FIRST STEPS OF THE INFRARED SIMULATION DEVELOPMENT BY TUNGSTEN FILAMENT LAMPS.

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Abstract. *This paper deals with the development and manufacturing of a radiometer plate to be used in space simulation tests of space systems to measure of absorbed heat flux imposed by a Tungsten Filament Lamp. The radiometer plate is composed of an aluminum plate (670x550 mm), on which 56 radiometers are placed, black painted square copper plates (39x39x0,6 mm). On each radiometer a thermocouple was installed on the opposite surface to that being measured and these were isolated from the aluminum plate by nylon strands (∅0,20 mm) MLI (isolating shrouds). In order to install the lamp a vertical rod was placed at the center of one of the extremities of the aluminum plate and to this rod a horizontal rod was connected which made it possible to place the lamp in the corner position. The principal results were obtained in a high vacuum environment (≅ 10^{-7} Torr) in a 1x1 m thermal vacuum chamber. To guarantee that the thermal loads emanated only from the lamp, the chamber was kept at a temperature of –180^0C. Several tests were carried out which fixed the height of the lamp to the plate with varied ranges of power (251, 299, 330, 375, 399, 453, 500 W). The Laboratory's data acquisition system was used to obtain the temperature data of each radiometer. This system handles 500 measuring channels with acquisition at 30 seconds intervals. From this information the heat fluxes are calculated and presented in the form of graphs. From the results obtained it was possible to evaluate the absorbed heat flux for each radiometer and discover a wider distribution field of the incident radiation from the lamp.*

Keywords*: radiometer plate, tungsten filament lamp, space simulation, absorbed heat flux, thermal vacuum chamber*

1. Introduction

The basic aim of Space Simulation (SS) is to qualify the satellite, or a given spacecraft device so that these may operate reliably in space. The simulation techniques differ from one another basically according to the experimental arrangement used in the imposition of the heat source and the space background. The main techniques are: Solar simulation (the use of a simulator equipped with Xenon lamps), as described by Nuss (1987); Tungsten Filament Lamps (TFL), which operate in the near infrared range (Messidoro et al., 1983); Heating Plates (Cardoso and Garcia, 1989); Skin Heaters (Ramos et al., 1988); A combination of techniques, as presented by, Braig et al., (1988). The skin heater and heating plate techniques are applied in the far infrared radiation spectrum, which is out of the solar spectrum range, to which a given satellite is exposed to during its orbital life. The use of solar simulation is the most adequate because of the closeness of the solar spectrum; however, the high cost of a simulator is not viable in the light of the present Brazilian economic situation. For this reason, Tungsten Filament Lamp (TFL) simulation, where the high tungsten filament temperature (2.500 K) and high heat radiation transmission of the filament package (quartz) produces a spectrum closer to that the solar spectrum (Messidoro et al., 1983), has become an attractive alternative. In order to develop this space simulation technique which uses tungsten filament lamps as a source of thermal radiation, the Laboratory of Integration and Tests (LIT) thermal vacuum test group has projected and manufactured an experimental apparatus which consists of a radiometer plate and a Tungsten Filament Lamp, Research Inc. 500T3/CL. This apparatus made it possible to study the behaviour of these lamps in terms of uniformity and intensity. Preliminary tests of flux and uniformity were carried out at Laboratory environmental conditions. The principal results were obtained in a high vacuum environment (≅ 10^{-7} Torr) in a 1x1 m. thermal vacuum chamber. In order to guarantee that the thermal loads emanated only from the lamp, the chamber was kept at a temperature of –180^0C. Several tests were carried out altering the power of the lamp. In order to measure the temperature data from each radiometer, the LIT data acquisition system, which handles 500 measuring channels with acquisition at 30 seconds intervals, was used. From this information the heat fluxes are calculated and presented in the form of graphs. From the results obtained it was possible to evaluate the power of the lamp, which provides the best distribution of absorbed heat flux by a space system thermal control surface.

2. Experimental apparatus

In order to study the behaviour of these tungsten filament lamps in terms of intensity an experimental apparatus was set up (Fig. 1), which consisted of a radiometer plate and a lamp and reflector set. The radiometer plate is composed of an aluminium plate on which 56 radiometers are placed. In order to install the lamp a vertical rod was placed at the center of one of the extremities of the aluminium plate, which made it possible to place the lamp in several positions.

