

THERMAL VACUUM TEST AND CALIBRATION OF THE "HUMIDITY SOUNDER FOR BRAZIL – HSB”

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Abstract: *In October 1999, the thermal vacuum staff of the Integration and Testing Laboratory (LIT) performed, in its largest (3x3m) vacuum chamber, the environmental simulation of the "Humidity Sounder for Brazil - HSB". This is a set of optical and electronic equipment, which is one of the payloads of the EOS Aqua PM-1 Satellite of the EOS - Earth Observing System Program. The Thermal Vacuum Test was performed in two phases: 1) A bake-out of the test set-up in 5 days; 2) A thermal cycling test and a radiometric calibration in 18 continuous days. The test set-up basically consisted of the 3x3m Thermal Vacuum Chamber, 350 kg Calibration Rig Structure, Space Radiator Panels, Earth Target, Space Target, and the Instrument (HSB). The temperature of the Thermal Vacuum Chamber Shroud was kept in the range of –50 ^{o}C to +50 ^{o}C. Fine temperature control was achieved by using the Space Radiator Panels and the Calibration Rig.*

Keywords*. HSB, Satellite, Thermal Vacuum, Space Simulation, Thermal Control*

1. Introduction

The HSB**,** Humidity Sounder for Brazil**,** is the object of a scientific and technical cooperation agreement between NASA and AEB, Brazilian Space Agency. The HSB was integrated into the Aqua PM-1 platform of the Earth Observing System (EOS). The goal of this program is to deepen the Earth multi-disciplinary studies and systematically monitor the changes on the global system. The HSB instrument was supplied by INPE and it flew in 2001 on Aqua PM-1 spacecraft, together with the Atmospheric Infrared Sounder (AIRS) and Advanced Microwave Sounding Unit (AMSU-A), constituting so an advanced sounding system. TRW was responsible for the Aqua PM-1 construction. INPE participated in the integration to the platform.

The HSB is part of the EOS Aqua PM-1 Mission. The Aqua PM-1 is the first of a series of spacecrafts, flying in an orbit that covers the Earth every 16 days. The EOS Program provides the comprehensive global observations necessary to understand how the processes that govern global change interact as part of Earth system. The HSB is a significant contribution to the improvement of modeling efforts, numerical weather prediction and monitoring of climate variations and trends.

The HSB instrument is a passive 4 channels radiometer that receives and measures radiation from the atmosphere in order to obtain data on humidity profiles for weather forecasting. The instrument was developed by Matra-Marconi Space (Bristol, UK), with the participation of the Brazilian company Equatorial Sistemas. The HSB receiver channels are configured to operate in DSB (Double Sideband) with frequencies centred at 150 GHz (channel 17) and 183,31 GHz (channels 18, 19 and 20). The HSB specifications is: Weight**:** 60 kg, Power**:** 80W, Spatial resolution: 13.5 km at nadir, Field of View**:** 1.1º, Data Rate: 4.2 Kbps, Swath: 1650 km, Dimensions: 526mm X 700mm X 650 mm, Temperature Sensitivity: 1.0 K to 1.2 K, Scan**:** angle: ± 48.95º period: 8/3 s. Figure 1 presents the HSB mounted over the balance machine platform at LIT.

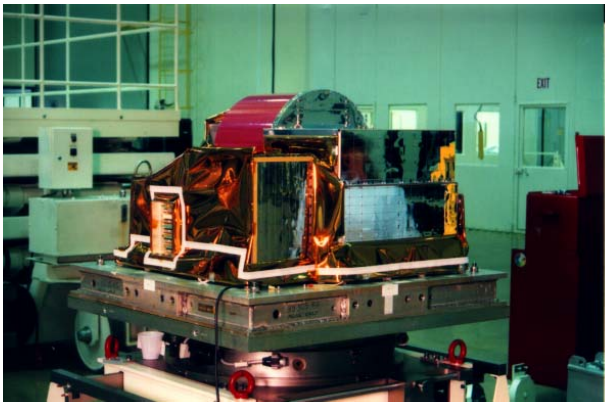

Figure 1. Humidity Sounder for Brazil – HSB.

