

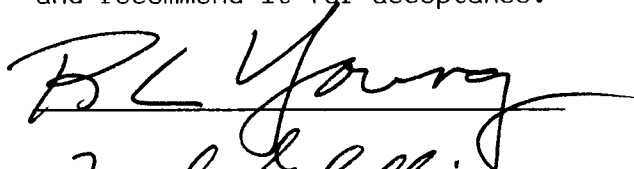
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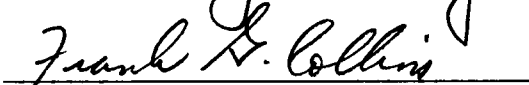
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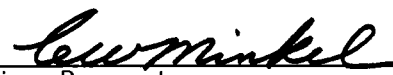
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DETERMINATION OF SURFACE HEAT-TRANSFER COEFFICIENTS
OF HYPERSONIC WIND TUNNEL AERODYNAMIC MODELS
USING EMISSION CHARACTERISTICS OF
THERMOGRAPHIC PHOSPHOR PAINTS

A Thesis .

Presented for the

Master of Science

Degree

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ABSTRACT

Wind tunnel tests were recently conducted to verify the applicability of a thermographic phosphor paint technique for the thermal mapping of model surfaces in hypersonic flow. The tests provided data that supported the routine use of the thermographic method in thermal analysis, and demonstrated that the paint technique could be an effective alternative to other thermal mapping methods. Two 0.0175 scale models of the Space Shuttle Orbiter were used for the tests. The models were provided by Rockwell International and were constructed of a filled, high-temperature epoxy material of very low conductivity. These models were used because they had previously provided heat-transfer data with the more conventional thermal mapping approach of using thin-skin thermocouples [1].

The tests were conducted at the Arnold Engineering Development Center (AEDC), Arnold Air Force Base, Tennessee. The facility used was the AEDC von Kármán Facility Hypersonic Wind Tunnel B. Fifteen (15) runs were made at Mach 8, with Reynolds numbers (per foot) of 0.5×10^6 , 2.0×10^6 , and 3.7×10^6 , and a tunnel total temperature of 890° F (1350° R). Model angles of attack varied from 20 to 35 degrees. The models were painted with two different phosphor paints, unique in their range of temperature sensitivity, which allowed a large temperature variation to be examined. Exposed to ultraviolet (UV) light during the tests, the phosphor painted surface emitted light, the intensity of which was measured and related to surface temperatures.

Heat-transfer coefficients were computed by using a theoretical thermal response function of transient heating of a semi-infinite slab and experimental surface temperatures. The coefficients obtained were compared to coefficients obtained using thin-skin thermocouples.

Agreement between the heat-transfer coefficients obtained by the two different methods was observed, though the accuracy desired by Rockwell International was not obtained. However, the thermographic phosphor technique is promising and further development is encouraged.

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NOMENCLATURE

ALPHA	Model angle of attack, deg
C	Constant used in calculating Nusselt number
C_p	Specific heat of model material, BTU/lb _m ·R
h	Surface heat-transfer coefficient, BTU/ft ² ·sec·R
$\bar{h}$	Average surface heat-transfer coefficient, BTU/ft ² ·sec·R
h_{REF}	Fay-Riddell reference heat-transfer coefficient, BTU/ft ² ·sec·R
k	Thermal conductivity of model material, BTU/sec·ft·R
$\bar{k}$	Boundary layer average thermal conductivity, BTU/sec·ft·R
x_{TD}	Depth of heat penetration, feet
M	Mach number
M_E	Mach number at boundary layer edge
Nu	Nusselt number
P_∞	Free-stream static pressure, psia
P_T	Tunnel stilling chamber pressure, psia
P_{T_2}	Stagnation pressure downstream of the normal shock, psia
Q_∞	Free-stream dynamic pressure, psia
$\dot{Q}''$	Total heat flux, BTU/ft ²
$\dot{q}''$	Surface heat-transfer rate, BTU/ft ² ·sec
Re	Reynolds number
R_N	Reference nose radius, feet
r	Recovery factor
T	Temperature, F (R)
T_i	Initial model temperature, F (R)

T_R	Adiabatic recovery temperature, F (R)
T_W	Wall temperature, F (R)
T_{AW}	Adiabatic wall temperature ($\equiv T_R$), F (R)
T_E	Temperature at boundary layer edge, F (R)
T_{pc}	Phase change temperature, F (R)
$\bar{T}$	Temperature distribution parameter
t	Time, sec
V	Velocity, ft/sec

Greek Symbols

α	Thermal diffusivity of model material, ft^2/sec
β	Semi-infinite slab parameter for $h(T_R)$
μ_{TT}	Air viscosity based on total temperature
η	Camera viewing angle, deg
Ω	Ultraviolet light incident angle, deg
ρ	Density of model material, lb_m/ft^3
$\sqrt{\rho C_p k}$	Lumped thermophysical property of model material, $\text{BTU}/\text{ft}^2 \cdot \text{sec}^{0.5} \cdot \text{R}$
τ_{TD}	Thermal diffusion time, sec

CHAPTER I

INTRODUCTION

The final product of most heat-transfer testing conducted in wind tunnels is a distribution of heat-transfer coefficients over the model [2, 3]. This requires that part of the model surface, i.e., external wall, behave as a transducer, where temperature changes along the model exterior are used to determine the rates or amounts of energy flow across the boundary layer [2, 3]. If the model is constructed of a relatively thick material with low conductivity, it can be considered analogous to a slab of infinite thickness for test periods up to a few minutes [2, 3]. This allows the model surface temperature to become a sensitive indicator of heat transfer, given that other thermal properties of the model material are known. Such properties include the thermal conductivity k , density ρ , and the specific heat C_p [2, 3].

Early in 1987, a series of wind tunnel tests were conducted at the Arnold Engineering Development Center (AEDC) to evaluate aerodynamic heating characteristics of a hypersonic airframe configuration developed by the Rockwell International Corporation. Information gathered would provide an experimental data base for the validation of various analytical techniques [4, 5]. Testing was conducted at the AEDC von Kármán Facility (VKF) in Hypersonic Wind Tunnel B, and a thermal mapping technique was used in order to obtain heat-transfer data.

Various thermal mapping techniques have been used in testing at AEDC. These techniques are based on measuring the surface temperature of test models during their exposure to convective heating in the wind tunnel [1]. The surface temperature data is then used to determine the associated convective heat-transfer coefficients. The primary difference between the various thermal mapping techniques is the approach used to obtain the surface temperature [1]. Two such techniques presently being used in testing at VKF are the phase-change paint technique and the infrared (IR) camera technique [1]. The phase-change paint technique uses a temperature sensitive paint coating on the model. This fusible coating changes from an opaque solid to a transparent liquid (i.e., melts) at a specific temperature (T_{pc}) [4, 6, and 7]. Isotherms along the model surface are defined by the interface between the solid and melted paint. The rate of progression of these isotherms, using paints of varying temperature sensitivities, provides a map of surface temperature variation over time [6, 7]. This information is used to calculate corresponding heat-transfer rates from the transient heat-conduction equation. However, this technique has several disadvantages. These include the need for multiple models, required cleaning and repainting of the model after each run, and a labor intensive data-reduction procedure [1]. The infrared camera technique of thermal mapping uses an infrared scanning system coupled with on-line computers and color printers. The product is an on-line color-coded analysis of the model's surface temperature distribution [5]. However, this technique

has poorer spatial resolution and requires an exact knowledge of the spectral emissivity of the model material over a potentially wide range of temperatures [1].

An additional thermal mapping approach is the thermographic phosphor technique. This approach offers improvements in some of the problem areas associated with other thermal mapping techniques, though it also has limitations. During the 1970s, the von Kármán Facility used this technique to map heating patterns on models in lower temperature test environments. However, the technique was abandoned for several years because the data-reduction methods were more labor intensive than those of phase-change paint [1]. Recent VKF developments in the areas of computer enhanced image analysis and high-temperature phosphor paints have once again made the thermographic phosphor technique a viable approach, especially for higher temperature environments [7]. It was this recently refined technique that was considered for the Rockwell International tests. However, before the desired model would be tested, additional testing would be conducted in order to confirm the technique's practicality. In this validation test, phosphor measurements were obtained on existing Space Shuttle Orbiter models for comparison with experimental data obtained from previous wind tunnel tests.

In February of 1987, wind tunnel testing was conducted in Tunnel B of AEDC/VKF on two 0.0175 scale models of the Space Shuttle Orbiter. The intent of the test was to simulate vehicle reentry conditions and examine the heating characteristics of the models' windward (i.e., lower) surface using the thermographic phosphor

technique. Acquired data would be compared to previously obtained thin-skin thermocouple data in order to evaluate the accuracy of the phosphor paint technique. Fifteen (15) test runs were made at Mach 8.

This thesis discusses the theory supporting the data analysis and analyzes the data obtained in the thermographic phosphor validation test. Data includes surface profile information on temperature, heat-transfer coefficients, and heat-transfer rates along the orbiter models' lower surface centerline. Comparison data between the phosphor approach and previously obtained experimental data is also examined. Recommendations for future work or development of the technique are provided.

CHAPTER II

TEST FACILITY DESCRIPTION

The tests were conducted in Hypersonic Wind Tunnel B of von Kármán Gas Dynamics Facility (VKF). This is a closed-circuit tunnel with a 50-inch diameter test section. Mach numbers of 6 and 8 are available by selecting one of two axisymmetric contoured nozzles for tunnel installation. The tunnel can be operated continuously at stagnation pressure levels from 20 to 200 psia at Mach 6, and from 50 to 900 psia at Mach 8, with air being provided by the VKF compressor plant. A natural-gas-fired combustion heater is used to obtain tunnel stagnation temperatures high enough to prohibit air liquefaction in the test section (up to 1350° R). The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external water jackets [7]. Beneath the tunnel test section is the model installation tank. Here, the models are mounted on a sting support mechanism for insertion into the tunnel. This model injection system allows for a model's insertion into and removal from the test section while the tunnel remains in operation [7]. This facility is maintained and operated by Arvin/Calspan, Inc., under contract to the U. S. Air Force.

The insertion of a model into the tunnel and its subsequent removal constitutes one injection cycle, referred to as a run. All data obtained are identified in the data tabulations by a run number [7]. Personnel enter the installation tank to prepare the model for each run. The tunnel and installation tank are separated by a pair of fairing doors and a safety door. Once preparations are complete,

personnel exit the tank, closing the access door. The tank is then vented to the tunnel flow, safety and fairing doors are opened, and the model is inserted in the airflow. With a test run completed, the sequence is reversed with the model being retracted back into the installation tank and the tank being vented to the atmosphere. Once venting is completed, the tank is accessible to personnel in order to prepare the model for another run.

CHAPTER III

THERMOGRAPHIC PHOSPHOR TECHNIQUE

When phosphor particles are exposed to ultraviolet (UV) radiation, the result is the temperature dependent emission of light known as phosphorescence. The intensity of the emitted light depends on the properties of the phosphor particles, the energy of the incident UV light, and the temperature of the phosphor treated surface. The following description of the thermographic phosphor technique is based upon its discussion in References 1 and 7, and is presented here to promote understanding of the testing effort.

The thermographic phosphor approach uses phosphor-laden paints as model surface coatings for aerothermal wind tunnel tests. The intensity of the light emitted by a given phosphor paint when exposed to a constant intensity UV light can be related directly to the paint temperature. The approach presumes that the temperature of the actual model surface can be taken to be that of the paint, assuming that the paint offers negligible resistance toward heat transfer. This requires that the paint have a thermal conductivity significantly greater than model material, and/or that the paint be applied to the surface with an acceptable minimal thickness. The phosphor paints used on the test consisted of phosphor particles suspended in a pigmentless binder. Phosphors can differ in the temperature range over which their emitted light shows a measurable intensity change. Therefore, some expectation must be held as to what the model surface temperature profile will be in order to select phosphor paints with

appropriate temperature sensitivity. Two phosphors were used for this test, acquired commercially through the U. S. Radium Corporation. One of the phosphor paints used particles of Radelin® #3251, which is useful for surface temperatures from approximately 140 to 230° F. The other phosphor paint used particles of Radelin® #2090, which is sensitive to temperatures from 320 to 425° F.

A video camera was used to monitor the light intensity emitted from the painted surface during the test. The camera output was then recorded by a computer based Image Analyzer System (IAS), a schematic of which is illustrated in Figure 1. This output can relate phosphorescence to surface temperature through calibration of each phosphor paint. Calibrations are performed by applying a sample of the batch of phosphor paint to be used on the model to the surface of a copper slug. The slug is then heated to a constant temperature and illuminated with UV light of equal intensity to that illuminating the model during testing. With the slug surface temperature being monitored by a thermocouple, the intensity of phosphorescence is recorded by the IAS as camera output. The phosphor paint calibration curves for both paints used at a given UV light intensity are shown in Figures 2 and 3. Note that the intensity of phosphorescence decreases exponentially with increasing paint temperature.

Ultraviolet light sources are placed in the tunnel installation tank and outside the top and side test section viewing ports in order to provide UV illumination of the model during testing. The lighting arrangement used during this test is shown in Figure 4. UV light intensity is measured in the test section prior to testing, with

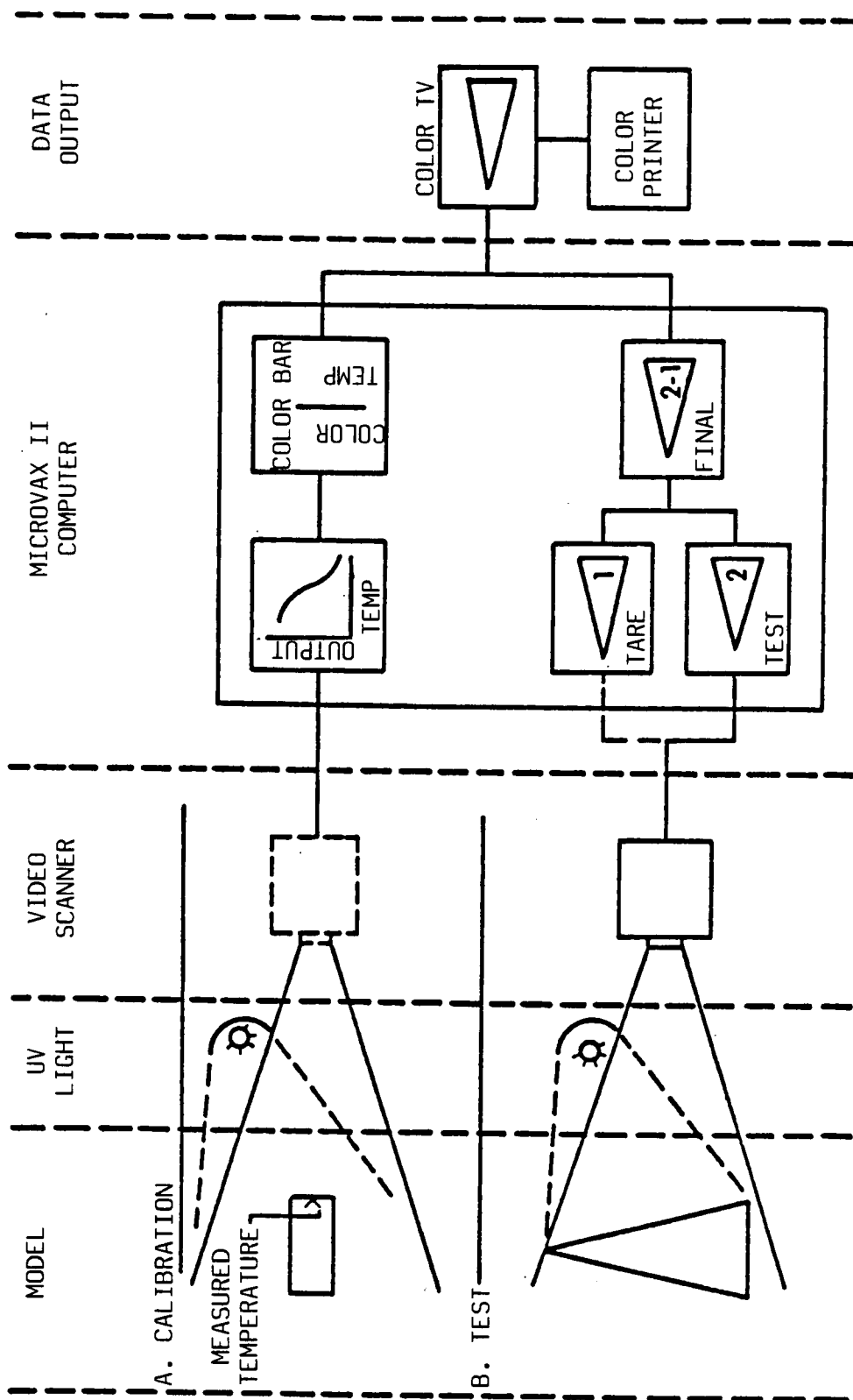


Figure 1. Schematic of the Image Analyzing System.

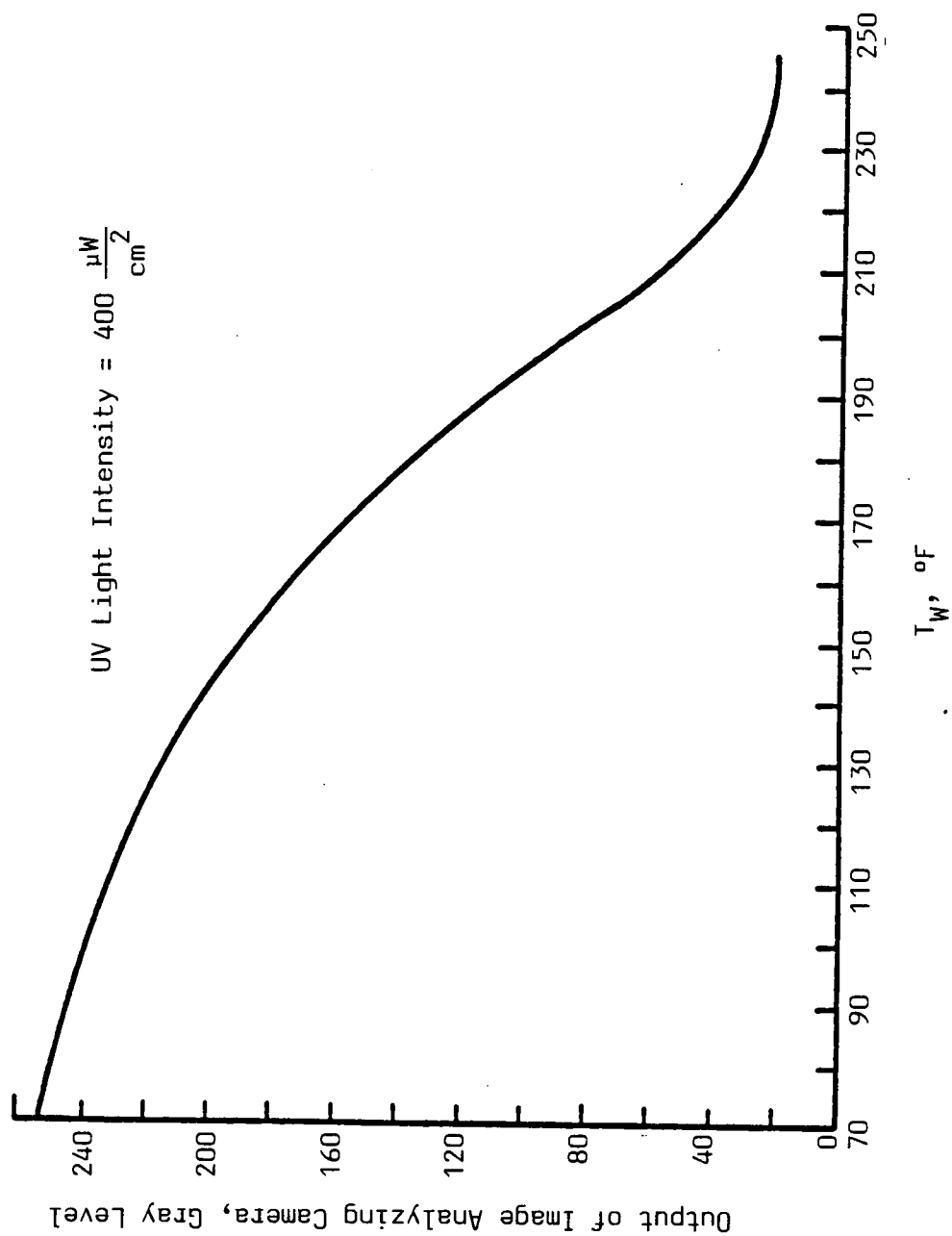


Figure 2. Calibration Curve of the Radelin® #3251 Thermographic Phosphor Paint.

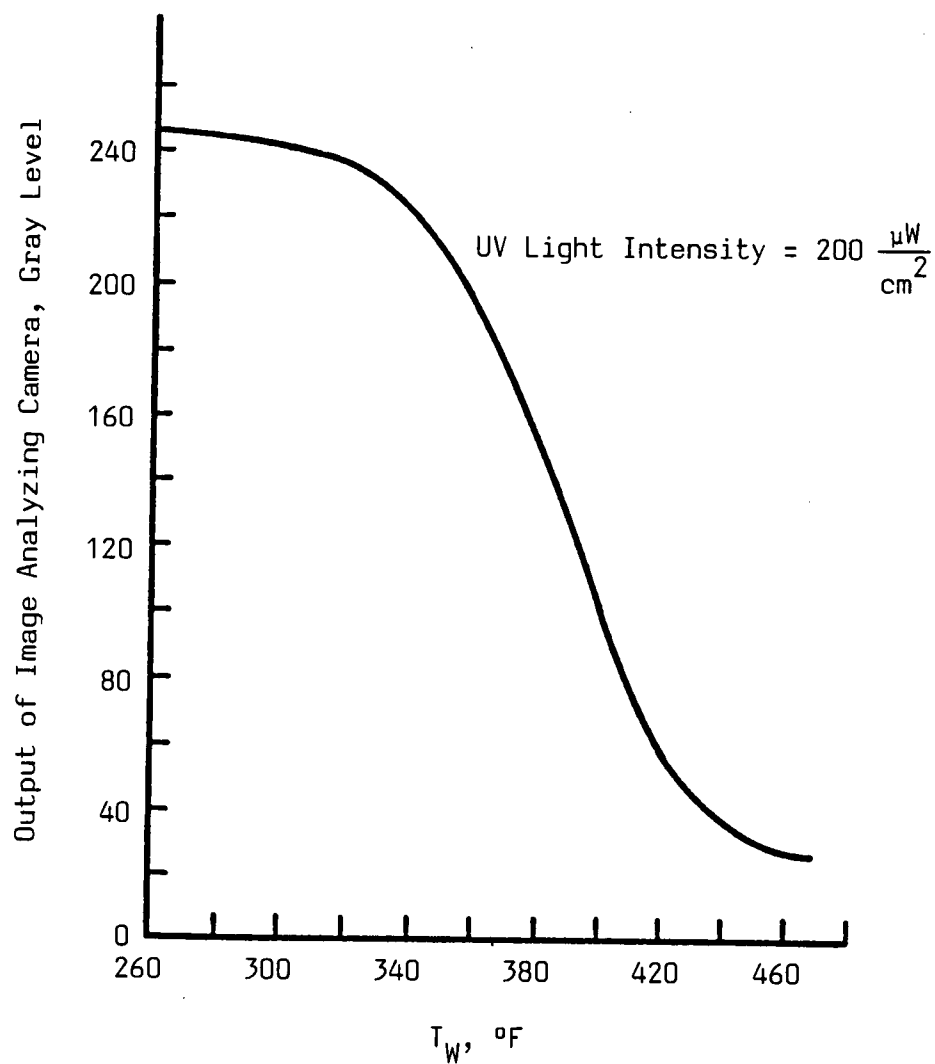


Figure 3. Calibration Curve of the Radelin® #2090 Thermographic Phosphor Paint.

