ANALYSIS OF THE UNIFORMITY OF HEAT FLUX FROM A SETUP OF TUNGSTEN LAMPS

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Abstract: This paper deals with a test that simulates a model of lamp arrangement after a numerical study. The test was carried on in a 1 x 1 m thermal vacuum chamber using a setup of four tungsten filament lamps, radiometers, power supplies, controllers and aluminum baffles. These radiometers are made by aluminum in cylinder format with a copper black sensor, which they are isolated from the main bodies. The lamp behavior was previously known by another test, which the main goal was to quantify the intensity lamp radiation on a given surface. Based in the results obtained, it was made a numerical method to simulate the heat flux from two or more lamps. Using extrapolation and theoretic behavior obtained from the lamp manufacturer, a numerical method to obtain uniformity heat fluxes on a larger surface was developed. Only in the borders, the uniformity values were different from the average. To increase the uniformity and refine the method, aluminum baffles (reflect surfaces) had been used in this setup. The final result was the analysis of the uniformity of the heat flux, to improve the model and to find a standard model. This final model is hoped to be used to simulate the IRA´s (infrared radiator areas) of CBERS-2B Satellite, to latter make the setups of each IRA and to fulfill a Thermal Balance Test, to simulate the space conditions that its will be suffer. This test will be necessary to qualify the satellite to flight.

Keywords: *tungsten filament lamp, aluminum baffles, space simulation, radiometers.*

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 ar e 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 (2500 K) 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, thermal-vacuum test group of the Integration and Testing Laboratory (LIT) has projected and manufactured an experimental apparatus which consists of a some radiometer, aluminum baffles and a array of four Tungsten Filament Lamps (model 500T3/CL) from company: Research Inc. The behavior of the lamp are known through one another experiment in LIT which if it observed that how much bigger the height of the lamp in relation the area, more uniform, as well as how much lesser the power of the lamp. Using the numerical results of this experiment was found a setup t o get a heat flow uniform. It was observed that the edges of the simulated area presented an inferior value of flow to central parts. In order to increase the value of the flow in the deficient region, the idea was to use reflecting surfaces, called baffles. In this manner, the energy radiated by lamps that did not arrive at the area in study, is reflected for itself. The objective of this work is to show the importance of these baffles to get a uniform flow in a determined area. The apparatus uses aluminum plates as baffles, radiometers, four lamps with support and power suppliers. Preliminary tests were carried out at laboratory atmospheric pressure conditions. The principal results were obtained in a high vacuum environment ($\cong 10^{-7}$ 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^{0}C. Several tests were carried out altering the wattage of the lamps. 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 analyzing the influence of baffles in the rise of the flow in the borders as in remaining of the area reached for the radiation. The next step of this study would be to simulate new setup with the lamps in order to confirm the results obtained in this experiment. With this, we would have conditions to create a model of simulation for any requirement, as much of area as of heat flow.

2. Experimental apparatus

In order to analyze it influences of the baffles in the flow of heat in a determined area, was used a described apparatus below (Fig. 1):

- Four aluminum plates with black paint in external surface and covered internally with aluminum leaf, in order to increase the reflector effect of this surface, and settled in order to form a box without upper and downer surfaces;

- Fifty radiometers constituted of a copper plate (sensors) with black paint in external surface and a thermocouple in internal surface. These sensors are fixed in the aluminum body through small supports of Teflon with rip. To isolate the internal part of the body of radiometer an isolating blanket (Multilayer Insulation – MLI) was glued in the inferior part;

- The lamp had been fixed in a steel support that is only supported in the box of baffles for possible changes. The symmetry of setup helped in the confection of these supports.

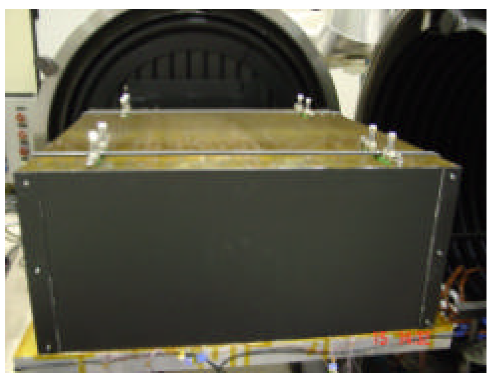

Figure 1: Experimental apparatus.

