IMPACT STE-U THERMAL BALANCE

AND

THERMAL VACUUM QUALIFICATION

TEST PLAN

Document #

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1. TEST PURPOSE

a) Thermal Balance: To verify the thermal design of the STE-U and STE Pre-amp.
- Determine the adequacy of the STE-U and Sunshade thermal coatings.
- Establish the adequacy of the STE-U thermal isolator and thermal design.
- Use thermal balance data to verify and if necessary to modify the STE-U thermal math model in order to accurately predict flight thermal performance.

b) Thermal Vacuum Cycling: To qualify operational performance of the STE instrument and Pre-amp over the predicted mission temperature extremes.
- Verify that exposures to predicted non-operating temperature extremes plus 10ºC margin do not result in performance degradation (one-cycle).
- Verify acceptable performance over the predicted operating temperature extremes plus a minimum of 10ºC margin (six cycles).

2. APPROACH

a) Bake-out - Bake-out the test article and chamber fixtures under vacuum at +40ºC. until contamination monitoring instrumentation indicates an acceptable out-gassing level has been attained (QCM rate < TBD) or 48 hours whichever comes first.

b) Thermal Balance - Establish thermal balance of the STE-U and STE Pre-amp in test environments similar to the expected flight environments using the resulting data to verify and modify the thermal math model as required. Chamber conditions set to attain thermal equilibrium in at least one hot and one cold environmental condition:
- The hot case to be based on EOL surface properties with maximum solar heating for the AHEAD spacecraft after reaching heliocentric orbit.
- The cold case to be based on BOL surface properties with minimum solar heating for the BEHIND spacecraft after reaching heliocentric orbit.

c) Thermal Vacuum Cycling - Reconfigure the chamber setup after TB testing to provide additional cooling for the STE-U in order for the instrument to reach the cold qualification temperature level:
- The test to include one unpowered survival cycle and six operational cycles that are 10ºC (minimum) beyond extremes.
- Each operational cycle to include an instrument comprehensive performance test (CPT) at the plateaus.
- Turn on capability to be demonstrated at the plateaus of the first and last cycle.
- Out-gassing certification to be conducted at conclusion of last cycle.

3. TEST ARTICLE DESCRIPTION

a) The Protoflight STE-U, Sunshade, and Pre-amp are used in this test with thermal coatings as currently specified for the flight design (Figure 1). A flight-like blanket covers the top of the STE-U Sunshade per the specified flight thermal design.

b) The Pre-amp is mounted on a test adapter plate (Figure 2) that has the identical surface finish as the equivalent part of the Boom housing. The adapter is bolted to the chamber baseplate, which is temperature controlled via heaters and a cooling loop. The Pre-amp is mounted to the adapter using flight standoffs to provide proper heat flow across the interface.

c) The Pre-amp is insulated with a flight-like MLI test blanket that simulates the flight blanket in the Boom Housing area with an estimated effective emittance of less than 0.01. The external surface emittance of the test blanket has a surface emittance property nearly identical to the flight blanket.

d) The STE-U is mounted to the Pre-amp (Figure 1) using the flight isolator specified for the STE-U thermal design. The STE-U sunshade is also isolated from the Pre-amp via an isolator at its interface and under the attachment screw heads.

e) A heat strap attached between the STE-U and the lower chamber cold-plate will be added to the test configuration for the thermal vacuum cycling test.

4. THERMAL INSTRUMENTATION

The STE-U, Sunshade, and Pre-amp are instrumented with thermocouples to provide required temperature data to enable test control and post-test correlation with math model results. Locations of thermal sensors are designated in Table 1. Thermocouples are secured to the surfaces to be measured with Aluminum tape.

5. CHAMBER AND TEST ARTICLE TEMPERATURE CONTROL

a) For thermal balance testing, the facility shrouds are controlled with LN^2 to provide as cold a space sink simulation as possible (< -110ºC). The math model used for the correlation analysis will include shroud geometry and measured temperatures.
b) Solar input to the top of the Pre-amp blanket and to the STE-U Sunshade are not required to be simulated in this test because they are not a major contributor to the thermal balance of the STE-U or the Pre-amp.
c) The chamber baseplate is equipped with a cooling loop and heaters providing control capability from –40ºC to +50ºC. The Baseplate controls the adapter temperature that is intended to simulate the Boom housing interface.
d) The heat strap incorporated after TB for TV cycling is coupled to the lower chamber cold-plate to enable cold qualification temperatures to be reached. The Cold-plate is temperature controlled via an LN^2 loop and heaters providing precise control capability from <–110ºC to -30ºC.
e) Heaters are mounted on the shrouds for chamber warm-up. Designation of cooling loops and heater locations are provided in the chamber operating procedure.

