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HEAT FLUX CALIBRATION FACILITY CAPABLE OF SSME CONDITIONS

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There is a need to more thoroughly characterize the hostile space shuttle main engine (SSME) turbopump environment. It has been estimated that component surface heat flux in the hot-gas environment is about 10 MW/m^2, and this is about 50 times that encountered in aircraft engines. Also, material temperature transients can be as high as 1000 K in about 1 second. These transients can cause durability problems such as material cracking. Heat flux sensors placed in the turbopump components can partially characterize this environment by measuring surface heat flux. These heat flux data can be used to verify analytical-stress, boundary-layer, and heat-transfer design models.

Preliminary plans were discussed at the first SSME durability conference for designing and fabricating a new facility for the calibration and durability testing of prototype heat flux sensors for the SSME (ref. 1). This facility is necessary for assessment of new heat flux gauge concepts needed in the hostile SSME turbopump environment.

CALIBRATION FACILITY

Figure 1 is a photograph of the calibration facility. A 100 kW Vortek arc-lamp and Anorad high-speed positioning system are shown positioned in the test cell. A Hewlett-Packard 900-236 minicomputer is located in a control room behind the control room window shown in figure 1. The interrelation of calibration facility components is schematically presented in figure 2. The minicomputer is used to control a microcomputer built into the arc-lamp power module. The same minicomputer also controls a microcomputer located in the positioning system apparatus. Prototype heat flux sensors are placed at desired positions in the arc-lamp beam. Thermocouples attached to the heat flux sensor produce voltages which are scanned and read in a multiprogrammer and then stored in the computer. Calculation of heat flux is then performed using the stored voltages after they have been converted to temperature readings.

ARC-LAMP ACCEPTANCE TESTS

The Vortek arc-lamp system design is described in reference 1. Figure 3 presents a comparison of heat flux measurements made in the Lewis facility and previously on an identically designed arc-lamp located in the Vortek facility. (Although the Lewis facility was not completed at this time, there were sufficient apparatuses available to make the test.) The same water-cooled heat flux sensor was used to perform both measurements. The agreement of heat flux data obtained with the two lamps (fig. 3) is satisfactory and demonstrates an ability to repeat the heat flux within experimental error. Heat flux measurements and calibrations in the Lewis facility will also be compared with calibrations of radiant heat flux sources at Case Western Reserve University and Pratt and Whitney. The comparisons are part of a grant with Case Western Reserve University to develop a credible basis for heat flux calibration at high heat flux loads.

TRANSIENT HEAT FLUX MEASUREMENT AND ACCURACY

It is not feasible to use commercial water-cooled heat flux gauges on SSME turbine surfaces because these gauges are too big and water cooling is not practical. Therefore, heat flux gauge design must be reinvestigated with particular emphasis given to minimally intrusive instrumentation - possibly thin-film or miniature plug-type sensors. To aid in design, a transient heat flux prediction model for heat flow with variable thermal properties has been analytically and experimentally developed. The model characteristics were studied using transient temperature data taken with heat flux gauges designed at Lewis Research enter for flux measurement in rocket engines in 1960 (ref. 2). This study is guiding the design of heat flux gauges for SSME and suggests that SSME heat fluxes can be measured with an accuracy of about ±1 to 20 percent.

REFERENCES

1. Liebert, C.H.: Heat Flux Sensor Calibrator. Structural Integrity and Durability of Reusable Space Propulsion Systems. NASA CP-2381, 1985, pp. 195-198.

2. Liebert, Curt H.; Hatch, J.E.; and Grant, R.W.: Application of Various Techniques for Determining Local Heat Transfer Coefficients in a Rocket Engine From Transient Experimental Data. NASA TN D-277, 1960.

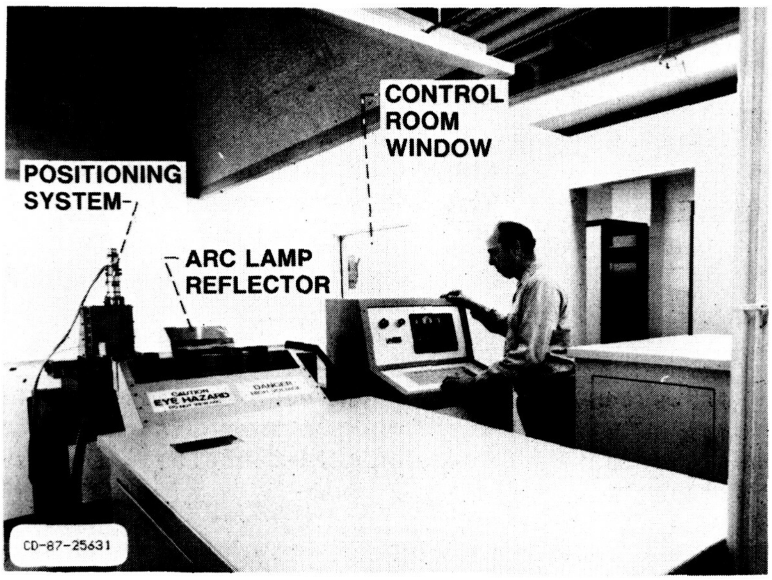

Figure 1. - View of calibration facility.

