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INVESTIGATION OF THE DEVELOPMENT OF LAMINAR BOUNDARY-LAYER INSTABILITIES ALONG A BLUNTED CONE

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Measurements of mean-flow and fluctuating-flow parameters were made in the boundary layer of a spherically blunted (0.7-in. radius), 7-deg (half-angle) cone in an investigation of the stability of laminar boundary layers. The flow-fluctuation measurements were made using hot-wire anemometry techniques. Flow-field profiles and model surface pressures were also measured. The testing was performed at free-stream Mach number 8 with a free-stream unit Reynolds number of 1.6-million per foot. The test equipment and techniques, and the data acquisition and reduction procedures are described. Analysis of the hot-wire anemometer data is beyond the scope of this report.

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SAMPLE DATA

NOMENCLATURE

ALPHA, ALPI	Angle of attack, deg
CONFIG	Model configuration designation
CURRENT	Anemometer heating current, mamp
DATA TYPE	Code indicating nature of data tabulated:
	"2" - Model surface pressure and temperature measurements
	"4" - Mean boundary-layer profile measurements using pitot pressure and total temperature probes
	"6" - Probe flow calibration data
	"9" - Quantitative hot-wire anemometer data at particular point locations within a survey or within the free stream
DEL	Boundary-layer total thickness, in.
DEL*	Boundary-layer displacement thickness, in.
DEL**	Boundary-layer momentum thickness, in.
DEW	Tunnel stilling chamber dew point temperature, °F
DITTD	Enthalpy difference at boundary-layer thickness, DEL, ITTD-ITWL, Btu/lbm
DITTL	Local enthalpy difference, ITTL-ITWL, Btu/lbm
EBAR	Anemometer mean voltage, mv
ERMS	Anemometer output rms voltage, mv
ETA	Effective total-temperature probe recovery factor ETA=(TTLU-T)/(TT-T) or (TTTU-T)/(TT-T)
ITTD	Enthalpy based on TTD, Btu/lbm
ITTL	Enthalpy based on TTL, Btu/lbm
ITWL	Enthalpy based on TWL, Btu/lbm
LRE	Local unit Reynolds number, $in.^{-1}$

LRED	Unit Reynolds number at the boundary-layer thickness, DEL, $in.^{-1}$
LRET	Local "normal shock" unit Reynolds number (based on MUTTL), $in.^{-1}$
LRETA	"Normal shock" unit Reynolds number at the anemometer location (based on MUTTL), $in.^{-1}$
LRETD	"Normal shock" unit Reynolds number at boundary-layer thickness, DEL (based on MUTTD), $in.^{-1}$
M, MACH	Free-stream Mach number
MA	Mach number interpolated to the anemometer location
MD	Local Mach number at boundary-layer thickness DEL
ME	Mach number at boundary-layer edge
ML	Local Mach number
MU	Dynamic viscosity based on T, $lbf\text{-}sec/ft^2$
MUTD	Dynamic viscosity based on TD, $lbf\text{-}sec/ft^2$
MUTL	Dynamic viscosity based on TL, $lbf\text{-}sec/ft^2$
MUTT	Dynamic viscosity based on TT, $lbf\text{-}sec/ft^2$
MUTTD	Dynamic viscosity based on TTD, $lbf\text{-}sec/ft^2$
MUTTL	Dynamic viscosity based on TTL, $lbf\text{-}sec/ft^2$
P	Free-stream static pressure, psia
PHI, PHII	Roll angle, deg
POINT	Data point number
PP	Probe pitot pressure, psia
PPD	Pitot pressure at boundary-layer thickness DEL, psia
PPE	Pitot pressure at boundary-layer edge, psia
PT	Tunnel stilling chamber pressure, psia

PT2	Free-stream total pressure downstream of a normal shock wave, psia
PW	Model surface pressure, psia
PWL	Model wall static pressure used for boundary-layer survey calculations, psia
Q	Free-stream dynamic pressure, psia
RE	Free-stream unit Reynolds number, $in.^{-1}$
RE/FT	Free-stream unit Reynolds number, ft^{-1}
RETD	"Normal shock" Reynolds number based on total temperature probe thermocouple diameter and viscosity of MUTT
RHO	Free-stream density, lbm/ft^3
RHOD	Density at boundary-layer thickness DEL, lbm/ft^3
RHOL	Local density, lbm/ft^3
RN	Model nose radius, in.
RUN	Data set identification number
S	Curvilinear surface distance measured from model stagnation point, in.
SD PW	Model wall pressure standard deviation
T	Free-stream static temperature, ^{o}R or ^{o}F
TAP	Pressure orifice identification number
TCXXX	Identification number of thermocouples on model interior surface
TD	Static temperature at boundary-layer thickness DEL, ^{o}R
TDRK	Temperature of Druck probe transducer, ^{o}R
THETA	Peripheral angle on the model measured from ray on model top, positive clockwise when looking upstream, deg
TL	Local static temperature, ^{o}R

TT	Tunnel stilling chamber temperature, °R or °F
TTA	Local total temperature interpolated to the anemometer location, °R
TTD	Total temperature at boundary-layer edge thickness, DEL, °R
TTE	Total temperature at boundary-layer edge, °R
TTL	Local total temperature, at pitot probe height °R
TTLU	Uncorrected (measured) probe recovery temperature, interpolated to ZP, °R
TTTU °R	Uncorrected (measured) probe recovery temperature,
TWL	Model wall temperature used for boundary-layer survey calculations, °R
UD	Local velocity component parallel to model surface at boundary-layer thickness, DEL, ft/sec
UE	Local velocity component parallel to model surface at boundary-layer edge, ft/sec
UL	Local velocity component parallel to model surface, ft/sec
V	Free-stream velocity, ft/sec
X	Axial location measured from virtual apex of cone model, in.
XC	Calculated X location of survey station, in.
XSTA	Nominal X location of survey station, in.
ZA	Anemometer probe height, distance to probe centerline along normal to model surface, in.
ZP	Pitot-pressure probe height, distance to probe centerline along normal to model surface, in.
ZT	Total-temperature probe height, distance to probe centerline along normal to model surface, in.

1.0 INTRODUCTION

The work reported herein was performed by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), under Program Element 61102F, Control Number 2307, at the request of the Air Force Wright Aeronautical Laboratory (AFWAL/FIMG) and the AEDC Directorate of Aerospace Flight Dynamics Test (AEDC/DOF). The AFWAL program manager was Kenneth F. Stetson and the AEDC/DOF program manager was Elton R. Thompson. The results were obtained by the Calspan Corporation/AEDC Operations, operating contractor for the Aerospace Flight Dynamics testing effort at the AEDC, AFSC, Arnold Air Force Base, Tennessee, 37389. The test was performed in the von Karman Gas Dynamics Facility (VKF) Hypersonic Wind Tunnel (B) on July 16-21, 1986, under the AEDC Project Number CF03VB (Calspan Project Number V--B-07).

This test was the sixth in a series of studies designed to investigate the development of laminar boundary-layer instabilities on sharp and blunt cones in hypersonic flow (Refs. 1-2). The present study was devoted to instabilities associated with a spherically-blunted cone model. Boundary-layer and free-stream flow-field data were obtained using hot-wire anemometer-, total temperature-, and pitot pressure- probes. Model surface pressure distributions were also obtained. The model configuration was a 7-deg (half-angle) cone with a spherically blunted nosetip of 0.70 in. radius.

Testing was performed at Mach number 8 at a free-stream unit Reynolds number of 2.6 million per foot and zero angle of attack. Hot-wire anemometer probe calibrations were obtained over a range of stilling chamber pressures between 200 and 575 psia with a nominally constant stilling chamber temperature of 850 deg F.

Inquiries to obtain copies of the test data should be directed to AEDC/DOF, Arnold Air Force Base, Tennessee 37389. A microfiche record has been retained in the VKF at AEDC.

2.0 APPARATUS

2.1 TEST FACILITY

Tunnel B (Fig. 1) is a closed circuit hypersonic wind tunnel with a 50-in.-diam test section. Two axisymmetric contoured nozzles are available to provide Mach numbers of 6 and 8, and the tunnel may be operated continuously over a range of pressure levels from 20 to 300 psia at Mach number 6, and 50 to 900 psia at Mach number 8, with air supplied by the VKF 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 Ref. 3.

2.2 TEST ARTICLE

The model used for this investigation was one of the two Lubard models (fabricated by AEDC) which are seven-degree half-angle cones constructed of 304 stainless steel. These models have a 40 in. virtual length and a 9.82 in. base diameter and a series of interchangeable nose sections including a nominally-sharp nose and several spherically blunted noses of various radii. The blunted nose section of 0.70 in. radius was used for the present investigation.

The first five test entries used the Lubard pressure/heat-transfer model which has been used for several other test programs and is now in very poor condition. Thus, for this entry, the Lubard force model was used and instrumented for additional surface pressure measurements.

During the tests performed in 1981, it was discovered that near the nose region of this configuration the maximum disturbance energy point in the flow over the body, as detected by the hot-wire sensor, is located outside the boundary layer. As the surveys move toward the base of the model, however, this maximum energy point approaches and enters the boundary layer. To ensure that this phenomenon was bracketed by the test surveys, an existing frustum extension was attached at the model base to extend the model length by 10.5 in.

The model was instrumented with 25 pressure orifices. Table 1 lists the location of this instrumentation and indicates that the top centerline (THETA = 0) of the model was the main ray of pressure instrumentation. Pressure orifices were also located on the THETA = 90-, 180-, and 270-deg rays at three additional axial stations. A sketch of the model geometry and instrumentation locations is given in Fig. 2.

In order to monitor the model shell temperature, four thermocouples were mounted to the internal model wall. These were located at THETA = 270 degrees (or -90 deg from the main ray of pressure orifices). Actual axial locations of these thermocouples are given in Table 1. (See also, Fig. 2).

The model was installed as far upstream in the wind tunnel as practical, to permit surveying the boundary layer as far downstream as possible. The model installation is shown in Fig. 3.

2.3 FLOW-FIELD SURVEY MECHANISM

Surveys of the flow field were made using a retractable survey system (X-Z Survey Mechanism) designed and fabricated by AEDC. This mechanism makes it possible to change survey probes while the tunnel remains in operation. The mechanism is housed in an air lock immediately above a port in the top of the Tunnel B test section. Access to the test section is through a 40-in.-long by 4-in.-wide opening which can be sealed by a pneumatically operated door when the mechanism is retracted. Separate drive motors are provided to (1) insert the mechanism into the test section or retract it into the housing, (2) position the mechanism at any desired axial station over a range of 35 in., and (3) survey a flow field of approximately 10-in. depth. A pneumatically-operated shield was provided to protect the probes during injection and retraction through the tunnel boundary layer, during changes in tunnel conditions, and at times when the probes were not in use.

The probes required for flow-field survey measurements are rake-mounted on the X-Z mechanism at the foot of a strut that is extended or retracted to accomplish the survey. The direction of the survey with respect to the vertical is fixed by manually sweeping the strut to the selected angle between 5 deg (swept upstream) and -15 deg (swept downstream) and locking the strut in position.

A sketch of the survey probe rake is shown in Fig. 4. The top and rear surfaces of the rake are designed to mate to the strut of the X-Z Survey Mechanism. The rake is provided with four 0.10-in. I.D. tubes through which are mounted the hot-wire anemometer-, the pitot pressure-, and total temperature probes. The fourth tube was used in the present test for housing a "touch-sensor" probe that caused the survey mechanism to halt when the probe made contact with the model surface. The tubes were slotted to accommodate spring clips attached to the rake which were used to hold the probes in position.

2.4 FLOW-FIELD SURVEY PROBES

The hot-wire anemometer probes (Fig. 5a) were fabricated by the VKF. Platinum-10% rhodium wires, drawn by the Wollaston process, of 20- or 50-micro-inch nominal diameter and approximately 140 diameters length, were attached to sharpened 3-mil nickel wire supports using a bonding technique developed by Philco-Ford Corporation (Ref. 4). The wire supports were inserted in an alumina cylinder of 0.032 in. diameter and 0.25 in. length, which was, in turn, cemented to an alumina cylinder of 0.093 in. diameter and 3.0 in. length that carried the hot-wire leads through the probe holder of the survey mechanism.

The pitot pressure probe (Fig. 5b) had a cylindrical tip of 0.007-in. inside diameter. This probe was fabricated by cold-drawing a stainless steel tube through a set of wire-drawing dies until the desired inside diameter was obtained. The outside surface of the drawn tube was subsequently electropolished to a diameter of 0.015 in. to minimize interference with the flow field surveyed.

The unshielded total temperature probe was fabricated from a length of sheathed thermocouple wire (0.020-in. O.D.) with two 0.004-in.-diameter wires. The wires were bared for a length of about 0.015

in. and a thermocouple junction of approximately 0.005-in. diameter was made. Details of this probe are shown in Fig. 5c.

2.5 TEST INSTRUMENTATION

2.5.1 Standard Instrumentation

The measuring devices, recording devices, and calibration methods for all parameters measured during this test are listed in Table 2. Also, Table 2 identifies the standard wind tunnel instruments and measuring techniques used to define test parameters such as the model attitude, the model surface pressure, probe positions, and probe measurements. Additional special instrumentation used in support of this test effort is discussed in the following subsections.

2.5.2 Model Surface Instrumentation

Eighteen surface pressure taps were located along the zero ray of the model. In addition, two taps were located on the 90-deg ray, three on the 180-deg ray, and two on the 270-deg ray. These taps, having approximate diameters of 0.064 in., were connected by tubing either to one-psid Druck® or 2.5-psid ESP transducers of the Tunnel B Standard Pressure System.

Model shell temperatures were monitored by four Chromel®-Alumel® thermocouples attached to the interior surface of the model. These thermocouples were mounted at THETA = 270 deg at nominal axial locations of X = 15-, 24-, 34-, and 45 in. (see Table 1).

2.5.3 Hot-Wire Anemometry

Flow fluctuation measurements were made using hot-wire anemometry techniques. Constant-current hot-wire anemometer instrumentation with auxiliary electronic equipment was furnished by AEDC. The anemometer current control (Philco-Ford Model ADP-13) which supplies the heating current to the sensor is capable of maintaining the current at any one of 15 preset levels individually selected using push-button switches. The anemometer amplifier (Philco-Ford Model ADP-12), which amplifies the wire-response signal, contains the circuits required to compensate the signal electronically for thermal lag which is a characteristic of the finite heat capacity of the wire. A square-wave generator (Shapiro/Edwards Model G-50) was used in determining the time constant of the sensor whenever required. The sensor heating current and mean voltage were fed to autoranging digital voltmeters for a visual display of these parameters and to a Bell and Howell model VR3700B magnetic tape machine and to the tunnel data system for recording. The sensor response a-c voltage was fed to an oscilloscope for visual display of the raw signal and to a wave analyzer (Hewlett-Packard Model 8553B/8552B) for visual display of the spectra of the fluctuating signal and was recorded on magnetic tape for subsequent analysis by

AEDC. A detailed description of the hot-wire anemometer instrumentation is given in Ref. 5.

The a-c response signal from the hot-wire anemometer was recorded using the Bell and Howell Model VR3700B magnetic tape machine in the FM- WBII mode. This channel, when properly calibrated and adjusted, has a signal-to-noise ratio of 35 db for a 1.000 volt rms output and a frequency response of +1 to -3 db over a frequency range of 0 to 500 kHz. A sine wave generator is used to check each channel at several discrete frequencies, using an rms-voltmeter which is periodically checked on 1, 10, and 100 volt ranges. The sensor heating current and mean voltage signals from the hot-wire anemometer were also tape-recorded using the FM-WBI mode. Magnetic tape recordings were made at a tape speed of 120 in./sec.

2.5.4 Pitot Probe Pressure Instrumentation

Pitot probe pressures were measured during surveys of the model boundary layer using a 15-psid Druck transducer calibrated for 10-psid full scale. The small size of the pitot probe (Section 2.4) was characterized by time delays for the stabilization of the pressure level within the probe tubing between orifice and transducer, when the probe was moved across the boundary layer. In order to reduce this lag time, the pitot pressure transducer was housed in a water-cooled package attached to the trailing edge of the strut on which the probe rake was mounted (Section 2.3). The distance between orifice and transducer was approximately 18 inches. The resultant lag time was of the order of one second.

3.0 TEST DESCRIPTION

3.1 TEST CONDITIONS AND PROCEDURES

A summary of the nominal test conditions is given below.

M	PT, psia	TT, °R	V, ft/sec	Q, psia	T, °R	P, psia	RE/FT x 10^{-6}
8.0	575	1311	3822	2.64	95	0.06	2.6

A summary of the present testing is presented in Tables 3 and 4 together with that of each of the five previous efforts, two of which are documented in Refs. 1-2. These tables provide a complete summary of the various types of measurements made with each configuration for the six tests. The individual tests may be identified by RUN numbers. For Test 1, RUN < 200; for Test 2, 200 < RUN < 300; Test 3, 300 < RUN < 400; Test 4, 400 < RUN < 500; Test 5, 500 < RUN < 700; and for the present testing, RUN > 700.

