NASA CONTRACTOR REPORT 166258

STUDY OF VTOL IN-GROUND-EFFECT FLOW FIELD INCLUDING TEMPERATURE EFFECT

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Moffett Field, California 94035

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VTOL IN GROUND EFFECT FLOWS FOR CLOSELY SPACED JETS WITH TEMPERATURE

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1 - SUMMARY

The primary purpose of this study was to obtain detailed pressure, temperature, and velocity data for twin-fan configurations in-ground-effect and to develop flow models to aid in predicting pressures and upwash forces on aircraft surfaces. For the basic experiments, 49.5mm-diameter jets were used, oriented normal to a simulated ground plane, with pressurized, heated air providing a jet. The experimental data consisted of: (1) the effect of jet height and temperature on the ground, model, and upwash pressures and temperatures, (2) the effect of simulated aircraft surfaces on the isolated flow field, (3) the jet-induced forces on a three-dimensional body with various strakes, (4) the effects of non-uniform coannular jets.

For the uniform circular jets, temperature was varied from room temperature (24°C) to 232°C. Jet total pressure was varied between 9,300 Pascals and 31,500 Pascals. For the coannular jets, intended to represent turbofan engines, fan temperature was maintained at room temperature while core temperature was varied from room temperature to 437°C. Fan and core total pressures were chosen to match the power settings most frequently used during the large-scale tests of Reference 1.

In general, the test data correlate well with the induced forces presented in Reference 1. No scale effects were found, and jet temperature and pressure did not affect the nondimensionalized induced lift. The induced lift in-ground-effect was found to be higher for the uniform circular jets than for the simulated fan jets.

Modifications to an existing wall-jet transition model adequately predict the trends with height above ground of upwash temperatures and pressures. The addition of a recirculation model is necessary to predict upwash temperatures in the presence of an aircraft.

2 - INTRODUCTION

Lift and control for V/STOL aircraft operating in-ground-effect present a critical condition in sizing the propulsion system. Ground proximity effects can result in large jet-induced lift losses or produce positive fountain lift, depending on the aeropropulsion configuration. The complexity of the resulting flow field and the sensitivity to many design parameters give rise to a large body of experimental data which model various aspects of the flow field. The primary purpose of this study was to expand the existing data base for a twin-fan V/STOL aircraft by exploring the effects of temperature and non-uniformities (temperature and pressure) in the jet. These effects were then added to an existing computerized prediction method.

Of almost equal importance, and possibly greater interest to the typical reader, this effort also investigated scale effects on jet-induced characteristics. To this end, the model used was a 1/24-scale replica of a TF 34-powered, large-scale model tested recently at NASA-Ames (Reference 1).

3 - SYMBOLS

A	=	Area; nozzle exit area
b	=	Thickness of viscous layer
D	=	Diameter; nozzle exit diameter
f	=	Analytic functions respresenting viscous profiles
F	=	Force; radial flux deflection function
ΔF	=	Interference force (total force on body minus thrust)
h	=	Nozzle height above ground
H	=	Heat; distance to ground
M	=	Mach number; momentum
NPR	=	Nozzle pressure ratio relative to ambient
NTR	=	Nozzle temperature ratio relative to ambient
P	=	Static pressure
q	=	Dynamic pressure
r	=	Jet radius; ground radius coordinate
r_o	=	Ground impingement radius
R	=	Radius from one jet impingement point
S	=	Jet spacing
T	=	Temperature; static temperature
V	=	Velocity
X	=	Distance perpendicular to Y and Z
Y	=	Distance from midpoint of line joining jet centerline
Z	=	Distance above ground; vertical jet or ground coordinate
Z'	=	Distance downward from nozzle exit
α	=	Exponent of profile function
γ	=	Isentropic exponent; ratio of specific heats
δ	=	Boundary layer thickness
Δ	=	Difference between local and ambient conditions
ζ	=	Non-dimensional wall thickness
η	=	Thrust efficiency factor; nondimensional thickness
Θ	=	Angular orientation around one jet impingement point
ρ	=	Density
γ	=	Angle in ground polar

SUBSCRIPTS

a, A = Ambient
B = Body
C = Core nozzle exit conditions; potential core
F = Flux, fan nozzle exit conditions
FD = Fully-developed
g = Value at ground effect height
H = Half value
J = Nozzle value; jet exit conditions for open circular nozzle
m, M = Maximum value; viscous layer
N = Nozzle
PC = Potential core
rec = Recirculation
S = Stagnation value; static
T = Thermal layer; total; stagnation
u = Upwash
V = Velocity layer
W = Wall jet

4 - EXPERIMENTAL BACKGROUND

4.1 Test Facility

The experiments conducted under this contract were performed in the Grumman Environmental Test Facility (ETF). This facility performs a wide range of system and component testing for Grumman and has two compressor systems capable of supplying heated air: the ram air system for pressures to 110 kPag and temperatures to 232°C, and the bleed air system for pressures to 3.45 MPag and temperatures to 760°C. A general overview of the installation in this facility is given in Figure 1; a detailed photo of the test arrangement is presented in Figure 2.

4.2 Air Supply

For most of the tests, the air was compressed by a Rootes-type blower (referred to in this facility as the "ram air compressor"). Compression heating of the flow was removed and the flow divided into two piping systems. One system was then heated by a controlled resistance electrical heating system with a maximum temperature of 249°C. Both the hot and cold flows were piped to the test site by 20.3-cm diameter insulated piping systems. Supply pressure was controlled by a feedback control system at the compressor control panel and a second control valve at the user's outlet area (Figure 3). For the experiments with core temperatures above 232°C, air was supplied by a piston-type compressor and gas and electric heaters in series (bleed-air systems).

4.3 Settling Chamber

The settling chamber for the fan nozzle was a cylindrical steel tank of 76.2-cm diameter and 218.4-cm length, adapted from underwater flow research. (See Figure 4). The first 91.4 cm of this chamber are occupied by a diffuser to spread the flow from the 20.3-cm diameter inlet evenly over the chamber cross-section. This is followed by a tube bundle of 9.5-cm diameter stainless steel tubes and two fine mesh screens. The heated air supply for the core flow enters through the bottom of the chamber after a combined turn and transition from a single 20.3-cm pipe to a pair of separate 5.1-cm tubes. This supply is con-

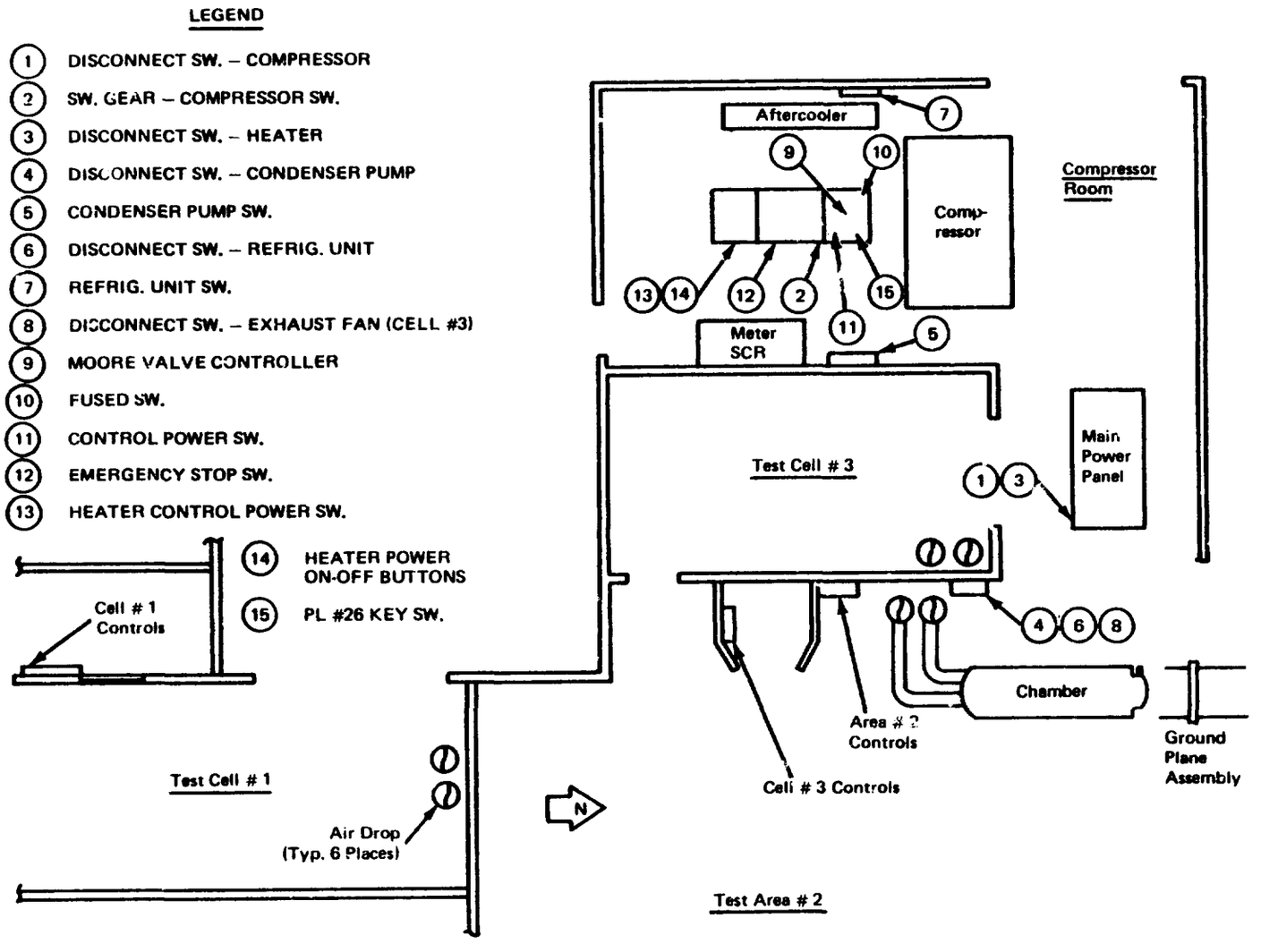

Figure 1 - Ram air system location plan, Plant 31.

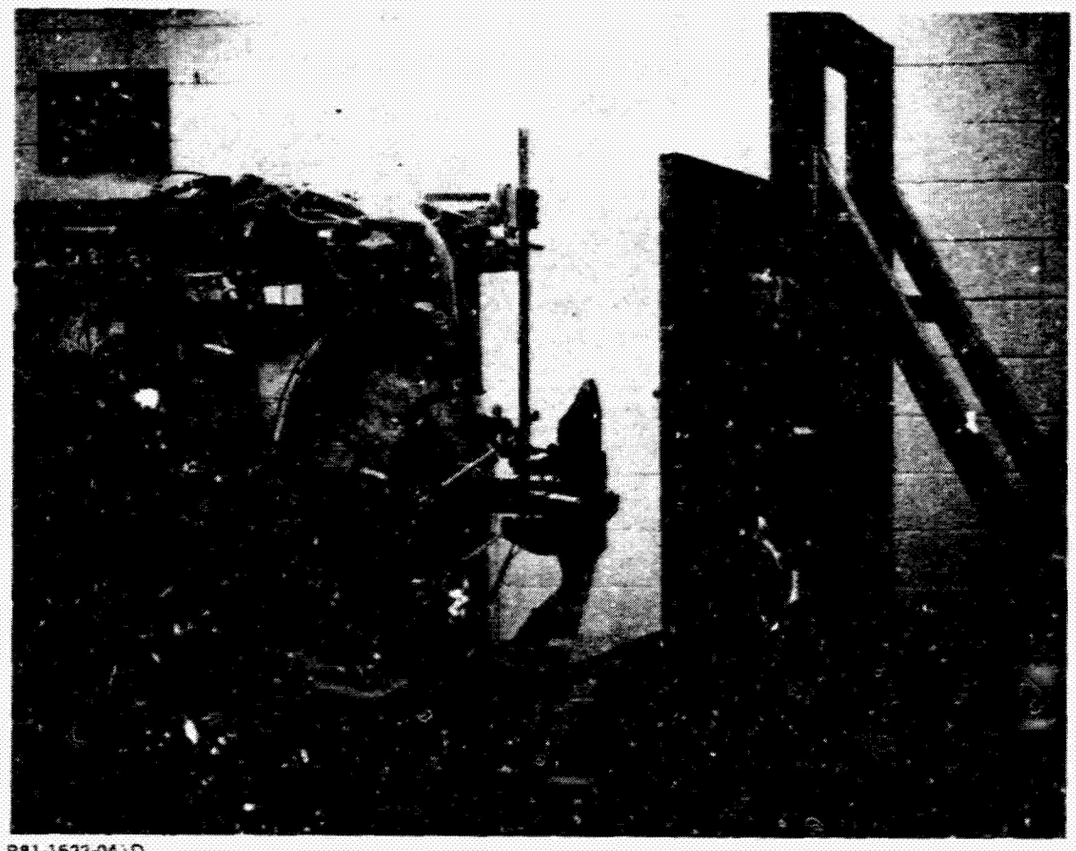

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Figure 2 - Test arrangement.

tinued inside the chamber by flexible, insulated pipes to the nozzle entrances. For the open-jet experiments, this tubing system was entirely removed and the piping system was changed to bring heated air in through the diffuser inlet.

4.4 Nozzles

The outer fan nozzle, which is also the hardware for the open-circular-jet experiments, is an ASME elliptical profile flow metering contour with an inside diameter of 5.0 cm. (Figure 5). This nozzle is continued as a straight tube for 30.5 cm in a tradeoff of boundary layer growth and heat transfer in the nozzle flow against the need to separate the model from the front face of the chamber, thus preventing the chamber from interfering with the recirculation flow field. The inner core nozzle for the heated flow begins with a contraction from the 5.1-cm flexible supply tubes beginning 5.1 cm before the fan flow

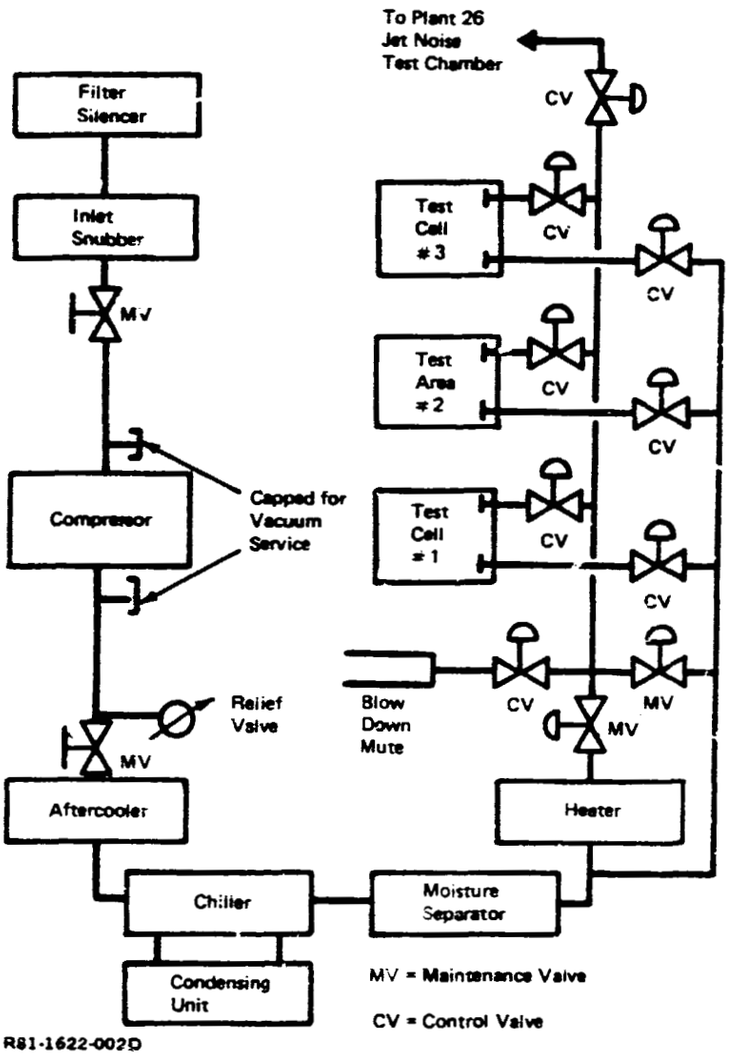


Figure 3 - Ram air system schematic.

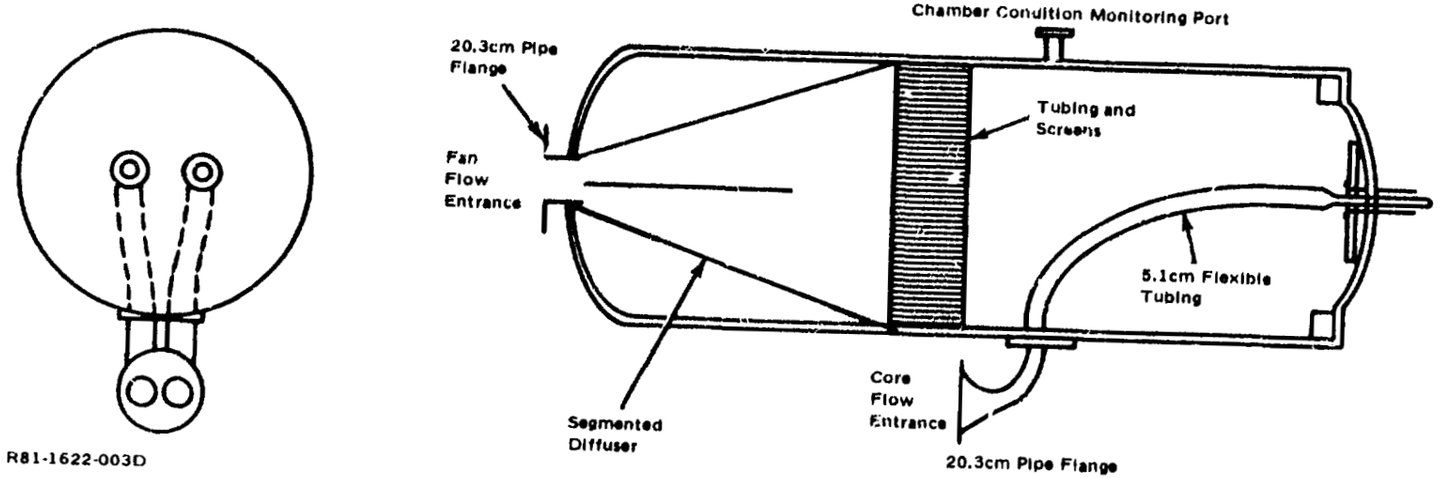
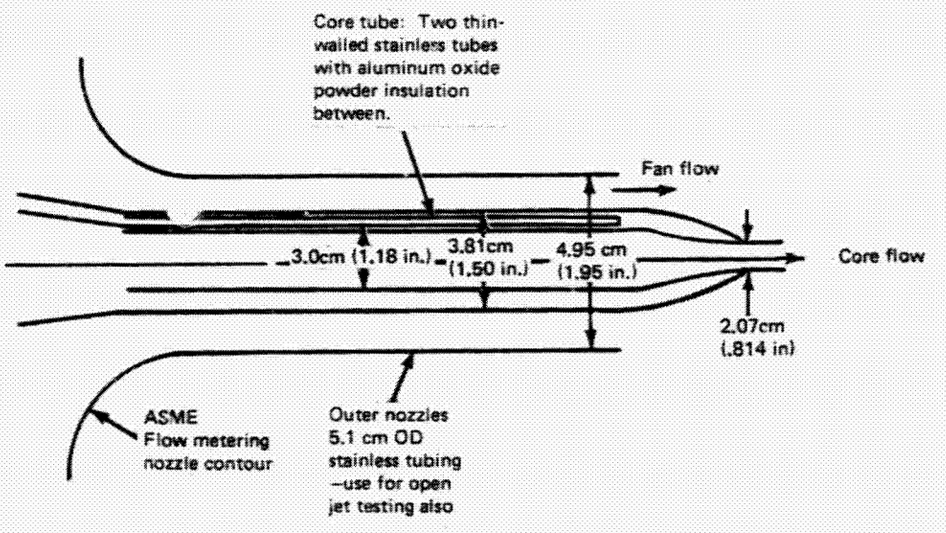


Figure 4 - Settling chamber arrangement.



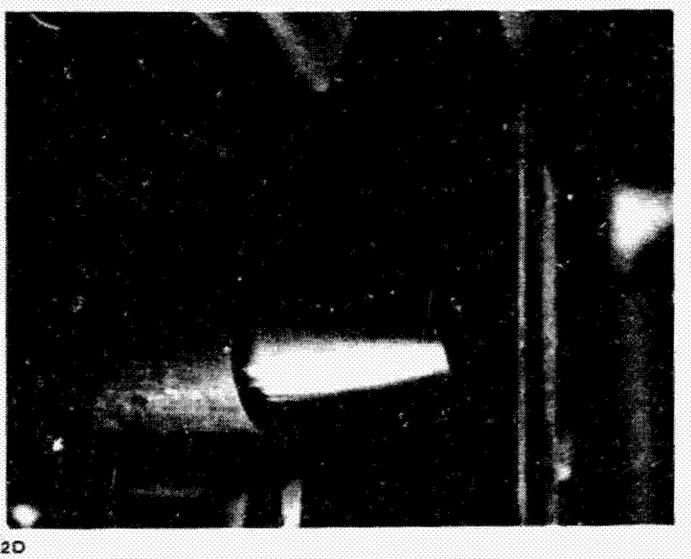


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Figure 5 - Fan-jet nozzle simulation.

nozzle entrance. This contraction connects to a double wall tubing system with an outer diameter of 3.8 cm (the scale centerbody diameter) and an inner diameter of 3.0 cm. The area between the two walls of this contraction section and the constant area section running to the final core nozzle contraction were insulated with aluminum oxide powder. The final contraction to the 20.7-mm core exit diameter and the core centerbody outer profile are accomplished in one solid machined segment. The core-flow tube is held in place by a machine screw in the simulated core pylon, and three thin finger-type supports near the nozzle entrance.