Satellites and Payloads, as HSB is, are subjected to extensive ground thermal testing to verify the thermal designed and ensure successful operational use in flight. The MIL-STD-1540B (1982) standardizes the test requirements and establishes a uniform set of definitions, environmental criteria, and test methods for space vehicles, subsystems and components. The design environments are composed of the various environmental stresses to which the satellite (or payload) is designed. The thermal stresses used in the design consider equipment operation, internal heating, eclipse conditions, space-vehicle orientation, environmental heating (including solar, earthshine infrared, and albedo radiation), ascent heating, and degradation of thermal surfaces during the mission lifetime. These stresses are used in the analytic modeling efforts to predict, over the operational life of the spacecraft, the worst-case hot and cold temperatures for the component, subsystem, and satellite. From these results, acceptance and qualification temperatures are derived (Gilmore, 1994).

The main objective of the HSB thermal vacuum test has been to verify the functional performance of the payload at acceptance temperatures and vacuum level. Acceptance temperatures mean the maximum and minimum predicted temperatures, which each HSB's equipment can support during its orbital life. Without the convective environment, temperatures and stresses closely simulate on-flight conditions (Garcia et al., 2002). This paper provides the information about generalities of the thermal vacuum test and the calibration of the HSB. This was performed inside of the 3x3m Thermal Vacuum Chamber (TVC) at Integration and Tests Laboratory (Figure 2), from October 6 to 24, in 1999.

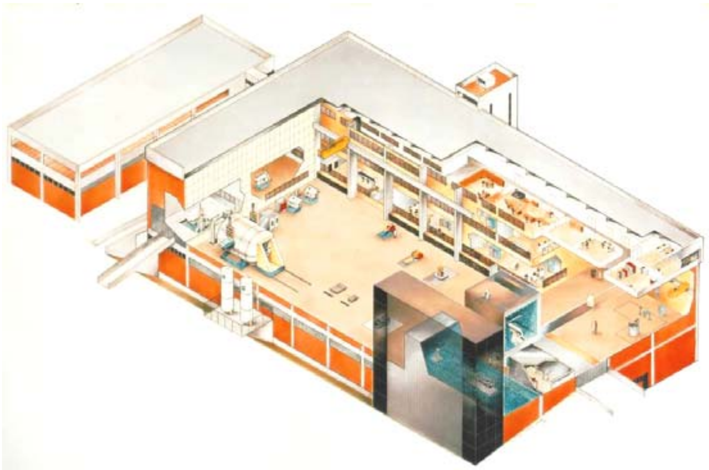

Figure 2. Integration and Tests Laboratory – LIT.

2 . Thermal Vacuum Test and Calibration of the HSB

The Thermal Vacuum Test (TVT) and the Calibration of the HSB were performed in two phases:

1) Bake-out of the test set-up, fulfilled in 5 days;
2) Thermal vacuum test and a radiometric calibration, fulfilled in 18 continuous days.

2.1. Bake-Out of the Test Set-Up

To guarantee a high degree of cleanness of the Thermal Vacuum Chamber and of all test set-ups, they were submitted to a bake-out. This procedure removed any undesirable substance that could contaminate the HSB instrument, during the second phase (TVT and calibration).

The test facility used to perform the bake-out was also the LIT 3x3m Thermal Vacuum Chamber. The Cal-Rig was installed in a support as shown in Figure 3. The pressure during the bake-out was kept under 10^{-5}Torr and the temperature of the chamber shroud was maintained at 80º*C* [+3º*C*] for 24 hours.

The bake-out ran with no problems. The specimen got temperatures and duration level in conformity to specification for this activity. The bake-out result was verified by chemical analyses and they did not detect any contamination, guaranteeing total confidence for the second phase.

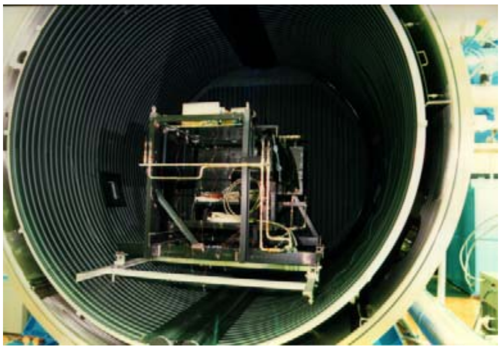

Figure 3. Installation of the Cal-Rig inside of LIT Thermal Vacuum Chamber to perform the bake-out.

