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CARINA AEROTHERMAL TEST AT MACH 8

M. G. Hammond

Calspan Corporation/AEDC Operations

July 1991

Final Report for April 16-18, 1991

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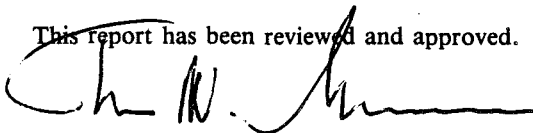
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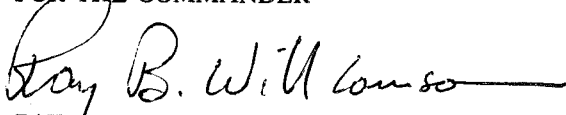
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THOMAS W. GREENMAN, 1 Lt, USAF
Reentry Systems Division
Dir Aerospace Flt Dyn Test
Deputy for Operations

Approved for publication:

FOR THE COMMANDER



RAY B. WILLIAMSON, Major, USAF
Chief, Reentry Systems Division
Aerospace Flight Dyn Test
Deputy for Operations

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NOMENCLATURE

AB	Model base area (see Table 2)
ALPHA	Model angle of attack, deg
ALPI	Indicated sector pitch angle, deg
CA	Total axial-force coefficient, body axis, axial force/(Q * SREF)
CAB	Axial-force coefficient for model base pressures, -CPBA * AB/SREF
CAF	Forebody axial-force coefficient, body axis, CA - CAB
CCW	Cross-wind coefficient, wind axis
CDW	Drag coefficient, wind axis
CLL	Rolling-moment coefficient, body axis, rolling-moment/(Q * SREF * LREFL)
CLLW	Rolling-moment coefficient, wind axis
CLM	Pitching-moment coefficient, body axis pitching moment/(Q*SREF*LREFM)
CLMW	Pitching-moment coefficient, wind axis
CLN	Yawing-moment coefficient, body axis, yawing moment/(Q*SREF*LREFN)
CLNW	Yawing-moment coefficient, wind axis
CLW	Lift coefficient, wind axis
CN	Normal-force coefficient, body axis, normal force/(Q*SREF)
CONFIGURATION	Model configuration designation (see Table 1)
CP	Pressure coefficient, (PW-P)/Q
CPBA	Average base pressure coefficient, (PBA - P)/Q
C.R.	Center of rotation
CY	Side-force coefficient, body axis, side force/(Q*SREF)
FCRN	Flow correction run number

GAGE ID	Gage identification number
H(TT)	Heat-transfer coefficient based on TT, $H(TT) = QDOT/(TT-TW)$, Btu/ft ² -sec-°R or W/M ² -°K
ITT	Enthalpy based on TT, Btu/lbm
ITW	Enthalpy based on TW, Btu/lbm
(L/D)W	Lift-to-drag ratio, wind axis
LM	Model length (see Table 2)
LREFL LREFM LREFN	Model moment reference lengths, (see Table 2)
M	Free-stream Mach number
MODEL PRESSURE	Model pressure identification number
MU	Dynamic viscosity based on free-stream temperature, lbf-sec/ft ² or PA-sec
P	Free-stream static pressure, psia or PA
PB1-4	Model base pressures, psia or PA
PBA	Average model base pressure, (PB1+PB2+PB3+PB4)/4, psia or PA
PHI	Total model roll angle, deg
PHII	Indicated roll angle, deg
PK101 PK116 PK201 PK232	Reference pressure measured by ESP® module 1, channels 1 and 16, and ESP® module 2, channel 1 and 32, psia
PKNOWN 7 PKNOWN 8 PKNOWN S	Reference pressure measured by the standard pressure system and Sonics® transducer, psia
PN	Data point number
PT	Tunnel stilling chamber total pressure, psia or PA
PT2	Stagnation pressure downstream of a normal shock, psia or PA
PTNK	Installation tank pressure, psia or PA
PW	Calculated model pressure, psia or PA

Q	Free-stream dynamic pressure, psia or PA
QDOT	Measured heat-transfer rate, Btu/ft ² -sec or W/M ²
RE	Free-stream unit Reynolds number, ft ⁻¹ or M ⁻¹
RHO	Free-stream density, lbm/ft ³ or KG/M ³
RUN	Data set identification number
S(TT)	Stanton number based on TT, $S(TT) = QDOT / (RHO * V * (ITT - ITW))$
S/R	Surface distance to model instrumentation location where R = 5.0, S/R = 0 at model stagnation point (see Table 4)
SREF	Model reference area, (see Table 2)
T	Free-stream static temperature, °R or °K
THETA, θ	Angular location of model instrumentation, deg (see Table 4)
TIMEINJ	Time of model injection, elapsed time from lift-off to arrival at tunnel centerline, sec
TIMERD	Time from lift-off at which heat-transfer gage data were reduced, sec
TT	Tunnel stilling chamber total temperature, °R or °K
TW	Gage surface temperature, °R or °K
V	Free-stream velocity, ft/sec or M/sec
XCPN	X-coordinate of the pitch-plane center-of-pressure location expressed in terms of LREFM
XMRC	Axial distance from model nose to model moment reference center, (see Table 2)

1.0 INTRODUCTION

The work reported herein was conducted by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 921Z39, Control Number 9Z39, at the request of the Directorate of Aerospace Flight Dynamics Test (DOF), AEDC, Arnold AFB, TN 37389, for Science Applications International Corporation (SAIC), 501 Office Center Drive, Suite 420, Fort Washington, PA 19034. The AEDC/DOF project manager was 1LT Thomas Greenman and the SAIC project manager was Mr. Anthony Martellucci. The test results were obtained by Calspan Corporation, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Base, Tennessee. The test was conducted in the Hypersonic Wind Tunnel B of the von Karman Gas Dynamics Facility (VKF), during the period from April 16, 1991 to April 18, 1991, under AEDC Project Number CR23VB.

The purpose of this test was to determine the effects of corner radius and afterbody angle on surface pressure, heat-transfer rate, and static stability data needed to validate vehicle design/analysis codes and confirm performance of the Carina Space Recovery Vehicle. Carina is a low-cost, recoverable reentry vehicle designed as a microgravity research platform.

Surface pressure and heat-transfer data were acquired on the baseline configuration at Mach 8 and a Reynolds number of 0.75, 1.0, and 2.0 million per foot. Discrete angles of attack were set between 0 and 20 deg, and roll angles were set between -165 and 180 deg. Static stability and base pressure data were acquired on the baseline configuration and three additional configurations at Mach 8 and a Reynolds number of 1.0 and 2.0 million per foot. Oil flow visualization data were obtained on all four configurations at Mach 8 at a Reynolds number of 1.0 million per foot. Angle-of-attack and roll angle variations for each configuration are defined in the Test Run Summary.

The purpose of the report is to document the test and to describe the test parameters. The report provides information to permit use of the data but does not include any data analysis, which is beyond the scope of the report.

The final data from the test have been transmitted to SAIC. Requests for the data should be addressed to AEDC/DOF, Arnold AFB, TN 37389. A copy of the data is on file at the AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel B (Fig. 1) is a continuous, closed-circuit, variable density wind tunnel with a 50-in.-diam test section and two interchangeable axisymmetric contoured nozzles to provide Mach numbers of 6 and 8. The tunnel can be operated continuously over a range of pressure from 40 to 300 psia at Mach number 6, and 100 to 900 psia at Mach number 8, with air supplied by the main compressor

plant. Stagnation temperatures sufficient to avoid air liquefaction in the test section (up to 1350°R) are obtained through the use of a natural gas-fired combustion heater. The entire tunnel (throat, nozzle, test section, and diffuser) is cooled by integral, external water jackets.

The tunnel is equipped with a model injection system, which allows removal of the model from the test section while the tunnel remains in operation. A description of the tunnel may be found in the Test Facilities Handbook (Ref. 1).

2.2 TEST ARTICLES

The test articles furnished by SAIC were scaled models of the Carina Space Recovery Vehicle. All models were designed and fabricated by Micro Craft, Inc. of Tullahoma, TN. Carina is an axisymmetric model of a blunt, low lift-to-drag reentry vehicle. The baseline configuration consisted of a 0.5-in. corner radius and a 13-deg after-body angle. Additional model components were used to achieve different corner radii and after body angles. A separate model of the baseline configuration was used during the heat-transfer/pressure phase of the test. Details of the different configurations can be seen in Fig. 2, and a photograph of model components is provided in Fig. 3. The models were constructed of stainless steel (17-4). Boundary-layer trips were not used. Model configuration designations are outlined in Table 1, and coefficient reference lengths and areas are presented in Table 2. Installation sketches are provided in Fig. 4, and an installation photograph is presented in Fig. 5.

Base pressure tubes were aligned 0.05 in. from the model base during the force phase of the test. A windshield assembly was also used at the base of the model to protect the aft portion of the balance and the water cooling lines. A schematic of base pressure locations is presented in Fig. 6. The pressure tubes and windshield assembly can be seen in Fig. 7.

2.3 TEST INSTRUMENTATION

The instrumentation, recording devices, and calibration methods used for all measured parameters are listed in Table 3.

2.3.1 Model Force Instrumentation

Model forces and moments were measured with a six-component, 500-lb strain gage balance (ID No. 4.00-Y-36-043) supplied and calibrated by AEDC.

2.3.2 Pressure Instrumentation

Model base pressures and surface pressures were measured with an Electronically Scanned Pressure (ESP®) module. The module contains 16 fast-response pressure transducers with a range of ± 1.0 psid. The relatively small size of the pressure module made it possible to mount the instrument in a sting segment downstream of the model base during

the force phase. In addition to the ± 1.0 -psid module, a 48-channel, ± 2.5 -psid pressure module was mounted on-board the model during the heat transfer/pressure phase to measure 35 surface pressures. Only base pressures were measured during the force phase.

2.3.3 Heat-Transfer Instrumentation

The heat-transfer/pressure model was instrumented with 9 coax gages and 17 Schmidt-Boelter gages. The coax gage is a surface thermocouple that is comprised of an insulated Chromel wire fixed concentrically within a constantan jacket. The Schmidt-Boelter gage consists of a 0.025-in.-thick anodized aluminum wafer wrapped with a small (0.002-in.-diam) thermocouple wire. One half of the wire-wrapped wafer was copper plated creating a series thermocouple. The wafer was potted into an aluminum heat sink. Each gage also used an iron constantan thermocouple to provide the gage temperature. The thermocouple outputs were used to determine the rate of heat flux and the gage surface temperature using gage calibration factors determined using laboratory techniques traceable to the National Institute of Standards and Technology (formerly National Bureau of Standards). Heat flux and surface temperature were used in calculating the heat-transfer coefficient. Figure 8 provides the layout for the heat-transfer gages and pressure orifices, and Table 4 gives the actual locations.

2.3.4 Flow Visualization

Model flow-field shadowgraph/schlieren still photographs were obtained on all configurations at selected model attitudes. The photographs were obtained with a single-pass optical flow-visualization system. Color schlieren movies were obtained for selected runs, and 70-mm still photographs were obtained for each oil flow run. Prior to performing the oil flow portion of the test, a dummy balance was installed to avoid oil contamination of the strain gages on the force balance.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS

A test summary showing all configurations tested and the variables for each is presented in Table 5. A summary of nominal test conditions is given below:

M	PT, psia	TT, °F	Q, psia	P, psia	T, °F	V, ft/sec	RE, ft ⁻¹
7.98	455.0	850	2.107	0.047	97.4	3859	2.0 x 10 ⁶
7.93	207.5	785	0.981	0.022	93.1	3753	1.0 x 10 ⁶
7.88	150.0	760	0.716	0.016	91.5	3712	0.75 x 10 ⁶

3.2 TEST PROCEDURES

3.2.1 General

In Tunnel B, the model is mounted on a sting support mechanism in an installation tank directly underneath the tunnel test section. The tank is separated from the tunnel by a pair of fairing doors and a safety door. When closed, the fairing doors, except for a slot for the pitch sector, cover the opening to the tank. The safety door seals the tunnel from the tank area. After the model is prepared for a data run, the personnel access door to the installation tank is closed, the tank is vented to the tunnel flow, the safety and fairing doors are opened, the model is injected into the airstream, and the fairing doors are closed. After the data are obtained, the model is retracted into the tank, and the sequence is reversed with the tank being vented to atmosphere to allow access to the model in preparation for the next run. The sequence is repeated for each configuration or test condition change.