6. SUMMARY OF TEST CONFIGURATION

a) The Pre-amp and STE-U are installed in the chamber as described in Sections 3 through 5.
b) The MLI test blanket encloses the Pre-amp and adapter plate so that they do not directly view the chamber shroud.
c) The cutout in the Pre-amp blanket for the STE-U attachment is closed out around the STE-U isolator as specified for the flight design.
d) Flight thermal isolators are installed in the mounting interfaces of STE-U and STE-U Sunshield. Screws used for fastening the STE-U and Sunshield are isolated using isolation washers under the screw heads as specified for the flight thermal design. All screws in the assembly are torqued per mechanical specifications.
e) For TV cycling, a heat strap coupled to the lower chamber Cold-plate is attached to the STE-U at the specified location (TBD).

7. TEST PREPS; SETUP AND CHECKOUT SEQUENCE

a) Install temperature sensors in locations specified in Table 1 during the setup procedure using approximately one square inch of Aluminum tape.
b) Mount the adapter plate on the chamber baseplate. These items need to be conductively coupled for effective thermal control of the adapter.
c) Mount Pre-amp on the adapter using flight standoffs. Torque screws per the mechanical ICD to ensure proper heat flow across the interface. Connect electrical cabling from the Pre-amp to chamber feed-through connector and verify.
d) The STE-U and Sunshade will be installed on the Pre-amp mounting block prior to setup in the chamber. Flight thermal isolators and screw head isolation washers will be included and screws torqued as specified in the mechanical ICD.
e) The STE-U and Pre-amp will also be hard-wired together and electrically tested prior to delivery to the test facility.
f) Install Pre-amp thermal blanket and tape along its edge to the back of the baseplate.
g) Fit the Sunshade with its flight sun-side MLI blanket if not already installed.
h) Wrap any exposed electrical cables and thermocouple harness with MLI.
i) Position TQCM for measurement of chamber contamination and checkout operation.
j) Remove red-tag purge hardware.
k) Verify thermocouple and test heaters are operating properly.
l) Conduct ambient instrument checkout.
m) Conduct engineering and program management inspection of test setup.
n) Close chamber and prepare for pumpdown.

8. TEST PROCEDURE

Bake-out and Thermal Balance Test

Test Conditions and Criteria:

- The bake-out will be conducted with instrument power OFF.
- TB tests will be conducted with the instrument powered in the operational mode.
- Thermal balance test conditions are specified in Table 2.
- Equilibrium criteria for thermal balance of the STE-U and Pre-amp shall be defined as a temperature change of less than 0.5°C over a 3-hour period.
- STE rate of temperature change during transitions is limited to TBDºC per minute.
- During cold to hot transitions, the STE door will be closed and the average shroud temperature kept 10ºC cooler than the instrument.

Test Sequence:

a) Pumpdown chamber per chamber operating procedure.
b) Conduct a bake-out of the test configuration by raising the shrouds and baseplate to +40ºC. The bake-out will begin when the average STE-U and Pre-amp temperatures reach bake-out temperature level.
c) After 24 hours, lower the TQCM control to –20°C and begin recording data.
d) Continue bake-out until out-gassing criteria is reached or for 48 hours whichever occurs first.
e) When the bake-out is completed, start LN^2 to chamber shrouds and establish chamber at hard vacuum conditions with shrouds and Cold-plate <–110°C.
f) Enable Baseplate temperature control and stabilize the adapter at –17°C ± 1°C.
g) Allow chamber temperatures, the STE-U, and the Pre-amp to cool to predicted cold case temperature levels as specified in Table 2 for TB Case 1.
h) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
i) When equilibrium for TB Case 1 is attained, record all temperature and heater data.
j) Raise Baseplate temperature control and stabilize the adapter at +33°C ± 1°C as specified in Table 2 for TB Case 2.
k) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
l) When equilibrium for TB Case 2 is attained, record all temperature and heater data.
m) The UCB program manager, UCB test engineer, and OSC thermal control engineer will review all thermal balance test data to verify that no additional test cases are required to verify the STE-U thermal design.
n) Return test articles and chamber temperatures to ambient conditions keeping chamber shroud temperatures at least 10°C colder than the STE-U to preclude condensing contaminates on sensitive instrument surfaces.
o) When safe temperature levels are attained, re-pressurize chamber according to the chamber operating procedure.