2.1. The radiometer arrangement

The arrangement of radiometers, Fig 2, is constituted of 50 units, having been each one formed by three parts: aluminum body, isolating parts, sensor and thermocouple (Fig 2 – top/left). The aluminum body (Fig 2 –top/center) is a cylinder with holes to put the telfon isolates parts, to fix the radiometer on a plate, to making vacuum inside and to facility the passage of electrical wires and thermocouple. The sensor is thermal radiation isolated from the inferior body base by MLI (which it is adhered in this base). The sensor is a circular copper plate ($\varnothing$ = 35 mm, thickness = 0.6 mm), black painted on the superior face (space qualified paint, model PU1 MAP with 50 μm thickness, ε = 0.865 and α = 0.898). On the sensor opposite side, to make temperature measurements, a thermocouple was installed on each one (Fig. 2 – center part). These radiometers were thermally isolated from the aluminium body by three Teflon points, which were fixed in the aluminum body (Fig. 2 – right top). The radiometers were produced in LIT/INPE, which has specialized tools to fabricate MLI, machining, to measurement of thermo-optical properties and to perform contamination analysis. This lab has painting facilities, too.

The main steps, in the production process of the radiometers, are the following (Fig. 2 – middle and top parts): a) manufacturing of the copper circular plates (radiometer sensors); b) black painting on sensors (carried out at the LIT Painting Laboratory, which guarantees the same conditions and characteristics of the satellite surfaces); c) production of MLI; d) manufacturing of aluminum body with Teflon isolation putting; f) MLI adhering; g) attachment of the thermocouples to the back sensor (the same technique is employed when satellites are tested in Space Simulations); h) precision assembling of the sensors in the Teflon cylinder isolations (precision bonding of the sensor to the Teflon isolations because they have to have a minimum contact among them, consequently minimizing heat losses.).

After preparing all 50 radiometers (as described above), the setup preparation was fulfilled. The radiometers were placed over a base plate, which were protected by an adhered Kapton film (size 1x1m).

