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INTEGRATION AND SOFTWARE FOR THERMAL TEST OF HEAT RATE SENSORS

FINAL REPORT

Contract NAS8-33522

Prepared for National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

by

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FOREWORD

This report presents final results of a study to develop and make operational a microcomputer controlled radiant heat lamp test fac' 'ty for the purpose of testing heat rate sensors and thermal instrumentati: development. The work was performed by Carl J. Wojciechowski, project engineer, of the Systems Engineering Section and Kenneth R. Shrider of the Instrumentation Development & Application Section of the Lockheed-Huntsville Research & Engineering Center under NASA Contract NAS8-33522.

The period of performance of this study was from July 1980 through 9 April 1982.

The NASA Contracting Officer's Representative for this contract was Mr. W. B. White, EC23.

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Section 1
INTRODUCTION

Instrumentation islands are installed aboard the Space Shuttle External Tank to measure thermal flight parameters during ascent. Analytical thermal models of these islands had to be verified and compared with ground test data in order to retrieve the valuable flight data. This situation created a need to conduct a test in a microcomputer controlled heat test facility. Lockheed assisted MSFC in performing these tests by: (1) developing and making operational a microcomputer controlled radiant heat facility; (2) providing software for the facility; (3) performing the facility calibration; (4) performing the ET island tests; (5) performing post-test calibrations, and; (6) reducing the data to engineering units and verifying the accuracy of the data. In addition, Lockheed-Huntsville provided a software package for the HP 9825 controller for development tests on the SRB actuator tail stock. The program recorded data (pressure, temperature, strain gage output and time) as specified and provides formatted output as required for data analysis.

Additional testing was conducted with the test facility to determine the temperature and heat flux rate and loads required to effect a change of color in the ET tank external paint. This requirement resulted from the review of photographs taken of the ET at separation from the Orbiter which showed that 75% of the external tank paint coating had not changed color from its original white color. The paint on the remaining 25% of the tank was either brown or black, indicating that it had degraded due to heating or that the Spray On Foam Insulation (SOFI) had receded in these areas.

This report contains a discussion of the development of the facility and its operational capability. It also discusses the various tests which were conducted and their results.

Section 2
TECHNICAL DISCUSSION

The effort under this contract was conducted basically in two phases. The first phase involved developing a microcomputer controlled radiant heat test facility. Calibration data for the Space Shuttle (SS) External Tank (ET) instrumentation islands were obtained using the facility. The software experience gained from developing this facility enabled Lockheed-Huntsville to provide software support, at minimal expense to MSFC, for the SS Solid Rocket Booster (SRB) actuator tail stock development tests.

The second phase of the effort involved conducting tests using the radiant heat test facility on ET foam test specimens to determine surface temperatures and heat flux levels required to char the surface paint finish.

2.1 FIRST PHASE EFFORT - INTEGRATION AND SOFTWARE FOR THERMAL TEST OF HEAT RATE SENSORS

The capabilities of the available GFE microcomputer components and test hardware were compared with the thermal test requirements. Several deficiencies were noted. Lockheed purchased and delivered to the test site in MSFC Building 4755, Room 122, the following items:

1. A 330 A, 277 V, ac single phase power regulator with voltage control.

2. An additional input data capability for the Hewlett Packard data acquisition system, in particular, a field installation kit for 20 additional channels.

The original GFE 10 in. by 10 in. lamp array which was not water cooled was deemed inadequate for the current test program. Therefore, Lockheed located within MSFC and acquired from Mr. Rick Bachtel, EP44, a 18 in. by 18 in. lamp bank array with water cooled reflectors for use in this test program. This new array is capable of long test times. The lamp bank array was refurbished as the array had not used for several years.

To simulate the cold propellant tank (heat sink) on which the ET instrumentation islands are mounted, MSFC furnished a liquid nitrogen (LH_2) tank with approximate dimensions of 39 in. by 41 in. by 13 in. Lockheed fabricated a test bed on which the lamp bank array and LN_2 tank was mounted. The entire test bed was designed to rest on a table under an overhead hood. NASA-MSFC provided a curtain enclosure to direct any smoke into the hood which may be generated during testing. The exhaust fan is capable of handling 50 scfm airflow, and provided an air exchange rate of twice a minute for the curtain entrained air.

A photograph of the completed test facility is shown in Fig. 1. Significant hardware components are called out on the photograph. Figure 2 is a closeup photograph of the ET island test area, and shows the ET instrumentation island installed on the LN_2 tank, the radiant lamp bank which is turned 180 deg and in the calibration position, the calibration test fixture which simulates the instrumentation island and the feedback control calorimeter. Figure 3 shows the MSFC-supplied LN_2 storage tank. As presently set up, with a lamp to target distance of 3 in., the lamp bank array is capable of applying a maximum heat rate of 12.8 Btu/ft^2-sec to the test sample. This level is more than adequate to accomplish the test objectives. The microcomputer is programmed so that it will control the heat rate output of the lamp bank based on the feedback calorimeter reading. The calibration plate consisted of a 1-in. thick phenolic plate with five water cooled calorimeters installed, one at the center, and four calorimeters at the identical ET instrumentation island locations. The

