STEREO Impact Boom Thermal Cycling Report

Document # IMP-564-DOC
Revision: A

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1. OVERVIEW

The STEREO Boom thermal cycling tests for the Proto-flight Boom were conducted August 11 through 18, 2003 at the Space Sciences Laboratory in Berkeley, California using the STEREO IMPACT Boom Thermal Vacuum Chamber. Mario Marckwordt, Ken McKee, Robert Ullrich, Bill Donakowski, Paul Turin and Jeremy McCauley were in attendance for instrument handling, verification and test observation.

Thermal cycling was conducted on the Boom (See Figure 1) between survival temperatures of -33°C and 40°C with a minimum four (4) hour soak at each extreme. There were 8 cycles total during this test (6 ½ continuous cycles followed by 3 half cycles). Deployment was performed after the seventh "hot" (40°C) soak. The chamber was then vented for inspection of the boom and restowing. The stowed Boom was returned to the tank for a cold thermal cycle, after which deployment was attempted following the "cold" (-33°C) soak. Cold deployment did not occur due to galling in the Pinpuller Assembly (See PFR-1001). Subsequent diagnosis allowed simple modification of parts to resolve the PFR. The Boom was then cycled cold again and a successful deployment was achieved following the "cold" soak. This deployment has been shown to be valid and repeatable by a later deployment following a cold thermal vacuum cycle (January 9, 2004). This failure is not believed to be temperature related; rather, it was the result of repeated wear within the Pinpuller Assembly. This wear does not occur after modification of the assembly.

All thermal cycling and deployments were completed and no further testing is required. Post-test inspection during stowing operations showed no degradation to the boom mechanically, structurally, or functionally, except for the modifications added as described above.

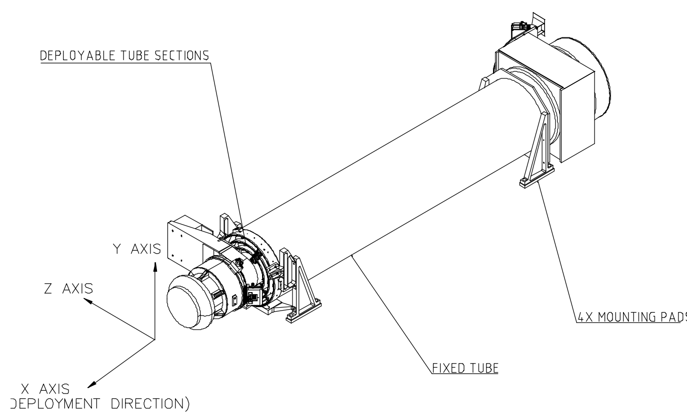


Figure 1: Definition of Shake Axes

2. REFERENCE DOCUMENTS (Attached):

APL Document APL 7381-9003 Rev A – STEREO Environment Definition, Observatory and Instrument Test Requirements Document (Not attached)
UCB Document IMP-563-DOC – Thermal Vacuum Cycling Test Procedure
PFR-1001 – Qual Boom Deploy 2003-08-15
STEREO IMPACT Protoflight Boom Test Results Meeting Presentation, August 21, 2003

3. PASS/FAIL CRITERIA

The Boom was successfully deployed after completion of the seventh hot soak. Deployment was watched via video taken inside the chamber. Manual inspection after cooling and venting verified all pins had locked and the Boom was fully deployed. Resonance testing verified the Boom stiffness was within expected values.

Two deployments were attempted following the seventh and eighth cold soaks. Both deployments failed due to galling of the Pinpuller Assembly. A third deployment was attempted after modification to the Pinpuller Assembly. This deployment was successful. Deployment was watched via video camera from inside the chamber. Manual inspection after warming and venting verified that all pins had locked and the Boom was fully deployed. Resonance testing verified the Boom stiffness was within expected values.

3.1 COLD DEPLOY FAILURE EXPLANATION AND RESPONSE

The following excerpt is from the STEREO IMPACT Protoflight Boom Test Results Meeting Presentation, August 21, 2003 (See also PFR-1001):

Thermal Vacuum testing of the Impact Proto-flight Boom was begun on 11 August 2003 with Proto-flight unit installed in chamber, armed for hot deployment. The Baseplate Thermocouple was used as the main control for the temperature of the testing. The upper and lower shrouds were set to track the baseplate. 12 additional TCs were positioned at various locations on the Instrument and their outputs recorded. Chamber pressure ranged from 2.5 X 10-5 (hot cycles) to 6.8 X 10-6 Torr (cold) during the cycling. 6 cycles from ambient at start (~22 0C) to hot (40 0C) , to cold (-33 0C) and back to ambient, were performed without interruption of the system.