3.2.2 Data Acquisition

3.2.2.1 Force Data

Model attitude positioning and data recording were accomplished with the point-pause and continuous-sweep modes of operation, using the Model Attitude Control System (MACS). Model pitch and roll requirements were entered into the controlling computer prior to the test. Model positioning and data recording operations were performed automatically during the test by selecting the list of desired model attitudes and initiating the system.

Point-pause data were obtained for selected values of ALPHA and PHI. Each data point for this mode of operation represents the result of a Kaiser-Bessel digital filter utilizing 16 samples taken over a span of 0.50 sec. Continuous-sweep data were obtained for a fixed value of PHI with a pitch rate of 1.0 deg/sec. A data sample was recorded every 0.0320 sec and a sliding Kaiser-Bessel digital filter was applied to 16 samples to produce a data point every 0.48 deg in pitch. The data were then interpolated to obtain the data desired for the requested model attitudes.

3.2.2.2 Heat-Transfer/Pressure Data

Model attitude positioning was performed manually before each inject. Each inject was performed at discrete pitch and roll angles, and the angles were constant throughout the run. The data acquisition sequence was started just prior to injection while the model was still in the tank and continued until the model was retracted into the tank.

3.2.2.3 Oil Flow Visualization

Each oil flow run was performed at discrete pitch and roll angles. Prior to each run, oil was blotted on the model surface with a corrugated sponge. The model was then injected into the tunnel where

70-mm still photographs were taken every 4 sec until the flow pattern had established. The model was then retracted.

3.3 DATA REDUCTION

3.3.1 Force Data

Model static force and base pressure data were obtained simultaneously utilizing the data acquisition procedures as described in Section 3.2. The force and moment measurements were reduced to coefficient form using the digitally filtered data points and correcting for first- and second-order balance interaction effects, model tare weight, and balance-sting deflections. Model attitude and tunnel stilling chamber pressure were also calculated from digitally filtered values.

Model force and moment coefficients are presented in the body and wind axis systems. The static stability and total axial-force coefficients were corrected for small tunnel flow nonuniformities. Wind axis system coefficients were calculated using the forebody axial-force coefficient (CAF). Reference lengths and areas for model aerodynamic coefficients are given in Table 2 for each configuration.

3.3.2 Coax Gage Data

The coax gage provides a measurement of the surface temperature of the test panel material, which is assumed to be a homogenous, one-dimensional, semi-infinite solid. For this reason it is important that the thermophysical properties of the gage parts and the test panel material be closely matched. The coax gage heat flux at each instrumented location was computed for each time point (t_n) from the measured surface temperature by the following equation derived from semi-infinite solid considerations

$$QDOT(t_n) = \frac{2C(t_n)}{\sqrt{\pi}} \sum_{j=1}^n \frac{TW(t_j) - TW(t_{j-1})}{\sqrt{t_n - t_j} + \sqrt{t_n - t_{j-1}}} \quad (1)$$

The coax gage surface temperature, $TW(t_j)$, was computed using a curve fit of voltage versus temperature published by the National Institute of Standards and Technology (formerly National Bureau of Standards) (1974). The value of $C(t_n)$ for the coax gages was calculated from

$$C(t_n) = 5.26 \times 10^{-4} \left[\frac{TW(t_n) + TW(t_1)}{2} \right] + 0.12688 \quad (2)$$

To reduce the effects of any noise in the gage output, the values of QDOT were averaged for fifteen consecutive readings after the test article reached the tunnel centerline. The gage surface temperature was also averaged.

The heat-transfer coefficient, $H(TT)$, for each coax gage was computed from

$$H(TT) = \frac{QDOT}{(TT - TW)} \quad (3)$$

3.3.3 Model Surface Pressures

Prior to the operating shift the ESP pressure modules were calibrated by applying known and zero pressure differentials across the modules. From this data, scale factors were calculated for each port of each module. Model pressure (PW) for each orifice was calculated with a second-order curve fit,

$$PW = A_0 + A_1 \left[\text{Reading} - CZ \right] + A_2 \left[\text{Reading} - CZ \right]^2 + \text{Reference Pressure} \quad (4)$$

where A_0 , A_1 , and A_2 are calibration coefficients, and CZ is the corrected zero calculated by

$$CZ = \text{Updated zero reading} - \text{Zero reading at calibration} \quad (5)$$

Reference pressure was measured using a miniature vacuum gage.

A pressure coefficient (CP) was calculated for each orifice

$$CP = (PW - P)/Q \quad (6)$$

The known pressure measurement was calculated using

$$P_{KNOWN} = (Reading - Zero Reading)(SF) + Reference Pressure \quad (7)$$

where SF is the calibration scale factor.

3.3.4 Schmidt-Boelter Gage Data

Measurements obtained from the Schmidt-Boelter gages are gage output (E) and gage temperature (TGE). The gage output is converted to heating rate via a laboratory calibrated gage scale factor (CSF):

$$QDOT = (E) (CSF) \quad (8)$$

The gage wall temperature used in computing the gage heat-transfer coefficient is obtained from the output of the gage thermocouple (TGE) and the temperature difference (TGDEL) across the gage wafer. TGDEL is proportional to the gage output, E, and is calculated by:

$$TGDEL = (KG) (E) \quad (9)$$

where KG is the gage temperature calibration factor. The gage wall temperature is:

$$TW = TGE + TGDEL \quad (10)$$

The heat-transfer coefficient for each gage was computed using Eq. (3).

3.3.5 Oil Flow Data

Tunnel conditions were the only data tabulated for oil flow runs.

3.4 MEASUREMENT UNCERTAINTIES

In general, instrumentation calibrations and data uncertainty estimates were made using methods described in Ref. 2. Measurement uncertainty is a combination of bias and precision errors defined as:

$$U = \pm \left(B + t_{95} S \right) \quad (11)$$

where B is the bias limit, S is the sample standard deviation and t_{95} is the 95th percentile point for the two-tailed Student's t distribution (95-percent confidence interval) which for sample sizes greater than 30 is taken equal to 2.

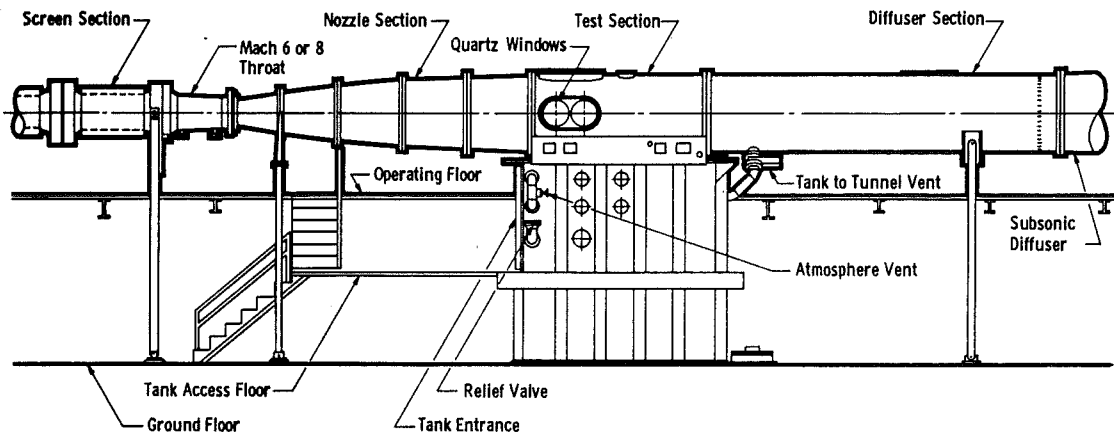
Estimates of the measured data uncertainties are given in Table 3a. Static load hangings on the force and moment balance simulated the range of loads and center-of-pressure locations anticipated during the test, and measurement errors were based on differences between applied loads and corresponding values calculated from the balance equations used in the data reduction. Load hangings to verify each balance calibration are made in place on the assembled model. Data uncertainties for the coax and Schmidt-Boelter gages were determined from laboratory calibrations. Other data uncertainties were determined from in-place calibrations through the data recording system and data reduction program. Propagation of the bias and precision errors of measured data through the calculated data was made in accordance with Ref. 2 and results are given in Table 3b.

4.0 DATA PACKAGE PRESENTATION

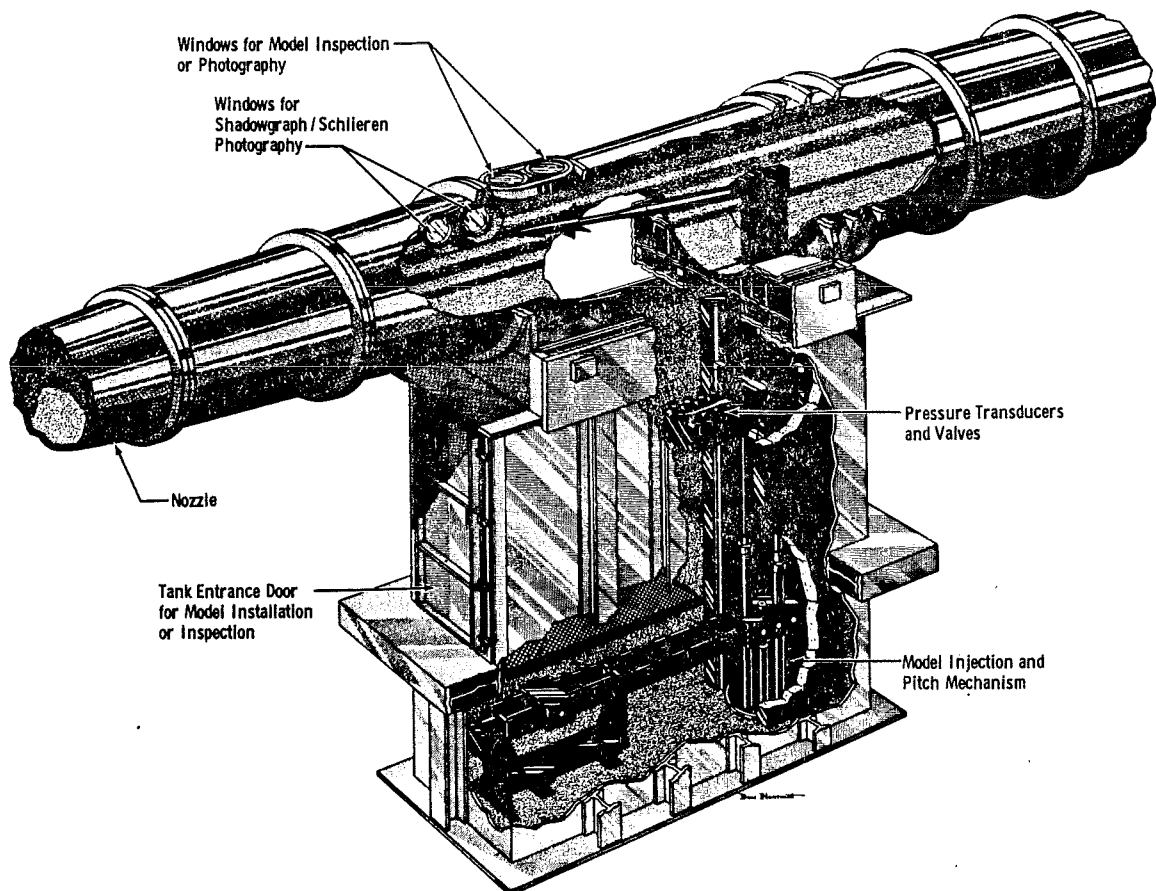
The data package contains tabulated data presented in English and SI units. The force data included coefficients in the body and wind axes. Sample tabulations of heat-transfer/pressure data, force data, and tunnel conditions are presented in Samples 1-4. All photographic data, including model installation and shadowgraph/schlieren photographs, were a part of the data package.