Thermal Vacuum Cycling Test

Test Conditions and Criteria:

- Reconfigure the test setup by incorporating a heat strap that conductively couples the STE-U to the lower chamber Cold-plate.
- Thermal vacuum cycling test conditions are specified in Table 3 and the test profile is shown in Figure 3.
- The start of each soak is determined when the instrument control temperature reaches within 3°C of the specified qualification level (Figures 4).
- Turn-on and/or the CPT will be conducted after reaching each soak level. The soak duration is at least one hour plus completion of the CPT (Figure 5).
- STE rate of temperature change during transitions is limited to TBDºC per minute.
- During cold to hot transitions, the STE door will be closed and the average shroud temperature kept 10ºC cooler than the instrument.

Survival Cycle:

a) Pumpdown chamber per chamber operating procedure but do not start LN^2 to chamber shrouds until after the first hot soak is completed.
b) Set thermal control of shrouds and Cold-plate at +40°C or as required to achieve non-operational STE-U and Pre-amp temperatures of +40°C ± 3°C.
c) Adjust Baseplate and Cold-plate temperatures to control Pre-amp and STE-U at hot case level of +40°C ± 3°C.
d) After a minimum one-hour soak, begin transition to cold soak level flooding chamber shrouds and lower Cold-plate with LN^2 while maintaining the Baseplate temperature above Cold TV case minimum level per Table 3.
e) Set thermal control of the Cold-plate at –110°C and verify that the instrument temperature is also controlled near this level via the heat strap connection.
f) Adjust Cold-plate control to achieve STE-U temperature level of –110°C ± 3°C.
g) Set Baseplate temperature at –32°C and adjust to control Pre-amp temperature at cold soak level of –35°C ± 3 °C.
h) After minimum one-hour soak at the non-op level, begin transition to the hot soak level for start of operational cycles.

Operational Cycles:

a) Transition to hot soak level by increasing temperatures as specified in Table 3.
b) Set thermal control of the Cold-plate at –35°C and verify that the STE-U temperature is also controlled near this level via the heat strap connection.
c) Adjust Cold-plate control to achieve STE-U operational temperature of –35°C ± 2 °C.
d) Set Baseplate temperature at +43°C and adjust to control Pre-amp temperature at hot case level of +40°C ± 2°C.
e) When hot case levels are achieved, turn-off the instrument for one-hour to achieve quasi-thermal stabilization. Conduct a hot start turn-on and CPT.
f) After one-hour or completion of functional testing, begin transition to cold soak by reducing temperatures as specified in Table 3.

g) Set thermal control of the Cold-plate at –105°C and verify that the STE-U temperature is also controlled near this level via the heat strap connection.
h) Adjust the Cold-plate control to achieve STE-U temperature of –105°C ± 2 °C.
i) Set Baseplate temperature at –27°C and adjust to control Pre-amp temperature at cold case level of –30°C ± 2 °C.
j) When cold case levels are achieved, turn-off the instrument for one-hour to allow quasi-thermal stabilization. Conduct a cold start turn-on and CPT.

Repeat Operational Cycles and Securing Procedure:
a) Conduct five additional operational cycles. (Turn-on demonstrations are required only during the last cycle).
b) After completing the last cold soak, increase temperatures to ambient maintaining chamber shrouds at least 10°C colder than the STE-U to preclude condensing contaminates on sensitive instrument surfaces.
c) When the test article and shrouds reach near ambient temperature levels, conduct an 8-hour out-gassing soak.
d) With the TQCM set at –20°C, record out-gassing rates in order to certify STE-U contamination requirements have been met.
e) After program management approval, re-pressurize chamber according to the chamber operating procedure.

9. POST-TEST ANALYSIS AND REPORT

A post-test thermal analysis of the STE-U and Pre-amp shall be performed using test data to specify the measured heat flow across interfaces and correct thermal couplings as required. Model predictions for the test conditions run should match recorded data within 5 °C. After establishing that the math model predicts temperatures and heat flow accurately, re-run flight predictions for worst-case environments.