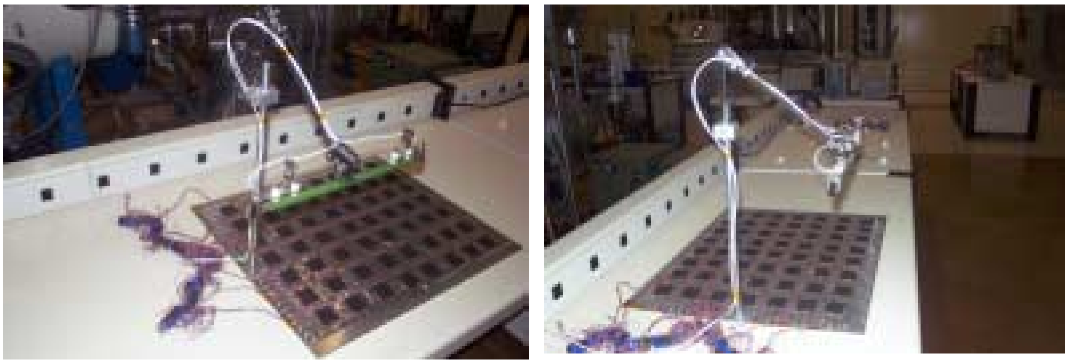

Figure 1: Experimental apparatus.

2.1. The radiometer plate

The radiometer plate, Fig. 1, is composed of a rectangular aluminium plate 670 mm long by 550 mm wide, on which 56 radiometers were placed, along with black painted square copper plates (39x39x0.6 mm), (PU1 MAP with 50 μm thickness, ε=0.884 and α=0.898). On the opposite side to that being measured, a thermocouple was installed on each radiometer. These radiometers were thermally isolated from the aluminium plate by nylon strands (∅ 0,20 mm) and MLI (isolating shrouds). The assembly of the radiometers on the plate, along the x-and **y-** coordinates, follows a spacing of 70 mm in relation to the center of each radiometer . The radiometers were produced in LIT/INPE, which has specialized tools available for the production of MLI, machining, measurement of optical properties and a contamination analysis laboratory and painting facilities.

The principle steps in the production process of the radiometer plate is as follows (Fig. 2): Production and coating of the aluminium plate and MLI; attachment of the nylon strands; manufacturing of the copper plates (radiometer sensors); painted black on the measuring side (carried out at the Painting Laboratory LIT, which guarantees the same conditions and characteristics as satellite surfaces); attachment of the thermocouples to the back of the copper plates (the same technique employed when testing satellites during Space Simulation tests is used); precision assembly of the radiometers on the aluminium plate (precision bonding of the radiometers to the nylon strands so there is no contact between any of them, consequently minimizing losses.).

Figure 2: Manufacturing process of the radiometer plate.

2.2. Tungsten filament lamp

In order to establish an exact position for the lamp and reflector (5236.5 golded reflector) set in relation the radiometer plate, a mechanical device for positioning the lamp was devised (Fig. 3). This device is made up of: a vertical circular rod with an articulation joint soldered to the center of one of the extremities of the aluminium plate; and a articulated arm with two (2) degrees of freedom (x and y), composed of circular rods, spheres and articulation joints. The third degree of freedom of the device (z) is performed by the attachment of the arm to the articulation joint of the vertical rod. In this way it was possible to vary and guarantee the position of the lamp. Figure 4 shows the positioning of the lamp in relation to the radiometer.

Due the filament package (quartz) to have a high heat radiation transmission, its influence was not considerate in this work.

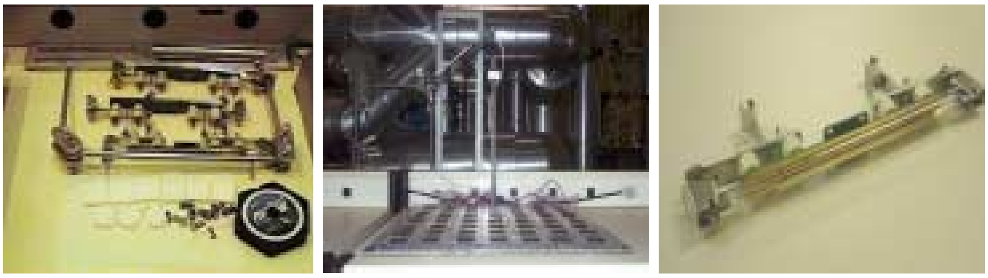

Figure 3: Lamp arrangement device.