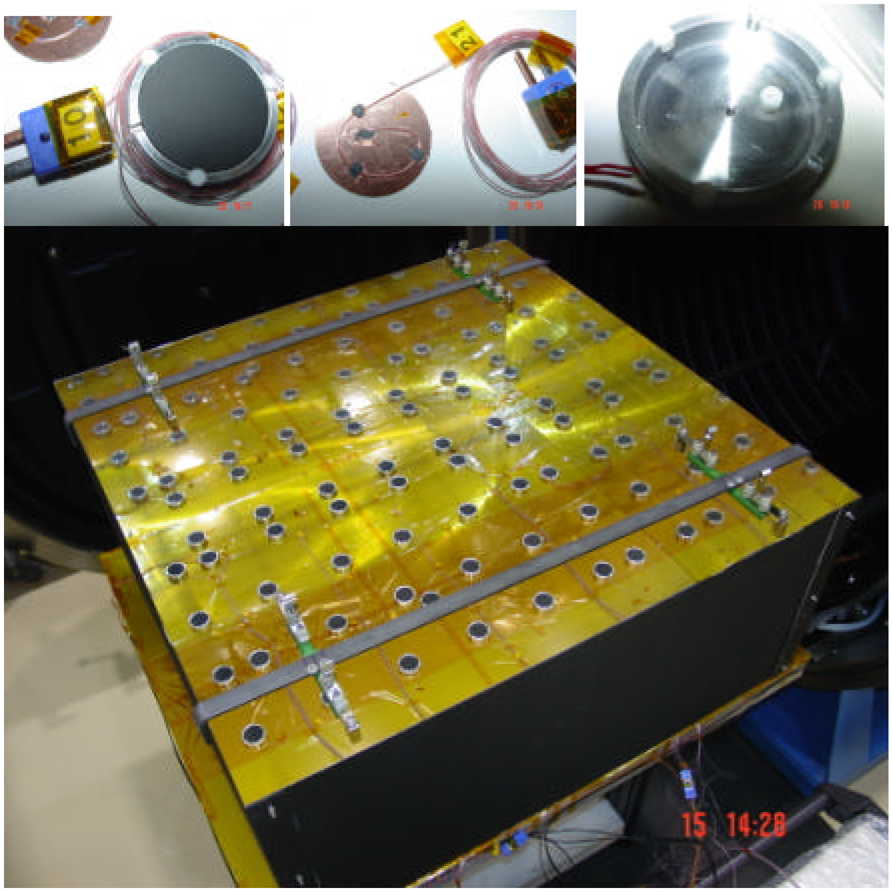

Figure 2: Bottom: view of the setup: radiometers, base plate, lamps and support. Top: phases of the manufacturing radiometer process.

2.2. Tungsten filament lamp

In order to establish an exact position for the lamp and reflector (model 5236.5 golded reflector) set in relation the radiometer plate, a mechanical device for positioning the lamp was assembled (Fig. 3). In this way, it was possible to vary and guarantee the position of the lamps. Figure 4 shows the positioning of a lamp in relation to a given radiometer.

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%
Relative Response to Heat -up	Seconds
Relative Response to Cool-down	Seconds
Mechanical Shock	Good
Thermal Shock	Excellent

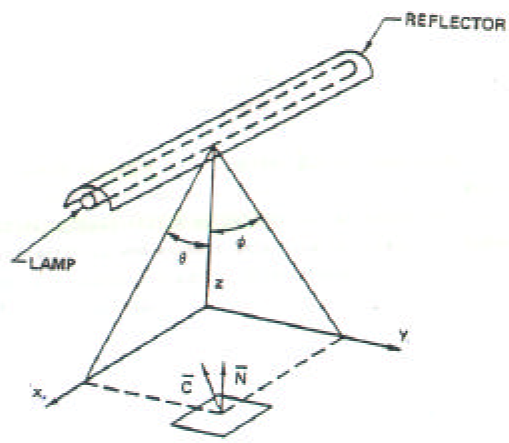

Figure 4: Positioning of the lamp in relation to a radiometer.

3. Experimental test

In order to analyze how the baffles influences the heat flux from an array of lamps as a source of thermal radiation in terms of uniformity, some experimental tests were carried out using the 1x1m LIT thermal vacuum chamber. The apparatus was fixed, not needing to be modified during the fulfillments of the experiments. The necessary changes are the voltage and the chain of the power suppliers (one for each lamp), whose those feed the lamps. It is considered that all electric energy are absorbed by lamps, in order to be able to calculate the value of the power of lamp through the values of measured chain and voltage in the proper source.

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 equally the wattage of the lamps. A Tectrol DC power source of 500W, Fig 6, was used to control the wattage, 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.

Figure 6: Power supply (one for each lamp).

4. Results

Values of absorbed heat radiation field (measured by radiometers and radiation sources from tungsten filament lamps) were obtained by carrying out experimental tests. Positions of the lamps were in agreement with Fig. 7. The distance of the lamps from the radiometer base plates (height) was fixed in 400 mm. The tests are carried out using following lamp powers (P): 497, 317, 168, 88 and 30 Watts.