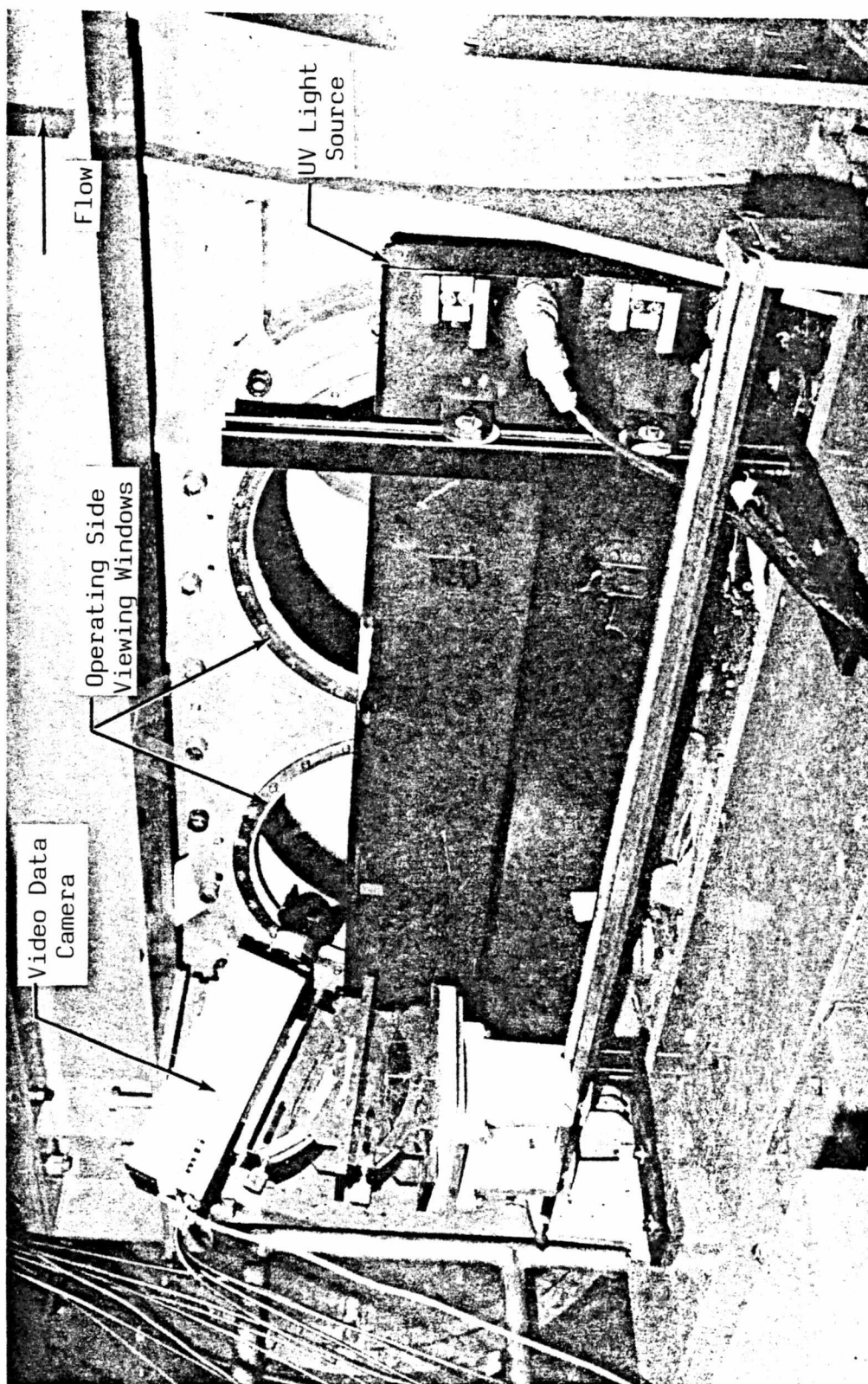


Figure 4. Ultraviolet Light Source and Video Data Camera Installation on Tunnel B.

adjustments made to provide as near uniform illumination of the model as possible. These adjustments are necessary in order to obtain uniform excitation of the phosphor over the entire model surface. In addition, the UV lamps are filtered to cut off reflected visible light. Furthermore, the IAS is used to record a tare image of the model at each model orientation to be tested. Such images are recorded at ambient conditions with the same UV lighting as planned for the actual test. These tare images are later subtracted from model images made during the test in order to compensate for small nonuniformities in UV illumination and phosphor paint application.

When actual testing is in progress, the IAS is used to obtain and store individual frames of data from the video camera output of the model. The IAS records such data at predetermined intervals (identified by sequence numbers) during the actual test, along with the time that each frame of data is taken. The imaging system used by AEDC allows for a video resolution of approximately 0.04 in. over a 30-inch model.

In 1986, AEDC acquired the Kontron Image Processing System (KIPS), a newer and faster IAS than had been available. This new system allows for the near on-line presentation of the phosphor data, processing the data between runs. Tare data is subtracted from actual test data, and the resulting intensity is related to a surface temperature based upon the calibration curve. Temperature data of the model surface are then illustrated on color plots. Black and white examples of these plots are shown in Figures 5 through 8, which illustrate changes in the temperature profile with exposure time in the tunnel.

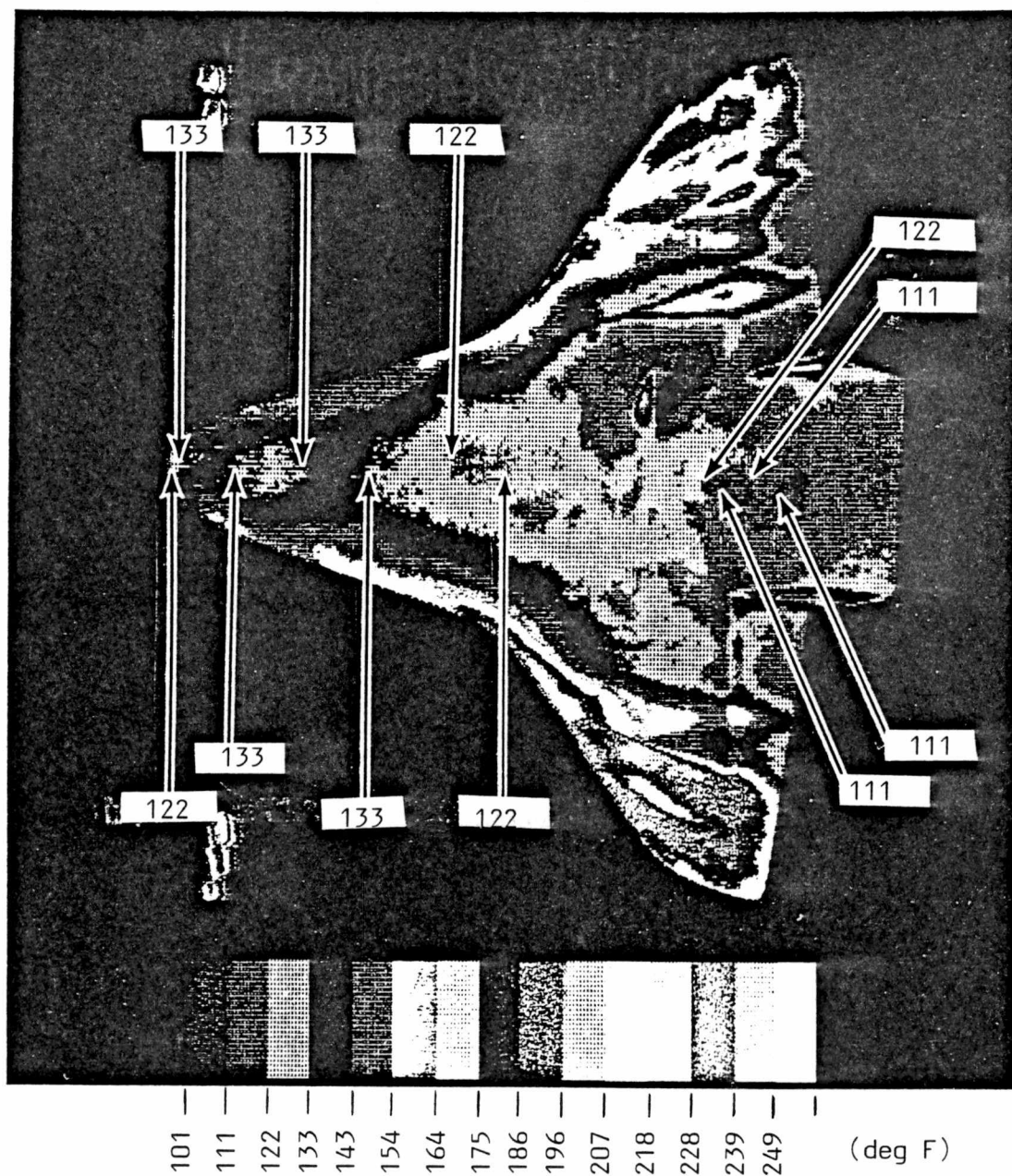


Figure 5. Run 10 Temperature Profile of the Model Lower Surface at an Exposure Time of 1.93 Seconds.

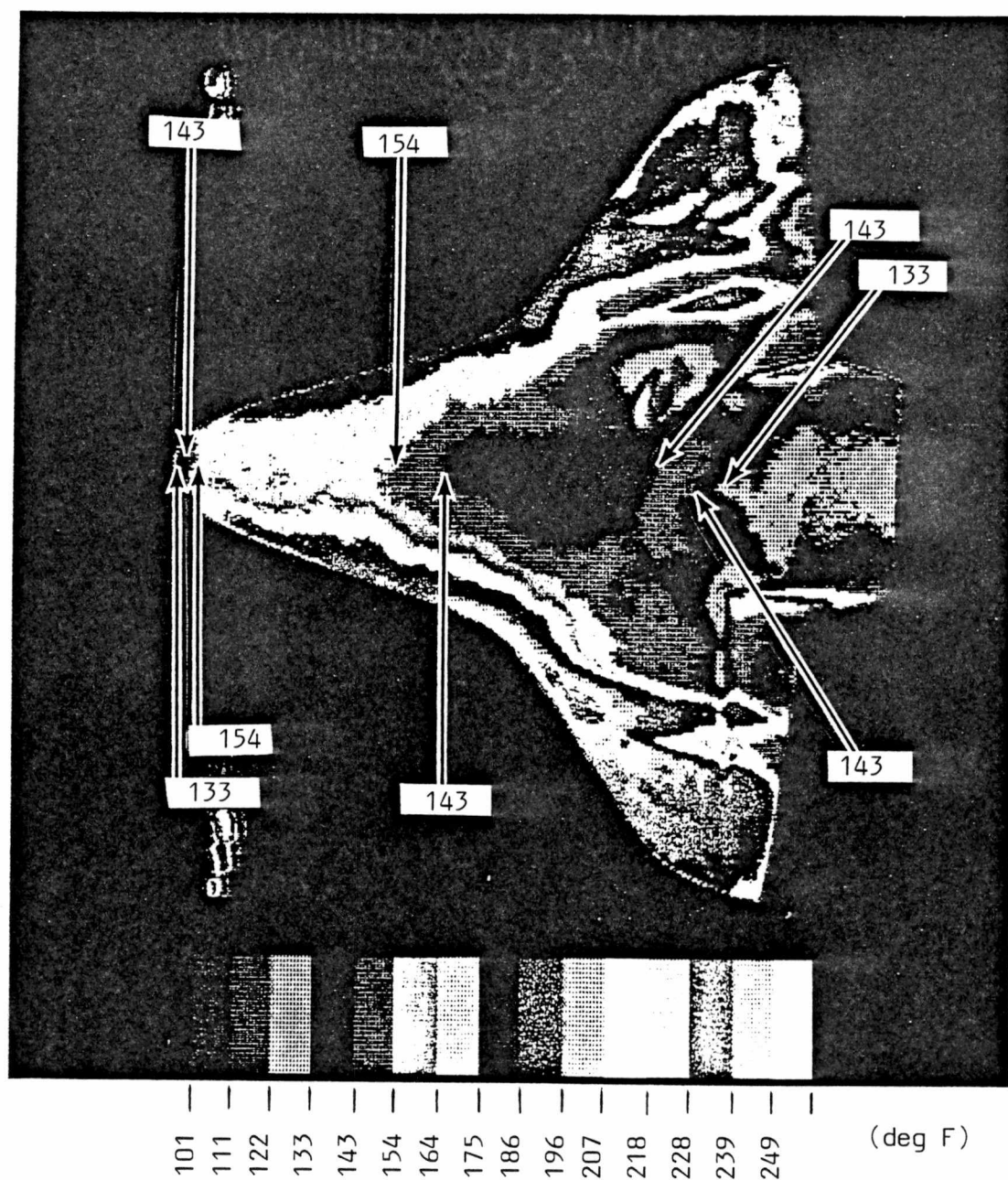


Figure 6. Run 10 Temperature Profile of the Model Lower Surface at an Exposure Time of 4.83 Seconds.

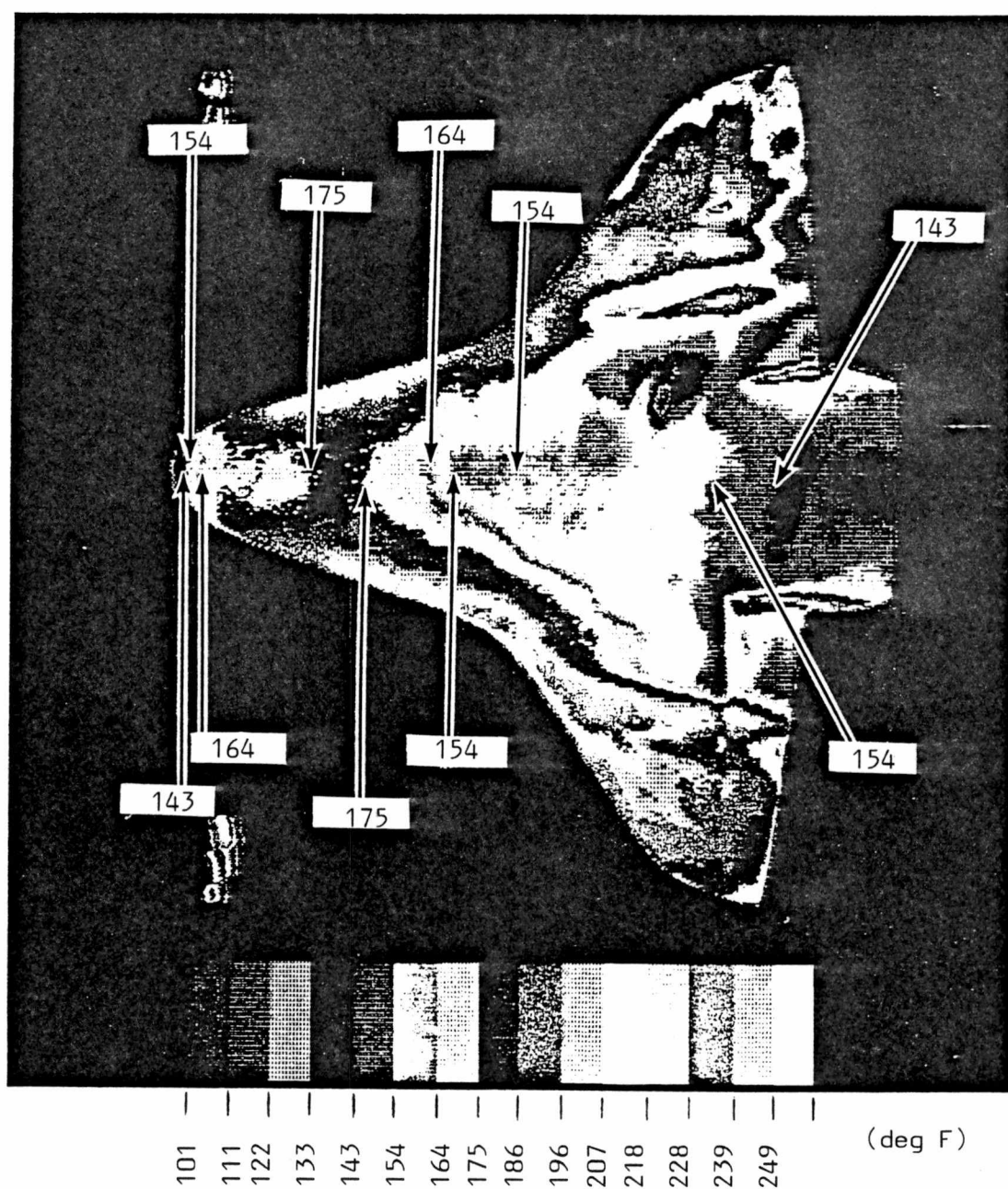


Figure 7. Run 10 Temperature Profile of the Model Lower Surface at an Exposure Time of 8.23 Seconds.

Note that each color represents a temperature range, with the addition of more colors (up to 32 possible) allowing for smaller and more refined temperature intervals. The exact temperature, however, is only known at the interfaces between adjacent regions of differing colors. The corresponding heat-transfer coefficient is finally computed using the interface temperature, the amount of time the model was exposed to convective heating, and the model thermal properties as inputs to the data-reduction equations.

CHAPTER IV

THEORY

The method described herein is an application of the semi-infinite slab solution in order to determine the heat-transfer coefficients. Here, the heat-transfer coefficients are dependent upon exposure time of the model in the tunnel, the test environment, and the thermal properties of the model wall. The relationship between the heat-transfer coefficient and the other parameters is determined from the solution to the equation governing the transient one-dimensional flow of heat [6]. This equation is

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2}. \quad (1)$$

The actual tunnel transient test is most accurately described by the following initial and boundary conditions:

$$T(x,t) = T_i \quad \text{at} \quad t = 0, \quad (2)$$

$$T(x,t) = T_i \quad \text{at} \quad x = \infty, \quad (3)$$

and

$$\frac{\partial T(x,t)}{\partial x} = \frac{-h}{k} [T_R - T(x,t)] \quad \text{at} \quad x = 0. \quad (4)$$

where $T(0,t) = T_w$, the wall temperature of the model, T_R is the adiabatic recovery temperature, k is the thermal conductivity, α is the thermal diffusivity, and h is the surface heat-transfer coefficient. Further assumptions made are:

1. the depth of heat penetration into the model wall is very small when compared to the wall thickness and the surface radius of curvature; therefore, it is assumed that the wall temperature response is similar to that of a semi-infinite slab;
2. the model is isothermal when injected into the tunnel airflow;
3. the surface experiences an instantaneous step in the aerodynamic heat-transfer coefficient at time zero. Such an occurrence usually takes place in wind tunnels with constant stagnation conditions for a laminar boundary layer and rapid injection of the model [6].

Consider a semi-infinite slab under conditions of nonnegligible thermal resistance and surface resistance. The temperature distribution for this body is [1, 8, 9]

$$\frac{T(x,t) - T_R}{T_i - T_R} = \operatorname{erf} \left(\frac{x}{2\sqrt{\alpha t}} \right) + \left[\exp \left(\frac{hx}{k} + \frac{h^2 \alpha t}{k^2} \right) \right] \left[1 - \operatorname{erf} \left(\frac{x}{2\sqrt{\alpha t}} + \frac{h\sqrt{\alpha t}}{k} \right) \right]. \quad (5)$$

Substitution of Equation (5) into the Fourier's relation

$$\dot{q}'' = -k \frac{\partial T}{\partial x} \quad (6)$$

identifies the surface heat-transfer rate, $\dot{q}''$, as

$$\dot{q}'' = k(T_R - T_i) \left[\frac{1}{\sqrt{\pi \alpha t}} + \frac{h}{k} \exp\left(\frac{h^2 \alpha t}{k^2}\right) \right] \left[1 - \operatorname{erf}\left(\frac{h\sqrt{\alpha t}}{k}\right) - \left[\frac{k}{h\sqrt{\pi \alpha t}} \exp\left(\frac{-h^2 \alpha t}{k^2}\right) \right] \right]. \quad (7)$$

Therefore, the total heat flux during a given time period of duration τ from the beginning of the heating process is

$$\dot{Q}'' = \int_0^{\tau} \dot{q}''(t) dt. \quad (8)$$

Note that Equations (5) and (7) are solved in terms of error functions. The error function of some parameter β , $\operatorname{erf}(\beta)$, is defined as

$$\operatorname{erf}(\beta) = \frac{2}{\sqrt{\pi}} \int_0^{\beta} e^{-\lambda^2} d\lambda, \quad (9)$$

where λ is a dummy variable of integration. Associated with the error function is the complementary error function, $\operatorname{erfc}(\beta)$, defined as

$$\operatorname{erfc}(\beta) = \frac{2}{\sqrt{\pi}} \int_{\beta}^{\infty} e^{-\lambda^2} d\lambda. \quad (10)$$

Therefore, $\operatorname{erf}(\beta)$ and $\operatorname{erfc}(\beta)$ are related by

$$\operatorname{erfc}(\beta) = 1 - \operatorname{erf}(\beta). \quad (11)$$

The general temperature distribution, Equation (5), is now solved for the model wall temperature, T_w , as a function of time.

Recall that $T(x,t) = T_W$ at $x = 0$. The solution then becomes

$$\frac{T_W - T_R}{T_i - T_R} = \operatorname{erf} \left[\frac{h^2 \alpha t}{k^2} \right] \left[1 - \operatorname{erf} \left[\frac{h \sqrt{\alpha t}}{k} \right] \right] \text{ for } x = 0. \quad (12)$$

If the parameter β is defined as

$$\beta = \frac{h \sqrt{\alpha t}}{k}, \quad (13)$$

then the wall temperature behavior is given by

$$\frac{T_W - T_R}{T_i - T_R} = \exp(\beta^2) [1 - \operatorname{erf}(\beta)] \quad (14)$$

or

$$\begin{aligned} T_W &= T_R + (T_i - T_R) (\exp(\beta^2)) (1 - \operatorname{erf}(\beta)) \\ &= T_R [1 - \exp(\beta^2) (1 - \operatorname{erf}(\beta))] + T_i \exp(\beta^2) (1 - \operatorname{erf}(\beta)). \end{aligned} \quad (15)$$

Then,

$$\begin{aligned} T_W - T_i &= T_R [1 - \exp(\beta^2) (1 - \operatorname{erf}(\beta))] \\ &\quad - T_i [1 - \exp(\beta^2) (1 - \operatorname{erf}(\beta))] \\ &= (T_R - T_i) [1 - \exp(\beta^2) (1 - \operatorname{erf}(\beta))], \end{aligned} \quad (16)$$

and introducing Equation (11) yields

$$\frac{T_W - T_i}{T_R - T_i} = 1 - \exp(\beta^2) \operatorname{erfc}(\beta). \quad (17)$$

Introducing a temperature distribution parameter $\bar{T}$, where

$$\bar{T} = \frac{T_W - T_i}{T_R - T_i}, \quad (18)$$

the solution at the wall becomes

$$\bar{T} = 1 - \exp(\beta^2) \operatorname{erfc}(\beta). \quad (19)$$

The parameter β can now be solved in terms of $\bar{T}$ in Equation (19). Once β is known, Equation (13) can be rearranged to solve for the heat-transfer coefficient. Introducing the equation for thermal diffusivity,

$$\alpha = \frac{k}{\rho C_p}, \quad (20)$$

into Equation (13), one obtains

$$h(T_R) = \beta \sqrt{\frac{\rho C_p k}{t}} \quad (21)$$

where $h(T_R)$ is the heat-transfer coefficient as a function of the adiabatic recovery temperature, C_p is the specific heat of the model material, ρ is the material density, and t is the exposure time of the model to the tunnel environment. Note that $h(T_R)$ does not account for surface heating due to thermal radiation. Such heat-transfer effects were considered insignificant for this test.

The above theory presumes invariance in α and k with changing temperature, and the thermal properties of the model body material closely reflect this invariance to allow application of the

semi-infinite slab solution. The lumped thermophysical property, $\sqrt{\rho C_p k}$, of the material does indeed demonstrate a slight variance with temperature, yet the deviation was not considered significant enough to disrupt theory application. However, this variance was taken into account during data reduction. Values of $\sqrt{\rho C_p k}$ for specific ranges of temperature were provided by Rockwell and are summarized in Table 1.

Since the intensity of phosphorescence of the phosphor paint varies continuously as the surface temperature changes over time, an ensemble of surface heat-transfer coefficients are found as a function of time. Given a wall temperature at some location (x,y) and a time t_j , Equation (17) can be shown as

$$\frac{T_W(x,y,t_j) - T_i}{T_R - T_i} = 1 - \exp(\beta_j^2) \operatorname{erfc}(\beta_j), \quad (22)$$

where T_i is the initial model temperature. From this equation, β_j is computed and used in Equation (21) to calculate $h_j(T_R)$, where

$$h_j(T_R) = \beta_j \sqrt{\frac{\rho C_p k}{t_j}}. \quad (23)$$

Given a fixed aerodynamic position on the model surface (i.e., fixed vehicle orientation, angle of attack) and fixed freestream conditions, the values of $h_j(T_R)$ should all be the same. Therefore, an average of these values should provide an average surface coefficient, $\bar{h}(T_R)$ for a given location on the model surface. Hence,

$$\bar{h}(x,y,T_R) = \frac{1}{N} \sum_{j=1}^N h_j(T_R). \quad (24)$$

Table 1. Orbiter Model Material Lumped Thermophysical Properties
With Respect to Temperature.

T_w (deg °F)	$\sqrt{\rho C_p k}$ (BTU/ft ² ·R·sec ^{0.5})
140 - 152	0.048
153 - 200	0.049
201 - 248	0.050
249 - 350	0.051
351 - 425	0.052
426 - 525	0.051
526 - 530	0.050

Thus, even though the body may be experiencing nonuniform surface heating, the surface heat-transfer coefficients can be obtained. Note that in having the surface heat-transfer coefficients and the wall temperatures, a correction procedure could be formulated to account for time-varying boundary-layer transport properties. Consider the relation for Nusselt number, Nu ,

$$Nu = C (Re)^m (Pr)^n \left[\frac{(\rho\mu)_W}{(\rho\mu)_{AW}} \right]^2, \quad (25)$$

where

$$Nu = \frac{hL}{\bar{K}}, \quad (26)$$

and C is some constant. The boundary layer average thermal conductivity, $\bar{K}$, is often selected as,

$$\bar{K} = \frac{1}{2} \left[k(T_W) + k(T_{AW}) \right]. \quad (27)$$

Thus, for a given h_j , a corresponding Nu_j can be determined to within the constant C_j . Hence, h_j provides a set of C_j , where

$$\bar{C} = \frac{1}{N} \sum_{j=1}^N C_j. \quad (28)$$

In this way, the boundary-layer theory is used to obtain not the $\bar{h}$, but rather the $\bar{C}$ used in the heat-transfer theory appropriate for the (x,y) location on the body.