Specification of the lamp used in the apparatus and experimental test is as follows:

Type	500T3/CL Research Inc, Tungsten Filament Wire, T3 Quartz Lamp
Overall Length	224(mm)- 8.81 (inches)
Lighted Length	127(mm) 5 (inches)
Rated Voltage	120 V
Current at Rated Voltage	4.17Amps
Total Power Dissipated at Rated Voltage	500W
Average Life	5000 hours
Color Temperature	2500 K
Possible Corona Region in Dry Air	None
Brightness	Bright White
Usual Size, Inches (mm)	0.375 or Dia. Tube(9.525)
Usual Range of Peak Energy Wavelength	0.89 to 1.5 Microns
Radiation	72 to 86%
Convection	28 to 14%
Relative Response to Heat-up	Seconds
Relative Response to Cool-down	Seconds
Mechanical Shock	Good
Thermal Shock	Excellent

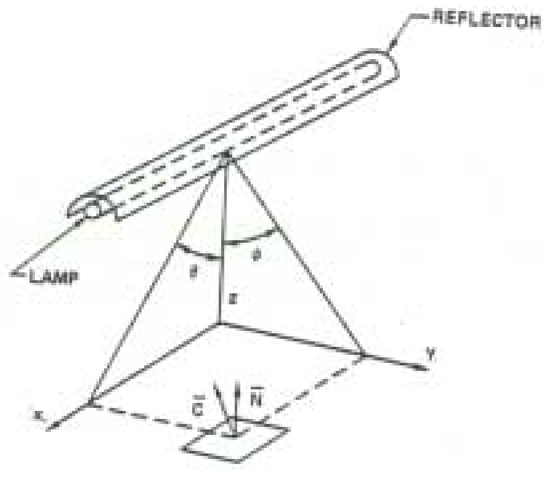

Figure 4: Positioning of the lamp.

3. Experimental test

In order to discover how the lamp acts as a source of thermal radiation in terms of intensity some experimental tests were carried out using the LIT 785 liter thermal vacuum chamber. For the purpose of obtaining a wider distribution field of the incident radiation the lamp was placed on the radiometer plate in a position so that its corner coincided with the center of the radiometer plate. Figure 5 shows the arrangement used during the experimental test.

Figure 5: Experimental arrangement.

During tests the thermal vacuum chamber was kept at high vacuum ($\cong 10^{-7}$ Torr), and to guarantee that the thermal loads originated only from the lamps the chamber was kept at a temperature of -180^{0}C. Several tests were carried out varying the power of the lamp. A Tectrol DC power source of 1000W was used to control the power, and 56 thermocouples TT-T-30, HP 3054 scanner and a Pentium 166MMX computer were used to obtain temperature data from each of the radiometers. The LIT data acquisition system handles 500 measuring channels with acquisition at 30 seconds intervals.

4. Results

Values of intensity and the distribution field of the heat flux absorbed by a radiometer plate imposed by a tungsten filament lamp were obtained by carrying out experimental tests which fixed the position of the lamp in relation to its coordinates (x, y and z) and at the same time varying the power of the lamp. The lamp was positioned at a distance of 35 cm from the tested radiometer plate using different power of 251, 299, 330, 375, 399, 453, 500 Watts. The relative position of each radiometer on the plate was designated by the coordinates x and y, whose origin is 0,0 at the corner of the plate. Figure 6 shows the position of each radiometer.

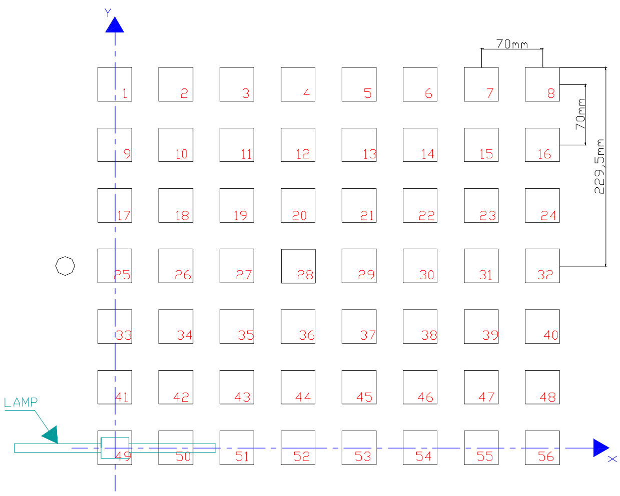

Figure 6: Positioning of the radiometers.