Write and publish a test report. Include the modified thermal model predictions and any established thermal changes required as a result of the thermal balance test.

TABLES AND FIGURES

TABLE 1: Description of Temperature Sensors (Thermocouples and Flight PRTs)

Sensor #	Location / Description	TB Cold Case Temp (°C)	TB Hot Case Temp (°C)
TC1	Upper Shroud Control		
TC2	Lower Shroud Control		
TC3	Baseplate Control		
TC4	Cold Plate Control		
TC5	Cold Plate @ Heat Strap I/F		
TC6	Baseplate Opposite Adapter		
TC7	Adapter Center		
TC8	Pre-amp Center opposite Adapter		
TC9	Pre-amp @ STE-U Interface		
TC10	STE-U Sunshade (Center)		
TC11	Sunshade Bracket I/F (?) TBD *		
TC12	STE–U @ Isolator I/F (?) TBD *		
TC13	Spare / Lower Shroud		
TC14	Upper Shroud Track		
TC15	Upper Shroud Track		
TC16	Room		
	STE-U Flight PRT		
	Pre-amp Flight PRT		

* These thermocouples will not be used if they cannot be located as designated without affecting surface finish integrity and/or thermal balance characteristics.

TABLE 2: Description of TB Test Conditions

Item/Description	Bake-out (°C)	Cold Case 1 (°C)	Hot Case 2 (°C)	Temp Control
Shrouds	20 to 50	<–110	<–110	LN² & Test Heaters
Cold Plate (CP)	20 to 50	<–110	<–110	LN² & Test Heaters
Chamber Baseplate	40 ± 3°C	–17	+33	LN² & Test Heaters
Test Adapter	40 ± 3°C	–17	+33	Via conduction from baseplate
Pre-amp *	40 ± 3°C	–20 (Flight Temp)	+30 (Flight Temp)	Via conduction from adapter
STE-U *	40 ± 3°C	–95 to –80 (Fight Temp)	–70 to –55 (Flight Temp)	Radiation coupling to shrouds

* Test temperature goals are based on worst case flight predicts plus margin for modifying the thermal design to increase Pre-amp and STE-U temperatures by up to 20 C if performance indicates an improvement would result.

TABLE 3: Description of TV Test Conditions

Item/Description	Non-Op Soaks (°C)	Cold Soak (°C)	Hot Soak (°C)	Temp Control
Shrouds	+40 / <–110	<–110	<–110	LN² & Test Heaters
Cold Plate (CP) *	+40 /<–110	<–105	–35	LN² & Test Heaters
Chamber Baseplate **	+43 / -32	–27	+43	LN² & Test Heaters
Test Adapter	+43 / -32	–27	+43	Via conduction from baseplate
Pre-amp	+40 / -35	– 30 (Qual level)	+40 (Qual level)	Via conduction from adapter
STE-U	+40 / –110	–105 (Qual level)	–35 (Qual level)	Radiation to shroud & heat strap to CP

* CP temperature will need to be adjusted to attain STE-U qualification level.
**Baseplate temperature will need to be adjusted to attain Pre-amp qualification level.