4.5 Ground Plane

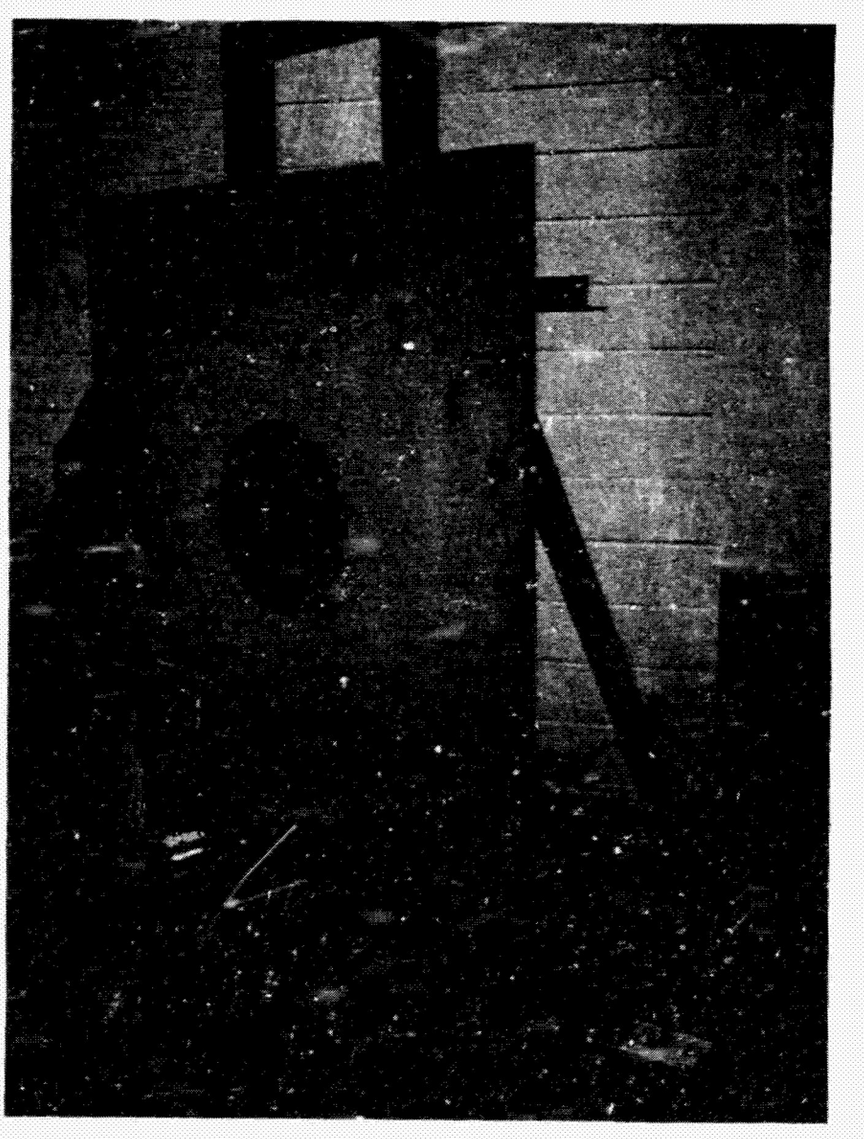
The simulated ground plane consists of a 2.5-cm thick aluminum plate 121.9-cm square, with a circular insert of steel for the pressure tap and wall jet probe mountings. (Figure 6a). This plate was mounted on a framework which rode on rails that were aligned parallel to the nozzles. The ground plane was moved by a screw that was driven by a variable speed motor/controller. The instrumentation locations are shown in Figure 6b, c, and d, (pressure taps, surface temperature thermocouples and wall jet rakes). Numbering of the instrumentation locations matches that of the full-scale ground plane (Ref. 1), with additional instrumentation designated by "R".

4.6 Aircraft Model

The model (Figure 7) was a 1/24 scale reproduction of the Grumman Design 698-411B tested in the NASA-Navy-Grumman full-scale demonstrator program. This model was constructed of a partially-hollow high-temperature-plastic fuselage section housing the balance and pressure/temperature lines, a metal bottom plate for pressure and temperature instrumentation, metal strakes at the fuselage chines, and separately attachable plastic wings and empennage.

4.7 Instrumentation

4.7.1 Pressure. - Pressures were measured with Validyne model DP15 or DP103 transducers, powered by single channel CD-15 or MC1-10 multichannel systems using CD18 or CD19 carrier demodulators. Transducers were calibrated versus an oil filled manometer, either singly (transducers used for probe measurements) or in groups with the manometer calibration pressure applied through a manifold (ground plane or aircraft surface).



a) Test set-up

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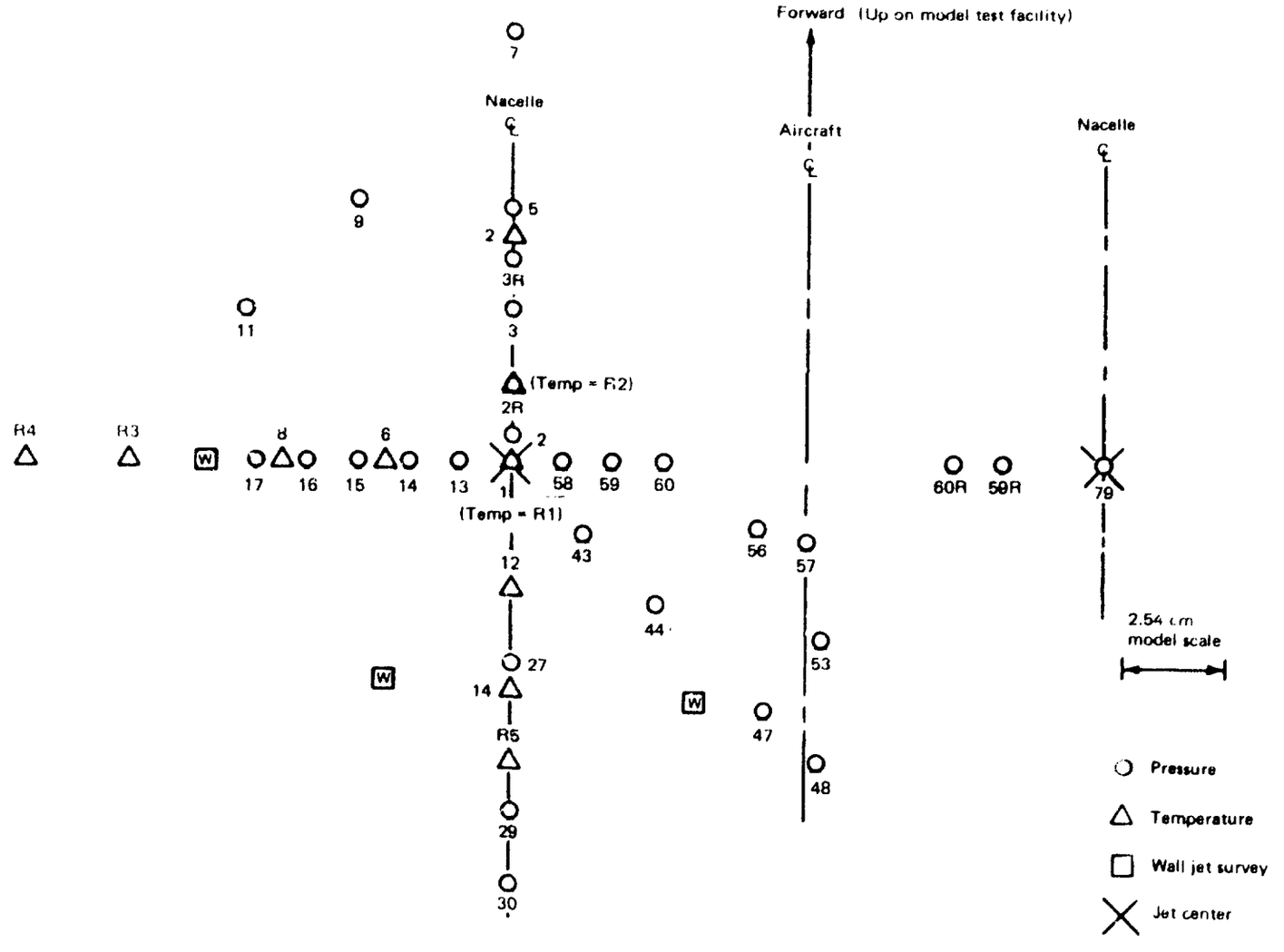
Figure 6 - Ground plane.



b) Ground plane instrumentation locations

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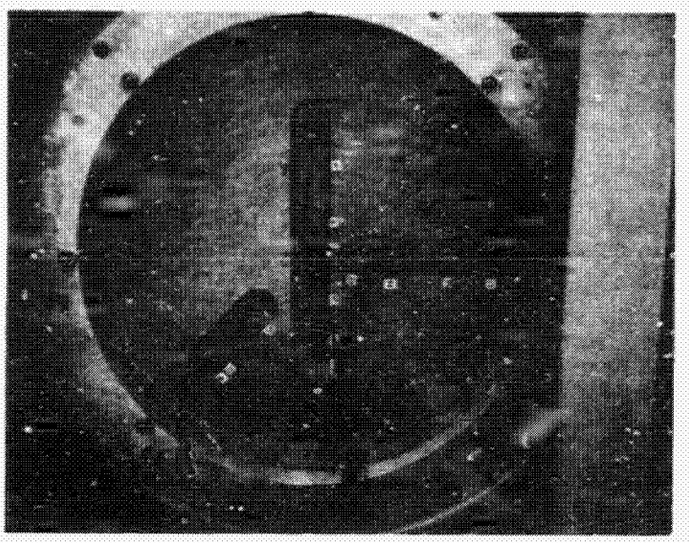
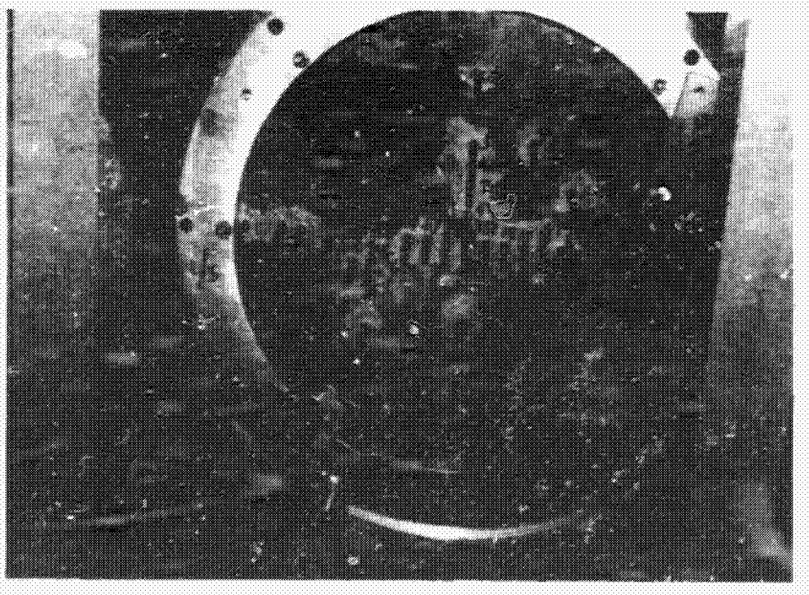
Figure 6 - (Continued.)



c) Thermocouple installation



d) Pressure and wall jet instrumentation

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Figure 6 - Concluded.

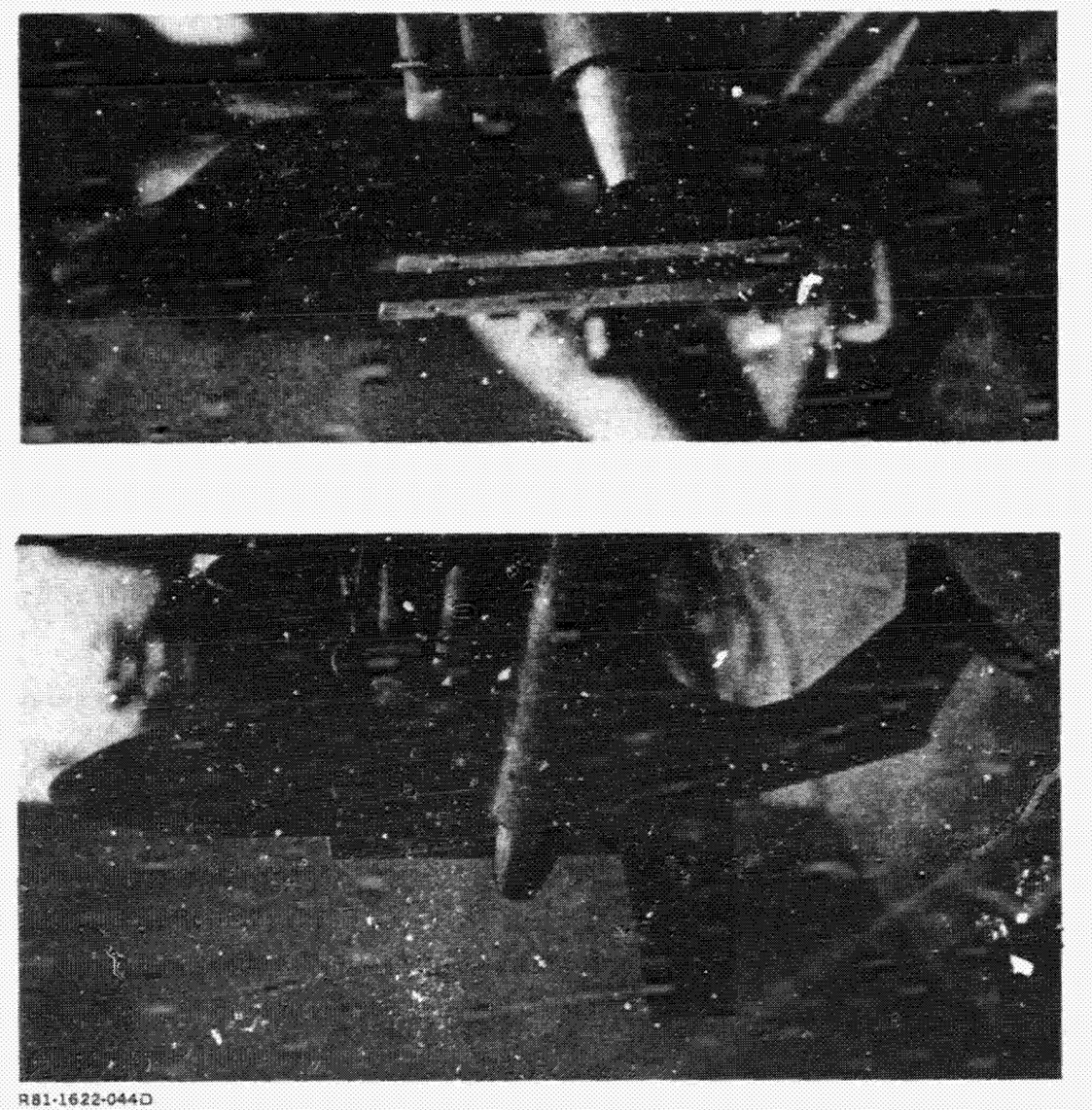

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Figure 7 - 1/24 scale model.

Pressure tap locations on the ground plane are discussed in Section 4.5. Full-scale locations on the line connecting the nozzle impingement centerline, at 90^{o} to the line through one jet-centerline, and at 45^{o} were used, with a few additional locations added. The full-scale tap identification numbers were used for the model tests to aid comparisons.

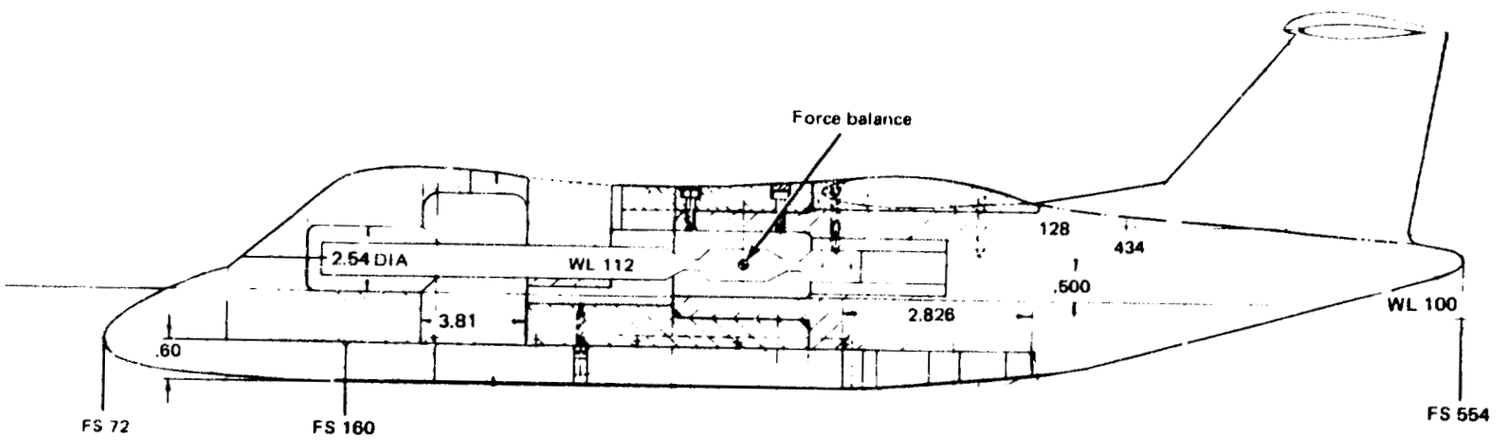
Pressure tap locations on the aircraft model are shown in Figure 8. Full scale locations were matched for many of these taps, but some taps were

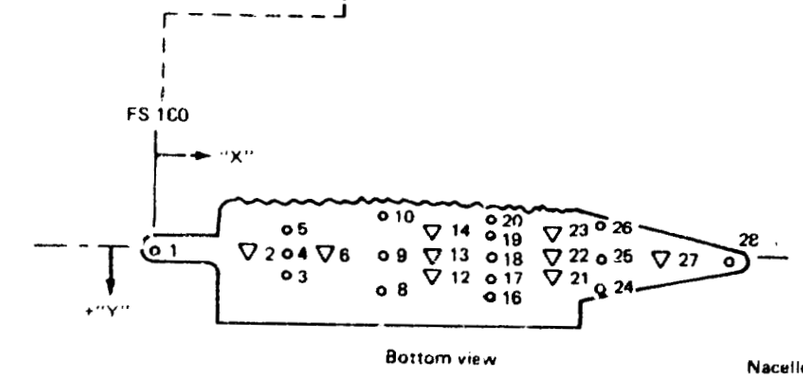
relocated so that temperature (thermocouple) instrumentation could be added.

4.7.2 Temperature. - All temperature measurements were made with chromel-alumel (Type k) thermocouples connected by a multi-connection switch box to either an Omega model 2175A or a Fluke model 2166A linearized thermocouple readout amplifier. The ground plane surface temperatures and those on the flat segment of the aircraft bottom were measured with thermocouples spot welded to thin (0.4 mm) stainless steel areas. On the aircraft, the entire flat bottom was formed from one thin piece of stainless steel, and thicker pieces were spot-welded in areas for pressure tap installation. (Figure 8). The 30.5-cm diameter ground plane insert was 4.2-cm thick, and the areas for temperature measurement were machined to the 0.4-mm thickness for a distance of at least 1.3 cm from all thermocouples. (See Figure 6c). The thin skin allows greater spatial resolution in temperature measurements, which is important in small-scale testing.

4.7.3 Probes. - Three separate probe assemblies were used for measurements in the free jet, wall jet, and upwash flows (Figure 9). In each probe assembly the temperature data were taken by a bare thermocouple probe protruding from a 1.5-mm diameter stainless steel sheath that was located close to one of the pressure probes. Bare thermocouples were chosen, rather than a more conventional shielded thermocouple probe, in order to obtain good spatial resolution and time response and to avoid flow disturbances that would be associated with a housed probe. Temperature measurements with bare thermocouples require correction to account for radiation losses. Temperature corrections were acquired for the thermocouple probes in each assembly by recording output in a flow field of known temperature over a wide temperature range. We used the open jet nozzle configuration for this work. Each probe assembly was placed on the centerline of one nozzle shortly downstream of the exit and a housed thermocouple probe (United Sensor type KT-12-C/A) was placed at a corresponding point in the flow from the other nozzle.

The probe assembly used for free-jet data (Fig. 9a) consisted of 1.6-mm O.D. sharp-lipped pitot tube with a 0.5-mm diameter thermocouple displaced 2.5 mm laterally from the tip of the pitot tube. Wall jet data were taken with a





Nacelle ℄

PRESS △ TEMP	NO.	FUSE STA	SENSOR COORDINATES "X"	SENSOR COORDINATES "Y"
○	1	160	0	0
▽	2	200	4.22	0
○	3-5	215	5.82	.71, 0, -.81
▽	6	238	8.26	0
○	8-10	255	10.0	1.57, 0, -1.57
▽	12-14	280	12.7	.79, 0, - 79
○	16-20	300	14.7	1.52, .76, 0, -.81, -1.68
▽	21-23	325	17.5	1.4, 0, -1.45
○	24-26	345	19.6	1.4, 0, -1.45
▽	27	370	22.2	0
○	28	400	25.4	0

NOTE: All dimensions in centimeters

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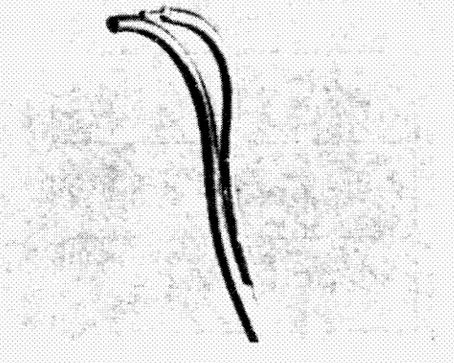
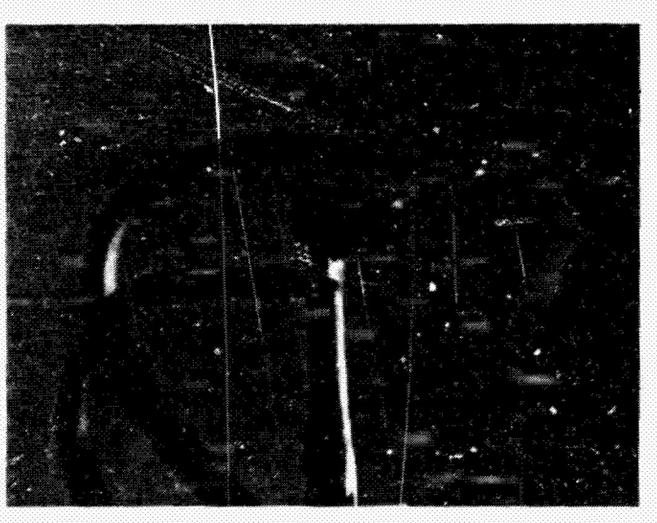
Figure 8 - Model instrumentation.



a) Free-jet probe

b) Wall-jet probe



c) Upwash probe

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Figure 9 - Flow field probes.

1.3-mm O.D. pitot tube (Fig. 9b) that was flattened to 9.5 x 1.5-mm dimensions at the tip, with a 0.5-mm diameter thermocouple that was displaced laterally 1.8 mm. The probe assembly for upwash measurements consisted of a 3.0-mm O.D. Kiel probe with a 1.6-mm O.D. static tube displaced 4.3 mm on one side, and 0.5-mm diameter thermocouple displaced 3.0 mm on the other side of the Kiel probe (Figure 9c).

The free-jet probe assembly and the upwash probe assembly were supported by a motor-driven traverse that was mounted on the same rails as the ground plane carriage. Probes were traversed in the plane containing the two jet centerlines, along paths perpendicular to those centerlines.

The support for the wall-jet probe assembly passed through a hole in the ground plane and attached to a manually driven screw traverse that was fastened to the back of the ground plane (Figure 10). The probe location relative to the wall was measured from the voltage output of a thin film linear resistance transducer that was attached to the screw drive.

4.8 Experimental Techniques

All experiments were conducted under steady or pseudo-steady operating conditions. After initial startup time (approximately one hour) changes in pressure operating conditions took only a few minutes. Total temperature changes were much slower, primarily because of the heat capacity of the supply piping.