2.2. Thermal Vacuum Test and Radiometric Calibration

These activities were shared among five staffs. The main responsibilities involved for each one were:

- Integration and Test Laboratory (INPE/LIT) – thermal vacuum staff:
    - ❖ Thermal Vacuum Chamber;
    - ❖ Liquid Nitrogen Supplying;
    - ❖ Temperature Data Acquisition System;
    - ❖ Thermoelectric Quartz Micro Balance operation.
- Matra-Marconi Space (MMS):
    - ❖ Operation of the HSB instrument;
    - ❖ Electrical Ground Support Equipment (EGSE).
- Met Office (UK):
    - ❖ Earth and Space Targets
    - ❖ Data handling of the HSB instrument
- NASA (Goddard Space Flight Center):
    - ❖ Thermoelectric Quartz Micro Balance supplying;
- Supervising of all activities.
- Equatorial Sistemas:
    - ❖ Space Radiator Panels;
    - ❖ Mechanical Ground Support Equipment (MGSE).

Basically, the test set-up for HSB test was composed of the:

- 3x3m Thermal Vacuum Chamber;
- 350 kg Calibration Rig Structure;
- Space Radiator Panels;
- Earth Target Simulator;
- Space Target Simulator;
- Instrument (HSB).

The 3x3m Thermal Vacuum Chamber (TVC) is the biggest Brazilian chamber, which was built in 1987 to support Brazilian satellite programs. Its function is to provide the necessary environment in order to perform space simulation.

The Calibration Rig Structure is part of the mechanical ground support, which was designed to adapt the TVC interfaces for HSB and the two target simulators (Cardoso, 1998). It was an Equatorial Sistemas´s responsibility. Part of assembling of the Cal-Rig in the TVC is shown in Figure 4.

Figure 4. Adaptation of the Calibration Rig Structure in the LIT 3x3m Thermal Vacuum Chamber.

The temperature of the Thermal Vacuum Chamber Shroud (internal black part whose temperatures are imposed) was kept in the range of -50°C to +50°C (Cardoso, 1999). Fine temperature control was achieved by using the Space Radiator Panels (SRP) and the Calibration Rig. To obtain this control, some actions were necessary to be firstly implemented. One of the more important points was the feeding the SRP with liquid nitrogen (LN2) with a very short fluctuation. The SRP worked as isothermal enclose to simulate the orbital conditions. The maximum pressure fluctuation in the SRP was bellow than 0.08 psi/hour for short term and one psi/hour for long term. To achieve these specifications, it was necessary to install a new large cryogenic tank (26,000 litres) in the LIT building, whose investment was around of US$ 30,000. Figure 5 presents the installation of this tank in the LIT area.

For convergence criteria, the temperature stability requirement was 0.05°C/min calculated over 20 min. To regulate this, the SRP, behind of LN2 feeding, was also warmed and controlled by circuit heaters-controllers with very fine adjustments. Figure 6 shows the internal side of the SRP (with the Space Target at the center).

Figure 5. Installation of the new bigger cryogenic tank (26.000 litres).

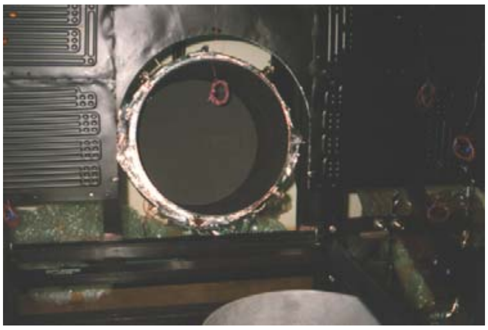

Figure 6. Space Radiator Panels operating as an isothermal enclosure to HSB orbital thermal simulation.