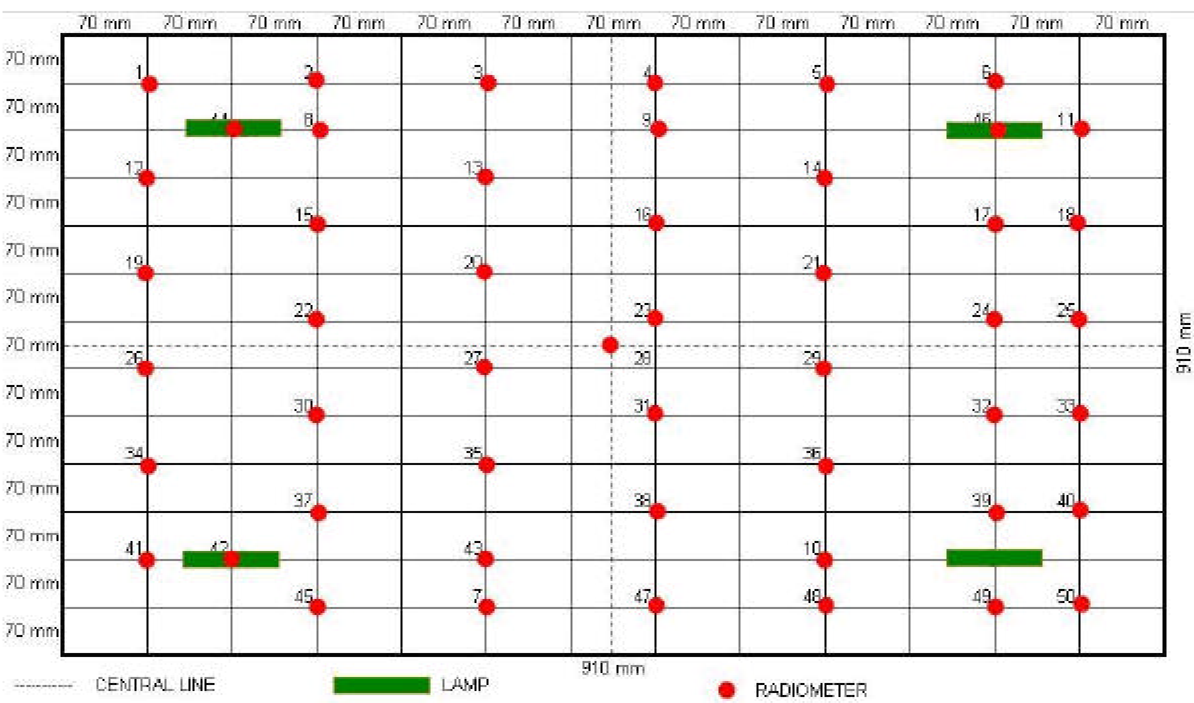

Figure 7: Positioning of the radiometers (green color: position of lamps; red: positions of radiometers).

Once the temperatures were obtained (emissivity of each radiometer was previously measured), it was possible to calculate the absorbed heat flux using Eq. (1). It considers that the radiometer emits a heat flux (to cryogenic thermal-vacuum chamber shroud) equal to absorbed heat radiation, from the lamps. This consideration implied to say that the heat losses are negligible.

$$\alpha \boldsymbol{I} = \varepsilon \sigma \boldsymbol{T}^{4} \qquad (1)$$

Figures 8, 9,10, 11 and 12 show the results of Absorbed Heat Radiation Flux by each radiometer for a given lamp wattage (P).

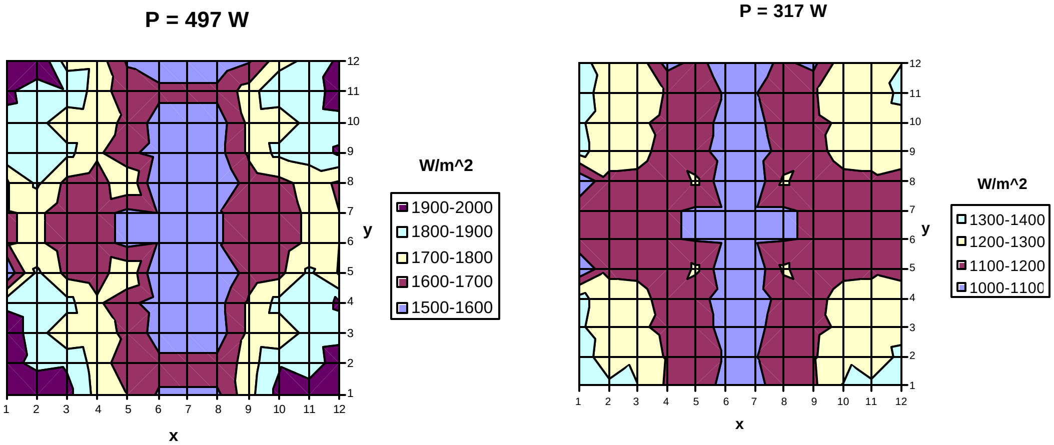

Figure 8: Absorbed Heat Radiation (W/m^2) in the radiometer plate for lamp power P = 497W (left) and P = 317 W (right).