Under most of the operating conditions for this contract, we utilized the techniques we developed earlier (Refs. 2, 3 and 4) of continuously recording test variables versus input parameters in an analog form on an X-Y recorder. This allowed a constant monitoring of test results. Operating conditions could be changed to allow for results observed (such as gradients or fluctuations). The most frequent examples of this are the recording of interference force, ground-plane pressures, and vehicle surface pressures versus height above ground, or probe temperature and pressures versus probe position.

Probe and ground plane position were converted to voltage by a cable-

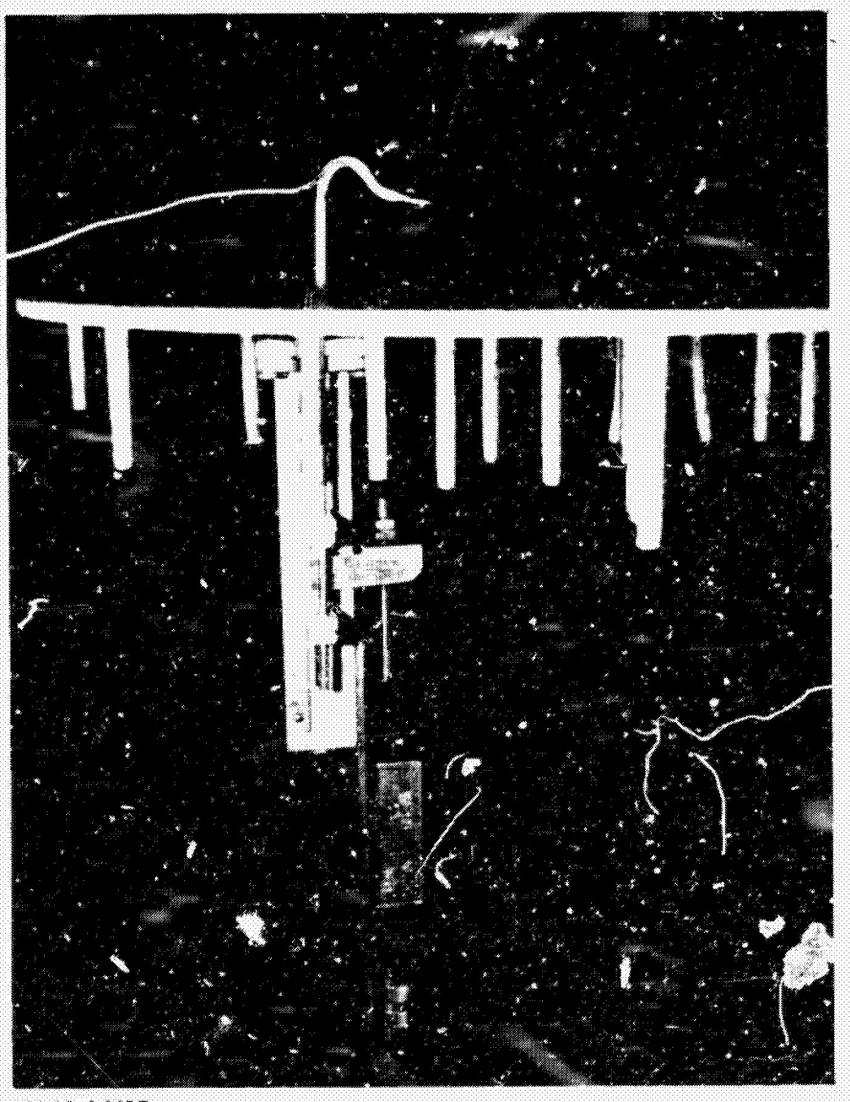

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Figure 10 - Wall-jet traversing system.

driven rotary potentiometer (Figure 11) for most cases, and a linear potentiometer for the wall-jet measurements (Figure 10). Voltage was supplied by Hewlett Packard Model 6216A D.C. power supplies and adjusted so that a "calibrated" scale setting could be used on the recorder (allowing changes in scale with ease). Position was controlled by a variable speed DC motor/controller and a screw drive.

For the aspects of the experiments requiring many measurements simultaneously (such as ground plane and aircraft surface pressures) data were recorded simultaneously by an on-site minicomputer (Hewlett-Packard Model 1000(X) through A/D converters.

The aircraft force measurements were taken on separate runs from the pressure and temperature measurements because of force interference from the pressure and temperature leads which could not be eliminated. The instrumented lower surface and the instrumentation leads attached to it were removed for the force tests. A plain lower surface was fabricated to match the external contours of the instrumented lower surface and used to cover the cavity in the fuselage during the force tests.

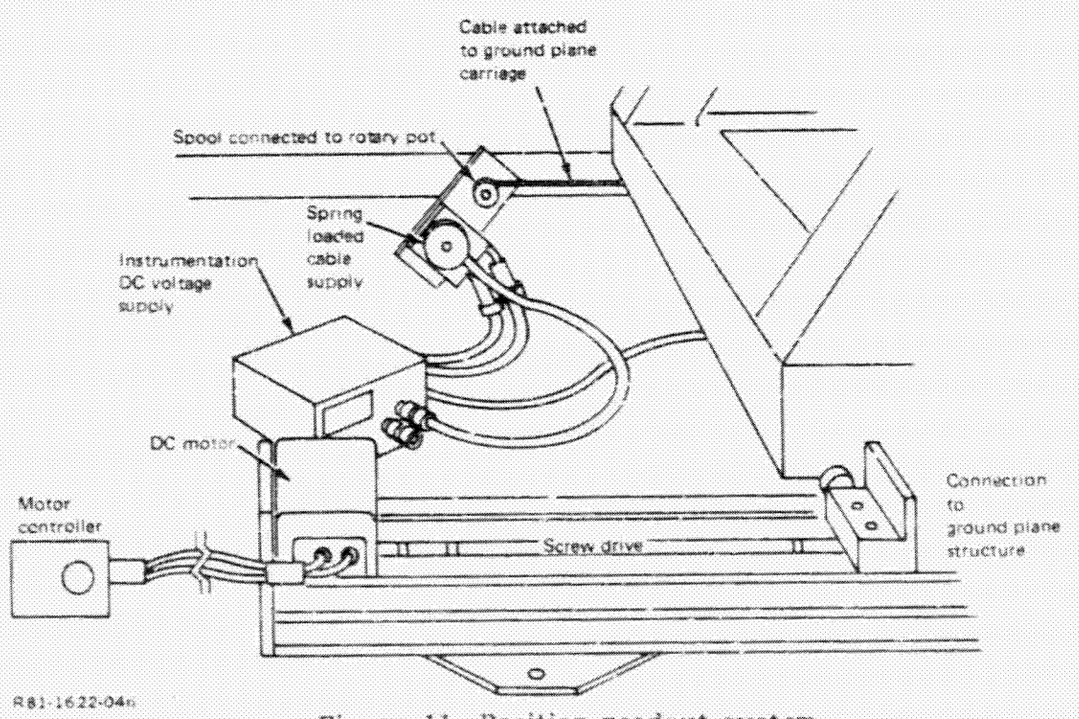

Figure 11- Position readout system.

5 - R JLTS

5.1 Fan-Jet Nozzles

The sketch of fan-jet impingement geometry in Fig. 12 illustrates the co-ordinate system used to describe probe and nozzle locations. All data were taken with the spacing between nozzles scaled to the full-scale model of Reference 1, with the jets normal to the ground and with the aircraft model present.

5.1.1 Nozzle Flow. - Figures 13 and 14 show pressure profiles taken across the fan and nozzle exit, with baseline pressure conditions and a 24°C total temperature in both flows. The total-pressure profile at the core exit is quite flat. The profile across the fan exit shows a well-defined maximum near the center of the annulus. The maximum value of the pitot pressure at the exits was used to define the nozzle pressure ratios (1.103 for the core and 1.195 for the fan at baseline conditons). Most of the fan-jet impingement data were taken with these nozzle pressure ratios, chosen to match those conditions most frequently used in the full-scale experiments. After the initial series of experiments, during attempts to compare full-scale and model results, it was discovered that the full-scale conditions to be matched were based on area averaged total pressures. Additional tests were conducted at the most critical conditions with the correct pressures. Non-dimensional results were found to have very little dependence on the total pressure.

Integration of the pressure profiles in Figures 13 and 14 (assuming axial symmetry) gives a value of 36.5 N thrust for one fan-jet nozzle. However, this approach provides only an approximation of the thrust because the fan flow is not truly axially symmetric (engine support pylon blockage on one side of the fan duct) and because this method of determining thrust does not account for pressure forces on the outer cowl of the core nozzle (centerbody).

A more accurate determination of nozzle thrust was made by measuring the impingement on a 0.914-meter square ground-plane plate that was instrumented with three strain beams. With baseline pressure conditions, the thrust produced by one nozzle was found to be 36.2 N. Maintaining pressure within 5% of the baseline conditions, the core exit temperature was raised from 24° to

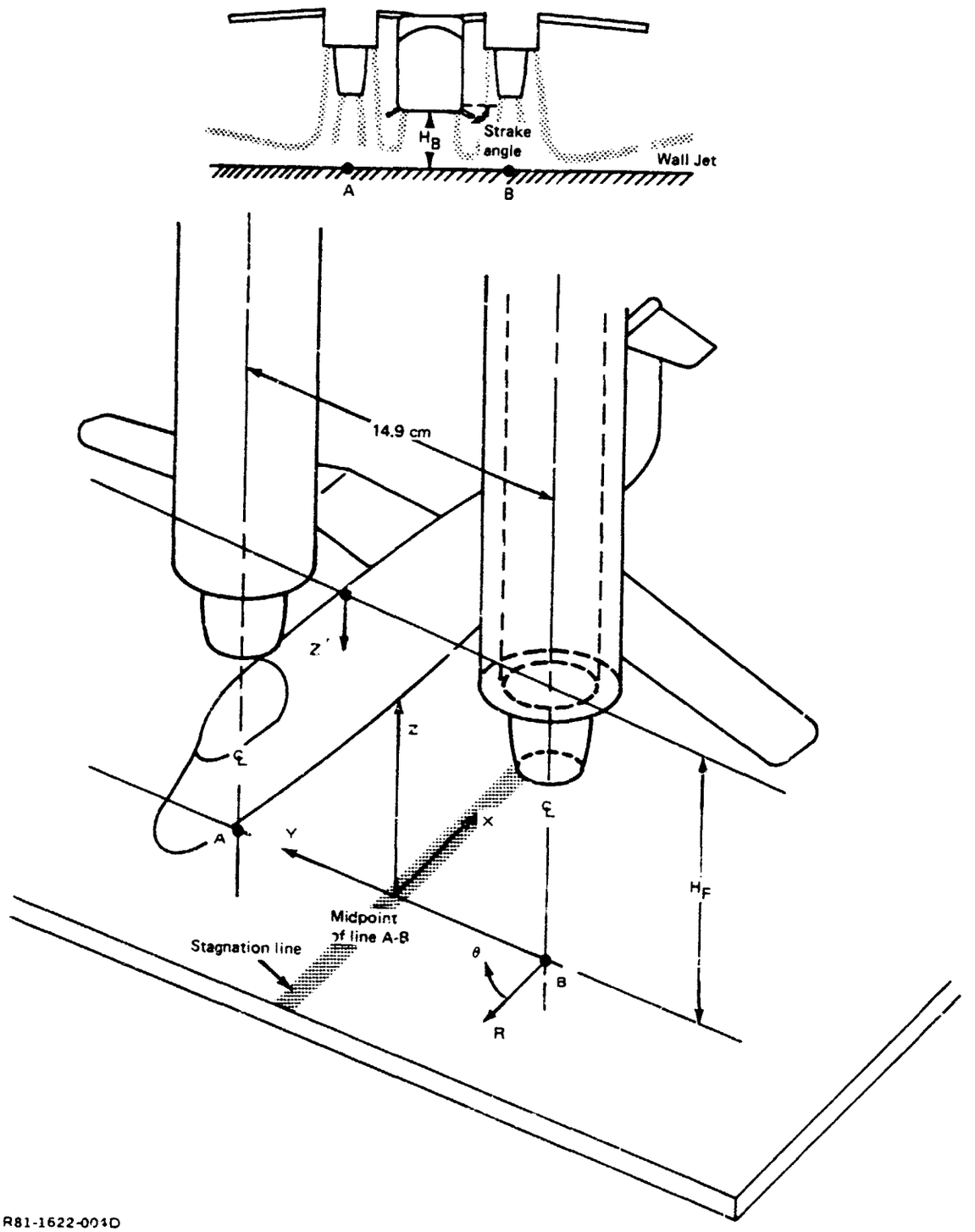

Figure 12 - Coordinate system and nomenclature.

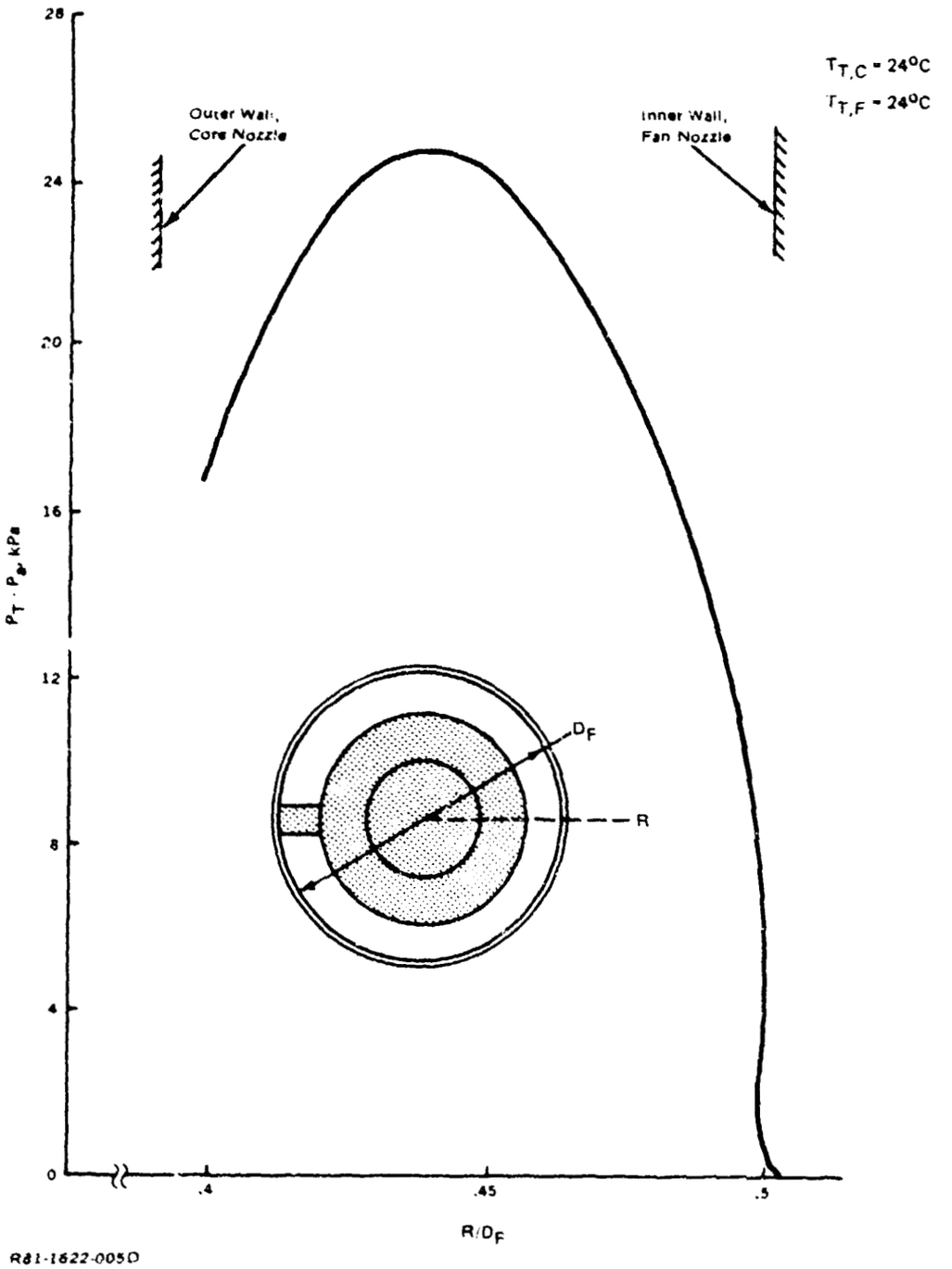

Figure 13 - Pitot pressure profile at fan nozzle exit, baseline pressure operation.

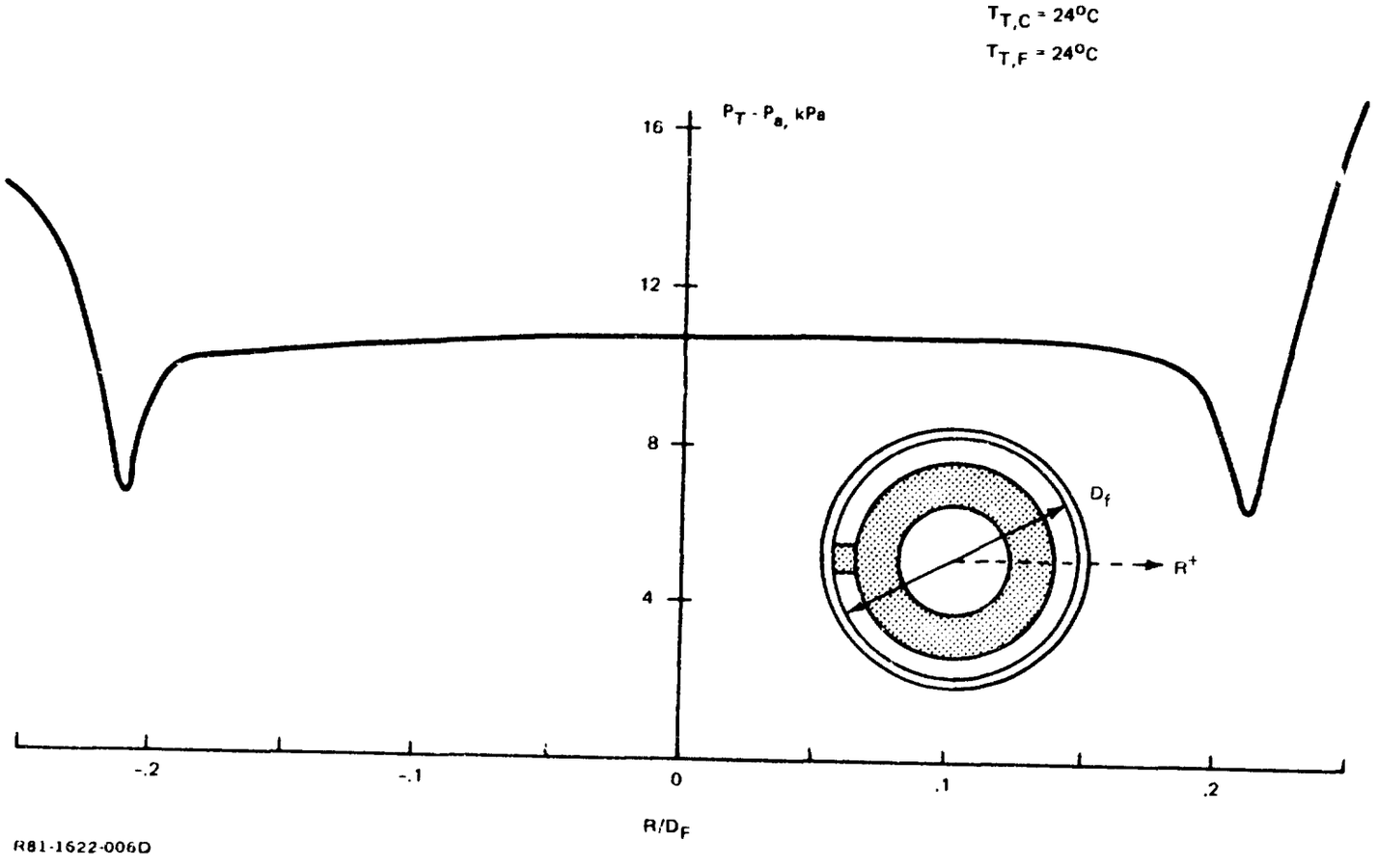

Figure 14 - Pitot pressure profile at core nozzle exit, baseline pressure operation.

168°C. As shown in Figure 15, there was a negligible variation in nozzle thrust over this range of core exit temperatures when minor variations in total pressure at the core exit and the fan exit were taken into account.

The thrust of a fan-jet nozzle was measured for a range of both core and fan nozzle total pressures. The thrust was found to be a linear function of fan and core pressures (Figure 16). This is true over a range of pressures exceeding those used in this study. An empirical fit of the data yields $F = 1.55\, q_{fan,\ avg.} + 0.719\, q_{core} - 0.445$, in which q is in kilopascals and F is in Newtons. As an indication of the origin of this equation, the following relationship was assumed: (1)

$$F = \left(K_1 + K_2\right)\ 2q_{fan}A_{fan} + K_3 2q_{core}A_{core} \qquad (2)$$

where K_1 and K_3 represent the relative thrust efficiencies and K_2 refers to the drag of the core centerbody in the fan flow. For the nozzles used in the study, $A_{fan} = 7.8\ cm^2$ and $A_{core} = 3.37\ cm^2$

From integration of the core nozzle exit profiles, K_3 was found to be 0.0962.

Combining the terms relative to the core, $\left(K_1 + K_2\right) \times 2\, A_{fan} = K_4$

we have the relationship

$$F = K_4 \times q_{fan} + 0.650\, q_{core}. \qquad (3)$$

Solving for K_4 with room-temperature, baseline condition data yields $K_4 = 1.46$.