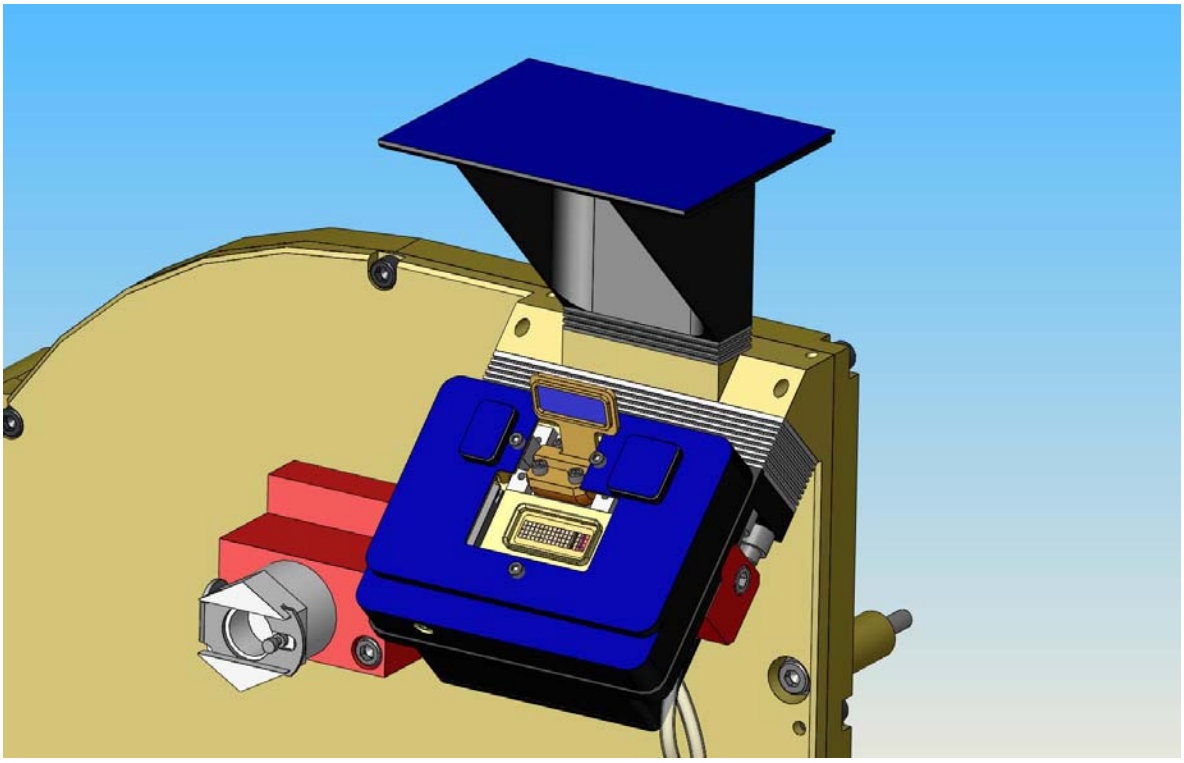


FIGURE 1: STE-U Thermal Coatings and Mounting Configuration