The 7th cycle was split into 2 parts: a hot soak, followed by a deployment using the SMAR primary circuit. The hot deployment was successful, performed at 11:00 on 14 August.

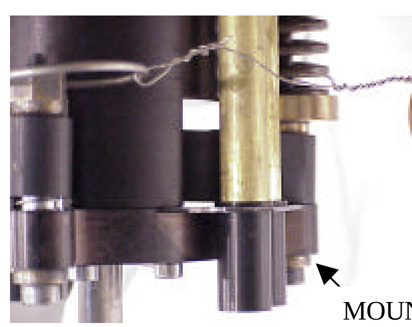
The chamber was then vented, and the Impact Proto-flight Boom was restowed, and replaced in the chamber. The unit was pumped down to vacuum, then given a cold soak. The cold deployment was then scheduled for 10:00 on 15 August, using the SMAR secondary circuit. The cold deployment did not function.

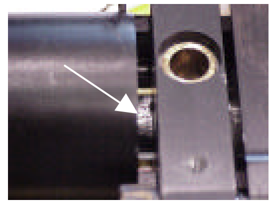
The Thermal Vacuum test was halted, and the chamber heated, vented and opened for investigation of the anomaly. There were no obvious signs of difficulties with the unit on the test stand, the tubes were locked, and would not deploy. The unit was 'safed' by installing the safety pin, and removed from the chamber. After removal, the tubes were free, and were able to be moved manually. The unit was then investigated by subsystem to attempt to identify the problem. The flyweight brake (f.w.b.), initially suspected, was operational, and appeared to be assembled correctly. It was removed from the assembly, disassembled and inspected for incorrect operation. No problems were noted. There was sufficient slack on the lanyard to allow the spool lock to release and the lanyard to pay out. (This was verified prior to removal from test stand, and again after). The lanyard and harness were not wrapped around any object, thereby preventing deployment. The bobbin was removed and appeared nominal. Harness was unaffected. SMAR pinpuller appeared to have functioned correctly. The SMAR was reset, and a 'first motion' test was performed successfully. The 50mm tube pushed out normally, lanyard was free to pay out. The deployment was halted by manual restraint of the tubes while the boom was reset. No 'smoking gun' was found. Theories were offered regarding the f.w.b. hanging up, twisted harness and other lower probability scenarios.

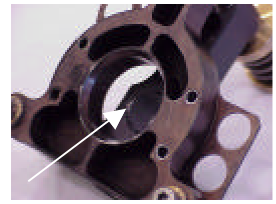
The proto-boom was reinstalled on the test stand, carefully inspected for proper assembly and installation. The chamber was closed, pumped down, and the cold portion of the test repeated. The cold deployment was then scheduled, using the SMAR secondary circuit. The 2nd cold deployment did not function.

The Thermal Vacuum test was halted, and the chamber heated, vented and opened for investigation of the anomaly. There were no obvious impairment of the unit on the test stand, the tubes were again locked, and would not deploy, so the unit was removed from the test stand. The boom was not 'safed' this time with the safety pin. The unit was then investigated by subsystem removal, to attempt to identify the problem. The flyweight brake (f.w.b.) was operational, and appeared to be assembled correctly. The bobbin was nominal. Harness was unaffected. SMAR pinpuller appeared to have functioned correctly. The source of the anomalous behavior was then apparent: The tail of the tip piece was trapped in the SMAR 'floating' mount.

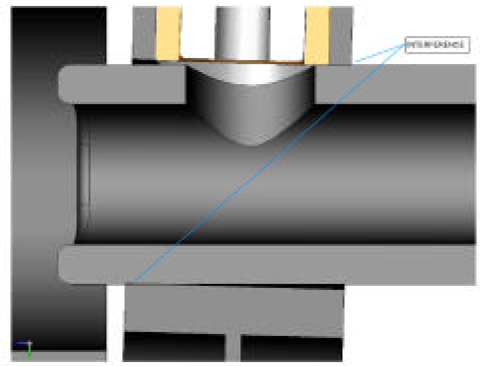
The mount is used to preload the tubes for resisting launch loads. There are 2 fixed pivots, and a coil spring used to apply the load to the tip piece tail. The release of the SMAR pinpuller allowed the coil spring to unload faster