In the continuous flow 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 and 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 change.

Prior to each operating shift, the Tunnel B circuit was purged to minimize the amount of particulate matter in the flow. This was necessary for protection of the extremely sensitive hot-wire probes from particulate impacts.

Probes mounted to the X-Z mechanism are deployed for measurements by the following sequence of operations: the air lock is closed, secured over the mechanism, and evacuated; and the access door to the tunnel test section is opened. The various drive systems (see Section 2.3) are used to inject the probes into the test section and position the probes at a designated survey station along the length of the model, the shield protecting the probes is raised, exposing them to the flow, and the flow field is traversed in the direction normal to the model surface to the probe height (or heights) selected for measurements. When the traverse has been concluded, the shield is closed over the probes and the mechanism is repositioned along the model. When the surveys are completed or when a probe is to be replaced, the X-Z Mechanism is retracted from the flow and the access door is closed. The air lock is then opened for probe work.

The survey probe height relative to the model was monitored using a high-magnification closed-circuit television (CCTV) system. The camera for this system was fitted with a telescopic lens system which gives a magnification factor of 20 for the monitor image. The probe and model were back-lighted using the collimated light beam of the Tunnel B shadowgraph system which produced a high-contrast silhouette of the model-probe outline. The camera was mounted on a horizontal-vertical traversing mount to facilitate alignment of the camera with the probe at various model stations visible through the test section windows. The video camera was interfaced with an image analyzer/digitizer system (IADS) which was used to measure the distance between the probe and model surface using computer-assisted image analysis techniques. The software for making these measurements was designed to locate the lower edge of the probe and the upper edge of the model surface automatically, thus minimizing inconsistencies associated with location of the edges by an operator using a cursor. The measurement accuracy was further improved by calibrating the system prior to testing, using the automated edge-location technique to locate edges separated by a known distance.

A hardcopy of the video image of the probes and model edge was provided in near real-time showing, by means of a graphics line, the location of the edges measured and displaying a printout of the measured distance and other pertinent documentation (Ref. 2, Fig. 6). The accuracy of this measurement technique was determined to be better than ±0.0007 in. over a range of 0.003 to 0.2 in. under air-off conditions. Provisions were made to determine the magnitude of edge movement caused by probe and model vibrations and to calculate a correction factor for the measurements if required. However, vibrations of the model and probes were negligible when measurements were made under the present test conditions.

The model was oriented in roll to avoid interference of the surface instrumentation with the boundary-layer probes. The flow-field surveys were obtained only after the model had reached equilibrium temperature. Initial probe positioning near the model surface prior to each survey was accomplished by manual maneuvers of the probe controller while observing the CCTV monitor. The flow-field surveys were accomplished in the following sequence: (1) the survey mechanism was positioned at the desired model axial station (XSTA) by the controller operating in either manual or automatic mode and locked in axial position; (2) the survey mechanism was driven downward in the direction normal to the surface by the controller until the "touch-sensor" probe (Section 2.3) made contact with the surface; (3) measurements of probe positions relative to the surface and to each other were made using the IADS and the information was manually entered into the data system; (4) the probes were traversed across the flow field in selected increments by the controller in either manual or automatic mode to acquire the desired data; (5) the axial position of the survey mechanism was unlocked and the mechanism was repositioned at the next survey station along the model.

3.2 DATA ACQUISITION

The primary test technique used in the present investigation of the initial development of instabilities in a laminar boundary layer was hot-wire anemometry. In addition, mean-flow boundary-layer profile data (pitot pressure and total temperature) were acquired in order to define the flow environment in the vicinity of the hot-wire. Surface pressure distributions on the model were obtained to supplement the profile data. The various types of data acquired are summarized in Table 3. Model stations for mean-flow surveys are listed in Table 4.

3.2.1 Hot-Wire Anemometry Data

The hot-wire anemometer data acquired during the present testing were of two general categories: (1) continuous-traverse surveys of the boundary layer to map the response of the hot-wire anemometer as a function of distance normal to the surface and (2) quantitative hot-wire measurements using the wire operated at each of a series of wire heating currents at one or two locations on each profile. The anemometer probes used are identified in Table 3f.

Data of the first category were acquired with the hot wire operated using a single heating current, in the present case the maximum (practical) current. The probe was generally translated in a continuous manner from near the model surface outward to a distance of approximately three times the boundary layer thickness. These data were recorded as analog plots of the hot-wire response (rms of the a-c voltage component) versus probe height normal to the model surface. The plot was used primarily for the purpose of determining the station in the boundary-layer profile where the hot-wire output reached a maximum level.

Quantitative hot-wire data (second category) were acquired at locations determined from the continuous-traverse surveys (first category data). The point of maximum rms voltage output of the hot wire, the "maximum energy point" of the profile, was selected for quantitative measurements at each model station. The quantitative data were acquired using each of a sequence of two or more wire heating currents; one current was nominal-zero to obtain a measurement of the electronic noise of the anemometer instrumentation. Each wire heating current, wire mean voltage (d-c component) and the rms value of the wire voltage fluctuation (a-c component) were measured 40 times using the Tunnel B data system. At the same time, these hot wire parameters were being recorded (generally, a five-second record duration) on magnetic tape with a tape transport speed of 120 in./sec.

3.2.2 Flow-Field Survey Data

Mean-flow boundary-layer profiles extended from a height of 0.02 in. above the model surface to somewhat beyond the edge of the boundary layer. A profile typically consisted of 25 to 40 data points (heights). The probe direction of travel was normal to the surface.

3.2.3 Model Surface Data

Surface pressure distributions on the model were obtained to supplement the boundary-layer profile data. Model shell temperatures were measured using the internal thermocouples.

3.2.4 Anemometer and Total Temperature Probe Calibrations

The evaluation of flow fluctuation quantitative measurements made using hot-wire anemometry techniques requires a knowledge of certain thermal and physical characteristics of the wire sensor employed. In the application of the hot wire to wind tunnel tests, two complementary calibrations are used to evaluate the wire characteristics needed. The first calibration of each hot-wire probe is performed in the instrumentation laboratory prior to the testing: the probe is placed in an oven, and the resistance of the wire is determined as a function of applied wire heating current at several oven temperatures between room temperature and 600°F. The wire reference resistance at 32°F and the thermal coefficient of resistance, also at 32°F, are obtained from the results; the wire aspect (length-to-diameter) ratio is determined, using the wire resistance per unit length specified by the manufacturer with each supply of wire. Moreover, it has been established that the exposure of the probes to the elevated temperatures of the oven calibration often serves to eliminate probes with inherent weaknesses.

Each hot-wire probe used for flow-field measurements is calibrated in the wind tunnel free-stream flow to obtain both the heat-loss coefficient (Nusselt number) and the temperature recovery factor characteristics of the wire sensor as functions of local Reynolds number. The variations of Reynolds number in the free stream are obtained by varying the tunnel total pressure (PT) while holding the tunnel total temperature (TT) at a nominally constant level. The resulting relationships are used to determine the values of the various wire sensitivity parameters required in the reduction of the quantitative measurements.

A calibration of the recovery factor of the total-temperature probe as a function of local Reynolds number was made in the free-stream flow of the tunnel test section simultaneously with the calibration of the hot-wire probes. The local total temperature for the probes in free-stream flow was assumed to be equal to the measured stilling chamber temperature, TT (see Section 3.3.4).

3.3 DATA REDUCTION

3.3.1 Hot-Wire Anemometry (Data Types 6 and 9)

In the present discussion, as it pertains to the reduction of hot-wire anemometer data, only the basic measurements tabulated in the data package that accompanies this report will be considered. (Examples of these tabulations are shown in the Sample Data.) The data processing associated with spectral analysis, modal analysis, and determination of amplification rates of laminar disturbances is beyond the scope of this report. Extended data reduction of the hot-wire results to achieve these analyses is planned for the present measurements.

The basic measurements associated with quantitative hot-wire data are the following parameters: wire heating current, wire mean voltage, and the rms value of the wire fluctuating response voltage. The average value of 40 measurements of each of these three parameters was determined over a period of 5 sec for each nominal wire heating current employed, and the results were tabulated under the designation "DATA TYPE 9" together with certain associated model, flow field, and tunnel conditions. (See Sample 1.)

Free-stream tunnel conditions that are applicable to anemometer and total-temperature probe calibrations are tabulated under the designation "DATA TYPE 6". (See Sample 2.)

3.3.2 Mean Flow-Field Surveys (Data Type 4)

The mean flow-field data reduction included calculation of the local Mach number and other local flow parameters, determination of the height of each probe relative to the model surface, correction of the total-temperature probe using an appropriate recovery factor, definition of the boundary-layer total thickness, and evaluation of the displacement and momentum thicknesses. Sample tabulated data are shown in Sample 3, and typical plotted results are shown in Fig. 6. The data reduction procedures are outlined as follows.

The local Mach number in the flow field around the model was determined using the measured pitot pressure (PP) and the local model static pressure (PWL) with the Rayleigh pitot formula.

The height of each probe above the model surface, in the normal direction, was calculated for each point in a given flow-field survey, taking into consideration the following parameters: the initial vertical distance determined from the CCTV image, the distance traversed in the vertical direction from the initial position employing the survey probe drive, the lateral displacement of the probe from the vertical plane of symmetry of the model, and the local radius of the model at the survey station.

The height of the pitot pressure probe above the model surface (ZP) was used as the reference for all probes because the pitot probe was located in the vertical plane of symmetry of the model. The recovery temperature measurements (TTTU) of the total temperature probe were used to interpolate (three-point) a value (TTLU) corresponding to each height of the pitot probe. Correction of the interpolated recovery temperature, using the probe calibration data, was achieved by iteration on the local Reynolds number beginning with the value calculated using the recovery temperature (TTLU) to determine an initial value for the local dynamic viscosity (MUTTL). The iteration was continued until successive values of the "corrected" total temperature differed by no more than 0.1 deg R. For those surveys wherein the pitot probe was positioned below the total-temperature probe (closer to the model surface), the corrected total temperature at the corresponding pitot probe heights was determined from a second-order curve fit using three points, namely: the model surface temperature (TWL) and the corrected total temperature at the first two probe heights, where it was available.

The total thickness of the model boundary layer in any given profile was inferred from the profile of the total-temperature probe recovery temperature (TTLU). Recovery temperatures measured above the edge of the boundary layer (in the shock layer) remained constant or essentially independent of the probe height. There was generally a very distinct "overshoot" in the recovery temperature profile immediately before the onset of the constant portion of the profile. The height at which this constant portion of the profile began was defined as the edge of the boundary layer, and the corresponding distance normal to the model surface was defined as the boundary-layer total thickness (DEL). Displacement and momentum thicknesses were determined by integration accounting for the model cone angle and local radius of curvature. Probe/model interference was noted for some of the data points near the model surface; these points were omitted from the integrations.

Model surface pressure distributions were measured during mean flow-field surveys, "DATA TYPE 4" (Sample 3). These measurements were made each time that probe data were acquired and the 25 to 40 values for each pressure were averaged. The averaged values and their respective standard deviations are included in the tabulations of DATA TYPE 4.

3.3.3 Model Surface Measurements (Data Type 2)

Model surface pressure distributions generally were obtained when the survey probe mechanism was located so as not to interfere with the measurements. These data are tabulated under the designation "DATA TYPE 2". (See Sample 4.)

The local model surface pressure, PWL, used in the boundary-layer calculations was determined using a fairing of the measured pressure distributions (selected runs of DATA TYPE 2). The static pressure was assumed to be constant across the boundary layer and shock layer and equal to the local model surface pressure at each survey station. The fairing of the surface pressure distribution used for each test condition is shown in Fig. 7.

3.3.4 Total Temperature Probe Calibration (Data Type 6)

The recovery factor ETA used in reducing the total temperature probe survey data is defined generally as a function of the local Reynolds number based on probe diameter. In the case of the probe used in the present test, the factor ETA was essentially independent of Reynolds number; that is, ETA = constant for the test conditions being considered.

Free-stream tunnel conditions that are applicable to the total-temperature probe calibration are tabulated under the designation "DATA TYPE 6" (Sample 2.)

3.4 MEASUREMENT UNCERTAINTIES

In general, instrumentation calibrations and data uncertainty estimates were made using methods recognized by the National Bureau of

Standards (NBS),(Ref. 6). Measurement uncertainty (U) is a combination of bias and precision errors defined as:

$$U = \pm(B + t_{95}S)$$

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, which equals approximately 2 for degrees of freedom greater than 30.

Estimates of the measured data uncertainties for this test, including the basic hot-wire anemometer measurements discussed in this report, are given in Tables 2a and b. Estimates of uncertainties in flow fluctuations derived from the hot-wire anemometer measurements and in other calculated flow survey parameters fall outside the scope of this report. In general, measurement uncertainties are determined from in-place calibrations through the data recording system and data reduction program.

The propagation of the estimated bias and precision errors of the measured data through the data reduction was determined for free-stream parameters in accordance with Ref. 6, and is summarized in Table 2b.

4.0 DATA PACKAGE PRESENTATION

Boundary-layer profile data, model surface data, probe calibration data, and basic hot-wire anemometer data from the test were reduced to tabular and graphical form for presentation as a Data Package. Examples of the basic data tabulations are shown in the Sample Data.

Figure 6 is an example of the plotted mean-flow boundary-layer survey results for the blunt cone configuration at a particular survey station which are included in the Data Package.

REFERENCES

1. Siler, L. G. and Donaldson, J. C. "Boundary-Layer Measurements on Slender Blunt Cones at Free-Stream Mach Number 8," AEDC-TSR-79-V71, December 1979.

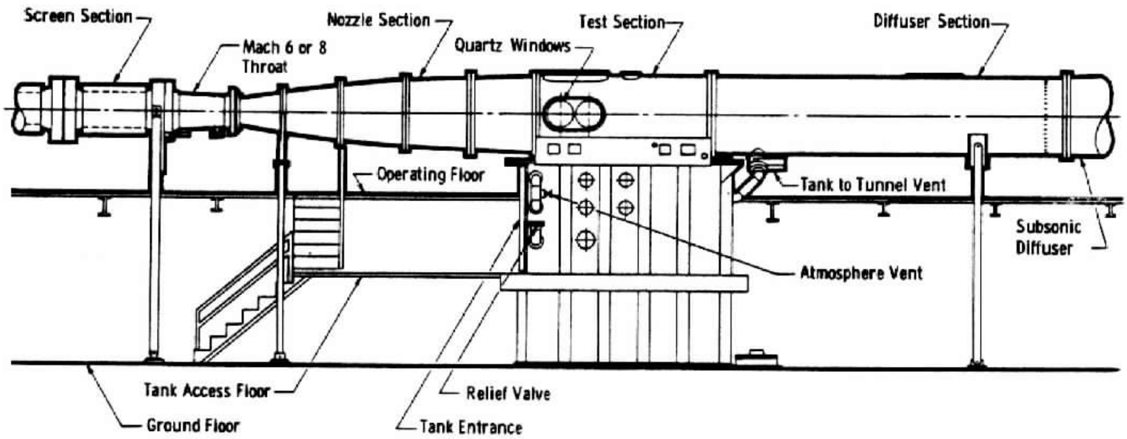
2. Donaldson, J. C. and Simons, S. A., "Investigation of the Development of Laminar Boundary-Layer Instabilities Along a Sharp Cone," AEDC-TSR-85-V16, April 1985.

3. Boudreau, A. H. "Performance and Operational Characteristics of AEDC/VKF Tunnels A, B, and C." AEDC-TR-80-48 (AD-A102614), July 1981.