The center of the lamp was kept in a central position in relation to the corner of the radiometer plate (position 0,0), so as to guarantee a better analysis of the wider incident radiation coming from the lamp. Once the temperatures, emissivity of each radiometer was known, it was possible to calculate the absorbed heat flux using Eq. 1, which considers that the heat flux the radiometer emits is equal to that which it absorbs from the lamp taking into consideration that the heat losses are negligible.

$$\alpha I = \varepsilon \sigma T^4 \quad (1)$$

Figures 7, 8, 9,10 and 11 show the results of the intensity and distribution of absorbed heat flux (αI) by the radiometer plate for a given height (H) and power (P).

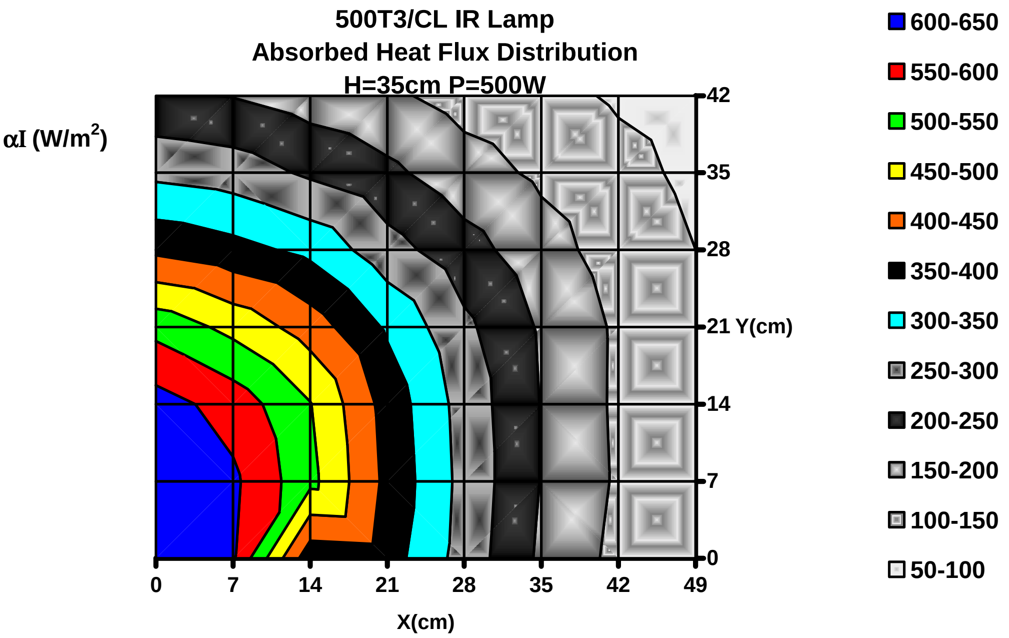

Figure 7: Absorbed heat flux in the radiometer plate for P=500W.