5.0 REFERENCES

1. Test Facilities Handbook (Twelfth Edition). "von Karman Gas Dynamics Facility, Vol. 3." Arnold Engineering Development Center, March 1984.
2. Abernethy, R. B. et al. and Thompson, J. W. "Handbook Uncertainty in Gas Turbine Measurements." AEDC-TR-73-5 (AD755356), February 1973.



a. Tunnel assembly



b. Tunnel test section
Fig. 1. Tunnel B

CONFIGURATION	R_c , in.	A , deg	D , in.	B , in.
1	0.50	13	9.860	5.812
2	0.25	13	9.968	5.812
3	1.00	13	9.659	5.812
4	0.50	8	9.860	7.492

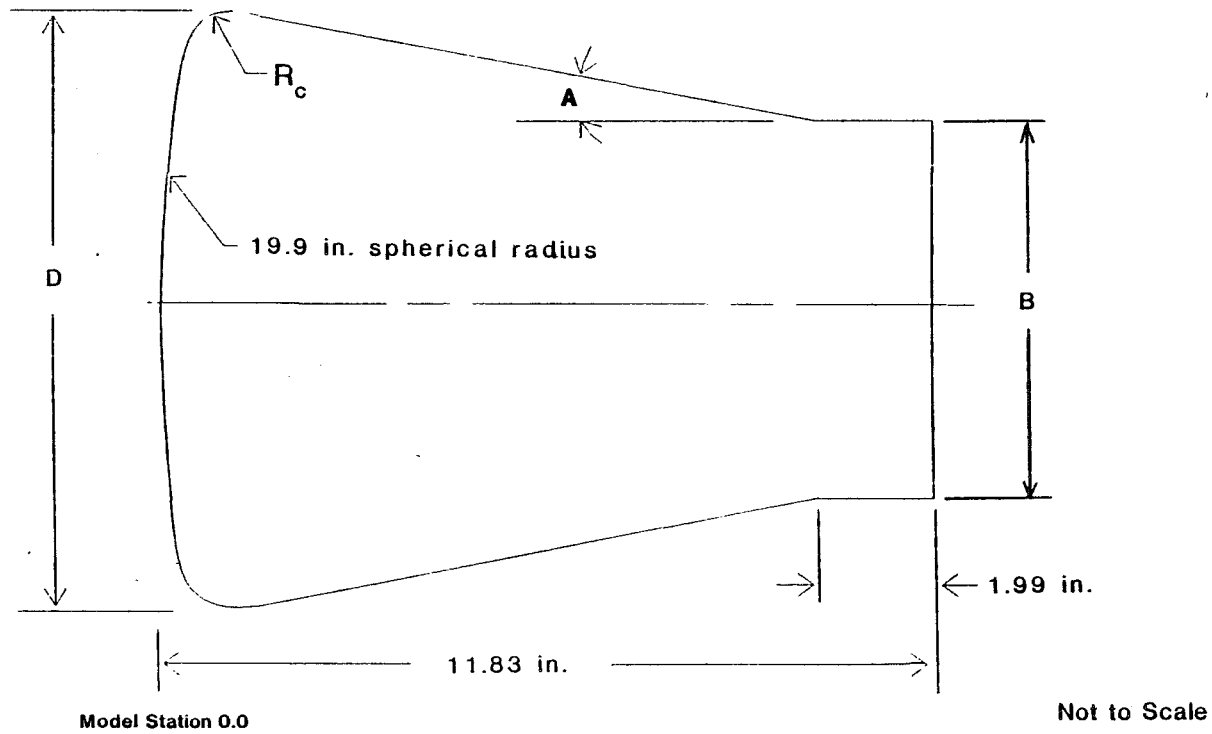


Figure 2. Model Configuration Details



a. Force Model
Figure 3. Model Components



b. Heat-transfer/pressure model

Figure 3. Concluded.