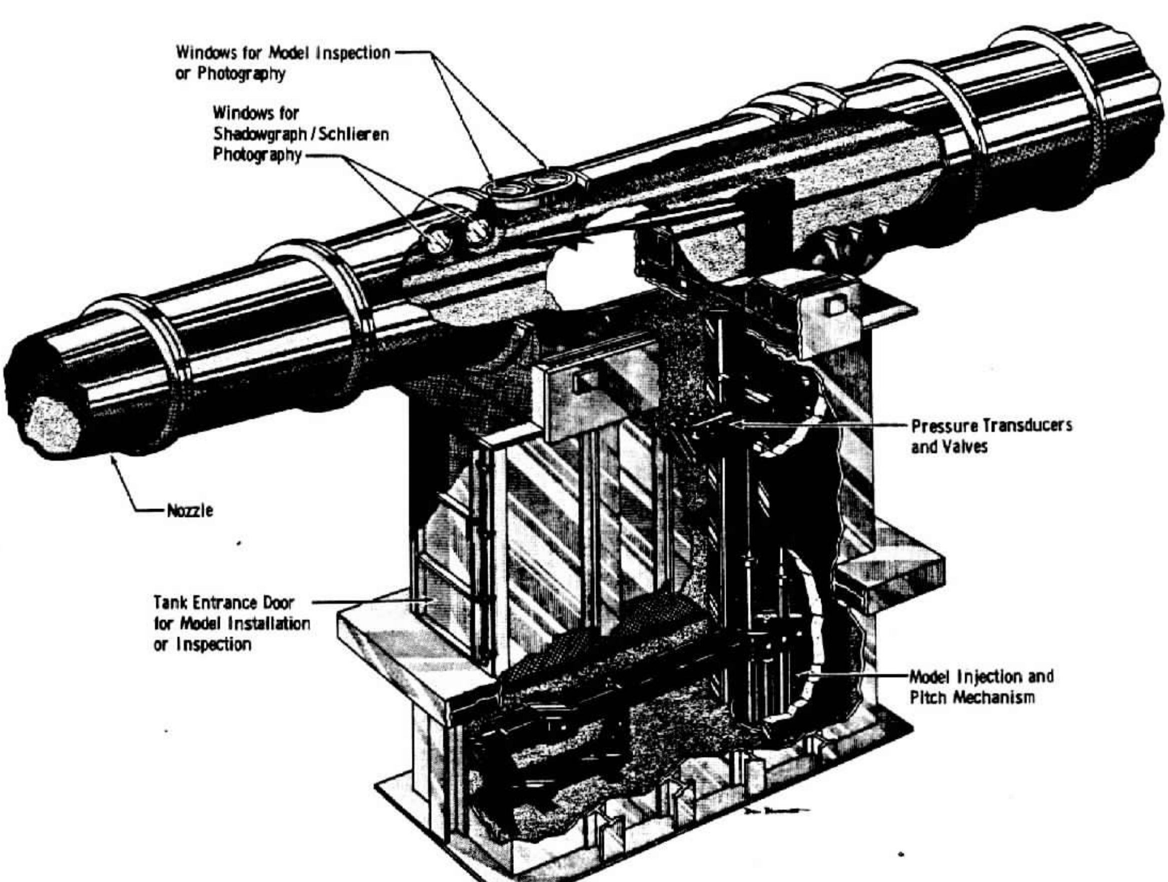
4. Doughman, E. L. "Development of a Hot-Wire Anemometer for Hypersonic Turbulent Flows," Philco-Ford Corporation Publication No. U-4944, December 1971; and The Review of Scientific Instruments, Vol. 43, No. 8, August 1972, pp. 1200-1202.

5. Donaldson, J. C., Nelson, C. G., and O'Hare, J. E. "The Development of Hot-Wire Anemometer Test Capabilities for $M_\infty = 6$ and $M_\infty = 8$ Applications," AEDC-TR-76-88 (AD A029570), September 1976.

6. 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

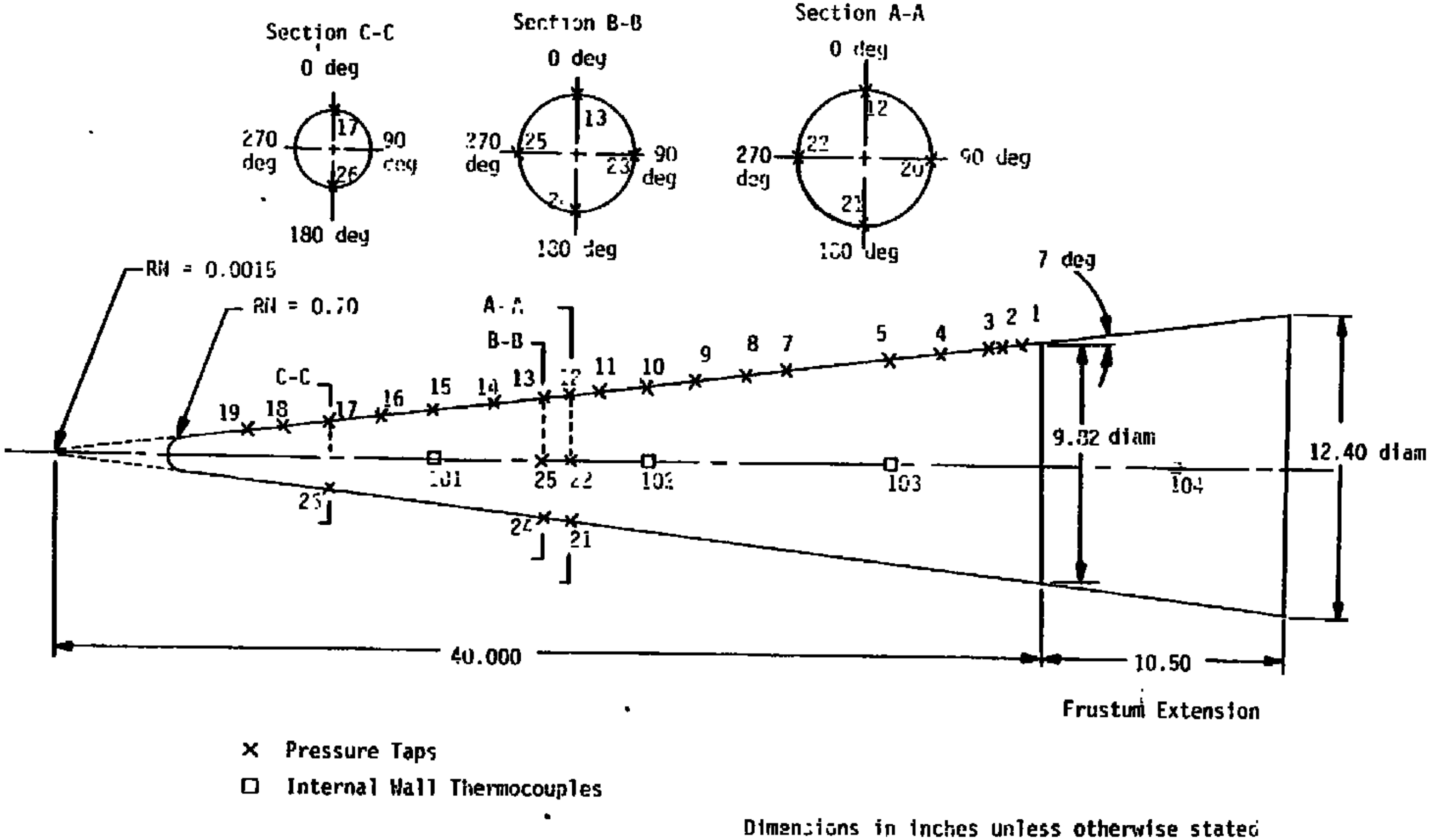


FIGURE 2. Model Geometry and Gage Locations

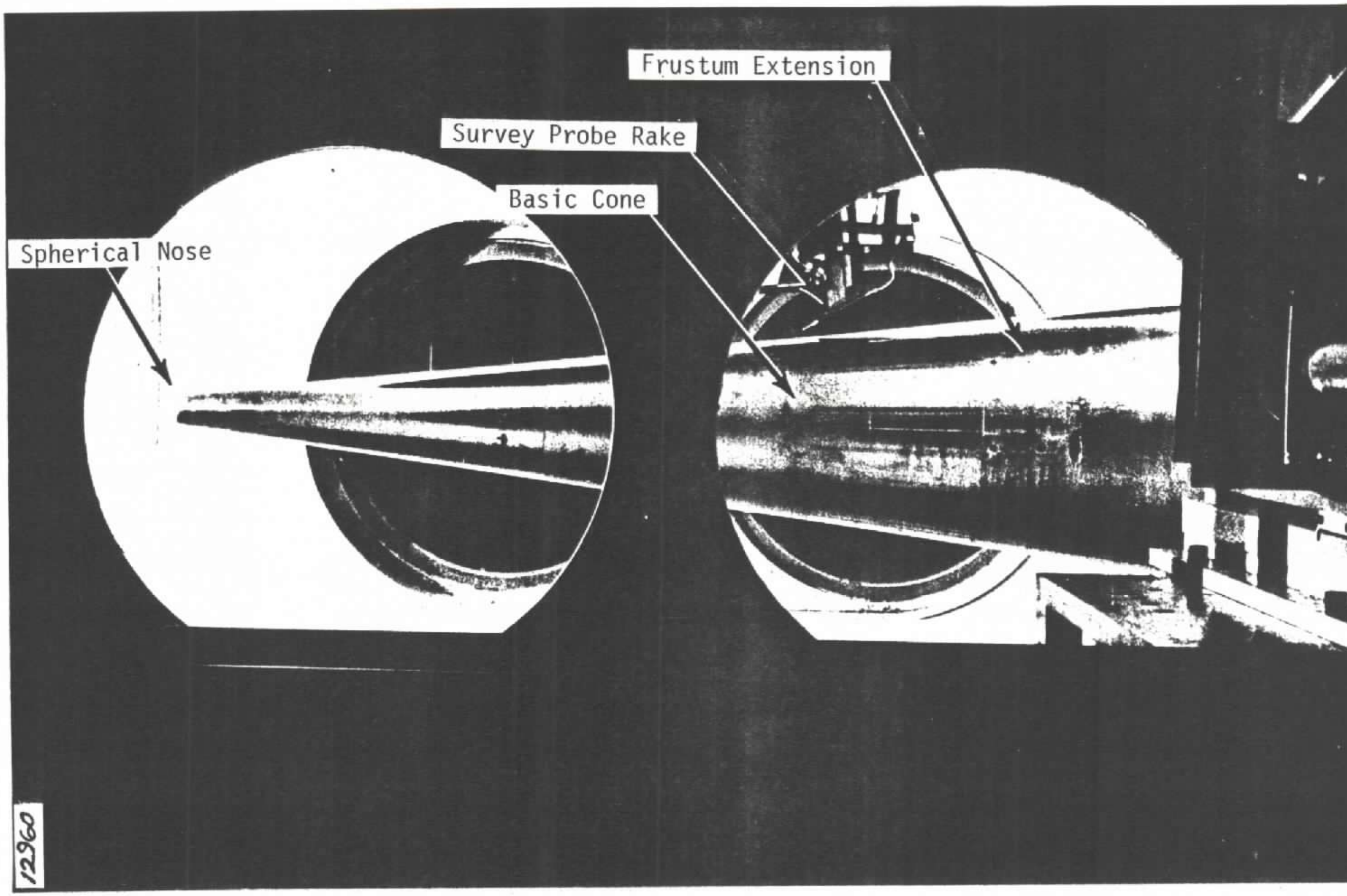
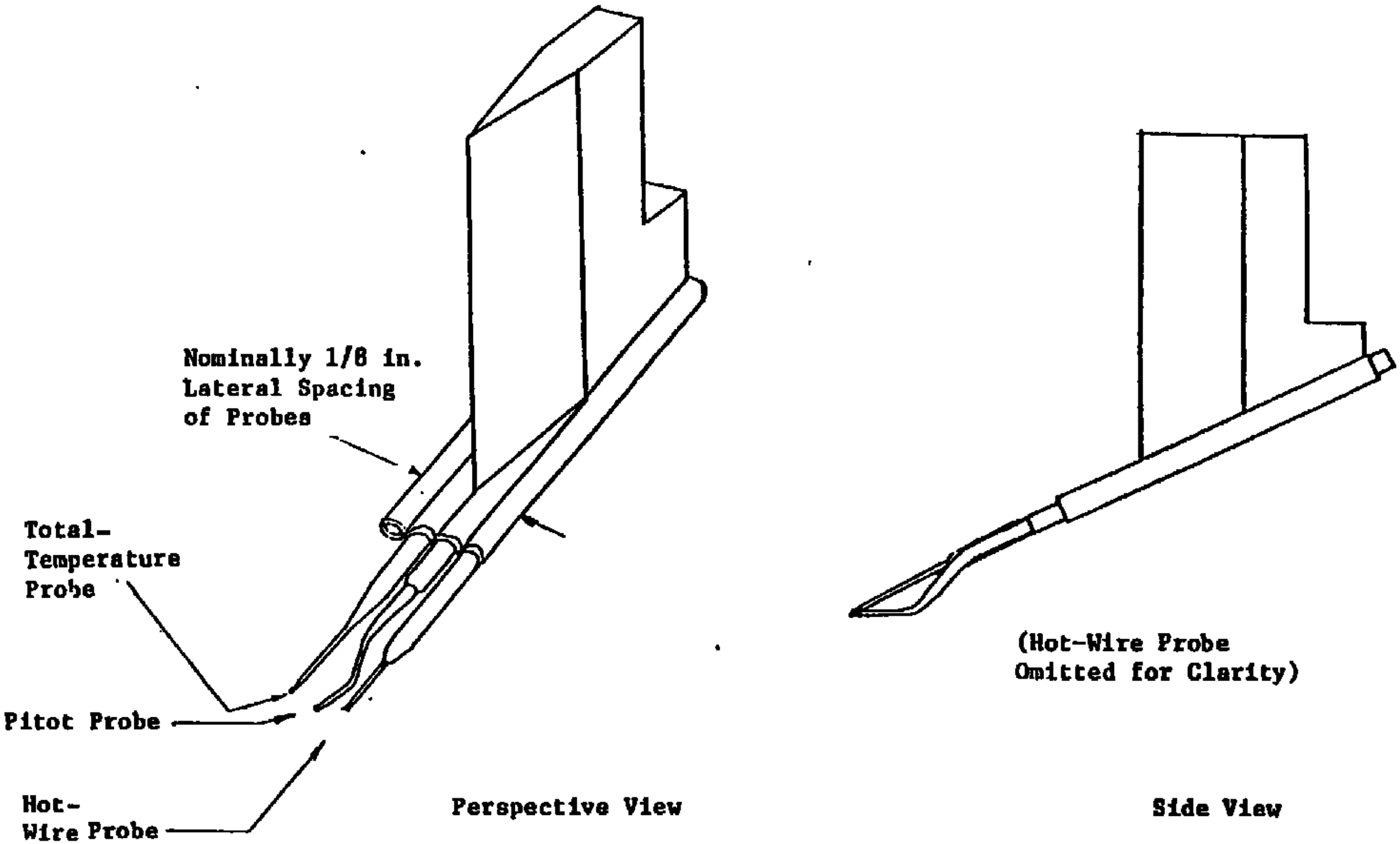
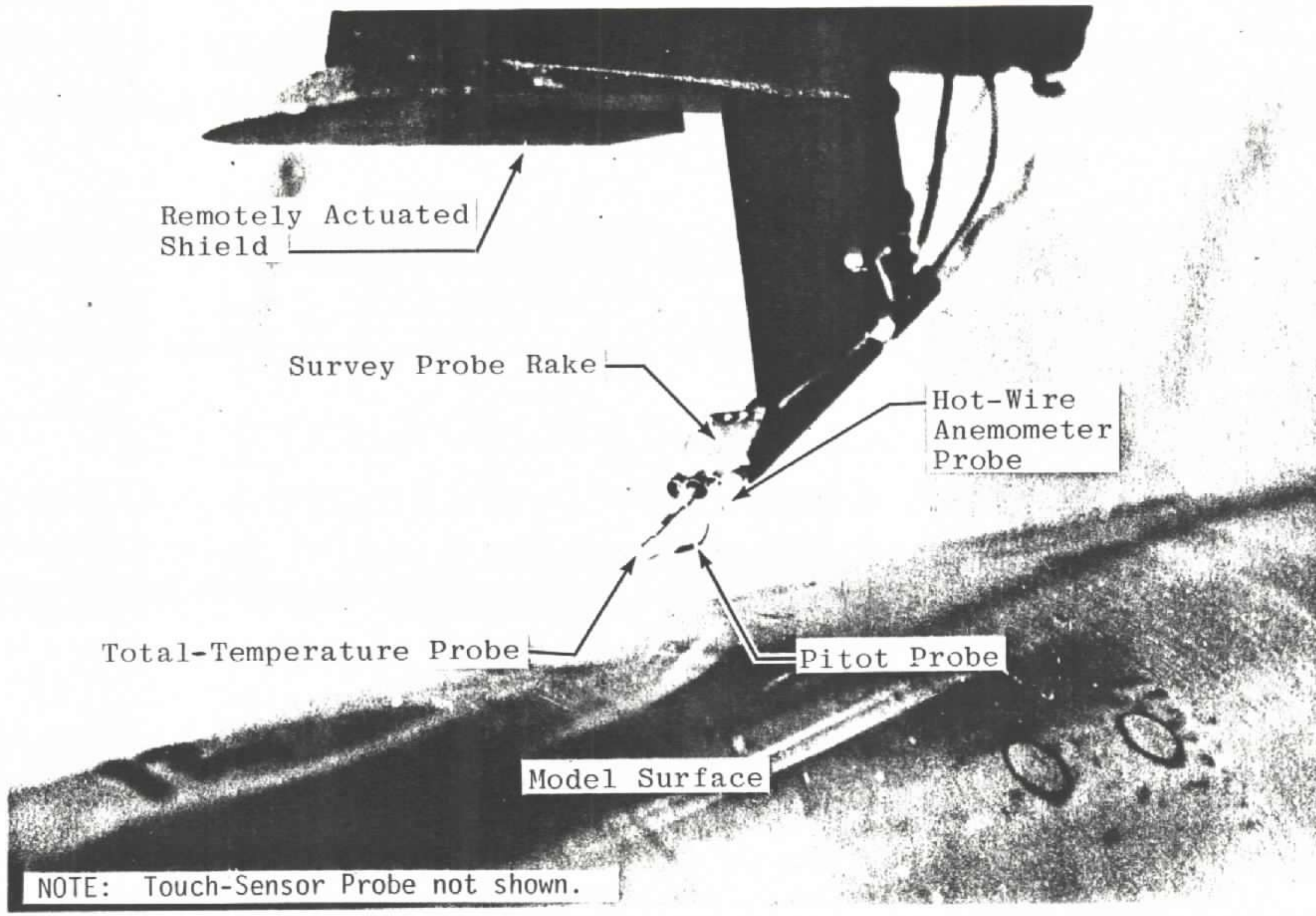