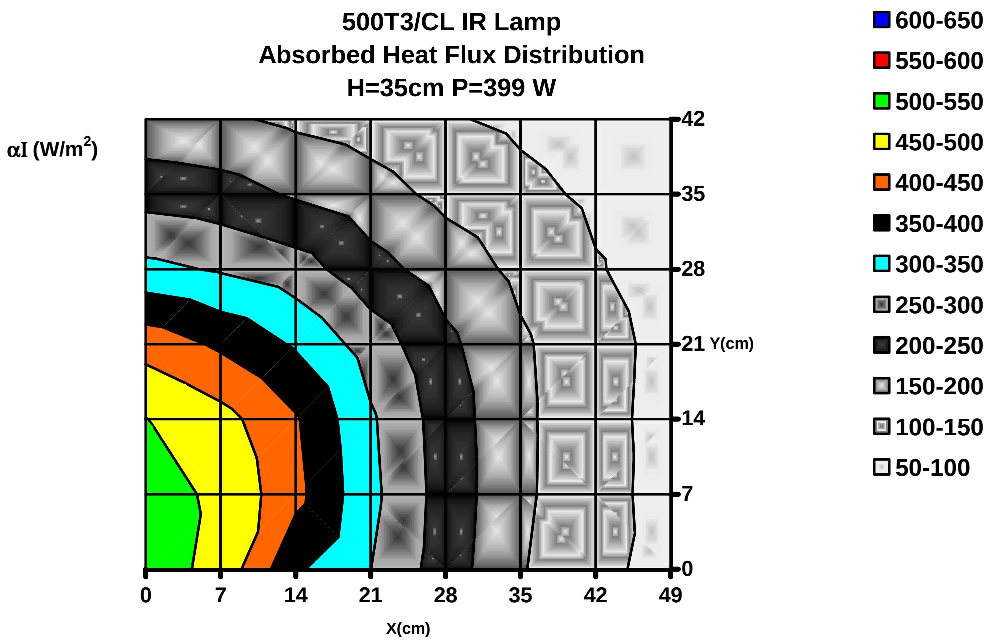

Figure 8: Absorbed heat flux in the radiometer plate for P=399W.

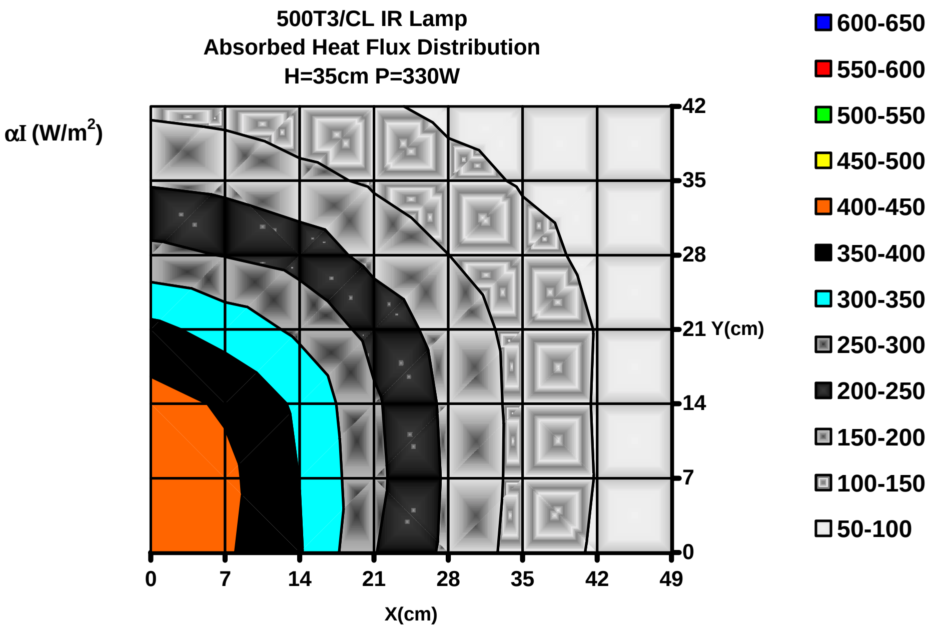

Figure 9: Absorbed heat flux in the radiometer plate for P=330W.