MOUNT
TIP PIECE

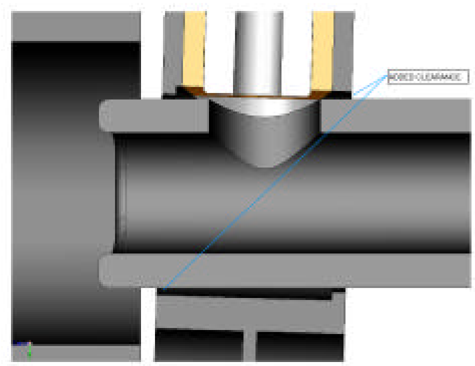




than the tip piece could clear the floating mount. The release of the SMAR induces a tilt to the mount. Due to the tight tolerance required, there was insufficient room for the tip piece to withdraw from the tilted mount, and thus became locked into the SMAR mount. This was not seen during the previous anomaly as the latching had been released when the safety pin was installed. Close inspection revealed galling of the Ti tip piece, as wear had accumulated from deployments. The mount functioned as a sliding clamp, with 2 edges grabbing the tip piece. The second picture shows the wear on the mount from hanging up the tip. The previous successful deployments had allowed the non-galled tail of the tip piece to slide through the mount.



The solid model was re-examined for verification of the anomalous condition. This drawing is the section view, post SMAR firing. Coil preload spring has pushed the mount against the housing sooner than the tip piece can clear the through hole. The tip piece binds in the mount.



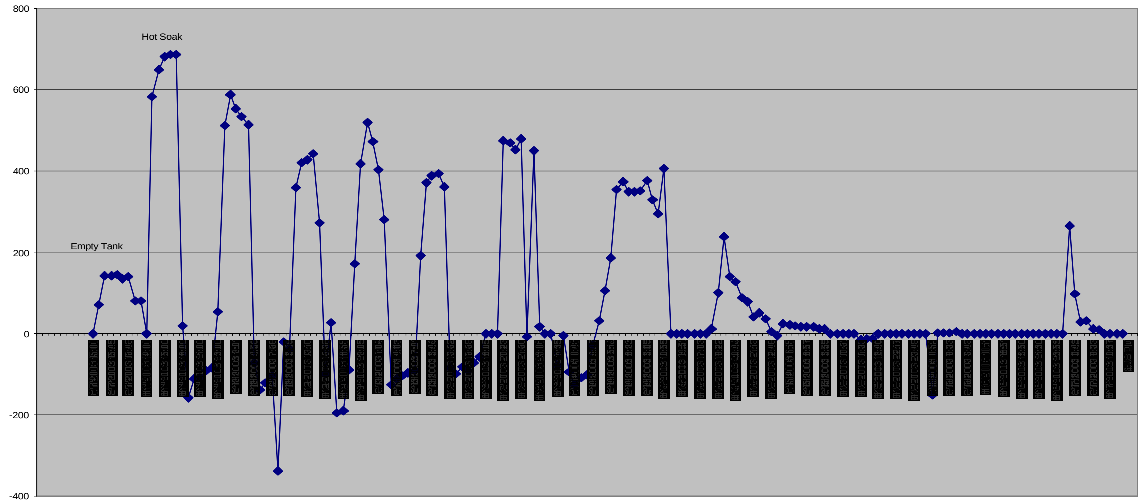
This drawing is the section view, post SMAR firing. The hole has been relieved by milling an offset into both sides of the mount, while leaving a lip to guide the tip while the pinpuller is installed and preloaded. The tip piece no longer binds in the mount.

3.2 SUBSEQUENT TESTING

Repeatability of the cold test was verified January 9, 2004 with another deployment at survival cold condition after a 4 hour soak. Full deployment was verified after heating and venting by manual inspection, which verified all pins locked and the Boom was fully deployed.