The Earth Target is a black body, with absorbing aluminium substrate with precision of 5 PRT (platinum resistance temperature sensor), located at a distance of 650 mm from the HSB scan center. It had a length of 300 mm and consisted of 4 cooling rings, 4 small heaters, and a cooper shroud. The function, obviously, was to simulate the Earth during the test and calibration. Its temperature was driven around in –20°C (temperature normally adopted for the Earth in thermal control design for satellites). The Earth Target is presented in the Figure 7.

Figure 7. Earth Target: Left photo shows external side in lateral position. Right photo shows internal side in top position.

The Space Target is a cooper shroud of 400 mm in length with LN2 cooling, located at 1350 mm from the HSB scan center. Its function was to simulate the space as very cool sink. The temperature of this target was kept around LN2 temperature (– 190°C). Figure 8 presents the Space Target.

Also, inside of the HSB, there is an Internal Calibration Target. This is an Eccosorb coated magnesium core on which the temperature measurements are made with seven PRT of 4000Ω and accuracy of 0.01% in the range –20 to +50°C. The Internal Calibration Target has an emissivity of 0.9999976 at 148 GHz and 0.9999937 at 191 GHz.

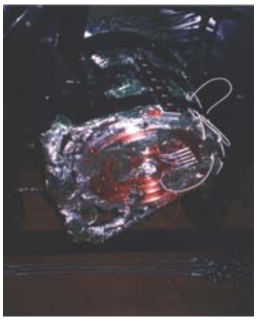

Figure 8. Space Target. Left photo: external side. Right photo: top position, showing internal part.

3. Temperature Profiles

During 18 continuous days of test, the temperature of the TVC and Cal-Rig were driven to simulate the main orbital conditions to reach in the acceptance predicted temperatures and verify the HSB functioning. Also, following the same procedure, the calibration of the HSB instrument was performed. Here, in this paper, are been presented only some of the more important temperature profiles developed during these activities. Garcia (1999) presents the HSB report where can be found all test results. Figures 9 and 10 present the temperature profile imposed to TVC shroud during the test. This temperature profile was necessary to guarantee the acceptance temperature distribution level in the HSB (Figures 13 and 14), under high vacuum, and in the calibration rig (Figures 11 and 12). In this way, the HSB operations were verified and the calibration fulfilled during the temperature soaks (steady-states).

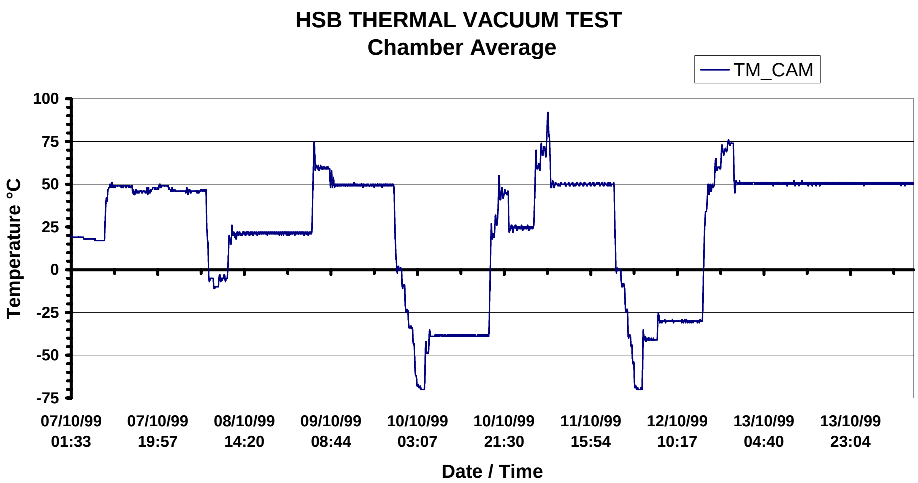

Figure 9. Average Temperature Profile developed in the TVC (Oct./07-13)

