IMPACT SWEA and STE-D THERMAL BALANCE

AND

THERMAL VACUUM QUALIFICATION

TEST PLAN

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TABLES AND FIGURES

1. TEST PURPOSE

a) Thermal Balance: To verify the thermal design of the SWEA and STE-D.
- Verify the SWEA/Boom thermal interface and determine the adequacy of the MLI blanket and survival heater power.
- Establish the adequacy of the STE-D thermal isolator and thermal design.
- Use thermal balance data to verify and if necessary to modify the SWEA and STE-D thermal math models in order to accurately predict flight thermal performance.

b) Thermal Vacuum Cycling: To qualify operational performance of the SWEA and STE-D instruments 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 SWEA and STE-D 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 cold and one hot condition:
- The survival case to be based on the BOL coldest environmental conditions.
- The operational cold case to be based on BOL surface properties with minimum solar heating for the BEHIND spacecraft after reaching heliocentric orbit.
- The operational hot case to be based on EOL surface properties with maximum solar heating for the AHEAD spacecraft after reaching heliocentric orbit and include a delta test heater input to account for uncertainties in the thermal math model.

c) Thermal Vacuum Cycling - Reconfigure the chamber setup after TB testing to provide additional cooling for the STE-D 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 SWEA and Flight STE-D are used in this test with thermal coatings as currently specified for the flight design (Figure 1). A Protoflight SWEA blanket built by APL will be used for this test.

b) The SWEA will be mounted on a 50-mm boom section that is identical 50-mm flight boom (Figure 2). The boom is mounted so that its temperature will be determined by radiant coupling to the chamber shrouds similar to flight where its temperature will be determined by radiation to space.

c) The SWEA is insulated with a proto-flight MLI blanket that has an estimated effective emittance of less than 0.01. The external surface emittance of this blanket has a surface emittance property nearly identical to the flight blanket.

d) The STE-D is mounted to the SWEA (Figure 1) using the flight isolator specified for the STE-D thermal design.

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

4. THERMAL INSTRUMENTATION

The SWEA and STE-D 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 and pressed tightly to the surface by rubbing with a nylon stick (or equivalent) to press out all air pockets. Kapton tape is not recommended for this purpose.

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 is not required because the SWEA and STE-D are shadowed entirely by the upper boom during normal operations and therefore is not a major contributor to the thermal balance of the SWEA or STE-D.
c) The chamber baseplate is equipped with a cooling loop and heaters providing control capability from –40ºC to +50ºC. The Baseplate controls the upper end of the 50-mm boom at the mounting location.
d) A 5-watt test heater will be installed on the SWEA pedestal base for use during thermal balance and the thermal-vacuum cycling test.
e) 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.

f) 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 SWEA and STE-D are installed in the chamber as described in Sections 3 through 5.
b) The SWEA blanket encloses the instrument as in the flight configuration with direct view of the chamber shroud.
c) The flight thermal isolator is installed in the mounting interface of STE-D. Screws used for fastening the STE-D are isolated using isolation washers under the screw heads as specified for the flight thermal design.
d) The cutout in the SWEA blanket for the STE-D attachment is closed out around the STE-D isolator as specified for the flight design.
e) For TV cycling, a heat strap coupled to the lower chamber Cold-plate is attached to the STE-D 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) Run electrical cabling from the SWEA within the 50mm Gr/E tube as in the flight configuration.
c) Install the STE-D on the SWEA pedestal as in the flight configuration. Torque screws as specified in the mechanical ICD.
d) Hard-wire the STE-D and SWEA together and conduct electrical testing prior to delivery to the test facility.
e) Install the 5-watt test heater on the pedestal base.
f) Install the SWEA thermal blanket and verify no gaps are present.
g) Verify that the chamber mounting plate is insulated on the side where the boom will be mounted.
h) Mount the boom to the chamber baseplate as shown in Figure-3. The boom will be conductively controlled at the upper-end mounting location by the baseplate temperature and radiatively coupled to the chamber shrouds.
i) Connect to the chamber feed-through connector and verify. Wrap any exposed electrical cables and thermocouple harness with MLI.
j) Position the TQCM for measurement of chamber contamination and checkout operation.
k) Remove red-tag purge hardware.
l) Verify thermocouple and test heaters are operating properly.
m) Conduct ambient instrument checkout.
n) Conduct engineering and program management inspection of test setup.
o) 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-D and SWEA 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 the SWEA 3.5-watt survival heater and set the Baseplate temperature control at –40°C.
g) Allow the chamber shrouds, the STE-D, and the SWEA to cool to predicted survival cold case temperature levels as specified in Table 2 for TB Case 1. Verify that the SWEA survival heater turns on at or near -20°C and off at approximately -10°C.
h) Allow the survival heater to cycle at least three times to verify a degree of temperature repeatability and equilibrium.
i) When TB Case 1 is completed, record all temperature and heater data.
j) Turn-on the SWEA and STE-D instruments and perform functional checkouts.
k) After verifying that the SWEA is operating properly, disable the survival heater.
l) Operate the instruments in the normal flight mode with the chamber environment set as specified in Table 2 for TB Case 2.
m) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
n) When equilibrium for TB Case 2 is attained, record all temperature and heater data.
o) Activate the SWEA test heater and set at 2-watts or as specified by the OSC thermal control engineer. Continue to operate the instruments in the normal mode.
p) The chamber environment will be maintained for TB Case 3 as set for TB Case 2.
q) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
r) When equilibrium for TB Case 3 is attained, record all temperature and heater data.