Substituting, we find

$$\Delta F = 1.46\, q_{fan,\ avg.} + 0.650\, q_{core,\ avg} \qquad (4)$$

This agrees quite closely with the empirical relation of Eq. (1)

Figure 17 shows free-jet total-pressure profiles that were taken (with both fan jet nozzles operating) at successive axial stations for a total temperature at the exit of 24°C. The lack of symmetry in each of the fan flows can be attributed to the core pylon blockage in the fan nozzles. The apparent convergence of the two flows, indicated by measurement on these profiles of center-to-center distance between the two flows at several axial stations, was

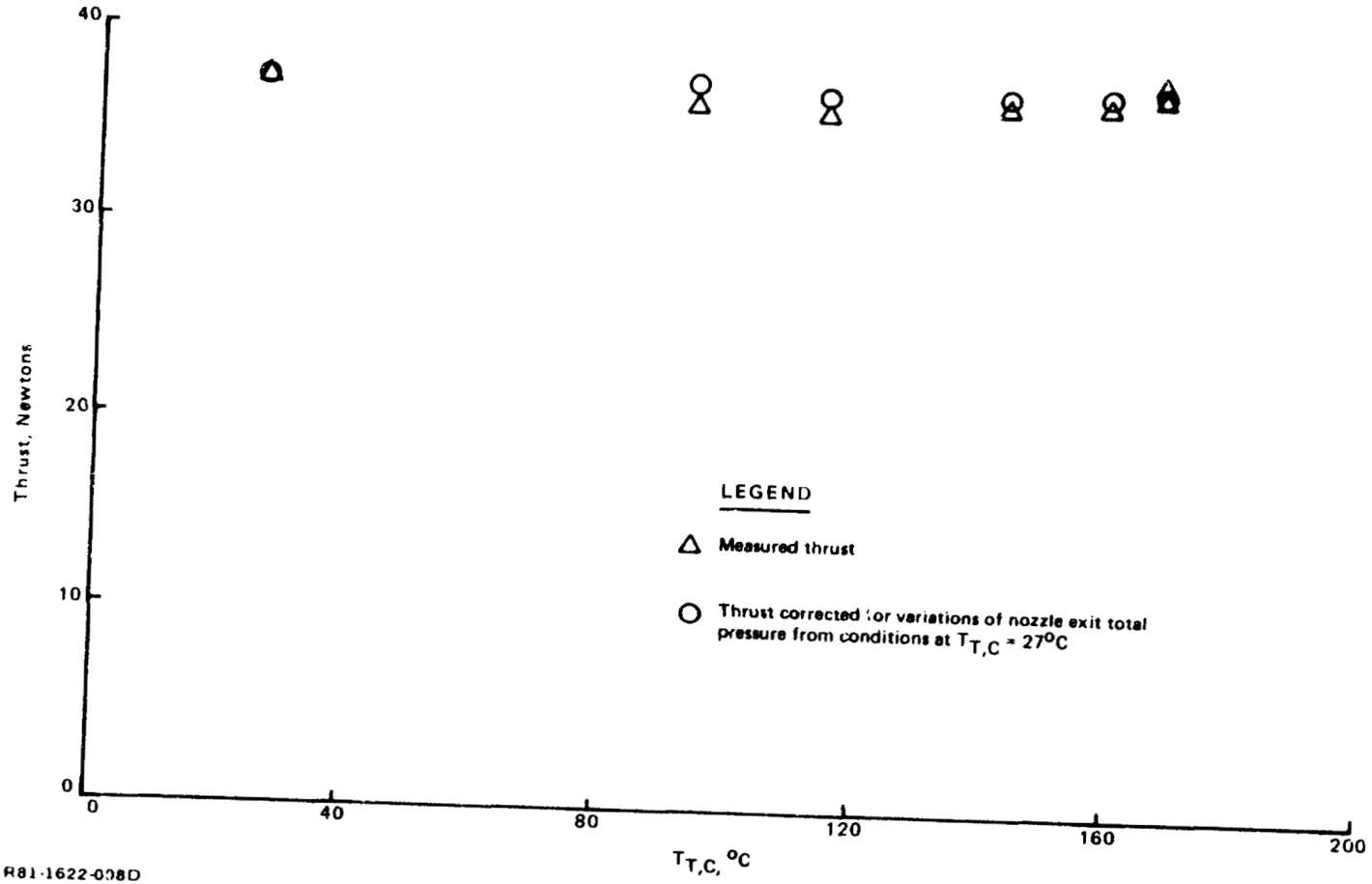

Figure 15 - Variation of nozzle thrust with core exit temperature for baseline nozzle pressure conditions.

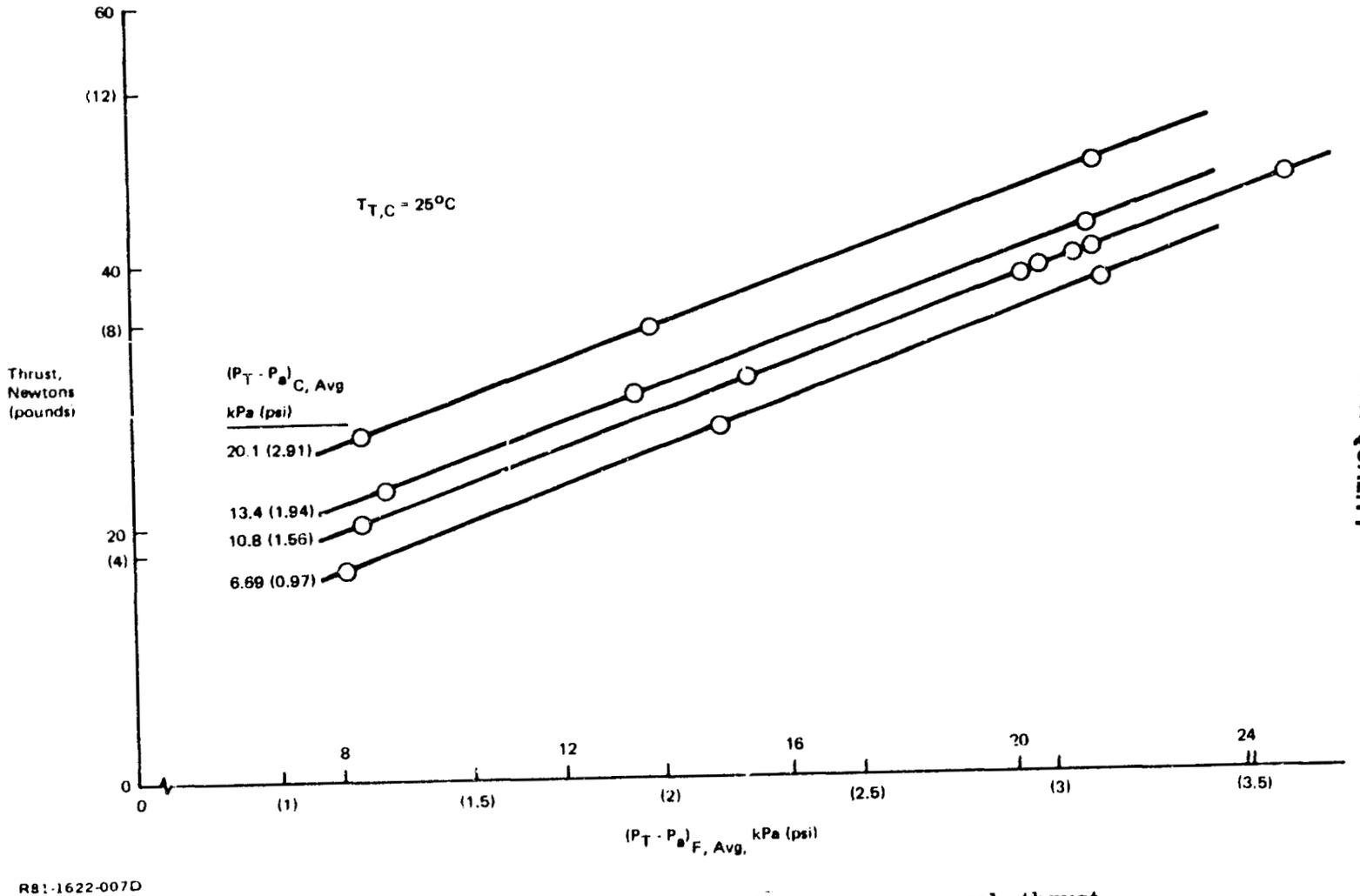

Figure 16 - Effect of fan and core total pressure on nozzle thrust.

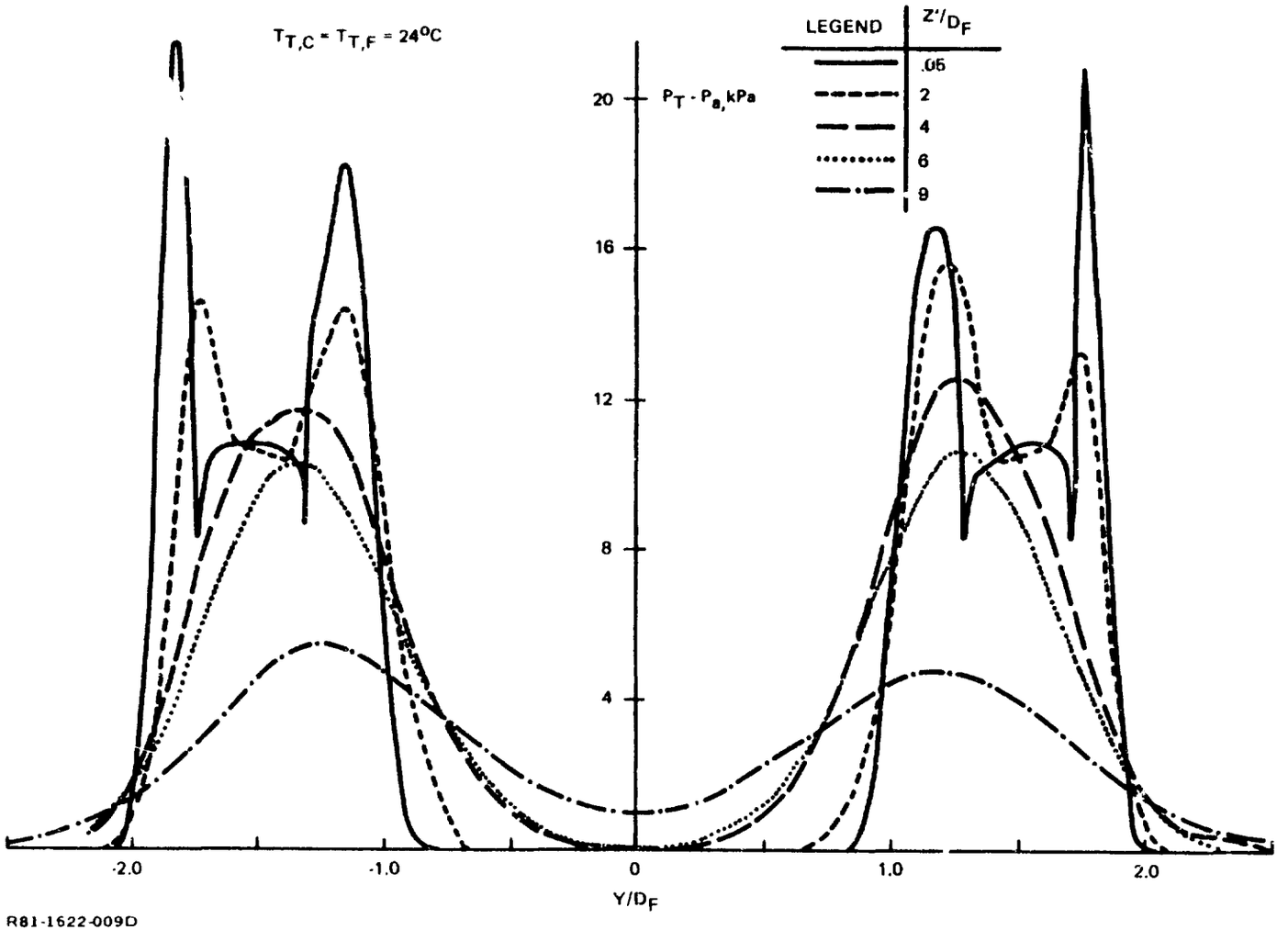

Figure 17 - Free-jet pitot pressure profiles, baseline operation.

not caused by actual convergence of either the fan or core nozzle hardware. The reason for this characteristic of the free-jet pitot pressure profiles is still under active investigation, but it is assumed to be due to the pylon-induced asymmetries.

5.1.2 Ground Flow. - Pressures taken on the ground surface were recorded by a 30-channel A/D system connected to an HP-1000 minicomputer as the ground height was varied. In addition, some pressure data were taken at fixed ground heights as continuous profiles by displacing the ground plane in the y-direction. Figure 18 shows the variation of ground pressure along a line between the two jet impingement points for three body heights above ground. These ground pressure profiles were taken using baseline nozzle pressure conditions and 24°C core nozzle exit temperature. The maximum ground pressure in the stagnation line region (central section of the profiles) shows little variation with body height. The ground pressure in the impingement regions (outer sections of the profiles) shows an inward shift of the ground impingement center for each jet as ground height is increased, which is analogous to the convergence of the free jet centerlines illustrated by Figure 17.

Ground temperature measurements were taken at points around one jet impingement region for the same three heights above ground, using almost the same nozzle pressure conditions and a core exit temperature of 425°C. Figure 19 shows the ground temperature radial variation from one jet impingement point for three different angular orientations (θ). A curve was faired through the round symbols, corresponding to $\theta = 90^{\circ}$ (oriented in the wing spanwise direction). Note that, for $\theta = 0^{\circ}$, the ground temperature was lower, and for $\theta = 180^{\circ}$ the temperatures were higher, than this curve. The higher ground temperature under the wing may have been caused by blockage of air entrainment into the jet exhaust by the presence of the wing.

Figure 20 shows representative wall-jet profiles of total pressure and total temperature that were obtained by traversing a probe normal to the ground at the ground location scaled to rake number 6. Data were taken at the three ground heights corresponding to those run during the full-scale tests. Data were obtained at this ground location and at two other locations (rakes number

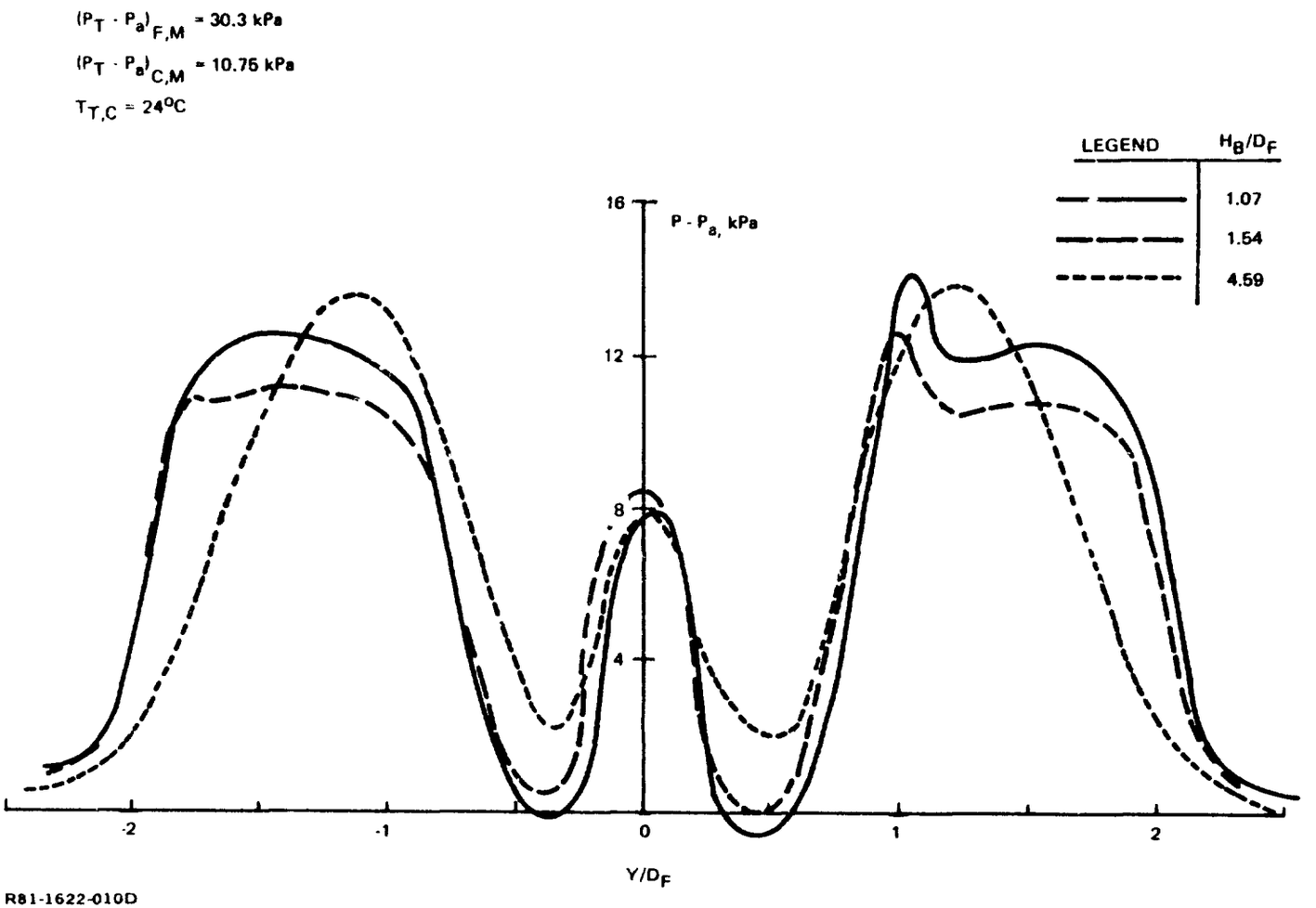

Figure 18 - Ground pressure profiles, fan-jet impingement.

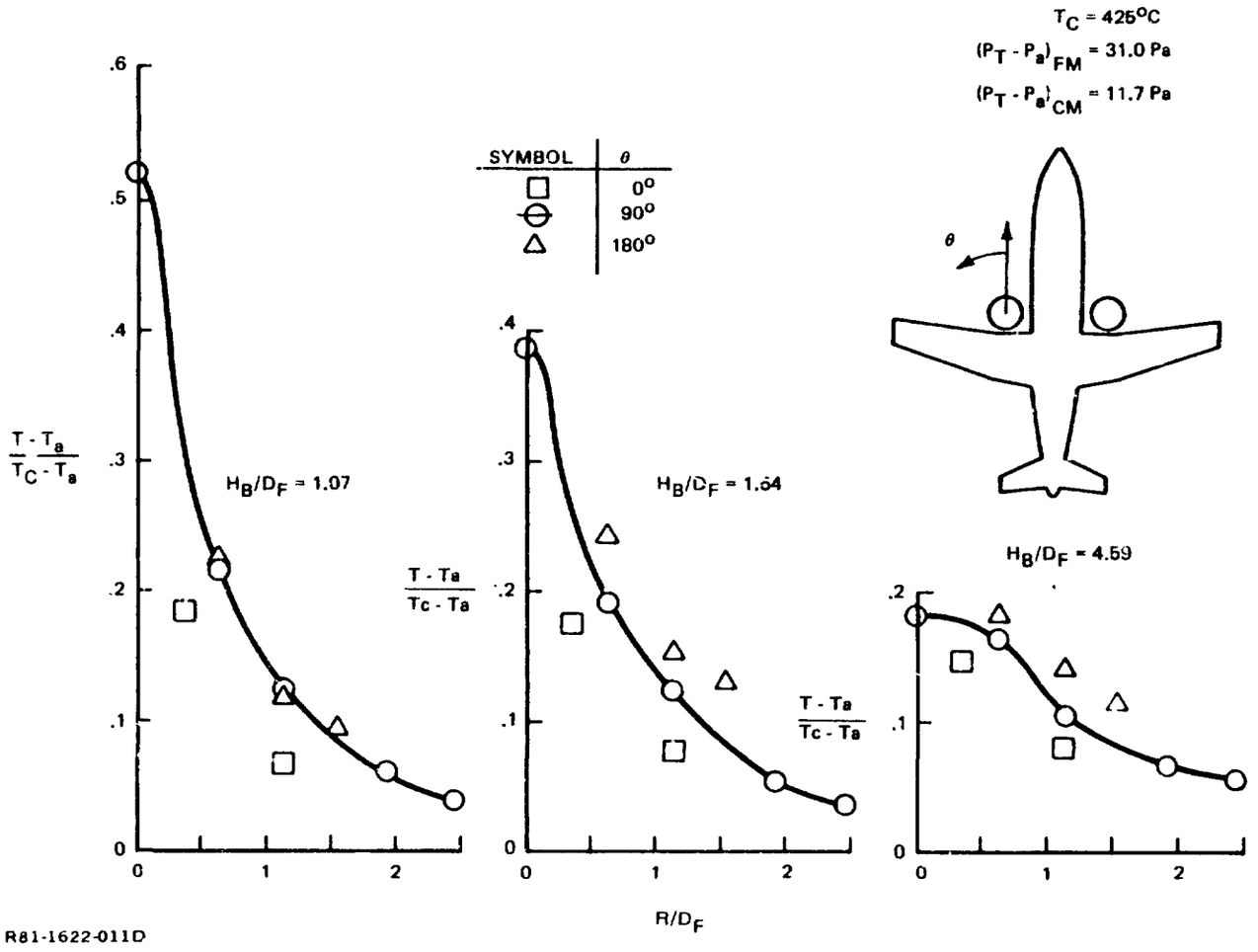

Figure 19 - Ground temperature measurements.

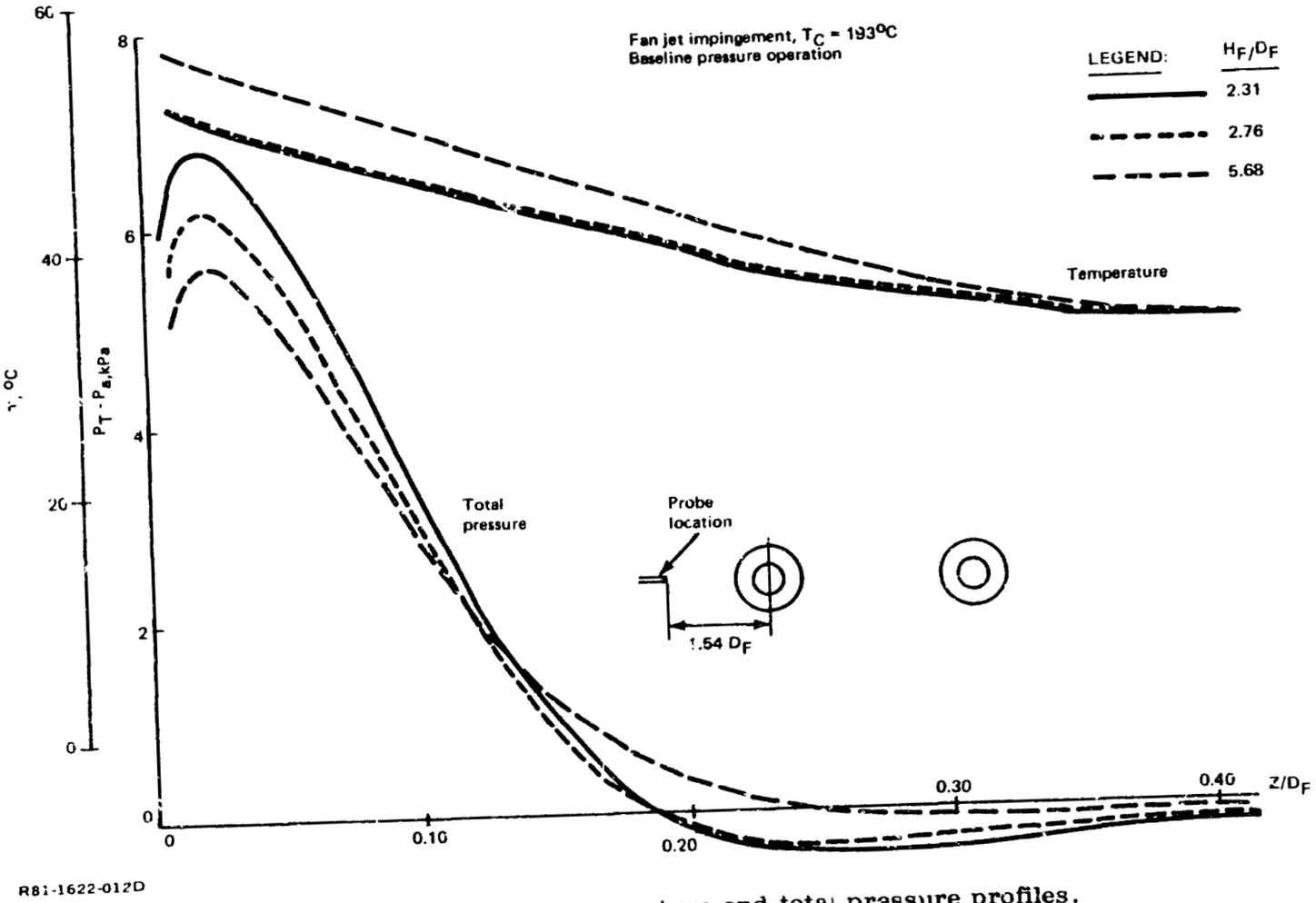

Figure 20 - Wall jet temperature and total pressure profiles.