Figure 3. Test Installation



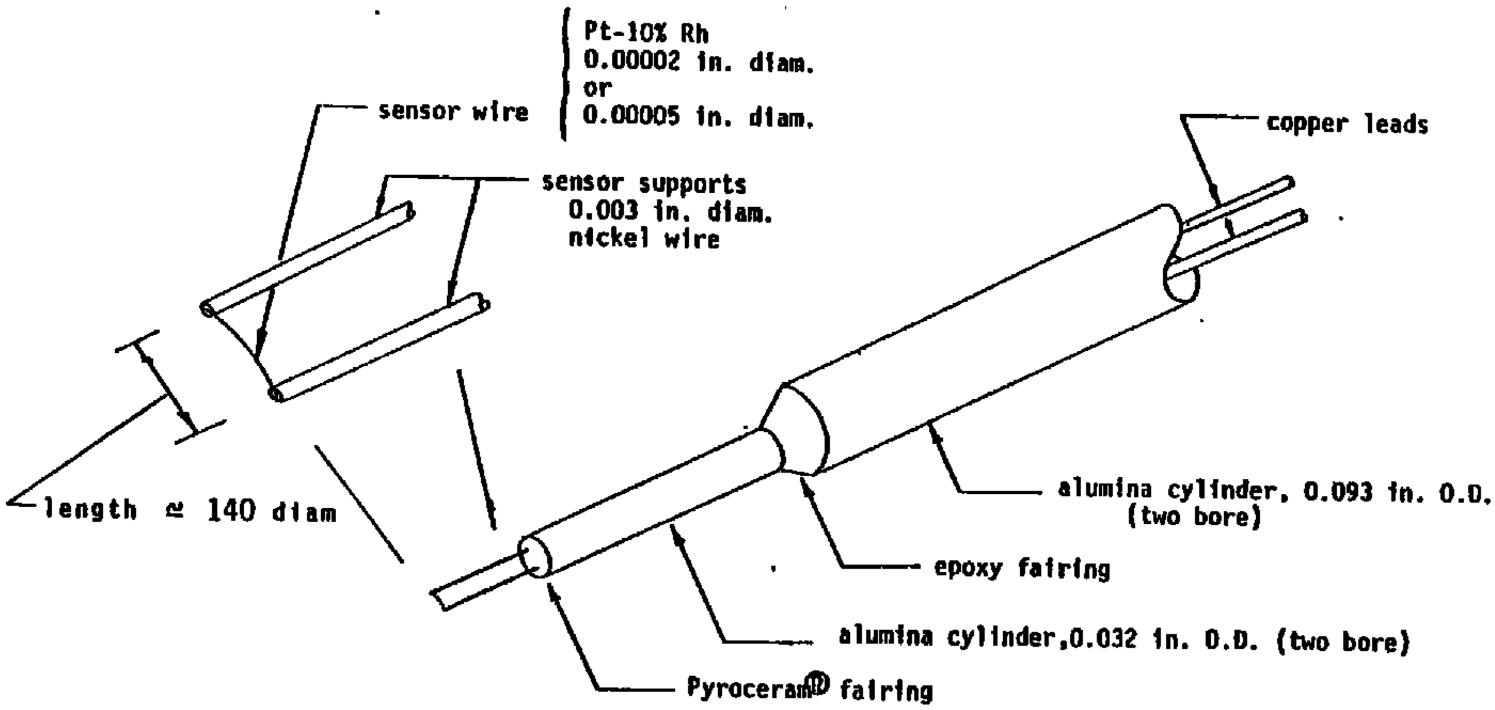
a. Rake and Probe Installation

Figure 4. Survey Probe Rake



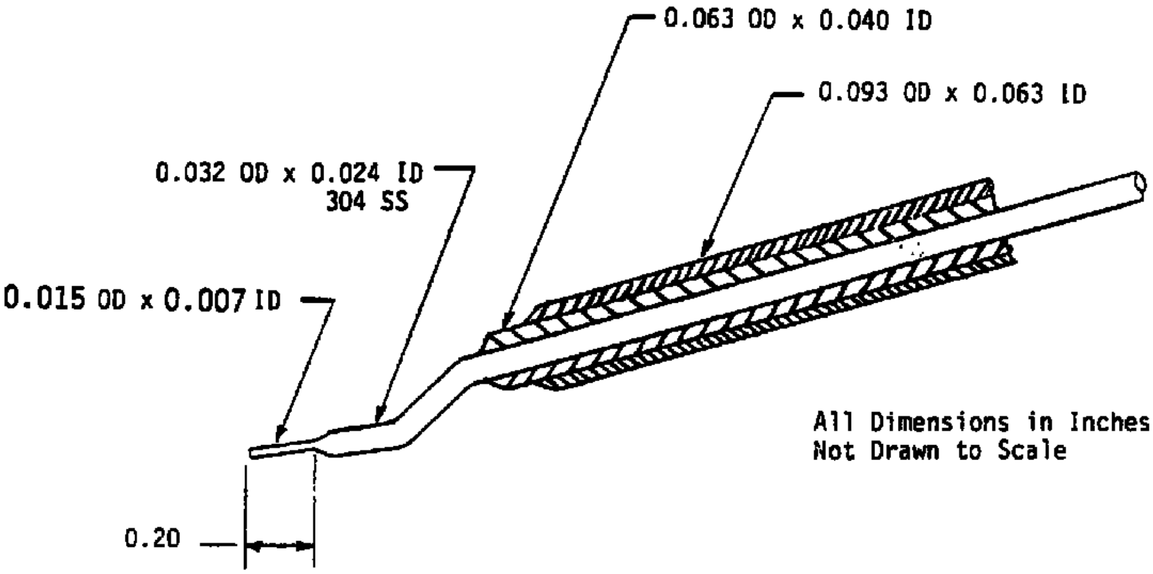
b. Rake/probe mounted above model surface