s) 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 SWEA and STE-D thermal design.
t) 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.
u) 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-D 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 temperatures reaches within 3°C of the specified qualification level (Figure 4).
- Instrument 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 the hot non-operational SWEA and STE-D temperatures of +40°C ± 3°C.
c) Adjust Cold-plate temperatures to control the STE-D at the hot Survival level of +40°C ± 3°C.
d) After a minimum one-hour soak, begin transition to cold Survival levels per Table 3 flooding chamber shrouds and Cold-plate with LN^2. Verify that the Cold-plate reaches to –110°C and the Baseplate controls at –40°C ± 3°C.
e) Allow SWEA and STE-D temperatures to cool to non-operational levels specified in Table 3.
f) Adjust Cold-plate control to achieve STE-D temperature level of –100°C ± 3°C.
g) Turn on SWEA test heater when temperature reaches -40°C ± 3°C and maintain at this level.
h) After minimum one-hour soak at the non-op level, begin transition to the hot soak for start of operational cycles.

Operational Cycles:

a) Transition to hot soak level by increasing temperatures as specified in Table 3.
b) Turn on instruments for the cold to hot transition.

c) Set thermal control of the Cold-plate at –35°C to achieve STE-D temperature near this level via the heat strap connection.
d) Adjust Cold-plate control to achieve STE-D operational temperature of –35°C ± 3°C.
e) Activate SWEA test heater and raise temperature to +25 C ± 3°C.
f) 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.
g) After one-hour or completion of functional testing, begin transition to cold soak by reducing temperatures as specified in Table 3.
h) Turn off SWEA test heater and operational power allowing SWEA to cool to cold soak levels.
i) Reduce Cold-plate temperature to -110°C and adjust to achieve STE-D temperature of –90°C ± 3 °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.
k) After one-hour or completion of functional testing, begin transition to hot soak by repeating the previous cold to hot transition.

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 – Boom Mounting Location		
TC7	SWEA Pedestal Housing		
TC8	SWEA Pedestal Base		
TC9	50 mm Boom at SWEA Pedestal I/F		
TC10	50 mm Boom 3 inches from Pedestal		
TC11	50 mm Boom 7 inches from Pedestal		
TC12	50 mm Boom 11 inches from Pedestal		
TC13	Spare / Lower Shroud		
TC14	Upper Shroud Track		
TC15	Upper Shroud Track		
TC16	Room		
PRT	STE-D Flight PRT		
PRT	SWEA 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)	Survival 1 & Cold Case 2 (°C)	Hot Case 3 (°C)	Temp Control
Shrouds	20 to 50	<–110	<–110	LN^2 & Test Heaters
Cold Plate (CP)	20 to 50	<–110	<–110	LN^2 & Test Heaters
Chamber Baseplate	40 ± 3°C	–40	-40	LN^2 & Test Heaters
Boom Mount	40 ± 3°C	–40	-40	Via conduction from baseplate
SWEA	40 ± 3°C	–30 to -10 (Flight Temp)	-10 to 0 (Flight Temp)	Op power and test heater input
STE-D	40 ± 3°C	–90 to –75 (Fight Temp)	–70 to –50 (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 SWEA temperature if heat loss via conduction to the boom is as currently predicted.