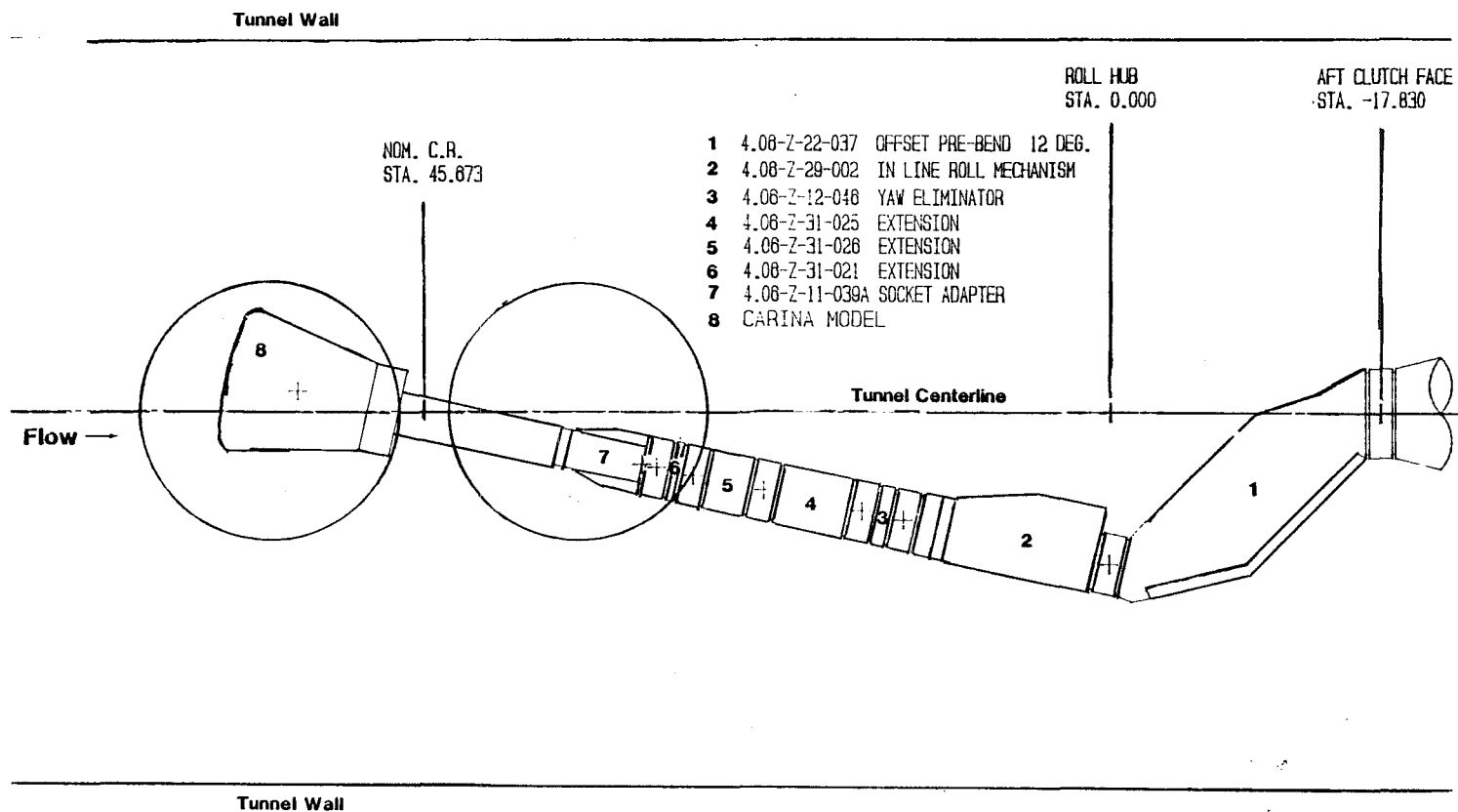


Figure 4. Carina Installation in Tunnel B
a. Heat-Transfer/Pressure Installation

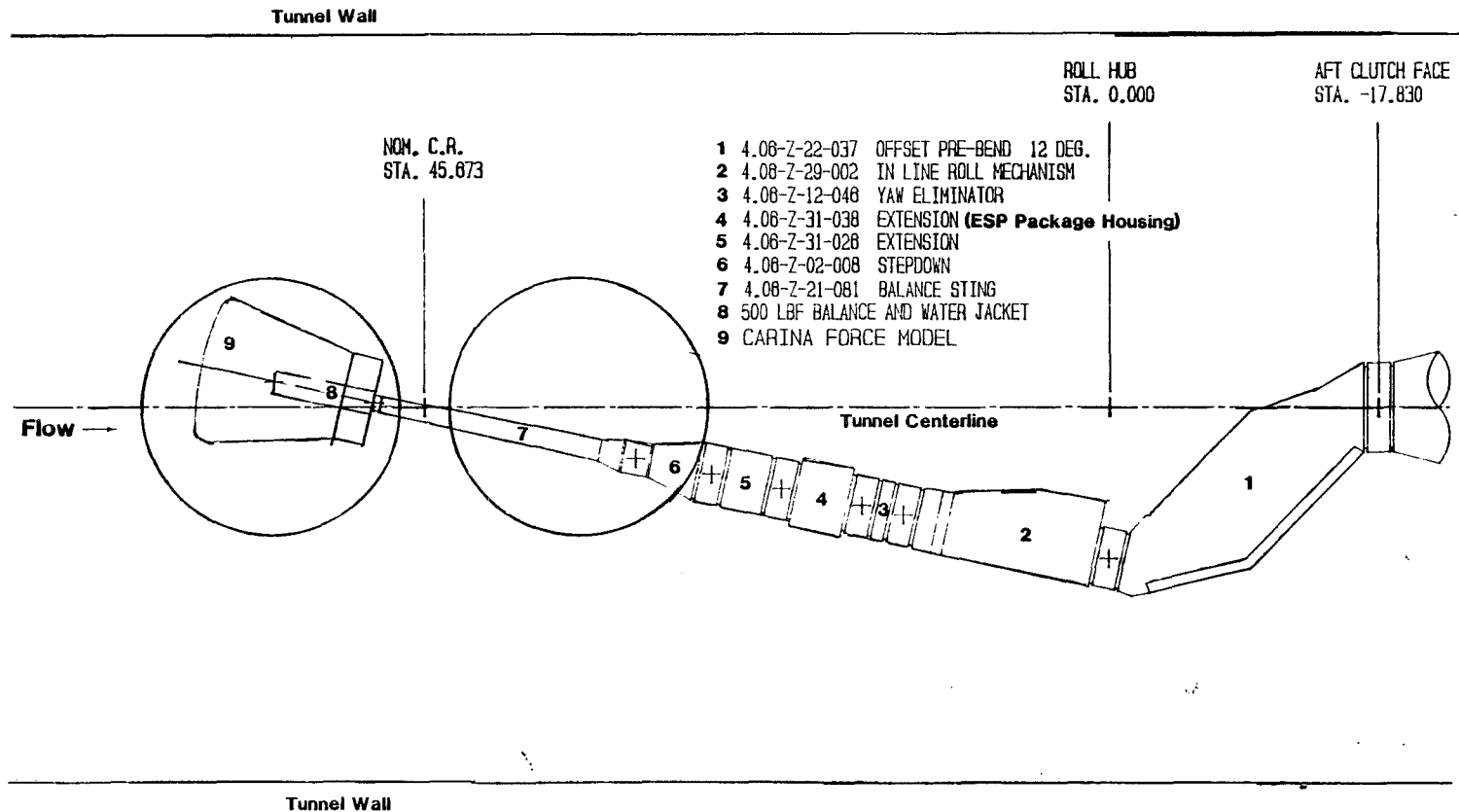


Figure 4. Continued
b. Force Installation

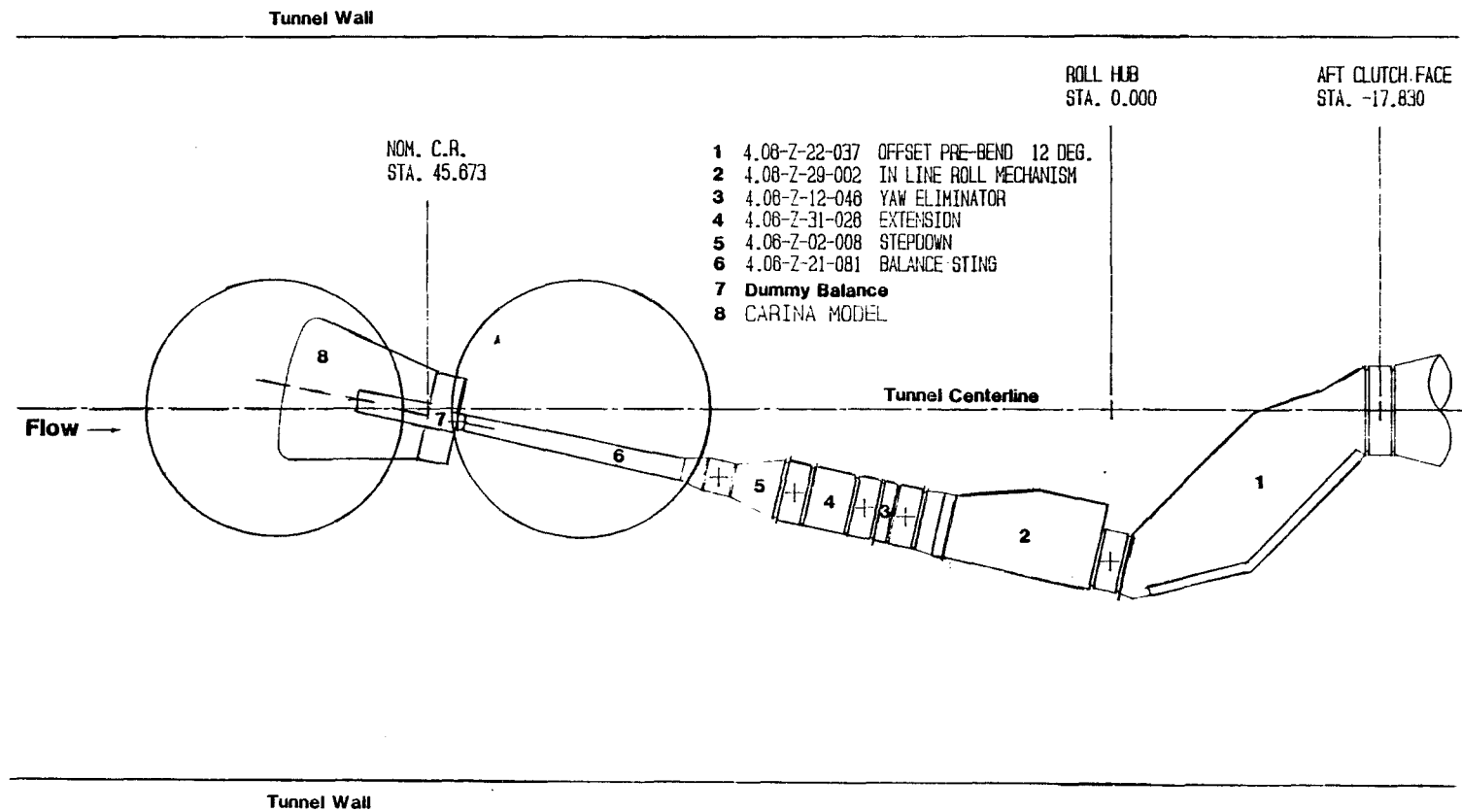


Figure 4. Concluded

c. Oil Flow Installation



Figure 5. Carina heat-transfer/pressure model installed in Tunnel B

Looking Forward at Base of Model

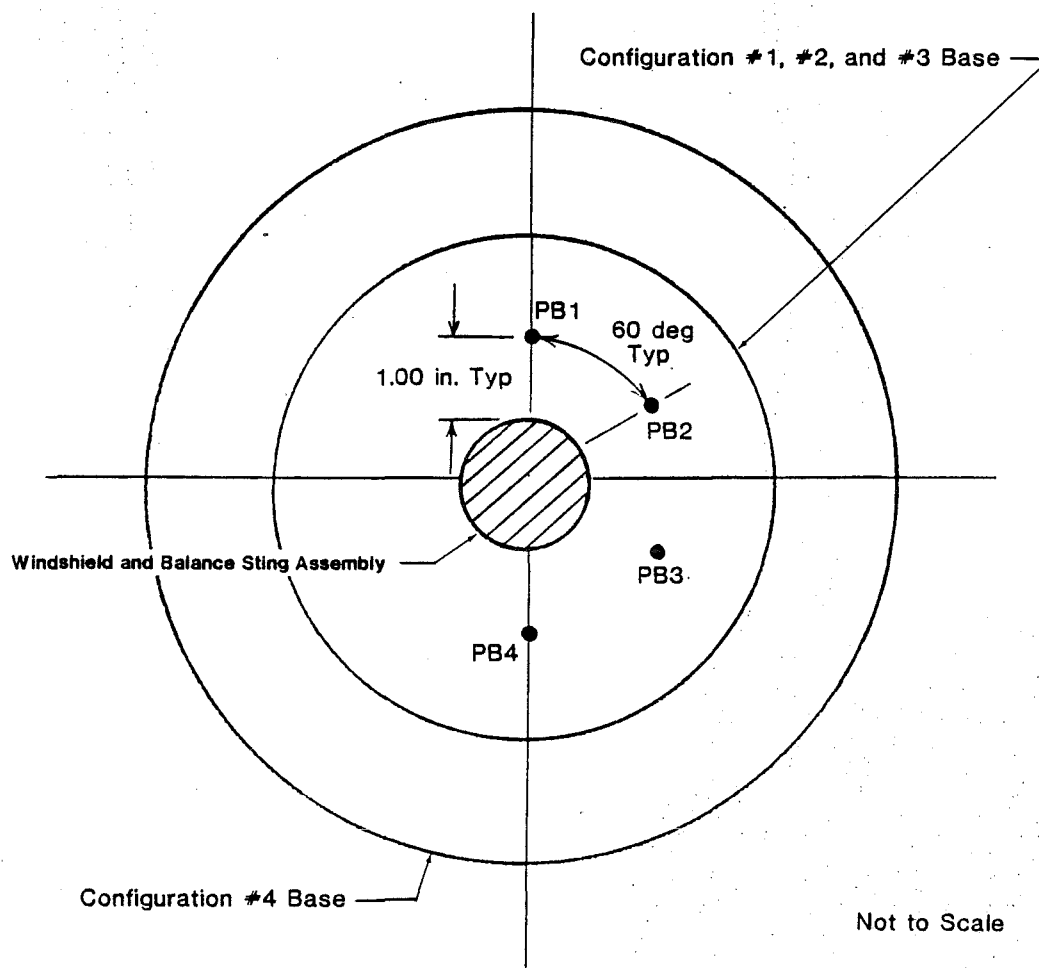


Figure 6. Carina Force Model Base Pressure Orifice Locations

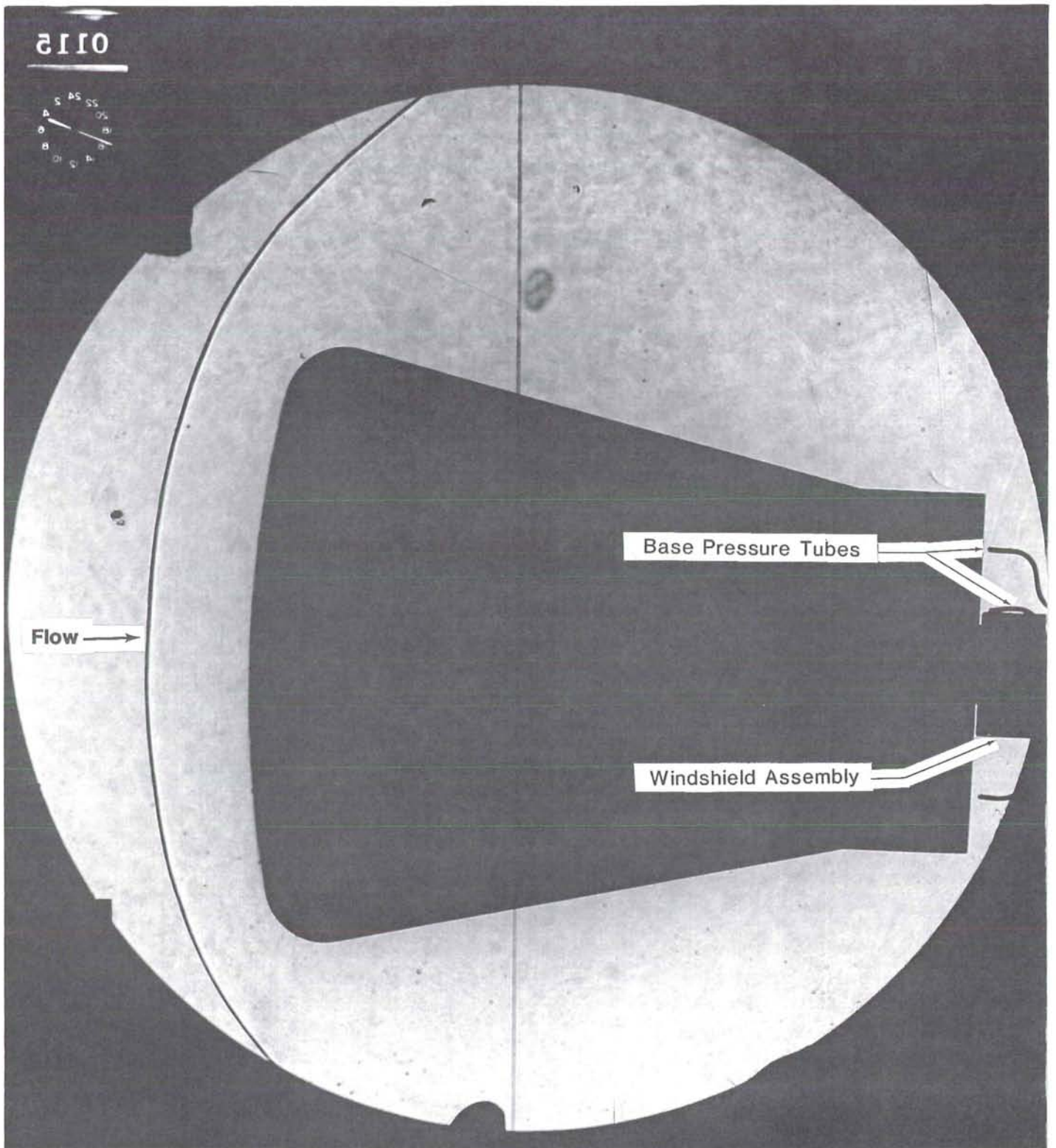


Figure 7. Carina model configuration 3 in Tunnel B

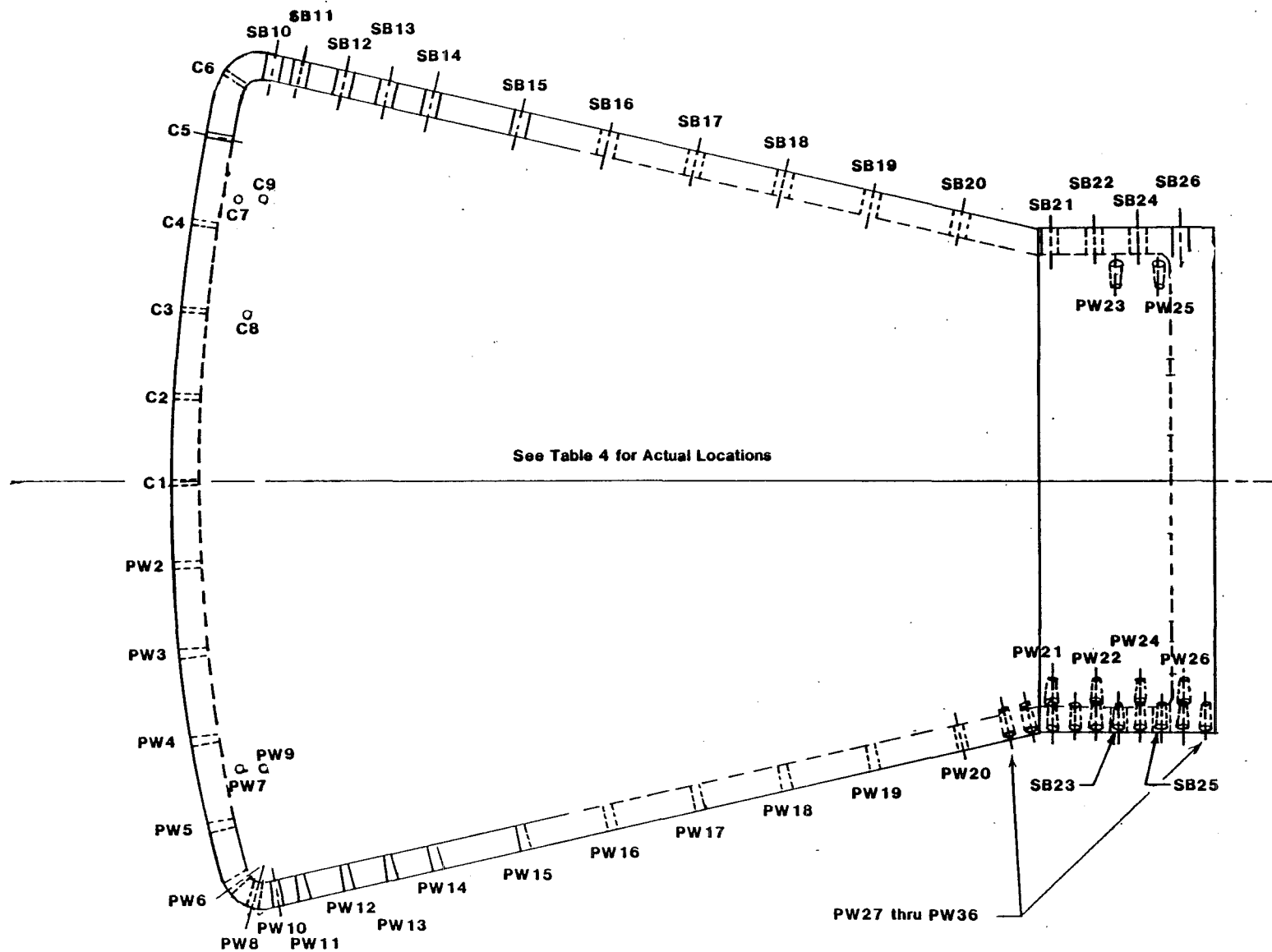


Figure 8. Heat-Transfer/Pressure Model Instrumentation Locations

Table 1. Model Configuration Designation

Configuration	Corner Radius, in.	Afterbody Angle, deg
#1	0.50	13
#2	0.25	13
#3	1.00	13
#4	0.50	8

Table 2. Coefficient Reference Lengths and Areas

a. English Units

Configuration	#1	#2	#3	#4
SREF, in. ²	76.356	78.038	73.275	76.356
AB, in. ²	26.530	26.530	26.530	44.084
LM, in.	11.83	11.83	11.83	11.83
XMRC, in.	0.0	0.0	0.0	0.0
LREFL, LREFM, LREFN, in.	9.860	9.968	9.659	9.860

b. SI Units

Configuration	#1	#2	#3	#4
SREF, m ²	0.0493	0.0503	0.0473	0.0493
AB, m ²	0.0171	0.0171	0.0171	0.0284
LM, m	0.3005	0.3005	0.3005	0.3005
XMRC, m	0.0	0.0	0.0	0.0
LREFL, LREFM, LREFN, m	0.2504	0.2532	0.2453	0.2504

Table 3. Estimated Uncertainties
a. Measured Parameters

PARAMETER DESIGNATION	STEADY STATE ESTIMATED MEASUREMENT*							RANGE	TYPE OF MEASURING DEVICE	TYPE OF RECORDING DEVICE	METHOD OF SYSTEM CALIBRATION
	PRECISION (S)			BIAS (B)		UNCERTAINTY $\pm(B+1.95S)$					
	Percent of Reading	Unit of Meas.	DF	Percent of Reading	Unit of Meas.	Percent of Reading	Unit of Meas.				
PT		0.1	>30		0.1		0.3	0-900 psia	Paroscientific Digiquartz Pressure Transducer	Digital Data Acquisition System	In place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
TT		1.0 1.0	>30 >30	0.375	2.0	4.0 2.0+0.375%		32-530°F 530-2300°F	Cr-Al Thermocouples	Microprocessor Averaged Digital Thermometer	Thermocouple verification of NITS conformity/voltage substitution calibration
ALPI PHII		0.025 0.15	>30 >30		0° 0°		0.05 0.30	±15 deg ±180 deg	Rotary Potentiometers	Digital Data Acquisition System/Analog to Digital Converter	Multiple comparisons with a digital inclinometer calibrated in the standards laboratory
Reference pressure for PwI		0.0004	10		0.001		0.002	0 to 0.015 psia	VKF Miniature Vacuum Gage (MVG)	Digital Data Acquisition System/Analog to Digital Converter	In place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
PwI, i = 10, 12, 14, 16, 18, 20, 21, 24, 26, 27, 29, 31, 33, 35 PB1, i = 1-4		0.001	30		0.002		0.004	±1 psid	Electronically Scanned Pressure transducer (ESP)	Digital Data Acquisition System/Analog to Digital Converter	In place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
PwI, i = 2-9, 11, 13, 15, 17, 19, 22, 23, 25, 28, 30, 32, 34, 36		0.002	30		0.003		0.007	±2.5 psid	Electronically Scanned Pressure transducer (ESP)	Digital Data Acquisition System/Analog to Digital Converter	In place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