8 and 10). Figure 21 shows a tabulation of representative features of the pressure and temperature profiles taken at all three ground locations and three ground heights. In this figure, the maximum wall-jet total pressures have been normalized by the maximum total pressure at the fan exit and the wall-jet thickness (at one quarter the maximum profile dynamic pressure) has been normalized by fan-nozzle outside exit diameter.

The temperature data shown in Figure 20 were taken with a bare thermocouple that was located adjacent to the total pressure tube. These data must be corrected to account for radiation losses. The correction has been applied to the data listed in Figure 21.

5.1.3 Upwash Flow. - Flow properties in the upwash were measured by traversing a probe assembly through the centerline of the upwash in the y-direction with the model in place. The total pressure, static pressure and total temperature profiles were measured along a line .56D below the model lower surface, using baseline nozzle pressure conditions and core exit temperatures of 24°C, 128°C, and 192°C. Data could not be taken at the lowest body height tested full-scale (1.07D) because the probe would have been in the upwash formation region. For the greatest full-scale body height (4.59D), the upwash was not recorded because the level was too low. Data were taken at the intermediate full-scale body height (1.54D), Figure 22, and at a somewhat higher body height (1.99D), Figure 23.

Figures 22 and 23 show the variation of total pressure and of the difference between total and static pressures across the upwash for the lowest and highest core temperatures. It was found that the upwash pressure profiles were well-centered around the midpoint between the nozzle centerlines and that they were essentially independent of core exit temperature. The temperature across the upwash was almost constant and can be represented by the centerline values plotted in Figure 24.

5.1.4 Model Forces. - Ground-induced interference forces were measured for both the 15° and 45° strake angle configuration for several nozzle pressures and temperatures. The first example, varying fan total pressure with core temperature equal to fan temperature (approximately 24°C), is shown in Figure 25.

H_B/D_F	Wall Jet Station	R/D_F	θ	$\frac{(P_T - P_a)_M}{(P_T - P_a)_{FM}}$	$\frac{Z_{.25}}{D_F}$	$\frac{(T_T - T_a)_M}{(T_T - T_a)_C}$
1.54	6	1.54	90°	.276	.132	.173
1.54	8	1.28	150°	.433	.122	.233
1.54	10	1.54	218°	.354	.108	.112
1.99	6	1.54	90°	.253	.130	.173
1.99	8	1.28	150°	.396	.118	.241
1.99	10	1.54	218°	.346	.113	.112
4.60	6	1.54	90°	229	.138	.200
4.60	8	1.28	150°	.320	.138	.227
4.60	10	1.54	218°	.323	.169	.112

Notes: 1) Baseline pressure operation

2) $T_{T,C} = 193°C$

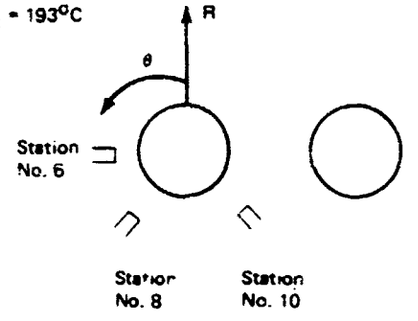

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Figure 21 - Data from wall jet profiles resulting from fan jet impingement.

For both the 15° and 45° strakes, changing fan total pressure with core total pressure held constant produced a progression of interference forces with no change in the qualitative behavior with height above ground. Note that, for all these cases, the fan total pressure was well above the core total pressure. The behavior may be changed if the core total pressure becomes equal to or larger than the fan total pressure because of changes in the impinging jet behavior.

A more meaningful view of the effects of the fan total pressure can be found in the non-dimensional presentation with interference force normalized by

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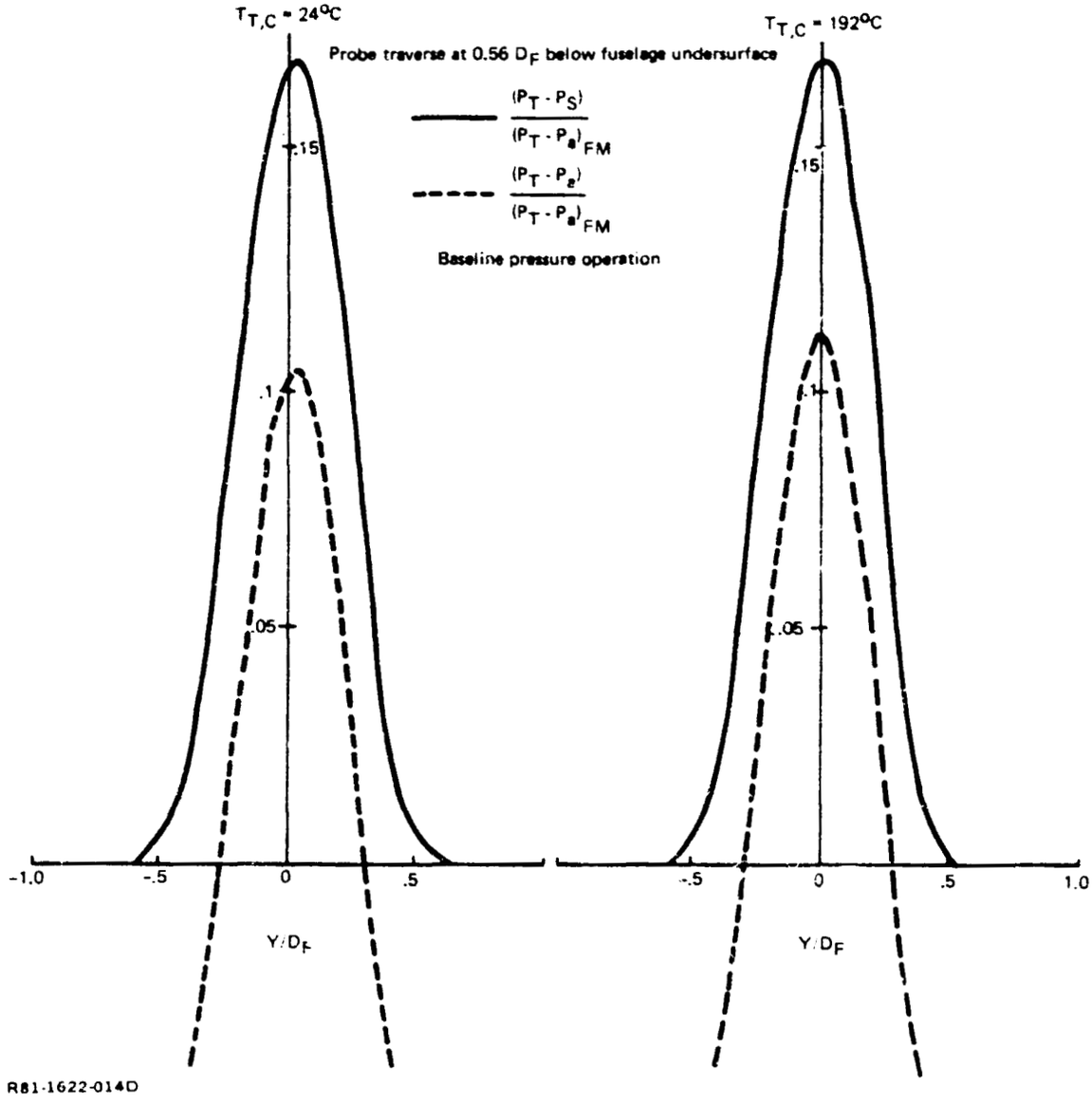

Figure 22 - Pressure profiles across upwash centerline, H_B/D_F = 1.54.

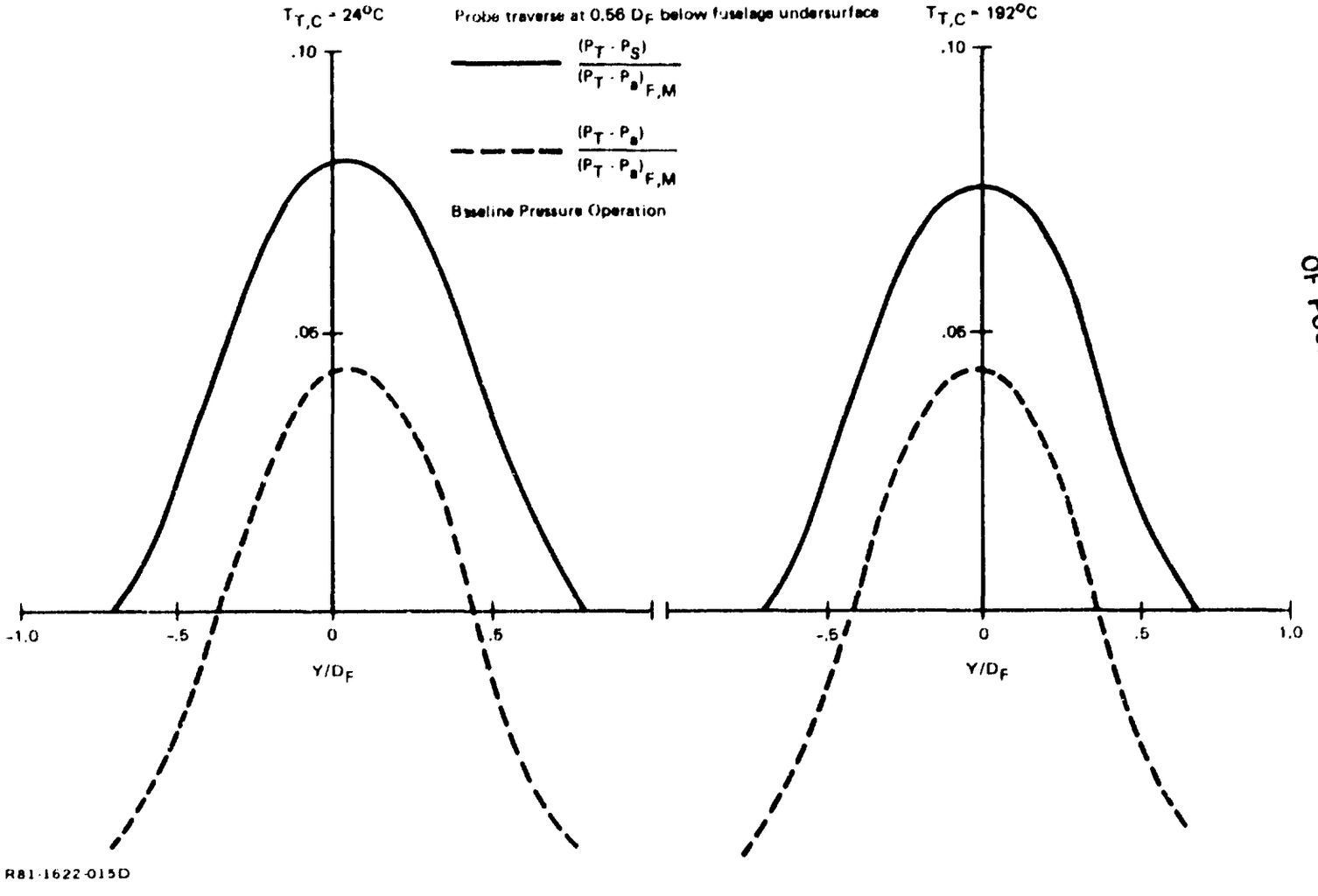

Figure 23 - Pressure profiles across upwash centerline, $H_B/D_F = 1.99$.

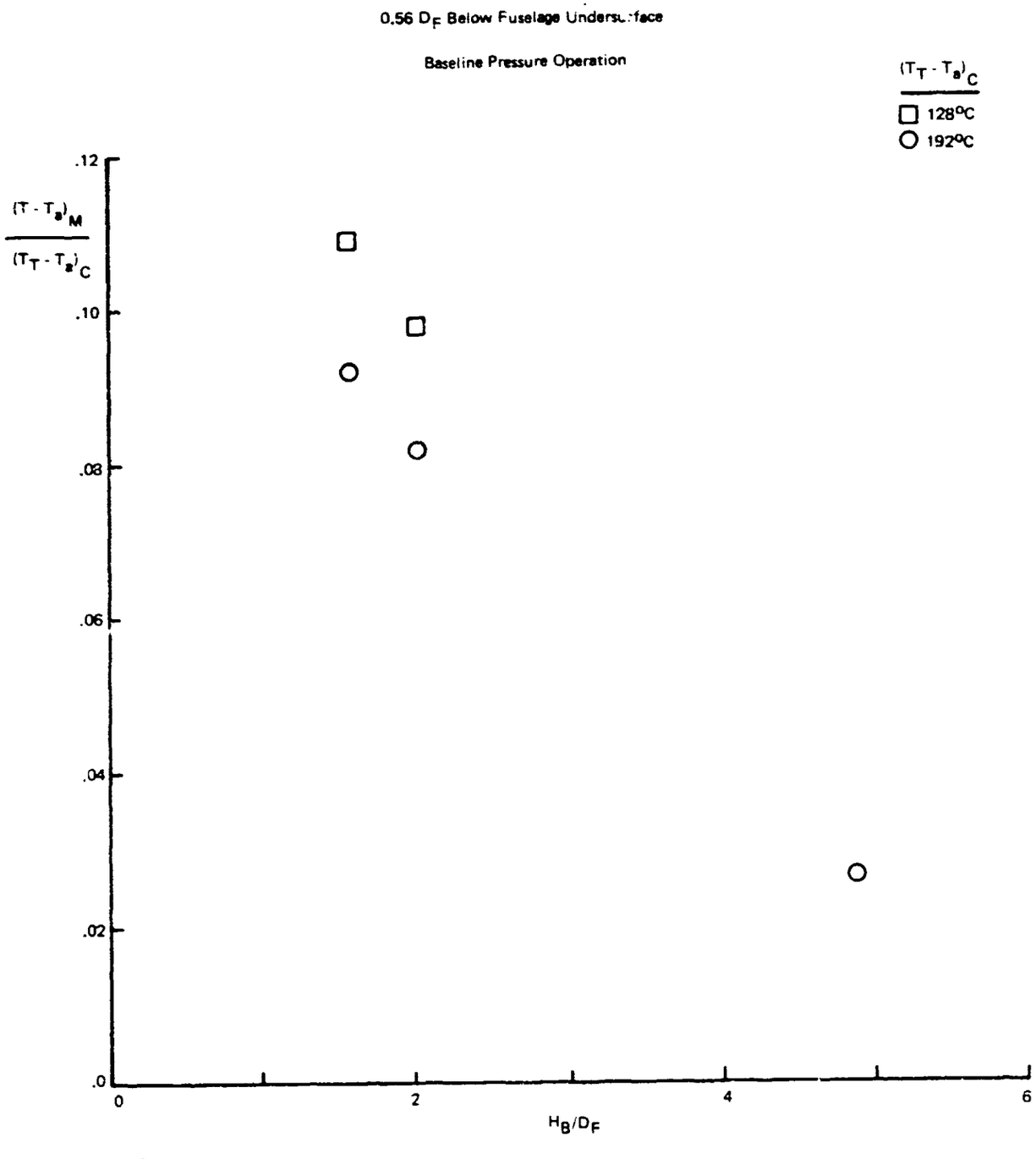

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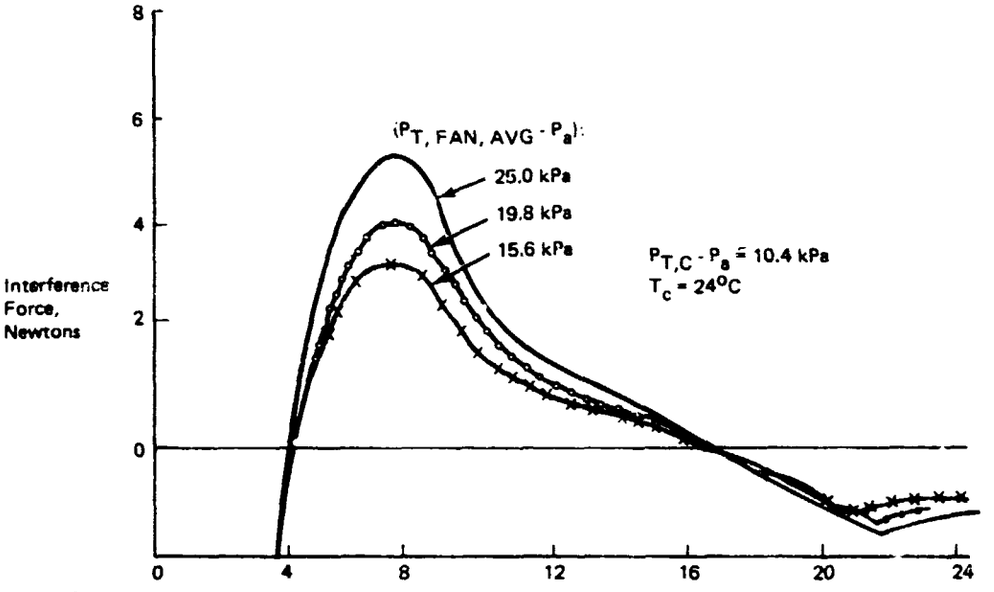
Figure 24 - Variation of centerline upwash temperature with ground height.



a) 15° strakes

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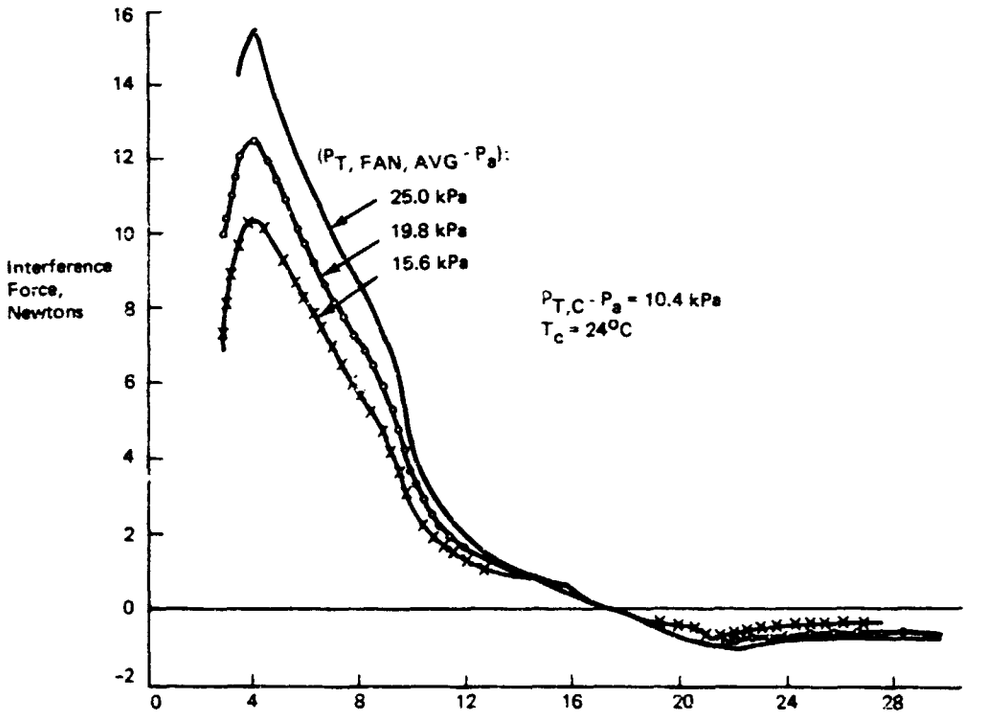

b) 45° strakes

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Figure 25 - Effect of fan pressure on interference forces.

the nozzle thrust shown in Figure 26. The total pressure level has no significant effect on the non-dimensional interference forces. Full scale data (from Ref. 1) are shown on this plot for reference.

At a fan average total pressure of 19.8 kPa gauge (and core total pressure, again, at 10.4 kPa gauge) five core total temperatures were run: 43°C, 104°C, 254°C, 322°C and 416°C. As shown in Figure 27, there is essentially no effect of temperature on the interference forces. Experiments were also conducted with the nozzle exit flow more closely matching the full-scale engine conditions. For a fan total pressure of 25 kPa gauge, model forces were measured with core exit temperature of 421°C and 43°C. Figure 27 shows these results compared to the full-scale data (Ref. 1). Again, there is a very small effect of temperature on interference forces. The close agreement between the model test results and the full-scale data indicates that good simulation of aircraft ground interference forces can be obtained with a 1/24th scale model even without core temperature simulation.

5.1.5 Model Surface Pressures and Temperatures. - Pressure and temperature measurements were taken on the model undersurface with the baseline nozzle pressure conditions and core nozzle exit temperatures of 128°C and 192°C. Figure 28 shows dimensionless temperature distributions along the model underside (x-direction) for three heights above ground. The temperature across the model surface (y-direction) showed little variation. Values of the surface temperature coefficient $((T-T_a)/(T_c-T_a))$ at station number 22 (0.54D aft of the nacelle centerline) are very close to values found with a probe on the upwash centerline at 0.56D below the model surface (Figure 24). This comparison provides some verification for the model surface temperature data, which were taken by thermocouples attached to the inner surface of the metallic underside of the model as described in Subsection 4.7.2. Figure 29 shows the variation of model temperature and pressure with body height above ground. The temperature was measured at station number 22 and the pressure at the midpoint between nozzles.