Figure 4. Concluded

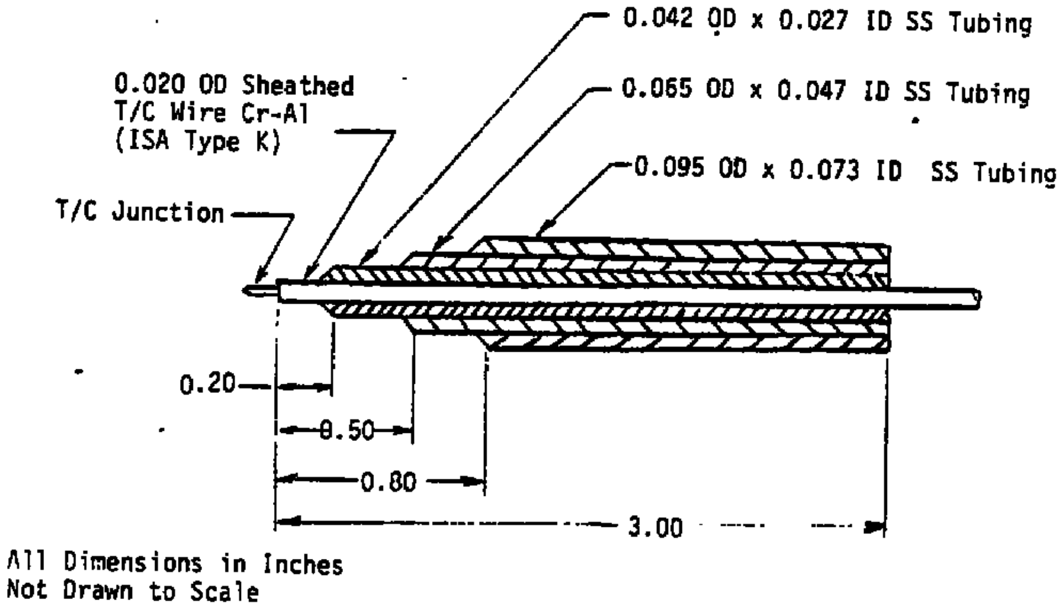


a. Hot-wire anemometer probe

Figure 5. Probe details



b. Pitot probe



c. Total-temperature probe

Figure 5. Concluded

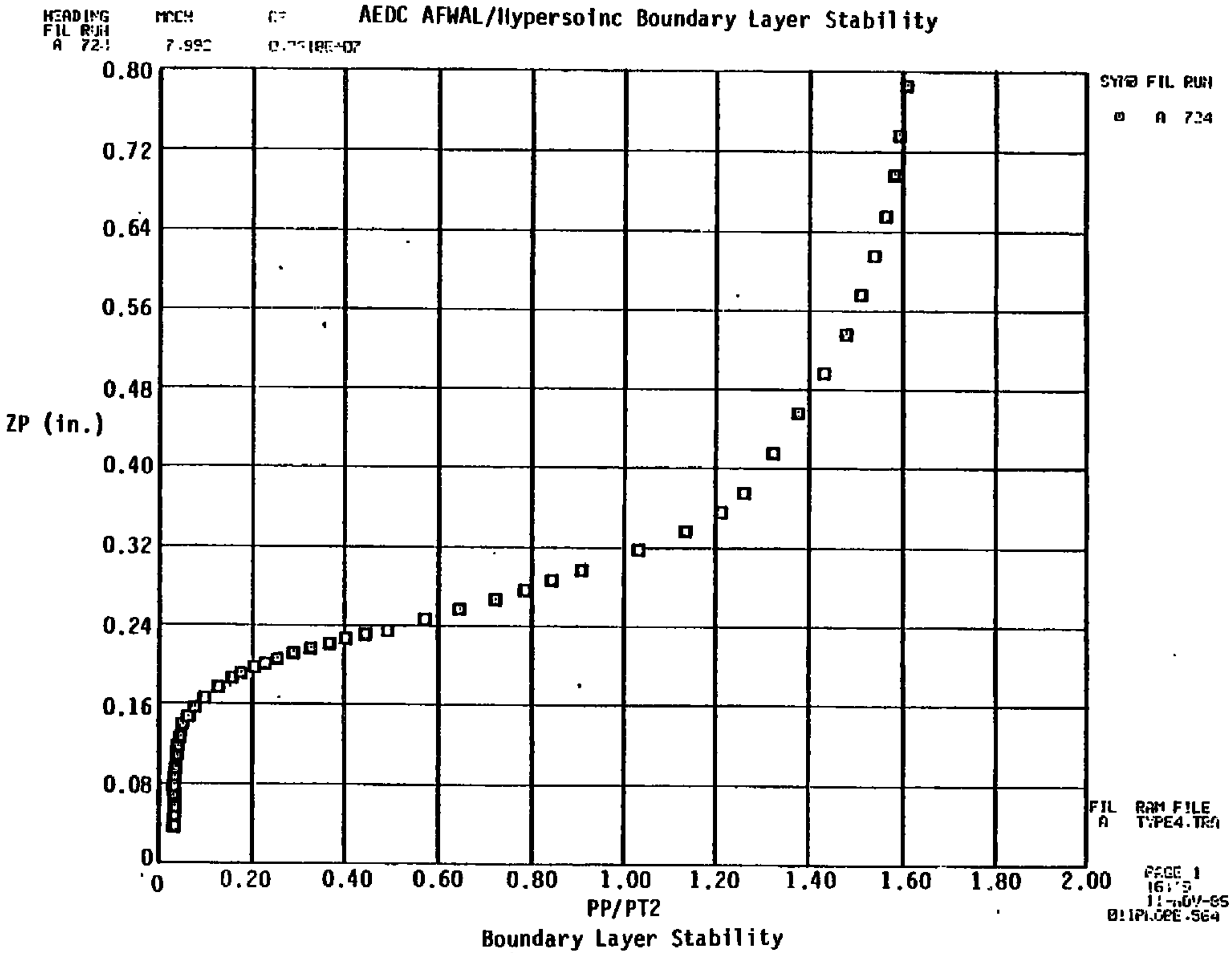


Figure 6. Typical Results of a Mean-Flow Boundary-Layer Survey

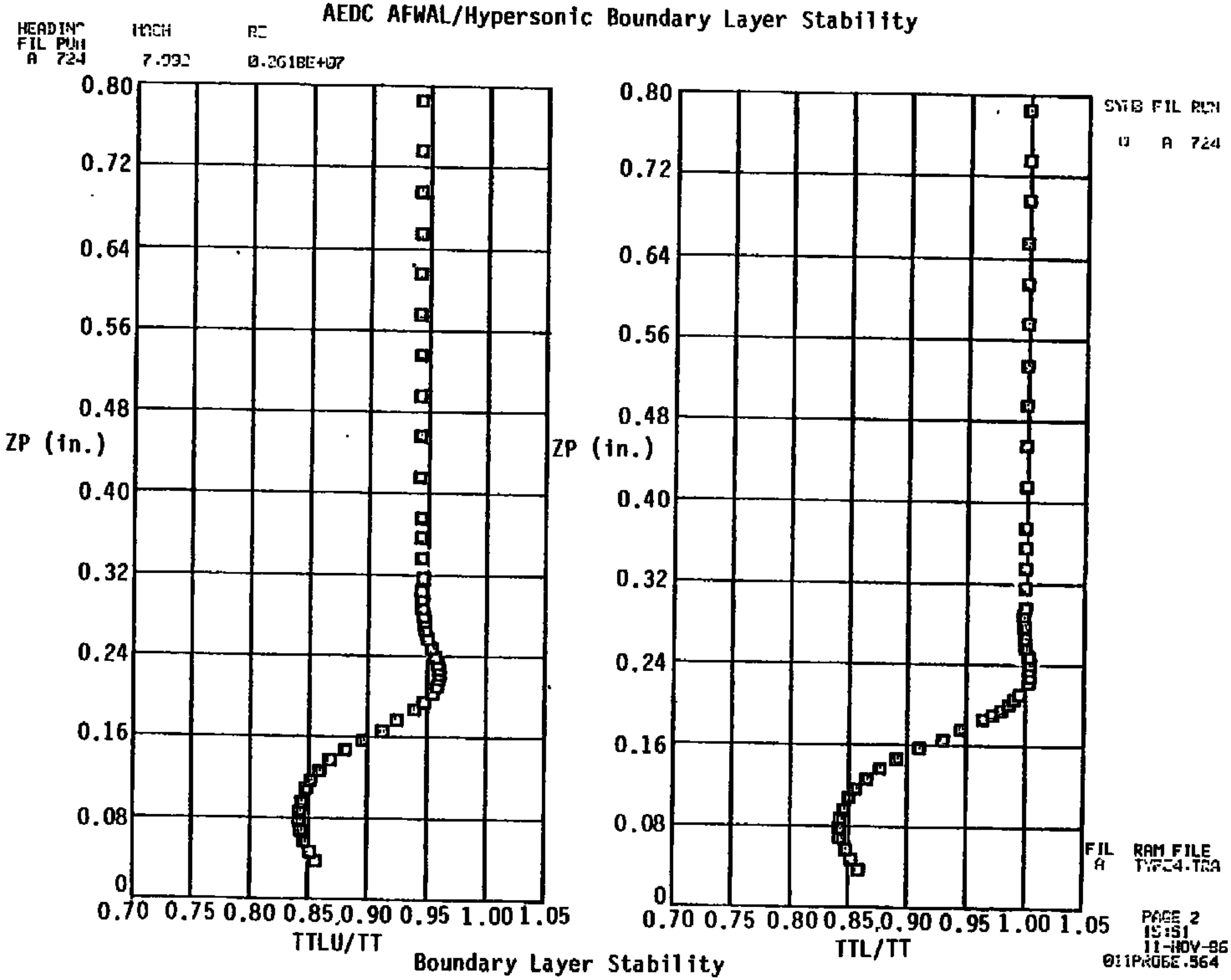


Figure 6. Continued

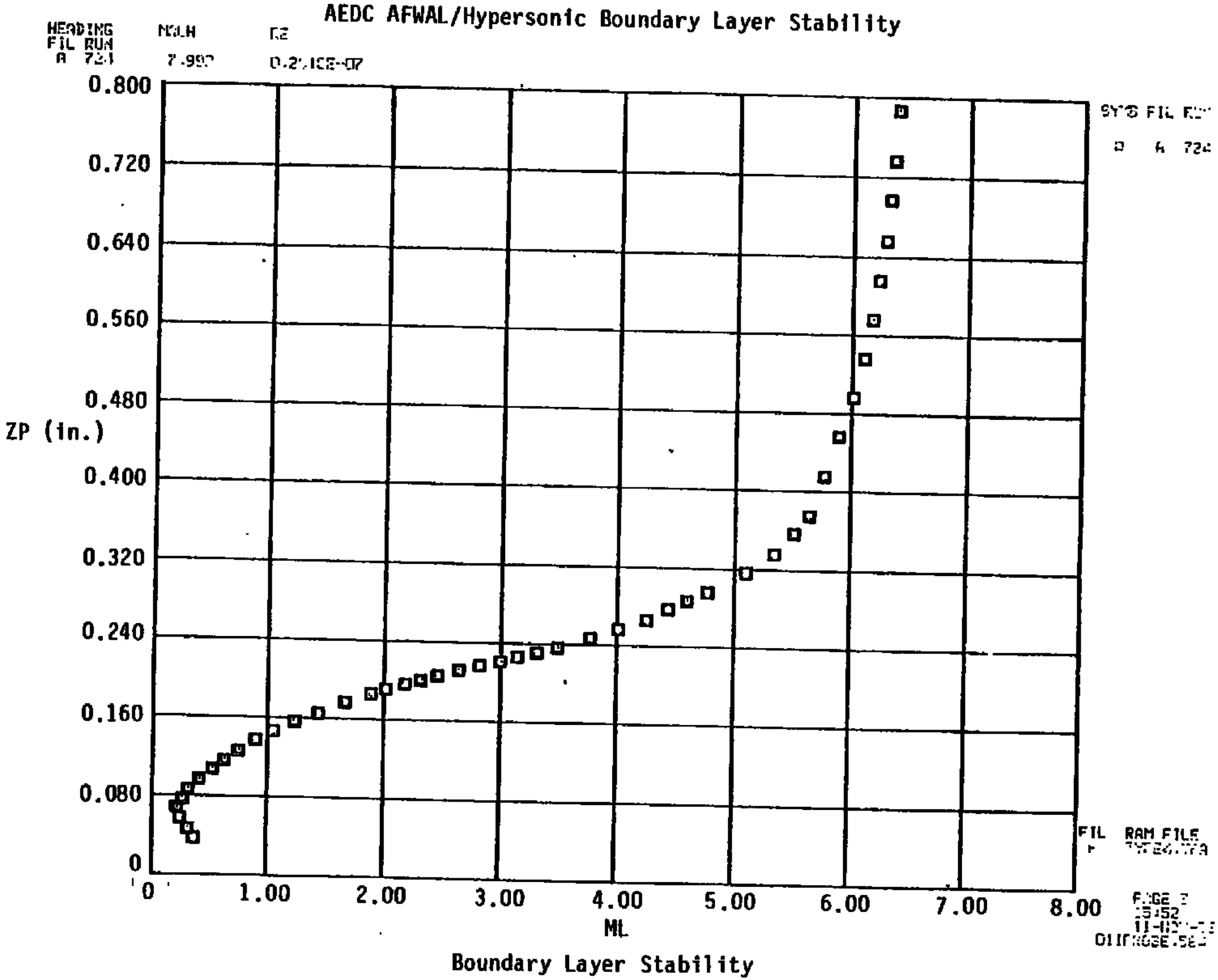


Figure 6. Concluded

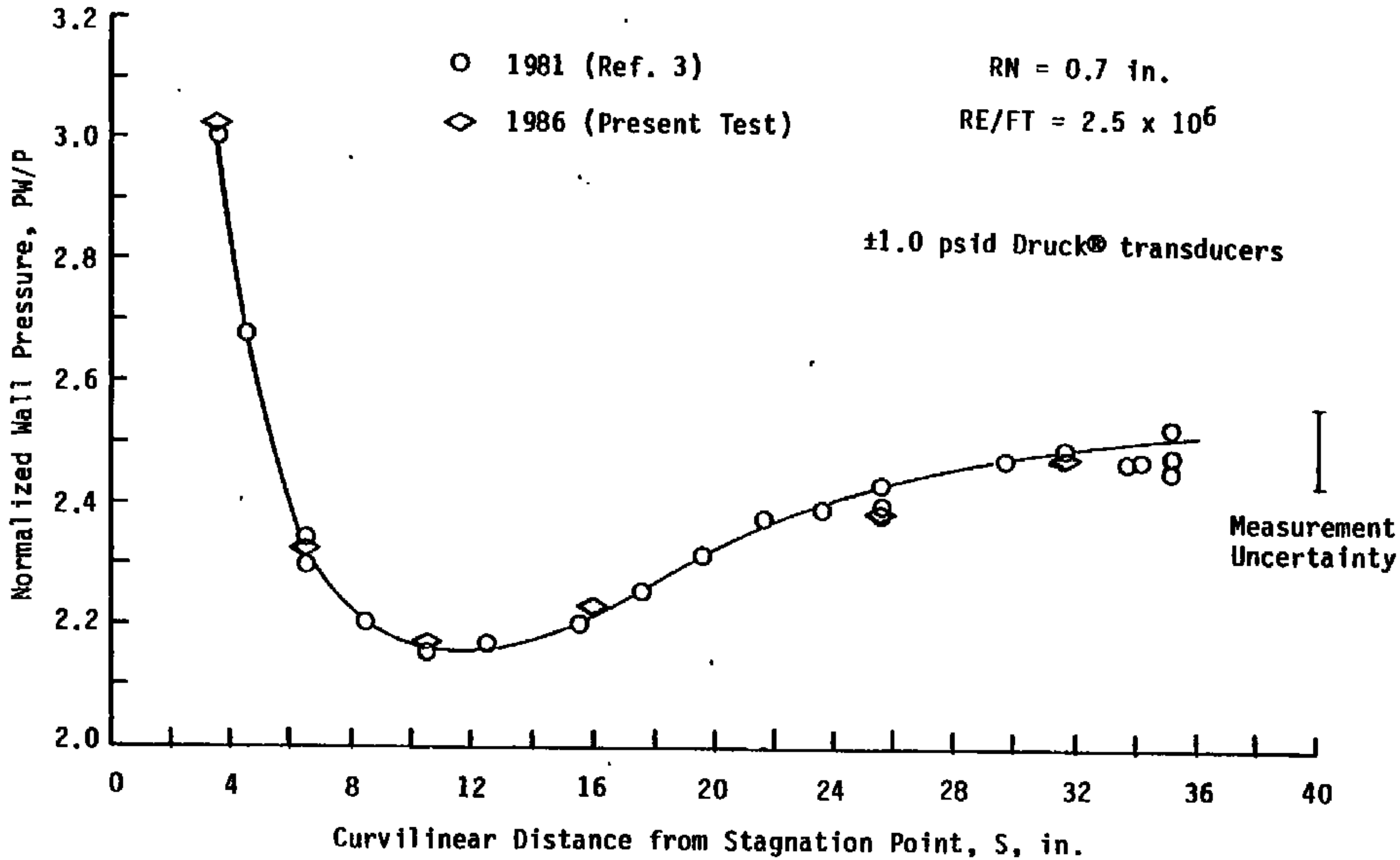


Figure 7. Typical Surface Pressure Distribution

Table 1. Model Instrumentation Locations

PRESSURE ORIFICE No.	THETA, deg	X, in.	S, in.
1	0	39.494	35.103
2		38.500	34.102
3		37.999	33.597
4		36.023	31.606
5		34.038	29.606
7		30.064	25.602
8		28.078	23.602
9		26.093	21.602
10		24.112	19.606
11		22.127	17.606
12		20.474	15.940
13		19.473	14.932
14		16.994	12.434
15		15.014	10.439
16		13.028	8.439
17		11.043	6.439
18		9.058	4.439
19		8.094	3.467
20	90	20.478	15.944
21	180	20.478	15.944
22	270	20.474	15.944
23	90	19.489	14.948
24	180	19.483	14.942
25	270	19.489	14.948
26	180	11.043	6.439

INTERNAL THERMOCOUPLE No.			
101	270	15.0	10.4
102		24.1	19.6
103		34.0	29.6
104		45.	41.

TABLE 2. 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 Index (S)			Bias (B)		Uncertainty ±(B + t_{95}S)					
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement				
Stilling Chamber Pressure (PT & PTR), psi		±0.1 psi	)30		±0.1 psi		±0.3 psi	0 to 900 psi	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 lab
Total Temperature (TT), °F		±1°F ±1°F	)30)30	±0.375	±2°F	±(.375% + 2°F)	±4°F	32 to 530 °F 530 °F to 2300°F	Chromel®-Alumel® Thermocouple	Digital Thermometer and Micro Processor Averaged (TTP) Digital Thermometer for Redundant (TTR)	Thermocouple verification of NBS conforming voltage substitution calibration
Roll Angle (PHI) degs		±0.15°	)30			0•	±0.3°	±180°	Potentiometer	Digital data acquisition system/analog-to-digital converter	Heidenhain rotary encorder ROD700 Resolution 0.0006° Overall accuracy 0.001°
Pitot Pressure (PP), psi		±0.002 psi			±0.010 psi		±0.014 psi	(10 psid	Druck® ± 15 psid strain gage transducers	Analog to digital converter/digital data acquisition system	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the standards laboratory
TTU, °F		±1 °F ±1 °F	)30)30	±0.375	±2°F	±(.375% + 2°F)	±4 °F	(530 °F (2300 °F	Unshielded Chromel®-Alumel® Thermocouple	-	Thermocouple verification of NBS conformic voltage substitution calibration

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

Note. • Bias assumed to be zero

TABLE 2. CONTINUED

a. CONTINUED

Parameter Designation	Steady-State Estimated Measurement* Precision Index (S) Percent of Reading	Precision Index (S) Unit of Measurement	Precision Index (S) Degree of Freedom	Bias (B) Percent of Reading	Bias (B) Unit of Measurement	Uncertainty ±(B + t95S) Percent of Reading	Uncertainty ±(B + t95S) Unit of Measurement	Range	Type of Measuring Device	Type of Recording Device	Method of System Calibration
Model Pressure (PW), psi	±0	00075 psi	)30	± 1.0		±(0 0015	psi + 1.0%)	0 ≤ P ≤ 0 15 psid	Druck® ± 15 psid strain gage transducers	Analog to digital converter/digital data acquisition system	In-place application of multiple pressure levels measured with a pressure measuring device calibrated in the Standards Lab
	±0	002 psi	)30	±0.1		±(0.004	psi + 0 1%)	0 15 ≤ P ≤ 1 5 psid			
	±0	.002 psi	)30		±0 003 psi		±0 007 psi	(2.5	ESP® 2.5 psid strain gage transducer		
Model Temperature (TW), °F		±1 °F	)30		±2 2 °F		±4 2°F	(600 °F		Digital data acquisition system analog-to-digital converter.	Thermocouple verification of NBS conformic voltage substitution calibration
		±1 °F	)30	±0 375	.	±0 380		(1600 °F	Chromel®-Alumel® Thermocouple		
ZP, ZT, ZA, in		±0 001 in	)30		±0 002 in.		±0.004 in.	(9 0 in	Potentiometer and Optical	Digital data acquisition system analog-to-digital converter.	Precision Micrometer
(Survey Station), in		±0 011 in.	)30		±0 012 in		±0.034 in.	(26 in	Potentiometer and Optical Graticule	Digital Data Acquisition System A/D Converter Optically Positioned Zero	Precision Micrometer
ERMS, mv CURRENT, ma EBAR, mv	±0 5 ±0.5 ±0.5				0+ 0+ 0+	±1 ±1 ±1		(1200 mv (5 ma (300 mv	Philco Ford Corp. Model #ADP-12/13 Hot-wire Anemometer System	Digital data acquisition system analog-to-digital converter.	Precision Digital Voltmeter

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

Note: + Bias assumed to be zero.

TABLE 2. CONTINUED

a. CONCLUDED

Parameter Designation	Steady-State Estimated Measurement*							Range**		Type of Measuring Device	Type of Recording Device	Method of System Calibration
	Precision Index (S)			Bias (B)		Uncertainty ±(B + t_{95}S)						
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement	Amplitude	Frequency			
Flow Turbulence	Unknown		—	Unknown		Unknown		DC to 1 volt RMS (Heating current up to 5 ma)	DC to 250 KHZ or 500 KHZ (frequency response band determined by filters used)	Hot-wire Anemometer System (20 micro-inch diam and 50 micro-inch diam)	• Analog data recorded on tape for subsequent playback and reduction • 40 loops of data recorded on digital data acquisition system (AD converter) for each run	Wire characteristics by oven calibration Heat-transfer characteristics by calibration in tunnel free-stream

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

** Range of present measurements

TABLE 2. CONCLUDED

b. Calculated Parameters									
Parameter Designation	Estimated Measurement*							RE/FT $\times 10^{-6}$ Nom.	MACH, Nominal
	Precision Index (S)			Bias (B)		Uncertainty $\pm (B + t_{95}S)$			
	Percent of Reading	Unit of Measurement	Degree of Freedom	Percent of Reading	Unit of Measurement	Percent of Reading	Unit of Measurement		
P, psi	0.82		)30	0.02		1.65		2.5	8.0
PT2, apsi	0.57			0.02		1.16			
Q, psi	0.57			0.02		1.16			
T, °F	0.25			0.24		0.74			
V, ft/sec	0.04			0.12		0.20			
RHo, lbm/ft^3	0.59			0.25		1.43			
MU, $lbf\text{-}sec/ft^2$	0.25			0.24		0.74			
M	0.13++			0+		0.26			
RE, per ft	0.36			0.37		1.09			

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

NOTE: + Bias assumed to be zero.

++ Determined from test section repeatability and uniformity during tunnel calibration.

TABLE 3. Test Summary

a. Surface pressure and temperature
(Type 2 Data)

MODEL CONFIG	ALPHA, deg	PHI, deg	RN, in.	RE/FT $\times 10^{-6}$	RUN
7-deg Cone	0	-90	0.0015	1.3	358
			0.150	2.5	72,73
			0.350	2.5	210,211
			0.700	2.5	302,303,305
					312,313,314
					315,317,322
					330,339,340,
					341,343,349
	0	0	0.700	2.6	701,706,715
		45			721
		45		2.5	729,738,742
	0	-85	2.000	3.5	130,131
			0.0015	0.5	408,409,410
				2.6	411,412
				1.0	429
	-2			1.0	430
	+2			1.0	431
	+2			0.6	448,449
	0			0.6	450,451
	-2			0.6	452,453
	-4			1.0	471,472
	-2			2.3	477
	0	0	0.0015	2.0	524
		-110			525,526,529,531,
					532,553,554,564,
					565,577,578,604,
					605,606,607
	-4	20	0.0015		608,609
	-4	0			617,618
	+4	0			619,620
	0	-110	0.0015	3.0	579,580,581,582,
					583,584,591,592,
					595,596
		0	0.0015		586,587

NOTES: 1. Test 1, RUN < 200; Test 2, 200 < RUN < 300; Test 3, 300 < RUN < 400; Test 4, 400 < RUN < 500; Ref. 5, 500 < RUN < 700; and for present testing, RUN > 700.

2. Surface pressure measurements are also included on Boundary-Layer Survey Data (Type 4).

TABLE 3. Continued

b. Mean-Flow Boundary-Layer Survey Matrix (Type 4 Data)

RN, in.	RE/FT $\times10^{-6}$	ALPHA, deg	X STATION (NOMINAL) 6	8	10	11	15	16	18	20	24	25	26	28	30	31	32	35	36	37	42
0.0015	0.5	0																		272	
	1.0	0			112		111			110		109			108			107		286[a]	
	1.0	+2				459[b]			458[b]										456[b] 457[bc]		
	1.3	0												373	372		371		370		
	2.0		601				602				603										
	3.0		600																		
0.15	2.5				106	105				76 104		103			75 102			74 101			
0.25	2.5				255[e] 254							249			241 208[c] 207[c]			240 242[c]			
0.70	2.5												376			377				378	
	2.6							727[f]							726[f]				725[f]		724[f]
0.90	2.5											257[e] 256									
2.00	3.5							124 125				123						122			

NOTES:

1. PHI = -90 deg except where noted.
2. Test 1, Run < 200; Test 2, 200 < Run < 300; Test 3, 300 < Run < 400; Test 4, 400 < Run < 500; Test 5, 500 < Run < 700; and for present testing, Run > 700.
3. Superscripts:
   a - Alpha = -2.0 deg, PHI = 0 deg, windward survey
   b - PHI = -85 deg
   c - Cold wall data; TWL = 525-, 640-, 540-deg R. for Runs 207, 208, 242, respectively.
   All other data obtained at hot wall conditions (TWL ≥ 860 deg R).

   e - Extended survey of preceding RUN, all outside boundary layer.
   f - PHI = 45 deg.