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

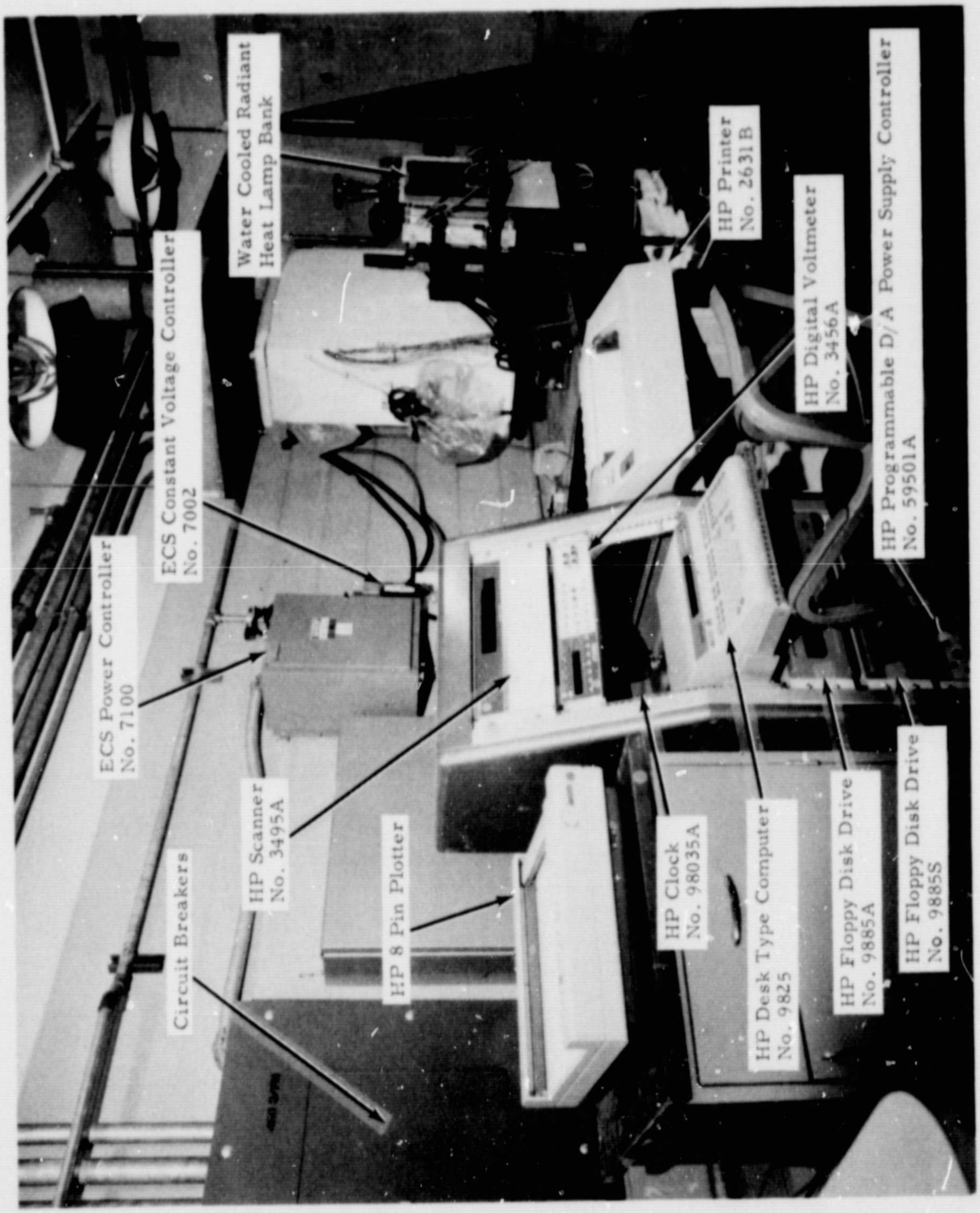

Fig. 1 - Microcomputer Controlled Radiant Lamp Test Facility

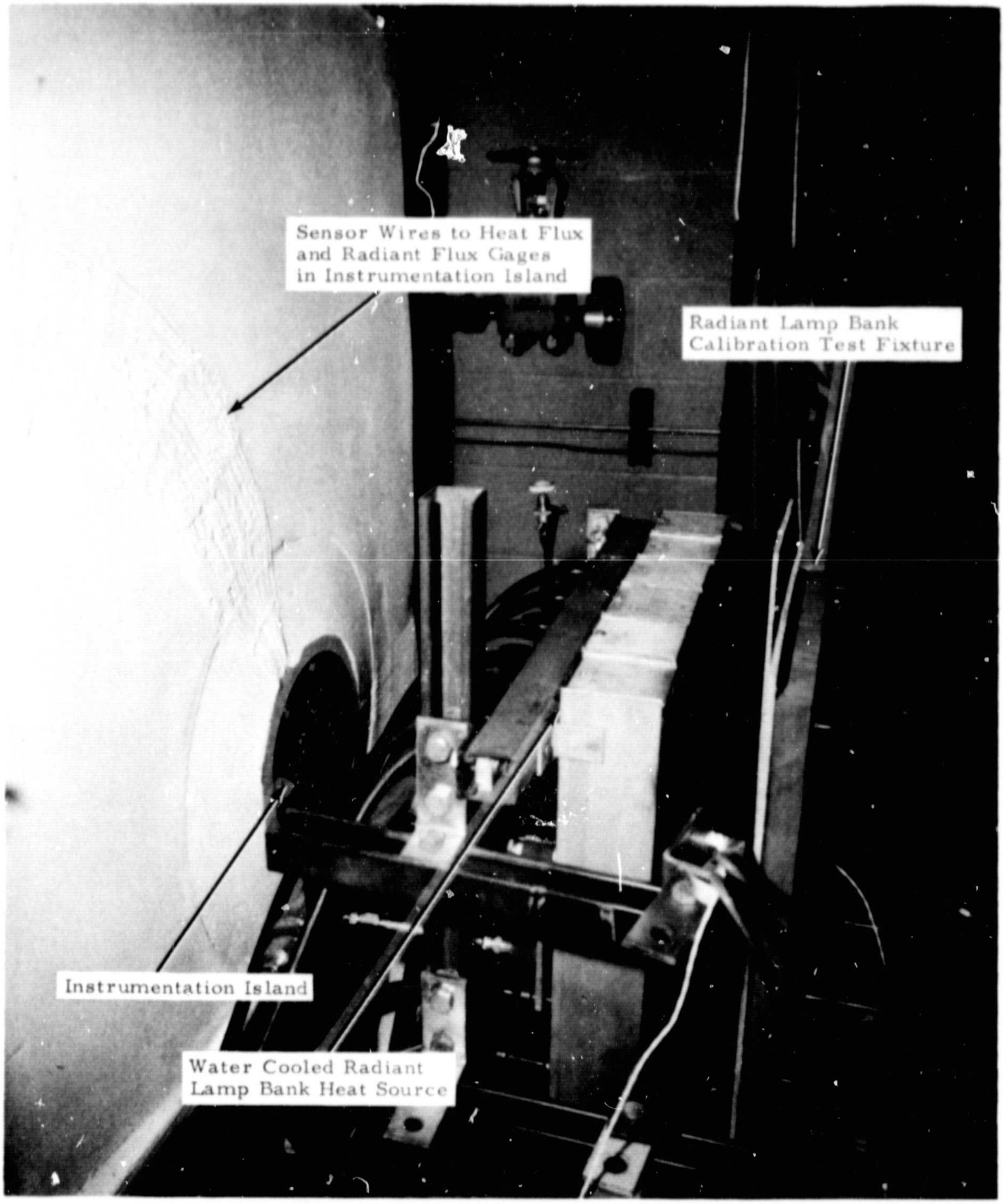

Fig. 2 - Photograph of ET Instrumentation
Island Installed on LN_2 Tank

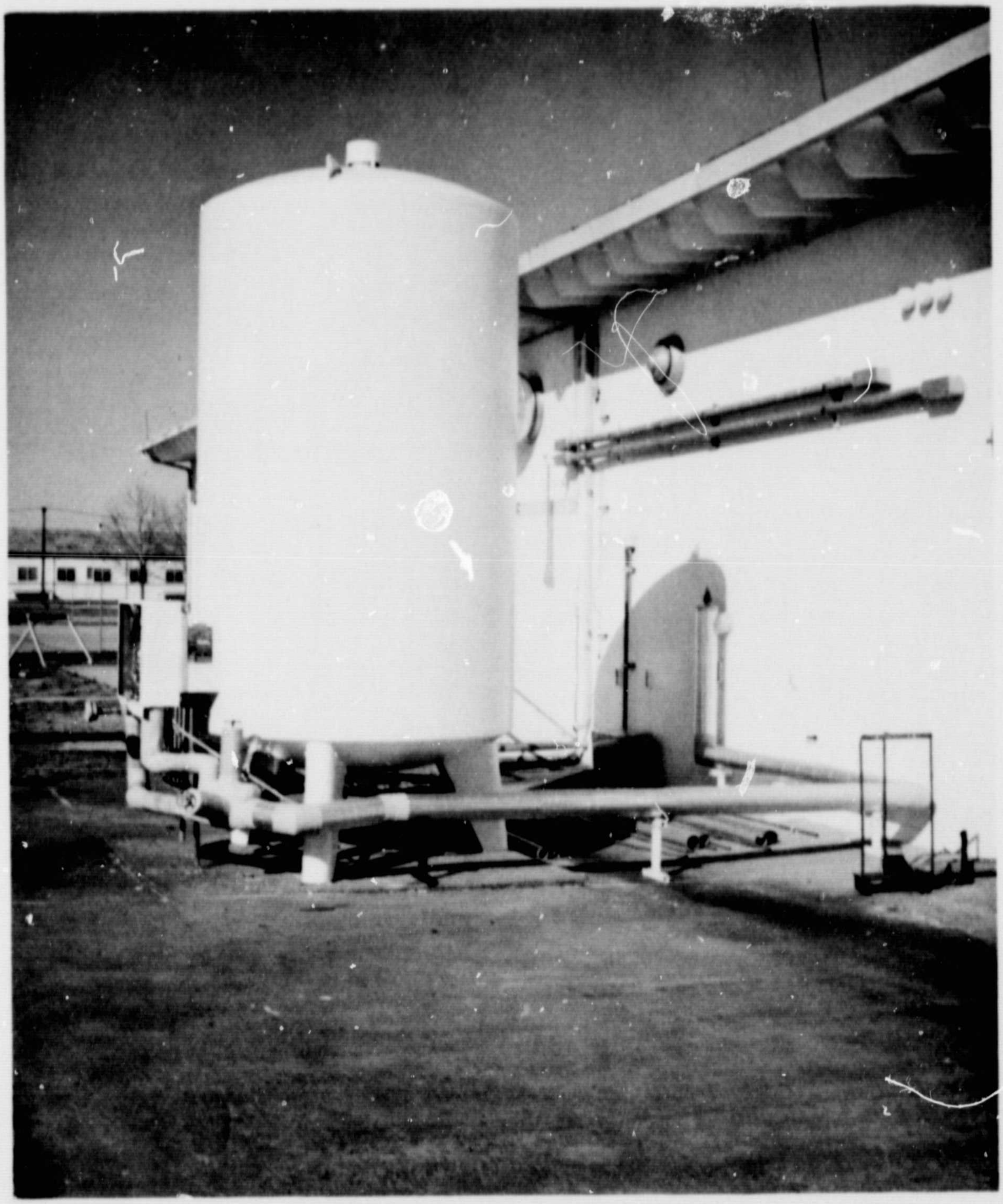

Fig. 3 - Photograph Showing LN_2 Storage Tank

position of the feedback calorimeter was adjusted and its signal gains also adjusted so that its indicated heat flux level was identical to the center calorimeter reading. Figures 4 through 6 demonstrate the ability of the lamp bank control computer to follow a prescribed heat flux time history. The dotted line on each figure represents the desired heat flux profile for the island center. The solid line indicates the actual heat flux profile obtained by the center calorimeter. The dashed line is the feedback calorimeter heat flux. All three figures show that the feedback reference flux is in close agreement with the center heat flux. The disagreement between desired and actual heat flux beyond 130 sec was considered inconsequential to the test objectives. The trajectory designation such as "21," "22" or "171" is decoded as follows, i.e., the last digit 1 or 2 indicates either nominal (1) or three-sigma dispersion (2), the other leading digits designate the island number (per NASA-MSFC).

Prior to performing these final calibrations, it was observed that two types of bulbs were used throughout the lamp bank array as evidenced by two levels of brightness. Additional bulbs were procured at MSFC, and the odd brightness bulbs were replaced.

2.1.1 Software for the Microcomputer Controlled Radiant Heat Test Facility

Lockheed supplied several specialized software programs for use in the test facility. A brief description of the test software is provided in the following paragraphs.

The software for this test facility does the following:

1. Controls the lamp bank to simulate the heat rate condition the island will experience in flight.

2. Obtains and records on disk, voltages from instruments on the island.

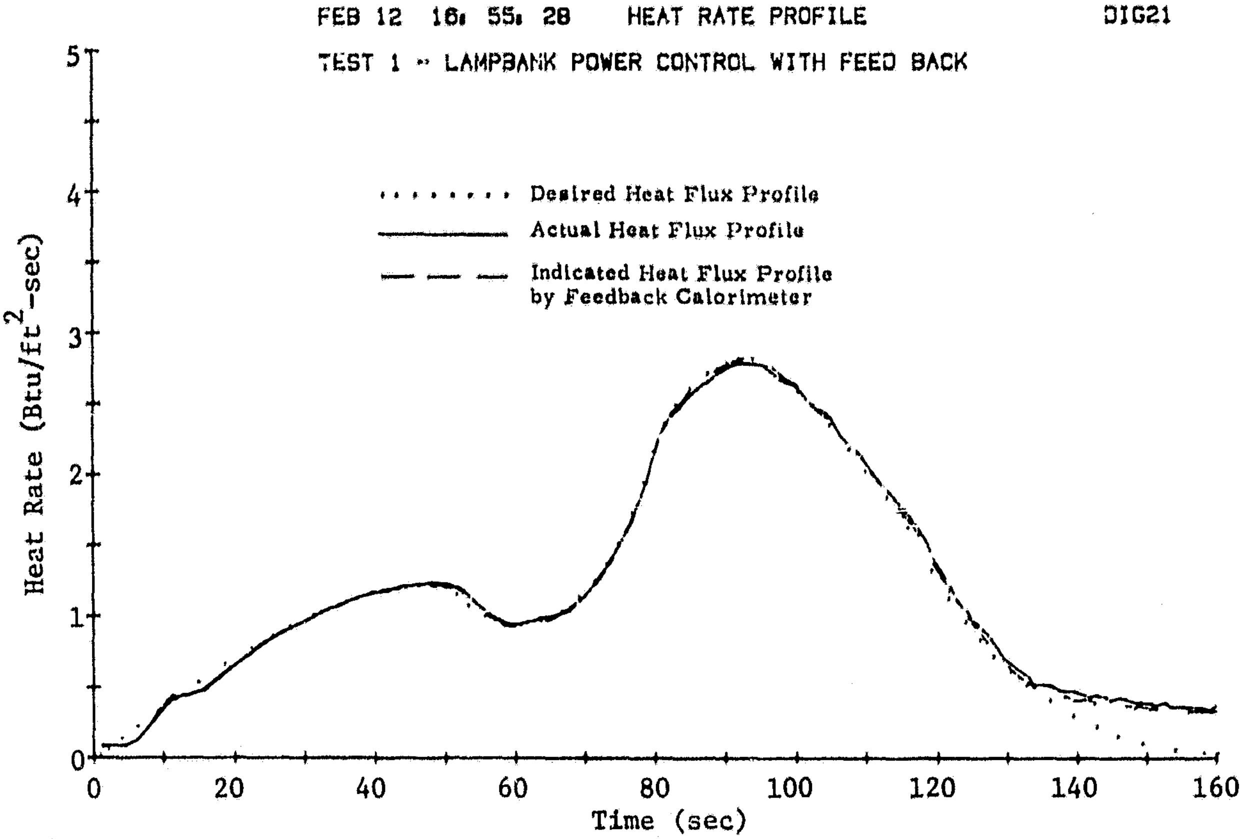

Fig. 4 - Heat Rate vs Time for Trajectory 21

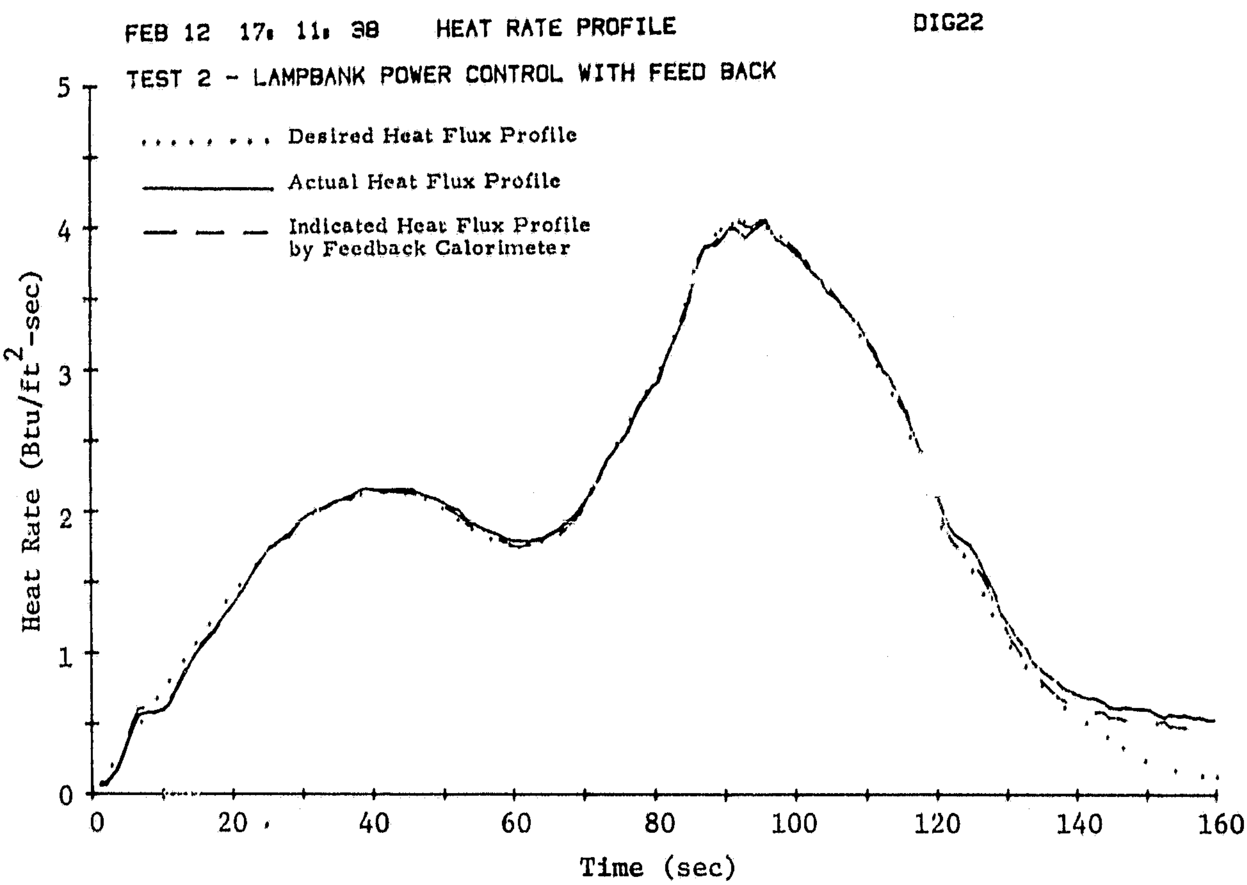

Fig. 5 - Heat Rate vs Time for Trajectory 22

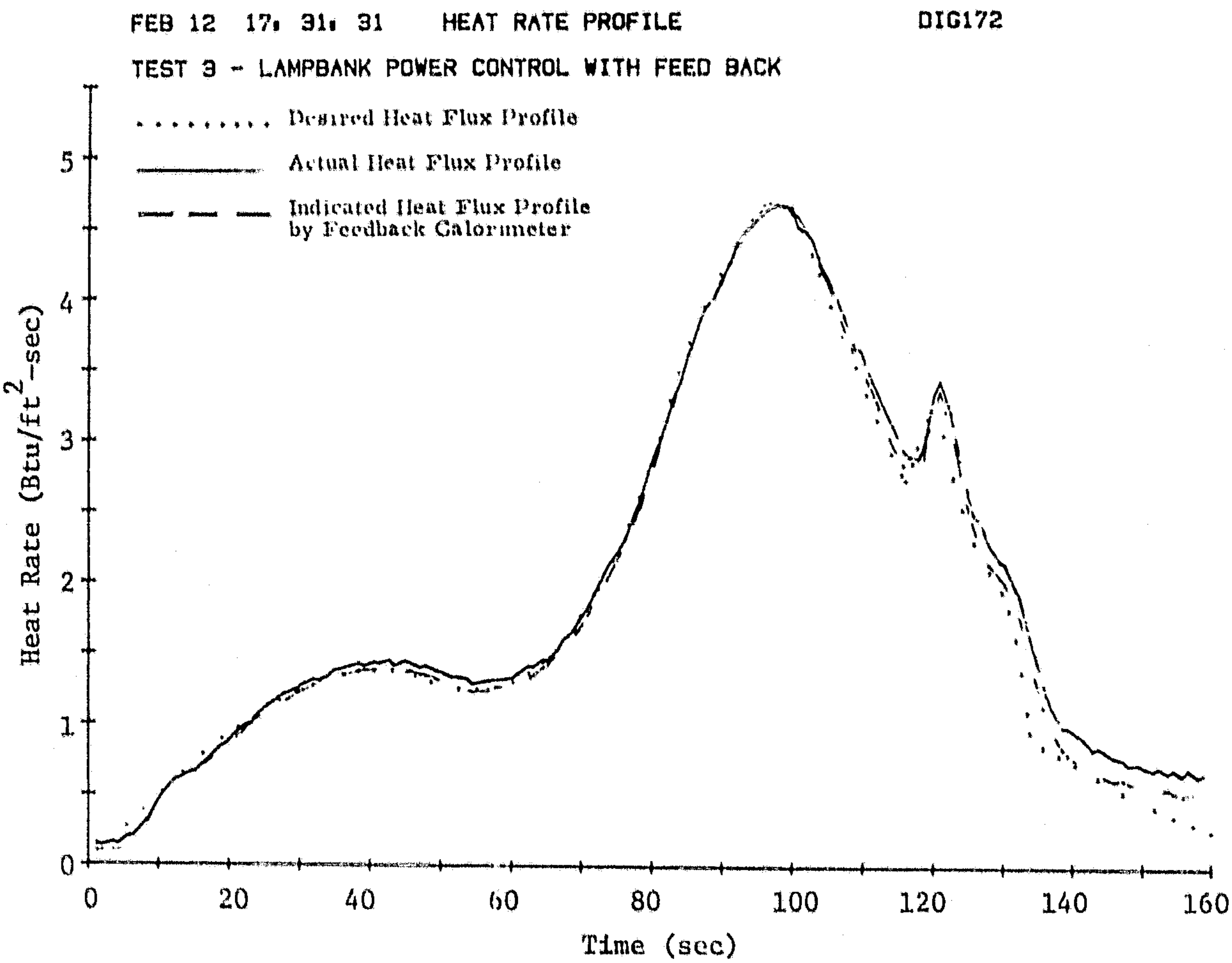

Fig. 6 - Heat Rate vs Time for Trajectory 172

3. Post test data processing.

4. Plots engineering data along with curves from the simulation code.

The data are stored using an analog-to-digital voltmeter, a scanner, a clock, and a flexible disk drive. Exercising the data acquisition program has determined that 22 is approximately the maximum number of data channels that can be recorded and stored in 1 sec. Therefore, for a 1-sec sample rate, no more than 22 data channels can be used.

A description of each of the software programs is given next.

DIGPT2

This program is used for digitizing data from a plot using the 9874A Digitizer. The data are then stored on disk. (The 9874A Digitizer does not work well when the plots are of a conducting medium such as pencil.) The heat rate profiles for controlling the lamps were digitized with this program.

DIGPT1

This program is used for digitizing data from a plot using the 9872A plotter. The data are then stored on disk. (Use of the 9872A plotter is slower than the 9874A digitizer but has no problem with plots of conducting medium such as pencil.) The heat rate profiles for controlling the lamps were digitized with this program.

PTDIG1

This program is used for plotting the digitized data. Data that were stored on disk by program DIGPT1 or program DIGPT2 are read and plotted on the 9872A plotter. The main purpose of this program is to verify the digitized data.

HEATR3

This program controls the lamp bank with steps in control signal and plots the heat rate as observed by two calorimeters. The operator signals the end of a step at which time the data are taken. The operator then keys in the next step in the control signal. The plot of the calorimeters is in the form of heat rate versus control voltage.

HTMR4

This program turns the lamp bank on at a prescribed control voltage for a period of 60 sec and then off for 60 sec. Data are taken every 0.5 sec for two calorimeters and plotted (heat rate versus time). The purpose of this program is to determine the time response of the heat rate to the control voltage at both the center of the island and the side where the feedback calorimeter is located.

FEEDB2

This program controls the lamp bank to follow a heat rate profile with the use of a feedback calorimeter. The prescribed heat rate profile, the heat rate used for feedback, and another measured heat rate are plotted versus time. The purpose of this program is to determine gain factors necessary for the program to force the lamp banks to follow the heat rate profile; also, to determine adjustment factors necessary for the feedback calorimeter to follow the heat rate at the center of the island.

FEEDA3

This is the main data recording program. It controls the lamp bank to follow a heat rate profile using the feedback calorimeter. While this is being done, all the instruments are read every 2 sec and the data stored on disk.

PRINT2

This is the main printing program. PRINT2 reads the data written on disk by FEEDA3. The raw data from the island are converted to engineering units and printed on the HP2631A line printer.

PLTD1

This is the main plotting program. PLTD1 reads the data written on disk by FEEDA3. Raw data from the island are converted to engineering units and plotted along with the simulation curves versus time. The plotting is done on the HP9872A four pen plotter.

FEEDB3

This program controls the lamp bank to follow a heat rate profile with the use of a feedback calorimeter. The prescribed heat rate profile, the heat rate used for feedback and five other measured heat rates are plotted versus time. The purpose of this program is to determine the sensitivity of heat rate due to position on the surface of the island. Five calorimeters are located in a pattern identical to the island pattern.

The program flow charts for all the above programs have been forwarded to Mr. W. B. White, EC23, under separate cover.