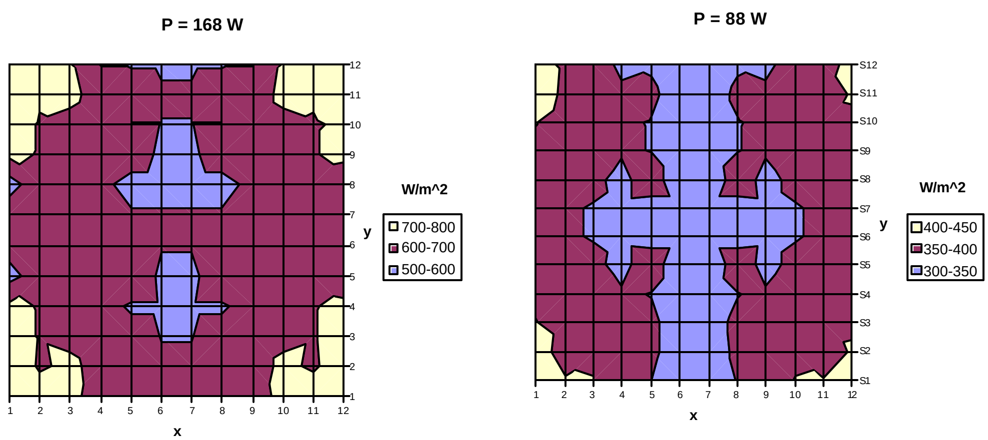

Figure 9: Absorbed Heat Radiation (W/m^2) in the radiometer plate for lamp power P = 168 W (left) and P = 88 W (right).

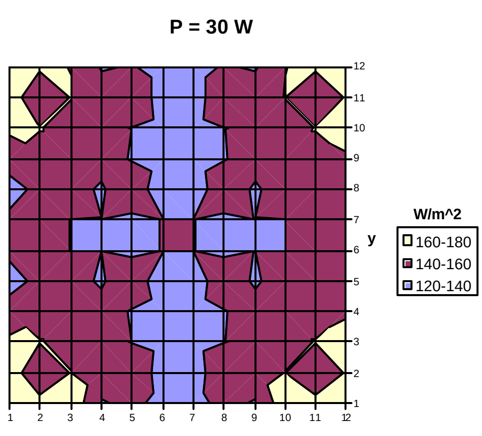

Figure 10: Absorbed Heat Radiation (W/m^2) in the radiometer plate for lamp power P = 30 W.