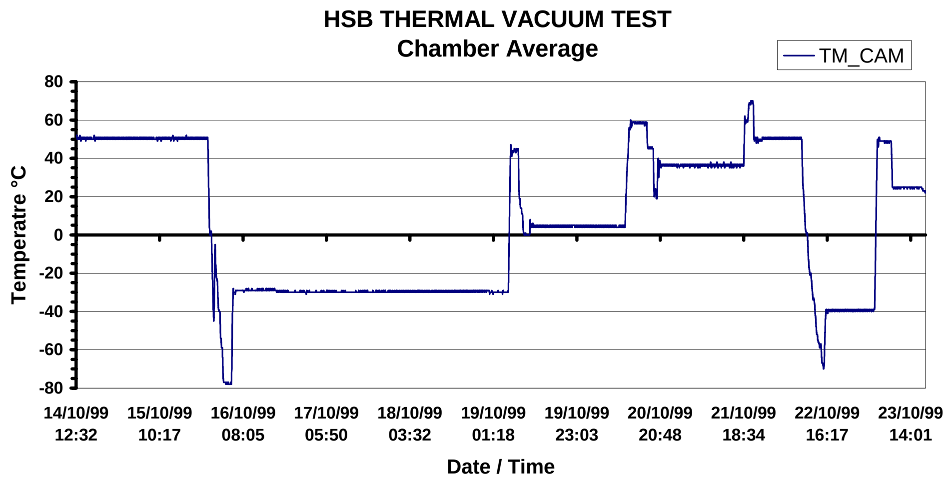

Figure 10. Average Temperature Profile developed in the TVC (Oct./14-23).

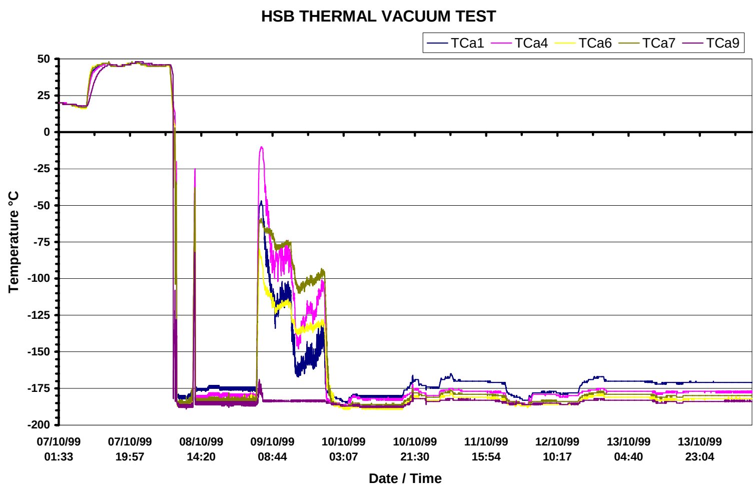

Figure 11. Temperature Profile developed in the Cal Rig.

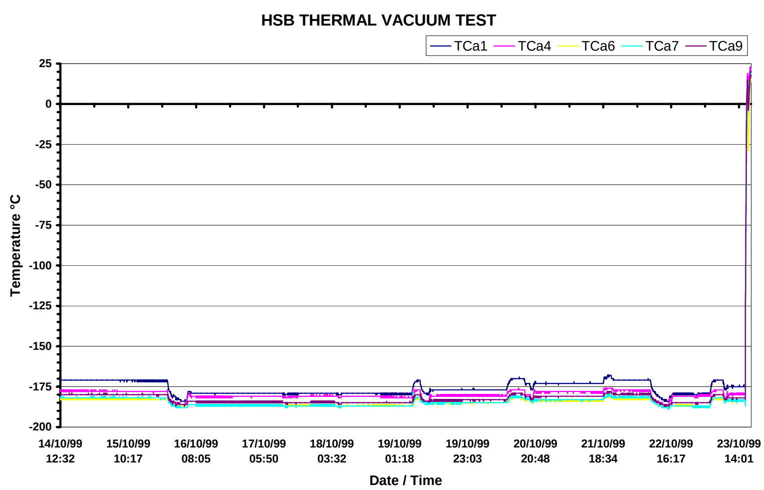

Figure 12. Temperature Profile developed in the Cal Rig.