The amount of time that the model is exposed to the tunnel environment is important, in that the model must not experience significant departure from its initial interior temperature. As long as the internal temperature of the model remains near T_i , the use of the semi-infinite slab temperature profile remains valid (note Equation (3)). Therefore, the time required for accurate measurement of phosphorescence must be short compared with the thermal diffusion time of the model wall. This thermal diffusion time, τ_{TD} , is independent of the aerodynamic heat-transfer coefficient and depends only on the thermal diffusivity of the wall and the allowable depth, ℓ_{TD} , of heat penetration [6]. A conservative equation for the thermal diffusion time is given as

$$\tau_{TD} = 0.2 \frac{\ell_{TD}^2}{\alpha} \quad (29)$$

and was derived by NASA/Langley in considering the accuracy of heat-transfer data obtained from models coated with phase-change paint. Equation (29) was obtained by assuming a cubic distribution of temperature with depth in a slab subjected to an instantaneously applied constant heat-transfer rate at one surface. A solution to the equation was then obtained for a value of τ_{TD} for which a significant change in temperature occurred at depth ℓ_{TD} [6]. It is important that ℓ_{TD} is small compared with pertinent model dimensions, such as wall thickness and nose radius. Therefore, in order for the semi-infinite slab solution to remain acceptable,

$$t \leq \tau_{TD} \quad (30)$$

must be a constraint on the time permissible to conduct measurements on phosphorescence. Figure 9 shows the response to Radelin® #2090 phosphor paint on different model materials. Note that the thermal diffusion time for a 0.25-inch thick wall of Novamide® is approximately 30 seconds. The material used to construct the test models had very similar thermal properties to that of Novamide®, with walls much thicker than 0.25 inch. In addition, exposure times during testing were generally kept below 30 seconds. Therefore, the constraint of Equation (30) was maintained during testing.

It has been shown that the heat-transfer coefficient can be calculated, provided the values of T_i , T_R , t , and $\sqrt{\rho C_p k}$ are known. By far the most elusive of these parameters is the adiabatic recovery temperature, T_R . Based on the definition of the recovery factor, one can obtain the equation

$$\frac{T_R}{T_T} = \left(1 - \frac{T_E}{T_T} \right) r + \frac{T_E}{T_T}, \quad (31)$$

where, for laminar flow,

$$r = \sqrt{P_r} \quad (32)$$

and for turbulent flow,

$$r = \sqrt[3]{P_r}, \quad (33)$$

where T_E is the temperature at the boundary layer edge.

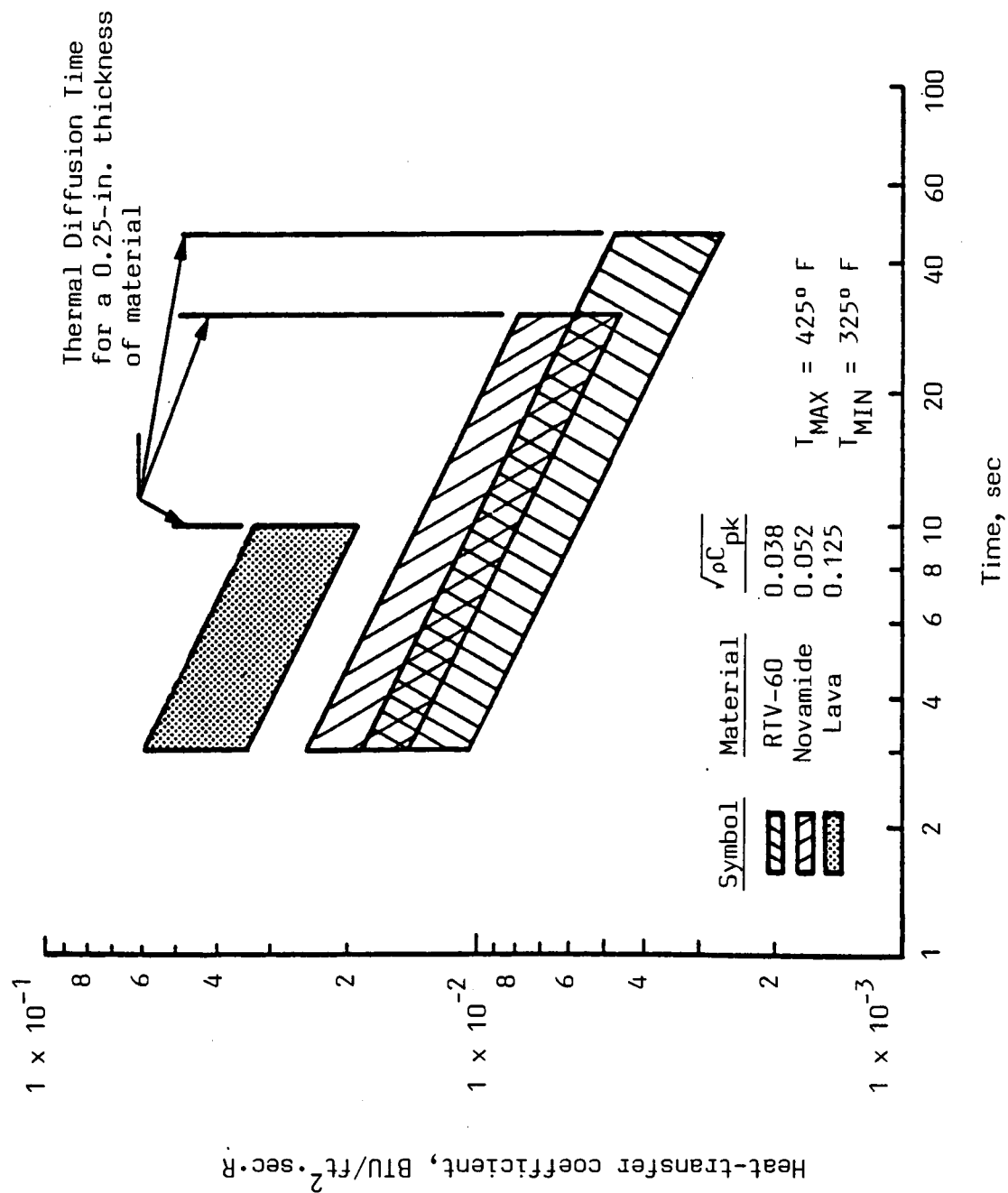


Figure 9. Response of the Radelin® #2090 Phosphor Paint on Different Model Materials.

The temperature ratio at the boundary layer edge is

$$\frac{T_E}{T_T} = \left(1 + 0.2 M_E^2 \right)^{-1}. \quad (34)$$

Since the edge Mach number, M_E , is usually unknown, wind-tunnel heat-transfer data are often reduced using the assumption that $T_R = T_T$. Furthermore, stagnation enthalpies found in the wind tunnel are significantly lower than those experienced in flight. The result is that the wall temperature ratio, T_W/T_T , experienced in the wind tunnel is normally greater than that of a flight vehicle, and the heat-transfer coefficients experienced in flight can be significantly larger than those based on the $T_R = T_T$. In the VKF it has become a common practice to reduce heat-transfer data based on three assumed values of T_R . These values are

$$T_R = T_T \quad (35)$$

$$T_R = 0.9 T_T, \quad (36)$$

and

$$T_R = 0.85 T_T, \quad (37)$$

which illustrate the sensitivity of the calculated h to the assumed value of recovery temperature used [7].

In presenting heat-transfer coefficient results, it is often convenient to use reference coefficients to normalize the data. Equilibrium stagnation point heat-transfer coefficients, derived from

the work of Fay and Riddell, were used to normalize the data obtained on this test [10]. These reference coefficients are given by

$$h_{REF} = \frac{8.17173 (P_{T2})^{0.5} (\mu_{TT})^{0.4}}{(R_N)^{0.5} (T_T)^{0.15}} \left(1 - \frac{P_\infty}{P_{T2}} \right)^{0.25} [0.2235 + (1.35 \times 10^{-5}) (T_T + 560)], \quad (38)$$

where P_{T2} is the stagnation pressure downstream of a normal shock, μ_{TT} is air viscosity based on T_T , P_∞ is the free-stream pressure, and R_N is a reference nose radius.

CHAPTER V

TEST DESCRIPTION

This convective heat-transfer test was conducted using 0.0175 scale models of the Space Shuttle Orbiter in the AEDC/VKF Wind Tunnel B. An orbiter model was selected to validate the thermographic phosphor technique because its configuration was well documented and had an extensive experimental data base. Two models, designated as series 56-0, were provided by the Space Transportation Systems Division of Rockwell International. The orbiter models were constructed of a filled high-temperature epoxy material called Lockheed LH. This material is very similar in appearance and properties to Novamide® 700-55, an epoxy often used in the construction of models for hypersonic testing. Indeed, these models had been used in previous thermal mapping tests. An illustration of the models can be seen in Figure 10.

Both models were painted twice in preparation for testing. A white paint undercoating was first applied to both models in order to provide a good reflective background. A primary coat of the phosphor paint was then applied, consisting of Sperex clear coating mixed with the selected phosphor powders. One model was painted with the Radelin® #3251 phosphor powder paint, while the other model was painted with the Radelin® #2090 phosphor powder paint. The paint layer is assumed to be thin enough such that the entire layer is at a temperature equal to the model surface temperature. From measurements made of paint layer thickness on previous tests, the paint layer has a

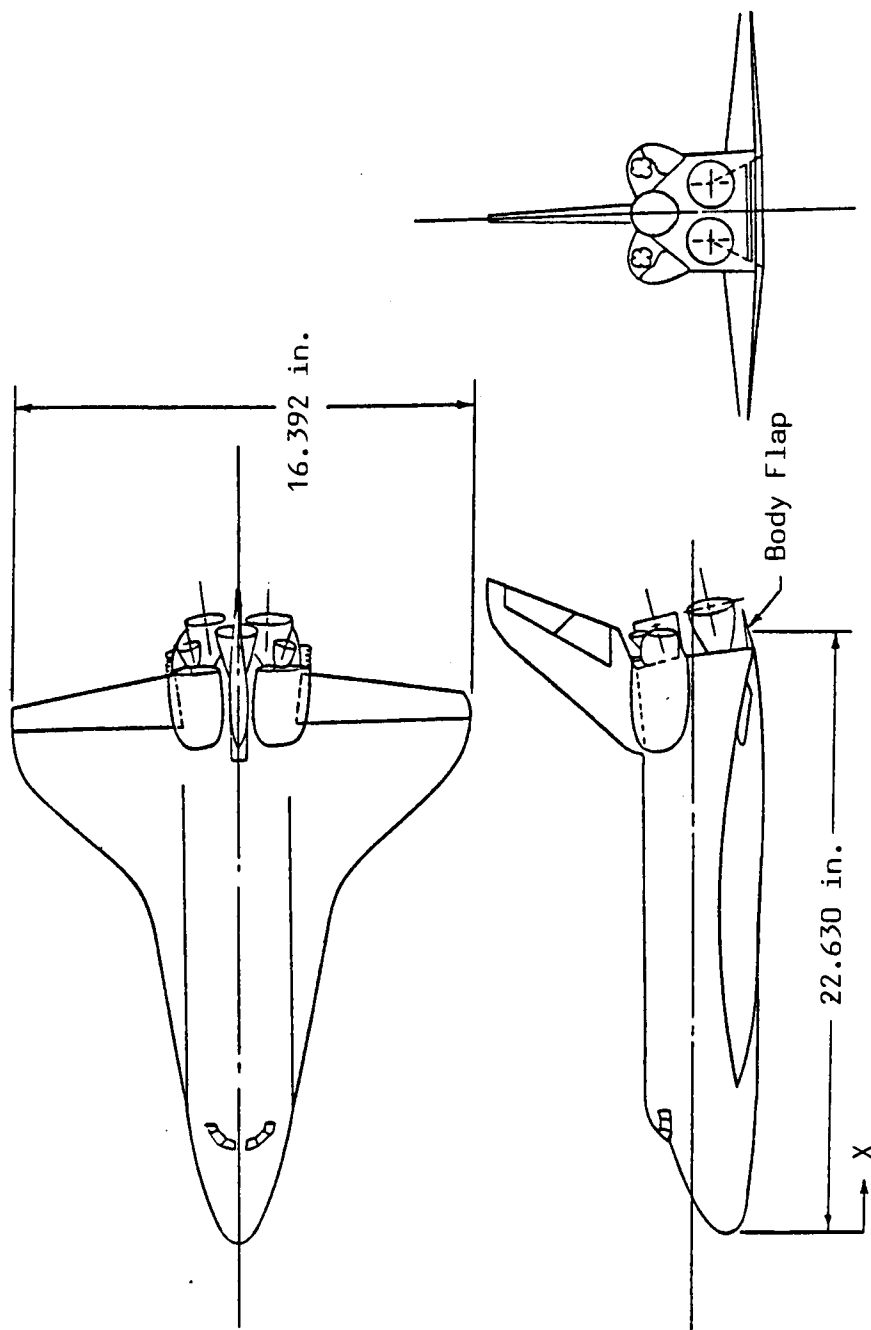


Figure 10. Model of the Space Shuttle Orbiter at 0.0175 Scale.

depth of generally less than 0.001 inch. A picture of one model is shown in Figure 11. The pretest phosphor paint calibration was then performed by the IAS, defining the relationship between the intensity of phosphorescence to that of the model surface temperature. Calibration was performed using phosphor paint from the same batch applied to the models, and using the same intensity of UV light illumination provided in the tunnel test section during actual testing.

Cameras and UV lamps were installed outside the tunnel windows. The IAS was again used to record a tare image of the model at each angle of attack to be considered. The model was sting mounted by its aft end and injected into the tunnel inverted, allowing for better exposure of the model's windward bottom surface. The tares, taken under the same UV lighting conditions as the actual test, were used to establish a model reference intensity. Using these tares in the image analysis compensated for any nonuniform application of the phosphor paint or any nonuniform UV illumination of the model. The intensity of the UV source varied with the paint being used. The model using Radelin® #3251 was exposed to an intensity of $400 \mu\text{W}/\text{cm}^2$ of UV light, while the model using Radelin® #2090 was exposed to a UV intensity of $200 \mu\text{W}/\text{cm}^2$.

The acquisition of the wind tunnel instrumentation data was automatically controlled by a Digital Equipment Corporation (DEC) PDP 11/40 computer. This computer uses VKF's Random Access Data System (RADS) with all instrumentation signals preprocessed by a digital data scanner, operating in conjunction with an analog subsystem [7]. The data were then transmitted to a DEC-10 computer for

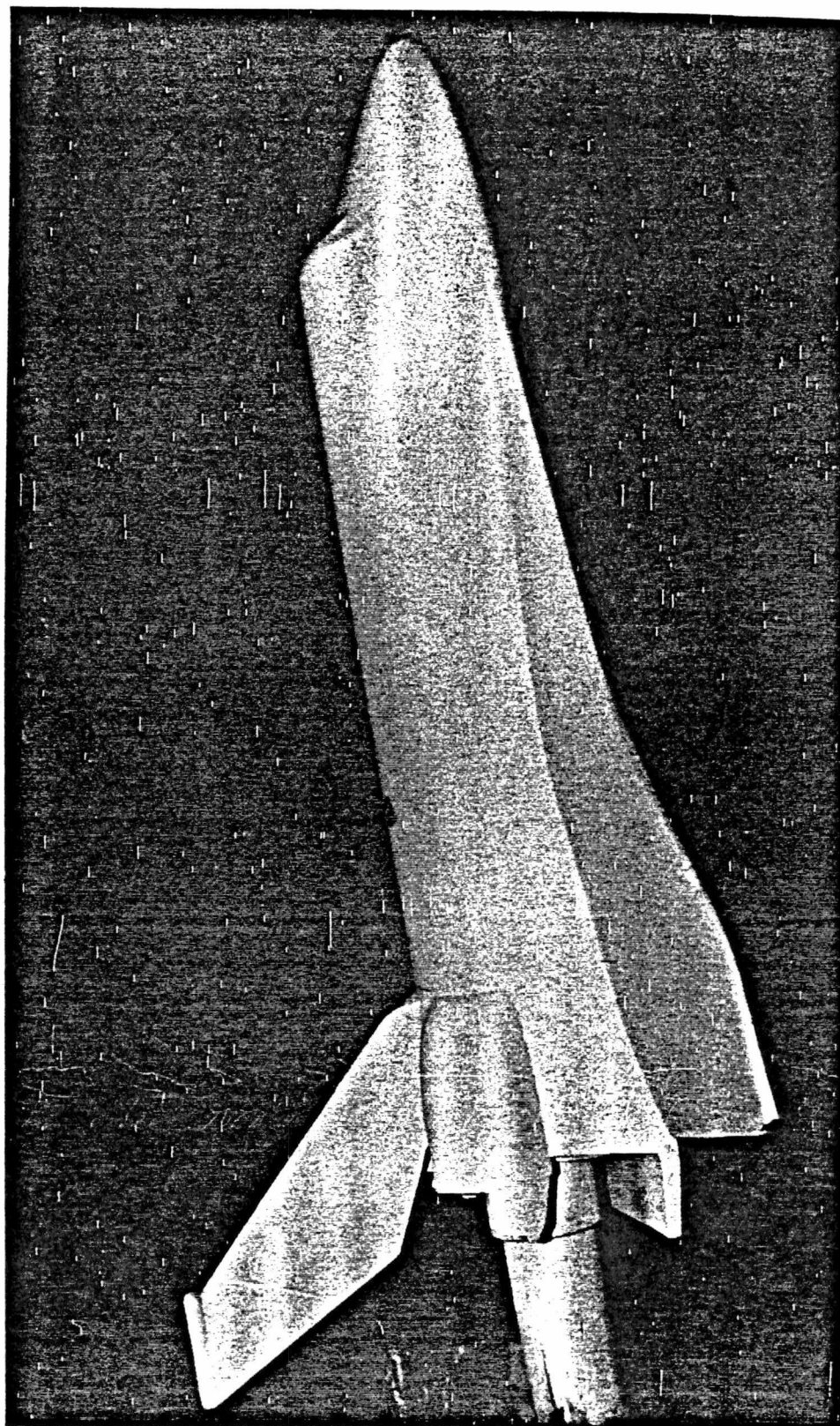


Figure 11. Phosphor Painted Model of the Space Shuttle Orbiter.

processing. During actual testing, the data system was started at the time of model injection (lift-off), with continuous data taken during a run, at a rate of approximately 10 complete data scans per second [7].

Just prior to each run, the initial temperature of the model was measured and the model attitude was set. The model was then injected into the wind tunnel airflow. The IAS began taking data when the model arrived at the tunnel centerline, digitizing and storing individual frames of video data from each camera. The frames were taken at model exposure times that were determined by pretest thermal analysis, with the time of each frame being recorded by the RADS [7]. Color representations of the surface temperature profile were also produced by the IAS, including color thermal maps that were displayed on IAS video monitors and photographed. Figure 5 is an example of such a display.

At the conclusion of each run, the model was retracted from the tunnel test section and allowed to cool using the high-pressure air cooling system in the tunnel holding tank. The model was kept in the holding tank for several minutes after the cooling system was shut off in order to allow the model to reach thermal equilibrium. Once thermal equilibrium was achieved, the next run could begin.

Fifteen (15) runs were conducted at Mach 8 at Reynolds numbers (per foot) of 0.5×10^6 , 2.0×10^6 , and 3.7×10^6 . The angles of attack for the models ranged from 20 to 35 degrees. Four (4) video cameras were set up outside the tunnel providing top, bottom, and side views of the models. A summary of the test matrix is provided in

Table 2. Note that the model with Radelin® #2090 phosphor paint was used at the higher Reynolds number (3.7×10^6). This was due to the phosphors having a higher temperature sensitivity. Likewise, the model using Radelin® #3251 phosphor paint was used at the lower Reynolds number (0.5×10^6) because of its sensitivity to a lower temperature range.

Table 2. Orbiter Model Test Summary.

Run Number	Model Paint	Re/ft ($\times 10^{-6}$)	Angle of Attack (deg)	Time in Tunnel (sec)
1	2090	2.0	30.0	---*
2	2090	2.0	30.0	---*
3	2090	2.0	20.0	13
4	2090	2.0	35.0	24
5	2090	2.0	30.0	28
6	2090	3.7	30.0	13
7	2090	3.7	35.0	13
8	2090	3.7	30.0	13
9	2090	3.7	30.0	37
10	3251	2.0	30.0	12
11	3251	2.0	20.0	12
12	3251	2.0	30.0	12
13	3251	0.5	30.0	27
14	3251	0.5	20.0	36
15	3251	0.5	30.0	36

* No tab data due to DEC-10 problems. Run 5 is probably very similar.

Note: The model paints used are designated by numbers. Paint 3251 has a temperature sensitivity between 140 and 230° F. Paint 2090 has a temperature sensitivity between 320 and 425° F.

CHAPTER VI

DATA UNCERTAINTIES

The application of the thermographic phosphor technique for determining the thermal characteristics of the Space Shuttle models provided a means for rapid data processing without manpower intensive data-reduction methods. During the examination of the data, however, one had to take into account those factors which had an impact on data quality. The most important factors are discussed here.

One factor which is inherent to any of the thermal mapping techniques is the introduction of error due to the model having a nonuniform surface temperature at the start of a test run. Each run requires that a model have, initially, an isothermal wall of known temperature in all directions. Such initial conditions are necessary in order to use the one-dimensional heat conduction equations to obtain heat-transfer coefficients from temperature data. However, it becomes increasingly difficult to meet the isothermal constraint during a test. As more runs are made, the model internal temperatures increase and are not uniform throughout the model. Temperature gradients through the depth of the wall are generally very small, largely due to the wall material used. However, spatial variation in temperature can become quite large over the model surface, and must be eliminated (or effectively reduced) prior to a run. A hand-held probe was used on this test to measure surface temperature at various points on the model prior to its injection into the wind tunnel. From

these values, an approximate mean temperature was obtained, being defined as the initial model temperature for data processing. Differences between this mean initial temperature and the actual initial temperature at a given point would result in some amount of error incurred by the reduced data at that point. Figure 12 illustrates the sensitivity of the data-reduction method to initial temperature inaccuracies. Percentages of error in the computed heat-transfer coefficients is plotted as a function of varying amounts of initial wall temperature inaccuracies. Note that for the tunnel conditions given, the amount of error to the heat-transfer coefficient can reach 60 percent with a difference between actual and mean initial surface temperature of 30 degrees.

Another factor influencing data quality, and also common to any thermal mapping technique, is estimating the amount of uncertainty in the calculated heat-transfer coefficient when using the semi-infinite solid assumption. The amount of uncertainty approaches infinity as the model wall temperature approaches either its initial temperature or the adiabatic wall temperature (also known as the aerodynamic recovery temperature) [1]. Figure 13 shows this uncertainty as a function of the wall temperature. The calibrated temperature ranges for the two phosphors used for this test, is also shown. Note that though the Radelin® #3251 phosphor had a calibrated range of 80 to 225° F, the range used in the final data reduction was limited to considering a minimum temperature of 140° F. This was done to maintain the uncertainty of the heat-transfer coefficients to at or below 20 percent.

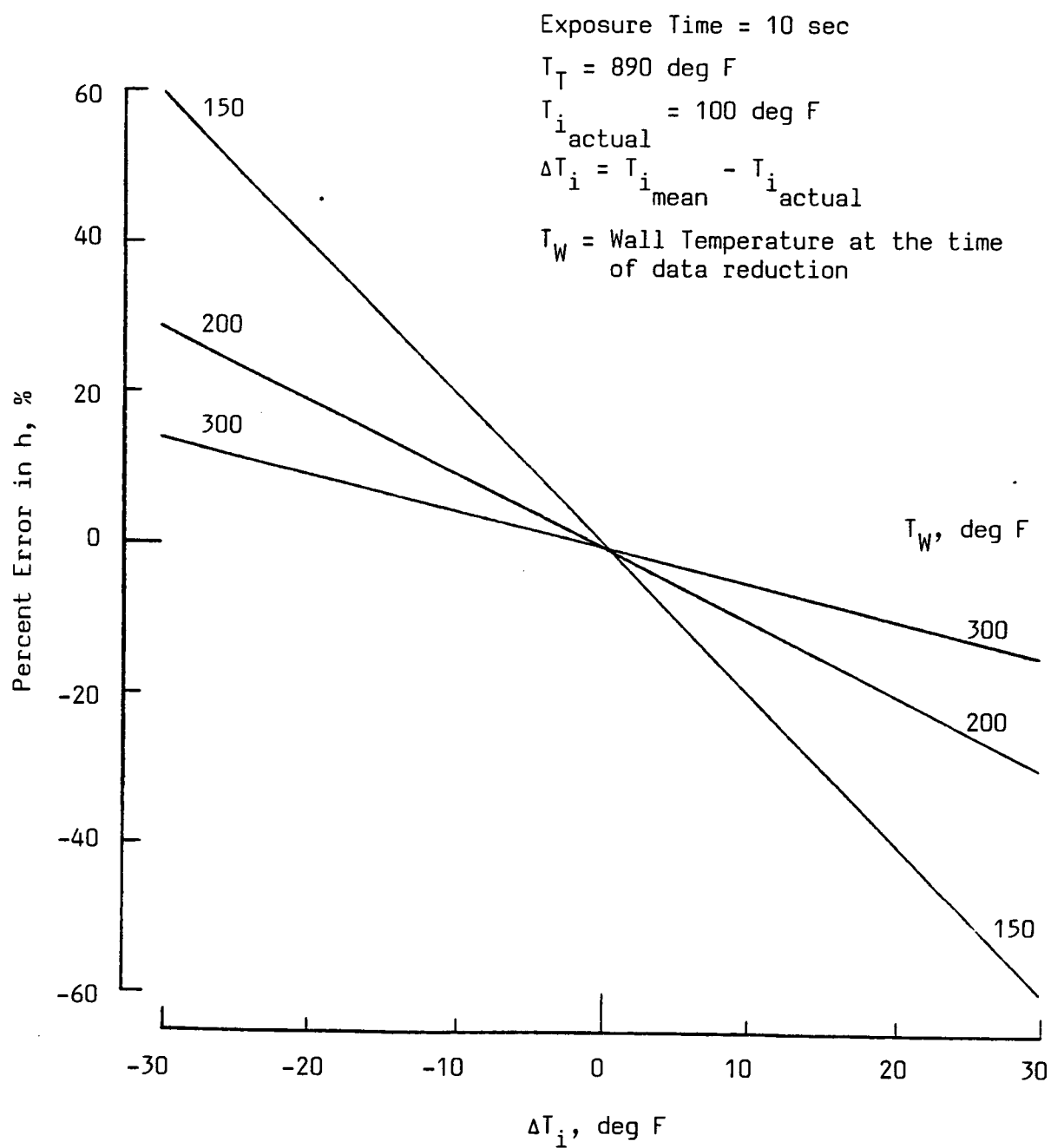


Figure 12. Error Produced in the Calculated Heat-Transfer Coefficient Due to Inaccurate Initial Temperature Measurements.