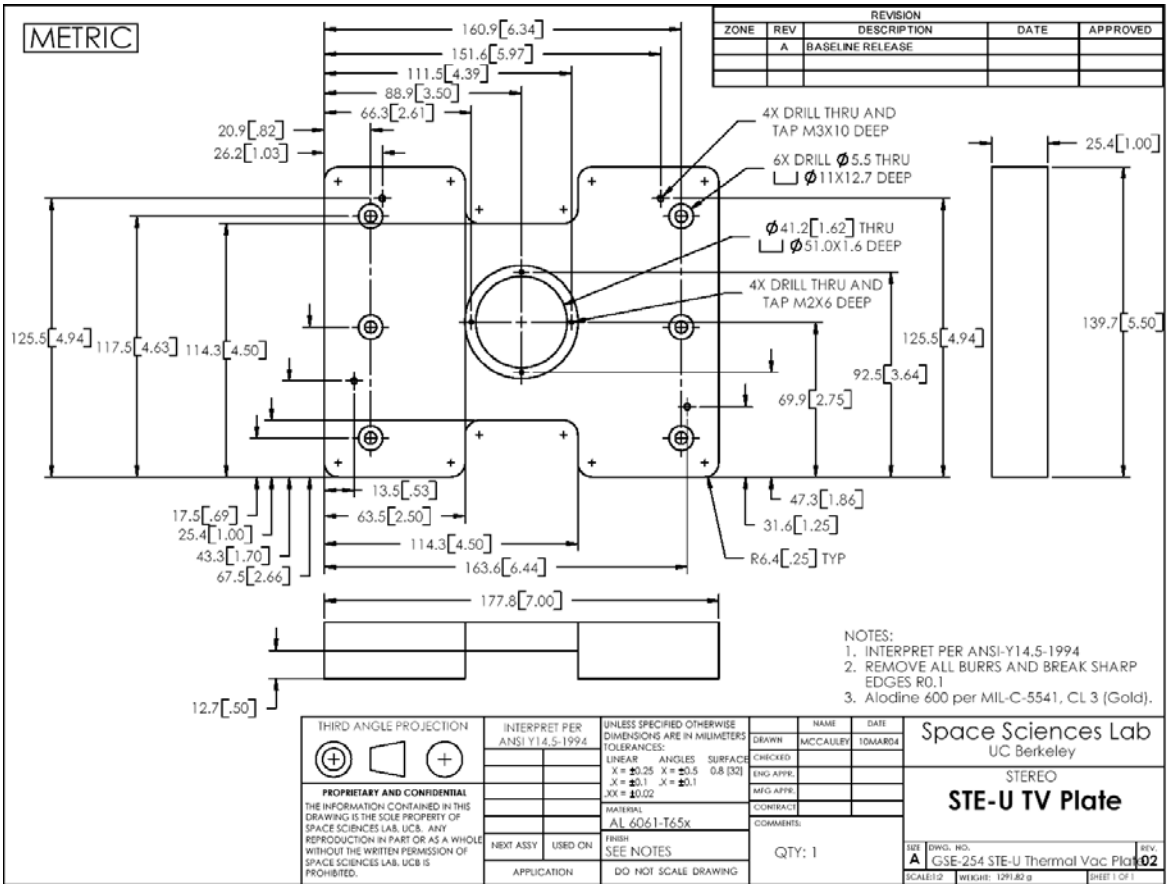


FIGURE 2: Pre-amp Test Adapter Configuration