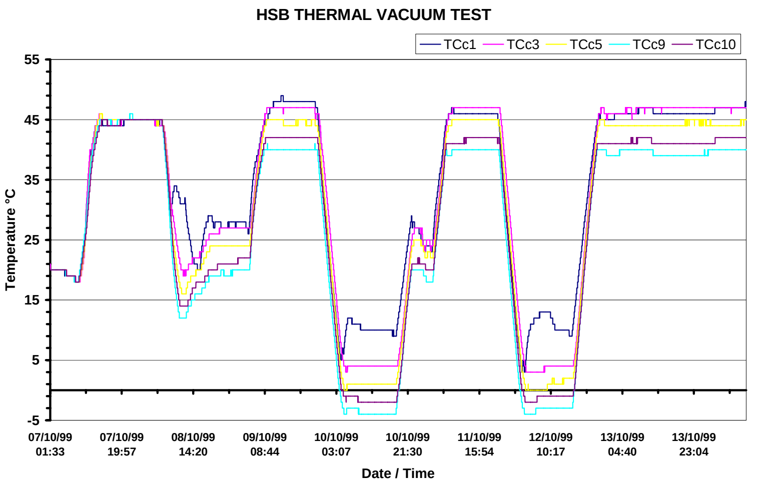

Figure 13. Temperature Profile developed in the HSB Instrument.

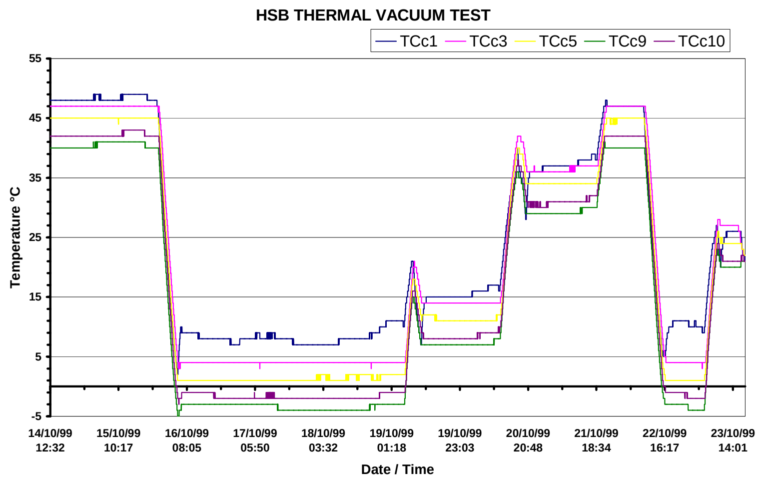

Figure 14. Temperature Profile developed in the HSB Instrument.

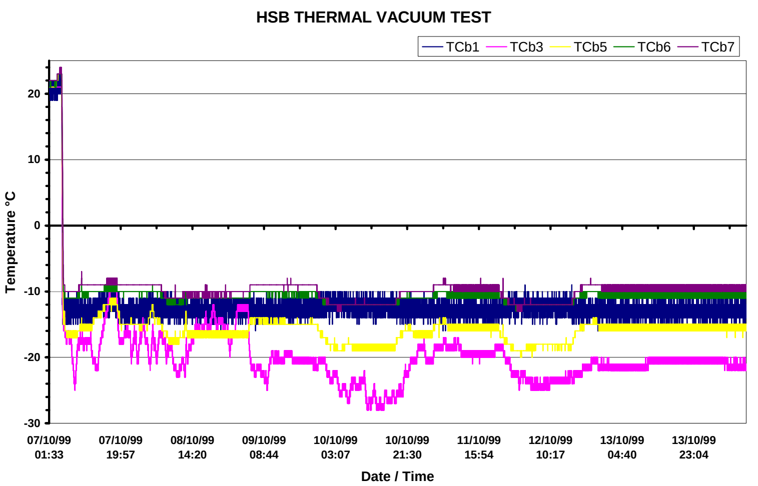

Figure 15. Temperature Profile developed in the TQCM.