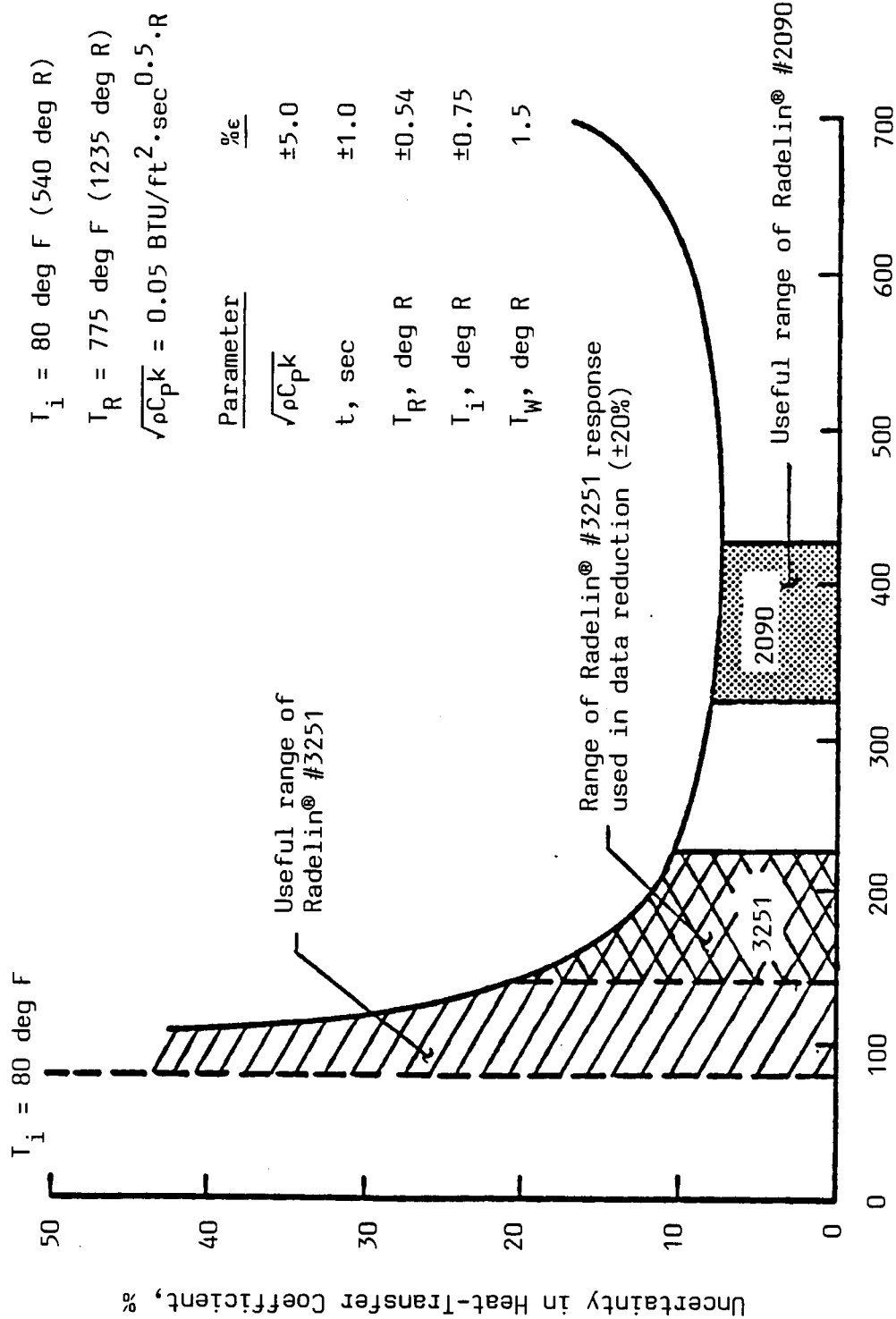
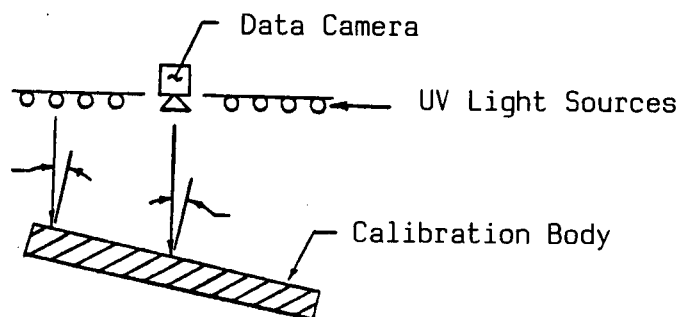
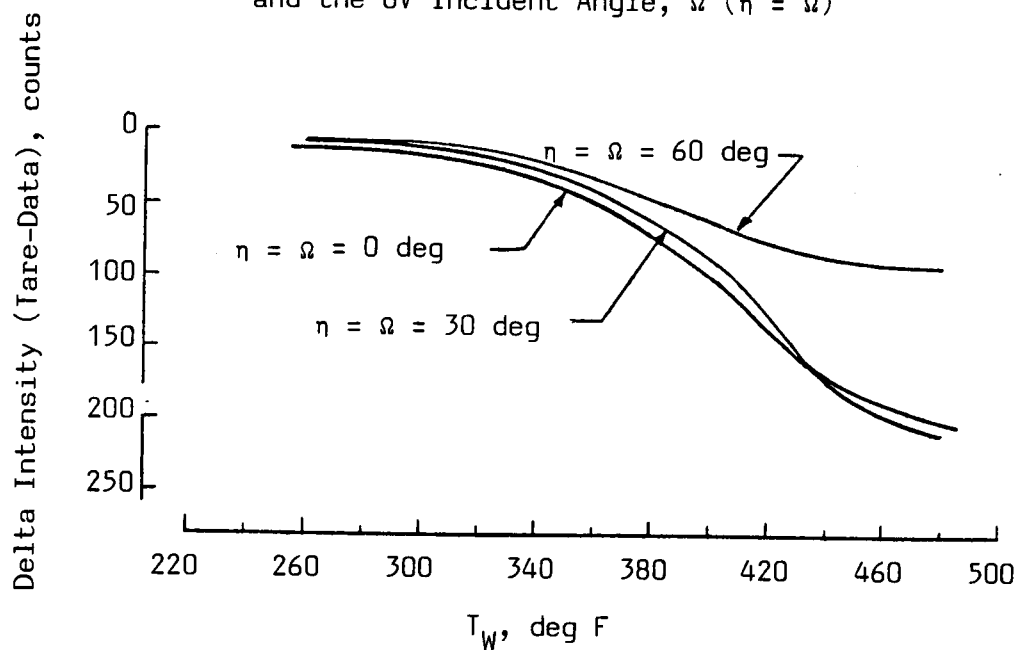


Figure 13. Uncertainty in the Heat-Transfer Coefficient Using the Thermographic Phosphor Technique.

An additional influencing factor, inherent to optically based emission detection systems, is "roll-off" error from the model surface. This is error due to UV incident angles and camera viewing angles which are not normal to the model surface. These effects, referred to as "roll-off," occur on curved model surfaces or flat plates inclined relative to the viewing/lighting direction [1]. Experiments were conducted at AEDC independent of the Space Shuttle orbiter model test to evaluate the effect of varying the camera viewing angle, η , and the UV incident angle, Ω . The experiments demonstrated that there was little disagreement between aligned data ($\eta = \Omega = 0^\circ$) and data from misalignments up to 30 degrees. Furthermore, it was found that UV lighting misalignment was the primary contributor to roll-off error. Though it was considered possible to correct the data for this misalignment, the further efforts required were not pursued. Therefore, it was recommended that phosphor data obtained with a viewing angle or UV incidence of greater than 35 degrees be considered erroneous [1]. An example of the experimental apparatus and of data obtained can be found in Figure 14.



Combined Effects of Camera Viewing Angle, η ,
and the UV Incident Angle, Ω ($\eta = \Omega$)



Results After Data Reduction

Figure 14. Effects of Non-Normal Camera Viewing Angle and the UV Incidence Angle.

CHAPTER VII

DATA EVALUATION

The proposed test run schedule listed in Table 2 was completed. The phosphor paint successfully withstood the Tunnel B environment, with comparisons between pre-test and post-test tares showing negligible degradation of the paints during the test. This fact put to rest fears that the paint would not survive the impact of the Mach 8 airflow, nor the total temperature of 890° F achieved in Tunnel B for any effective period of time.

Due to surface temperatures achieved on the model, runs 10 through 15 demonstrated the greatest sensitivity to the thermographic phosphor technique. Heat-transfer data from these runs, taken along the lower surface (windward) centerline of the model, are illustrated in Figures 15 through 20. In these figures, the heat-transfer ratio is plotted with respect to surface position for various exposure times during a run. Analogous data obtained from earlier model tests using thin-skin thermocouples is also plotted for comparison. In general, good agreement is observed between the thermographic phosphor data and the thin-skin thermocouple data. Also illustrated in these figures is an indication of the repeatability of the phosphor data within a given run. Repeatability refers to the extent of variation between data obtained at different sequences (i.e., exposure times) during a given run.

A technique-induced error, previously discussed, was that error brought about by directional sensitivity to camera viewing angle and

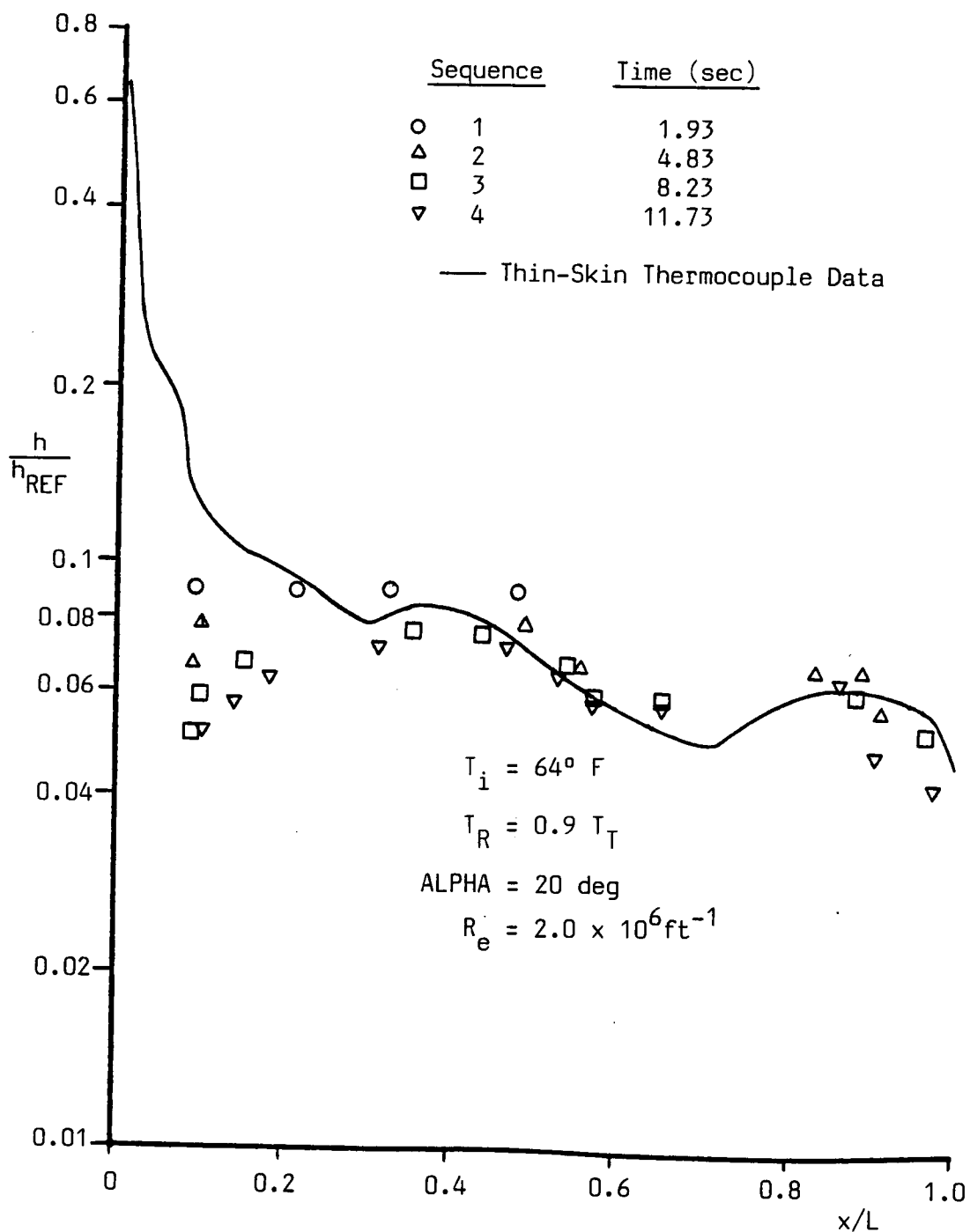


Figure 15. Comparison Between the Thermographic Phosphor and Thin-Skin Thermocouple Data Taken Along the Model Lower Surface Centerline for Run 10.

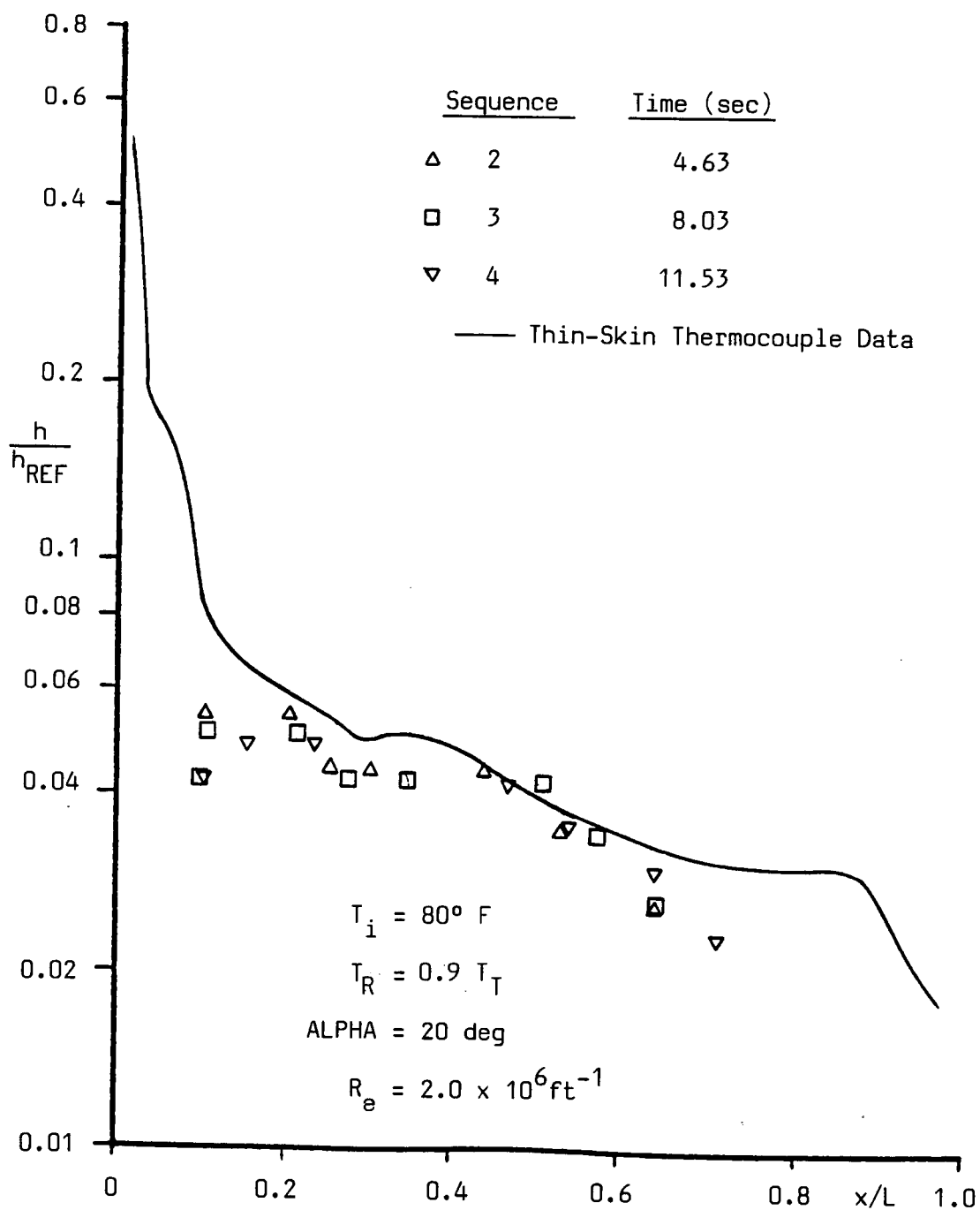


Figure 16. Comparison Between the Thermographic Phosphor and Thin-Skin Thermocouple Data Taken Along the Model Lower Surface Centerline for Run 11.

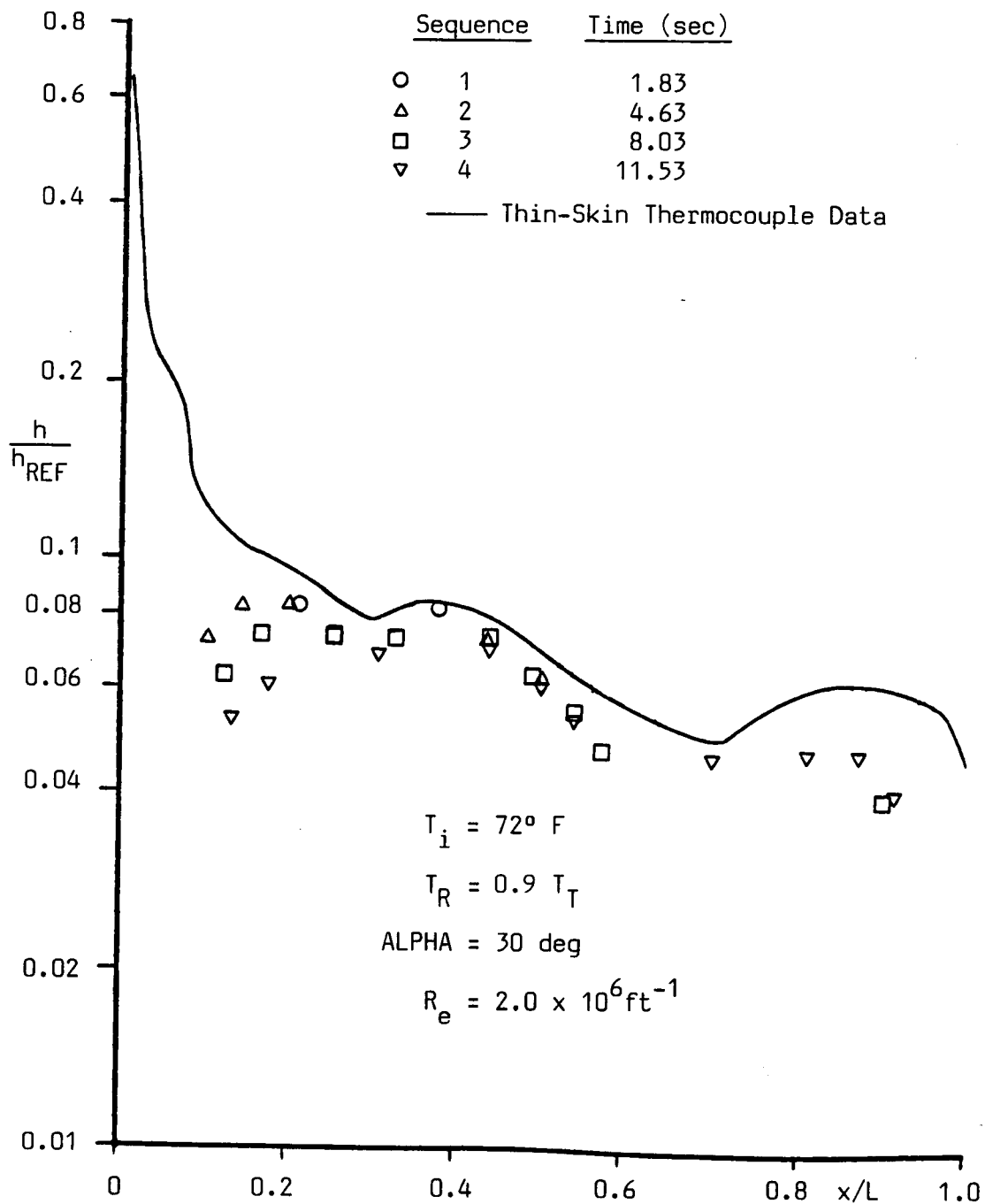


Figure 17. Comparison Between the Thermographic Phosphor and Thin-Skin Thermocouple Data Taken Along the Model Lower Surface Centerline for Run 12.

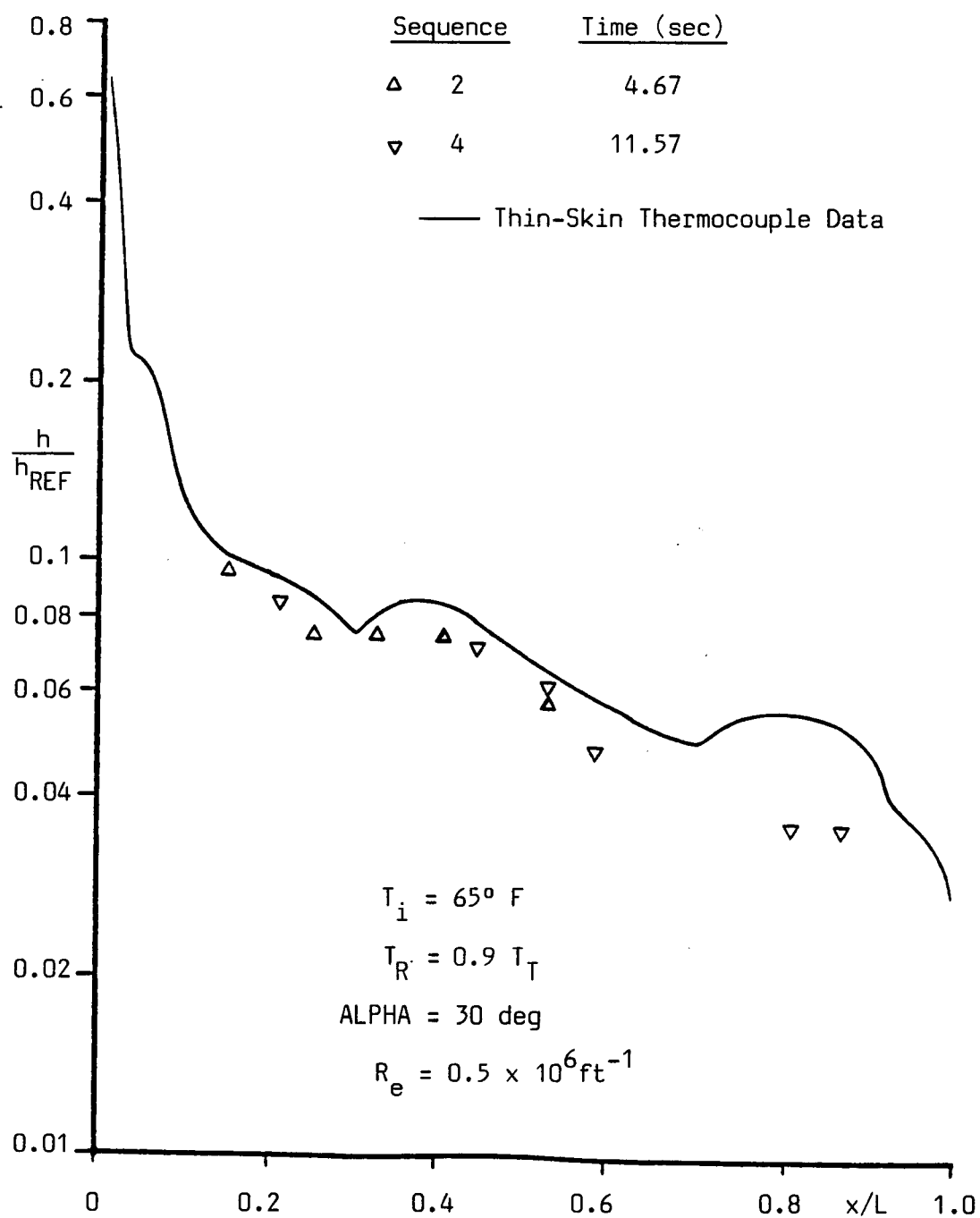


Figure 18. Comparison Between the Thermographic Phosphor and Thin-Skin Thermocouple Data Taken Along the Model Lower Surface Centerline for Run 13.