TABLE 3. Continued

c. Hot-Wire Qualitative Survey Matrix (Type 3/Type 4 Data), RUNS

RN, in.	RE/FT $\times 10^{-6}$	ALPHA, deg.	X STATION (NOMINAL)																	
			10	14	15	17	19	20	25	26	27	28	30	31	32	33	34	35	36	37
0.0015	1.0	0	51	46		42		34			26		21			16	15	12	11	8
	1.3	0										373	372		371				370	
0.15	2.5	0	96	88		84		79	67		64		60			57				54
0.25	2.5	0	255^{e} 254										208^{c} 207^{c}					240 242^{c}		
0.50	3.5	0	140		141	142		139	138									134		
0.70	2.5	0								376				377						378
0.90	2.5	0							257^{e} 256											
2.00	3.5	0																129 132		

NOTES:

1. Run numbers < 200 from Test 1; RUN numbers < 300 from Test 2; RUN numbers < 400 from Test 3.
2. Run numbers < 200 obtained as Data Type 3; Run numbers > 200 obtained as Data Type 4.
3. Superscripts:

   c - Cold Wall data, TWL ≈ 525-, 640-, 540-deg R. for RUNS 207, 208, 242, respectively. All others at hot wall conditions (TLW ≥ 860 deg R).
   e - Extended survey of preceding run, all outside boundary layer.

TABLE 3. Continued

d. PART-I. Hot-Wire Quantitative Run Matrix (Type 9 Data) for ALPHA = 0 RUNS

RN (in)	RE/FT ($\times 10^{-6}$)	ALPHA (deg)	X STATION 6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	FREE-STREAM RUN	FREE-STREAM X/ZP
	0.5	0								[illegible]		[illegible]		[illegible]		266		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	[illegible]	[illegible]						270	[illegible]
	1.0	0					50	49	48	47	45	46	43	44	96 455	95	93	92	91	30	29	28	27	25	24	23	22	21	20	19	18	17	16	9							
0.0015	1.5	0																																						55 39	4.7/6 9.8/2
	2.0	0	503	[illegible]	[illegible]	559	558	557	556	555	554	[illegible]	[illegible]	[illegible]	570	[illegible]	[illegible]	573	574	575	576			357	360	364	[illegible]	[illegible]	[illegible]	365	366	367	368	369							
	3.0	0	597		593	589	588																																	551	-1/7
0.15	2.5	0					75	74	73	72 90	87	85	85	83	82	81	78	71	70	69	68	66	65	63	62	61	59	58		56		57		59						98,99 100	25/4 98/2
0.25	2.5	0															NOTE 3					237 251 250	236	235 253 248 232	234 233	229 224	225 222	221 220	219 238 247 218 239 246	217 216	215 214	213 252 212 231	230 229	220 249 227 244							
0.50	3.5	0																														195 196								117 118	10 1/6 14.3/2
0.70	2.6	0											799 740 747 746 716 717	745 744	743 744	742	741	734	733	732	731 718 719	375	378	355	359	353	352	348 351	347	346	345	336 344 356	335	334	328 332 337	327 330 357	326	325 324		321 320	319 318
	2.6	C																																							
2.00	3.5	0																														128 127				722		723	720		

NOTES: 1. Roll attitude: PHI = -90 deg for RUN < 500; PHI = -110 deg for 500 < RUN < 700; PHI = 45 deg for RUN > 700.
2. Test 1, RUN < 200; Test 2, 200 < RUN < 300; Test 3, 300 < RUN < 400; Test 4, 400 < RUN < 500; Test 5, 500 < RUN < 700; and for present testing, RUN > 700.
3. Two distinct maximum disturbance energy peaks were noted for some runs. "Outer Peak" RUN numbers listed above dashed line; "Inner Peak" RUN numbers listed below dashed line.
4. SUPERSCRIPTS: s - Single sensitivity for RUN numbers so noted. For all other RUNs, data were obtained on 11 wire sensitivities.
e - No "inner peak" observed; data obtained at approximate height where peak was previously observed.

d. PART-II. Hot-Wire Quantitative Run Matrix (Type 9 Data) for ALPHA ≠ 0 RUNS

RN (in)	RE/FT ($\times 10^{-6}$)	ALPHA (deg)	X STATION 10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
0.0015	0.5	2.0		432	433		434		435		437		438		439		440		441		442		443		444		445			
0.0015	1.0	-2.0						427	426		425		424		423		422		285 421	284	283 420	282	281 419	280	279 418	278	277 417	276 416	275 415	274 414
0.0015	1.0	-4.0										474	470		471		469	468		467		466		465		464		463	452 451	460
0.0015	2.0	-4.0	612	613	611	614	610		615 616																					
0.70	2.5	-2.0																												975 976

NOTES 1. RUN numbers 300 from Test 2; TUN numbers between 400 and 500 from Test 4; 500 < RUN < 700 from Test 5.
2. Single wire sensitivity for each run.

TABLE 3. Continued

e. Hot-wire anemometer and total-temperature probe calibration in free-stream (Type 6 Data)

RUN	PT (range) psia	RE (range)x10^{-5}, per in.	Hot-Wire No.
6	202-355	0.75-1.3	6
7	150-352	0.56-1.3	7
37	152-352	0.57-1.3	7
52	352-579	1.3-2.1	8
77	349-577	1.3-2.1	14
80	300-582	1.1-2.1	15
92	300-577	1.1-2.1	17
114	400-804	1.4-2.9	3
126	399-808	1.4-2.9	2
133	398-806	1.4-2.9	1
137	399-807	1.4-2.9	16
209	200-580	0.74-2.1	31
226	201-579	0.76-2.1	33
243	199-579	0.74-2.1	40
301	214-581	0.80-2.1	4
304	298-583	1.09-2.1	6
306	582	2.1	7
316	296-581	1.09-2.1	8
323	583	2.1	8
329	298-582	1.09-2.1	11
331	302-583	1.10-2.1	15
333	582	2.1	17
342	360-581	1.32-2.1	16
350	360-582	1.31-2.1	52
413	226-601	0.85-2.2	33
454	228-602	0.84-2.2	33
523	220-440	0.84-1.7	54
552	300-440	1.1-1.7	76
702	139	0.54	69
704,705	199-576	0.77-2.2	63
711	200-503	0.77-1.9	67
712	275-505	1.1-1.9	61
713	193-427	0.75-1.6	64
714	226-579	0.87-2.2	35
720	231-577	0.89-2.2	38
728	229-553	0.88-2.1	39
737	229-553	0.88-2.1	36
741	215-546	0.83-2.1	37

NOTES:

1. Run numbers < 200 from Test 1; Run numbers < 300 from Test 2; Run numbers < 400 from Test 3; Run numbers < 500 from Test 4; Run numbers < 700 from Test 5; Run numbers > 700 from present test
2. Hot-wire probes were numbered independently for each of the six test programs represented in this table. For example, Hot-Wire No. 6 for RUN 6 was not the same sensor as that used for RUN 304.

TABLE 3. Concluded

f. Hot-wire identification

Hot-Wire No.	RUN No.	Wire Diameter
6	6	20 μ-in.
7	7-5,	
8	52-71	
14	77-79	
15	80-91	
17	92-100	
3	114-121	
2	126-128	
1	133-136	
16	137-142	
HF-4	207-208	
31	209-225	20 μ-in.
33	226-239,250-285	
39	242	
40	243-249	
4	301	20 μ-in.
6	304	
7	306-311	
8	316,318-321,323	
11	324-329	
15	331-332	
17	333-338	
16	342,344-349	
52	350-357,359-378	50 μ-in.
33	414-427,432-447 455,460-470,473-476	20 μ-in.
54	523	20 μ-in.
76	551,552,555-559 561-563,566-576	50 μ-in.
71	585	50 μ-in.
74	588-590	50 μ-in.
177	597	50 μ-in.
73	610-616	50 μ-in.
69	702	50 μ-in.
63	704,705,709,710	
67	711	
61	712	
64	713	
35	714,716,-719	20 μ-in.
38	720,722,723	
39	728,731-736	
36	737,739,740	
37	741,743-748	

NOTES: 1. Run numbers < 200 from Test 1; Run numbers < 300 from Test 2; Run numbers < 400 from Test 3; Run numbers < 500 from Test 4; Run numbers < 700 from Test 5; Run numbers > 700 from present test

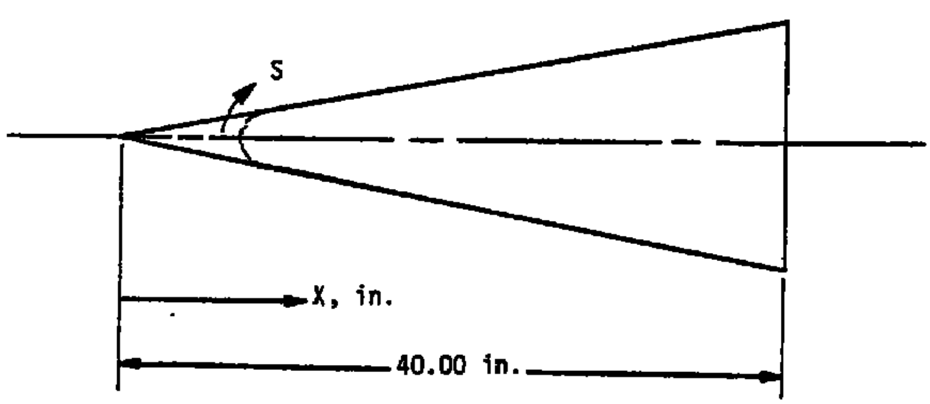
2. A hot-film probe was used for RUNS 207-208 (HF-4)

3. Hot-Wire probes were numbered independently for each of the six test programs represented in this table. For example, Hot-Wire No. 6 for RUN 6 was not the same sensor as that used for RUN 304.

TABLE 4. Stations for Mean-Flow Surveys

X(STATION)	S, in.							
	RN, in.	0.0015	0.15	0.25	0.50	0.70	0.90	2.00
6		6.00*						
10		10.07	9.08	8.40	6.73			
11		11.18						
14		14.10	13.11					
15		15.10,14.93*	14.11		11.76			
16						11.43		2.73
17		17.12	16.13		13.78			
18		18.08						
19					15.95			
20		20.14	19.15					
24		24.01*						
25		25.18	24.19	23.51	21.84		19.16	11.80
26						21.51		
27		27.19	26.20					
28		28.20						
30		30.22	29.23	28.55		25.54		
31						26.55		
32		32.23						
33		33.24	32.25					
34		34.25						
35		35.25	34.26	33.59	31.91			21.87
36		36.26				31.58		
37		37.27	36.28			32.59		
42						37.60		

* Indicates present test data.



DATE COMPUTED 3-NOV-[illegible]
DATE RECORDED 21-JUL-[illegible]
TIME RECORDED 3: 7:43
TIME COMPUTED 06:26
PROJECT NO V 8-07

TEST POINT 735 PAGE 1

CONFIG: BLUNT 7-DEG CONE (RN = 0.79 IN.)
XSTA = 20.00 IN.

DATA TYPE 9
HOT WIRE ANEMOMETER DATA

POINT	CURRENT (AMP)	ECAP (MV)	ERMS (MV)	PT (PSIA)	TT (DEG R)	P (PSIA)	Q (PSIA)	T (DEG R)	RE (PER FT)	ZA (IN.)
1	0.202	22.91	135.21	5.516E+02	1.310E+03	5.699E-02	2.546E+00	9.514E+01	2.090E+05	1.906E-02
2	0.002	0.01	137.95	5.519E+02	1.310E+03	5.702E-02	2.548E+00	9.514E+01	2.091E+05	2.674E-01
3	0.202	24.79	138.29	5.512E+02	1.310E+03	5.695E-02	2.545E+00	9.514E+01	2.088E+05	2.674E-01
4	0.402	49.87	139.51	5.501E+02	1.310E+03	5.684E-02	2.540E+00	9.514E+01	2.084E+05	2.674E-01
5	0.608	75.85	142.93	5.507E+02	1.310E+03	5.690E-02	2.542E+00	9.514E+01	2.086E+05	2.674E-01
6	0.811	102.17	147.02	5.519E+02	1.310E+03	5.702E-02	2.548E+00	9.514E+01	2.091E+05	2.674E-01
7	1.012	129.02	152.73	5.513E+02	1.310E+03	5.696E-02	2.545E+00	9.514E+01	2.088E+05	2.674E-01
8	1.200	154.65	159.15	5.504E+02	1.310E+03	5.687E-02	2.541E+00	9.514E+01	2.085E+05	2.674E-01
9	1.404	183.84	169.54	5.507E+02	1.310E+03	5.690E-02	2.542E+00	9.514E+01	2.086E+05	2.674E-01
10	1.555	206.15	180.56	5.517E+02	1.310E+03	5.700E-02	2.547E+00	9.514E+01	2.090E+05	2.674E-01
11	1.695	227.77	192.64	5.511E+02	1.310E+03	5.694E-02	2.544E+00	9.514E+01	2.088E+05	2.674E-01
12	1.853	253.10	210.80	5.502E+02	1.310E+03	5.685E-02	2.540E+00	9.514E+01	2.084E+05	2.674E-01
13	1.991	276.14	230.36	5.504E+02	1.310E+03	5.687E-02	2.541E+00	9.514E+01	2.085E+05	2.674E-01

ALPHA = 0.04 DEG XC 19.97 (IN.)

TP [illegible] 735

SAMPLE 1. Hot-Wire Anemometer Data (Type 9)

DATE COMPUTED 3-NOV-66
DATE RECORDED 21-JUL-66
TIME RECORDED 3: /143
TIME COMPUTED 06:20
PROJECT NO V 0-07

RUN NUMBER 735 PAGE 2

CONFIG: BLUNT 7-DEG CONE (RN = 0.70 IN.)
XSTA = 20.00 IN.

DATA TYPE 9
HOT WIRE ANEMOMETER DATA

POINT	PT (PSIA)	TT (DEG R)	PTI (PSIA)	TE (DEG R)	ZI (IN)	PP (PSIA)	ML	TTIU/TT	TIL/TT
1	5.516E+02	1.310E+03	1.255E-01	1.038E+03	2.500E-02	1.791E-01	7.3147E-01	8.856E-01	8.926E-01
2	5.519E+02	1.310E+03	1.256E-01	1.038E+03	2.736E-01	2.719E+00	4.0570E+00	9.466E-01	0.000E+00
3	5.512E+02	1.310E+03	1.254E-01	1.038E+03	2.736E-01	2.716E+00	4.0568E+00	9.469E-01	0.000E+00
4	5.501E+02	1.310E+03	1.252E-01	1.038E+03	2.736E-01	2.713E+00	4.0583E+00	9.471E-01	0.000E+00
5	5.507E+02	1.310E+03	1.253E-01	1.038E+03	2.736E-01	2.717E+00	4.0599E+00	9.471E-01	0.000E+00
6	5.519E+02	1.310E+03	1.256E-01	1.038E+03	2.736E-01	2.720E+00	4.0573E+00	9.472E-01	0.000E+00
7	5.513E+02	1.310E+03	1.254E-01	1.038E+03	2.736E-01	2.716E+00	4.0563E+00	9.472E-01	0.000E+00
8	5.504E+02	1.310E+03	1.252E-01	1.038E+03	2.736E-01	2.714E+00	4.0579E+00	9.472E-01	0.000E+00
9	5.507E+02	1.310E+03	1.253E-01	1.038E+03	2.736E-01	2.719E+00	4.0614E+00	9.473E-01	0.000E+00
10	5.517E+02	1.310E+03	1.255E-01	1.038E+03	2.736E-01	2.720E+00	4.0585E+00	9.469E-01	0.000E+00
11	5.511E+02	1.310E+03	1.254E-01	1.038E+03	2.736E-01	2.715E+00	4.0562E+00	9.468E-01	0.000E+00
12	5.502E+02	1.310E+03	1.257E-01	1.038E+03	2.737E-01	2.714E+00	4.0568E+00	9.465E-01	0.000E+00
13	5.504E+02	1.310E+03	1.252E-01	1.038E+03	2.736E-01	2.718E+00	4.0613E+00	9.471E-01	0.000E+00

ALPHA = 0.04 DEG XC 19.97 (IN.)

n = 7.989

RUN NUMBER 735

SAMPLE 1. Concluded

DATE COMPUTED 3-NOV-[illegible]
DATE RECORDED 16-JUL-[illegible]
TIME RECORDED 221571 [illegible]
TIME COMPUTED [illegible]
PROJECT NO [illegible] [illegible]-07

RUN NUMBER 764 PAGE 1

CONFIG: [illegible] 7-DEG CONE (RN = 0.70 IN.)
XSTA = 0.00 IN.