4. TQCM MEASUREMENTS

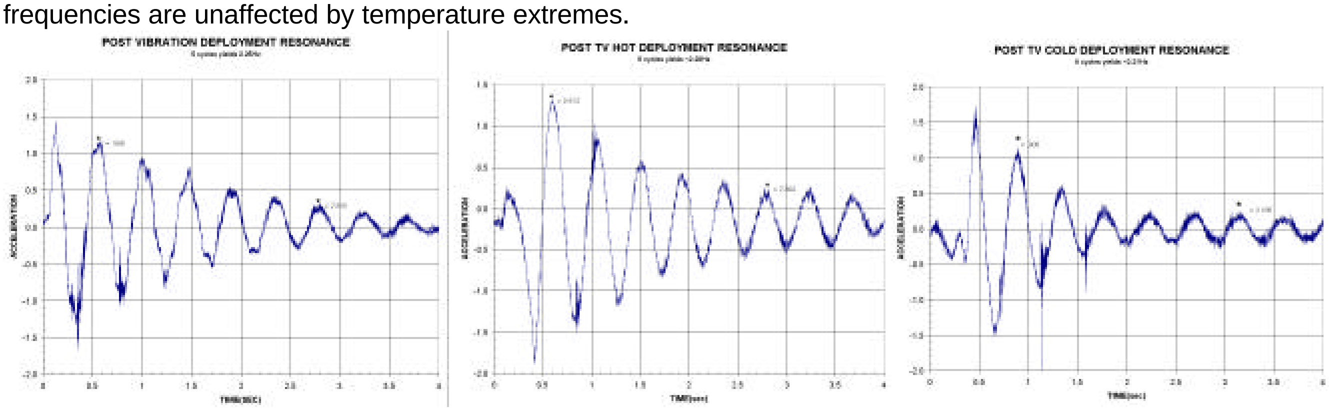
A TQCM was monitored within the chamber at all times during thermal vacuum cycling. The following is a plot of the TQCM activity. Each successive hot soak showed a lower value of the rate of climb the TQCM measured. The system started with a rate of about 680 Hz/hr and finished at approximately 350 Hz/hr.



TQCM Data showing the change in measured frequency with time.

5. RESONANCE TESTING

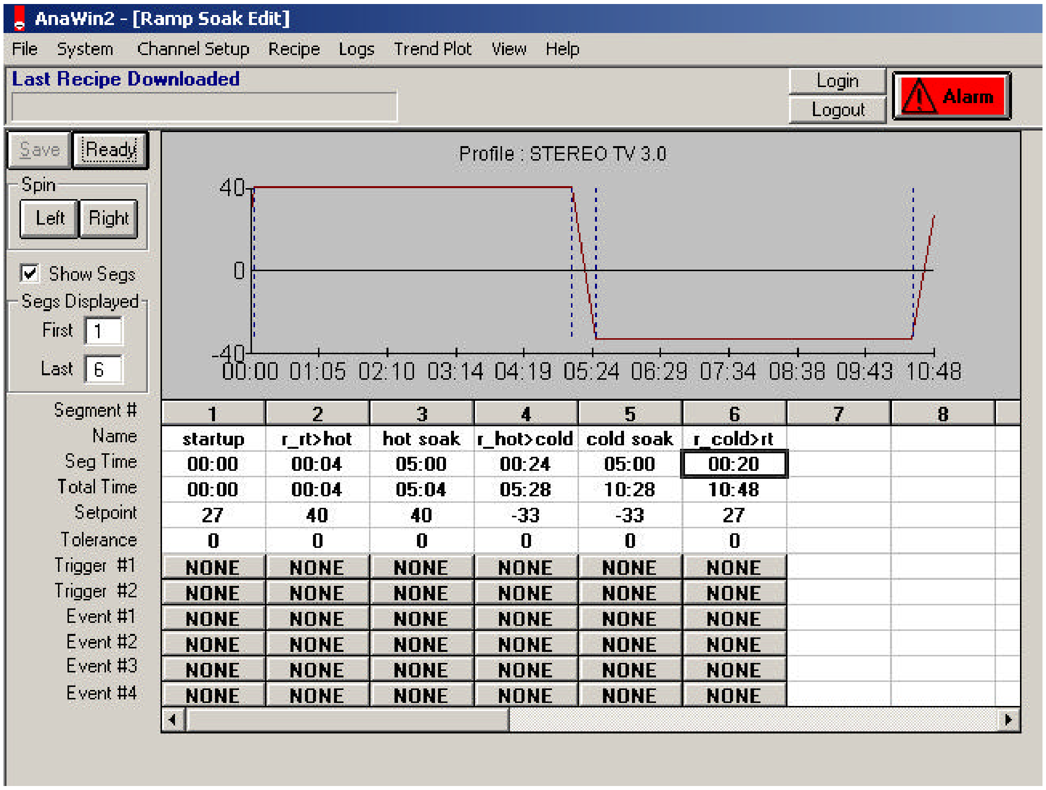
Resonance testing was done to verify that the Boom was fully deployed with all pins locked and to verify that the Boom structural response was similar regardless of deployment temperature. Resonance was measured using an Endevco 61-A500 Isotron Accelerometer through a Model 133 signal conditioner into DAQView. The resultant plots are shown below as is a plot from a room temperature test post-vibration and prior to thermal vacuum testing. For the post-vibration test, averaging 5 cycles gives 2.25Hz with all mass dummies included. For the hot case deployment, averaging 5 cycles gives 2.28Hz with all mass dummies included. For the cold case deployment, averaging 5 cycles gives 2.21Hz with all mass dummies included. The consistency of these numbers is within the accuracy of the calculations. Thus, the devices show that deployment resonance frequencies are unaffected by temperature extremes.