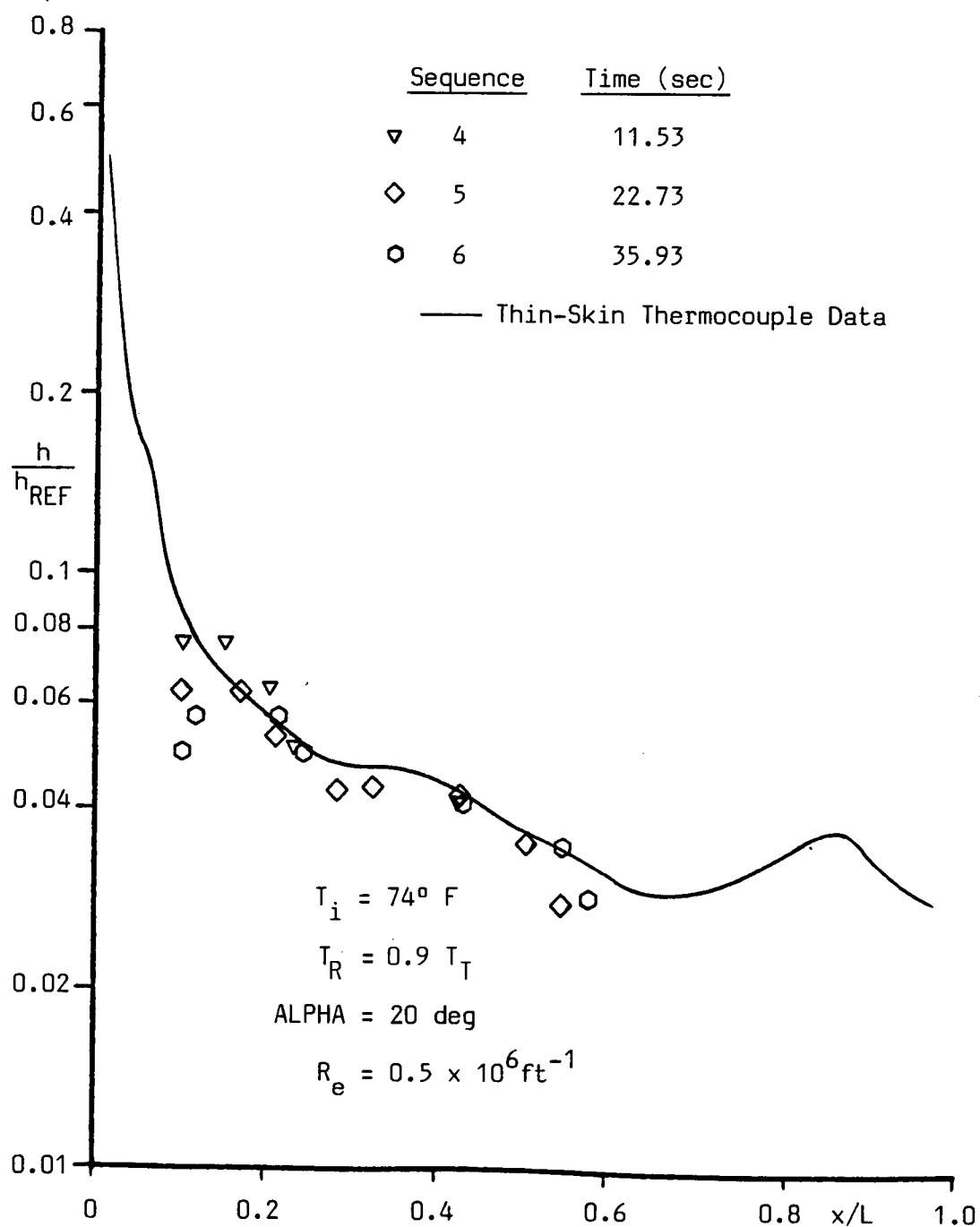


Figure 19. Comparison Between the Thermographic Phosphor and Thin-Skin Thermocouple Data Taken Along the Model Lower Surface Centerline for Run 14.

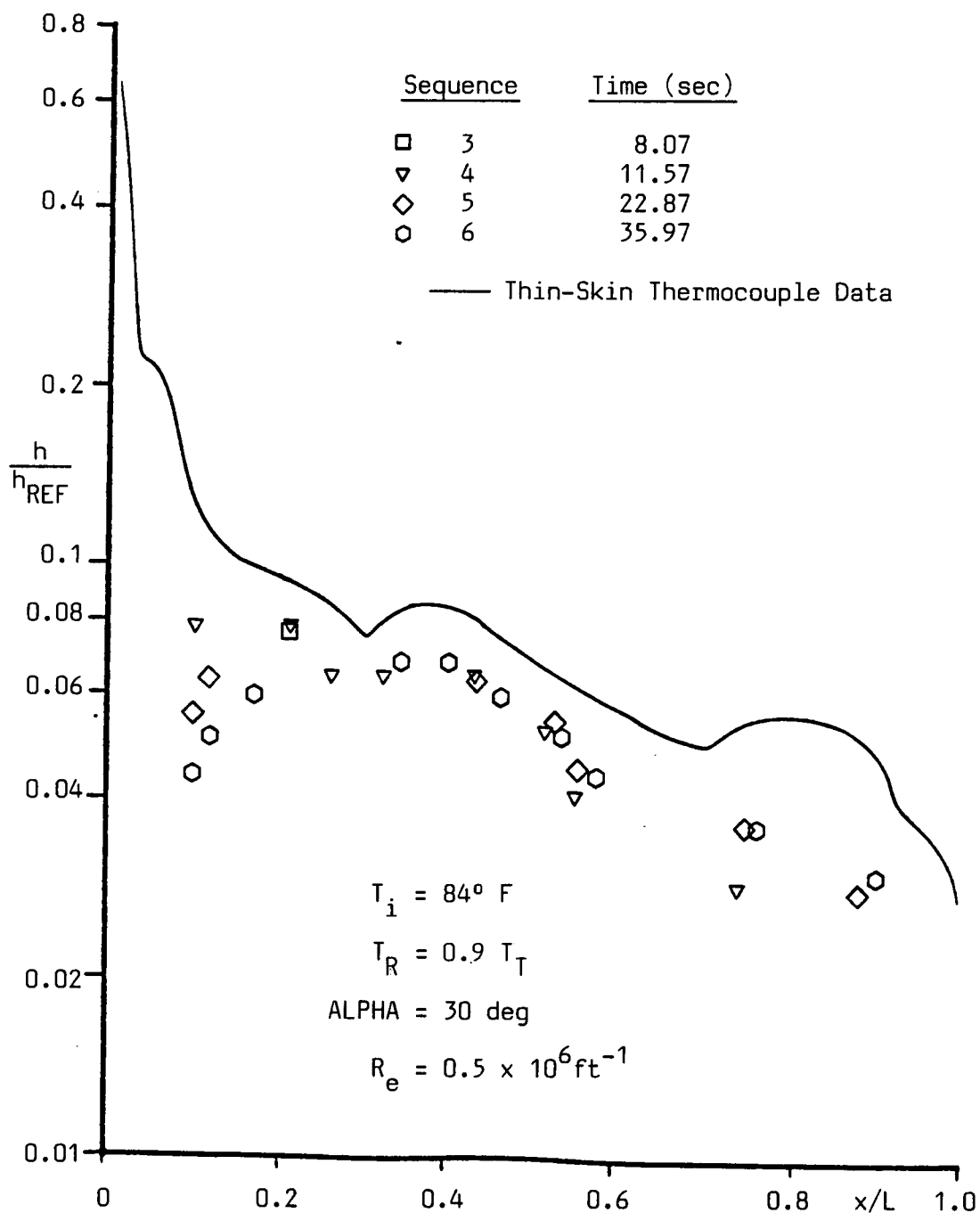


Figure 20. Comparison Between the Thermographic Phosphor and Thin-Skin Thermocouple Data Taken Along the Model Lower Surface Centerline for Run 15.

UV incident angle. The accuracy of phosphor data had to be suspect if obtained from a phosphor-treated surface with an excessive inclination from the camera or UV light source. Therefore, the nose region of the model was quite sensitive to roll-off error, since the curvature would bring about large camera viewing and UV incident angles. This problem is illustrated in each of the figures, with significant differences observed between the phosphor data and thin-skin thermocouple data at positions of $x/L < 0.15$. Forward of this point, the phosphor data should be considered invalid and either discarded or subjected to some procedure for correction.

A problem encountered during testing was the injection of a model having a nonuniform temperature distribution. The cooling system in the Tunnel B installation tank was known to be more effective on the aft end of the model than on the forward end. Once the cooling system was shut off, it was important to expose the model to a stable, ambient environment for an extended period of time. This was needed in order to allow the model to reach thermal equilibrium. Figures 15 and 17 show data from runs 10 and 12, respectively. Tunnel conditions and model configuration were the same for both runs. However, run 10 began with a lower mean initial temperature than run 12. Run 10 was also conducted only after the model had experienced a long period of ambient exposure, allowing an isothermal wall to develop prior to injection. This was not the case for run 12, initiated shortly after exposure to the active cooling system. Comparison of Figures 15 and 17 shows that a lower heat-transfer rate was measured from run 12, then from run 10. This difference became

more pronounced toward the aft end of the model. It is suspected that this variation is due to erroneous measurements of the model surface temperature prior to run 12. Since the cooling system was more effective on the model's aft regions, these regions were slightly cooler than the forward regions of the model at the time of initial wall temperature measurement and model injection. Figure 9 illustrates that the calculated heat-transfer coefficient can be erroneously low when the actual wall temperature at injection is below the initial wall temperature used in the data reduction. In examining Figures 18 and 20 (runs 13 and 15, respectively), a similar problem appears to exist for run 15 when compared to run 13; both runs occurred under the same tunnel conditions and model configuration. These observed biases provide testament to the importance of obtaining a uniform wall temperature prior to model testing.

CHAPTER VIII

CONCLUSIONS

Several issues were of concern at the beginning of this test. These included the accuracy of the thermographic phosphor as compared to data obtained from the more conventional approach of using thin-skin thermocouples. Additional interests were the survivability of the phosphor paint under hypersonic flow conditions and the effects of UV incident lighting direction on data accuracy. From general observations made during the test and examination of the data obtained, the conclusions about the use of this technique are that:

1. the thermographic phosphor data generally compared well to data obtained from thin-skin thermocouples;
2. the technique is sensitive to uneven cooling of the model; a uniform internal temperature distribution along the model surface is required in order to accurately measure the initial model wall temperature at time of injection;
3. model surface inclination from the incident UV lighting direction should be kept to a minimum and is recommended not to exceed 35° ; data obtained from angles beyond 35° are considered suspect; and
4. the phosphor paint maintained its integrity during repeated exposure to Mach 8 flow at 890° F and Reynolds numbers up to $3.5 \times 10^6 \text{ ft}^{-1}$; no appreciable degradation was observed.

Though the thermographic phosphor technique is a promising approach to heat-transfer analysis, additional development is encouraged. Improvements need to be made in data-reduction procedures to reduce error associated with UV incident sensitivity. Also, improvements in model cooling are needed to allow for more rapid attainment of an isothermal surface prior to testing.

At present, the thermographic phosphor technique appears satisfactory for "flat plate type" surfaces, but not for the nose regions of aerodynamic models where temperature gradients are too large to resolve accurately. Thus, the use of phosphor paint could be part of a combined technique using thermocouples in the model's nose region and paint on the remainder of the body. However, further attention needs to be given to improve model interior cooling, and may best be done by designing models specifically for use with the phosphor technique. This technique may also lend itself to surface-blowing experiments where the use of thin-skin thermocouples would make the experiment too expensive to conduct. It may also be useful in testing models with roughened surfaces, or in testing specific components of a model.

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APPENDIX
TABULATED HEAT-TRANSFER DATA
FOR RUNS 10 THROUGH 15

Run	TIME INJ SEC	MODEL ROLL DEG	ALPHA MODEL DEG	HREF RTU/FT2-SEC-R					
10	2.00	180.00	30.00	.363E-01					
HACH	FT	T	Q	V	RND	NU	LBF-SEC/FT2	MEAS-06	
7.93	PSIA	DEGR	PSIA	FT/SEC	LHM/FT3	.000E-07		FT-1	
	448.0	1349.7	99.4	3876.0	.132E-02			1.985	
ORBITER MODEL									
PHOSPHOR - 3251 PAINT									
TIME EXPOSED - 1.93 SEC									
INITIAL TEMP - 64.0 DEG F									
COLOR CODE									
COLOR	INITIAL TEMP	HEAT TRANSFER COEFF, RTU/FT2-SEC-DEG	HEAT TRANSFER COEFF, RTU/FT2-SEC-DEG	HEAT TRANSFER COEFF, RTU/FT2-SEC-DEG	RATIO TO HREF	RATIO TO HREF	RATIO TO HREF	RATIO TO HREF	RATIO TO HREF
	TEMP-DEG F	H(1)	H(1)	H(1)	H(1)/HREF	H(1)/HREF	H(1)/HREF	H(1)/HREF	H(1)/HREF
		USED	USED	USED					
WHITE	140.	0.048	3.06E-03	3.71E-03	4.16E-03	0.43E-02	1.02E-01	1.15E-01	
GRAY	146.	0.048	3.43E-03	4.05E-03	4.54E-03	9.18E-02	1.12E-01	1.25E-01	
BROWN	151.	0.048	3.56E-03	4.33E-03	4.86E-03	9.01E-02	1.19E-01	1.34E-01	
TAN	157.	0.049	3.84E-03	4.68E-03	5.26E-03	1.06E-01	1.29E-01	1.45E-01	
CORAL	163.	0.049	4.12E-03	5.03E-03	5.60E-03	1.14E-01	1.39E-01	1.56E-01	
BLUE	168.	0.049	4.46E-03	5.33E-03	6.00E-03	1.20E-01	1.47E-01	1.65E-01	
TURQUOISE	174.	0.049	4.66E-03	5.70E-03	6.42E-03	1.28E-01	1.57E-01	1.77E-01	
SKY BLUE	179.	0.049	4.91E-03	6.02E-03	6.78E-03	1.35E-01	1.66E-01	1.87E-01	
OLIVE	185.	0.049	5.11E-03	6.40E-03	7.22E-03	1.44E-01	1.76E-01	1.99E-01	
GREEN	191.	0.049	5.52E-03	6.79E-03	7.67E-03	1.52E-01	1.87E-01	2.11E-01	
LIME	196.	0.049	5.78E-03	7.17E-03	8.05E-03	1.59E-01	1.96E-01	2.22E-01	
YELLOW	201.	0.050	6.05E-03	7.46E-03	8.45E-03	1.67E-01	2.06E-01	2.33E-01	
ORANGE	208.	0.050	6.43E-03	7.94E-03	9.01E-03	1.77E-01	2.19E-01	2.48E-01	
RED	213.	0.050	6.70E-03	8.29E-03	9.41E-03	1.85E-01	2.29E-01	2.60E-01	
SALMON	219.	0.050	7.04E-03	8.73E-03	9.94E-03	1.94E-01	2.41E-01	2.73E-01	
BLACK	224.	0.050	7.33E-03	9.10E-03	1.04E-02	2.02E-01	2.51E-01	2.85E-01	
	230.	0.050	7.67E-03	9.55E-03	1.09E-02	2.12E-01	2.63E-01	3.00E-01	

TUP APT CAMERA 1
SEQUENCE 1

RUN	TIME INJ SEC	MODEL ROLL DEG	ALPHA MODEL DEG	HMCP RTU/FT2-SEC-R .163E-01	Y	HMCP LHM/FT3 .132E-02	MU LHM-SEC/FT2 .600E-01	ME-E+06 FT-1 1.985
10	2.00	180.00	30.00					
MACH	PT	PSIA	P	Q	PSIA	HMCP		
7.93	449.0	1449.7	0.049	99.4	2.137	.17/SEC 3876.0		
ORRITER MODEL								
PHOSPHOR - 3251 FAINT								
TIME EXPOSED - 4.83 SEC								
INITIAL TEMP - 64.0 DEG F								
COLOR	INTENSITY	TEMPERATURE	RU-CR-01/2 USED	HMCP TRANSFER COEFF, RTU/FT2-SEC-DEG H(.90UTT)	TOP APT CAMERA SEQUENCE	HMCP H(.90UTT)/ HREF	HMCP H(.90UTT)/ HREF	HMCP H(.90UTT)/ HREF
WHITE	140.	1.93E-03	0.048	2.35E-03	2.63E-03	5.33E-02	6.47E-02	7.24E-02
GRAY	146.	2.10E-03	0.048	2.56E-03	2.87E-03	5.80E-02	7.05E-02	7.90E-02
BROWN	151.	2.25E-03	0.048	2.74E-03	3.07E-03	6.20E-02	7.54E-02	8.47E-02
TAN	157.	2.42E-03	0.049	2.96E-03	3.32E-03	6.68E-02	8.15E-02	9.15E-02
CUBALI	163.	2.60E-03	0.049	3.18E-03	3.58E-03	7.18E-02	8.76E-02	9.86E-02
BLUE	168.	2.76E-03	0.049	3.37E-03	3.79E-03	7.60E-02	9.29E-02	1.05E-01
TURQUOISE	174.	2.94E-03	0.049	3.60E-03	4.06E-03	8.11E-02	9.93E-02	1.12E-01
SKY BLUE	179.	3.10E-03	0.049	3.80E-03	4.28E-03	8.55E-02	1.05E-01	1.18E-01
OLIVE	185.	3.29E-03	0.049	4.04E-03	4.56E-03	9.08E-02	1.11E-01	1.26E-01
GREEN	191.	3.49E-03	0.049	4.29E-03	4.85E-03	9.61E-02	1.18E-01	1.34E-01
LIME	196.	3.65E-03	0.049	4.50E-03	5.09E-03	1.01E-01	1.24E-01	1.40E-01
YELLOW	201.	3.82E-03	0.050	4.71E-03	5.34E-03	1.05E-01	1.30E-01	1.47E-01
ORANGE	206.	4.00E-03	0.050	5.02E-03	5.69E-03	1.12E-01	1.38E-01	1.57E-01
RED	213.	4.24E-03	0.050	5.24E-03	5.95E-03	1.17E-01	1.44E-01	1.64E-01
SALMON	219.	4.45E-03	0.050	5.51E-03	6.27E-03	1.23E-01	1.52E-01	1.73E-01
BLACK	224.	4.63E-03	0.050	5.75E-03	6.54E-03	1.28E-01	1.58E-01	1.80E-01
	230.	4.85E-03	0.050	6.03E-03	6.87E-03	1.34E-01	1.66E-01	1.89E-01

RUN	TIME INJ SEC	MODEL ROLL I-EG	ALPHA MODEL DEG	HEAT BTU/FT2-SEC-R	MMEF BTU/FT2-SEC-R	PT PSIA	TT DEGR	F PSIA	Q PSIA	V FT/SEC	MNO LHM/FT3	MU LBF-SEC/FT2	MEME+UD FT-1
10	2.00	186.00	30.00		.364E-01				2.137	3876.0	.132E-02	.800E-07	1.985
UNBITER MODEL													
PHOSPHOR - 3251 PAINT													
TIME EXPOSED - 9.23 SEC													
INITIAL TEMP - 64.0 DEG F													
COLOR CHIT													
COLOR	INTERPACK TEMP/DEG F	HO-CR=1/2 USED	HEAT TRANSFER COEFF, BTU/FT2-SEC-DEG H(1,90TT)	BTU/FT2-SEC-DEG H(1,90TT)	RATIO 10 HREF H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF	H(1,90TT)/ HREF
WHITE	140.	0.048	1.48E-03	1.80E-03	2.01E-03	4.08E-02	4.95E-02	5.55E-02					
GRAY	146.	0.048	1.61E-03	1.96E-03	2.20E-03	4.44E-02	5.40E-02	6.05E-02					
BROWN	151.	0.048	1.72E-03	2.10E-03	2.45E-03	4.75E-02	5.79E-02	6.49E-02					
TAN	157.	0.049	1.86E-03	2.26E-03	2.54E-03	5.12E-02	6.24E-02	7.01E-02					
COBALT	163.	0.049	2.00E-03	2.44E-03	2.74E-03	5.50E-02	6.71E-02	7.55E-02					
BLUE	166.	0.049	2.11E-03	2.58E-03	2.91E-03	5.82E-02	7.12E-02	8.01E-02					
TURQUOISE	174.	0.049	2.25E-03	2.76E-03	3.11E-03	6.22E-02	7.61E-02	8.57E-02					
SKY BLUE	179.	0.049	2.38E-03	2.91E-03	3.28E-03	6.55E-02	8.02E-02	9.05E-02					
OLIVE	185.	0.049	2.52E-03	3.10E-03	3.50E-03	6.95E-02	8.54E-02	9.64E-02					
GREEN	191.	0.049	2.67E-03	3.29E-03	3.71E-03	7.36E-02	9.06E-02	1.02E-01					
LIME	196.	0.049	2.80E-03	3.45E-03	3.90E-03	7.71E-02	9.50E-02	1.07E-01					
YELLOW	201.	0.050	2.93E-03	3.61E-03	4.09E-03	8.07E-02	9.95E-02	1.13E-01					
ORANGE	208.	0.050	3.11E-03	3.84E-03	4.36E-03	8.57E-02	1.06E-01	1.20E-01					
RED	213.	0.050	3.24E-03	4.01E-03	4.58E-03	8.94E-02	1.11E-01	1.26E-01					
SALMON	219.	0.050	3.41E-03	4.27E-03	4.80E-03	9.39E-02	1.16E-01	1.32E-01					
BLACK	224.	0.050	3.55E-03	4.40E-03	5.01E-03	9.77E-02	1.21E-01	1.38E-01					
	230.	0.050	3.71E-03	4.62E-03	5.26E-03	1.02E-01	1.27E-01	1.45E-01					