DATA TYPE 6, PROBE FLOW CALIBRATION

POINT	M	PT (PSIA)	TT (DEG F)	RE	PP (PSIA)	ML	TTTU (DEG R)	TTTU/TT	ETA	RE1D**.5
1	7.91	199.23	1307.67	7.71[illegible]+04	1.6755	8.0164	1210.8560	0.9260	0.9201	6.489E+00
2	7.93	199.64	1308.67	7.72[illegible]+04	1.6799	8.0154	1210.8908	0.9253	0.9193	6.492E+00
3	7.95	266.87	1309.67	1.025E+05	2.2177	8.0217	1207.3466	0.9219	0.9157	7.460E+00
4	7.95	267.17	1309.67	1.026E+05	2.2415	8.0207	1207.5569	0.9220	0.9159	7.464E+00
5	7.96	347.61	1310.67	1.327E+05	2.9063	8.0268	1204.2479	0.9188	0.9124	8.466E+00
6	7.96	347.01	1309.67	1.320E+05	2.9019	8.0264	1203.9853	0.9193	0.9129	8.463E+00

RUN NUMBER 764

SAMPLE 2. Probe Flow Calibration (Type 6)

DATE COMPUTED 3-AUG-66
DATE RECORDED 18-JUL-66
TIME RECORDED 5:51:10
TIME COMPUTED 08:22
PROJECT NO V 8-07

RUN NUMBER 724 PAGE 1

CONFIG: BLUNT 7-DEG CONE (RN = 0.70 IN.)
XSTA = 42.00 IN.

DATA TYPE 4
FLOW FIELD SURVEYS

POINT	PT (PSIA)	TT (DEG F)	PT2 (PSIA)	P (PSIA)	ZP (IN)	PP (PSIA)	PSL (PSIA)	THG (DEG R)	ZT (IN)	TFTO (DEG R)	ZA (IN)	TTA (DEG R)	MA	DELTA (PER IN)
1	577.03	1310.7	4.920	0.059	0.0370	0.161	0.150	947.1	0.0233	1130.6	0.0233	1098.5	3.32E-01	7.963E+02
2	574.12	1310.7	4.896	0.059	0.0470	0.169	0.149	947.1	0.0333	1127.6	0.0333	1123.3	3.67E-01	8.792E+02
3	575.23	1310.7	4.905	0.059	0.0570	0.156	0.150	947.1	0.0433	1119.3	0.0433	1120.9	3.31E-01	7.922E+02
4	576.93	1310.7	4.919	0.059	0.0670	0.155	0.150	947.1	0.0533	1112.5	0.0533	1113.5	2.60E-01	6.246E+02
5	576.23	1310.7	4.913	0.059	0.0770	0.157	0.150	947.1	0.0633	1107.8	0.0633	1108.4	2.21E-01	5.335E+02
6	574.77	1310.7	4.897	0.059	0.0870	0.160	0.149	947.1	0.0733	1104.9	0.0733	1105.8	2.43E-01	5.891E+02
7	575.23	1310.7	4.905	0.059	0.0970	0.168	0.150	947.1	0.0833	1105.1	0.0833	1106.2	2.88E-01	6.990E+02
8	577.03	1310.7	4.920	0.059	0.1070	0.181	0.150	947.1	0.0933	1106.2	0.0933	1106.7	3.73E-01	9.091E+02
9	575.61	1310.7	4.908	0.059	0.1170	0.197	0.150	947.1	0.1033	1109.5	0.1033	1112.7	4.88E-01	1.193E+03
10	573.62	1310.7	4.892	0.059	0.1270	0.216	0.149	947.1	0.1133	1114.9	0.1133	1119.6	5.95E-01	1.460E+03
11	575.63	1310.7	4.908	0.059	0.1370	0.254	0.150	947.1	0.1233	1122.9	0.1233	1129.6	7.11E-01	1.751E+03
12	577.43	1310.7	4.923	0.060	0.1470	0.301	0.150	947.1	0.1333	1134.3	0.1333	1143.5	8.45E-01	2.092E+03
13	575.33	1310.7	4.906	0.059	0.1570	0.370	0.150	947.1	0.1433	1149.0	0.1433	1161.1	9.91E-01	2.477E+03
14	573.61	1310.7	4.892	0.059	0.1670	0.471	0.149	947.1	0.1533	1166.9	0.1533	1183.1	1.15E+00	2.899E+03
15	575.93	1310.7	4.911	0.059	0.1770	0.614	0.150	947.1	0.1633	1188.7	0.1633	1209.4	1.35E+00	3.414E+03
16	577.23	1310.7	4.922	0.060	0.1870	0.771	0.150	947.1	0.1733	1207.6	0.1733	1232.1	1.58E+00	4.124E+03
17	574.03	1310.7	4.895	0.059	0.1920	0.849	0.149	947.1	0.1783	1213.9	0.1783	1243.3	1.70E+00	4.504E+03
18	575.03	1310.7	4.903	0.059	0.1970	0.992	0.150	947.1	0.1833	1223.2	0.1833	1255.7	1.82E+00	4.895E+03
19	576.93	1310.7	4.919	0.059	0.2020	1.115	0.150	947.1	0.1883	1232.0	0.1883	1266.5	1.93E+00	5.263E+03
20	575.53	1310.7	4.904	0.059	0.2068	1.242	0.150	947.1	0.1931	1238.7	0.1931	1275.8	2.04E+00	5.647E+03
21	573.93	1310.7	4.894	0.059	0.2120	1.406	0.149	947.1	0.1983	1245.5	0.1983	1286.5	2.22E+00	6.361E+03
22	576.02	1310.7	4.912	0.059	0.2170	1.599	0.150	947.1	0.2033	1251.2	0.2033	1294.9	2.36E+00	6.919E+03
23	577.53	1310.7	4.924	0.060	0.2220	1.801	0.150	947.1	0.2083	1255.5	0.2083	1301.9	2.51E+00	7.540E+03
24	575.13	1310.7	4.904	0.059	0.2270	1.974	0.150	947.1	0.2133	1257.6	0.2133	1306.9	2.68E+00	8.304E+03
25	573.82	1310.7	4.893	0.059	0.2320	2.180	0.149	947.1	0.2183	1259.2	0.2183	1311.3	2.80E+00	9.221E+03
26	576.23	1310.7	4.913	0.059	0.2370	2.419	0.150	947.1	0.2233	1260.3	0.2233	1314.8	3.03E+00	1.013E+04
27	576.93	1310.7	4.919	0.059	0.2470	2.806	0.150	947.1	0.2333	1257.6	0.2333	1315.9	3.36E+00	1.194E+04
28	574.02	1310.7	4.895	0.059	0.2570	3.169	0.149	947.1	0.2433	1253.1	0.2433	1314.3	3.60E+00	1.395E+04
29	574.97	1310.7	4.903	0.059	0.2670	3.538	0.150	947.1	0.2532	1248.2	0.2532	1311.6	3.92E+00	1.569E+04
30	577.13	1310.7	4.921	0.060	0.2770	3.809	0.150	947.1	0.2632	1244.6	0.2632	1309.7	4.16E+00	1.745E+04
31	576.02	1310.7	4.912	0.059	0.2870	4.139	0.150	947.1	0.2733	1242.4	0.2733	1306.7	4.37E+00	1.909E+04
32	573.62	1310.7	4.892	0.059	0.2970	4.634	0.149	947.1	0.2833	1241.0	0.2833	1306.3	4.53E+00	2.041E+04
33	575.73	1310.7	4.909	0.059	0.3170	5.060	0.150	947.1	0.3032	1239.8	0.3032	1309.0	4.87E+00	2.312E+04
34	577.73	1310.7	4.926	0.060	0.3370	5.504	0.150	947.1	0.3232	1238.2	0.3232	1308.8	5.17E+00	2.590E+04
35	574.53	1310.7	4.899	0.059	0.3570	5.932	0.149	947.1	0.3432	1237.3	0.3432	1306.6	5.40E+00	2.817E+04
36	574.63	1310.7	4.900	0.059	0.3770	6.180	0.149	947.1	0.3632	1236.8	0.3632	1306.9	5.50E+00	2.959E+04
37	577.03	1310.7	4.920	0.059	0.4168	6.507	0.150	947.1	0.4030	1236.1	0.4030	1306.8	5.73E+00	3.137E+04
38	576.83	1310.7	4.918	0.059	0.4570	6.766	0.150	947.1	0.4432	1235.7	0.4432	1306.7	5.85E+00	3.266E+04
39	573.42	1310.7	4.890	0.059	0.4970	7.007	0.149	947.1	0.4832	1235.1	0.4832	1306.7	5.97E+00	3.377E+04
40	575.73	1310.7	4.909	0.059	0.5370	7.256	0.150	947.1	0.5232	1235.4	0.5232	1309.1	6.08E+00	3.494E+04
41	577.63	1310.7	4.925	0.060	0.5770	7.139	0.150	947.1	0.5632	1234.7	0.5632	1306.7	6.15E+00	3.592E+04
42	574.83	1310.7	4.902	0.059	0.6170	7.542	0.149	947.1	0.6032	1231.8	0.6032	1306.9	6.21E+00	3.646E+04
43	573.93	1310.7	4.894	0.059	0.6570	7.656	0.149	947.1	0.6432	1234.5	0.6432	1306.8	6.27E+00	3.698E+04
44	576.33	1310.7	4.914	0.059	0.6970	7.706	0.150	947.1	0.6832	1234.4	0.6832	1306.9	6.31E+00	3.752E+04
45	577.04	1310.7	4.920	0.059	0.7370	7.831	0.150	947.1	0.7231	1234.4	0.7231	1306.9	6.33E+00	3.790E+04

SAMPLE 3. Flow-Field Survey Data (Type 4)

```
46  574.42  1310.7   4.898  0.059 0.7870  7.878  0.149  947.1  0.7731  1234.4  0.7731  1309.0  6.366E+00  3.815E+04
```

MEAN VALUES

```
  PHI =  45.0   DEG          PT = 575.6         PSIA               P =    0.0593 PSIA
    M =   7.99               TT =1310.7         DEG R            PWL =    0.150  PSIA
ALPHA =  -0.0   DEG         PT2 =    4.908      PSIA             TWL =  947.1    DEG R
  DEW =  -60.   DEG F        RE =    2.176E+05  PER IN             V = 3821.7    FT/SEC
                             MU =    7.657E-08  LBF-SEC/FT2        Q =    2.653  PSIA
                            RHO =    1.683E-03  LBM/FT3            T =   95.2    DEG R
```

SAMPLE 3. Continued

DATE COMPUTED 3-JUL-86
DATE RECORDED 16-JUL-86
TIME RECORDED 535110
TIME COMPUTED 06822
PROJECT NO V A-07

RUN NUMBER 724 PAGE 2

CONFIG: BLUNT 7-DEG CONE (RN = 0.70 IN.)
XSTA = 42.09 IN.

DATA TYPE 4
FLOW FIELD SURVEYS

LOOP	ZP (IN)	PE/PPE	ME	RE/RF	TTEB (DEG R)	TTE (DEG R)	TEB/TTE	TE (DEG R)	UE (FT/SEC)	UE/UE	REE (PER IN)	REFF (PER IN)
1	0.0370	0.052	3.63E-01	0.196	1124.5	1126.3	0.859	1097.4	5.848E+02	0.177	8.854E+02	8.705E+02
2	0.0470	0.050	3.09E-01	0.177	1116.8	1118.0	0.853	1097.0	5.015E+02	0.145	7.495E+02	7.403E+02
3	0.0570	0.049	2.40E-01	0.060	1110.8	1111.3	0.846	1098.7	3.898E+02	0.112	5.822E+02	5.779E+02
4	0.0670	0.049	2.20E-01	0.055	1106.5	1107.2	0.845	1096.6	3.573E+02	0.103	5.366E+02	5.333E+02
5	0.0770	0.050	2.59E-01	0.064	1104.6	1105.6	0.844	1091.0	4.149E+02	0.121	6.310E+02	6.285E+02
6	0.0870	0.050	3.14E-01	0.078	1105.4	1106.6	0.844	1085.1	5.067E+02	0.146	7.708E+02	7.611E+02
7	0.0970	0.053	4.12E-01	0.103	1107.2	1109.5	0.847	1073.1	6.672E+02	0.191	1.026E+03	1.006E+03
8	0.1070	0.057	5.28E-01	0.132	1111.3	1115.1	0.851	1056.1	8.416E+02	0.243	1.340E+03	1.299E+03
9	0.1170	0.062	6.37E-01	0.159	1117.5	1122.9	0.857	1038.6	1.007E+03	0.290	1.652E+03	1.589E+03
10	0.1270	0.069	7.59E-01	0.189	1126.8	1134.3	0.865	1017.2	1.186E+03	0.342	2.008E+03	1.876E+03
11	0.1370	0.080	8.98E-01	0.224	1139.4	1149.7	0.877	989.9	1.385E+03	0.400	2.462E+03	2.231E+03
12	0.1470	0.095	1.05E+00	0.261	1155.3	1168.6	0.892	957.7	1.593E+03	0.459	3.000E+03	2.631E+03
13	0.1570	0.117	1.22E+00	0.304	1174.5	1192.1	0.910	917.8	1.815E+03	0.524	3.659E+03	3.079E+03
14	0.1670	0.149	1.43E+00	0.356	1196.1	1218.7	0.930	864.9	2.062E+03	0.595	4.579E+03	3.649E+03
15	0.1770	0.194	1.67E+00	0.416	1212.1	1240.5	0.946	796.1	2.311E+03	0.667	5.926E+03	4.110E+03
16	0.1870	0.244	1.90E+00	0.473	1230.0	1263.9	0.964	734.0	2.523E+03	0.728	7.450E+03	5.171E+03
17	0.1920	0.268	2.01E+00	0.500	1237.2	1273.6	0.972	704.7	2.614E+03	0.754	8.231E+03	5.523E+03
18	0.1970	0.313	2.17E+00	0.544	1243.9	1284.1	0.980	656.7	2.746E+03	0.792	9.786E+03	6.209E+03
19	0.2020	0.352	2.32E+00	0.579	1249.9	1292.9	0.986	621.6	2.838E+03	0.819	1.117E+04	6.771E+03
20	0.2068	0.392	2.46E+00	0.614	1254.5	1300.1	0.992	587.2	2.927E+03	0.844	1.269E+04	7.345E+03
21	0.2120	0.444	2.64E+00	0.656	1257.1	1305.7	0.996	546.6	3.020E+03	0.871	1.481E+04	8.099E+03
22	0.2170	0.505	2.82E+00	0.701	1258.9	1310.3	1.000	500.9	3.107E+03	0.896	1.748E+04	8.995E+03
23	0.2220	0.568	2.99E+00	0.745	1260.2	1314.2	1.003	471.1	3.183E+03	0.918	2.096E+04	9.921E+03
24	0.2270	0.623	3.14E+00	0.783	1260.1	1316.0	1.004	442.1	3.240E+03	0.935	2.327E+04	1.071E+04
25	0.2320	0.688	3.31E+00	0.825	1258.0	1315.9	1.004	411.8	3.290E+03	0.951	2.687E+04	1.167E+04
26	0.2370	0.761	3.49E+00	0.874	1256.1	1315.8	1.004	383.1	3.348E+03	0.966	3.128E+04	1.279E+04
27	0.2470	0.866	3.76E+00	0.937	1251.3	1313.4	1.002	342.6	3.415E+03	0.985	3.930E+04	1.463E+04
28	0.2570	1.000	4.02E+00	1.000	1246.6	1310.7	1.000	318.2	3.467E+03	1.000	4.784E+04	1.634E+04
29	0.2670	1.117	4.24E+00	1.057	1243.6	1309.2	0.999	284.4	3.509E+03	1.012	5.721E+04	1.808E+04
30	0.2770	1.221	4.43E+00	1.104	1241.8	1308.5	0.998	265.3	3.541E+03	1.021	6.621E+04	1.964E+04
31	0.2870	1.306	4.59E+00	1.144	1240.6	1306.3	0.998	250.6	3.565E+03	1.026	7.428E+04	2.069E+04
32	0.2970	1.399	4.77E+00	1.187	1240.2	1308.9	0.999	236.1	3.590E+03	1.036	8.373E+04	2.224E+04
33	0.3170	1.597	5.09E+00	1.267	1238.6	1308.8	0.999	211.9	3.631E+03	1.047	1.052E+05	2.515E+04
34	0.3370	1.762	5.34E+00	1.330	1237.5	1308.8	0.999	195.1	3.658E+03	1.055	1.252E+05	2.756E+04
35	0.3570	1.872	5.52E+00	1.375	1236.9	1308.9	0.999	184.3	3.676E+03	1.060	1.402E+05	2.918E+04
36	0.3770	1.951	5.64E+00	1.404	1236.5	1308.9	0.999	176.0	3.686E+03	1.063	1.510E+05	3.033E+04
37	0.4168	2.054	5.77E+00	1.438	1235.9	1308.7	0.999	170.8	3.696E+03	1.067	1.653E+05	3.166E+04
38	0.4570	2.136	5.89E+00	1.467	1235.5	1308.7	0.998	164.9	3.707E+03	1.069	1.776E+05	3.306E+04
39	0.4970	2.211	6.01E+00	1.497	1235.1	1308.7	0.998	159.1	3.717E+03	1.072	1.904E+05	3.410E+04
40	0.5370	2.290	6.11E+00	1.521	1235.2	1309.1	0.999	154.8	3.724E+03	1.073	2.021E+05	3.531E+04
41	0.5770	2.346	6.17E+00	1.538	1234.6	1308.7	0.999	151.8	3.728E+03	1.075	2.111E+05	3.617E+04
42	0.6170	2.380	6.23E+00	1.552	1234.7	1308.9	0.999	147.4	3.733E+03	1.077	2.174E+05	3.663E+04
43	0.6570	2.417	6.28E+00	1.565	1234.5	1308.8	0.999	147.1	3.736E+03	1.078	2.236E+05	3.716E+04
44	0.6970	2.451	6.32E+00	1.573	1234.4	1308.9	0.999	145.8	3.738E+03	1.079	2.290E+05	3.766E+04
45	0.7370	2.473	6.34E+00	1.579	1234.1	1308.9	0.999	144.8	3.740E+03	1.079	2.325E+05	3.799E+04