Reference Pressure for PTNK		25	>30	10		50+10%		0-1000μHg	DV-3 Hastings Gage	Digital Data Acquisition System/Analog to Digital Converter	Comparisons to facility reference gage
PTNK		0.00075 0.00200	30 30	1.0 0.1		0.0015+1.0% 0.0040+0.1%		0.00-0.15 0.15-1.50 psid	Tunnel B/C Mech MUX System(±1psid Druck®)	Digital Data Acquisition System/Analog to Digital Converter	In place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
QDOT (Schmidt-Boelter gages)	3	0.03	30 30	3 3		0.06+3% 9%		0-1 1-10 Btu/ft²sec	Schmidt-Boelter Gage	Digital Data Acquisition System/Analog to Digital Converter	Radiant Heat Source / Secondary Standard
TO (Schmidt-Boelter gages)		1	>30		2		4	32-530°F	Schmidt-Boelter Gage (Fe-Cn Thermocouple)	Digital Data Acquisition System/Analog to Digital Converter	Thermocouple verification of NITS conformity/voltage substitution calibration
TW (Coax Gages)		1	>30		2		4	80-300°F	Coaxial Gage (Cr-Cn Thermocouple)	Digital Data Acquisition System/Analog to Digital Converter	Thermocouple verification of NITS conformity/voltage substitution calibration
Moment transfer distance, in.		0.0025	>30		0*		0.005		Precision height gages, micrometers	Manual	Calibrated in the Standards Laboratory
Normal Force		0.594	95		0.063		1.251	±500 lb	Six component strain gage balance	Digital Data Acquisition System/Analog to Digital Converter	Static Loadings
Pitching Moment		2.176	95		0.274		4.625	±1850 in.-lb			
Side Force		0.303	95		0.019		0.625	±250 lb			
Yawing Moment		1.113	95		0.086		2.313	±925 in.-lb			
Rolling moment		0.109	95		0.033		0.250	±100 in.-lb			
Axial Force		0.275	95		0.218		0.768	±300 lb			

* Reference: Abernethy, R. B. et al and Thompson, J. W. "Handbook of Uncertainty in Gas Turbine Measurements" AEDC-TR-73-5, Feb 1973

Table 3. Concluded
b. Calculated Parameters

Parameter Designation	Steady-State Estimated Measurement*						Nominal Reynolds Number	Nominal Parameter Value
	Precision Index (S)		Bias (B)		Uncertainty ±(B+195*S)			
	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement		
M		0.010		0+		0.020	1.004E+6	7.93
		0.010		0+		0.020	2.006E+6	7.98
P	0.819		0.048		1.686		1.004E+6	0.022
	0.814		0.022		1.650		2.006E+6	0.047
Q	0.567		0.048		1.183		1.004E+6	0.981
	0.563		0.022		1.149		2.006E+6	2.107
RE		3.7E+3		3.6E+3		1.1E+4	1.004E+6	1.004E+6
		7.2E+3		7.3E+3		2.2E+4	2.006E+6	2.006E+6
CN		0.0080		0.0008		0.0168	1.004E+6	0.1887
		0.0038		0.0004		0.0081	2.006E+6	0.1851
CLM		0.00635		0.00070		0.01341	1.004E+6	0.12970
		0.00304		0.00033		0.00641	2.006E+6	0.12730
CY		0.0040		0.0003		0.0083	1.004E+6	0.0125
		0.0019		0.0001		0.0039	2.006E+6	0.0077
CLN		0.00324		0.00021		0.00669	1.004E+6	0.00791
		0.00154		0.00010		0.00319	2.006E+6	0.00473
CLL		0.00015		0.00004		0.00035	1.004E+6	0.00258
		0.00008		0.00002		0.00018	2.006E+6	0.00159
CAF		0.0097		0.0032		0.0226	1.004E+6	1.5810
		0.0091		0.0015		0.0197	2.006E+6	1.5680
CA		0.0096		0.0030		0.0222	1.004E+6	1.5690
		0.0090		0.0014		0.0194	2.006E+6	1.5690
H(TT)					10 ^{PER}		-	-
S(TT)					10 ^{PER}		-	-
ALPHA						0.2 ^{PER}	-	±15
PHI						0.1 ^{PER}	-	±180

* Reference: Abernethy, R.B. et al and Thompson, J.W. "Handbook of Uncertainty in Gas Turbine Measurements" AEDC-TR-73-5, 5 Feb 73.

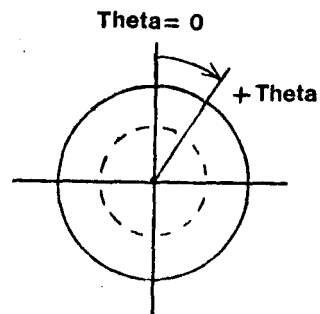
^{PER} Estimated value.

+ Assumed to be zero.