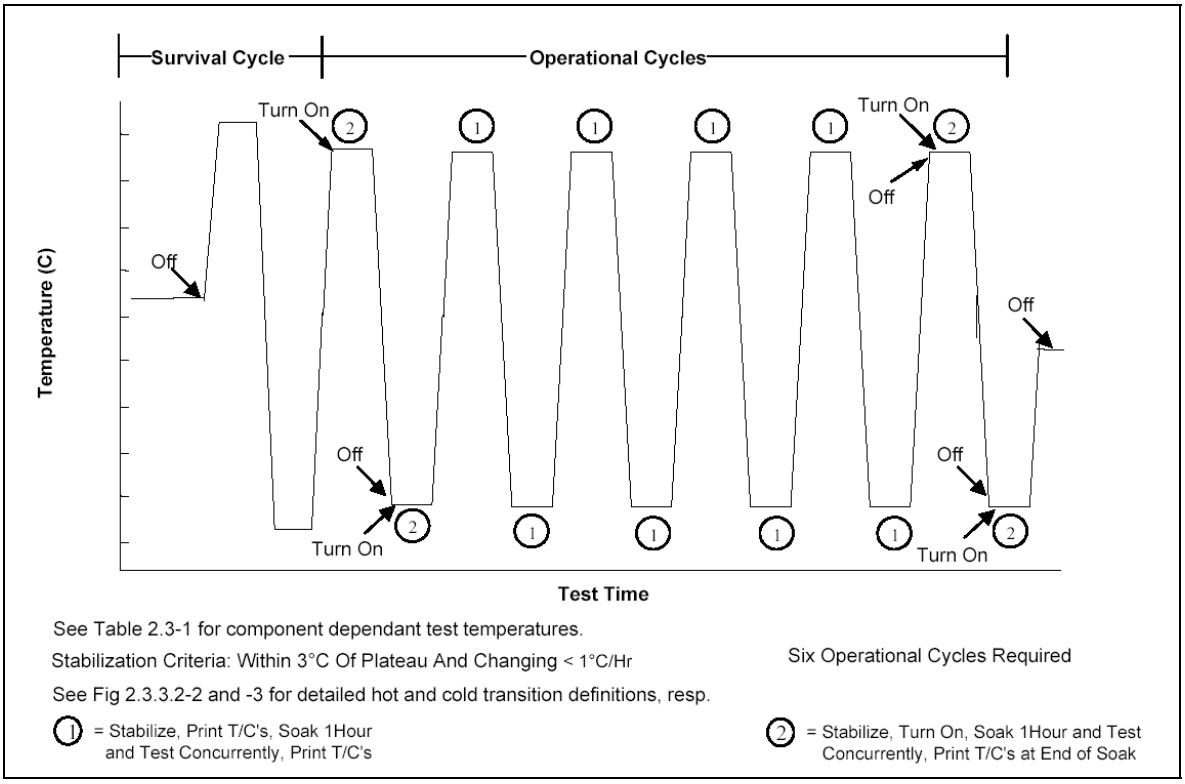
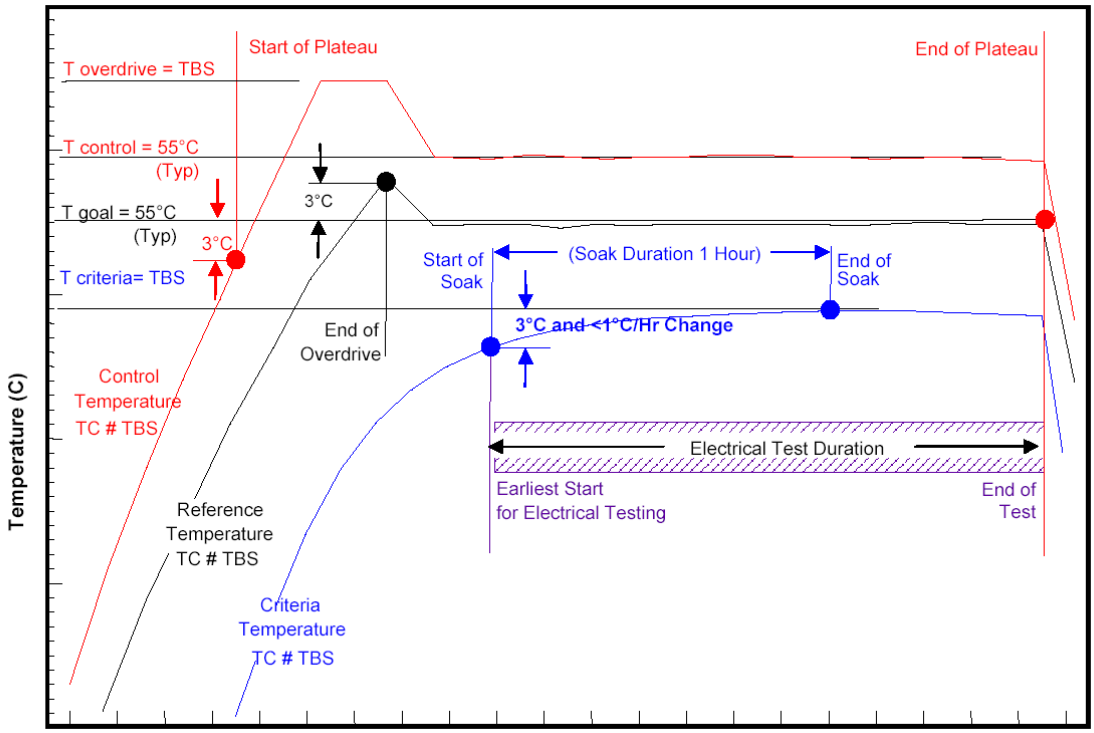