RUN	TIME INJ SEC	ALPHA MODEL DEG	HEAT TRANSFER COEFF. H(TT) H(11)	HTU/FT2-SEC-DEG H(1.90TT) H(1.951T)	RATIO TO HREF H(TT)/ HREF	HTU/FT2-SEC-DEG H(1.90TT) H(1.951T)	RATIO TO HREF H(TT)/ HREF	HTU/FT2-SEC-DEG H(1.90TT) H(1.951T)	RATIO TO HREF H(TT)/ HREF	HTU/FT2-SEC-DEG H(1.90TT) H(1.951T)	RATIO TO HREF H(TT)/ HREF
11	2.00	19.98	180.00	99.4	2.56E-03	3.11E-03	3.49E-03	7.06E-02	9.58E-02	9.61E-02	9.61E-02
MACH	PT	PSIA	DEGR	PSIA	DEGR	PSIA	DEGR	PSIA	DEGR	PSIA	DEGR
7.43	448.0	1349.7	99.4	2.137	2.84E-03	3.46E-03	3.66E-03	7.83E-02	9.53E-02	1.07E-01	1.07E-01
INTERPACK TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F	TEMP, DEG F
140.	146.	151.	157.	163.	168.	174.	179.	185.	191.	196.	201.
206.	213.	219.	224.	230.	236.	242.	248.	254.	260.	266.	272.
278.	284.	290.	296.	302.	308.	314.	320.	326.	332.	338.	344.
350.	356.	362.	368.	374.	380.	386.	392.	398.	404.	410.	416.
422.	428.	434.	440.	446.	452.	458.	464.	470.	476.	482.	488.
494.	500.	506.	512.	518.	524.	530.	536.	542.	548.	554.	560.
566.	572.	578.	584.	590.	596.	602.	608.	614.	620.	626.	632.
638.	644.	650.	656.	662.	668.	674.	680.	686.	692.	698.	704.
710.	716.	722.	728.	734.	740.	746.	752.	758.	764.	770.	776.
782.	788.	794.	800.	806.	812.	818.	824.	830.	836.	842.	848.
854.	860.	866.	872.	878.	884.	890.	896.	902.	908.	914.	920.
926.	932.	938.	944.	950.	956.	962.	968.	974.	980.	986.	992.
998.	1004.	1010.	1016.	1022.	1028.	1034.	1040.	1046.	1052.	1058.	1064.
1070.	1076.	1082.	1088.	1094.	1100.	1106.	1112.	1118.	1124.	1130.	1136.
1142.	1148.	1154.	1160.	1166.	1172.	1178.	1184.	1190.	1196.	1202.	1208.
1214.	1220.	1226.	1232.	1238.	1244.	1250.	1256.	1262.	1268.	1274.	1280.
1286.	1292.	1298.	1304.	1310.	1316.	1322.	1328.	1334.	1340.	1346.	1352.
1358.	1364.	1370.	1376.	1382.	1388.	1394.	1400.	1406.	1412.	1418.	1424.
1430.	1436.	1442.	1448.	1454.	1460.	1466.	1472.	1478.	1484.	1490.	1496.
1502.	1508.	1514.	1520.	1526.	1532.	1538.	1544.	1550.	1556.	1562.	1568.
1574.	1580.	1586.	1592.	1598.	1604.	1610.	1616.	1622.	1628.	1634.	1640.
1646.	1652.	1658.	1664.	1670.	1676.	1682.	1688.	1694.	1700.	1706.	1712.
1718.	1724.	1730.	1736.	1742.	1748.	1754.	1760.	1766.	1772.	1778.	1784.
1790.	1796.	1802.	1808.	1814.	1820.	1826.	1832.	1838.	1844.	1850.	1856.
1862.	1868.	1874.	1880.	1886.	1892.	1898.	1904.	1910.	1916.	1922.	1928.
1934.	1940.	1946.	1952.	1958.	1964.	1970.	1976.	1982.	1988.	1994.	2000.
2006.	2012.	2018.	2024.	2030.	2036.	2042.	2048.	2054.	2060.	2066.	2072.
2078.	2084.	2090.	2096.	2102.	2108.	2114.	2120.	2126.	2132.	2138.	2144.
2150.	2156.	2162.	2168.	2174.	2180.	2186.	2192.	2198.	2204.	2210.	2216.
2222.	2228.	2234.	2240.	2246.	2252.	2258.	2264.	2270.	2276.	2282.	2288.
2294.	2300.	2306.	2312.	2318.	2324.	2330.	2336.	2342.	2348.	2354.	2360.
2366.	2372.	2378.	2384.	2390.	2396.	2402.	2408.	2414.	2420.	2426.	2432.
2438.	2444.	2450.	2456.	2462.	2468.	2474.	2480.	2486.	2492.	2498.	2504.
2510.	2516.	2522.	2528.	2534.	2540.	2546.	2552.	2558.	2564.	2570.	2576.
2582.	2588.	2594.	2600.	2606.	2612.	2618.	2624.	2630.	2636.	2642.	2648.
2654.	2660.	2666.	2672.	2678.	2684.	2690.	2696.	2702.	2708.	2714.	2720.
2726.	2732.	2738.	2744.	2750.	2756.	2762.	2768.	2774.	2780.	2786.	2792.
2798.	2804.	2810.	2816.	2822.	2828.	2834.	2840.	2846.	2852.	2858.	2864.
2870.	2876.	2882.	2888.	2894.	2900.	2906.	2912.	2918.	2924.	2930.	2936.
2942.	2948.	2954.	2960.	2966.	2972.	2978.	2984.	2990.	2996.	3002.	3008.
3014.	3020.	3026.	3032.	3038.	3044.	3050.	3056.	3062.	3068.	3074.	3080.
3086.	3092.	3098.	3104.	3110.	3116.	3122.	3128.	3134.	3140.	3146.	3152.
3158.	3164.	3170.	3176.	3182.	3188.	3194.	3200.	3206.	3212.	3218.	3224.
3230.	3236.	3242.	3248.	3254.	3260.	3266.	3272.	3278.	3284.	3290.	3296.
3302.	3308.	3314.	3320.	3326.	3332.	3338.	3344.	3350.	3356.	3362.	3368.
3374.	3380.	3386.	3392.	3398.	3404.	3410.	3416.	3422.	3428.	3434.	3440.
3446.	3452.	3458.	3464.	3470.	3476.	3482.	3488.	3494.	3500.	3506.	3512.
3518.	3524.	3530.	3536.	3542.	3548.	3554.	3560.	3566.	3572.	3578.	3584.
3590.	3596.	3602.	3608.	3614.	3620.	3626.	3632.	3638.	3644.	3650.	3656.
3662.	3668.	3674.	3680.	3686.	3692.	3698.	3704.	3710.	3716.	3722.	3728.
3734.	3740.	3746.	3752.	3758.	3764.	3770.	3776.	3782.	3788.	3794.	3800.
3806.	3812.	3818.	3824.	3830.	3836.	3842.	3848.	3854.	3860.	3866.	3872.
3878.	3884.	3890.	3896.	3902.	3908.	3914.	3920.	3926.	3932.	3938.	3944.
3950.	3956.	3962.	3968.	3974.	3980.	3986.	3992.	3998.	4004.	4010.	4016.
4022.	4028.	4034.	4040.	4046.	4052.	4058.	4064.	4070.	4076.	4082.	4088.
4094.	4100.	4106.	4112.	4118.	4124.	4130.	4136.	4142.	4148.	4154.	4160.
4166.	4172.	4178.	4184.	4190.	4196.	4202.	4208.	4214.	4220.	4226.	4232.
4238.	4244.	4250.	4256.	4262.	4268.	4274.	4280.	4286.	4292.	4298.	4304.
4310.	4316.	4322.	4328.	4334.	4340.	4346.	4352.	4358.	4364.	4370.	4376.
4382.	4388.	4394.	4400.	4406.	4412.	4418.	4424.	4430.	4436.	4442.	4448.
4454.	4460.	4466.	4472.	4478.	4484.	4490.	4496.	4502.	4508.	4514.	4520.
4526.	4532.	4538.	4544.	4550.	4556.	4562.	4568.	4574.	4580.	4586.	4592.
4598.	4604.	4610.	4616.	4622.	4628.	4634.	4640.	4646.	4652.	4658.	4664.
4670.	4676.	4682.	4688.	4694.	4700.	4706.	4712.	4718.	4724.	4730.	4736.
4742.	4748.	4754.	4760.	4766.	4772.	4778.	4784.	4790.	4796.	4802.	4808.
4814.	4820.	4826.	4832.	4838.	4844.	4850.	4856.	4862.	4868.	4874.	4880.
4886.	4892.	4898.	4904.	4910.	4916.	4922.	4928.	4934.	4940.	4946.	4952.
4958.	4964.	4970.	4976.	4982.	4988.	4994.	5000.	5006.	5012.	5018.	5024.
5030.	5036.	5042.	5048.	5054.	5060.	5066.	5072.	5078.	5084.	5090.	5096.
5102.	5108.	5114.	5120.	5126.	5132.	5138.	5144.	5150.	5156.	5162.	5168.
5174.	5180.	5186.	5192.	5198.	5204.	5210.	5216.	5222.	5228.	5234.	5240.
5246.	5252.	5258.	5264.	5270.	5276.	5282.	5288.	5294.	5300.	5306.	5312.
5318.	5324.	5330.	5336.	5342.	5348.	5354.	5360.	5366.	5372.	5378.	5384.
5390.	5396.	5402.	5408.	5414.	5420.	5426.	5432.	5438.	5444.	5450.	5456.
5462.	5468.	5474.	5480.	5486.	5492.	5498.	5504.	5510.	5516.	5522.	5528.
5534.	5540.	5546.	5552.	5558.	5564.	5570.	5576.	5582.	5588.	5594.	5600.
5606.	5612.	5618.	5624.	5630.	5636.	5642.	5648.	5654.	5660.	5666.	5672.
5678.	5684.	5690.	5696.	5702.	5708.	5714.	5720.	5726.	5732.	5738.	5744.
5750.	5756.	5762.	5768.	5774.	5780.	5786.	5792.	5798.	5804.	5810.	5816.
5822.	5828.	5834.	5840.	5846.	5852.	5858.	5864.	5870.	5876.	5882.	5888.
5894.	5900.	5906.	5912.	5918.	5924.	5930.	5936.	5942.	5948.	5954.	5960.
5966.	5972.	5978.	5984.	5990.	5996.	6002.	6008.	6014.	6020.	6026.	6032.
6038.	6044.	6050.	6056.	6062.	6068.	6074.	6080.	6086.	6092.	6098.	6104.
6110.	6116.	6122.	6128.	6134.	6140.	6146.	6152.	6158.	6164.	6170.	6176.
6182.	6188.	6194.	6200.	6206.	6212.	6218.	6224.	6230.	6236.	6242.	6248.
6254.	6260.	6266.	6272.	6278.	6284.	6290.	6296.	6302.	6308.	6314.	6320.
6326.	6332.	6338.	6344.	6350.	6356.	6362.	6368.	6374.	6380.	6386.	6392.
6398.	6404.	6410.	6416.	6422.	6428.	6434.	6440.	6446.	6452.	6458.	6464.
6470.	6476.	6482.	6488.	6494.	6500.	6506.	6512.	6518.	6524.	6530.	6536.
6542.	6548.	6554.	6560.	6566.	6572.	6578.	6584.	6590.	6596.	6602.	6608.
6614.	6620.	6626.	6632.	6638.	6644.	6650.	6656.	6662.	6668.	6674.	6680.
6686.	6692.	6698.	6704.	6710.	671						

RUN	TIME INJ SEC	MODEL RULL DEG	ALPHA MODEL DEG	HDEF RTU/FT2-SEC-H	V	RND LHM/FT3	MU LHM-SEC/FT2	HDEF FT-1
11	2.00	180.00	19.98	.163E-01				1.985
KACH	PT	IF	P	PSIA	0			
7.93	488.0	1344.7	0.049	2.137	FT/SEC			
					3876.0			
INPRTER MODEL								
PHOSPHOR - 3251 PAINT								
TIME EXPOSED - 4.63 SEC								
INITIAL TEMP - 80.0 DEG F								
CULUM	COLOR	CUM	INT-TRACE TEMP-DEG F	RN-CK=1/2 USED	HEAT TRANSFER COEFF, RTU/FT2-SEC-DEG H(FT)	H(FT)	RATIO TO HDEF H(FT)/HDEF	H(FT)/HDEF
WHITE	160.	0.048	1.56E-03	1.90E-03	2.13E-03	4.31E-02	5.34E-02	5.87E-02
GRAY	166.	0.048	1.74E-03	2.11E-03	2.37E-03	4.79E-02	5.82E-02	6.53E-02
BROWN	151.	0.048	1.88E-03	2.29E-03	2.57E-03	5.19E-02	6.32E-02	7.09E-02
TAN	157.	0.049	2.06E-03	2.51E-03	2.82E-03	5.68E-02	6.93E-02	7.78E-02
CORAL	163.	0.049	2.24E-03	2.74E-03	3.09E-03	6.17E-02	7.54E-02	8.49E-02
BLUE	168.	0.049	2.39E-03	2.93E-03	3.39E-03	6.59E-02	8.07E-02	9.09E-02
TURQUOISE	174.	0.049	2.58E-03	3.16E-03	3.56E-03	7.11E-02	8.71E-02	9.82E-02
SKY BLUE	179.	0.049	2.74E-03	3.36E-03	3.79E-03	7.55E-02	9.26E-02	1.04E-01
UNLIVE	185.	0.049	2.93E-03	3.60E-03	4.07E-03	8.08E-02	9.93E-02	1.12E-01
GREEN	191.	0.049	3.13E-03	3.85E-03	4.35E-03	8.62E-02	1.06E-01	1.20E-01
LIME	196.	0.049	3.29E-03	4.05E-03	4.59E-03	9.07E-02	1.12E-01	1.27E-01
YELLOW	201.	0.050	3.46E-03	4.27E-03	4.84E-03	9.54E-02	1.18E-01	1.33E-01
ORANGE	208.	0.050	3.70E-03	4.51E-03	5.19E-03	1.02E-01	1.26E-01	1.43E-01
RED	213.	0.050	3.88E-03	4.80E-03	5.45E-03	1.07E-01	1.32E-01	1.50E-01
SALMON	219.	0.050	4.09E-03	5.08E-03	5.77E-03	1.13E-01	1.40E-01	1.59E-01
BLACK	224.	0.050	4.27E-03	5.31E-03	6.04E-03	1.18E-01	1.46E-01	1.67E-01
	230.	0.050	4.49E-03	5.59E-03	6.38E-03	1.24E-01	1.54E-01	1.76E-01

TUP APT CAMPNA 1
SEQUENCE 2

RUN	TIME INJ SEC	MODEL HULL DEG	ALPHA MODEL DEG	HREF RTU/F12-SEC-K	Y FT/SEC	RHO LBM/FT3	MU LBM-SEC/F12	KELK-00 FT-1
11	2.00	180.00	19.98	.363E-01	3876.0	.132E-02	.000E-07	1.985
PACH	PT	P	DEGR	PSIA	RTU/F12-SEC-K	FT/SEC	LBM/FT3	LBM-SEC/F12
7.93	1349.7	0.049	99.4	2.137	.363E-01	3876.0	.132E-02	.000E-07
ORBITER MODEL								
PHOSPHOR - 3251 PAINT								
TIME EXPOSED - 0.03 SEC								
INITIAL TEMP - 80.0 DEG F								
COLOR	COLOR CODE	INTERFACIAL K0-CR001/2 USED	HEAT TRANSFER COEFF, RTU/F12-SEC-DEG H(TT) H(90TT) H(45TT)	TUP APT CAMERA SEQUENCE 3	NATIO TO HREF H(TT)/HREF H(90TT)/HREF H(45TT)/HREF	MATIU TO HREF H(TT)/HREF H(90TT)/HREF H(45TT)/HREF	MATIU TO HREF H(TT)/HREF H(90TT)/HREF H(45TT)/HREF	MATIU TO HREF H(TT)/HREF H(90TT)/HREF H(45TT)/HREF
WHITE	146.	0.048	1.19E-03	1.44E-03	1.62E-03	3.27E-02	3.94E-02	4.46E-02
GRAY	146.	0.048	1.32E-03	1.60E-03	1.80E-03	3.63E-02	4.42E-02	4.96E-02
BROWN	151.	0.048	1.43E-03	1.74E-03	1.95E-03	3.94E-02	4.80E-02	5.39E-02
TAN	157.	0.049	1.56E-03	1.91E-03	2.14E-03	4.31E-02	5.26E-02	5.91E-02
CUMULI	163.	0.049	1.70E-03	2.08E-03	2.33E-03	4.69E-02	5.71E-02	6.44E-02
BLUE	168.	0.049	1.82E-03	2.22E-03	2.50E-03	5.01E-02	6.11E-02	6.90E-02
TURQUOISE	174.	0.049	1.96E-03	2.40E-03	2.70E-03	5.40E-02	6.61E-02	7.46E-02
SKY BLUE	179.	0.049	2.08E-03	2.55E-03	2.88E-03	5.73E-02	7.03E-02	7.93E-02
OLIVE	185.	0.049	2.22E-03	2.73E-03	3.09E-03	6.13E-02	7.54E-02	8.51E-02
GREEN	191.	0.049	2.37E-03	2.92E-03	3.30E-03	6.54E-02	8.05E-02	9.10E-02
LIME	196.	0.049	2.50E-03	3.08E-03	3.49E-03	6.89E-02	8.49E-02	9.61E-02
YELLOW	201.	0.050	2.63E-03	3.24E-03	3.67E-03	7.24E-02	8.94E-02	1.01E-01
ORANGE	208.	0.050	2.81E-03	3.48E-03	3.94E-03	7.75E-02	9.50E-02	1.09E-01
RED	213.	0.050	2.94E-03	3.65E-03	4.14E-03	8.11E-02	1.01E-01	1.14E-01
SALFON	219.	0.050	3.11E-03	3.85E-03	4.38E-03	8.56E-02	1.06E-01	1.21E-01
BLACK	224.	0.050	3.24E-03	4.03E-03	4.59E-03	8.94E-02	1.11E-01	1.26E-01
	230.	0.050	3.41E-03	4.25E-03	4.84E-03	9.41E-02	1.17E-01	1.33E-01

RUN	TIME INJ		MIDEL RILL		ALPHA MODEL		HNET		BIU/PT2-SEC-R		MU	HNET+00 PT-1 1.995
	SEC	SEC	DEC	DEC	PSIA	PSIA	PT/SEC	PT/SEC				
11		2.00	180.00	19.98	99.3	2.137	30/6.0					
ORBITER MODEL												
PHOSPHOR - 3251 PAINT												
TIME EXPOSED - 11.53 SEC												
INITIAL TEMP - 80.0 DEG F												
COLOR	INTERFACE TEMP/DEG F	RU-CR=1/2 USED	HEAT TRANSFER H(TT)	COEFF, H(.90TT)	BIU/PT2-SEC-DEG H(.95TT)	TOP APT CAMERA SEQUENCE	4	1				
WHITE	140.	0.049	9.91E-04	1.20E-03	1.35E-03	2.71E-02	3.32E-02	3.72E-02				
GRAY	146.	0.048	1.10E-03	1.34E-03	1.50E-03	3.03E-02	3.69E-02	4.14E-02				
BROWN	151.	0.048	1.19E-03	1.45E-03	1.63E-03	3.29E-02	4.00E-02	4.49E-02				
TAN	157.	0.049	1.30E-03	1.59E-03	1.79E-03	3.60E-02	4.39E-02	4.93E-02				
CUBALT	163.	0.049	1.42E-03	1.73E-03	1.95E-03	3.91E-02	4.74E-02	5.30E-02				
BLUE	166.	0.049	1.52E-03	1.85E-03	2.09E-03	4.19E-02	5.11E-02	5.76E-02				
TURQUOISE	174.	0.049	1.63E-03	2.00E-03	2.26E-03	4.50E-02	5.52E-02	6.22E-02				
SKY BLUE	179.	0.049	1.73E-03	2.13E-03	2.40E-03	4.79E-02	5.87E-02	6.62E-02				
OLIVE	185.	0.049	1.86E-03	2.28E-03	2.58E-03	5.12E-02	6.29E-02	7.10E-02				
GREEN	191.	0.049	1.98E-03	2.44E-03	2.76E-03	5.40E-02	6.72E-02	7.60E-02				
LINE	196.	0.049	2.09E-03	2.57E-03	2.91E-03	5.75E-02	7.09E-02	8.02E-02				
YELLOW	201.	0.050	2.19E-03	2.71E-03	3.07E-03	6.04E-02	7.46E-02	8.45E-02				
ORANGE	206.	0.050	2.35E-03	2.90E-03	3.29E-03	6.47E-02	8.00E-02	9.07E-02				
RED	213.	0.050	2.46E-03	3.04E-03	3.40E-03	6.77E-02	8.39E-02	9.52E-02				
SALMON	219.	0.050	2.59E-03	3.22E-03	3.60E-03	7.15E-02	8.86E-02	1.01E-01				
BLACK	224.	0.050	2.71E-03	3.36E-03	3.83E-03	7.46E-02	9.27E-02	1.06E-01				
	230.	0.050	2.85E-03	3.54E-03	4.04E-03	7.85E-02	9.77E-02	1.11E-01				

RUN	TIME INJ SEC	MUDEL KULL DEC	ALPHA MUDEL DEC	HREF H(U)/FT2-SEC-R	V	NMU LRM/FT3	MU LRF-SEC/FT2	RESE+00 FT-1
12	2.00	180.00	30.00	.363E-01	J6/6.0	.132E-02	.800E-07	1.900
ORBITER MUDEL								
PHOSPHOR - 32S1 PAULT								
TIME EXPOSED - 1.43 SEC								
INITIAL TEMP - 72.0 DEG F								
COLOR	COLOR CODE	INTERFAC. TEMP-DEG F	KO-CR=1/2 USED	HEAT TRANSFER COEFF., RTU/FT2-SEC-DEG H(TI) H(,9UITT) H(,85ITT)	FUP ART CAMERA SEQUENCE	NATIO TO HREF H(TT)/ HREF	H(,85ITT)/ HREF	
WHITE	140.	0.048	0.048	2.82E-03	3.42E-03	7.76E-02	9.44E-02	1.06E-01
GRAY	146.	0.048	0.048	3.09E-03	3.76E-03	8.52E-02	1.04E-01	1.16E-01
BROWN	151.	0.048	0.048	3.33E-03	4.05E-03	9.16E-02	1.12E-01	1.25E-01
TAN	157.	0.049	0.049	3.61E-03	4.40E-03	9.95E-02	1.21E-01	1.36E-01
CUBALI	163.	0.049	0.049	3.90E-03	4.76E-03	1.07E-01	1.31E-01	1.48E-01
BLUE	168.	0.049	0.049	4.15E-03	5.07E-03	1.14E-01	1.40E-01	1.57E-01
TURQUOISE	174.	0.049	0.049	4.44E-03	5.44E-03	1.22E-01	1.50E-01	1.69E-01
SKY BLUE	179.	0.049	0.049	4.70E-03	5.76E-03	1.29E-01	1.59E-01	1.79E-01
OLIVE	185.	0.049	0.049	5.01E-03	6.15E-03	1.38E-01	1.70E-01	1.91E-01
GREEN	191.	0.049	0.049	5.32E-03	6.55E-03	1.47E-01	1.80E-01	2.04E-01
LIME	196.	0.049	0.049	5.59E-03	6.89E-03	1.54E-01	1.90E-01	2.15E-01
YELLOW	201.	0.050	0.050	5.86E-03	7.23E-03	1.61E-01	1.99E-01	2.26E-01
ORANGE	208.	0.050	0.050	6.25E-03	7.72E-03	1.72E-01	2.13E-01	2.41E-01
RED	213.	0.050	0.050	6.53E-03	8.08E-03	1.80E-01	2.23E-01	2.53E-01
SALMON	219.	0.050	0.050	6.87E-03	8.52E-03	1.89E-01	2.35E-01	2.67E-01
BLACK	224.	0.050	0.050	7.16E-03	8.89E-03	1.97E-01	2.45E-01	2.79E-01
	230.	0.050	0.050	7.52E-03	9.35E-03	2.07E-01	2.58E-01	2.94E-01

PDN	TIME INJ SEC	MODEL NULL DEG	ALPHA MODEL DFC	HREF 810/F12-SEC-M	TOP AFT CAMERA				SEQUENCE			
12	2.00	180.00	30.00	.163E-01	V	Q	P	I	HREF	FT/SEC	MMU	HE-2500 F1-1 1.906
MACH	PT	PSJA	PSJA	PSJA	DEGR	PSJA	PSJA	DEGR	MMU	FT/SEC	MMU	HE-2500 F1-1 1.906
7.93	448.2	1349.7	0.049	0.049	99.4	2.137	2.137	99.4	.132E-02	800E-07	800E-07	
UNBATER MODEL												
PHOSPHOR - 3251 PAINT												
TIME EXPOSED - 4.63 SEC												
INITIAL TEMP - 72.0 DEG F												
COLOR CODE												
COLOR	INTERFACE TEMP, DEG F	PD-CM**1/2 USED	HEAT TRANSFER COEFF, RTU/F12-SEC-DEG H(TT)	HREF	HREF	HREF	HREF	HREF	HREF	HREF	HREF	HREF
WHITE	140.	0.048	1.77E-03	2.15E-03	2.41E-03	2.41E-03	2.41E-03	2.41E-03	4.00E-02	5.92E-02	6.63E-02	6.63E-02
GRAY	146.	0.048	1.94E-03	2.36E-03	2.65E-03	2.65E-03	2.65E-03	2.65E-03	5.35E-02	6.51E-02	7.30E-02	7.30E-02
BROWN	151.	0.048	2.09E-03	2.54E-03	2.86E-03	2.86E-03	2.86E-03	2.86E-03	5.76E-02	7.01E-02	7.87E-02	7.87E-02
TAN	157.	0.049	2.47E-03	2.77E-03	3.11E-03	3.11E-03	3.11E-03	3.11E-03	6.25E-02	7.62E-02	8.57E-02	8.57E-02
COBALT BLUE	163.	0.049	2.45E-03	2.99E-03	3.37E-03	3.37E-03	3.37E-03	3.37E-03	6.75E-02	8.25E-02	9.28E-02	9.28E-02
BLUE	168.	0.049	2.61E-03	3.19E-03	3.59E-03	3.59E-03	3.59E-03	3.59E-03	7.18E-02	8.78E-02	9.88E-02	9.88E-02
TURQUOISE	174.	0.049	2.79E-03	3.42E-03	3.85E-03	3.85E-03	3.85E-03	3.85E-03	7.70E-02	9.43E-02	1.06E-01	1.06E-01
SKY BLUE	179.	0.049	2.95E-03	3.62E-03	4.08E-03	4.08E-03	4.08E-03	4.08E-03	8.14E-02	9.98E-02	1.13E-01	1.13E-01
ULTR. GREEN	185.	0.049	3.15E-03	3.87E-03	4.36E-03	4.36E-03	4.36E-03	4.36E-03	8.67E-02	1.07E-01	1.20E-01	1.20E-01
GREEN	191.	0.049	3.34E-03	4.12E-03	4.65E-03	4.65E-03	4.65E-03	4.65E-03	9.22E-02	1.13E-01	1.29E-01	1.29E-01
LIME	196.	0.049	3.51E-03	4.33E-03	4.90E-03	4.90E-03	4.90E-03	4.90E-03	9.68E-02	1.19E-01	1.35E-01	1.35E-01
YELLOW	201.	0.050	3.68E-03	4.54E-03	5.15E-03	5.15E-03	5.15E-03	5.15E-03	1.01E-01	1.25E-01	1.42E-01	1.42E-01
ORANGE	206.	0.050	3.93E-03	4.85E-03	5.50E-03	5.50E-03	5.50E-03	5.50E-03	1.06E-01	1.34E-01	1.52E-01	1.52E-01
RED	213.	0.050	4.10E-03	5.08E-03	5.77E-03	5.77E-03	5.77E-03	5.77E-03	1.11E-01	1.40E-01	1.59E-01	1.59E-01
SALMON	219.	0.050	4.37E-03	5.35E-03	6.09E-03	6.09E-03	6.09E-03	6.09E-03	1.17E-01	1.48E-01	1.68E-01	1.68E-01
BLACK	224.	0.050	4.50E-03	5.59E-03	6.36E-03	6.36E-03	6.36E-03	6.36E-03	1.24E-01	1.54E-01	1.75E-01	1.75E-01
	230.	0.050	4.72E-03	5.84E-03	6.70E-03	6.70E-03	6.70E-03	6.70E-03	1.30E-01	1.62E-01	1.85E-01	1.85E-01

PUM	TIME INJ SEC	MODEL RULL DEG	ALPHA MODEL DEG	HREF RTU/F12-SEC-R	MACH	F1 DEGR	P PSIA	F PSIA	D PSIA	V FT/SEC	RND LHM/FTJ	MU LBF-SEC/FT2	HE-E+06 FT-1
17	2.00	180.00	10.00	.303E-01		99.1	0.049	99.1	2.137	JH16.0	.112E-02	.000E-07	1.986
URBITER MODEL													
PHOSPHOR - 3251 PAINT													
TIME EXPOSED - 8.03 SEC													
INITIAL TEMP - 72.0 DEG F													
COLOR	COLOR CODE	INTERFACE TEMP/DEG F	NU-CN#1/2 USED	HEAT TRANSFER CUEFF, HTU/F12-SEC-DLG H(.90TT)	HREF M(HTT)/HREF	NATIO TO HREF H(.90TT)/HREF	M(OSTT)/HREF						
WHITE		140.	0.048	1.34E-03	1.61E-03	1.43E-03	3.70E-02	4.50E-02	5.04E-02				
GRAY		146.	0.048	1.47E-03	1.79E-03	2.01E-03	4.06E-02	4.94E-02	5.55E-02				
BROWN		151.	0.048	1.59E-03	1.93E-03	2.11E-03	4.37E-02	5.32E-02	5.98E-02				
TAN		157.	0.049	1.72E-03	2.10E-03	2.36E-03	4.78E-02	5.79E-02	6.50E-02				
CORALL		163.	0.049	1.86E-03	2.27E-03	2.56E-03	5.11E-02	6.26E-02	7.04E-02				
BLUE		168.	0.049	1.98E-03	2.42E-03	2.72E-03	5.45E-02	6.67E-02	7.50E-02				
TURQUOISE		174.	0.049	2.12E-03	2.60E-03	2.93E-03	5.84E-02	7.16E-02	8.06E-02				
SKY BLUE		179.	0.049	2.24E-03	2.75E-03	3.10E-03	6.18E-02	7.58E-02	8.55E-02				
OLIVE		185.	0.049	2.39E-03	2.93E-03	3.31E-03	6.59E-02	8.09E-02	9.13E-02				
GREEN		191.	0.049	2.54E-03	3.12E-03	3.53E-03	7.00E-02	8.61E-02	9.73E-02				
LIME		196.	0.049	2.67E-03	3.29E-03	3.72E-03	7.35E-02	9.06E-02	1.02E-01				
YELLOW		201.	0.050	2.80E-03	3.45E-03	3.91E-03	7.70E-02	9.51E-02	1.08E-01				
ORANGE		208.	0.050	2.98E-03	3.68E-03	4.18E-03	8.21E-02	1.02E-01	1.15E-01				
RED		213.	0.050	3.11E-03	3.85E-03	4.38E-03	8.58E-02	1.06E-01	1.21E-01				
SALMON		219.	0.050	3.28E-03	4.07E-03	4.62E-03	9.04E-02	1.12E-01	1.27E-01				
BLACK		224.	0.050	3.42E-03	4.24E-03	4.83E-03	9.42E-02	1.17E-01	1.33E-01				
		230.	0.050	3.59E-03	4.40E-03	5.09E-03	9.88E-02	1.23E-01	1.40E-01				