Table 4. Heat Transfer/ Pressure Model Instrumentation Locations

a. Heat Transfer Gages

GAGE	THETA	S/R
	deg	
C1	0	0
C2	0	0.200
C3	0	0.401
C4	0	0.602
C5	0	0.807
C6	0	0.960
C7	30	0.999
C8	60	1.028
C9	30	1.059
SB10	0	1.089
SB11	0	1.150
SB12	0	1.253
SB13	0	1.356
SB14	0	1.458
SB15	0	1.664
SB16	0	1.865
SB17	0	2.070
SB18	0	2.275
SB19	0	2.481
SB20	0	2.686
SB21	0	2.891
SB22	0	2.991
SB23	180	3.041
SB24	0	3.091
SB25	180	3.141
SB26	0	3.191



View Looking Aft

Table 4. Concluded

b. Surface Pressure Orifices

PRESSURE ORIFICE	THETA	S/R
PW2	180	0.200
PW3	180	0.401
PW4	180	0.602
PW5	180	0.807
PW6	180	0.960
PW7	210	0.999
PW8	180	1.028
PW9	210	1.059
PW10	180	1.089
PW11	180	1.150
PW12	180	1.253
PW13	180	1.356
PW14	180	1.458
PW15	180	1.664
PW16	180	1.865
PW17	180	2.070
PW18	180	2.275
PW19	180	2.481
PW20	180	2.686
PW21	210	2.891
PW22	210	2.991
PW23	30	3.041
PW24	210	3.091
PW25	30	3.141
PW26	210	3.191
PW27	165	2.788
PW28	165	2.839
PW29	165	2.891
PW30	165	2.941
PW31	165	2.991
PW32	165	3.041
PW33	165	3.091
PW34	165	3.141
PW35	165	3.191
PW36	165	3.242

Table 5. Test Run Summary**a. Heat/Pressure Runs**

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft-1)
2001	#1 0.50 in. Corner Radius, 13 Deg Body	0	0	2
2002		2	0	2
2003		5	0	2
2004		10	0	2
2005		15	0	2
2006		20	0	2
2007		0	-30	2
2008		2	-30	2
2009		5	-30	2
2010		10	-30	2
2011		15	-30	2
2012		20	-30	2
2013		0	30	2
2014		5	30	2
2015		5	60	2
2016		5	180	2
2017		0	0	1
2018		0	0	1
2019		2	0	1
2020		5	0	1
2021		10	0	1
2022		15	0	1
2023		20	0	1
2024		0	0	1

Table 5. Continued

a. Continued

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft ⁻¹)
2025	#1 0.50 in. Corner Radius, 13 Deg Body	2	-30	1
2026		5	-30	1
2027		10	-30	1
2028		15	-30	1
2029		20	-30	1
2030		0	30	1
2031		2	30	1
2032		5	30	1
2033		10	30	1
2034		15	30	1
2035		20	30	1
2036		0	60	1
2037		2	60	1
2038		5	60	1
2039		10	60	1
2040		15	60	1
2041		20	60	1
2042		0	90	1
2043		2	90	1
2044		5	90	1
2045		10	90	1
2046		15	90	1
2047		20	90	1

Table 5. Continued

a. Continued

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft ⁻¹)
2048	#1 0.50 in. Corner Radius, 13 Deg Body	0	120	1
2049		2	120	1
2050		5	120	1
2051		10	120	1
2052		15	120	1
2053		20	120	1
2054		0	150	1
2055		2	150	1
2056		5	150	1
2057		10	150	1
2058		15	150	1
2059		20	150	1
2060		0	180	1
2061		2	180	1
2062		5	180	1
2063		10	180	1
2064		15	180	1
2065		20	180	1
2066		0	-165	1
2067		2	-165	1
2068		5	-165	1
2069		10	-165	1
2070		15	-165	1
2071		20	-165	1
2072		20	-120	1

Table 5. Continued

a. Concluded

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft ⁻¹)
2073	#1 0.50 in. Corner Radius, 13 Deg Body	0	0	0.5
2074		5	0	0.5
2075		0	0	0.75
2076		5	0	0.75
2077		5	-30	0.75
2078		5	30	0.75
2079		5	60	0.75
2080		5	90	0.75
2081		5	120	0.75
2082		5	150	0.75
2083		5	180	0.75
2084		5	-165	0.75
2085		5	-120	0.75
2086		10	0	0.75
2087		10	-30	0.75
2088		10	30	0.75
2089		10	60	0.75
2090		10	90	0.75
2091		10	120	0.75
2092		10	150	0.75
2093		10	180	0.75
2094		10	-165	0.75

Table 5. Continued

b. Force Runs

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft ⁻¹)
2095	#1 0.50 in. Corner Radius, 13 Deg Body	0 to 20	0	2
2096		20 to 0	0	2
2097		0 to 20	0	2
2098		20 to 0	-180	2
2099	#2 0.25 in. Corner Radius, 13 Deg Body	0 to 20	0	2
2100		20 to 0	0	2
2101		0 to 20	0	2
2102		20 to 0	-180	2
2103	#3 1.00 in. Corner Radius, 13 Deg Body	0 to 20	0	2
2104		20 to 0	0	2
2105		0 to 20	0	2
2106		20 to 0	-180	2
2107	#4 0.50 in. Corner Radius, 8 Deg Body	0 to 20	0	2
2108		20 to 0	0	2
2109		0 to 20	0	2
2110		20 to 0	-180	2
2111	#4 0.50 in. Corner Radius, 8 Deg Body	0 to 20	0	1
2112		20 to 0	0	1
2113		0 to 20	0	1
2114		20 to 0	-180	1
2115	#1 0.50 in. Corner Radius, 13 Deg Body	0 to 20	0	1
2116		20 to 0	0	1
2117		0 to 20	0	1
2118		20 to 0	-180	1

Table 5. Continued**b. Concluded**

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft-l)
2119	#2 0.25 in. Corner Radius, 13 Deg Body	0 to 20	0	1
2120		20 to 0	0	1
2121		0 to 20	0	1
2122		20 to 0	-180	1
2123	#3 1.00 in. Corner Radius, 13 Deg Body	0 to 20	0	1
2124		20 to 0	0	1
2125		0 to 20	0	1
2126		20 to 0	-180	1

Table 5. Concluded**c. Oil Flow Runs**

RUN	CONFIGURATION	ALPHA (deg)	PHI (deg)	RE x 10 ⁻⁶ (ft ⁻¹)
2128	#1 0.50 in. Corner Radius, 13 Deg Body	0	0	1
2129		5	0	1
2130		2	0	1
2131		3.5	0	1
2132	#3 1.00 in. Corner Radius, 13 Deg Body	3.5	0	1
2133		2	0	1
2134	#2 0.25 in. Corner Radius, 13 Deg Body	0	0	1
2135	#1 0.50 in. Corner Radius, 13 Deg Body	2	0	1
2136		0	0	1
2137	#4 0.50 in. Corner Radius, 8 Deg Body	0	0	1
2138		2	0	1
2139		5	0	1

Notes: 1. Runs 2xxx are in English units.

Runs 3xxx are the same as runs 2xxx except the tabulated values are in SI units.

2. There is no run 2127.

3. Runs 2073, 2074 were taken with unsteady flow.

CARINA AEROTHERMAL

PAGE 1

ENGLISH UNITS

DATE COMPUTED: 9-MAY-91
TIME COMPUTED: 10:34:38
DATE RECORDED: 18-APR-91
TIME RECORDED: 0:58:38
000001037

RUN	CONFIGURATION	SREF, IN2	LREF (M, N, L), IN	XMRC	FCRN	PTNK	AB, IN2			
2097	0.50RC 13 DEG BODY	76.356	9.860 9.860 9.860	0.000	5095	0.323	26.53			
M	PT PSIA	TT DEG R	T DEG R	P PSIA	PT2 PSIA	Q PSIA	V FT/SEC	RHO LBM/FT3	MU LBF-SEC/FT2	RE FT-1
7.98	455.2	1293.7	96.1	0.0473	3.914	2.11	3833.59	0.133E-02	0.773E-07	0.205E+07

--- TUNNEL CONDITIONS AND BASE PRESSURES ---

PN	ALP1	PH11	PT	TT	Q	P	PB1	PB2	PB3	PB4	PBA	CPBA
1	-12.03	0.00	455.24	1293.7	2.109	0.047	0.0553	0.0504	0.0537	0.0494	0.0522	0.0023
2	-11.03	0.00	455.50	1292.7	2.110	0.047	0.0550	0.0505	0.0509	0.0500	0.0516	0.0020
3	-10.02	0.00	455.63	1293.7	2.111	0.047	0.0553	0.0513	0.0521	0.0504	0.0523	0.0023
4	-7.02	0.00	455.71	1293.7	2.111	0.047	0.0575	0.0522	0.0548	0.0505	0.0537	0.0030
5	-2.02	0.00	455.79	1293.7	2.111	0.047	0.0591	0.0518	0.0592	0.0471	0.0543	0.0033
6	3.01	0.00	455.44	1293.7	2.110	0.047	0.0500	0.0435	0.0543	0.0374	0.0463	-0.0005
7	8.00	0.00	455.58	1294.7	2.110	0.047	0.0387	0.0333	0.0461	0.0290	0.0368	-0.0050

Sample 1. Tabulated Force and Pressure Data, English Units

CARINA AEROTHERMAL

PAGE 2

ENGLISH UNITS

DATE COMPUTED: 9-MAY-91
 TIME COMPUTED: 10:34:38
 DATE RECORDED: 18-APR-91
 TIME RECORDED: 0:58:38
 600001038

RUN	CONFIGURATION				SREF, IN2	LREF (M. N. L). IN			XMRC	FCRN	PTNK	AB, IN2
2097	0.50RC 13 DEG BODY				76.356	9.860	9.860	9.860	0.000	5095	0.323	26.53
M	PT	TT	T	P	PT2	Q	V	RHO	MU	RE		
	PSIA	DEG R	DEG R	PSIA	PSIA	PSIA	FT/SEC	LBM/FT3	LBF-SEC/FT2	FT-1		
7.98	455.2	1293.7	96.1	0.0473	3.914	2.11	3833.59	0.133E-02	0.773E-07	0.205E+07		

— BODY AXES FORCE AND MOMENT COEFFICIENTS —

PN	ALPHA	PHI	CN	CLM	CY	CLN	CLL	CA	CAB	CAF	XCPN
1	0.05	-0.08	-0.0001	0.0002	0.0063	-0.0035	0.0007	1.5021	-0.0008	1.5029	0.6514
2	1.06	-0.08	0.0066	-0.0050	0.0064	-0.0036	0.0007	1.5014	-0.0007	1.5021	0.6517
3	2.07	-0.08	0.0138	-0.0106	0.0064	-0.0036	0.0007	1.5017	-0.0008	1.5025	0.6384
4	5.09	-0.08	0.0349	-0.0272	0.0065	-0.0038	0.0006	1.4972	-0.0010	1.4983	0.6512
5	10.15	-0.08	0.0686	-0.0536	0.0064	-0.0037	0.0006	1.4784	-0.0011	1.4796	0.6516
6	15.24	-0.08	0.1023	-0.0765	0.0065	-0.0036	0.0006	1.4466	0.0002	1.4464	0.6233
7	20.32	-0.08	0.1378	-0.0974	0.0067	-0.0037	0.0006	1.3964	0.0017	1.3947	0.5888

Sample 1. continued

CARINA AEROTHERMAL

PAGE 3

ENGLISH UNITS

DATE COMPUTED: 9-MAY-91
 TIME COMPUTED: 10:34:38
 DATE RECORDED: 18-APR-91
 TIME RECORDED: 0:58:38
 000001039

RUN	CONFIGURATION				SREF, IN2	LREF (M, N, L), IN			XMRC	FCRN	PTNK	AB, IN2
2097	0.50RC 13 DEG BODY				76.356	9.860	9.860	9.860	0.000	5095	0.323	26.53
M	PT	TT	T	P	PT2	Q	V	RHO	MU	RE		
	PSIA	DEG R	DEG R	PSIA	PSIA	PSIA	FT/SEC	LBM/FT3	LBF-SEC/FT2	FT-1		
7.98	455.2	1293.7	96.1	0.0473	3.914	2.11	3833.59	0.133E-02	0.773E-07	0.205E+07		

— WIND AXES FORCE AND MOMENT COEFFICIENTS —

PN	ALPHA	PHI	CLW	CLMW	CCW	CLNW	CLLW	CDW	(L/D)W
1	0.05	-0.08	-0.0014	0.0002	0.0050	-0.0035	0.0007	1.5029	-0.0009
2	1.06	-0.08	-0.0211	-0.0050	0.0050	-0.0036	0.0006	1.5020	-0.0140
3	2.07	-0.08	-0.0406	-0.0106	0.0049	-0.0036	0.0005	1.5020	-0.0270
4	5.09	-0.08	-0.0983	-0.0272	0.0050	-0.0038	0.0003	1.4955	-0.0657
5	10.15	-0.08	-0.1932	-0.0536	0.0048	-0.0037	0.0000	1.4685	-0.1315
6	15.24	-0.08	-0.2815	-0.0765	0.0048	-0.0036	-0.0003	1.4224	-0.1979
7	20.32	-0.08	-0.3550	-0.0974	0.0049	-0.0036	-0.0006	1.3558	-0.2618