FIGURE 3: STE-U and Pre-amp TV Qualification Cycling Profile (see Table 3 for temperature limits)

Transition to Hot Soak



Transition to Cold Soak

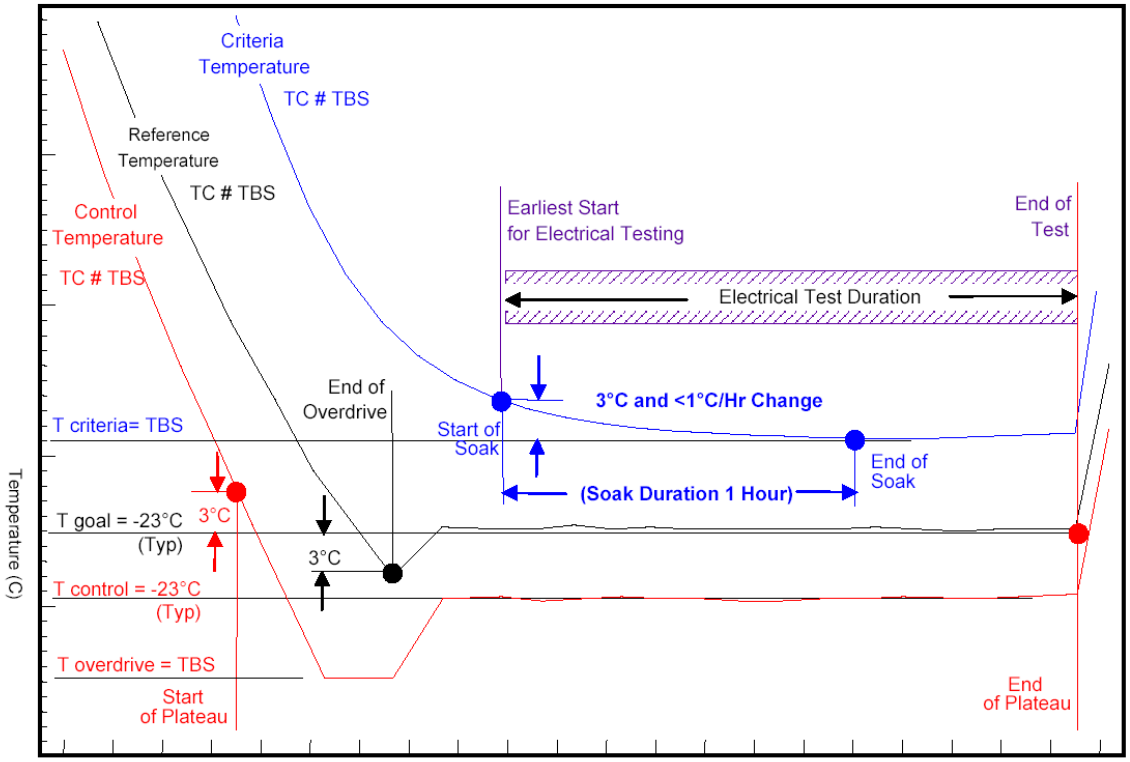


FIGURE 4: TV Soak and Performance Test Criteria

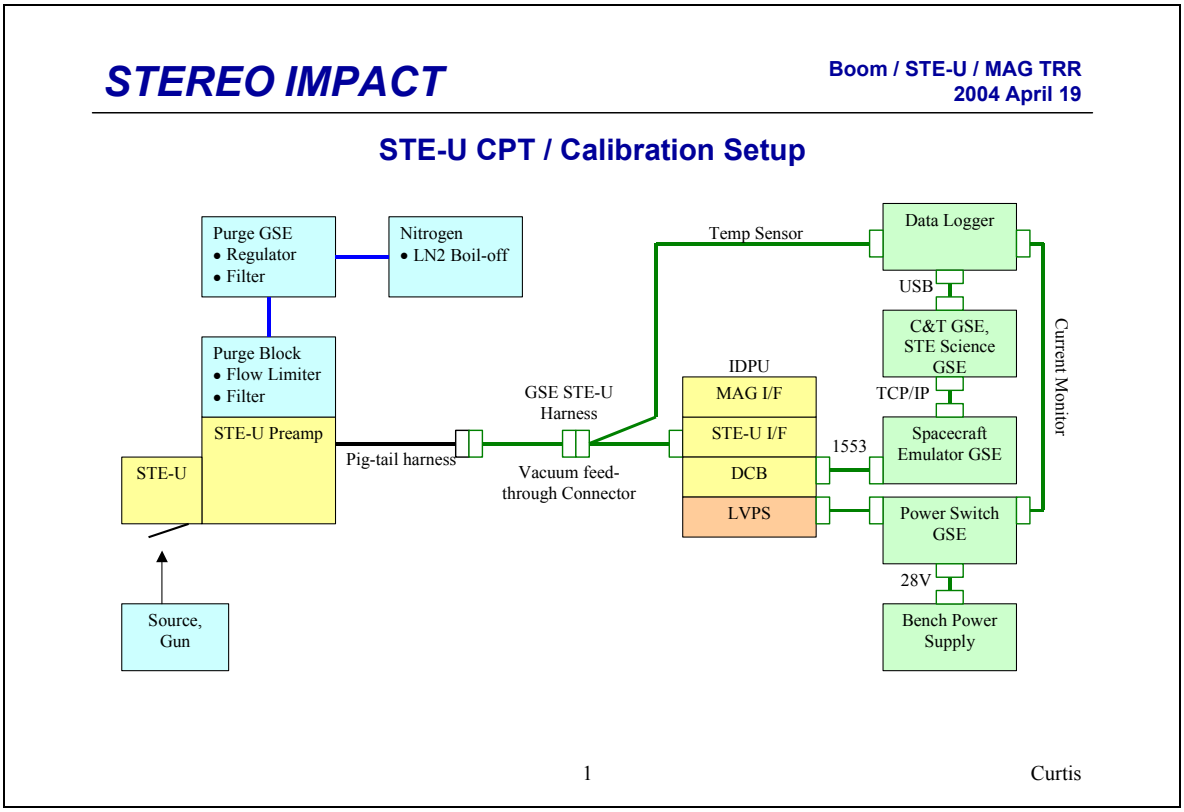


FIGURE 5: STE-U Comprehensive Performance Test (CPT)