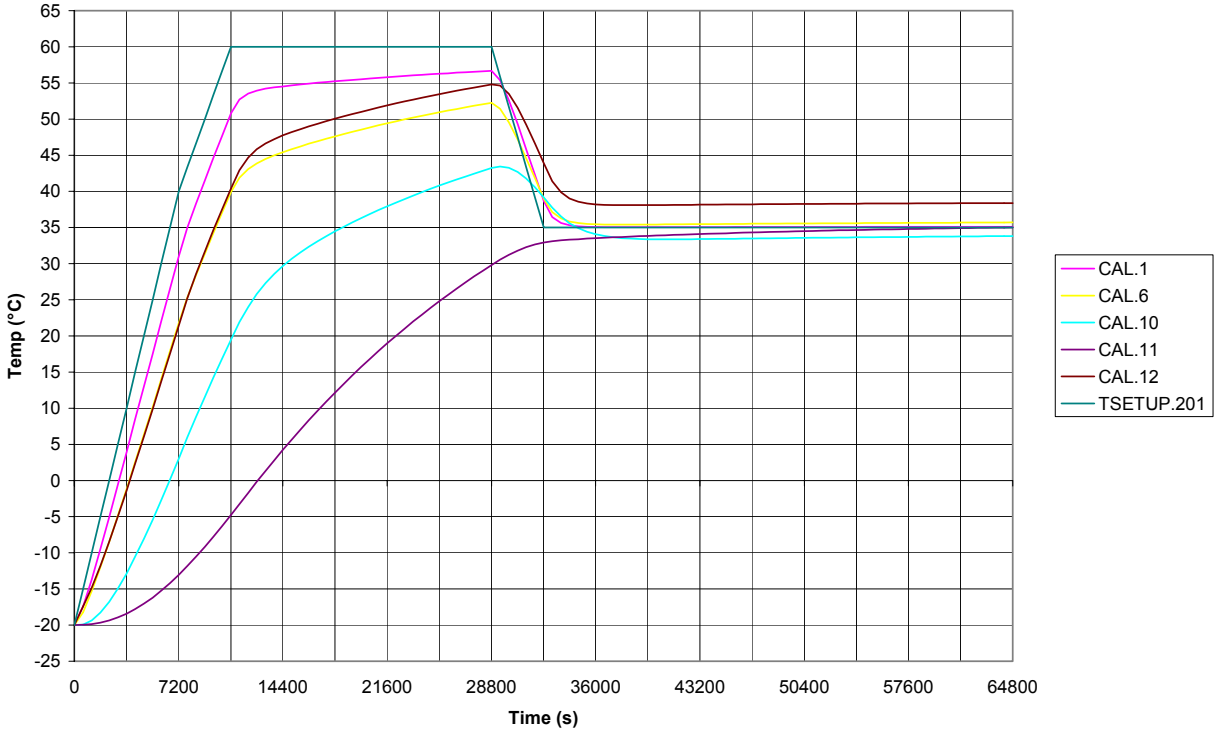
Hot Transition - Qualification Test Range



Cold Transition - Qualification Test Range



Hot Transition - Acceptance Test Range



Cold Transition - Acceptance Test Range