2.1.2 Test Plan for Calibration of the Heat Lamp Facility For Testing of ET Island Thermal Sensors

The original test plan that was used in the calibration phase of the test program is presented in Appendix A. The data obtained from this phase were valuable in developing the closed loop feedback control logic that is incorporated in the FEEDB2, FEEDA3 and FEEDB3 programs.

2.1.3 ET Instrumentation Island Tests

The ET instrumentation island test objectives were threefold. They were:

1. Investigate a procedure to obtain the Development Flight Instrumentation (DFI) calorimeter heat transfer coefficient on the ET where there are insufficient flight data.

2. Verify experimentally the results of an analytical model calculation to determine the calorimeter surface temperture.

3. Determine if experimental test could be used in conjunction with DFI data to obtain the calorimeter surface temperature.

The test objectives were accomplished with a series of six runs as specified in Table 1 on the following page.

Table 1

ET THERMAL SIMULATION TEST RUN SCHEDULE
per NASA-MSFC

Run No.	Island No.	STS-1 Trajectory	Remarks
1	30	Nom.	Very benign heat rate ($\dot{q}$)
2	4	Disp.	$\dot{q}$ twice run No. 1
3	2	Nom.	$\dot{q}$ higher and slope > run No. 1
4	2	Disp.	Highest $\dot{q}$ for cryogenic cooling
5	17	Nom.	No cryogenic cooling, similar to run 2
6	17	Disp.	No cryogenic cooling, highest $\dot{q}$ and slope

Lockheed's main function in these tests was to perform the tests as specified by NASA-MSFC and to verify the accuracy of the measured data.

After this was accomplished the measured data were turned over to Mr. W. B. White, EC23, for distribution. All of the planned ET island tests were run successfully. A post-test facility calibration was performed, and the results demonstrated to NASA-MSFC's satisfaction that the lamp facility is very repeatable to within 5% on heat rate. The variation of heat rate across the ET island surface was also less than 5%.

2.1.4 Software Package for the Development Tests on the SRB actuator tail stock (Amendment 1)

Lockheed supplied NASA-MSFC with a software package that consisted of a sequence of three HP 9825 computer programs for calibrating strain gages. The three programs are:

1. GAGE9 - This program is used to read and record strain gage output voltage, standard load cell output, pressure sensor output, power supply voltage and thermister temperature output. This program prints out the forces and raw data and records data on tape.

2. PAGE4 - This program reads the tape file written by GAGE9 program and prints and plots the data.

3. QUAD9 - This program plots the above data with a linear least squares curve fit of the data superimposed on the same plot.

2.2 SECOND PHASE EFFORT - ET FOAM PAINT TESTS

The effort under this phase consisted of conducting heat tests on ET foam specimens and reducing and analyzing the above data to determine surface temperatures, heat fluxes and heat loads required to discolor and char the foam surface finish.

The ET foam test specimens which were prepared by another vendor for this test were unacceptable in surface thermocouple instrumentation quality.

As a result Lockheed provided better thermocouple installation on the ET foam samples. The test plan called for installing five in-depth thermocouples at approximately 1/8-in. depth spacing and the use of a remote sensing surface temperature measuring instrument for the surface temperature data. The method which was used to install the in-depth thermocouples was to grind a 1/2-in. wide slot at the appropriate depth starting from one endof the specimen and terminating at the desired location near the center of the specimen. The remaining foam thickness could then be accurately measured before a 40-gage wire thermocouple was carefully placed in the bottom of the slot. The slot was then "foamed full" using the standard ET foam repair kit. The nominal thermocouple depths were 1/8, 1/4, 3/8, 1/2, and 5/8 in.

The lamp bank array and associated mounting hardware was reconfigured for these tests. For this series of tests, considering the low heat level desired and the additional requirement that surface viewing during testing was mandatory, a lamp to target distance of 12 in. was used. The 12-in distance was adjustable from 3 to 18 in. if required. In addition, a foam specimen holder had to be fabricated and mounted for ease of specimen installation. The calibration plate used in the first phase effort was cut down to match the specimen size so that it could be mounted in the same holder which was approximately a 12 in. square. The machined surface specimens were approximately one inch thick. The rough as-sprayed specimens varied in thickness from 1.25 to 1.50 in.

The test software requirements consisted basically of three separate programs. They were:

1. A calibration program which reads and plots the output from five calorimeters plus the reference calorimeter as a function of time and power level. The five calorimeters will be located in the test specimen area and will provide the heat rate distribution data in this area.

2. The on-line master test program which controls the incident heat flux to the specimen surface as indicated

by the reference calorimeter and the input heat rate versus time profile and records the data from six thermocouples and an infrared scanner.

3. The data reduction program which is an off-line program that performs three functions immediately after the test.
   a. Reduces data to engineering units.
   b. Generates analytical temperature results using a simple one-dimensional thermal model for comparison with the data at the surface and at various depths, and
   c. Plots the results for comparison purposes.

These software programs were assembled, installed and checked out on the computer at the test site.

The test facility was then recalibrated for the test configuration, i.e., lamp to specimen distance. During this calibration work it was discovered that the remote sensing surface temperature instrument was not functioning properly and was therefore not used.

2.2.1 ET Foam Test Results

The main test results obtained are summarized below.

1. The thermal model for the CPR 488 foam samples which have a painted surface must include the surface paint thickness in order to obtain agreement with test data. Thermal model results obtained are compared with the in-depth thermocouple data in Figs. 7 and 8. The thermal model used was a finite element model and not the simple one-dimensional model contained in the system software which could not handle the surface paint thickness. The analytical results shown in Figs. 7 and 8 were obtained using the Lockheed in-house PDP-11 computer. The two measured thermocouple depths of 0.3564 and 0.636 in. appear to be off when compared with the good agreement between analytical results and data at the other three depths. A

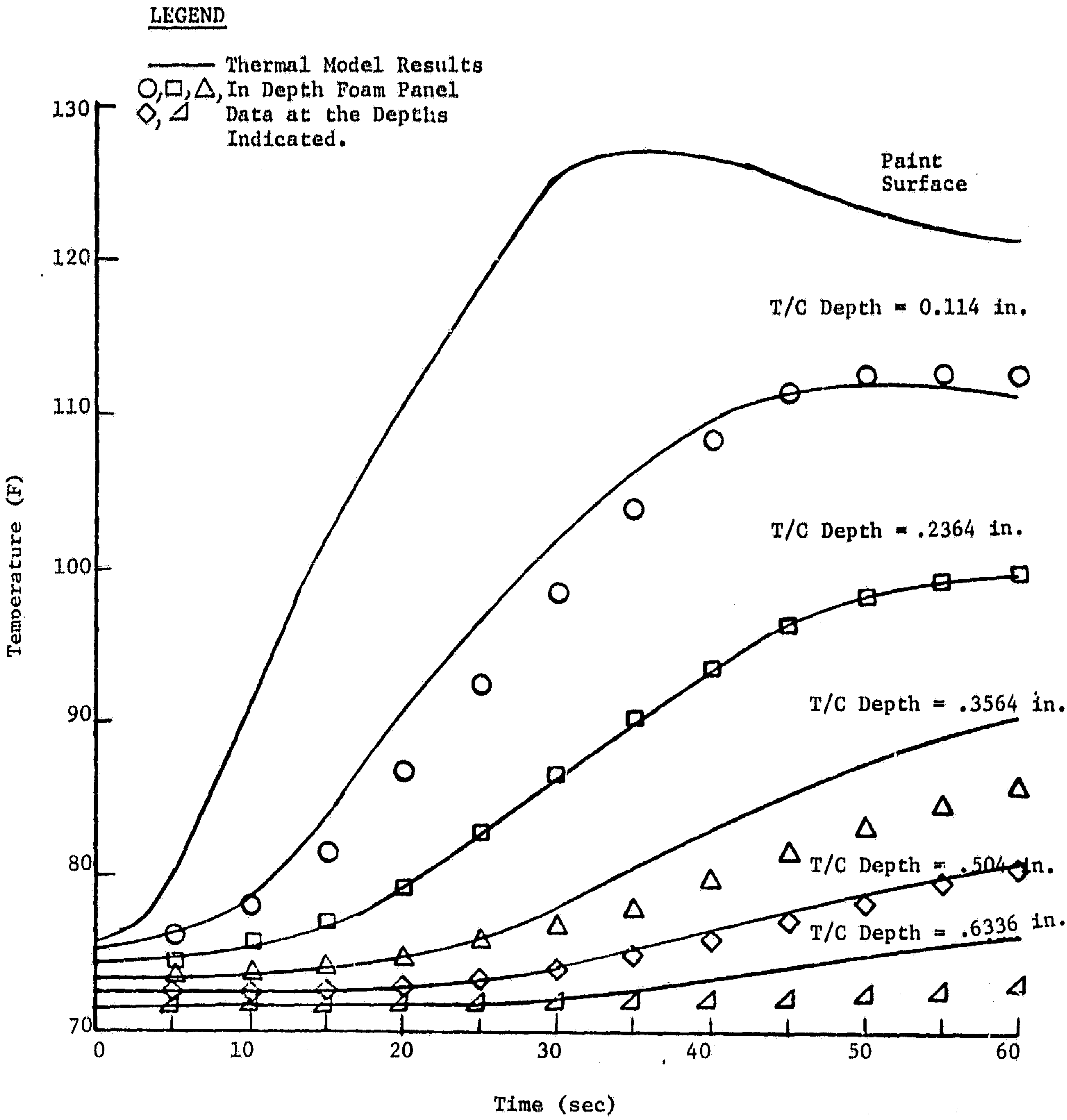

Fig. 7 – Comparison of Finite Element Thermal Model Results and In-Depth Temperature Data for Heat Rate Level = 0.25, Test SLB6B