Sample 1. concluded

CARINA AEROTHERMAL

PAGE 1

SI UNITS

DATE COMPUTED: 13-MAY-91
TIME COMPUTED: 08:32:15
DATE RECORDED: 18-APR-91
TIME RECORDED: 1:21:11
000001380

RUN	CONFIGURATION				SREF,M2	LREF (M, N, L) M			XMRC	FCRN	PTNK	AB,M2
3099	0.25RC 13 DEG BODY				0.050	0.253	0.253	0.253	0.000	5096	2123.259	0.02
M	PT	TT	T	P	PT2	Q	V	RHO	MU	RE		
	PA	DEG K	DEG K	PA	PA	PA	M/SEC	KG/M3	PA-SEC	M-1		
7.98	3147143.5	723.7	53.8	327.2614	27055.648	14576.86	1172.77	0.212E-01	0.373E-05	0.619E+06		

— TUNNEL CONDITIONS AND BASE PRESSURES —

PN	ALP1	PH11	PT	TT	Q	P	PB1	PB2	PB3	PB4	PBA	CPBA
1	-13.52	-0.02	3147143.50	723.7	14576.863	327.261	360.8309	352.1942	348.2056	338.7666	349.9993	0.0016
2	-13.07	-0.02	3147036.50	723.7	14576.381	327.251	361.5492	352.5143	348.1625	339.3936	350.4049	0.0016
3	-12.07	-0.02	3147470.25	723.7	14578.349	327.294	360.3300	350.0336	346.3342	340.9316	349.4073	0.0015
4	-11.08	-0.02	3148308.00	723.7	14582.145	327.378	359.2373	348.1014	344.9819	343.1852	348.8764	0.0015
5	-10.09	-0.02	3147678.00	723.7	14579.287	327.315	358.4970	347.8506	345.9180	345.4202	349.4215	0.0015
6	-9.09	-0.03	3148915.00	723.7	14584.893	327.439	356.0610	349.7874	347.7143	346.9590	350.1304	0.0016
7	-7.11	-0.02	3148685.75	723.7	14583.857	327.416	350.4754	348.7693	349.3834	348.3854	349.2534	0.0015
8	-5.12	-0.05	3148441.25	723.7	14582.749	327.391	348.6109	343.3849	353.7958	349.3700	348.7904	0.0015
9	-2.15	-0.04	3148736.75	723.7	14584.086	327.421	339.4887	328.2872	346.7191	334.2329	337.1820	0.0007
10	-0.17	-0.07	3148224.75	723.7	14581.767	327.370	326.2455	311.7387	332.0927	313.8080	320.9712	-0.0004
11	2.80	-0.04	3148224.75	723.7	14581.767	327.370	302.1397	285.3899	300.2831	278.4179	291.5576	-0.0025
12	4.77	-0.06	3147762.75	723.7	14579.671	327.323	284.5857	267.5067	276.3543	254.9335	270.8450	-0.0039
13	7.73	-0.07	3148759.50	723.7	14584.191	327.423	260.7194	245.0279	243.3575	222.8162	242.9803	-0.0058
14	8.01	-0.07	3148435.00	723.7	14582.720	327.391	253.3510	230.9219	232.3455	213.9320	232.6376	-0.0065

MODEL FLOWFIELD PHOTOGRAPHS TAKEN AT ALPHA = 0.19, 2.17, 5.10, 10.24, 15.36, 20.26,

Sample 2. Tabulated Force and Pressure Data, SI Units

CARINA AEROTHERMAL

PAGE 2

SI UNITS

DATE COMPUTED: 13-MAY-91
TIME COMPUTED: 08:32:15
DATE RECORDED: 18-APR-91
TIME RECORDED: 1:21:11
000001381

RUN	CONFIGURATION				SREF,M2	LREF (M, N, L),M			XMRC	FCRN	PTNK	AB,M2
3099	0.25RC 13 DEG BODY				0.050	0.253	0.253	0.253	0.000	5096	2123.259	0.02
M	PT PA	TT DEG K	T DEG K	P PA	PT2 PA	O PA	V M/SEC	RHO KG/M3	MU PA-SEC	RE M-1		
7.98	3147143.5	723.7	53.8	327.2614	27055.648	14576.86	1172.77	0.212E-01	0.373E-05	0.619E+06		

— BODY AXES FORCE AND MOMENT COEFFICIENTS —

PN	ALPHA	PHI	CN	CLM	CY	CLN	CLL	CA	CAB	CAF	XCPN
1	-1.46	-0.09	-0.0096	0.0077	0.0045	-0.0026	0.0007	1.5634	-0.0005	1.5639	0.7134
2	-1.00	-0.09	-0.0068	0.0053	0.0046	-0.0027	0.0007	1.5638	-0.0005	1.5643	0.7103
3	0.00	-0.09	-0.0006	0.0001	0.0046	-0.0027	0.0007	1.5651	-0.0005	1.5656	0.7036
4	1.00	-0.09	0.0058	-0.0052	0.0046	-0.0027	0.0007	1.5653	-0.0005	1.5658	0.7003
5	2.00	-0.09	0.0122	-0.0105	0.0046	-0.0027	0.0007	1.5655	-0.0005	1.5660	0.7050
6	3.00	-0.11	0.0184	-0.0157	0.0047	-0.0028	0.0007	1.5640	-0.0005	1.5646	0.7182
7	5.00	-0.09	0.0309	-0.0264	0.0046	-0.0027	0.0007	1.5599	-0.0005	1.5604	0.7196
8	7.00	-0.13	0.0429	-0.0372	0.0048	-0.0029	0.0007	1.5531	-0.0005	1.5536	0.7311
9	10.00	-0.11	0.0605	-0.0518	0.0047	-0.0028	0.0007	1.5382	-0.0002	1.5384	0.7203
10	12.00	-0.15	0.0721	-0.0606	0.0049	-0.0028	0.0007	1.5255	0.0001	1.5253	0.7073
11	15.00	-0.12	0.0894	-0.0726	0.0047	-0.0026	0.0007	1.5014	0.0008	1.5006	0.6842
12	17.00	-0.13	0.1015	-0.0802	0.0049	-0.0027	0.0007	1.4819	0.0013	1.4806	0.6660
13	20.00	-0.14	0.1204	-0.0914	0.0050	-0.0027	0.0007	1.4470	0.0020	1.4450	0.6394
14	20.28	-0.14	0.1226	-0.0928	0.0050	-0.0027	0.0006	1.4429	0.0022	1.4407	0.6377

Sample 2. continued

CARINA AEROTHERMAL

PAGE 3

SI UNITS

DATE COMPUTED: 13-MAY-91
 TIME COMPUTED: 08:32:15
 DATE RECORDED: 18-APR-91
 TIME RECORDED: 1:21:11
 000001382

RUN	CONFIGURATION				SREF,M2	LREF (M, N, L),M			XMRC	FCRN	PTNK	AB,M2
3099	0.25RC 13 DEG BODY				0.050	0.253	0.253	0.253	0.000	5096	2123.259	0.02
M	PT	TT	T	P	PT2	Q	V	RHO	MU	RE		
	PA	DEG K	DEG K	PA	PA	PA	M/SEC	KG/M3	PA-SEC	M-1		
7.98	3147143.5	723.7	53.8	327.2614	27055.648	14576.86	1172.77	0.212E-01	0.373E-05	0.619E+06		

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— WIND AXES FORCE AND MOMENT COEFFICIENTS —

PN	ALPHA	PHI	CLW	CLMW	CCW	CLNW	CLLW	CDW	(L/D)W
1	-1.46	-0.09	0.0302	0.0077	0.0032	-0.0025	0.0008	1.5636	0.0193
2	-1.00	-0.09	0.0205	0.0053	0.0033	-0.0027	0.0008	1.5642	0.0131
3	0.00	-0.09	-0.0006	0.0001	0.0033	-0.0027	0.0007	1.5656	-0.0004
4	1.00	-0.09	-0.0215	-0.0052	0.0033	-0.0028	0.0007	1.5657	-0.0138
5	2.00	-0.09	-0.0424	-0.0105	0.0032	-0.0027	0.0006	1.5655	-0.0271
6	3.00	-0.11	-0.0635	-0.0157	0.0033	-0.0028	0.0006	1.5634	-0.0406
7	5.00	-0.09	-0.1052	-0.0264	0.0031	-0.0028	0.0005	1.5571	-0.0676
8	7.00	-0.13	-0.1468	-0.0372	0.0031	-0.0029	0.0004	1.5472	-0.0949
9	10.00	-0.11	-0.2075	-0.0518	0.0029	-0.0029	0.0003	1.5256	-0.1360
10	12.00	-0.15	-0.2466	-0.0606	0.0028	-0.0029	0.0002	1.5070	-0.1636
11	15.00	-0.12	-0.3020	-0.0726	0.0027	-0.0027	0.0001	1.4726	-0.2051
12	17.00	-0.13	-0.3358	-0.0802	0.0028	-0.0028	0.0000	1.4455	-0.2323
13	20.00	-0.14	-0.3811	-0.0914	0.0027	-0.0028	-0.0002	1.3991	-0.2724
14	20.28	-0.14	-0.3844	-0.0928	0.0027	-0.0028	-0.0002	1.3938	-0.2758

Sample 2. concluded

CARINA AEROTHERMAL

PAGE 1

ENGLISH UNITS

DATE COMPUTED: 22-APR-91
TIME COMPUTED: 08:46:33
DATE RECORDED: 17-APR-91
TIME RECORDED: 2:55:40
000001475

RUN	ALPHA (DEG)	PHI (DEG)	CONFIGURATION			TIMERD (SEC)	TIMEINJ (SEC)			
2013	-0.020	29.99	#1 .50 CORNER RADIUS			3.809	2.796			
M	PT PSIA	TT DEG R	T DEG R	P PSIA	Q PSIA	V FT/SEC	RHO LBM/FT3	MU LBF-SEC/FT2	RE FT-1	
7.98	456.1	1309.7	97.4	0.0474	2.11	3858.59	1.315E-03	7.836E-08	2.012E+06	

HEAT TRANSFER GAGE DATA

GAGE ID	S/R	THETA DEG	TW DEG R	QDOT (BTU/FT2-SEC)	H(TT) (BTU/FT2-SEC-R)	S(TT)
C 1	0.000	0.0	574.4	4.185E+00	5.691E-03	4.507E-03
C 2	0.200	0.0	574.5	5.373E+00	7.309E-03	5.788E-03
C 3	0.401	0.0	568.9	4.991E+00	6.737E-03	5.337E-03
C 4	0.602	0.0	564.6	4.595E+00	6.167E-03	4.886E-03
C 5	0.807	0.0	560.4	4.426E+00	5.908E-03	4.682E-03
C 6	0.960	0.0	556.8	3.824E+00	5.079E-03	4.026E-03
C 7	0.999	30.0	553.4	1.910E+00	2.526E-03	2.002E-03
C 8	1.028	60.0	556.3	8.797E-01	1.168E-03	9.256E-04
C 9	1.059	30.0	547.1	3.499E-01	4.588E-04	3.639E-04
SB10	1.089	0.0	542.4	1.112E-01	1.449E-04	1.150E-04
SB11	1.150	0.0	542.2	1.221E-01	1.591E-04	1.262E-04
SB12	1.253	0.0	541.5	1.115E-01	1.451E-04	1.152E-04
SB13	1.356	0.0	542.8	1.181E-01	1.540E-04	1.222E-04
SB14	1.458	0.0	543.4	1.165E-01	1.521E-04	1.206E-04
SB15	1.664	0.0	544.3	1.192E-01	1.557E-04	1.235E-04
SB16	1.865	0.0	545.2	1.345E-01	1.759E-04	1.395E-04
SB17	2.070	0.0	546.7	1.625E-01	2.129E-04	1.689E-04
SB18	2.275	0.0	546.5	1.590E-01	2.084E-04	1.653E-04
SB19	2.481	0.0	547.0	1.687E-01	2.212E-04	1.754E-04
SB20	2.686	0.0	547.1	1.831E-01	2.401E-04	1.904E-04
SB21	2.891	0.0	550.8	5.895E-01	7.769E-04	6.160E-04
SB22	2.991	0.0	557.0	9.935E-01	1.320E-03	1.046E-03
SB23	3.041	180.0	564.1	1.221E+00	1.638E-03	1.298E-03
SB24	3.091	0.0	561.1	1.412E+00	1.886E-03	1.495E-03
SB25	3.141	180.0	566.0	1.377E+00	1.851E-03	1.467E-03
SB26	3.191	0.0	562.4	1.431E+00	1.915E-03	1.517E-03