NUM	TIME INJ SEC	TIME INJ SEC	ALPHA MODEL DEG	MREF RTU/F12-SEC-R .363E-01	RHO LHM/FTJ .132E-02	MU LHF-SEC/FT2 .900E-07	ALPHA FT-1 1.900
14	2.00	2.00	30.00				
MACH	PSIA	IT	PSIA	FT/SEC			
7.43	448.2	1399.7	0.049	3076.0			
URBITER MODEL							
PAUSPHOR - 3251 PAINT							
TIME CAPTURED - 11.53 SEC							
INITIAL TEMP - 72.0 DEG F							
COLOR	INTERFACE TEMP, DEG F	RO-CR*1/2 USED	HEAT TRANSFER COEFF, RTU/F12-SEC-DEG H(TT) H(.90TT) H(.85TT)	RATIO TO MREF H(TT)/H(.90TT)/HREF	H(.85TT)/HREF		
WHITE	140.	0.048	1.12E-03	1.36E-03	1.53E-03	3.09E-02	3.75E-02
GRAY	146.	0.048	1.43E-03	1.50E-03	1.68E-03	3.39E-02	4.13E-02
BROWN	151.	0.048	1.32E-03	1.41E-03	1.61E-03	3.65E-02	4.44E-02
TAN	157.	0.049	1.44E-03	1.75E-03	1.97E-03	3.96E-02	4.83E-02
CUBALT	163.	0.049	1.55E-03	1.90E-03	2.14E-03	4.28E-02	5.23E-02
BLUE	168.	0.049	1.65E-03	2.02E-03	2.27E-03	4.55E-02	5.56E-02
TURQUOISE	174.	0.049	1.77E-03	2.17E-03	2.44E-03	4.88E-02	5.97E-02
SKY BLUE	179.	0.049	1.87E-03	2.29E-03	2.59E-03	5.16E-02	6.32E-02
OLIVE	185.	0.049	1.99E-03	2.45E-03	2.77E-03	5.50E-02	6.75E-02
GREEN	191.	0.049	2.12E-03	2.61E-03	2.95E-03	5.84E-02	7.19E-02
LIME	196.	0.049	2.23E-03	2.74E-03	3.10E-03	6.13E-02	7.56E-02
YELLOW	201.	0.050	2.33E-03	2.88E-03	3.26E-03	6.43E-02	7.93E-02
ORANGE	206.	0.050	2.49E-03	3.07E-03	3.49E-03	6.85E-02	8.47E-02
RED	211.	0.050	2.60E-03	3.22E-03	3.65E-03	7.16E-02	8.87E-02
SALMON	219.	0.050	2.74E-03	3.39E-03	3.86E-03	7.54E-02	9.35E-02
BLACK	224.	0.050	2.85E-03	3.54E-03	4.04E-03	7.86E-02	9.76E-02
	230.	0.050	2.99E-03	3.74E-03	4.24E-03	8.25E-02	1.03E-01

RUN	TIME INJ SIC	TIME INJ DEC	MODFL. MODL DEC	ALPHA MODEL DEC	HREF BTU/FT2-SEC-R	HT BT/SEC	WMO LNM/FT3	KU LRF-SEC/FT2	MESE+00 FT-1
13	4.10	180.00	29.99	PSIA 0.013	101.6	3876.9	.345E-03	.019E-07	.500
UNBILER MODEL									
PHOSPHOR - 1251 PAINT									
TIME EXPOSED - 1.17 SEC									
INITIAL TEMP - 65.0 DEG F									
COLOR	CURR. CURF	INTERPAC TEMP-DEG F	MO-CK-1/2 USED	HEAT TRANSFER COEFF, BTU/FT2-SEC-DEG H(1.90TT)	H(1.90TT) H(1.90TT)	RATIO TO HREF H(1.90TT)/ HREF	H(1.90TT)/ HREF	H(1.90TT)/ HREF	H(1.90TT)/ HREF
WHITE	140.	0.048	0.048	3.14E-03	3.81E-03	4.26E-03	1.68E-01	2.05E-01	2.29E-01
GRAY	146.	0.048	0.048	3.42E-03	4.15E-03	4.66E-03	1.84E-01	2.28E-01	2.51E-01
BROWN	151.	0.048	0.048	3.66E-03	4.45E-03	4.99E-03	1.97E-01	2.33E-01	2.69E-01
TAN	157.	0.049	0.049	3.94E-03	4.81E-03	5.40E-03	2.12E-01	2.59E-01	2.91E-01
CUBALT	163.	0.049	0.049	4.24E-03	5.16E-03	5.84E-03	2.28E-01	2.79E-01	3.14E-01
BLUE	168.	0.049	0.049	4.49E-03	5.44E-03	6.17E-03	2.42E-01	2.95E-01	3.32E-01
TURQUOISE	174.	0.049	0.049	4.80E-03	5.87E-03	6.61E-03	2.59E-01	3.16E-01	3.56E-01
SKY BLUE	179.	0.049	0.049	5.06E-03	6.19E-03	6.98E-03	2.72E-01	3.33E-01	3.76E-01
OLIVE	185.	0.049	0.049	5.37E-03	6.59E-03	7.44E-03	2.89E-01	3.55E-01	4.00E-01
GREEN	191.	0.049	0.049	5.69E-03	7.00E-03	7.90E-03	3.06E-01	3.76E-01	4.25E-01
LIME	196.	0.049	0.049	5.96E-03	7.34E-03	8.30E-03	3.21E-01	3.95E-01	4.47E-01
YELLOW	201.	0.050	0.050	6.24E-03	7.69E-03	8.71E-03	3.36E-01	4.14E-01	4.68E-01
ORANGE	208.	0.050	0.050	6.63E-03	8.19E-03	9.29E-03	3.57E-01	4.41E-01	5.00E-01
RED	213.	0.050	0.050	6.92E-03	8.56E-03	9.71E-03	3.72E-01	4.60E-01	5.23E-01
SALMON	219.	0.050	0.050	7.27E-03	9.00E-03	1.02E-02	3.91E-01	4.85E-01	5.51E-01
BLACK	224.	0.050	0.050	7.50E-03	9.39E-03	1.07E-02	4.07E-01	5.05E-01	5.74E-01
	230.	0.050	0.050	7.92E-03	9.85E-03	1.12E-02	4.26E-01	5.30E-01	6.04E-01

NUM	TIME INJ SEC	MODEL	MODEL DEC	ALPHA MODEL DEC	HRER RTU/F12-SEC-R .166E-01	Y	FT/SEC 38/6.9	RNU LHM/FTJ .345E-03	MU LBP-SEC/FTJ .619E-07	NR:2+00 FT-1 .508
13	2.10	180.00	29.99	PSIA .560	0	101.9	101.9	101.9	101.9	101.9
14	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
15	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
16	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
17	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
18	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
19	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
20	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
21	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
22	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
23	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
24	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
25	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
26	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
27	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
28	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
29	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
30	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
31	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
32	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
33	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
34	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
35	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
36	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
37	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
38	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
39	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
40	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
41	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
42	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
43	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
44	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
45	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
46	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
47	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
48	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
49	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
50	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
51	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
52	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
53	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
54	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
55	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
56	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
57	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
58	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
59	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
60	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
61	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
62	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
63	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
64	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
65	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
66	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
67	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
68	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
69	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
70	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
71	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
72	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
73	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
74	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
75	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
76	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
77	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
78	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
79	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
80	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
81	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
82	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
83	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
84	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
85	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
86	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
87	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
88	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
89	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
90	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
91	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
92	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
93	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
94	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
95	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
96	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
97	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
98	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
99	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9
100	1352.7	0.013	0.013	PSIA 0.013	0	101.9	101.9	101.9	101.9	101.9

PUM	TIME INJ SEC	MODEL FULL DEG	ALPHA MODEL DEG	HREF RTU/FT2-SEC-R	PT	PSIA	Q	PSIA	FT/SEC	HNO	LMH/FTJ	RTU/FT2-SEC-R	RTU/FT2-SEC-R	RTU/FT2-SEC-R
13	2.10	180.00	29.99	.1466E-01	101.6	0.013	0.560	48/6.9	.345E-03	.819E-07	.500			
MACH	PT	PSIA	DEGR	1352.7	101.6	0.013	0.560	48/6.9	.345E-03	.819E-07	.500			
7.04	111.4	1352.7	101.6	0.013	0.560	48/6.9	.345E-03	.819E-07	.500					
UNITER MODEL														
PHOSPHUM - 3251 PAINT														
TIME EXPOSED -	11.57 SEC													
INITIAL TEMP -	65.0 DEG F													
COLOR CODE														
COLOR	INTERFAC TEMP/DEG F	RU-CK-1/2 USED	HEAT TRANSFER COEFF, RTU/FT2-SEC-DEG H(1.90TT)	H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)	RTU/FT2-SEC-DEG H(1.90TT)
WHITE	140.	0.048	1.23E-03	1.49E-03	1.67E-03	1.85E-03	2.03E-03	2.21E-03	2.39E-03	2.57E-03	2.75E-03	2.93E-03	3.11E-03	3.29E-03
GRAY	146.	0.048	1.34E-03	1.63E-03	1.82E-03	2.01E-03	2.20E-03	2.39E-03	2.58E-03	2.77E-03	2.96E-03	3.15E-03	3.34E-03	3.53E-03
BROWN	151.	0.048	1.43E-03	1.74E-03	1.95E-03	2.16E-03	2.37E-03	2.58E-03	2.79E-03	2.99E-03	3.20E-03	3.41E-03	3.62E-03	3.83E-03
TAN	157.	0.049	1.54E-03	1.88E-03	2.11E-03	2.34E-03	2.57E-03	2.80E-03	3.03E-03	3.26E-03	3.49E-03	3.72E-03	3.95E-03	4.18E-03
COBALT	163.	0.049	1.66E-03	2.03E-03	2.26E-03	2.49E-03	2.72E-03	2.95E-03	3.18E-03	3.41E-03	3.64E-03	3.87E-03	4.10E-03	4.33E-03
BLUE	168.	0.049	1.76E-03	2.15E-03	2.42E-03	2.69E-03	2.96E-03	3.23E-03	3.50E-03	3.77E-03	4.04E-03	4.31E-03	4.58E-03	4.85E-03
TURQUOISE	174.	0.049	1.88E-03	2.30E-03	2.59E-03	2.88E-03	3.17E-03	3.46E-03	3.75E-03	4.04E-03	4.33E-03	4.62E-03	4.91E-03	5.20E-03
SKY BLUE	179.	0.049	1.98E-03	2.42E-03	2.73E-03	3.04E-03	3.35E-03	3.66E-03	3.97E-03	4.28E-03	4.59E-03	4.90E-03	5.21E-03	5.52E-03
OLIVE	185.	0.049	2.10E-03	2.58E-03	2.91E-03	3.24E-03	3.57E-03	3.90E-03	4.23E-03	4.56E-03	4.89E-03	5.22E-03	5.55E-03	5.88E-03
GREEN	191.	0.049	2.23E-03	2.74E-03	3.09E-03	3.44E-03	3.79E-03	4.14E-03	4.49E-03	4.84E-03	5.19E-03	5.54E-03	5.89E-03	6.24E-03
LIME	196.	0.049	2.33E-03	2.87E-03	3.25E-03	3.58E-03	3.91E-03	4.24E-03	4.57E-03	4.90E-03	5.23E-03	5.56E-03	5.89E-03	6.22E-03
YELLOW	201.	0.050	2.44E-03	3.01E-03	3.41E-03	3.81E-03	4.21E-03	4.61E-03	5.01E-03	5.41E-03	5.81E-03	6.21E-03	6.61E-03	7.01E-03
ORANGE	206.	0.050	2.59E-03	3.21E-03	3.63E-03	4.05E-03	4.47E-03	4.89E-03	5.31E-03	5.73E-03	6.15E-03	6.57E-03	6.99E-03	7.41E-03
RED	213.	0.050	2.71E-03	3.35E-03	3.80E-03	4.25E-03	4.70E-03	5.15E-03	5.60E-03	6.05E-03	6.50E-03	6.95E-03	7.40E-03	7.85E-03
SALMON	219.	0.050	2.84E-03	3.52E-03	4.00E-03	4.48E-03	4.96E-03	5.44E-03	5.92E-03	6.40E-03	6.88E-03	7.36E-03	7.84E-03	8.32E-03
BLACK	224.	0.050	2.96E-03	3.67E-03	4.18E-03	4.69E-03	5.20E-03	5.71E-03	6.22E-03	6.73E-03	7.24E-03	7.75E-03	8.26E-03	8.77E-03
	230.	0.050	3.10E-03	3.85E-03	4.39E-03	4.90E-03	5.41E-03	5.92E-03	6.43E-03	6.94E-03	7.45E-03	7.96E-03	8.47E-03	8.98E-03

RUN	TIME INJ SEC	MODEL NO/L	ALPHA MODEL DEG	MREF RTU/FT2-SEC-H	PT	TT	PSIA	DEGR	T	O	PSIA	FT/SEC	RHO	NU	MREF
14	2.00	140.00	20.00	.106E-01											
MACH					PT	TT	PSIA	DEGR	T	O	PSIA	FT/SEC	RHO	NU	MREF
7.04	111.7	1350.7			111.7	1350.7	0.013	101.7			0.562	3874.0	0.347E-03	0.810E-07	0.510
UNRAITER MODEL															
PHOSPHOR - 3251 PAINT															
TIME EXPOSED - 1.73 SEC															
INITIAL TEMP - 74.0 DEG F															
COLOR	COLOR CODE	INTERFACE TEMP. DEG F	NO-CNA=1/2 USED	HEAT TRANSFER COEFF, RTU/FT2-SEC-DEG H(FT)	H(90TT)	H(95TT)	TUP	APT	CAMERA	SEQUENCE	RATIO TO MREF H(90TT)/ HREF	H(95TT)/ HREF			
WHITE	140.	0.048	0.048	2.61E-03	3.41E-03	3.41E-03	3.41E-03	1.51E-01	1.83E-01	2.05E-01					
GRAY	146.	0.048	0.048	3.09E-03	3.76E-03	4.24E-03	4.24E-03	1.66E-01	2.02E-01	2.27E-01					
BROWN	151.	0.048	0.048	3.33E-03	4.06E-03	4.55E-03	4.55E-03	1.79E-01	2.18E-01	2.45E-01					
TAN	157.	0.049	0.049	3.62E-03	4.42E-03	4.96E-03	4.96E-03	1.95E-01	2.37E-01	2.67E-01					
CORAL	161.	0.049	0.049	3.92E-03	4.79E-03	5.38E-03	5.38E-03	2.11E-01	2.57E-01	2.89E-01					
BLUE	168.	0.049	0.049	4.17E-03	5.10E-03	5.74E-03	5.74E-03	2.24E-01	2.74E-01	3.09E-01					
TURQUOISE	174.	0.049	0.049	4.48E-03	5.49E-03	6.18E-03	6.18E-03	2.41E-01	2.95E-01	3.32E-01					
SKY BLUE	179.	0.049	0.049	4.74E-03	5.81E-03	6.55E-03	6.55E-03	2.55E-01	3.12E-01	3.52E-01					
OLIVE	185.	0.049	0.049	5.06E-03	6.21E-03	7.01E-03	7.01E-03	2.72E-01	3.34E-01	3.77E-01					
GREEN	191.	0.049	0.049	5.38E-03	6.62E-03	7.48E-03	7.48E-03	2.89E-01	3.56E-01	4.02E-01					
LINE	196.	0.049	0.049	5.65E-03	6.96E-03	7.88E-03	7.88E-03	3.04E-01	3.74E-01	4.24E-01					
YELLOW	201.	0.050	0.050	5.93E-03	7.31E-03	8.28E-03	8.28E-03	3.19E-01	3.93E-01	4.45E-01					
ORANGE	206.	0.050	0.050	6.23E-03	7.62E-03	8.67E-03	8.67E-03	3.40E-01	4.20E-01	4.77E-01					
RED	211.	0.050	0.050	6.51E-03	8.19E-03	9.30E-03	9.30E-03	3.55E-01	4.40E-01	5.00E-01					
SALMON	219.	0.050	0.050	6.96E-03	8.64E-03	9.84E-03	9.84E-03	3.74E-01	4.64E-01	5.28E-01					
BLACK	224.	0.050	0.050	7.46E-03	9.02E-03	1.03E-02	1.03E-02	3.90E-01	4.85E-01	5.52E-01					
	230.	0.050	0.050	7.63E-03	9.49E-03	1.08E-02	1.08E-02	4.10E-01	5.10E-01	5.81E-01					

NUM	TIME INJ SEC	MIDEL ROLL DEG	ALPHA MODEL DEG	HREF BTU/FI2-SEC-R	RHO	MU	MEPE+06 FT-1 .510
14	2.00	180.00	20.00	.186E-01			
MACH	PT	P	T	V	RHO	MU	
7.94	PSIA 1111.7	PSIA 0.013	DEGR 101.7	FT/SEC 38/4.0	LHM/FT3 .347E-03	LHF-SEC/FT3 .818E-03	
ORBITER MODEL							
PHOSPHOR - 3251 PAINT							
TIME EXPOSED - 4.03 SEC							
INITIAL TEMP - 74.0 DEG F							
COLOR	COLOR CODE	NO-CRACKS 1/2 USED	HEAT TRANSFER COEFF, HTU/FT2-SEC-DEG H(1TT)	H(1.90TT) H(1.95IT)	H(1TT)/ HREF	KATIO TO HREF H(.90TI)/ HREF	H(.85TI)/ HREF
WHITE	140.	0.048	1.72E-03	2.08E-03	2.34E-03	1.12E-01	1.26E-01
GRAY	146.	0.048	1.49E-03	2.30E-03	2.50E-03	1.02E-01	1.30E-01
BROWN	151.	0.048	2.03E-03	2.48E-03	2.78E-03	1.09E-01	1.50E-01
TAN	157.	0.049	2.21E-03	2.70E-03	3.03E-03	1.19E-01	1.63E-01
CUBALT	163.	0.049	2.39E-03	2.92E-03	3.29E-03	1.29E-01	1.77E-01
BLUE	166.	0.049	2.55E-03	3.12E-03	3.51E-03	1.37E-01	1.89E-01
TURQUOISE	174.	0.049	2.74E-03	3.35E-03	3.78E-03	1.47E-01	2.03E-01
SKY BLUE	179.	0.049	2.90E-03	3.55E-03	4.00E-03	1.56E-01	2.15E-01
OLIVE	185.	0.049	3.09E-03	3.79E-03	4.28E-03	1.66E-01	2.30E-01
GREEN	191.	0.049	3.29E-03	4.04E-03	4.57E-03	1.77E-01	2.46E-01
TIME	196.	0.049	3.45E-03	4.25E-03	4.81E-03	1.86E-01	2.59E-01
YELLOW	201.	0.050	3.62E-03	4.47E-03	5.06E-03	1.95E-01	2.72E-01
ORANGE	208.	0.050	3.86E-03	4.78E-03	5.42E-03	2.08E-01	2.91E-01
RED	213.	0.050	4.04E-03	5.00E-03	5.68E-03	2.17E-01	3.05E-01
SALMON	219.	0.050	4.25E-03	5.28E-03	6.00E-03	2.29E-01	3.22E-01
BLACK	224.	0.050	4.44E-03	5.51E-03	6.27E-03	2.39E-01	3.37E-01
	230.	0.050	4.66E-03	5.80E-03	6.61E-03	2.50E-01	3.55E-01

RUN	TIME INJ SEC	MODEL ROUN DEC	ALPHA MODEL DEC	HREF RTU/FT2-SEC-K				
14	2.00	180.00	20.00	.186E-01				
MACH	PT	PT	P	Q	V	KRO	MU	KEE+06
7.84	PSIA	DEGR	PSIA	PSIA	FT/SEC	LAM/FT3	LBH-SEC/FT2	FT-1
	111.7	1350.7	0.013	101.7	.562	.347E-03	.818E-07	.510
ORBITAL MODEL								
PHOSPHOR - 1251 PAID1								
TIME EXPOSED - 4.03 SEC								
INITIAL TEMP - 74.0 DEG F								
COLOR	COLOR CODE	INTERFAC TEMP, DEG F	MO-CALC 1/2 USED	WHAT TRANSFER COEFF, RTU/FT2-SEC-DEG H(IT)	H(90IT) H(.85IT)	H(TT)/ HREF	RATIO TO HREF H(.90IT)/ HREF	M(.85IT)/ HREF
WHITE	140.	140.	0.048	1.30E-03	1.58E-03	1.77E-03	7.00E-02	8.50E-02
GRAY	146.	146.	0.048	1.43E-03	1.74E-03	1.90E-03	7.71E-02	9.38E-02
BROWN	151.	151.	0.048	1.54E-03	1.88E-03	2.11E-03	8.30E-02	1.01E-01
TAN	157.	157.	0.049	1.68E-03	2.05E-03	2.30E-03	9.03E-02	1.10E-01
COBALT	163.	163.	0.049	1.82E-03	2.22E-03	2.50E-03	9.77E-02	1.19E-01
BLUE	169.	169.	0.049	1.93E-03	2.37E-03	2.68E-03	1.04E-01	1.27E-01
TURQUOISE	174.	174.	0.049	2.08E-03	2.54E-03	2.87E-03	1.12E-01	1.37E-01
SKY BLUE	179.	179.	0.049	2.20E-03	2.70E-03	3.04E-03	1.18E-01	1.45E-01
OLIVE	185.	185.	0.049	2.34E-03	2.88E-03	3.25E-03	1.26E-01	1.55E-01
GREEN	191.	191.	0.049	2.49E-03	3.07E-03	3.47E-03	1.34E-01	1.65E-01
LIME	196.	196.	0.049	2.62E-03	3.23E-03	3.65E-03	1.41E-01	1.74E-01
YELLOW	201.	201.	0.050	2.75E-03	3.39E-03	3.84E-03	1.48E-01	1.82E-01
ORANGE	208.	208.	0.050	2.93E-03	3.63E-03	4.11E-03	1.58E-01	1.95E-01
RED	213.	213.	0.050	3.07E-03	3.80E-03	4.31E-03	1.65E-01	2.04E-01
SALMON	219.	219.	0.050	3.23E-03	4.01E-03	4.55E-03	1.74E-01	2.15E-01
BLACK	224.	224.	0.050	3.37E-03	4.18E-03	4.78E-03	1.81E-01	2.25E-01
	230.	230.	0.050	3.54E-03	4.40E-03	5.04E-03	1.90E-01	2.37E-01

TUP AT 1 CAMERA 3
SEQUENCE 3

NUM	TIME INJ SEC	MODEL NUM	ALPHA DEG	HREF BTU/FT2-SEC-R	TEMP	TT DEGR	PSIA	Q PSIA	V FT/SEC	RHU LBM/FT3	MU LBT-SEC/FT2	HEAT+06 FT-I .510
14	2.00	180.00	20.00	.166E-01		101.7	0.013	.562	3874.0	.347E-03	.010E-07	
UNITER MODEL												
PHOSPHOR - 3251 PAINT												
TIME CAPTURED - 11.53 SEC												
INITIAL TEMP - 74.0 DEG F												
COLOR	COLOR CODE	INTERFAC TEMP DEG F	PH-CK=1/2 USED	HEAT TRANSFER COEFF, BTU/FT2-SEC-DEG F (1.90TT) H(.051T)	TUP AFT SEQUENCE	CAMERA	1	2	3	4	MATIO TO HREF H(TT)/ H(.90TT)/ HREF	M(.051T)/ HREF
WHITE	140.	1.09E-03	0.048	1.32E-03	1.48E-03					5.84E-02	7.10E-02	7.95E-02
GRAY	146.	1.40E-03	0.044	1.46E-03	1.63E-03					6.43E-02	7.83E-02	8.71E-02
BRN	151.	1.49E-03	0.048	1.57E-03	1.76E-03					6.93E-02	8.44E-02	9.47E-02
TAN	157.	1.40E-03	0.049	1.71E-03	1.92E-03					7.54E-02	9.19E-02	1.03E-01
CORAL	163.	1.52E-03	0.049	1.85E-03	2.08E-03					8.16E-02	9.96E-02	1.12E-01
BLUE	168.	1.61E-03	0.049	1.97E-03	2.22E-03					8.68E-02	1.06E-01	1.19E-01
TURQUOISE	174.	1.73E-03	0.049	2.12E-03	2.39E-03					9.32E-02	1.14E-01	1.29E-01
SKY BLUE	179.	1.83E-03	0.049	2.25E-03	2.54E-03					9.86E-02	1.21E-01	1.36E-01
OLIVE	185.	1.96E-03	0.049	2.40E-03	2.71E-03					1.05E-01	1.29E-01	1.46E-01
GREEN	191.	2.08E-03	0.049	2.56E-03	2.90E-03					1.12E-01	1.38E-01	1.56E-01
LINE	196.	2.19E-03	0.049	2.70E-03	3.05E-03					1.18E-01	1.45E-01	1.61E-01
YELLOW	201.	2.29E-03	0.050	2.83E-03	3.21E-03					1.23E-01	1.52E-01	1.72E-01
UNANGE	206.	2.45E-03	0.050	3.03E-03	3.43E-03					1.32E-01	1.63E-01	1.85E-01
RED	213.	2.58E-03	0.050	3.17E-03	3.60E-03					1.38E-01	1.70E-01	1.93E-01
SALMON	219.	2.70E-03	0.050	3.34E-03	3.80E-03					1.45E-01	1.80E-01	2.04E-01
PINK	224.	2.81E-03	0.050	3.49E-03	3.97E-03					1.51E-01	1.88E-01	2.14E-01
	230.	2.95E-03	0.050	3.67E-03	4.19E-03					1.59E-01	1.97E-01	2.25E-01