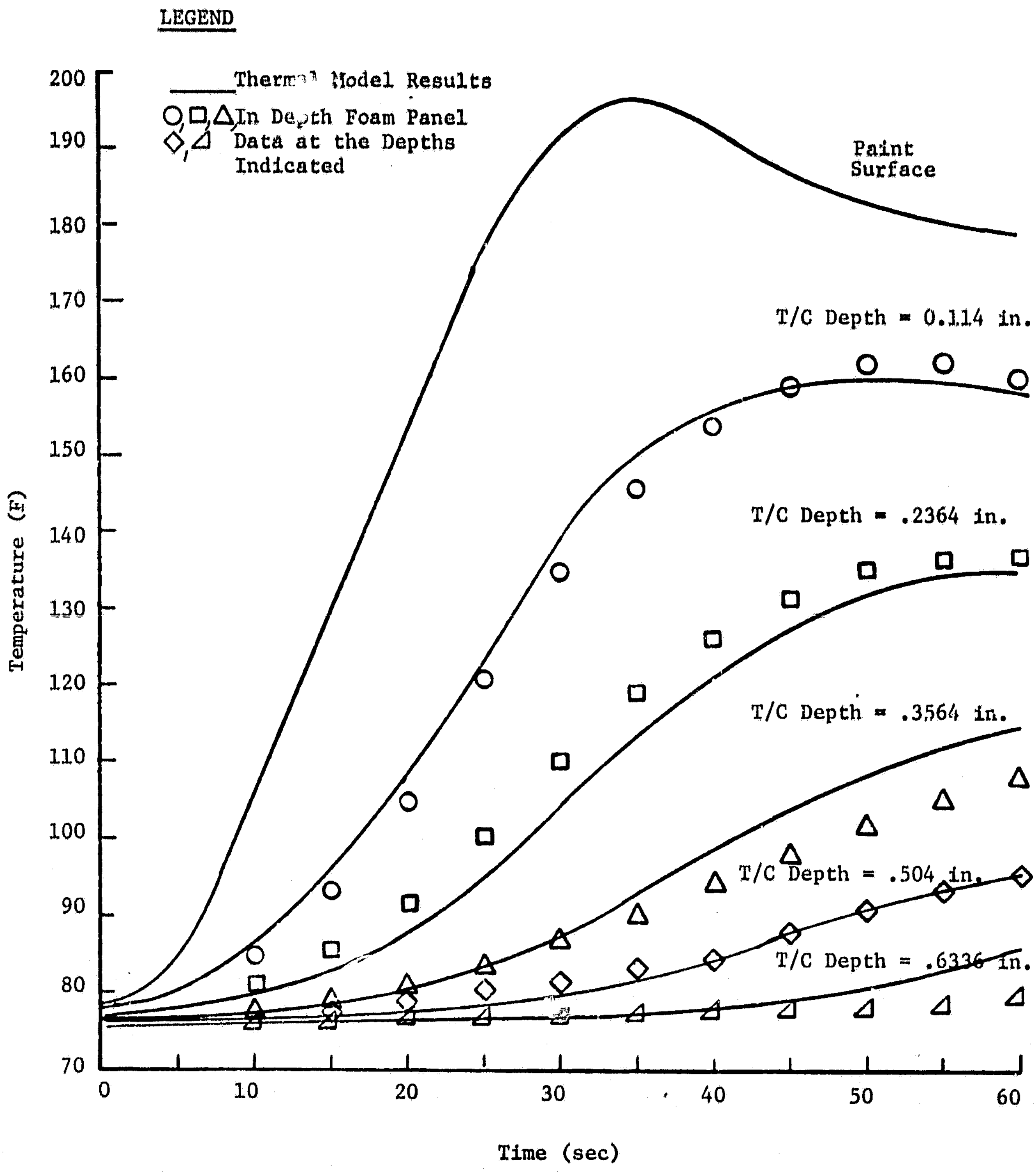

Fig. 8 – Comparison of Finite Element Thermal Model Results and In-Depth Temperature Data for Heat Rate Level = 0.75, Test SLB6D

depth error of 0.008 in. would account for the discrepancy between analytical and measured temperatures. Although, care was taken to minimize thermocouple movement during the "foaming in place" process, the liquid foam could have pushed the thermocouple up as the foaming was occurring. However, the main item of interest is the paint surface temperature results. Unfortunately we have no measured data for comparison on these two figures, but on subsequent figures excellent comparisons with data will be shown. The thermal properties used for the CPR 488 foam were obtained from Mr. Rick Bachtel, EP44. A foam density of 2.2 lbm/ft^3 was used. The specific heat is shown in Fig. 9, and the thermal conducitivity is shown in Fig. 10. The 95% upper confidence line shown in Fig. 10 was used. The paint thickness on the test specimens was measured as 0.007 in. The paint density specific heat and thermal conductivity used were 97 lbm/ft^3, 0.54 Btu/lbm-F, and 0.18 Btu/hr-ft-F. These properties were obtained from various sources for latex based paints. Lockheed has requested MSFC to confirm these properties, but no reply has been received to date. The lamp bank radiation absorptivity used was 0.71.

2. The Martin installed surface thermocouple (TC) must be shielded from the lamp bank and in good thermal contact with the painted surface for it to indicate close to the actual temperature as shown in Fig. 11. Without the radiation shield, the surface TC will indicate higher than actual temperature. Future foam samples should have the surface TC under the surface paint film.

3. The surface paint temperature at which the white paint turns black is between 255 F and 350 F. The 255 F temperature was obtained in the radiant lamp facility using shaded TC data along with the thermal model results. In the radiant lamp facility, the white paint turns black almost instantaneously at a given temperature. When the paint first starts to change color, the radiation absorption increases thereby hastening the blackening process. For