Model pressure and temperature data were also taken for a higher core temperature and a higher fan pressure that more closely matched the full-

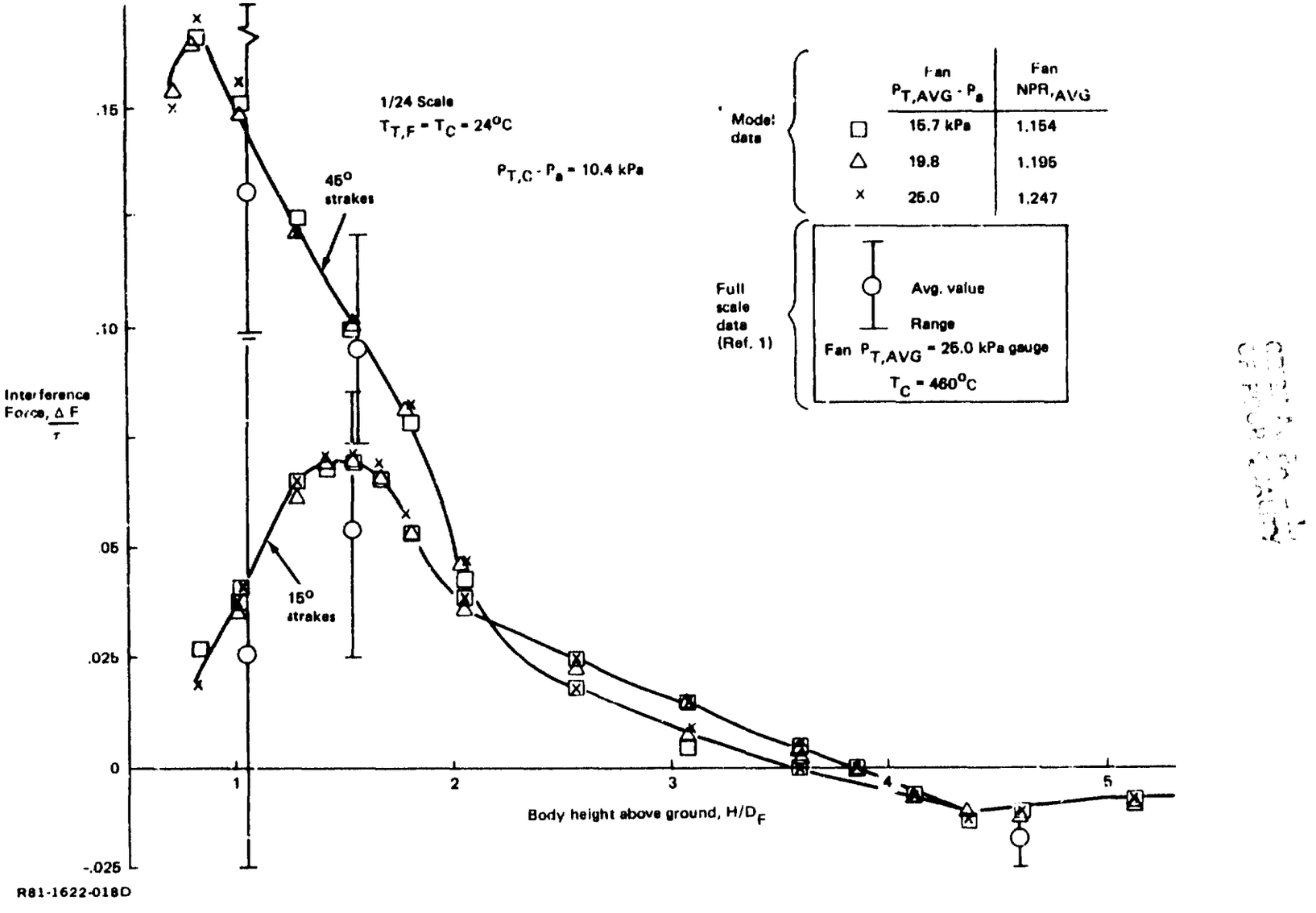
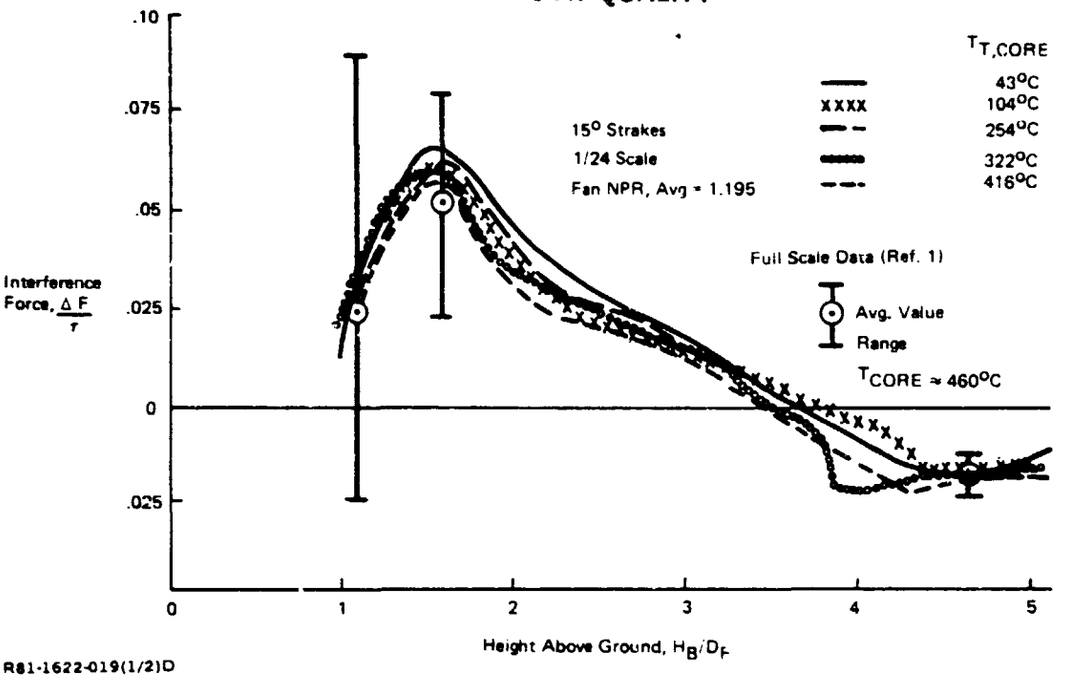


Figure 26 - Effect of fan nozzle pressure on interference forces



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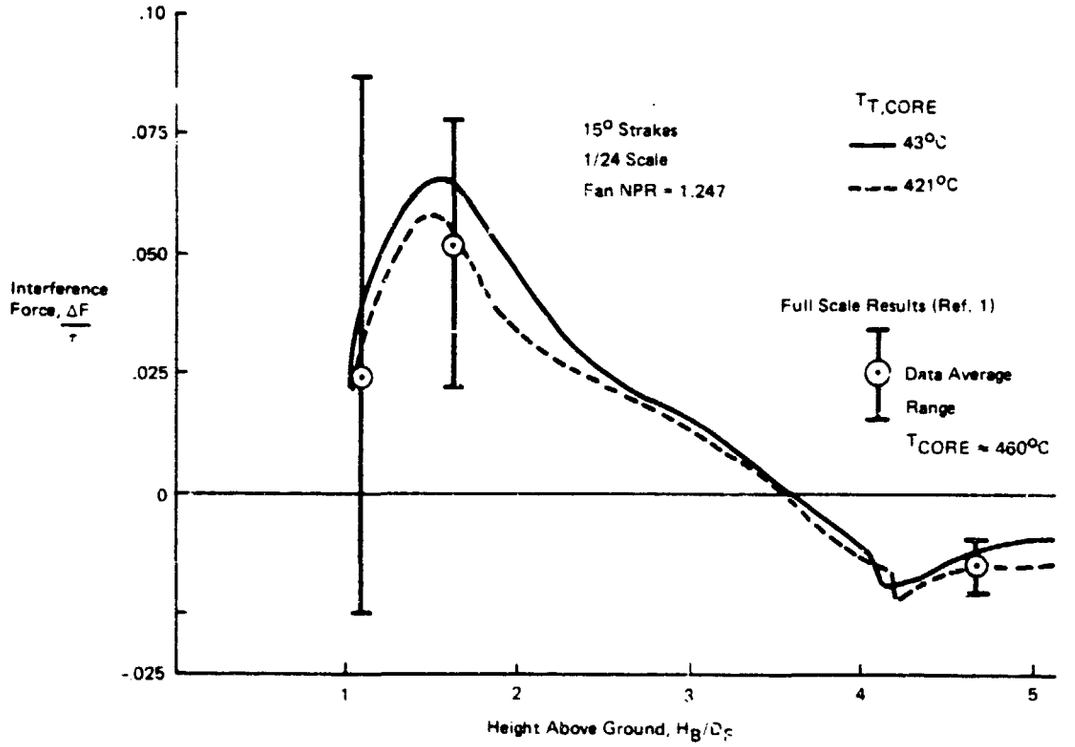

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Figure 27 - Effect of core temperature and fan pressure ratio on interference forces, $T_{T,F} = 24^{o}C$.

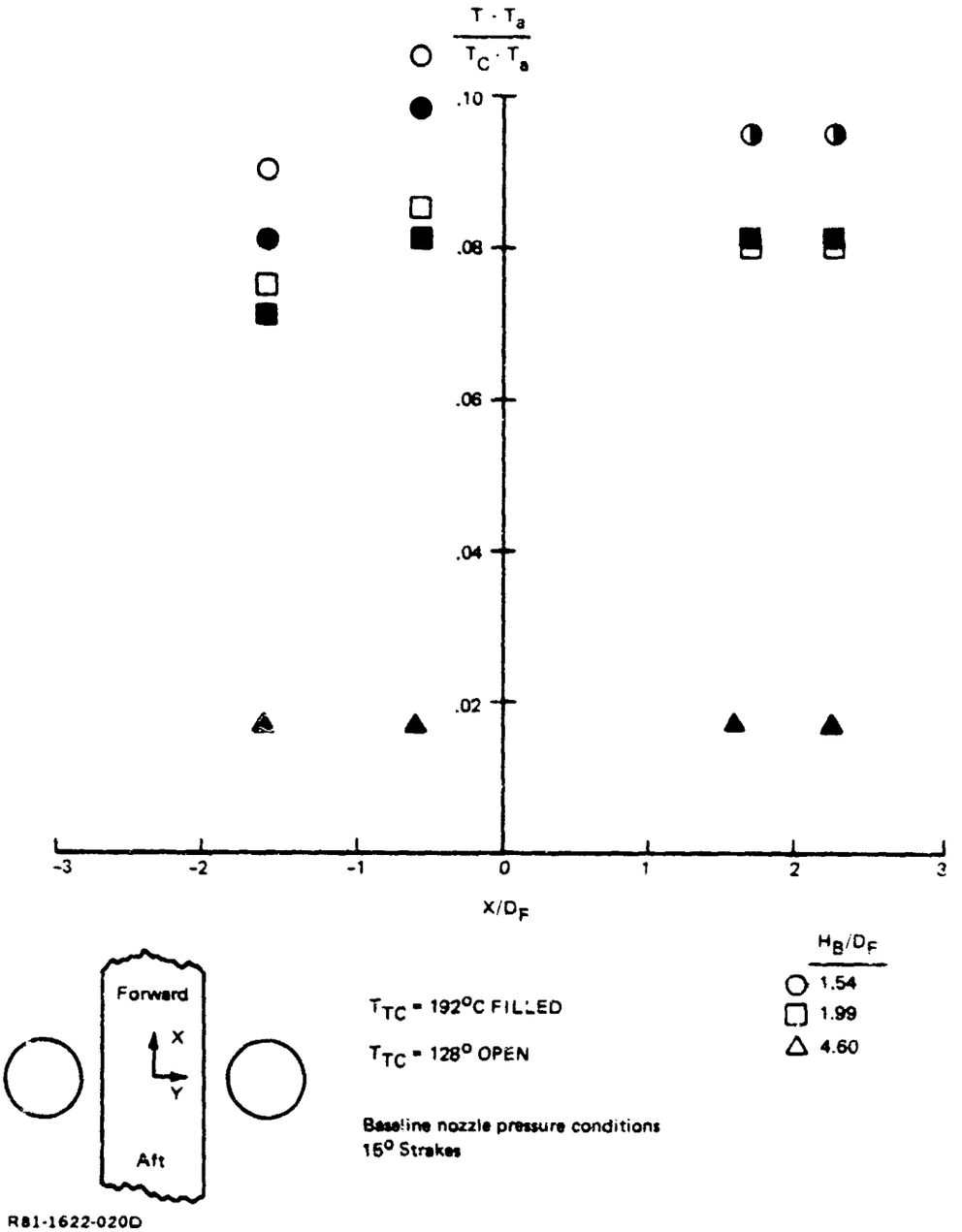

Figure 28 - Temperature distribution along model underside.

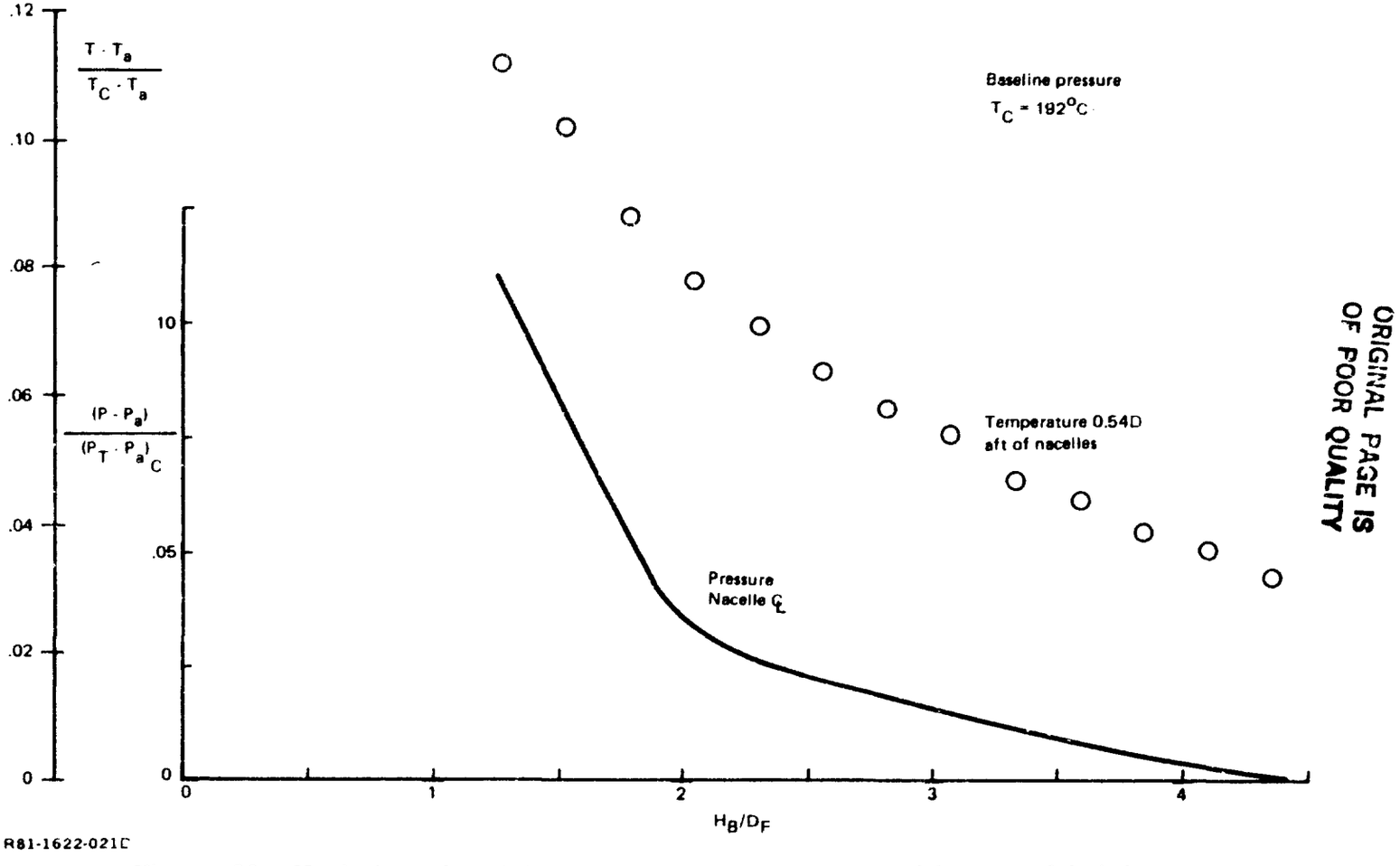

Figure 29 - Variation of model pressure and temperature with ground height.

scale tests. Figures 30 and 31 show pressure and temperature measurements taken at three heights above ground for a core exit temperature of 427°C. The relatively low model surface temperatures shown at $X/D_F = 0.5$ in Figure 31 are not due to faulty thermocouples. Temperatures on both sides (y-direction) of this centerline thermocouple showed the same values, which verified that the temperature profile along the model had a local minimum slightly forward of the nacelle centerline. The magnitude of this local minimum varied with height above ground. This distortion did not appear in the data taken at lower core temperature (Figure 28) because this centerline thermocouple and one of the side thermocouples were inoperative during the earlier tests.

Comparison of the data shown in Figure 31 with those shown in Figure 28 indicates that the model surface temperature does not scale well with wide variations in core exit temperature. The model surface temperature coefficient decreased by more than a factor of two when the core flow temperature was raised from 128°C to 421°C. The same poor temperature scaling appeared in probe temperature measurements on the upwash centerline (Figure 24). In this case, the local temperature coefficient in the flow decreased by 15 percent when the core exit temperature was raised from 128°C to 192°C.

Probe temperature surveys were made in the area corresponding to the inlets on the full-scale model ($1.8D_F$ above the model upper surface, close to the outer surface of the fan nozzles). It was found that the temperature in this region was very close to ambient, and fluctuating greatly. The maximum temperature rise observed for a nozzle total temperature of 192°C was approximately 2°C. The strakes apparently turn the flow enough to prevent any significant amount of upflow from reaching the inlet area. The inlet suction may affect the flow field to alter this behavior, but this is not expected to happen.

5.2 Open Circular Nozzles

5.2.1 Nozzle Flow. - Free jet data were taken with the ground plane removed, using settling chamber temperatures from ambient to 232°C, and a settling chamber pressure of 27.6 kPa above ambient. Total pressure and temperature profiles were recorded for probe traverses across both jet centerlines for dis-

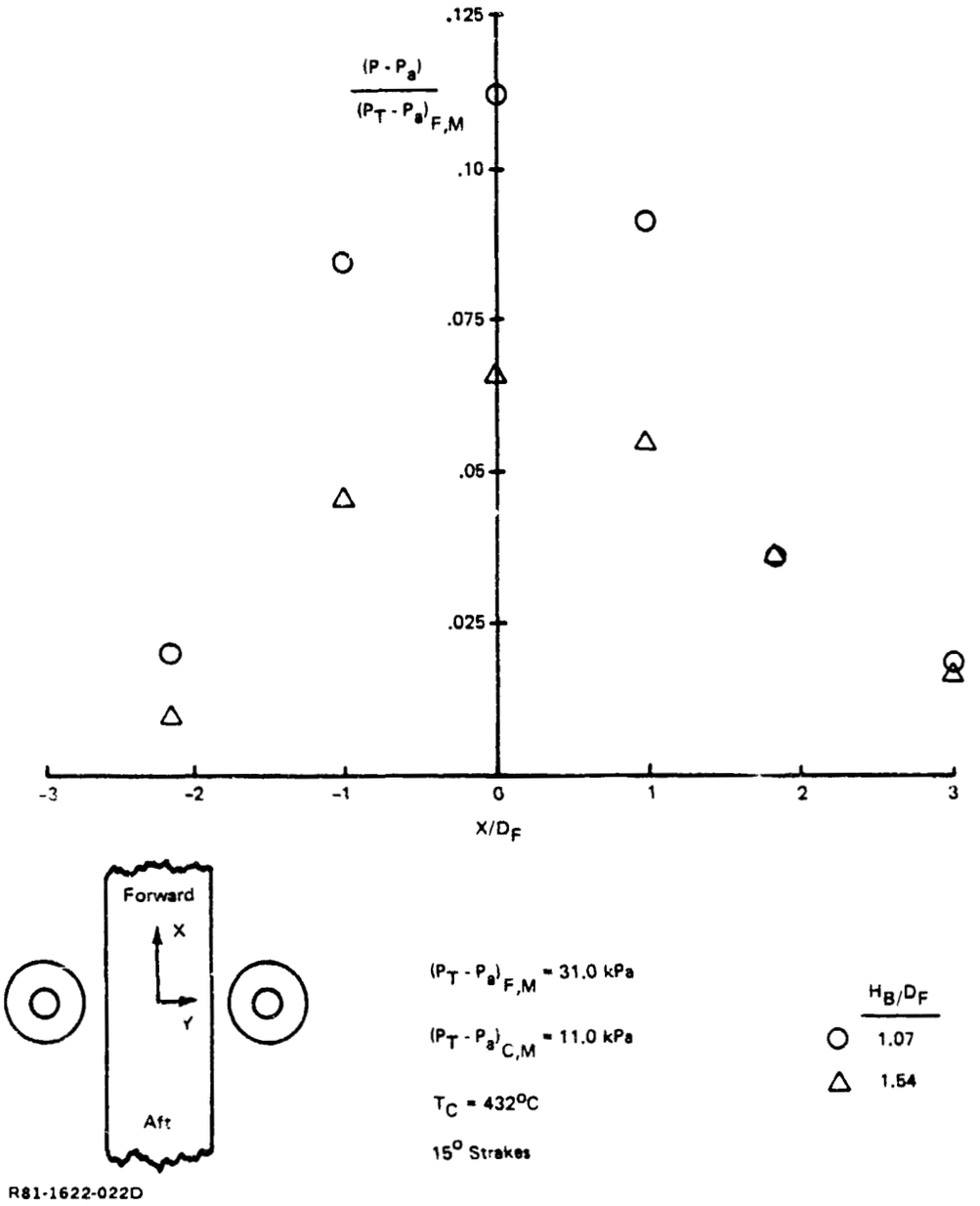

Figure 30a - Pressure distribution along model.

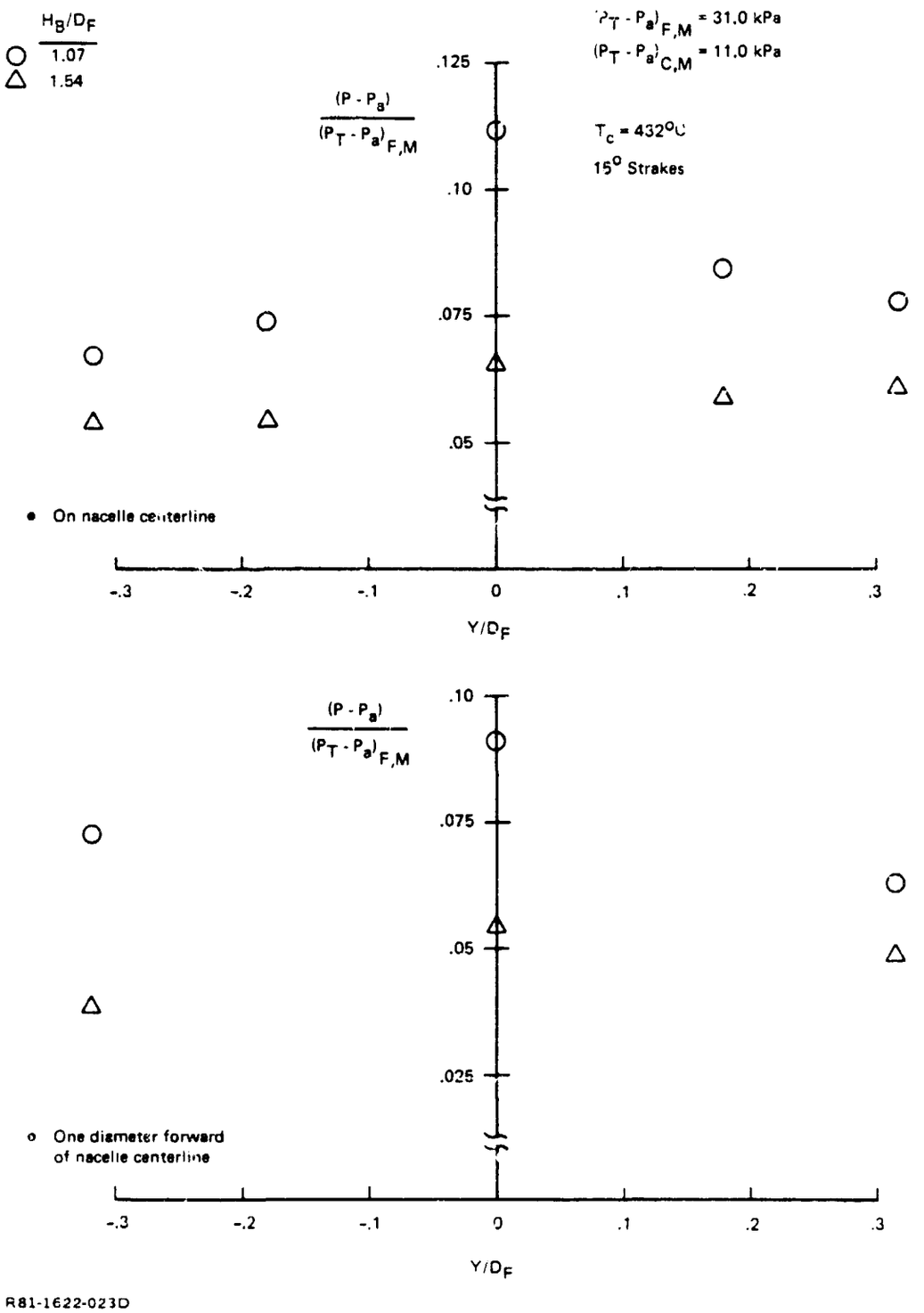

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Figure 30b - Pressure distribution across model.