SAMPLE 3. Continued

```
46  0.7070   2.486    6.37E+00   1.567  1234.4  1309.0   0.999   143.5    3.742E+03   1.079   2.357E+05   3.818E+04


                                                          MEAN VALUES                                         EDGE VALUES

   PHI =  45.0   DEG            PT = 575.6     PSIA       TWL/TTE =   0.7226                        PPE =  3.166E+00  PSIA
     F =   7.99                 TT =1310.7     DEG R          PWL =   0.150        PSIA              ME =  4.015E+00
 ALPHA=  -0.0    DEG            P  =    0.0593 PSIA           TWL = 947.1          DEG R            TTE =  1.311E+03  DEG R
                                 T =   95.2    DEG R                                                 UE =  0.347E+04  FT/SEC
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SAMPLE 3. Continued

DATE COMPUTED 3-NOV-66
DATE RECORDED 18-JUL-66
TIME RECORDED 5151110
TIME COMPUTED 06122
PROJECT NO V B-07

RUN NUMBER 724 PAGE 3

CONFIG: BLUNT 7-DEG CONE (RN = 0.70 IN.)
XSTA = 42.00 IN.

DATA TYPE 4
MODEL SURFACE MEASUREMENTS

TAP	S (IN)	THETA (DEG)	PW (PSIA)	SD PW (PSI)	PW/P
1	35.103	0	0.1429	0.0006	2.4082
2	34.102	0	0.1537	0.0004	2.5905
3	33.597	0	0.1366	0.0001	2.3019
4	31.606	0	0.1446	0.0002	2.4365
5	29.606	0	0.1346	0.0003	2.2719
7	25.602	0	0.1338	0.0002	2.2551
8	23.602	0	0.1356	0.0004	2.2890
9	21.602	0	0.1259	0.0003	2.1208
11	17.606	0	0.1426	0.0003	2.4024
12	15.940	0	0.1310	0.0002	2.2076
13	14.932	0	0.1205	0.0005	2.0297
14	12.434	0	0.1315	0.0003	2.2162
15	10.439	0	0.1275	0.0002	2.1481
16	8.439	0	0.1150	0.0003	1.9374
17	6.439	0	0.1328	0.0002	2.2374
18	4.439	0	0.1553	0.0004	2.6162
19	3.467	0	0.1769	0.0002	2.9813
20	15.944	90	0.1347	0.0004	2.2701
21	15.944	180	0.1288	0.0003	2.1701
22	15.940	270	0.1253	0.0003	2.1110
23	14.946	90	0.1256	0.0003	2.1164
24	14.942	180	0.1322	0.0002	2.2274
25	14.948	270	0.1297	0.0002	2.1857
26	6.439	180	0.1334	0.0003	2.2476

TC101 1062.670 TC102 1007.670 TC103 977.670 TC104 935.670

MEAN VALUES

PHI = 45.0 DEG PT = 575.0 PSIA TURR = 564.7 DEG R
M = 7.99 TT = 1310.7 DEG R
ALPHA = -0.0 DEG P = 0.0593 PSIA T = 95.2 DEG R
XC = 4.200E+01 IN

RUN NUMBER 724

SAMPLE 3. Continued

DATE COMPUTED 3-NOV-80
DATE RECORDED 18-JUL-80
TIME RECORDED 5151110
TIME COMPUTED 66122
PROJECT NO. B-07

RUN NUMBER 724 PAGE 4

COFFIN ROUGH 7-DEG CONE (RN = 0.70 IN.)
XSTA = 42.00 IN.

INTEGRAL EVALUATION

GROUP	ZP/DEL	PP/EPD	UL/UO	TTL/TTO	TL/TD	RHOUL/RHOU	UL/UD	ROTL/ROTO	GRE/GREE	DITTL/DITTD	GREF/GREFD
1	1.459E-01	5.395E-02	9.235E-02	8.589E-01	3.425E+00	2.931E-01	1.709E-01	2.539E+00	1.973E-02	4.870E-01	5.523E-02
2	1.854E-01	5.237E-02	7.857E-02	8.525E-01	3.424E+00	2.918E-01	1.553E-01	2.538E+00	1.873E-02	4.641E-01	4.697E-02
3	2.248E-01	5.111E-02	6.699E-02	8.474E-01	3.429E+00	2.919E-01	1.330E-01	2.540E+00	1.297E-02	4.456E-01	3.006E-02
4	2.641E-01	5.091E-02	5.591E-02	8.442E-01	3.422E+00	2.913E-01	1.035E-01	2.537E+00	1.190E-02	4.348E-01	3.383E-02
5	3.036E-01	5.153E-02	6.577E-02	8.430E-01	3.405E+00	2.944E-01	1.214E-01	2.529E+00	1.413E-02	4.361E-01	3.986E-02
6	3.431E-01	5.219E-02	7.976E-02	8.439E-01	3.384E+00	2.949E-01	1.464E-01	2.520E+00	1.718E-02	4.335E-01	4.426E-02
7	3.825E-01	5.520E-02	1.048E-01	8.460E-01	3.349E+00	2.988E-01	1.917E-01	2.502E+00	2.297E-02	4.410E-01	6.303E-02
8	4.218E-01	5.956E-02	1.343E-01	8.502E-01	3.298E+00	3.045E-01	2.134E-01	2.470E+00	2.999E-02	4.561E-01	8.241E-02
9	4.613E-01	6.450E-02	1.620E-01	8.562E-01	3.241E+00	3.090E-01	2.717E-01	2.440E+00	3.680E-02	4.777E-01	9.955E-02
10	5.006E-01	7.172E-02	1.929E-01	8.649E-01	3.175E+00	3.144E-01	3.436E-01	2.415E+00	4.475E-02	5.088E-01	1.106E-01
11	5.402E-01	8.495E-02	2.284E-01	8.766E-01	3.089E+00	3.242E-01	4.015E-01	2.372E+00	5.406E-02	5.511E-01	1.416E-01
12	5.795E-01	9.896E-02	2.609E-01	8.912E-01	2.989E+00	3.361E-01	4.615E-01	2.320E+00	6.885E-02	6.038E-01	1.669E-01
13	6.190E-01	1.215E-01	3.108E-01	9.090E-01	2.864E+00	3.495E-01	5.261E-01	2.254E+00	8.154E-02	6.081E-01	1.954E-01
14	6.584E-01	1.546E-01	3.646E-01	9.273E-01	2.699E+00	3.698E-01	5.975E-01	2.105E+00	1.020E-01	7.119E-01	2.115E-01
15	6.979E-01	2.015E-01	4.248E-01	9.459E-01	2.485E+00	4.033E-01	6.696E-01	2.014E+00	1.321E-01	8.022E-01	2.797E-01
16	7.372E-01	2.533E-01	4.830E-01	9.637E-01	2.291E+00	4.343E-01	7.312E-01	1.930E+00	1.600E-01	8.072E-01	3.261E-01
17	7.569E-01	2.766E-01	5.106E-01	9.711E-01	2.200E+00	4.540E-01	7.575E-01	1.875E+00	1.834E-01	8.943E-01	3.509E-01
18	7.766E-01	3.257E-01	5.557E-01	9.791E-01	2.050E+00	4.882E-01	7.757E-01	1.781E+00	2.161E-01	9.235E-01	3.930E-01
19	7.964E-01	3.661E-01	5.904E-01	9.858E-01	1.940E+00	5.173E-01	8.230E-01	1.710E+00	2.469E-01	9.480E-01	4.290E-01
20	8.154E-01	4.076E-01	6.264E-01	9.913E-01	1.833E+00	5.364E-01	8.561E-01	1.619E+00	2.827E-01	9.684E-01	4.660E-01
21	8.359E-01	4.615E-01	6.700E-01	9.956E-01	1.706E+00	5.655E-01	8.752E-01	1.552E+00	3.301E-01	9.819E-01	5.130E-01
22	8.556E-01	5.251E-01	7.157E-01	9.991E-01	1.562E+00	6.335E-01	9.004E-01	1.464E+00	3.695E-01	9.967E-01	5.707E-01
23	8.752E-01	5.913E-01	7.685E-01	1.002E+00	1.470E+00	6.833E-01	9.223E-01	1.382E+00	4.500E-01	1.006E+00	6.294E-01
24	8.949E-01	6.479E-01	7.992E-01	1.003E+00	1.360E+00	7.254E-01	9.390E-01	1.313E+00	5.164E-01	1.013E+00	6.794E-01
25	9.146E-01	7.155E-01	8.424E-01	1.003E+00	1.285E+00	7.769E-01	9.551E-01	1.239E+00	5.988E-01	1.012E+00	7.405E-01
26	9.343E-01	7.946E-01	8.870E-01	1.003E+00	1.196E+00	8.384E-01	9.701E-01	1.167E+00	6.909E-01	1.012E+00	8.110E-01
27	9.738E-01	9.213E-01	9.564E-01	1.001E+00	1.089E+00	9.380E-01	9.892E-01	1.081E+00	8.757E-01	1.005E+00	9.240E-01
28	1.013E+00	1.040E+00	1.021E+00	9.994E-01	9.683E-01	1.032E+00	1.005E+00	9.719E-01	1.066E+00	9.976E-01	1.037E+00
29	1.053E+00	1.161E+00	1.079E+00	9.983E-01	8.676E-01	1.127E+00	1.017E+00	8.967E-01	1.275E+00	9.937E-01	1.147E+00
30	1.092E+00	1.270E+00	1.127E+00	9.976E-01	8.280E-01	1.213E+00	1.020E+00	8.330E-01	1.476E+00	9.919E-01	1.290E+00
31	1.132E+00	1.359E+00	1.166E+00	9.976E-01	7.822E-01	1.281E+00	1.033E+00	7.994E-01	1.655E+00	9.913E-01	1.325E+00
32	1.171E+00	1.455E+00	1.217E+00	9.980E-01	7.386E-01	1.355E+00	1.040E+00	7.552E-01	1.806E+00	9.926E-01	1.411E+00
33	1.250E+00	1.651E+00	1.294E+00	9.980E-01	6.812E-01	1.515E+00	1.052E+00	6.797E-01	2.344E+00	9.927E-01	1.596E+00
34	1.329E+00	1.813E+00	1.356E+00	9.980E-01	6.095E-01	1.654E+00	1.060E+00	6.205E-01	2.796E+00	9.926E-01	1.750E+00
35	1.407E+00	1.917E+00	1.401E+00	9.981E-01	5.756E-01	1.730E+00	1.065E+00	5.919E-01	3.124E+00	9.929E-01	1.851E+00
36	1.486E+00	2.029E+00	1.433E+00	9.980E-01	5.557E-01	1.798E+00	1.064E+00	5.712E-01	3.304E+00	9.926E-01	1.924E+00
37	1.643E+00	2.136E+00	1.466E+00	9.979E-01	5.329E-01	1.884E+00	1.072E+00	5.478E-01	3.684E+00	9.924E-01	2.021E+00
38	1.802E+00	2.221E+00	1.497E+00	9.979E-01	5.147E-01	1.950E+00	1.074E+00	5.291E-01	3.958E+00	9.923E-01	2.097E+00
39	1.959E+00	2.300E+00	1.528E+00	9.979E-01	4.966E-01	2.016E+00	1.077E+00	5.154E-01	4.239E+00	9.923E-01	2.167E+00
40	2.117E+00	2.382E+00	1.552E+00	9.982E-01	4.832E-01	2.073E+00	1.079E+00	4.967E-01	4.504E+00	9.919E-01	2.247E+00
41	2.275E+00	2.442E+00	1.570E+00	9.979E-01	4.717E-01	2.121E+00	1.080E+00	4.809E-01	4.705E+00	9.928E-01	2.295E+00
42	2.433E+00	2.476E+00	1.584E+00	9.981E-01	4.661E-01	2.140E+00	1.082E+00	4.741E-01	4.848E+00	9.929E-01	2.326E+00
43	2.590E+00	2.513E+00	1.597E+00	9.980E-01	4.592E-01	2.175E+00	1.083E+00	4.720E-01	4.967E+00	9.926E-01	2.354E+00
44	2.748E+00	2.550E+00	1.608E+00	9.980E-01	4.556E-01	2.204E+00	1.083E+00	4.677E-01	5.103E+00	9.926E-01	2.390E+00
45	2.906E+00	2.572E+00	1.617E+00	9.981E-01	4.519E-01	2.223E+00	1.084E+00	4.616E-01	5.180E+00	9.930E-01	2.410E+00
46	3.103E+00	2.586E+00	1.620E+00	9.981E-01	4.460E-01	2.231E+00	1.084E+00	4.605E-01	5.253E+00	9.930E-01	2.422E+00

SAMPLE 3. Continued

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                                                        VALUES AT DELTA

  PHI  =  45.0   DEG      DEL   = 2.537E-01 IN          PPD = 3.046E+00 PSIA          RHOD  = 1.259E-03 LBM/FT3
    M  =   7.99           DEL*  = 1.540E-01 IN          MD  = 3.9317E+00              RHOUD = 4.345E+00 LBM/SEC-FT2
ALPHA  =  -0.0   DEG      DEL** = 1.374E-02 IN          TD  = 3.295E+02 DEG R         MUTD  = 2.508E-07 LBF-SEC/FT2
                                                        TTD = 1.311E+03 DEG R         HTTD  = 9.254E+01 BTU/LBM
                          LREO  = 4.488E+06 PER IN      UD  = 3.451E+03 FT/SEC        LREID = 1.576E+04 PER IN
```

SAMPLE 3. Concluded

DATE COMPUTED [illegible]
DATE RECORDED 18-JUL-[illegible]
TIME RECORDED 23 51[illegible]
TIME COMPUTED 06121
PROJECT NO V [illegible]-07

CONFIG: [illegible] 7-DEG CONE (RN = 0.70 IN.)
XBTA = [illegible] IN.

DATA TYPE 2
MODEL SURFACE MEASUREMENTS

TAP	S (IN)	THETA (DEG)	PS (PSIA)	[illegible]
1	35.103	0	0.1135	2.4102
2	34.102	0		
3	33.597	0	0.1373	2.3699
4	31.606	0	0.1408	2.3681
5	29.606	0	0.1411	2.3720
7	25.602	0	0.1376	2.3026
8	23.602	0		
9	21.602	0	0.126[illegible]	2.1191
10	19.606	0		
11	17.606	0	0.1366	2.[illegible]
12	15.940	0	0.1321	2.2205
13	14.932	0	0.1263	2.1[illegible]
14	12.434	0	0.1061	1.6176
15	10.139	0	0.1267	2.1037
16	8.439	0		
17	6.439	0	0.1359	2.2651
18	4.439	0		
19	3.167	0	0.1890	3.0266
20	15.944	90		
21	15.944	180	0.1286	2.1617
22	15.940	270		
23	14.948	90	0.1250	2.1912
24	14.942	180		
25	14.918	270	0.1294	2.1751
26	8.439	180		

TC101 1045.670 TC102 979.670 TC103 950.670 TC104 890.670

PHI = 0.0 DEG
R = 1.3920
ALPHA = 0.0 DEG
DIA = -59.

PT = 576.5 PSIA
TT = 1311.7 DEG R
P = 0.0595 PSIA
RE = 0.2181+006 PER IN.
PT2 = 4.919 PSIA

TBRR = 554.7 DEG R

RUN NUMBER 715

SAMPLE 4. Model Surface Measurements (Type 2)