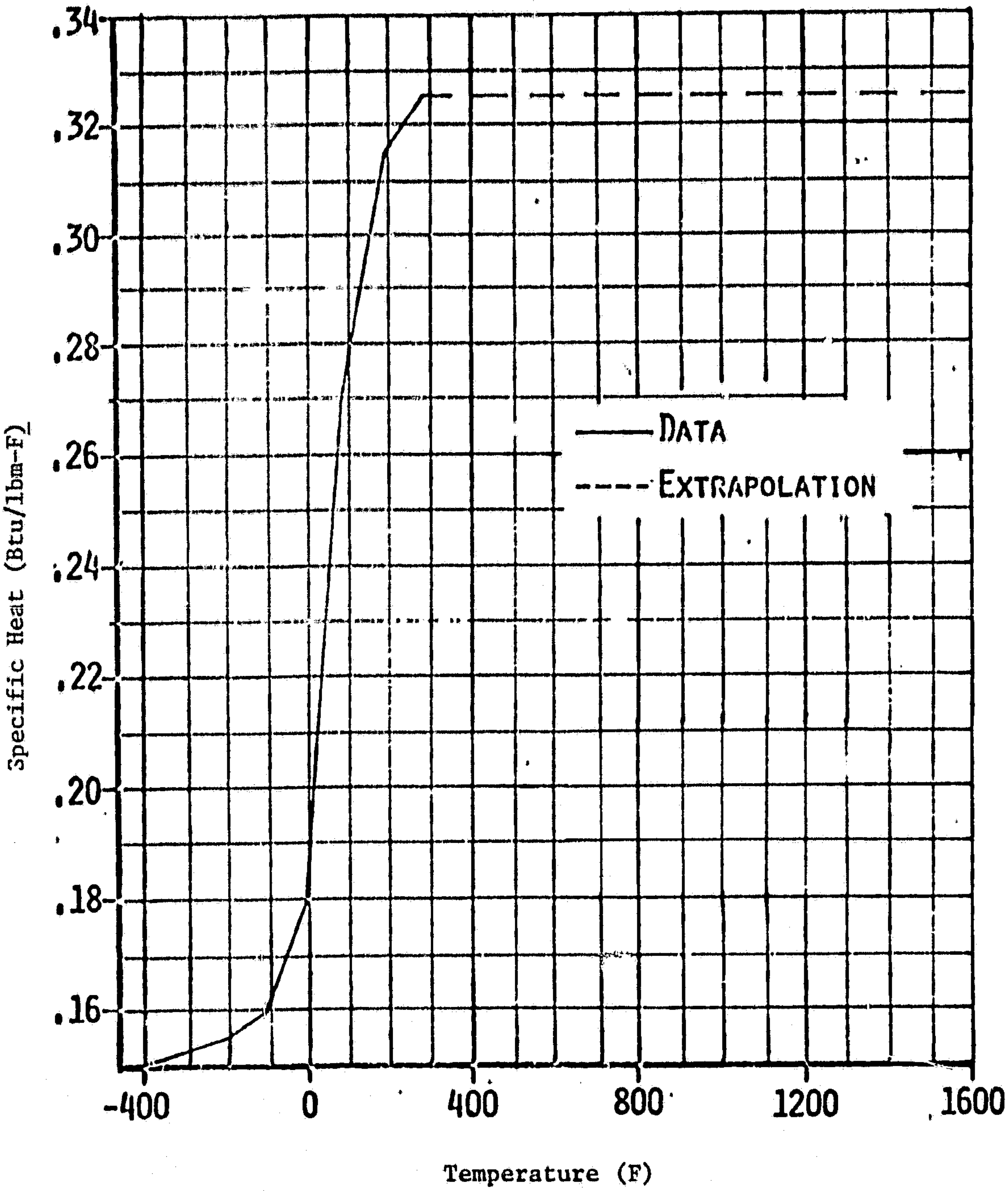

Fig. 9 - CPR-488 and PDL-4034 Specific Heat vs Temperature

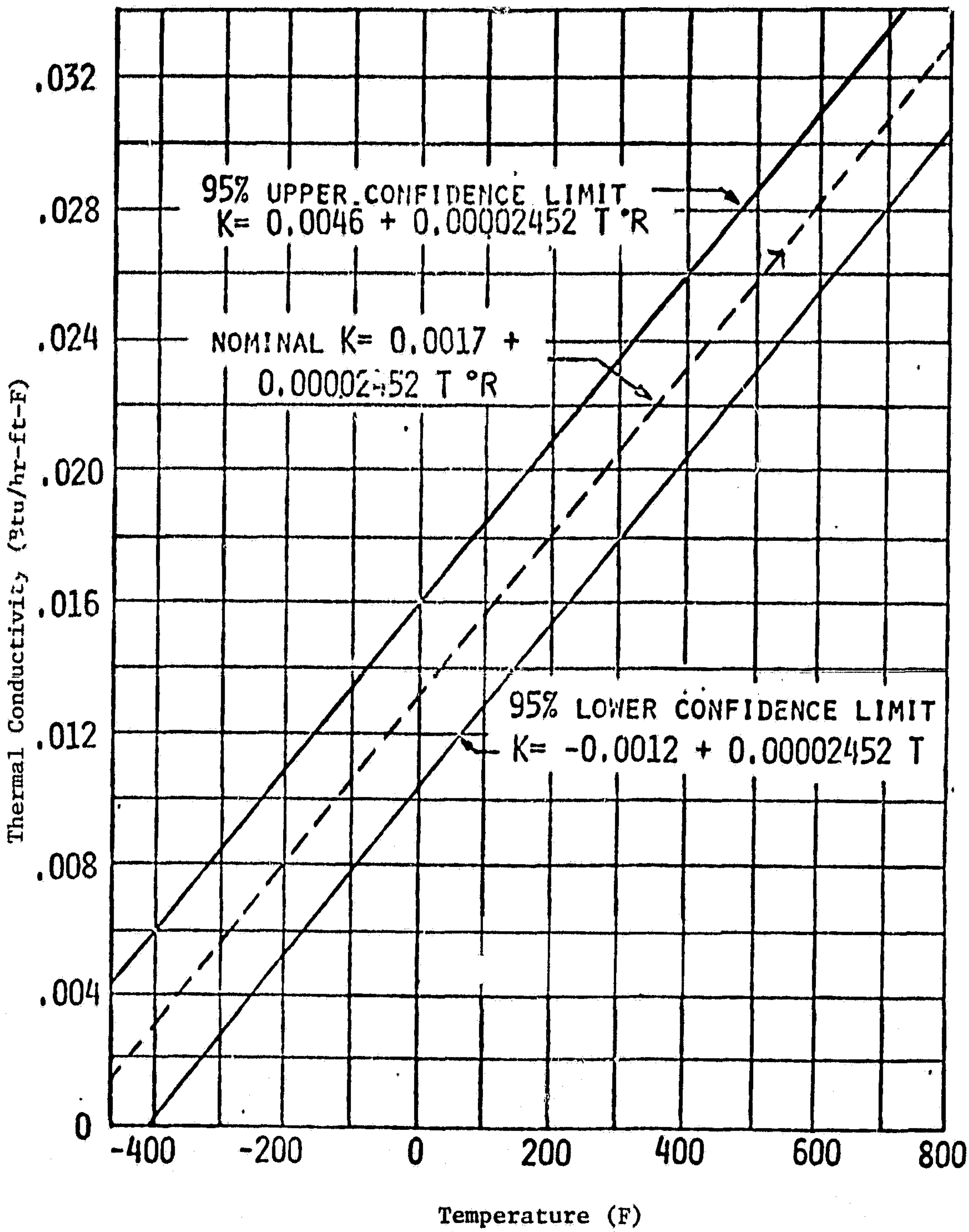

Fig. 10 - CPR-488 Thermal Conductivity vs Temperature

this reason, 300 F temperature is considered a lower number. Similar samples were exposed to a 1200 F convective heat source in the Lockheed laboratory and the 350 F temperature was obtained. Here again the surface thermocouple was pressed into the paint from the surface and a protuberance was evident. Therefore, the 350 F temperature is probably the upper limit. For the results indicated in Fig. 11 the two samples exposed to a Q_i of 1.25 and 1.00 turned black in the indicated range. For $Q_i = 1.25$ this gives an indicated heat load range of 21 to 22 Btu/ft^2. For $Q_i = 1.00$ the indicated heat load range of 24 to 27 Btu/ft^2 is obtained. For $Q_i = 0.75$ the panel did not turn black, although it experienced a heat load of 31 Btu/ft^2. However, it appears that if the panel had been allowed to heat for 10 sec more, the paint temperature would have exceeded 255 F and it probably would have turned black. Based on these results, it appears that paint temperature criteria as opposed to heat flux or heat load criteria is better for determining if paint will turn black.

4. The time required to darken an unpainted as opposed to a painted foam surfce is almost 75% longer. Tests were conducted in the radiant lamp facility and in the Lockheed laboratory using the 1200 F convective heat source. Measured surface temperature results obtained in the 1200 F convective heat source indicated that the foam surface turns brown at approximately 500 F. These results were preliminary and future tests must be conducted to confirm them.

2.2.2 ET Foam Test Results Correlation with Flight Data

Analyses were conducted to relate the ground test results with the flight video data. The flight video data for STS-2 consisted of still photographs taken at various times during staging of the ET. Using the photograph data as a guide, Fig. 12 was prepared. Shown in this figure are the burned paint areas denoted by the cross hatching. Also shown in Fig. 12 are the various Rockwell International (RI) defined Body Point locations

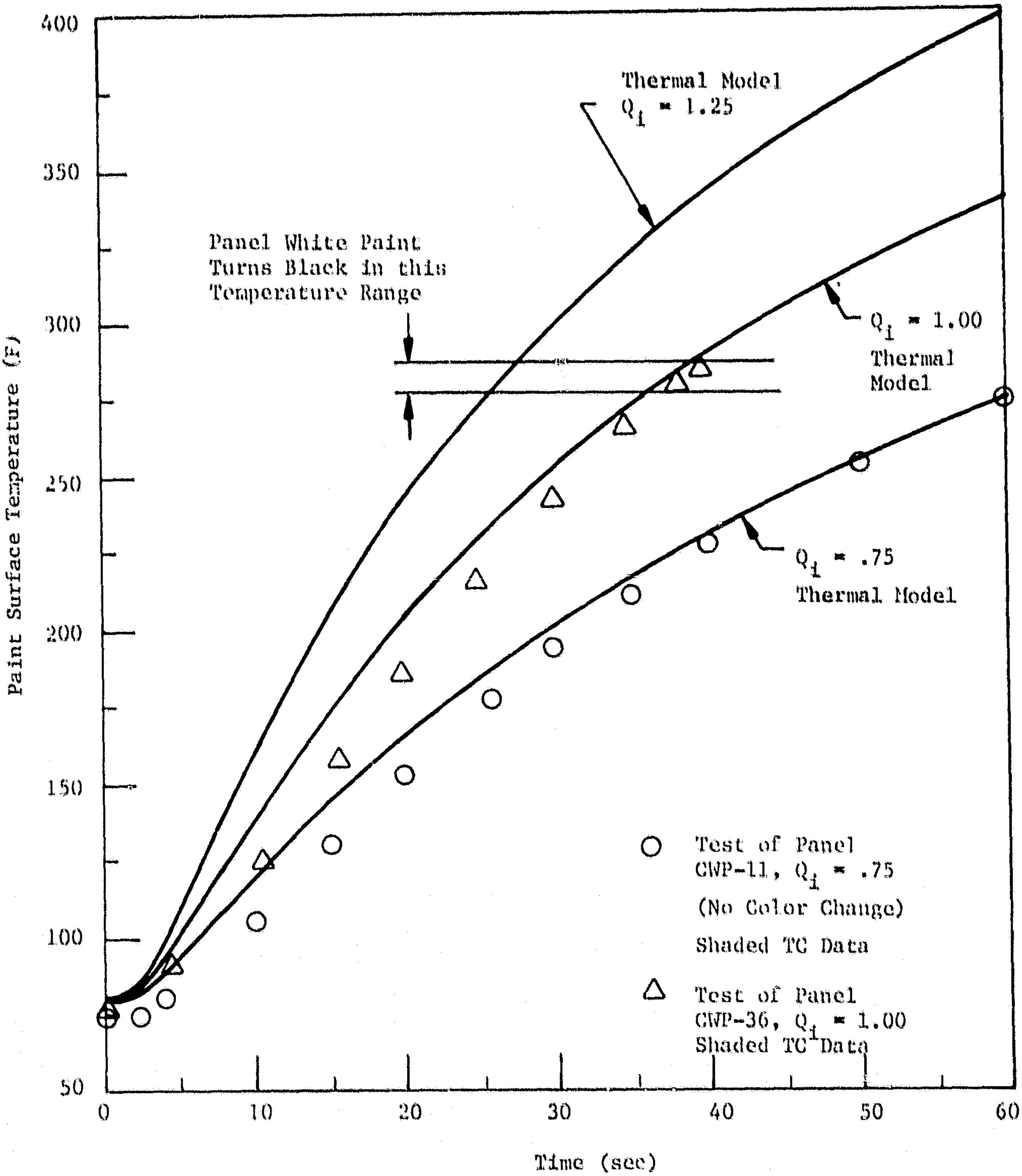

Fig. 11 - Comparison of Foam Surface Temperature Data and Thermal Model Results

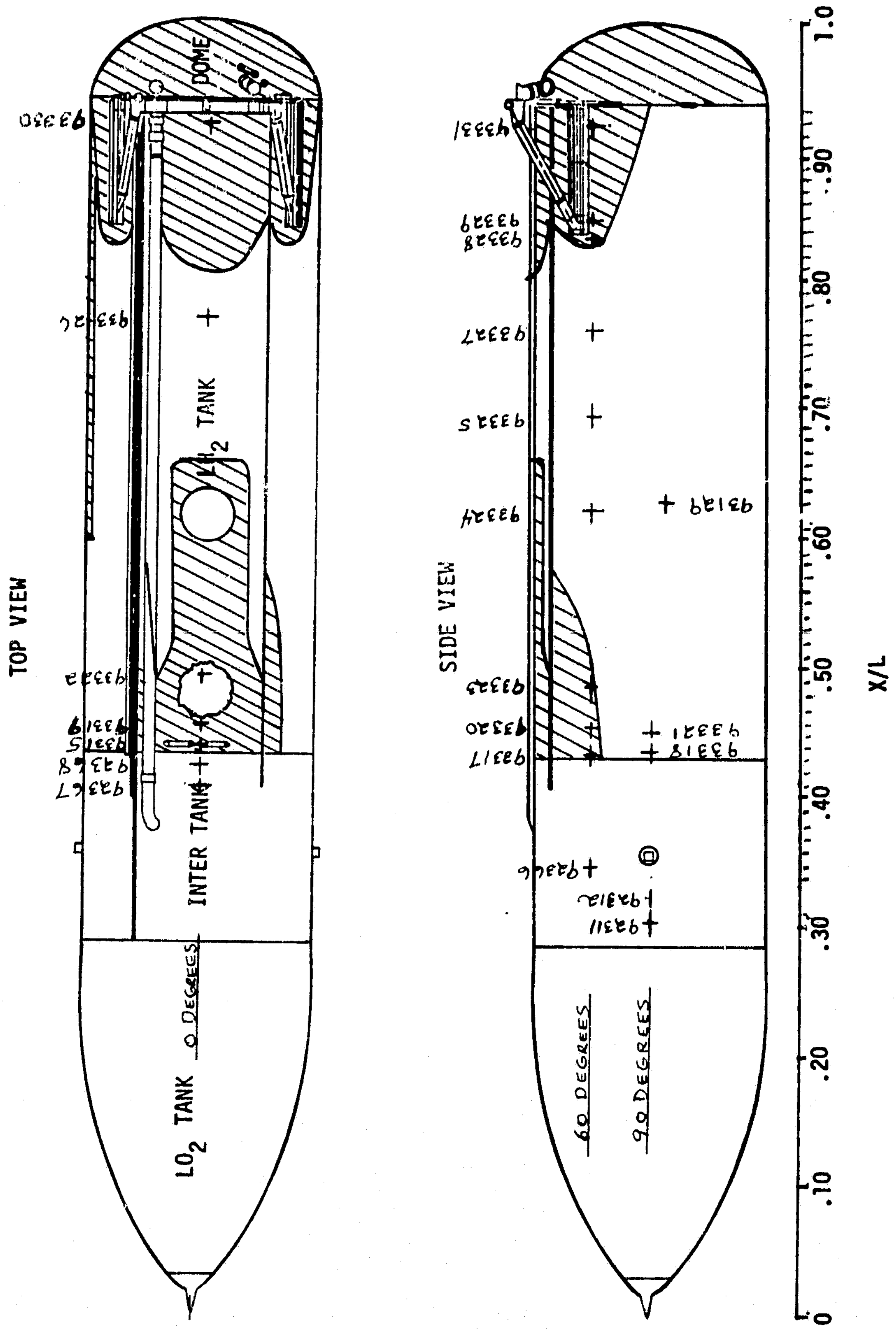

Fig. 12 - External Tank Configuration

denoted by small crosses. Also shown are the 0, 60 and 90 deg longitudinal lines on the ET. Shown in Fig. 13 are the predicted nominal STS-2 heat load distributions along the various longitudinal lines and the areas of white paint. Figures 14, 15 and 16 provide further predicted heat load clarification.