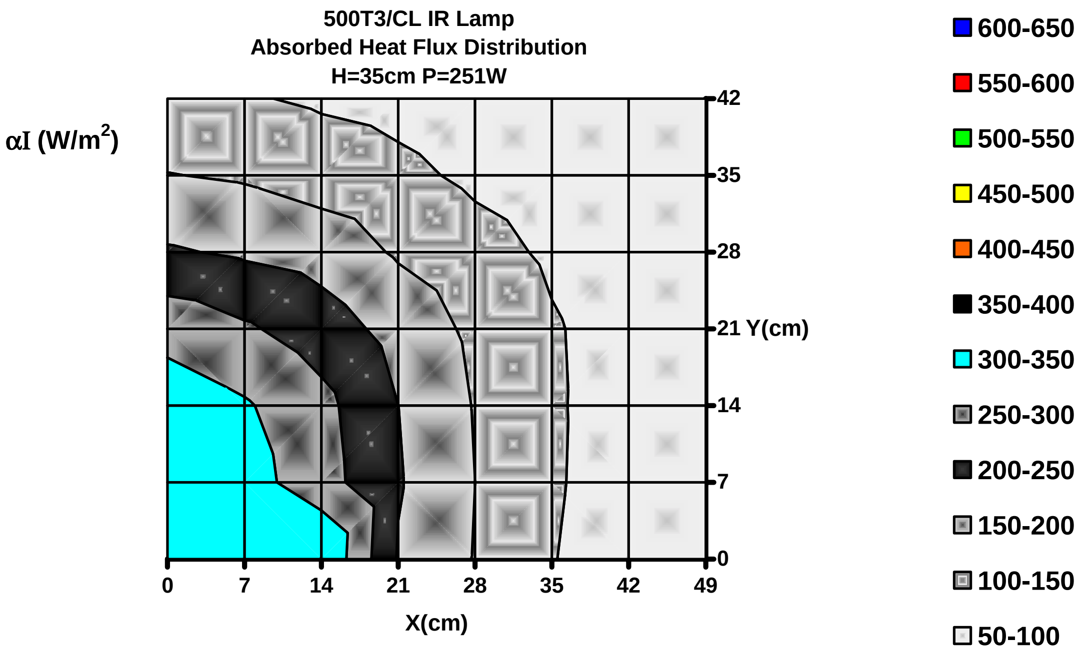

Figure 10: Absorbed heat flux in the radiometer plate for P=251W.

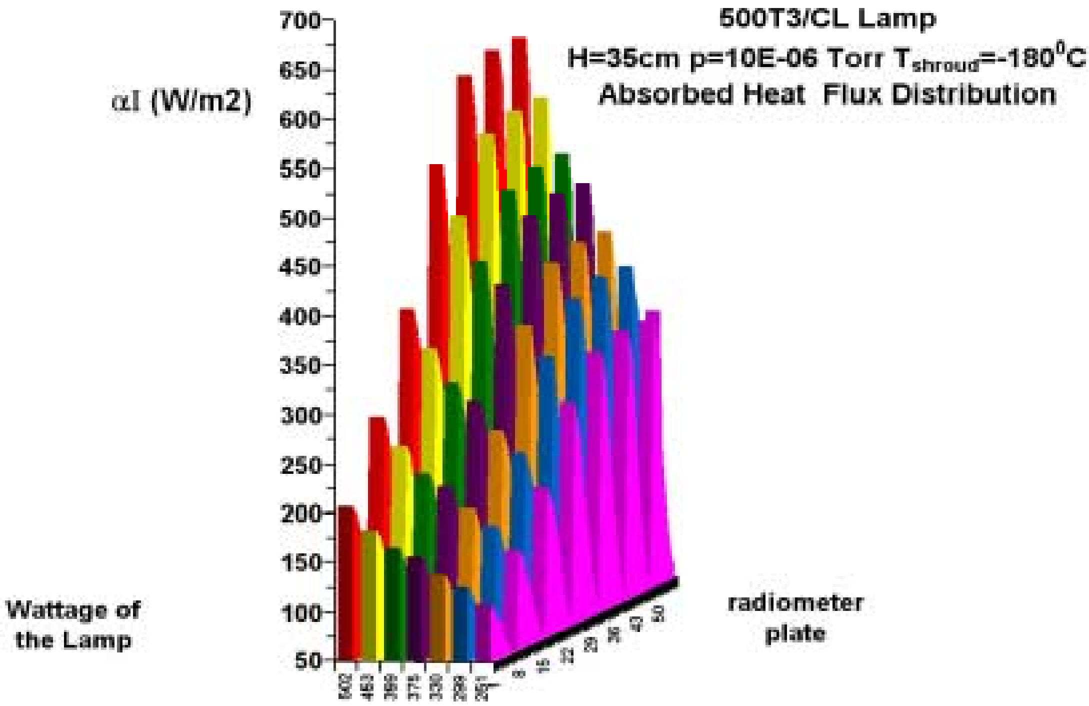

Figure 11: Absorbed heat flux in the radiometer plate in function of the power of the lamp for H=35cm.

5. Conclusions

Carrying out an analysis of the results it was possible to conclude the following: the positioning of the lamp in one of the corners of the radiometer plate allowed the lamp to obtain a wider incident radiation distribution field. Also, it was possible to determine the quantity (amount) of the energy radiation from the lamp and how far it could travel. These characteristics give the necessary conditions to use this technique as external thermal loads for space simulation of spacecraft. The high temperature of the lamp filament and small blockage of the heat sink give the good conditions to performance a simulation with reliability and low cost.

As this work was, essentially, to develop a experimental method, the next steps will be to develop a computational program, based on heat radiation theory coupled with experimental correlation, to predict the number of lamps, the necessary geometry and power of each group of lamps to simulate the main test cases for the predicted spacecraft life.

6. Acknowledgements

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7. References

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