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	LN^2 & Test Heaters
Cold Plate (CP)	+40 /<–110	<–105	–35	LN^2 & Test Heaters
Chamber Baseplate	+40 / -40	–27	-40 to 0	LN^2 & Test Heaters
Boom Mount	+40 / -40	–40	-40 to 0	Via conduction from baseplate
SWEA	+40 /-40	– 30 (Qual level)	+25 (Qual level)	Op power and test heater input
STE-D	+40 / –100	–90 (Qual level)	–35 (Qual level)	Radiation to shroud & heat strap to CP

FIGURE 1: SWEA and STE-D Thermal Coatings and Mounting Configuration

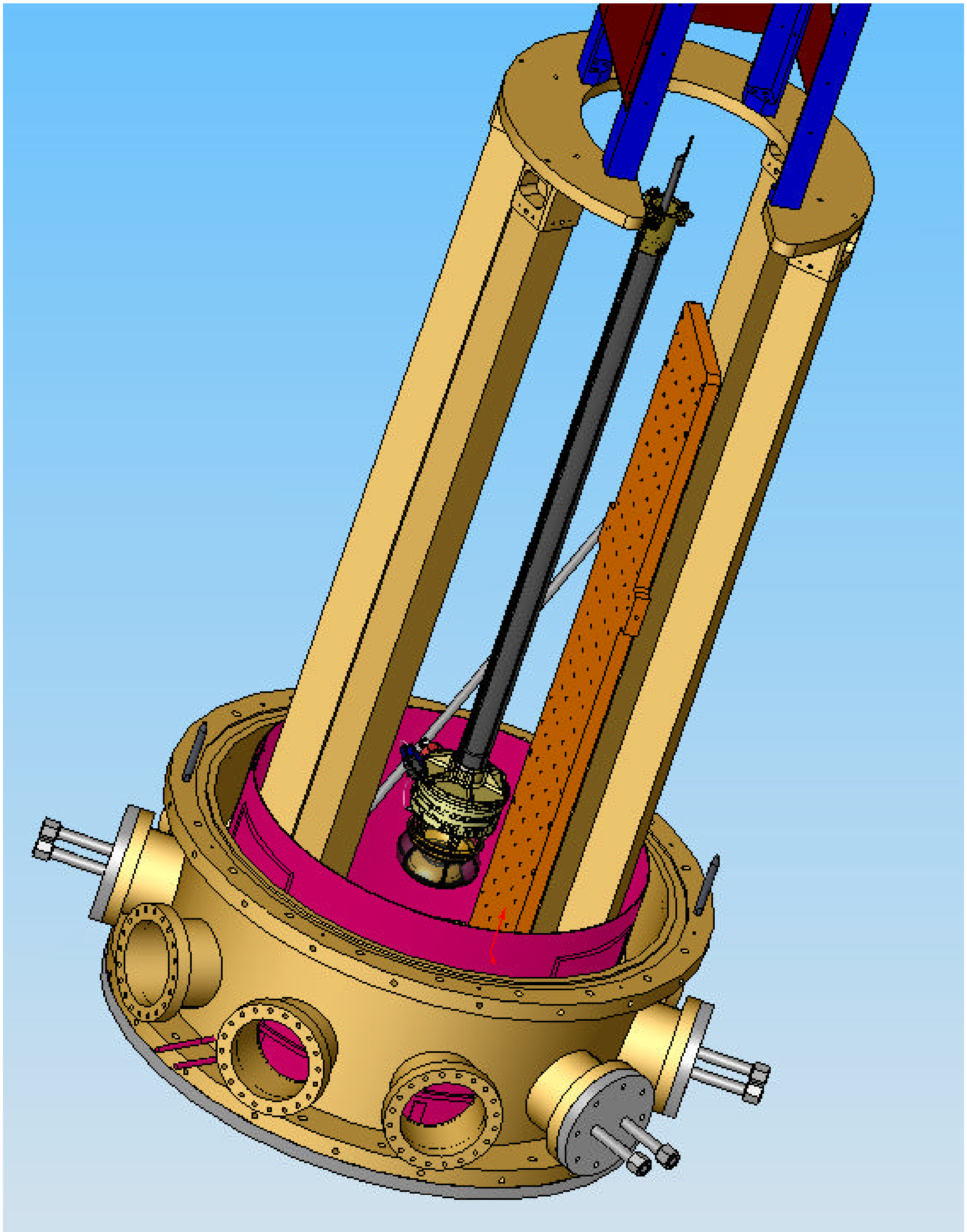


FIGURE 2: SWEA /Boom and STE-D Test Configuration

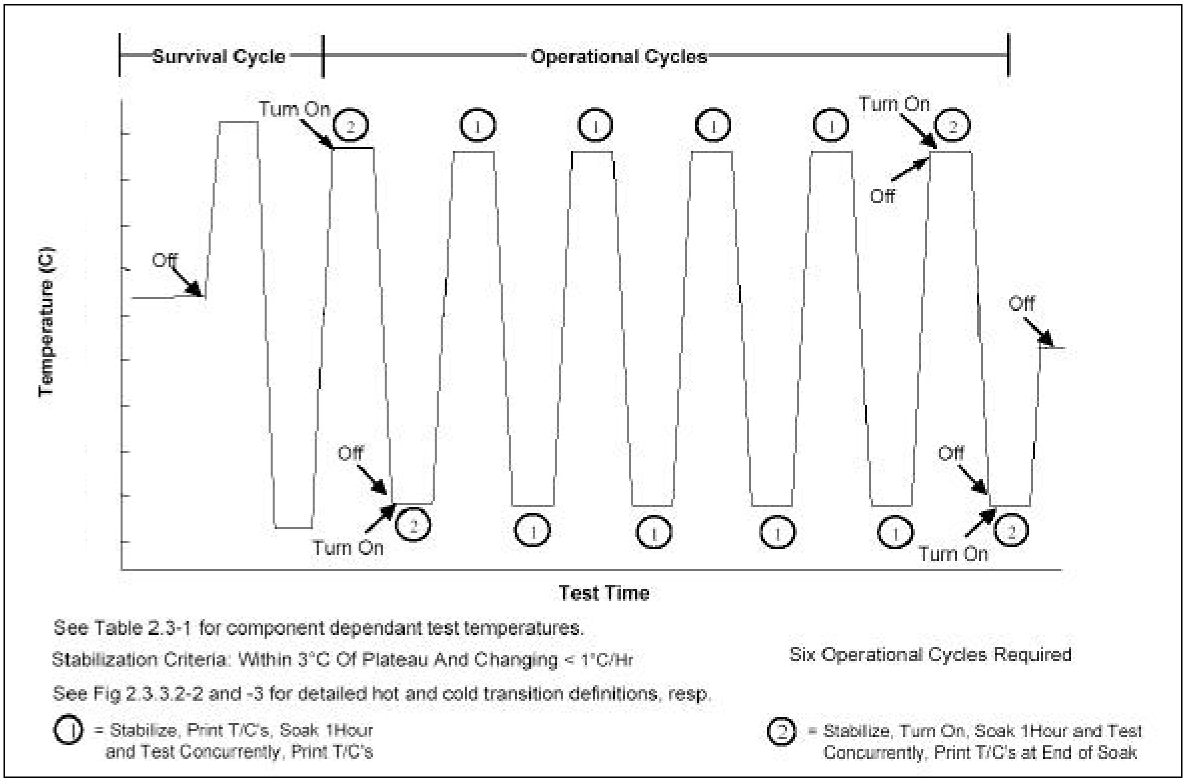
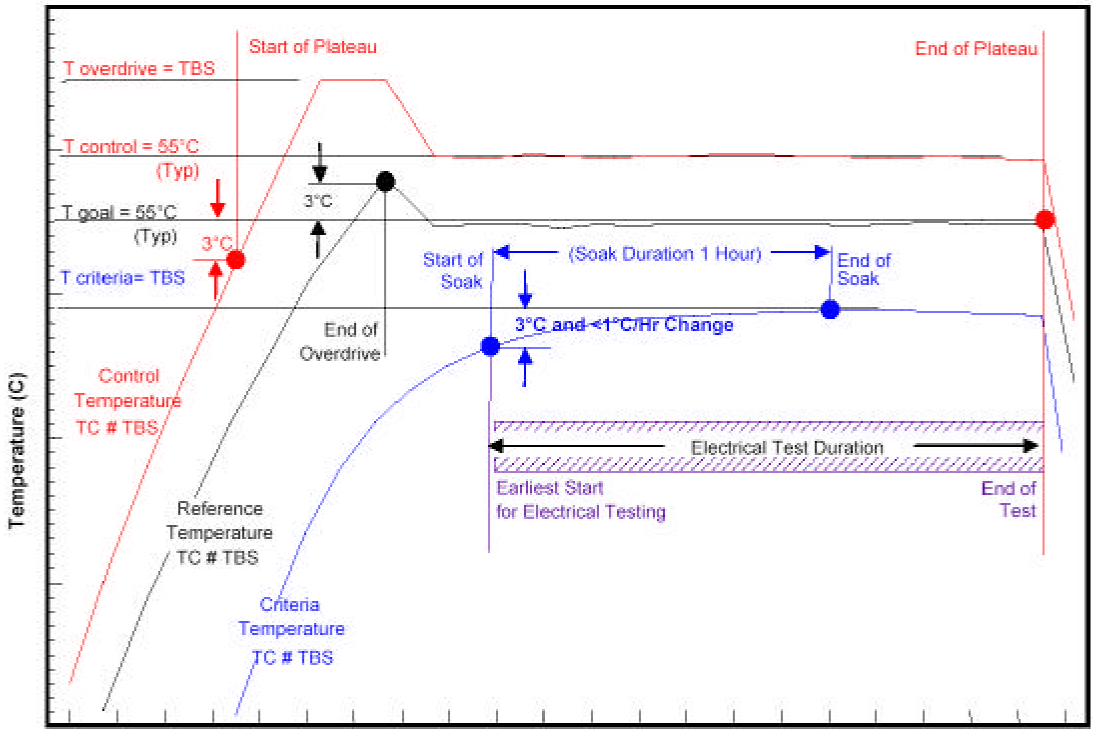