The ET for STS-3 is approximately 1200 lb lighter without its coat of paint. The ET surface area is approximately 12,566 ft^2. Assuming a paint density of 97 lbm/ft^3 results in an average paint coating of 0.012 in. The STS-2 preflight heat profile prediction for RI Body Point 93129 (Fig. 12) was used along with the thermal model to make paint temperature estimates for STS-2. The RI Body Point is located in a white paint area. The thermal model results are presented in Fig. 17. Shown in Fig. 17 are surface temperature time histories for various paint coating thicknesses. The uncertainty of 0.006 in. in paint thickness results in a 60 deg peak temperature difference. This big uncertainty means that only qualitative results can be obtained from this study. Also shown in Fig. 17 are the surface temperature results for no paint coating. This temperature peak is only 390 F which is much less than the 500 F temperature required to turn the bare foam surface brown.

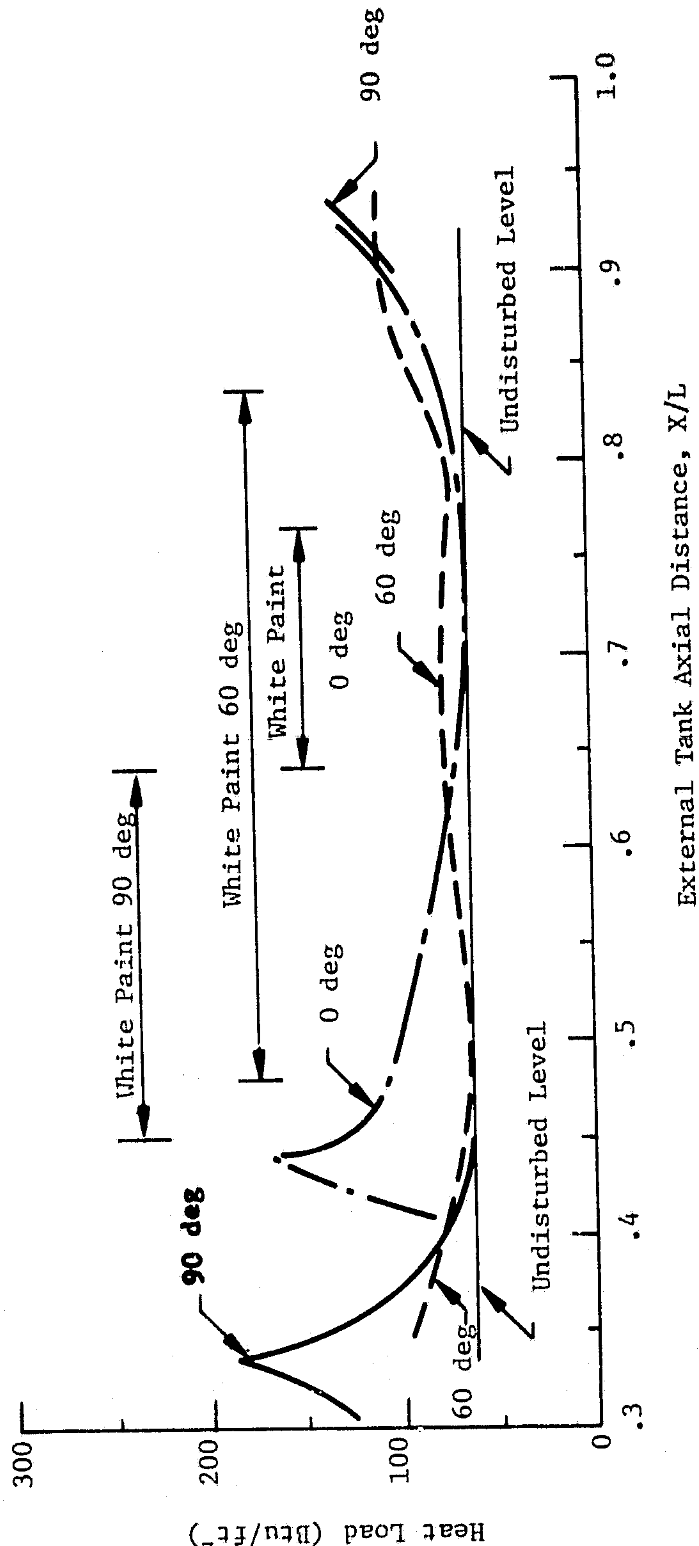

Fig. 13 - STS-2 Nominal Heat Load on Liquid Hydrogen Tank

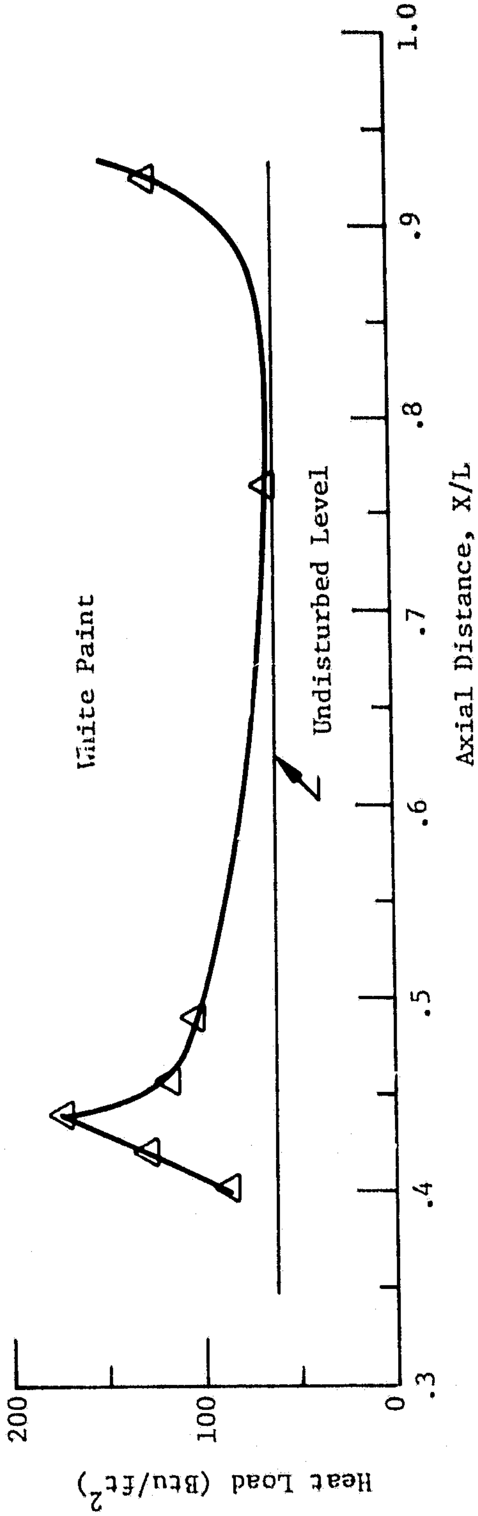

Fig. 14 - STS-2 Calculated Nominal Heat Load - External Tank (0 deg)

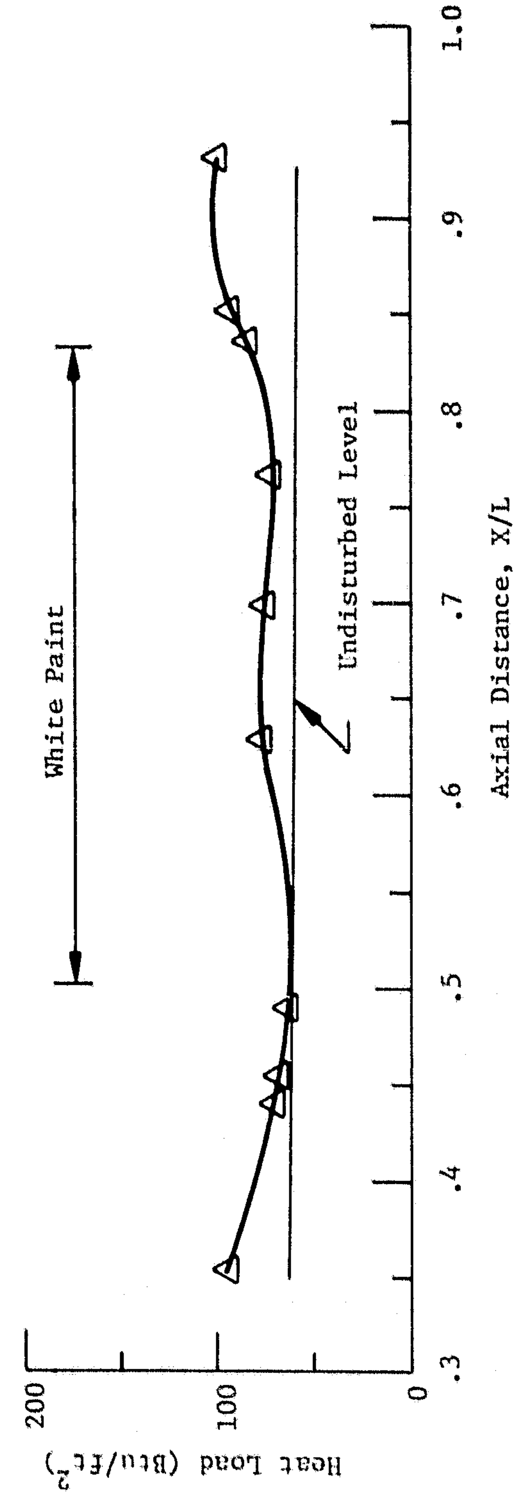

Fig. 15 - STS-2 Calculated Nominal Heat Load - External Tank (60 deg)