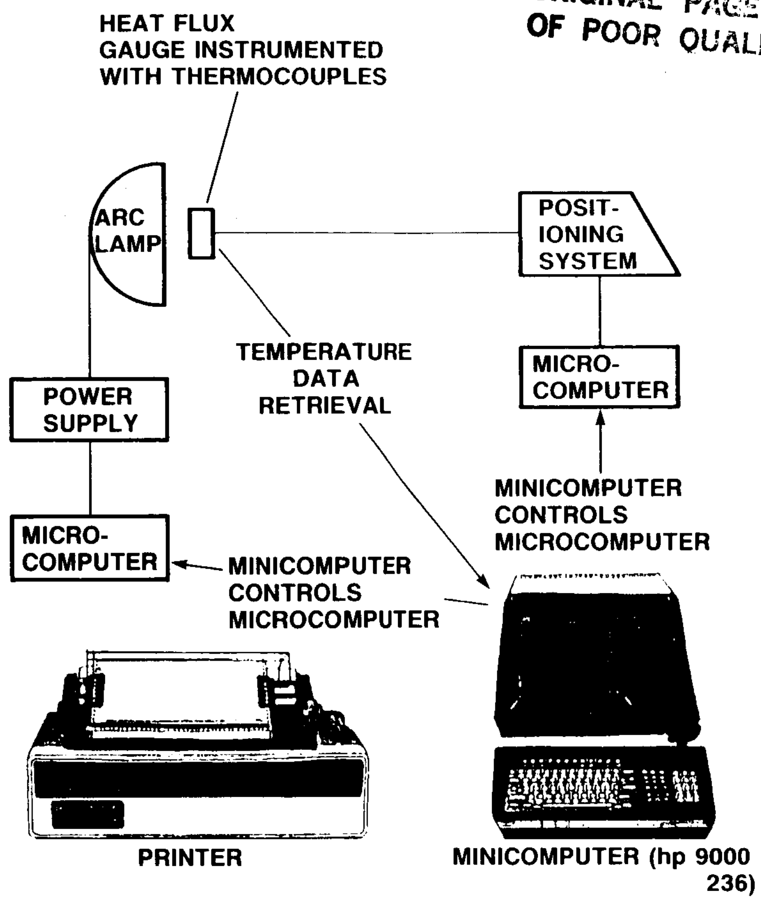

Figure 2. - Interrelation of calibration facility components.

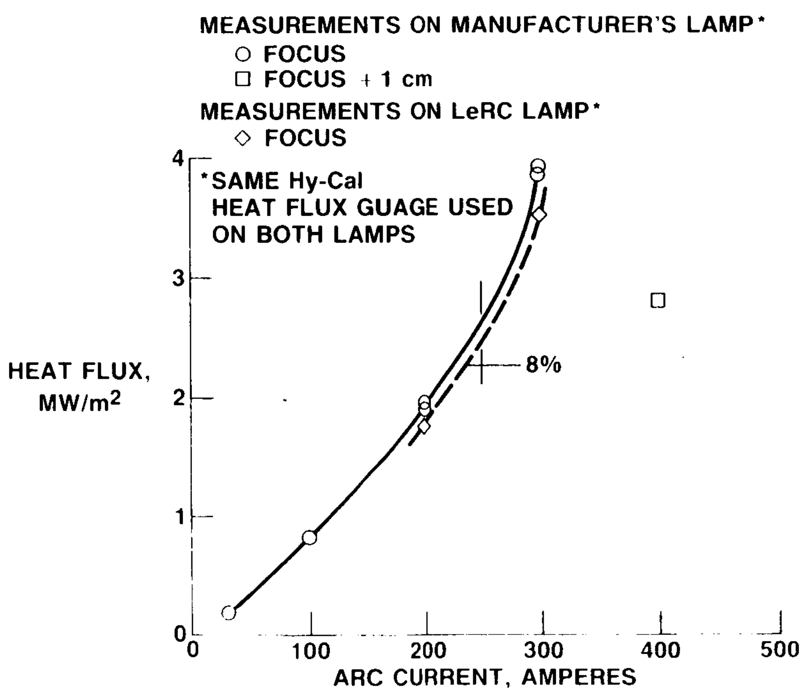

Figure 3. Comparison of heat flux measurements on manufacturer's lamp and Lewis lamp.