RUN2013

Sample 3. Tabulated Heat-Transfer and Surface Pressure Data, English Units

CARINA AEROTHERMAL

PAGE 3

ENGLISH UNITS

DATE COMPU. 22-APR-91
TIME COMPUTED: 08:46:34
DATE RECORDED: 17-APR-91
TIME RECORDED: 2:55:40
000001477

RUN	ALPHA (DEG)	PHI (DEG)	CONFIGURATION	TIMERD (SEC)	TIMEINJ (SEC)	M	PT PSIA	TT DEG R	T DEG R	P PSIA	Q PSIA	V FT/SEC	RHO LBM/FT3	MU LBF-SEC/FT2	RE FT-1
2013	-0.020	29.99	#1 .50 CORNER RADIUS	3.809	2.796	7.98	456.1	1309.7	97.4	0.0474	2.11	3858.59	1.315E-03	7.836E-08	2.012E+06

MODEL PRESSURE DATA

MODEL PRESSURE	S/R	THETA (DEG)	PW (PSIA)	PW /P	CP
PW 2	0.200	180.0	3.899	8.222E+01	1.824E+00
PW 3	0.401	180.0	3.848	8.112E+01	1.799E+00
PW 4	0.602	180.0	3.690	7.781E+01	1.725E+00
PW 5	0.807	180.0	3.340	7.042E+01	1.559E+00
PW 6	0.960	180.0	1.234	2.602E+01	5.618E-01
PW 7	0.999	210.0	0.449	9.471E+00	1.902E-01
PW 8	1.028	180.0	0.162	3.420E+00	5.434E-02
PW 9	1.059	210.0	0.059	1.245E+00	5.506E-03
PW10	1.089	180.0	0.035	7.282E-01	-6.103E-03
PW11	1.150	180.0	0.031	6.483E-01	-7.898E-03
PW12	1.253	180.0	0.034	7.097E-01	-6.518E-03
PW13	1.356	180.0	0.035	7.319E-01	-6.019E-03
PW14	1.458	180.0	0.041	8.544E-01	-3.269E-03
PW15	1.664	180.0	0.052	1.089E+00	2.005E-03
PW16	1.865	180.0	0.062	1.302E+00	6.782E-03
PW17	2.070	180.0	0.072	1.512E+00	1.149E-02
PW18	2.275	180.0	0.079	1.675E+00	1.515E-02
PW19	2.481	180.0	0.091	1.918E+00	2.061E-02
PW20	2.686	180.0	0.107	2.251E+00	2.808E-02
PW21	2.891	210.0	0.135	2.848E+00	4.149E-02
PW22	2.991	210.0	0.176	3.714E+00	6.093E-02
PW23	3.041	30.0	0.199	4.192E+00	7.168E-02
PW24	3.091	210.0	0.201	4.237E+00	7.269E-02
PW25	3.141	30.0	0.218	4.588E+00	8.055E-02
PW26	3.191	210.0	0.215	4.541E+00	7.951E-02
PW27	2.788	165.0	0.116	2.437E+00	3.227E-02
PW28	2.839	165.0	0.120	2.536E+00	3.449E-02
PW29	2.891	165.0	0.137	2.898E+00	4.262E-02
PW30	2.941	165.0	0.164	3.468E+00	5.541E-02
PW31	2.991	165.0	0.181	3.810E+00	6.310E-02
PW32	3.041	165.0	0.195	4.120E+00	7.005E-02
PW33	3.091	165.0	0.207	4.373E+00	7.575E-02
PW34	3.141	165.0	0.213	4.492E+00	7.841E-02
PW35	3.191	165.0	0.220	4.647E+00	8.190E-02
PW36	3.242	165.0	0.223	4.699E+00	8.305E-02
PK101	=	0.497			
PK116	=	0.497			
PK201	=	0.496			
PK232	=	0.496			
PKNOWN 7	=	0.498			
PKNOWN 8	=	0.497			
PKNOWN S	=	0.502			

Sample 3. concluded

CARINA AEROTHERMAL

PAGE 2

SI UNITS

DATE COMPUTED: 13-MAY-91
 TIME COMPUTED: 08:13:49
 DATE RECORDED: 17-APR-91
 TIME RECORDED: 1:41:22
 000002228

RUN	ALPHA (DEG)	PHI (DEG)	CONFIGURATION		TIMERD (SEC)	TIMEINJ (SEC)			
3004	9.998	0.16	#1 .50 CORNER RADIUS		3.809	2.796			
M	PT PA	TT DEG K	T DEG K	P PA	Q PA	V M/SEC	RHO KG/M3	MU PA-SEC	RE M-1
7.98	3.152E+06	728.1	54.1	3.278E+02	1.460E+04	1176.58	2.109E-02	3.755E-06	6.140E+05

HEAT TRANSFER GAGE DATA

GAGE ID	S/R	THETA DEG	TW DEG K	QDOT W/M2	H(TT) W/M2-K	S(TT)
C 1	0.000	0.0	313.7	4.385E+04	1.058E+02	4.093E-03
C 2	0.200	0.0	312.4	4.212E+04	1.013E+02	3.919E-03
C 3	0.401	0.0	310.9	4.104E+04	9.836E+01	3.806E-03
C 4	0.602	0.0	310.9	3.966E+04	9.506E+01	3.678E-03
C 5	0.807	0.0	310.6	3.925E+04	9.400E+01	3.638E-03
C 6	0.960	0.0	309.0	3.072E+04	7.328E+01	2.836E-03
C 7	0.999	30.0	306.0	1.533E+04	3.631E+01	1.406E-03
C 8	1.028	60.0	306.1	6.892E+03	1.633E+01	6.322E-04
C 9	1.059	30.0	303.6	2.788E+03	6.566E+00	2.542E-04
SB10	1.089	0.0	302.9	5.087E-01	1.196E-03	4.632E-05
SB11	1.150	0.0	302.9	5.561E-01	1.308E-03	5.064E-05
SB12	1.253	0.0	302.8	7.436E-01	1.748E-03	6.770E-05
SB13	1.356	0.0	303.3	7.265E-01	1.710E-03	6.621E-05
SB14	1.458	0.0	303.4	7.348E-01	1.730E-03	6.699E-05
SB15	1.664	0.0	302.8	7.583E-01	1.783E-03	6.904E-05
SB16	1.865	0.0	302.9	9.226E-01	2.170E-03	8.402E-05
SB17	2.070	0.0	303.5	1.398E+00	3.293E-03	1.275E-04
SB18	2.275	0.0	303.6	1.757E+00	4.140E-03	1.603E-04
SB19	2.481	0.0	304.5	2.345E+00	5.534E-03	2.143E-04
SB20	2.686	0.0	305.0	2.946E+00	6.961E-03	2.695E-04
SB21	2.891	0.0	305.2	3.700E+00	8.747E-03	3.386E-04
SB22	2.991	0.0	306.2	4.015E+00	9.516E-03	3.684E-04
SB23	3.041	180.0	309.7	1.299E+01	3.104E-02	1.201E-03
SB24	3.091	0.0	306.2	5.254E+00	1.245E-02	4.821E-04
SB25	3.141	180.0	310.2	1.368E+01	3.272E-02	1.266E-03
SB26	3.191	0.0	307.0	6.293E+00	1.494E-02	5.784E-04

RUN3004

Sample 4. Tabulated Heat-Transfer and Surface Pressure Data, SI Units

CARINA AEROTHERMAL

PAGE 4

SI UNITS

DATE COMPUTED: 13-MAY-91
 TIME COMPUTED: 08:13:50
 DATE RECORDED: 17-APR-91
 TIME RECORDED: 1:41:22
 000002230

RUN	ALPHA (DEG)	PHI (DEG)	CONFIGURATION		TIMERD (SEC)	TIMEINJ (SEC)	M	PT PA	TT DEG K	T DEG K	P PA	Q PA	V M/SEC	RHO KG/M3	MU PA-SEC	RE M-1
3004	9.998	0.16	#1 .50 CORNER RADIUS		3.809	2.796	7.98	3.152E+06	728.1	54.1	3.278E+02	1.460E+04	1176.58	2.109E-02	3.755E-06	6.140E+05

MODEL PRESSURE DATA

MODEL PRESSURE	S/R	THETA (DEG)	PW (PA)	PW /P	CP
PW 2	0.200	180.0	27322.359	8.336E+01	1.849E+00
PW 3	0.401	180.0	27650.576	8.436E+01	1.872E+00
PW 4	0.602	180.0	26977.176	8.230E+01	1.826E+00
PW 5	0.807	180.0	25361.871	7.738E+01	1.715E+00
PW 6	0.960	180.0	12279.588	3.746E+01	8.187E-01
PW 7	0.999	210.0	5060.683	1.544E+01	3.242E-01
PW 8	1.028	180.0	2382.567	7.269E+00	1.408E-01
PW 9	1.059	210.0	805.417	2.457E+00	3.272E-02
PW10	1.089	180.0	586.909	1.791E+00	1.775E-02
PW11	1.150	180.0	682.165	2.081E+00	2.428E-02
PW12	1.253	180.0	761.272	2.323E+00	2.970E-02
PW13	1.356	180.0	808.309	2.466E+00	3.292E-02
PW14	1.458	180.0	958.542	2.924E+00	4.321E-02
PW15	1.664	180.0	1023.765	3.123E+00	4.768E-02
PW16	1.865	180.0	1113.551	3.397E+00	5.383E-02
PW17	2.070	180.0	1123.217	3.427E+00	5.449E-02
PW18	2.275	180.0	1073.799	3.276E+00	5.111E-02
PW19	2.481	180.0	986.880	3.011E+00	4.515E-02
PW20	2.686	180.0	1078.409	3.290E+00	5.142E-02
PW21	2.891	210.0	1219.649	3.721E+00	6.110E-02
PW22	2.991	210.0	1632.793	4.981E+00	8.940E-02
PW23	3.041	30.0	665.254	2.030E+00	2.312E-02
PW24	3.091	210.0	1796.005	5.479E+00	1.006E-01
PW25	3.141	30.0	834.349	2.546E+00	3.470E-02
PW26	3.191	210.0	1773.274	5.410E+00	9.902E-02
PW27	2.788	165.0	1224.432	3.736E+00	6.142E-02
PW28	2.839	165.0	1215.337	3.708E+00	6.080E-02
PW29	2.891	165.0	1281.617	3.910E+00	6.534E-02
PW30	2.941	165.0	1609.535	4.910E+00	8.781E-02
PW31	2.991	165.0	1749.336	5.337E+00	9.738E-02
PW32	3.041	165.0	1798.329	5.486E+00	1.007E-01
PW33	3.091	165.0	1905.484	5.813E+00	1.081E-01
PW34	3.141	165.0	1862.146	5.681E+00	1.051E-01
PW35	3.191	165.0	1879.371	5.734E+00	1.063E-01
PW36	3.242	165.0	1865.391	5.691E+00	1.053E-01

RUN 3004

Sample 4. concluded