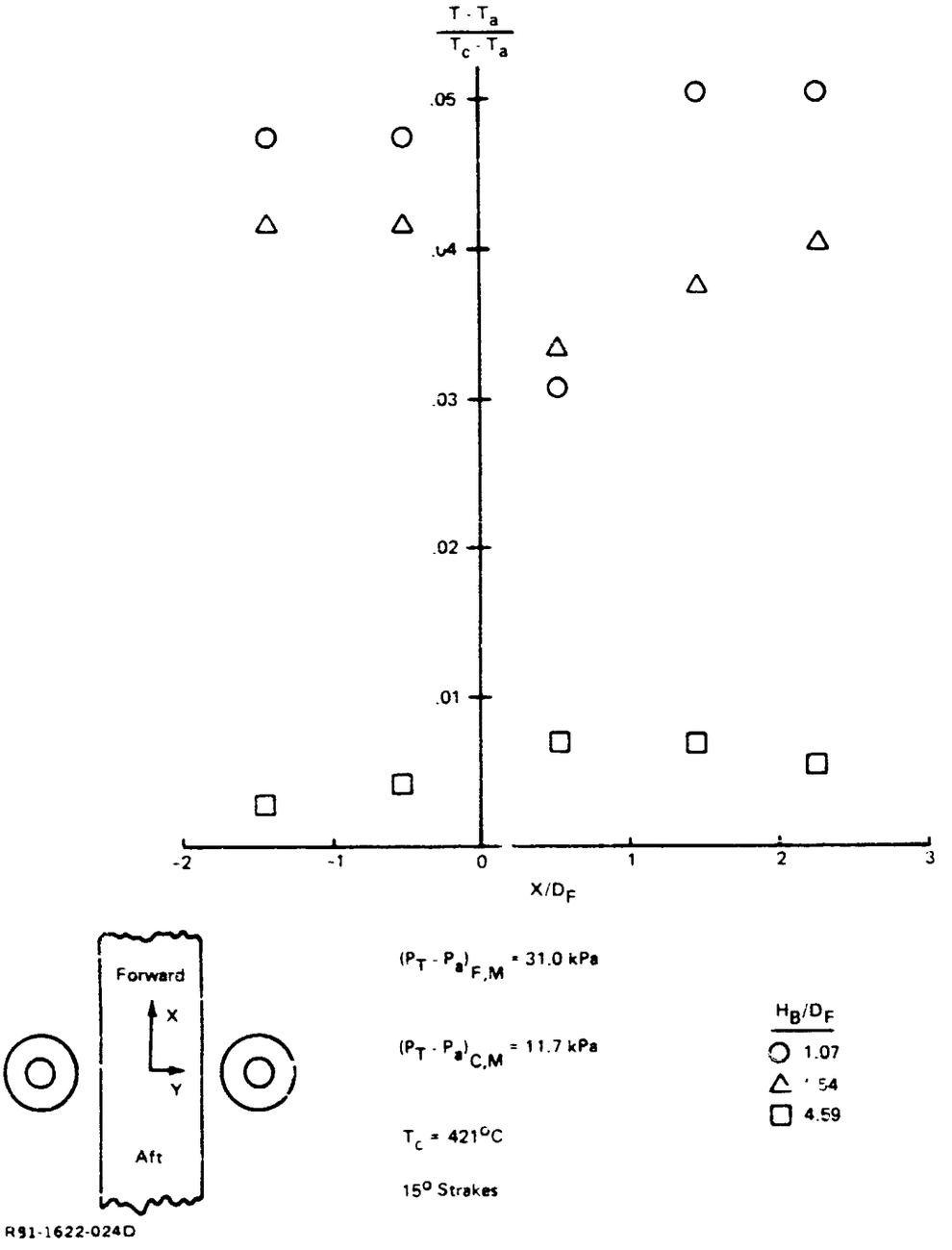

Figure 31 - Model temperature distribution.

tances (Z') from the jet exists up to 15 diameters. Figure 32 shows pitot pressure profiles obtained with a settling chamber temperature of 227°C. Profiles taken close to the exit exhibit a flat-topped profile with a 1 percent ripple that was caused by fluctuations with time of the air supply pressure. Note that there is no inward shift of the maximum pitot pressure points at large values of Z' as occurred in the free-stream data obtained with fan-jet nozzles. The corresponding temperature profiles are shown in Figure 33. These temperature data were plotted directly from the thermocouple output and have not been corrected for radiation losses. (This correction was typically of the order of 10°C.) The pressure profiles begin to merge about seven diameters from the nozzle exit. The temperature profiles show a greater radial spreading and begin to merge about five diameters from the nozzle exit.

Figure 34 shows data taken from profiles that were obtained with different settling chamber temperatures. The data show the decay of pitot pressure and temperature along one jet centerline with two jets in operation. The centerline pitot pressure decay is slightly greater for heated than for unheated jets. Several runs made with one nozzle blocked off showed no difference between the single- and dual-jet results in the centerline values of both pitot pressure and temperature out to Z' = 15 diameters. Hence, the decay in centerline properties obtained from two jet operation can be used to represent single-jet operation.

5.2.2 Ground Flow without Model. - Ground-pressure and wall-jet profiles were taken at three values of H/D corresponding to the full-scale test conditions. Ground pressure measurements were taken without the model to determine how closely the radial pressure distribution around one jet impingement point matched existing single-jet impingement data. Figure 35 shows the data taken along radial paths at two orientations around one jet centerline. The solid curve, taken from Ref. 2, represents an empirical approximation for the ground pressure distribution for a single jet with H/D between 2.0 and 5.0.

Wall-jet profiles (similar to those shown in Figure 20) were taken at the same values of H/D and the same ground locations used in the full-scale

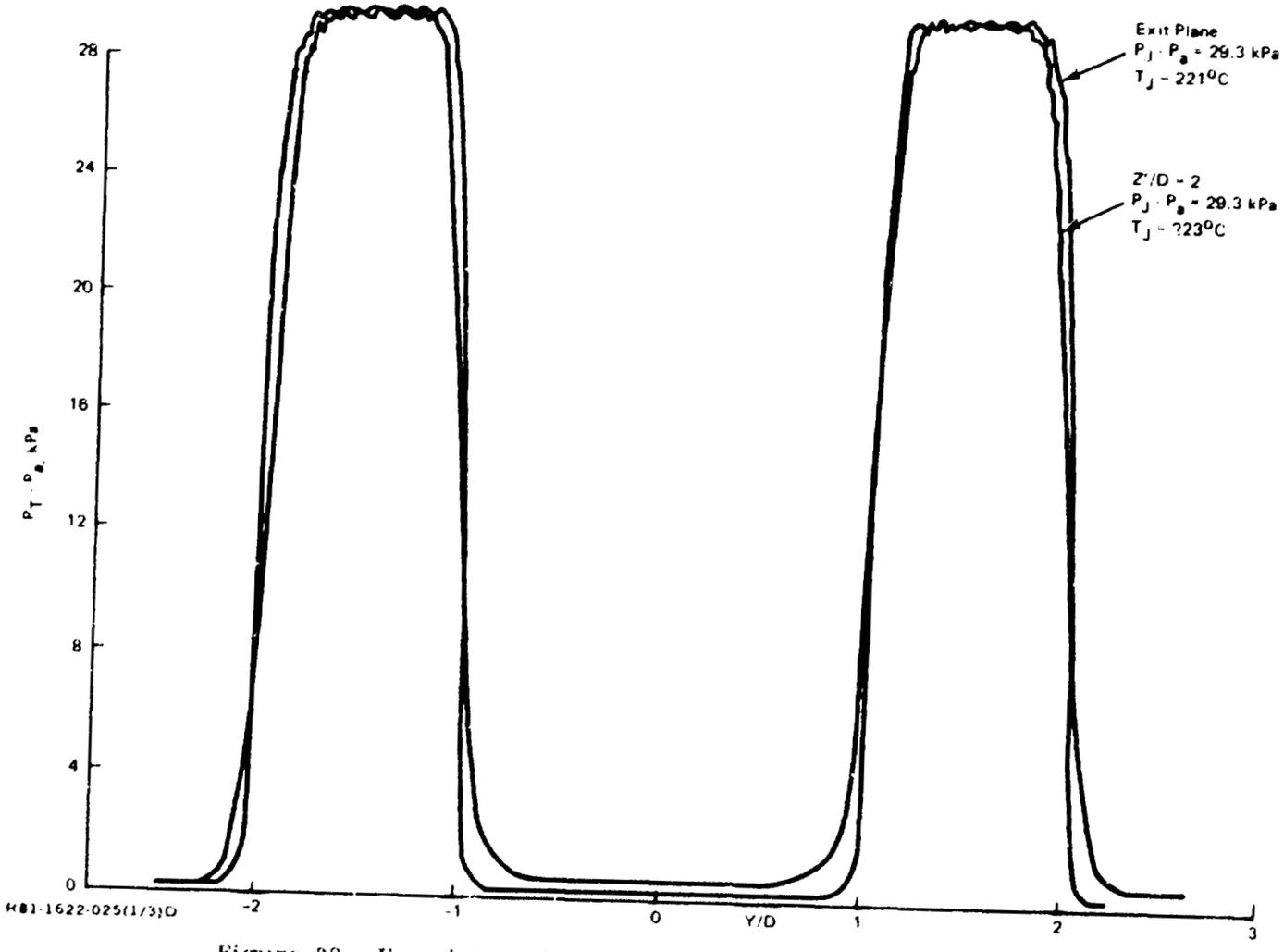

Figure 32 Free jet total pressure surveys, open circular nozzles.

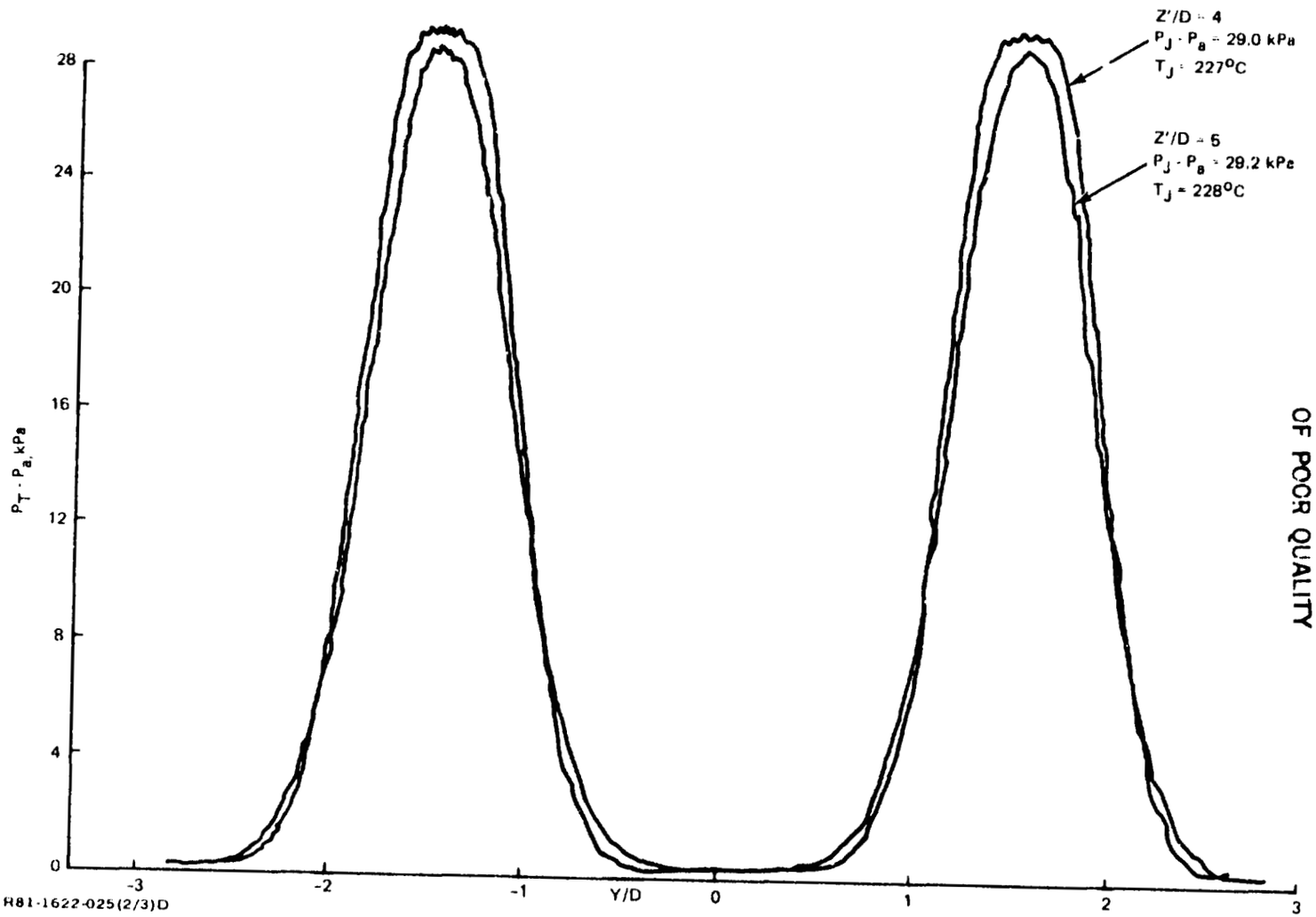

Figure 32 - (Continued).

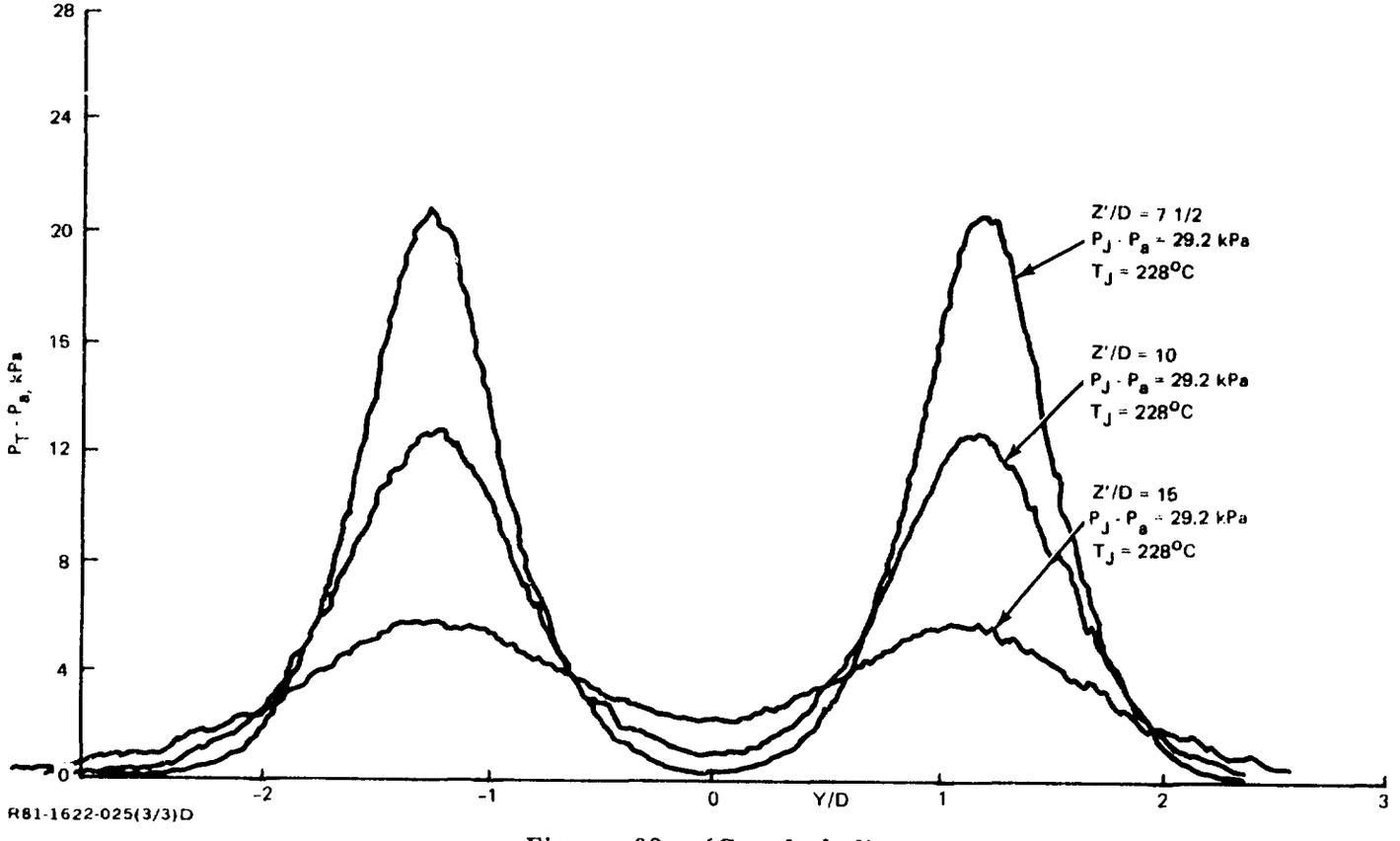

Figure 32 - (Concluded).

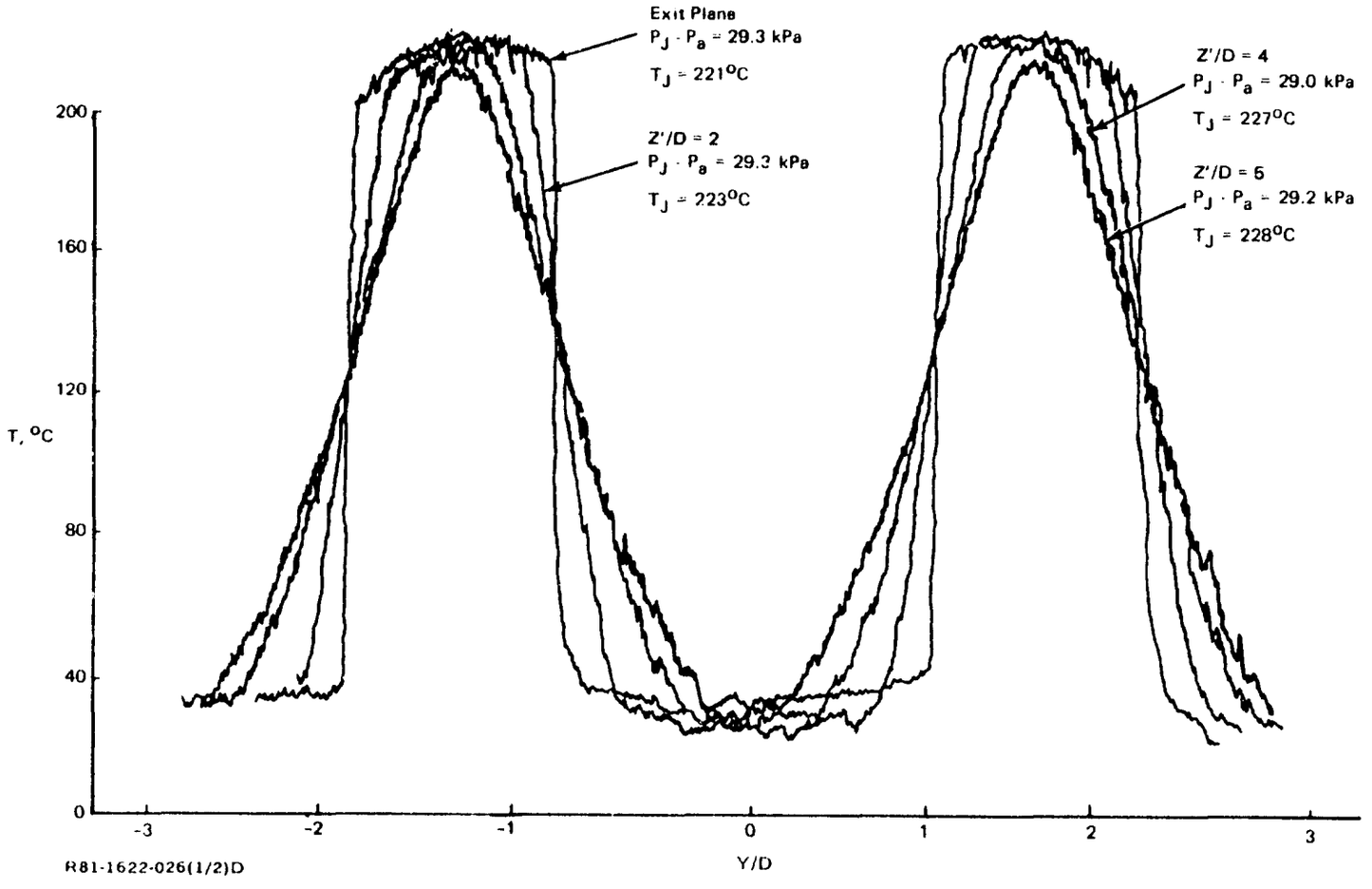

Figure 33 - Free jet total temperature surveys, open circular nozzles.