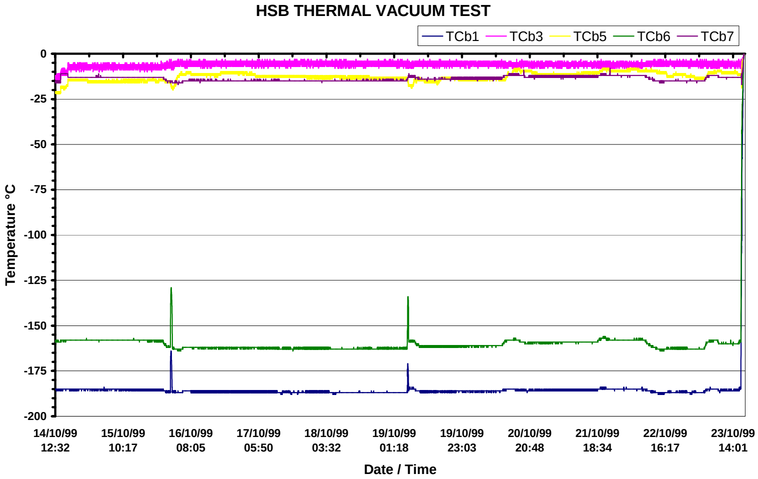

Figure 16. Temperature Profile developed in the TQCM.

The maximum environmental pressure requirement was of 10^{-5} Torr, but the vacuum developed during the test stayed at a very low level (much lower than specification).

4. Contamination Analyses

Three methods were implemented for monitoring the contamination during the HSB thermal vacuum test and calibration, as follow:

- Thermoelectric Quartz Micro Balance (TQCM);
- Witness plates;
- Wipe test.

TQCM was supplied by NASA (manufacturer: ITE Inc.; type: Faraday). Two TQCM sensors were used to monitor the contamination deposits during all activities phases. The locations of these sensors were:

- TQCM Sensor #1: located at aperture of the HSB, with a heat sink #1 and one liquid nitrogen cold trap;
- TQCM Sensor #2: located at vent of the HSB, with a heat sink #2, without any trap.

The temperatures of the heat sinks #1, #2 were held close to -10ºC, and LN2 cold trap held close to -175ºC (Figures 15 and 16 present above, respectively). It was achieved by using of three controllers plus one power supplier to warm up, and LN2 feeding to cool down. An electronic module plus one computer performed the acquisition of the two TQCM sensors. Figure 17 presents this set-up.

Figure 17. Thermoelectric Quartz Micro Balance Set-Up.

Also, a bake-out of the Electrical Ground Support Equipment (EGSE) was performed before the TVT and HSB calibration. The two TQCM sensors were used to certificate the thermal vacuum chamber to know firstly, its out-gassing background. During this phase, the two TQCMs had been located in the same position that they were for the HSB Thermal Vacuum Test and Calibration. The EGSE bake-out was driven by NASA guideline, which was previously transferred to LIT thermal vacuum staff. Following this guideline, the values adopted for thermal vacuum chamber out-gassing backgrounds were:

- TQCM#1: 90 Hz/h
- TQCM#2: 110 Hz/h

During the Thermal Vacuum Test, the HSB out-gassing verification was also driven by the same NASA guideline. Following this, TQCM frequency (i.e. Hz/hr) was bellow than 230 Hz/hr for 5 consecutive hours (this value was deducted the chamber out-gassing background, verified firstly during the EGSE bake-out). These figures are considered very nice representing a very high degree of cleanness or very low level of contamination.

Also, the witness plates and wipe test analyses were fulfilled after the HSB test. These methods confirmed that the level of contamination, met for TVC and Calibration, was much below of the NASA´s requirement.

5. Conclusion

It was performed a space simulation of a payload of one more important and complex satellites, which has already been designed (AQUA Satellite). The activities involved five different times from three countries (U.K., U.S.A. and Brazil). All procedures were followed by NASA's team (supervision of the Goddard Space Flight Center staff). The test conditions imposed to payload, developed temperature profiles very close to predicted for orbital life, increasing the confidence of the HSB thermal control design. All necessary boundary conditions for the HSB calibration were obtained with success, which allowed performing a very reliable calibration. The bake-out fulfilled (before the test) showed the good condition of the LIT thermal vacuum chamber and guaranteed the cleanness of the set-up (inside of NASA's standards of contamination). For the LIT/INPE thermal vacuum staffs, the best conclusion was the relationship among the staffs from different nationalities and the exchange of technologies among them, related to a high technology subject, so important for Brazil.

6. References

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