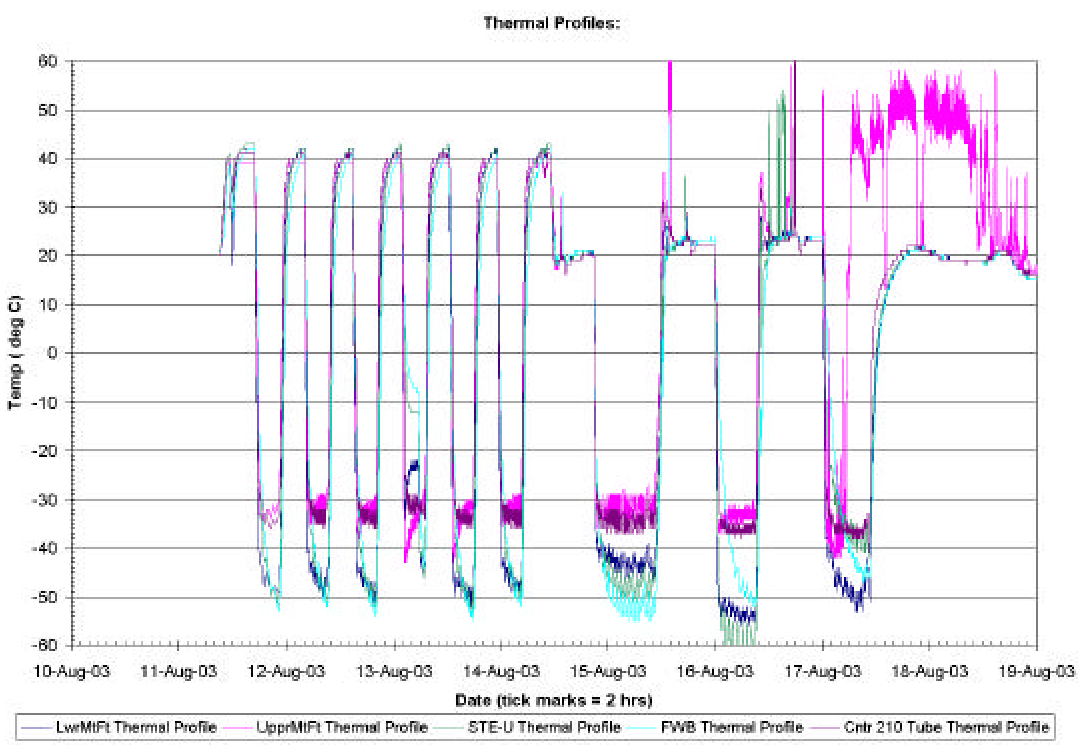
6. THERMOCOUPLE PLACEMENT

Thermocouple:	Placement:	TC8	Upper 210mm Ring
TC1	Upper Shroud (Control)	TC9	STE-U Mass Dummy
TC2	Lower Shroud (Control)	TC10	Pinpuller
TC3	Baseplate (Control)	TC11	Lower Baseplate
TC4	Flyweight Brake	TC12	Upper Baseplate
TC5	Lower Mounting Foot	TC13	Midspan 210mm Tube
TC6	Lower 210mm Ring	TC14	Upper Shroud
TC7	Upper Mounting Foot	TC15	Upper Shroud

7. THERMAL TEST PROFILE



8. THERMOCOUPLE PROFILES



9. PRESSURE PROFILE