FIGURE 3: SWEA and STE-D TV Qualification Cycling Profile (Table 3: Temperature limits)

Transition to Hot Soak



Transition to Cold Soak

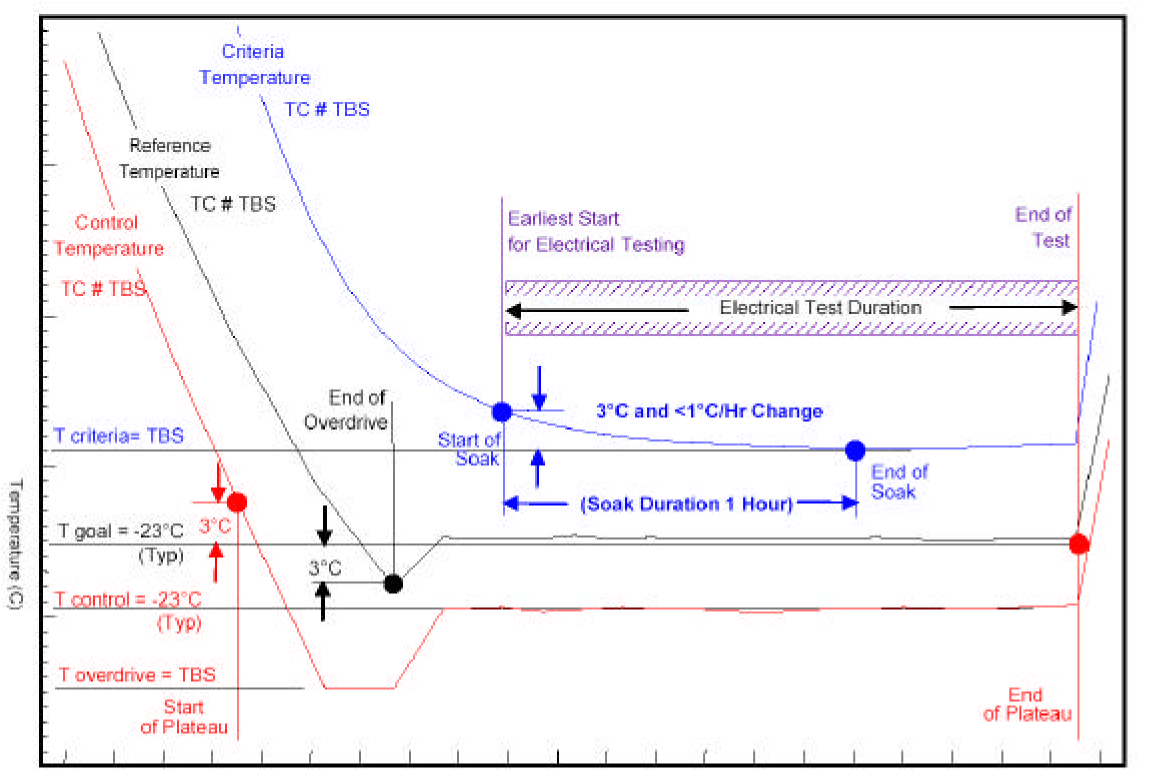


FIGURE 4: TV Soak and Performance Test Criteria

FIGURE 5: SWEA and STE-D Comprehensive Performance Test (CPT)