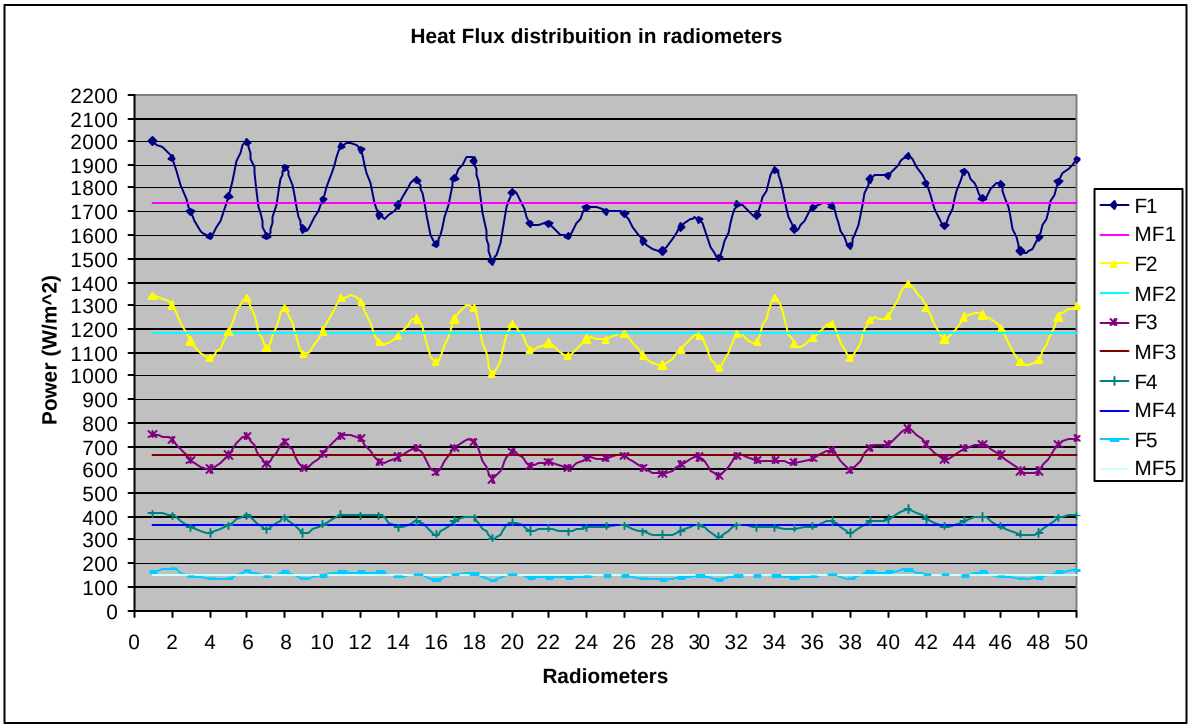

Figure 11: Distribution of radiometer temperature in each power imposed for the lamps (F1 = 497, F2 = 367, F3 = 168, F4 = 88 and F5 = 30 W).

Table 1: Average of temperature values and average error for the five values of lamp power.

Power (W)	*Heat Flux (W/m²)*	*Average error (%)*
497	*1735,73*	*6,78*
317	*1185,56*	*6,65*
168	*659,29*	*6,49*
88	*363,26*	*6,81*
30	*148,14*	*6,60*

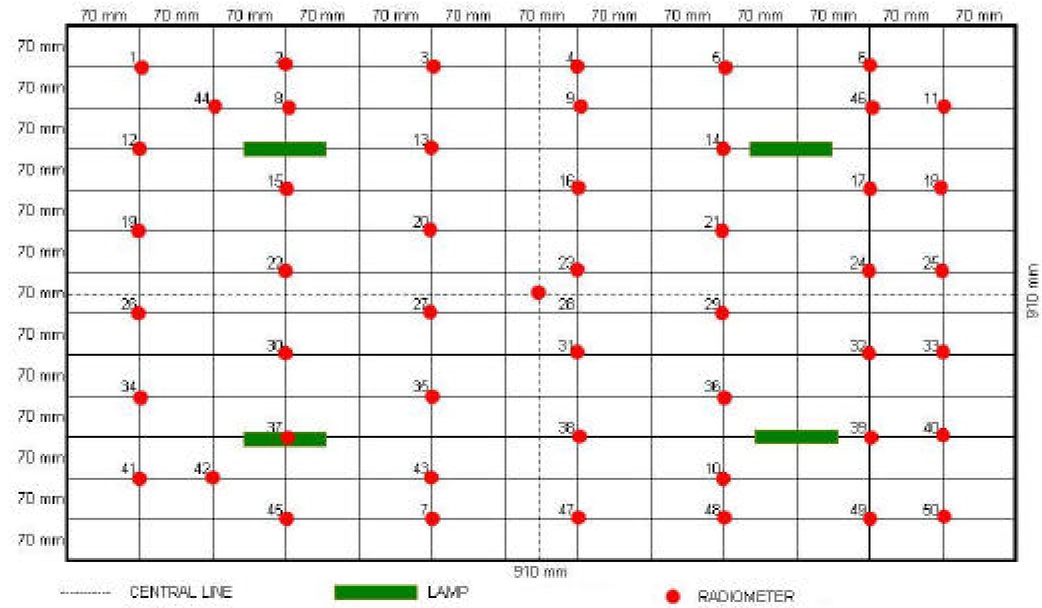

Figure 12: Suggested device to improve the uniformity of the heat flow.

5. Conclusions

The main result of the work was the influence of the baffle in the heat flux from tungsten's lamps. The results had shown a considerable uniformity, therefore it presented a small error, between six and seven per cent. The conclusion of these results drive us to fulfill the future works, as following: a) we have to change of the setup, in order to put lamps closer of the center positions; b) analyze the influence of base plate thermal emission to baffles, which can reflect back to radiometers; c) identify theoretical correlations to develop a computation model which could be useful for development of space simulation of satellites.

6. Acknowledgements

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7. References

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