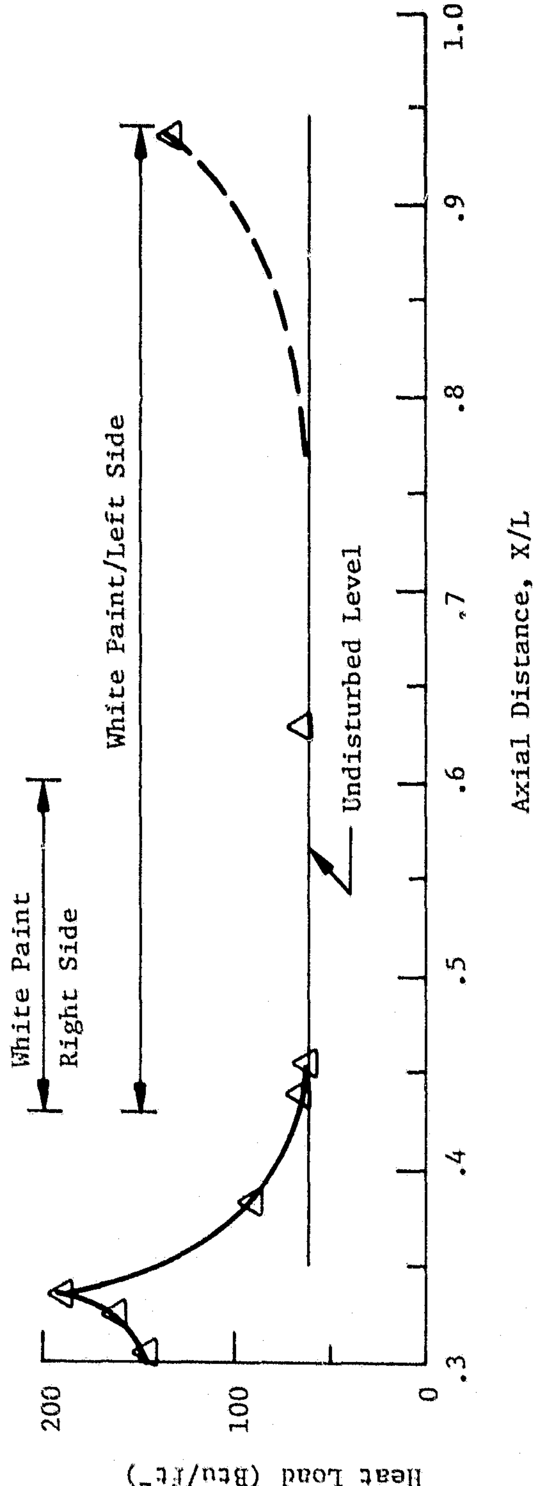

Fig. 16 - STS-2 Calculated Nominal Heat Load - External Tank (90 and 270 deg)

Notes:
1. $T_{initial}$ = 0 F

2. Environment for STS-2 Flight
Body Point - 93129
Q_{load} = 66.47 Btu
Q_{max} = 0.78 Btu/ft^2-sec

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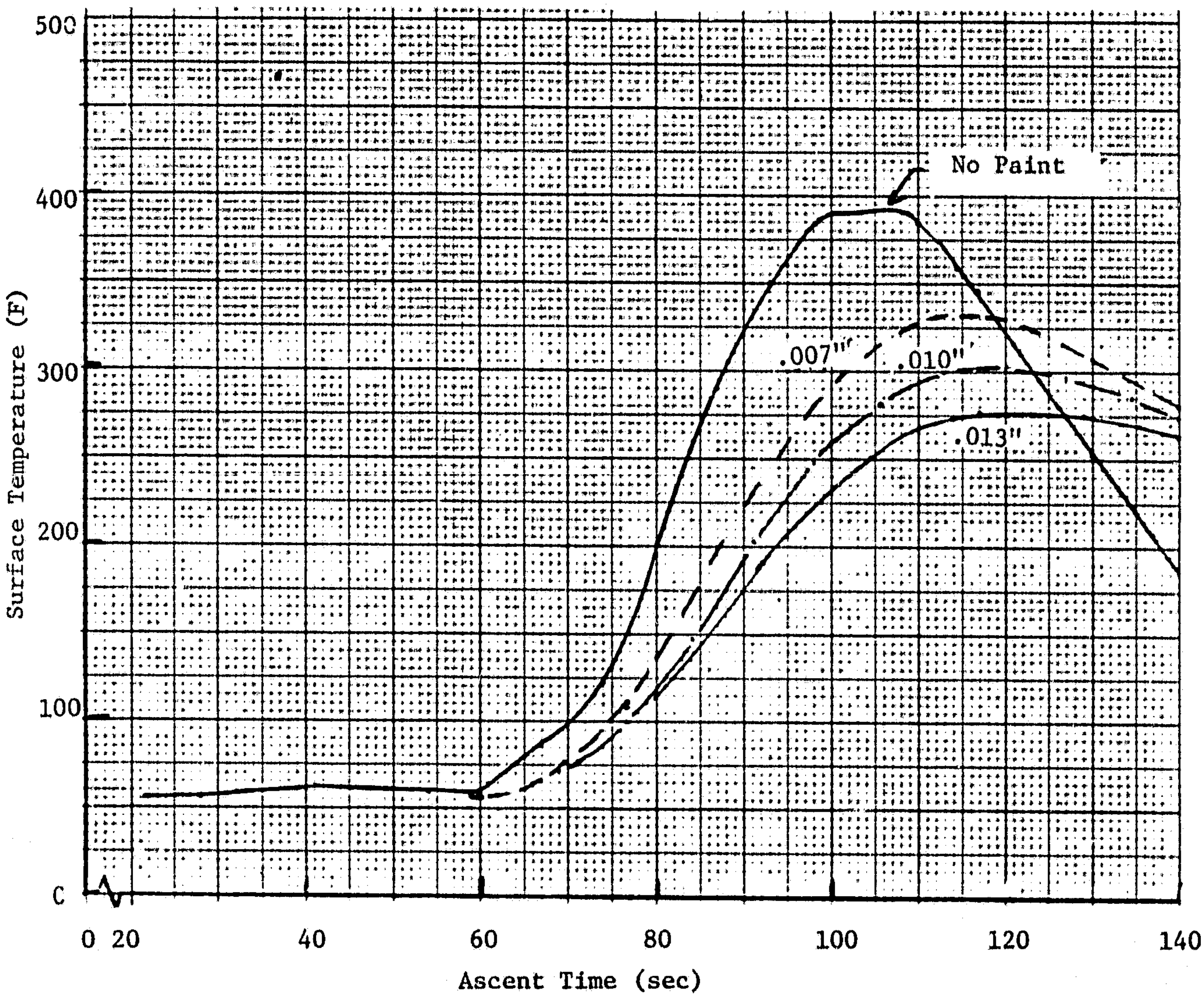

Fig. 17 - ET Paint Thickness Effect on Surface Temperature

Section 3
CONTRACT AND SUMMARY CONCLUSIONS

The first effort under this contract resulted in a very valuable test facility for MSFC in Building 4755, Room 122. The microcomputer radiant lamp facility is extremely versatile in terms of heat profile input and test heat flux output. This effort proved that a microcomputer controller as opposed to the old Data Trak system results in a tremendous increase in facility utility and output. The microcomputer controls not only the lamp bank according to a set of prescribed input conditions but also records, stores, reduces, prints and plots the data immediately following the test.

The second phase effort resulted in expanded knowledge regarding ET foam paint charring and turning black. Comparisons and correlations were made relating the ground test results to flight. The most significant results of this effort were that the white paint turns black between 300 F and 350 F and the unpainted surface will darken around 500 F. This effort also pointed out that for future tests NASA-MSFC should consider adding a hot convective heat source to the facility to more closely simulate flight conditions. In this way, the test engineers would have a choice on the mode of heating for the test, either radiant or convective.

Appendix A
CALIBRATION TEST PLAN

General: A test setup was developed to test the thermal sensors on the ET instrument islands mounted on an LN_2 tank. The test facility consists of a radiant lamp array and associated controls. The power supply for the lamp array is controlled by a program controller which accepts input from a computer. The planned tests require the test facility to provide a heating rate/time profile typical of that shown on Fig. 4. To produce this type of profile it is necessary to know what input to feed from the computer to the rest of the system. The calibration tests described herein will provide this input and demonstrate the results.

To conduct these calibration tests, the lamp array will be turned around 180 deg. A calibration model or plate with five water cooled calorimeters will be fabricated and mounted 3 in. from the front of the lamp array. (The calorimeters will be recalibrated before beginning the tests.) The calorimeter plate is mounted on "unistrut" bars so it can be moved horizontally and vertically for surveying heating rate distributions. This calorimeter plate is approximately the same size as the lamp array to account for multiple reflection effects. The calibration rig will also have a reference calorimeter permanently mounted to one side of the lamp array. This will be used in the future to provide feedback information for the control program. This reference calorimeter will be placed 9 in. laterally from the lamp centerline and 2 in. from the front of the lamps. The facility will be operated in an open loop mode for these calibration runs.

The tests will be accomplished in three phases as follows:

Phase I - Generate Curve of Incident q Versus "Power Setting"

To generate this curve the lamps are brought on at a lower level, 5% of full scale, and held for 60 sec, then a step increase in power level is made to 10% and held for another 60 sec, and so on until a heating rate level of 6 Btu/ft^2-sec is obtained. (This is expected at about 40% of full scale power level). From the results of this exercise a curve of incident heating rate to the calorimeter plate versus power level setting will be obtained.

Phase II - Generate Response - Time Curves

From the data generated in Phase I, power settings are selected to produce heating rates of 1, 2, 3, 4, 5 and 6 Btu/ft^2-sec. These constant settings are then input to the computer and response time curves (for heat-up and cool-down) are generated at each of these levels. Power is turned on for 60 sec and then turned off at each power setting. Results are then plotted.

Phase III - Generate Typical Flight Heating Rate Profiles

Using the results of Phase I and Phase II, the computer input/power setting requirements will be determined which will produce two typical flight heating rate-time profiles. The two selected profiles represent the maximum and minimum heat-up and cool-down rates. These two profiles are then run and the results recorded. The reference calorimeter readings are also recorded for monitoring the lamp output in future thermal sensor tests.

If the heat-up rate of the lamp array is not capable of matching the flight profile, this can possibly be overcome by using either higher power bulbs or more bulbs per reflector. If the cool-down rate is not fast enough, then a shutter arrangement should be added. However, neither of these is expected to be a problem.

If the lamp output does not match exactly the desired profile, some fine tuning will be necessary and the profiles rerun until they are acceptable. A deviation of 10% of the desired heating rate is recommended as an acceptable range.

Phase IV - Generate Lateral and Vertical Heating Rate Distributions

It is desired to know how the heating rates vary with distance away from the island center. The calorimeter plate is moved up and down and laterally in increments of 0.25 in. and readings taken out to 5 in. The nominal center point heating rate used will be 6 Btu/ft^2-sec

Safety Note

The following safety considerations should be observed:

- Have two large fire extinguishers on hand at test site.
- Have main breaker/cutoff readily accessible for emergency shutdown of all components.
- Check flow rate of exhaust fan to be sure it is capable of removing all exhaust fumes, etc.
- Provide a fireproof curtain around the calorimeter rig to shield other items in the room from "stray" radiant heating from lamps.