RUN	TIME INJ SEC	MODEL KOLL DEG	ALPHA MODEL DEG	MREF BIU/F12-SEC-R .166E-61	PT PSIA	TT DEGR	P PSIA	I DEGR	Q PSIA	V FT/SEC	RHO LBM/FT3	MU LBM-SEC/FT2	MEASUREMENT FT-1
14	2.00	180.00	20.00		0.013	1350.7	0.013	101.7	.562	3874.0	.347E-03	.019E-07	.510
UNWRITER MODEL.													
PHOSPHOR - 3251 PAINT													
TIME EXPOSED - 22.73 SEC													
INITIAL TEMP - 74.0 DEG F													
COLON	INTERPACK TEMP, DEG F	RD-CR=1/2 USED	HEAT TRANSFER COEFF, BTU/F12-SEC-DEG H(1.90TT)	CULUP CODE	RD-CR=1/2 USED	HEAT TRANSFER COEFF, BTU/F12-SEC-DEG H(1.90TT)	TUP	APT	CAMERA	SEQUENCE	M(TT)/ HREF	M(TT)/ HREF	M(45TT)/ HREF
WHITE	140.	0.048	7.74E-04	9.40E-04	1.05E-03	1.05E-03	1	5	1	1	4.16E-02	5.05E-02	5.66E-02
GRAY	146.	0.048	8.52E-04	1.04E-03	1.16E-03	1.16E-03					4.58E-02	5.57E-02	6.25E-02
BROWN	151.	0.048	9.18E-04	1.12E-03	1.25E-03	1.25E-03					4.93E-02	6.01E-02	6.75E-02
TAN	157.	0.049	9.98E-04	1.22E-03	1.37E-03	1.37E-03					5.37E-02	6.55E-02	7.36E-02
CUBALF	163.	0.049	1.08E-03	1.32E-03	1.49E-03	1.49E-03					5.81E-02	7.09E-02	7.98E-02
BLUE	168.	0.049	1.15E-03	1.41E-03	1.58E-03	1.58E-03					6.18E-02	7.56E-02	8.51E-02
TURQUOISE	174.	0.049	1.23E-03	1.51E-03	1.70E-03	1.70E-03					6.64E-02	8.13E-02	9.16E-02
SKY BLUE	179.	0.049	1.31E-03	1.60E-03	1.81E-03	1.81E-03					7.02E-02	8.61E-02	9.71E-02
OLIVE	185.	0.049	1.39E-03	1.71E-03	1.93E-03	1.93E-03					7.49E-02	9.20E-02	1.04E-01
GREEN	191.	0.049	1.48E-03	1.82E-03	2.06E-03	2.06E-03					7.97E-02	9.80E-02	1.11E-01
LIME	196.	0.049	1.56E-03	1.92E-03	2.17E-03	2.17E-03					8.37E-02	1.03E-01	1.17E-01
YELLOW	201.	0.050	1.63E-03	2.02E-03	2.28E-03	2.28E-03					8.79E-02	1.08E-01	1.23E-01
ORANGE	208.	0.050	1.74E-03	2.16E-03	2.44E-03	2.44E-03					9.38E-02	1.16E-01	1.31E-01
RED	213.	0.050	1.82E-03	2.26E-03	2.56E-03	2.56E-03					9.80E-02	1.21E-01	1.36E-01
SALMON	219.	0.050	1.92E-03	2.38E-03	2.71E-03	2.71E-03					1.03E-01	1.26E-01	1.46E-01
BLACK	224.	0.050	2.00E-03	2.49E-03	2.83E-03	2.83E-03					1.08E-01	1.34E-01	1.52E-01
	230.	0.050	2.10E-03	2.62E-03	2.98E-03	2.98E-03					1.13E-01	1.41E-01	1.60E-01

RUN	TIME INJ SEC	MINEL MULD DEG	ALPHA MODEL DEG	HAFT BIU/FT2-SEC-M	HAFT FT/SEC	RHO LHM/FT3	MU LHM-SEC/FT2	HEAT+UB FT-1
14	2.00	180.00	20.60	.106E-01	.562	.347E-03	.810E-07	.510
ORBITER MODEL								
PHOSPHOR - 1251 PAINT								
TIME EXPUSED - 35.93 SEC								
INITIAL TEMP - 74.0 DEG F								
COLOR	COLOR CODE	INTERFACE TEMP/DEG F	NO-CN=1/2 USED	HEAT TRANSFER COEFF, HTU/FT2-SEC-DEG H(.90TT)	HAFT H(.90TT)	RHO H(.90TT)/ HREF	MU H(.90TT)/ HREF	HEAT+UB FT-1
WHITE	140.	6.10E-04	0.048	7.48E-04	8.36E-04	3.31E-02	4.02E-02	4.51E-02
GRAY	146.	6.78E-04	0.048	8.25E-04	9.24E-04	3.64E-02	4.43E-02	4.97E-02
BROWN	151.	7.30E-04	0.048	8.89E-04	9.98E-04	3.92E-02	4.78E-02	5.37E-02
TAN	157.	7.94E-04	0.049	9.69E-04	1.09E-03	4.27E-02	5.21E-02	5.85E-02
CUBALT	163.	8.59E-04	0.049	1.05E-03	1.18E-03	4.62E-02	5.64E-02	6.35E-02
BLUE	168.	9.14E-04	0.049	1.12E-03	1.26E-03	4.92E-02	6.01E-02	6.77E-02
	174.	9.82E-04	0.049	1.20E-03	1.36E-03	5.28E-02	6.47E-02	7.29E-02
TURQUOISE	179.	1.04E-03	0.049	1.27E-03	1.44E-03	5.59E-02	6.85E-02	7.72E-02
SKY BLUE	185.	1.11E-03	0.049	1.36E-03	1.54E-03	5.96E-02	7.32E-02	8.26E-02
OLIVE	191.	1.18E-03	0.049	1.45E-03	1.64E-03	6.34E-02	7.80E-02	8.82E-02
GREEN	196.	1.24E-03	0.049	1.53E-03	1.73E-03	6.66E-02	8.21E-02	9.29E-02
LIME	201.	1.30E-03	0.050	1.60E-03	1.82E-03	6.99E-02	8.62E-02	9.77E-02
YELLOW	206.	1.39E-03	0.050	1.71E-03	1.94E-03	7.46E-02	9.22E-02	1.05E-01
ORANGE	213.	1.45E-03	0.050	1.79E-03	2.04E-03	7.79E-02	9.65E-02	1.10E-01
RED	219.	1.53E-03	0.050	1.89E-03	2.15E-03	8.21E-02	1.02E-01	1.16E-01
SALMON	224.	1.59E-03	0.050	1.98E-03	2.25E-03	8.56E-02	1.06E-01	1.21E-01
BLACK	230.	1.67E-03	0.050	2.08E-03	2.37E-03	8.99E-02	1.12E-01	1.27E-01

ROW	TIME INJ SEC	MODEL HULL DEG	ALPHA MODEL DEG	HREF BLU/FT2-SEC-R	1T DEGR	P PSIA	D PSIA	V FT/SEC	MM/FT3	MU LBT-SEC/FT2	WE-E+UB FT-1
15	2.10	180.00	30.01	.1865E-01	101.5	0.013	.562	3811.2	.347E-03	.617E-07	.512
UPBITER MODEL											
MIDSPHIN - 3251 PAINT											
TIME LAPSED - 1.77 SEC											
INITIAL TEMP - 84.0 DEG F											
COLOR	COLOR CODE	INTL WACK TEMP-DEG F	RU-CRACK 1/2 USED	HEAT TRANSFER H(FT)	CURFF, H(.901T)	RTU/FT2-SEC-DEG H(.951T)	MATIO TO HREF H(.901T)/ HREF	MATIO TO HREF H(.951T)/ HREF			
WHITE		140.	0.048	2.37E-03	2.88E-03	3.22E-03	1.27E-01	1.55E-01	1.73E-01	1.73E-01	
GRAY		146.	0.048	2.64E-03	3.22E-03	3.61E-03	1.42E-01	1.73E-01	1.94E-01	1.94E-01	
BROWN		151.	0.048	2.48E-03	3.51E-03	3.94E-03	1.55E-01	1.89E-01	2.12E-01	2.12E-01	
TAN		157.	0.049	3.16E-03	3.86E-03	4.34E-03	1.70E-01	2.08E-01	2.33E-01	2.33E-01	
CORAL		163.	0.049	3.45E-03	4.22E-03	4.75E-03	1.86E-01	2.27E-01	2.55E-01	2.55E-01	
BLUE		168.	0.049	3.70E-03	4.53E-03	5.10E-03	1.99E-01	2.44E-01	2.74E-01	2.74E-01	
TURQUOISE		174.	0.049	4.00E-03	4.91E-03	5.53E-03	2.15E-01	2.64E-01	2.97E-01	2.97E-01	
SKY BLUE		179.	0.049	4.46E-03	5.22E-03	5.89E-03	2.29E-01	2.81E-01	3.17E-01	3.17E-01	
OLIVE		185.	0.049	4.57E-03	5.61E-03	6.34E-03	2.46E-01	3.02E-01	3.41E-01	3.41E-01	
GREEN		191.	0.049	4.48E-03	6.01E-03	6.80E-03	2.63E-01	3.23E-01	3.66E-01	3.66E-01	
LIME		196.	0.049	5.15E-03	6.35E-03	7.19E-03	2.77E-01	3.42E-01	3.87E-01	3.87E-01	
YELLOW		201.	0.050	5.42E-03	6.70E-03	7.59E-03	2.92E-01	3.60E-01	4.08E-01	4.08E-01	
ORANGE		208.	0.050	5.81E-03	7.19E-03	8.16E-03	3.13E-01	3.87E-01	4.39E-01	4.39E-01	
RED		213.	0.050	6.09E-03	7.55E-03	8.58E-03	3.28E-01	4.06E-01	4.61E-01	4.61E-01	
PUR		219.	0.050	6.44E-03	7.99E-03	9.09E-03	3.46E-01	4.30E-01	4.89E-01	4.89E-01	
SALMON		224.	0.050	6.73E-03	8.37E-03	9.53E-03	3.62E-01	4.50E-01	5.12E-01	5.12E-01	
BLACK		230.	0.050	7.09E-03	8.83E-03	1.01E-02	3.81E-01	4.75E-01	5.41E-01	5.41E-01	

RUN	TIME INJ SEC	MODEL ROLL DEG	ALPHA MODEL DEG	MREF RTU/FT2-SEC-R				
15	2.10	180.00	30.01	.186E-01				
MACH	PT	TT	F	U	V	RHU	MU	MREF+00
7.04	PSIA	DEGR	DEGR	PSIA	FT/SEC	LHM/FTJ	LHM-SEC/FT2	FT-1
	111.7	1348.7	101.5	.562	38/1.2	.347E-03	.817E-07	.512
ORRITER MODEL								
PHOSPHOR - 3251 PAINT								
TIME EXPOSED - 4.67 SEC								
INITIAL TEMP - 84.0 DEG F								
CULON	CULON CUFF	INTERFACE TEMP/DEG F	MO-CK9-1/2 USED	HEAT TRANSFER COEFF. H(FT)	RTU/FT2-SEC-DEG H(.901T)	RATIO TO MREF H(FT)/ MREF	H(.951T)/ MREF	
WHITE	140.	0.048	1.16E-03	1.77E-03	1.98E-03	7.83E-02	9.52E-02	1.07E-01
GRAY	146.	0.046	1.03E-03	1.98E-03	2.24E-03	8.75E-02	1.07E-01	1.20E-01
BROWN	151.	0.048	1.77E-03	2.16E-03	2.44E-03	9.53E-02	1.16E-01	1.30E-01
TAN	157.	0.049	1.95E-03	2.36E-03	2.67E-03	1.05E-01	1.28E-01	1.44E-01
CORAL	163.	0.049	2.13E-03	2.60E-03	2.93E-03	1.14E-01	1.40E-01	1.57E-01
BLUE	166.	0.049	2.28E-03	2.79E-03	3.19E-03	1.23E-01	1.50E-01	1.69E-01
TURQUOISE	174.	0.049	2.66E-03	3.02E-03	3.40E-03	1.32E-01	1.62E-01	1.83E-01
SKY BLUE	179.	0.049	2.62E-03	3.22E-03	3.63E-03	1.41E-01	1.73E-01	1.95E-01
OLIVE	185.	0.049	2.61E-03	3.46E-03	3.90E-03	1.51E-01	1.86E-01	2.10E-01
GREEN	191.	0.049	3.01E-03	3.70E-03	4.19E-03	1.62E-01	1.99E-01	2.25E-01
LINE	196.	0.049	3.17E-03	3.91E-03	4.43E-03	1.71E-01	2.10E-01	2.38E-01
YELLOW	201.	0.050	3.34E-03	4.12E-03	4.67E-03	1.80E-01	2.22E-01	2.51E-01
ORANGE	206.	0.050	3.58E-03	4.33E-03	5.02E-03	1.92E-01	2.38E-01	2.70E-01
PED	213.	0.050	3.75E-03	4.65E-03	5.29E-03	2.02E-01	2.50E-01	2.84E-01
SALMON	219.	0.050	3.76E-03	4.97E-03	5.60E-03	2.13E-01	2.65E-01	3.01E-01
BLACK	224.	0.050	4.14E-03	5.15E-03	5.87E-03	2.23E-01	2.77E-01	3.15E-01
	230.	0.050	4.36E-03	5.43E-03	6.20E-03	2.35E-01	2.92E-01	3.43E-01

TUP APT CAMERA 1
SEQUENCE 2

RUN	TIME INJ SEC	MODEL NO.	ALPHA MODEL DEG	HREF BTU/FT ² -SEC-R	PT PSIA	DEGR	F	PSIA	DEGR	0	FT/SEC	NU LMH/FT ²	NU LMH/FT ²	RECEIVED FT-1
15	2.10	140.00	30.01	.106E-01	101.5	101.5	0.013	0.013	101.5	.562	3871.2	.017E-01	.512	
ORBITER MODEL														
PHOSPHOR - 3251 PAINT														
TIME EXPOSURE - 0.07 SEC														
INITIAL TEMP - 24.0 DEG F														
COLOR	COLOR CODE	INTERFACE TEMP/DEG F	RU-CAN-1/2 USED	HEAT TRANSFER COEFF, BTU/FT ² -SEC-DEG H(TT) H(90TT) H(.85TT)	TUP	APT	CAMERA	SEQUENCE	RATIO TO HREF H(TT)/HREF H(90TT)/HREF H(.85TT)/HREF					
WHITE	140.	0.048	0.048	1.11E-03 1.35E-03 1.51E-03	1	5.96E-02	7.45E-02	8.12E-02						
GRAY	146.	0.048	0.048	1.44E-03 1.51E-03 1.69E-03	3	6.66E-02	8.10E-02	9.09E-02						
BROWN	151.	0.048	0.048	1.38E-03 1.64E-03 1.84E-03	3	7.25E-02	8.63E-02	9.92E-02						
TAN	157.	0.049	0.049	1.49E-03 1.81E-03 2.03E-03	3	7.97E-02	9.73E-02	1.09E-01						
CUBALT	163.	0.049	0.049	1.62E-03 1.98E-03 2.23E-03	3	8.70E-02	1.06E-01	1.20E-01						
BLUE	168.	0.049	0.049	1.73E-03 2.12E-03 2.39E-03	3	9.32E-02	1.14E-01	1.28E-01						
TURQUOISE	174.	0.049	0.049	1.87E-03 2.30E-03 2.59E-03	3	1.01E-01	1.24E-01	1.39E-01						
SKY BLUE	179.	0.049	0.049	1.99E-03 2.45E-03 2.76E-03	3	1.07E-01	1.32E-01	1.48E-01						
OLIVE	185.	0.049	0.049	2.14E-03 2.63E-03 2.97E-03	3	1.15E-01	1.41E-01	1.60E-01						
GREEN	191.	0.049	0.049	2.29E-03 2.82E-03 3.19E-03	3	1.23E-01	1.51E-01	1.71E-01						
LIME	196.	0.049	0.049	2.41E-03 2.96E-03 3.37E-03	3	1.30E-01	1.60E-01	1.81E-01						
YELLOW	201.	0.050	0.050	2.54E-03 3.14E-03 3.55E-03	3	1.37E-01	1.69E-01	1.91E-01						
ORANGE	208.	0.050	0.050	2.72E-03 3.37E-03 3.82E-03	3	1.46E-01	1.81E-01	2.06E-01						
RED	213.	0.050	0.050	2.85E-03 3.54E-03 4.02E-03	3	1.53E-01	1.90E-01	2.16E-01						
SALMON	217.	0.050	0.050	3.02E-03 3.74E-03 4.26E-03	3	1.62E-01	2.01E-01	2.29E-01						
BLACK	224.	0.050	0.050	3.15E-03 3.92E-03 4.40E-03	3	1.70E-01	2.11E-01	2.40E-01						
	230.	0.050	0.050	3.32E-03 4.13E-03 4.71E-03	3	1.79E-01	2.22E-01	2.53E-01						

NUM	TIME INJ SEC	MODEL ROLL DEG	ALPHA MODEL DEG	HREF BTU/FT ² -SEC-H	MEASUREMENT
15	2.10	180.00	30.01	.106E-01	MEASUREMENT FT-1 .514
MACH	TT	P	D	V	MU
7.84	1348.7	PSIA 0.013	PSIA .562	FT/SEC 3811.2	LBM/FT ³ .347E-03
ORBITER MODEL					
PHOSPHOR - 3251 PAINT					
TIME EXPOSED - 11.57 SEC					
INITIAL TEMP - 84.0 DEG F					
COLOR	TEMP, DEG F	NO-CHECK 1/2 USED	HEAT TRANSFER COEFF, BTU/FT ² -SEC-DEG H(TT) H(.90TT) H(.95TT)	RATIO TO HREF H(TT)/HREF H(.90TT)/HREF H(.95TT)/HREF	
WHITE	140.	0.048	9.28E-04 1.13E-03 1.26E-03	4.98E-02 6.05E-02 6.70E-02	
GRAY	146.	0.048	1.03E-03 1.26E-03 1.41E-03	5.56E-02 6.77E-02 7.59E-02	
BROWN	151.	0.048	1.13E-03 1.37E-03 1.54E-03	6.05E-02 7.38E-02 8.28E-02	
TAN	157.	0.049	1.44E-03 1.51E-03 1.70E-03	6.65E-02 8.12E-02 9.13E-02	
CUBALF	163.	0.049	1.35E-03 1.45E-03 1.66E-03	7.27E-02 8.88E-02 9.99E-02	
BLUE	168.	0.049	1.45E-03 1.77E-03 2.00E-03	7.79E-02 9.53E-02 1.07E-01	
TURQUOISE	174.	0.049	1.57E-03 1.92E-03 2.16E-03	8.42E-02 1.03E-01 1.16E-01	
SKY BLUE	179.	0.049	1.67E-03 2.04E-03 2.31E-03	8.95E-02 1.10E-01 1.24E-01	
OLIVE	185.	0.049	1.79E-03 2.20E-03 2.48E-03	9.61E-02 1.18E-01 1.33E-01	
GREEN	191.	0.049	1.91E-03 2.35E-03 2.66E-03	1.03E-01 1.26E-01 1.43E-01	
LIME	196.	0.049	2.02E-03 2.49E-03 2.81E-03	1.08E-01 1.34E-01 1.51E-01	
YELLOW	201.	0.050	2.12E-03 2.62E-03 2.97E-03	1.14E-01 1.41E-01 1.60E-01	
ORANGE	208.	0.050	2.27E-03 2.81E-03 3.19E-03	1.22E-01 1.51E-01 1.72E-01	
RED	213.	0.050	2.38E-03 2.95E-03 3.36E-03	1.28E-01 1.59E-01 1.80E-01	
SALMON	219.	0.050	2.52E-03 3.13E-03 3.56E-03	1.35E-01 1.68E-01 1.91E-01	
BLACK	224.	0.050	2.63E-03 3.27E-03 3.73E-03	1.42E-01 1.76E-01 2.00E-01	
	230.	0.050	2.76E-03 3.45E-03 3.94E-03	1.49E-01 1.86E-01 2.12E-01	

RUN	TIME INJ SEC	MODEL ROLL DEG	ALPHA MODEL DEG	HREF RTU/FT2-SEC-R										
15	2.10	180.00	30.01	.186E+01										
NACH	PT	PSIA	P	Q	V	RHU	MU				REF			
7.04	111.7	111.7	0.013	PSIA	FT/SEC	LHM/FT3	LBF-SEC/FT2				FT-1			
	1348.7		0.013	.567	3871.2	.347E+03	.817E+07				.512			
URBITER MODEL														
PHOSPHOR - J251 PAINT														
TIME CAPUSED - 22.97 SEC														
INITIAL TEMP - 84.0 DEG F														
CULPIN	COLOR CODE	INTERFAC	RO-CAN=1/2 USED	HEAT TRANSFER H(1T)	COEFF, RTU/FT2-SEC-DEG H(.90IT)	H(1T)/ HREF	RATIO TO HREF H(.90IT)/ HREF				M(1.95IT)/ HREF			
WHITE	140.		0.048	6.58E-04	8.00E-04	6.97E-04	3.54E-02	4.30E-02	4.62E-02					
GRAY	146.		0.048	7.35E-04	8.05E-04	1.00E-03	3.95E-02	4.81E-02	5.60E-02					
BROWN	151.		0.048	8.01E-04	9.76E-04	1.10E-03	4.31E-02	5.25E-02	5.89E-02					
TAN	157.		0.049	8.80E-04	1.07E-03	1.21E-03	4.73E-02	5.78E-02	6.49E-02					
CORAL	163.		0.049	9.61E-04	1.18E-03	1.32E-03	5.17E-02	6.32E-02	7.11E-02					
BLUE	168.		0.049	1.03E-03	1.26E-03	1.42E-03	5.54E-02	6.78E-02	7.63E-02					
TURQUOISE	174.		0.049	1.11E-03	1.37E-03	1.54E-03	5.99E-02	7.34E-02	8.27E-02					
SKY BLUE	179.		0.049	1.18E-03	1.45E-03	1.64E-03	6.37E-02	7.82E-02	8.82E-02					
OLIVE	185.		0.049	1.27E-03	1.56E-03	1.76E-03	6.81E-02	8.40E-02	9.49E-02					
GREEN	191.		0.049	1.36E-03	1.67E-03	1.89E-03	7.31E-02	9.00E-02	1.02E-01					
LIME	196.		0.049	1.43E-03	1.77E-03	2.00E-03	7.71E-02	9.50E-02	1.08E-01					
YELLOW	201.		0.050	1.51E-03	1.86E-03	2.11E-03	8.12E-02	1.00E-01	1.14E-01					
ORANGE	208.		0.050	1.62E-03	2.00E-03	2.27E-03	8.70E-02	1.08E-01	1.22E-01					
RED	213.		0.050	1.70E-03	2.10E-03	2.39E-03	9.12E-02	1.13E-01	1.28E-01					
SALMON	219.		0.050	1.79E-03	2.22E-03	2.53E-03	9.64E-02	1.20E-01	1.36E-01					
BLACK	224.		0.050	1.87E-03	2.33E-03	2.65E-03	1.01E-01	1.25E-01	1.43E-01					
	230.		0.050	1.97E-03	2.46E-03	2.80E-03	1.06E-01	1.32E-01	1.51E-01					

VITA

Gordon Alan Lowrey, son of Gordon Melvin and Betty Ann (Brooks) Lowrey, was born September 21, 1956, in St. Petersburg, Florida. He attended Pinellas County Public Schools and graduated from Lakewood Senior High School, St. Petersburg, in June 1974. In September 1974 he entered Auburn University and received the degree of Bachelor of Aerospace Engineering in June 1978. Two years of the Pre-Medical curriculum at Auburn were also included in his undergraduate education. He entered the Graduate School at Auburn University in September 1978 and accepted a teaching assistantship within the Department of Aerospace Engineering for the Aviation Management curriculum. He was awarded the degree of Master of Science in Aerospace Engineering in August 1980.

After two years of employment with the McDonnell Douglas Technical Services Company, Inc. of Houston, Texas, he entered The University of Tennessee Space Institute (UTSI) in September 1982. In June 1986 he returned to private industry by joining Teledyne Brown Engineering of Huntsville, Alabama.

The author is a senior member of the American Institute of Aeronautics and Astronautics, and a member of Sigma Xi and the American Society of Mechanical Engineers. He is presently employed with the Space Transportation Systems Division of Rockwell International in Huntsville, Alabama.