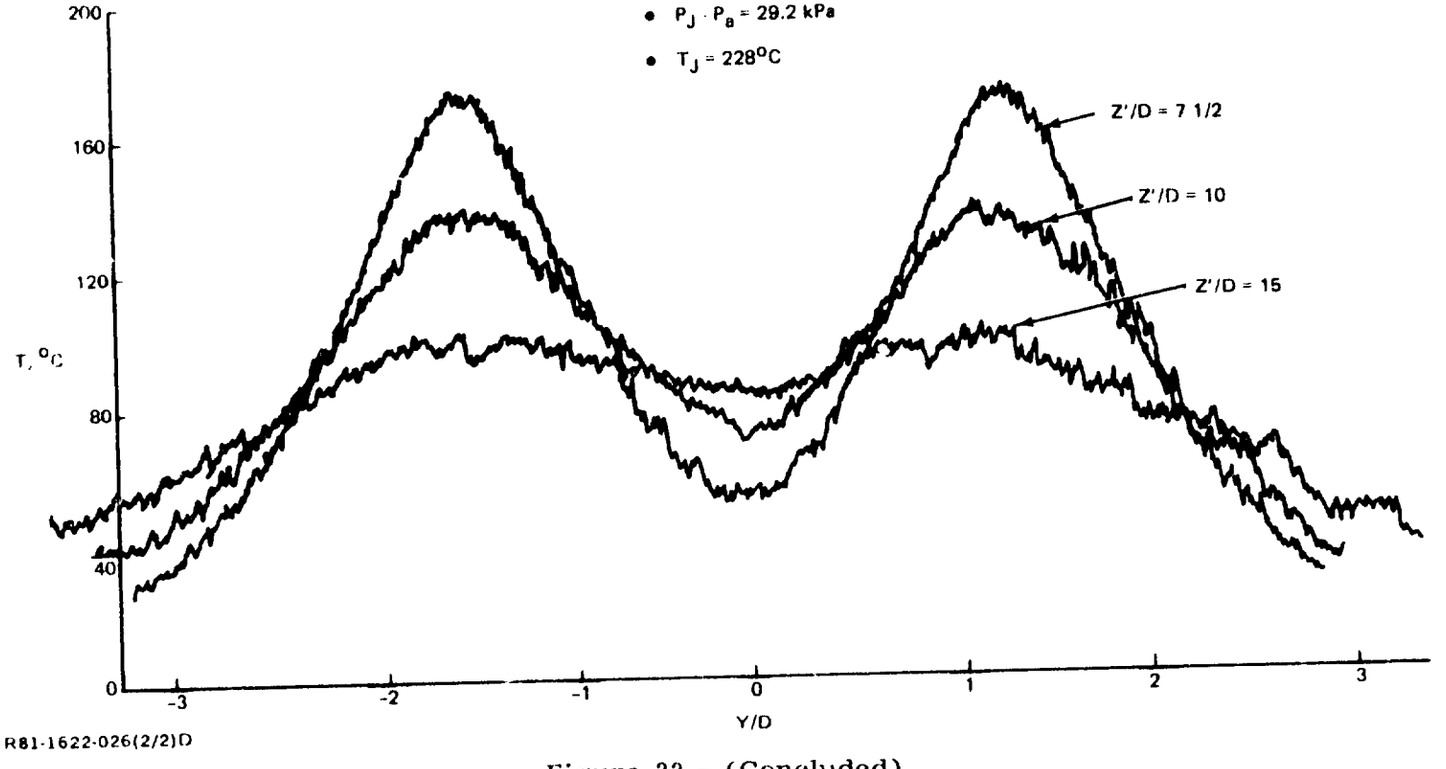

Figure 33 - (Concluded).

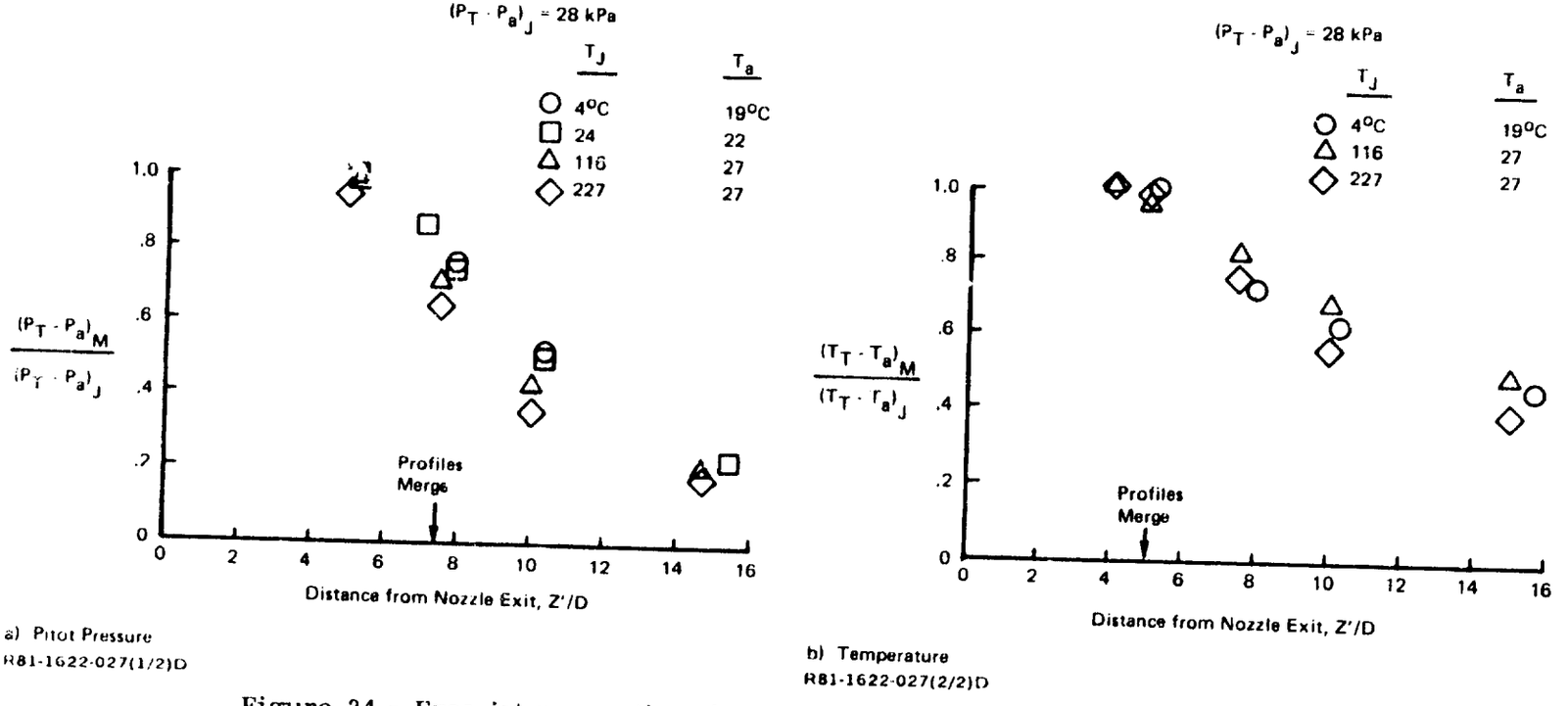

Figure 34 - Free jet properties along one flow centerline, two jets operating, open circular nozzles; data representative of single-jet operation.

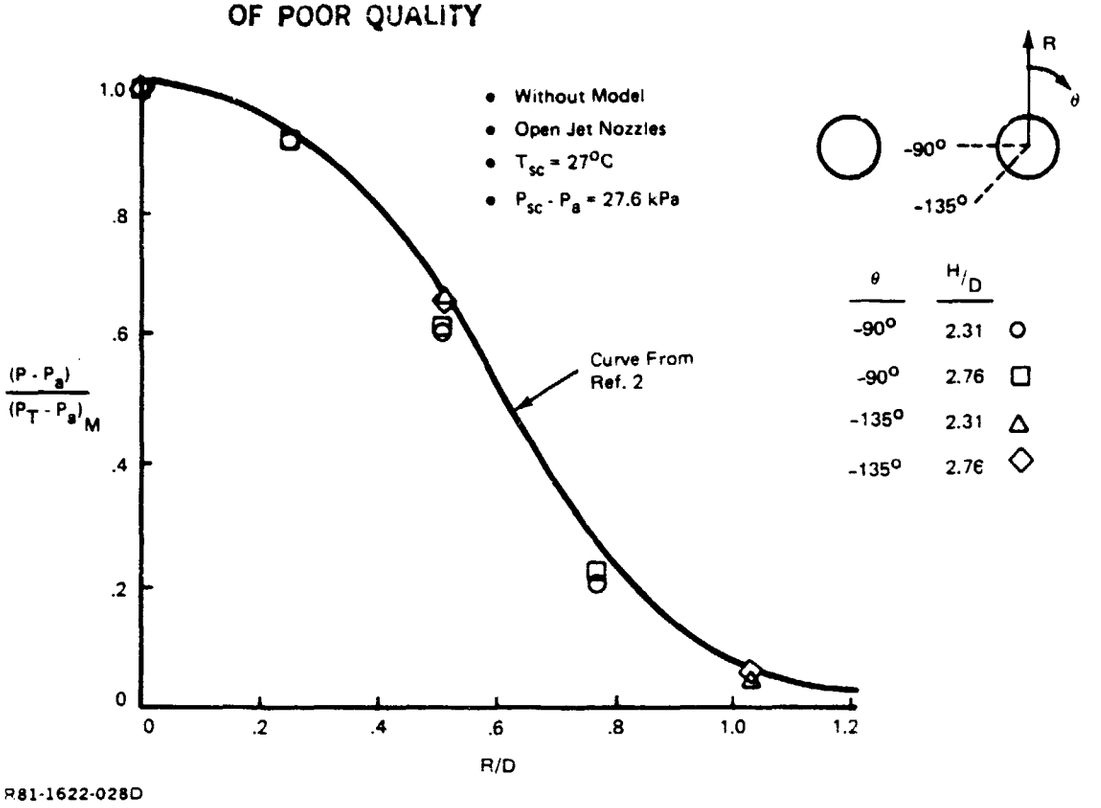

Figure 35 - Radial ground pressure distribution around one jet impingement center.

fan-jet tests. These measurements, summarized by plots of maximum total pressure and thickness in Figure 36, show little influence of temperature on the wall-jet pressure data.

This figure suggests that the wall-jet flow was not axially symmetric around one jet impingement point. Wall-jet profiles taken at the same radius from the closest impingement center show that the flow directed toward the stagnation line has a higher peak total pressure and a greater thickness than the flow directed away from it. This trend occurs for all tested heights above the ground and all settling chamber temperatures. This apparent lack of symmetry in the wall jet data around one impinging jet is probably a real distortion of the ground flow caused by the impingement of the second jet, but may have been caused by interference of the probe support with the upwash formation region when it was located at Station No. 10 (see sketch in Figure 36).

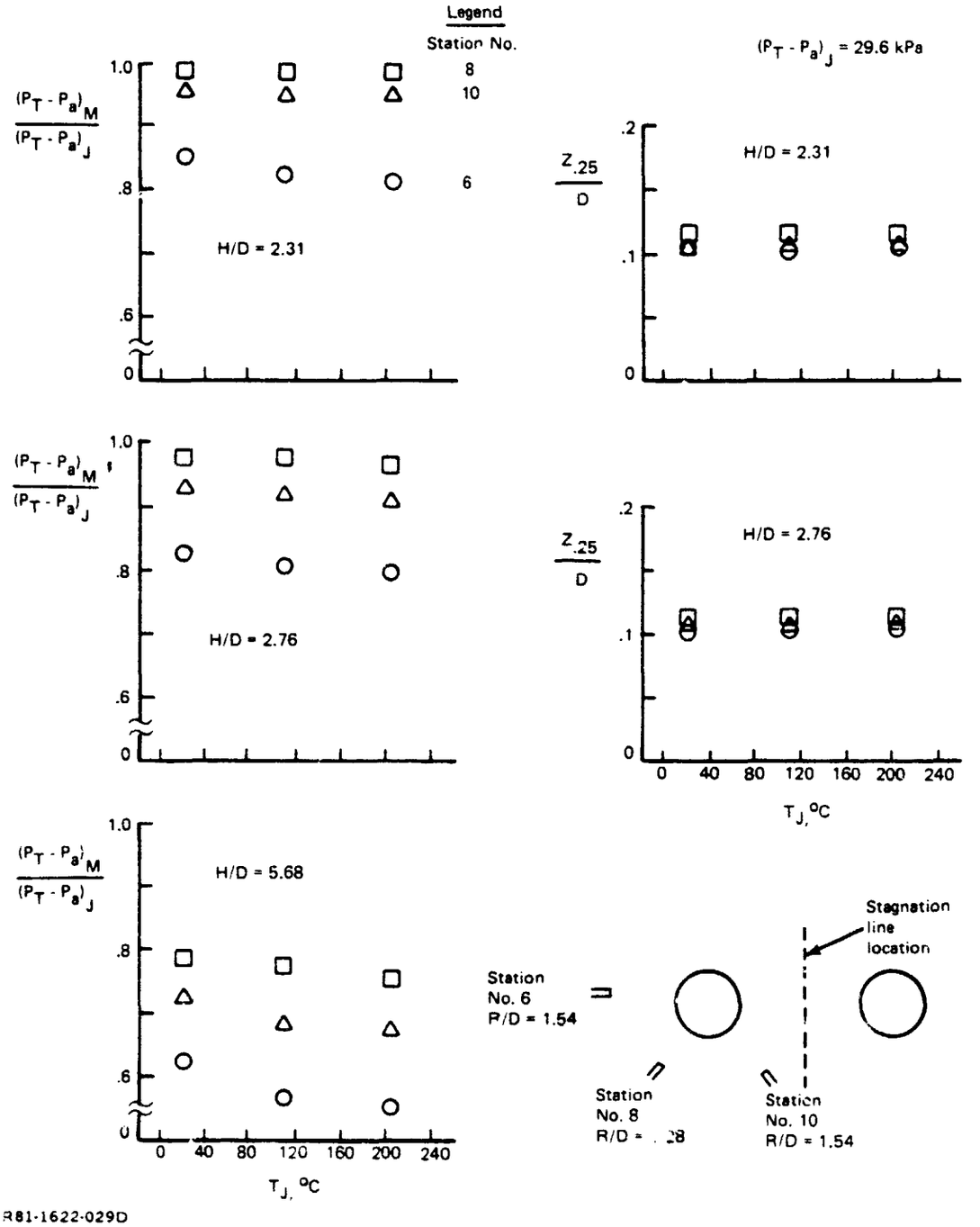

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Figure 36 - Data from wall jet profiles, open jet impingement.

5.2.3 Upwash Flow without Model. - Measurements were taken in the upwash without the model to evaluate flow properties in the absence of model blockage effects. The probes were traversed through the upwash at the nozzle exit plane for several values of H/D and a range of settling chamber temperatures. The results are summarized by the centerline values of upwash properties at the nozzle exit plane that are plotted in Figure 37. The data obtained from the pressure probes were essentially unaffected by temperature. Temperature profiles across the upwash were almost flat, and the exit plane temperatures show little variation with ground height out to H/D = 4.

Additional upwash surveys were made at a fixed nozzle height above ground by traversing the probe through the upwash at various probe heights above ground. The results are summarized in Figure 38 which shows the variation of temperature and pressure along the upwash centerline for H/D = 3. These pressure plots also show little influence of jet exit temperature.

The effect of settling chamber pressure on upwash properties with jet temperature equal to ambient was investigated by conducting exit-plane probe traverses at various ground heights. Figure 39 shows that the centerline properties at the nozzle exit plane, for ground heights of 2-1/2 nozzle diameters or greater, vary linearly with settling chamber pressure over a wide range. Furthermore, these measurements agree with past data taken at this jet spacing in our low-pressure facility. The lack of pressure scaling at low ground heights may be caused by the influence of the ground interaction flow on nozzle exit conditions. As brought out in Ref. 3, the pressure distribution inside the nozzles close to the exit (for this jet spacing) becomes non-uniform when the ground is brought closer than 2-1/2 diameters to the nozzle exit.

The magnitude of the upwash pressure data shown in Figure 39 illustrates that the upwash flow at the nozzle exit plane can be treated as an incompressible flow for all of the nozzle exit conditions and all of the ground heights, even though the nozzle exit flow itself was in the compressible flow range. Flow with a dynamic pressure less than about 5 kPa (corresponding to airflow velocity less than 90 m/sec) can be considered incompressible without a loss in accuracy. Below this value, the dynamic pressure can be found from the difference between total and static pressures. Dynamic pressure much

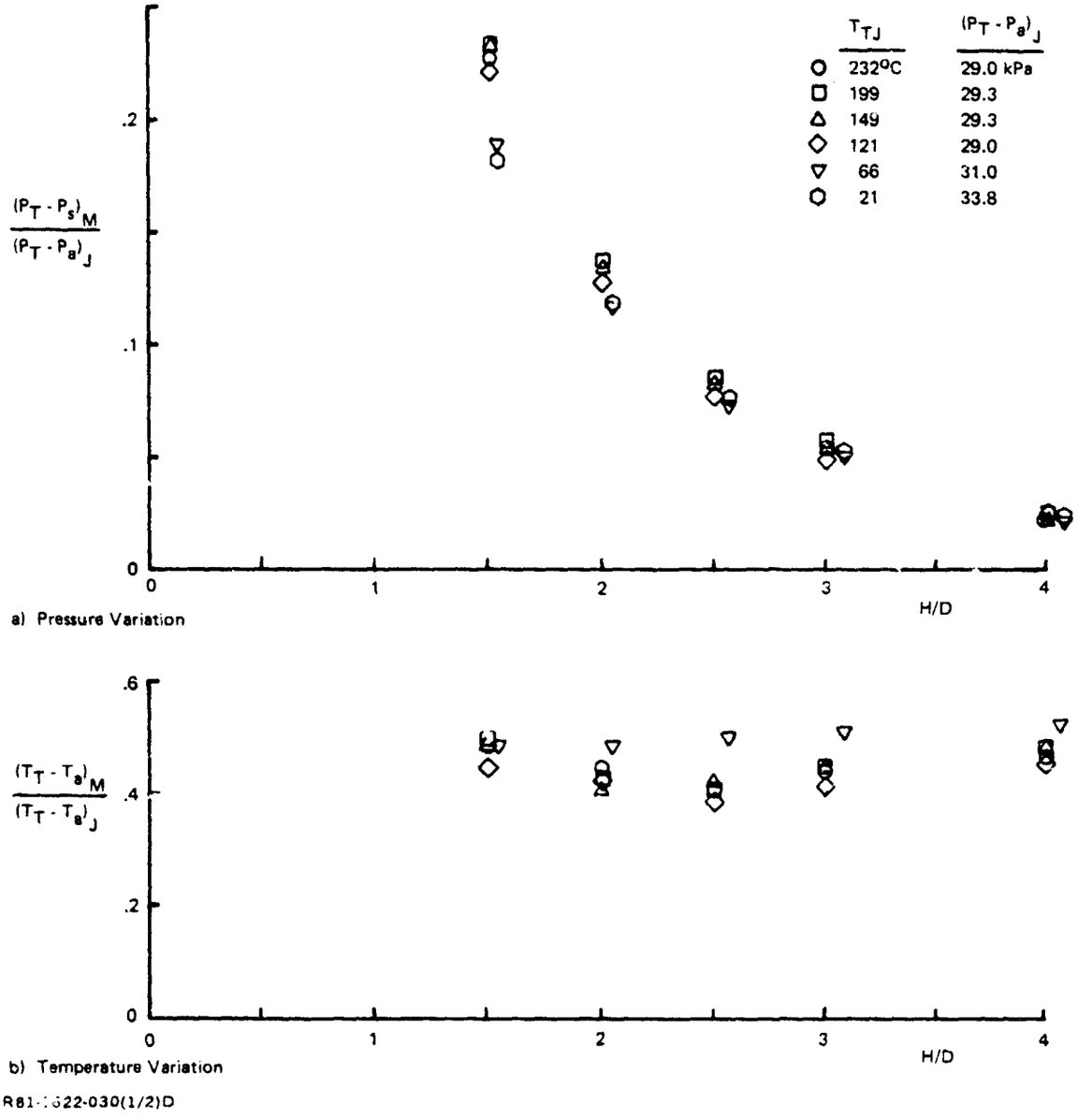

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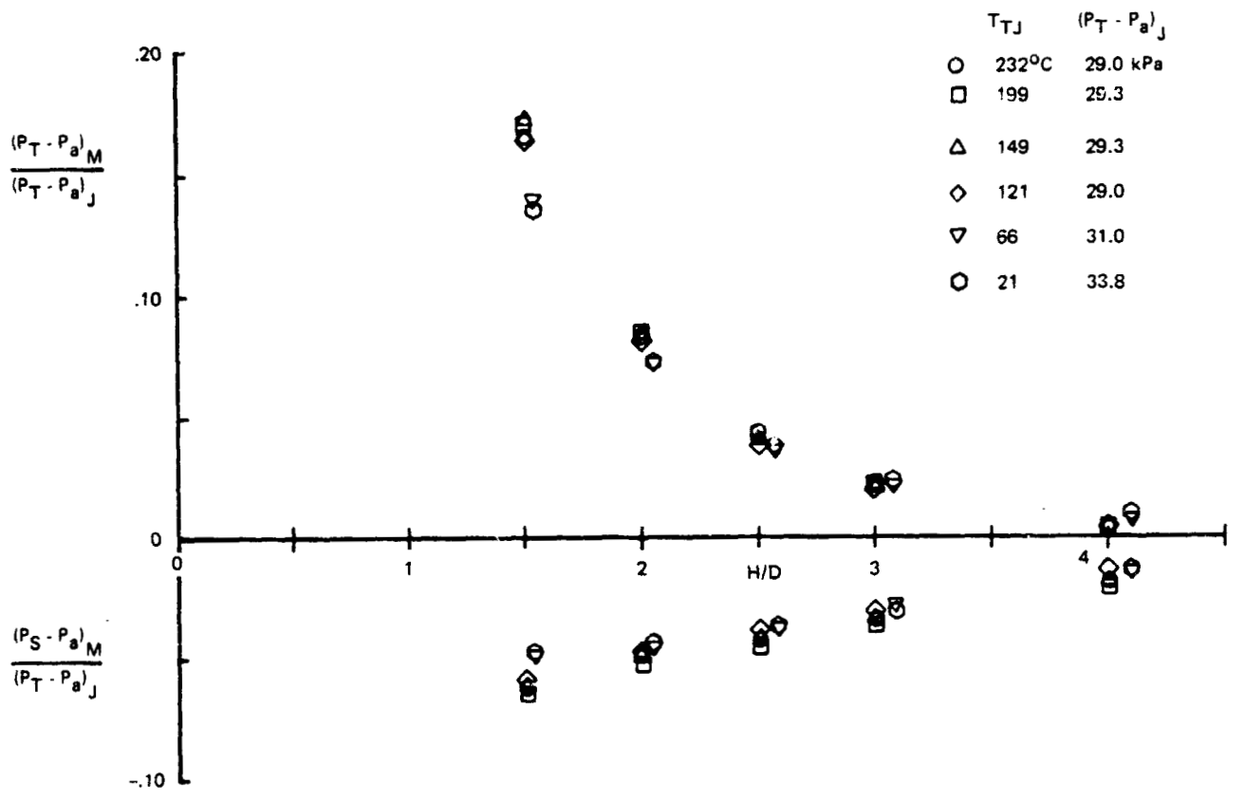
Figure 37 - Upwash properties at nozzle exit plane.



c) Total and Static Pressure

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Figure 37 - (Concluded).

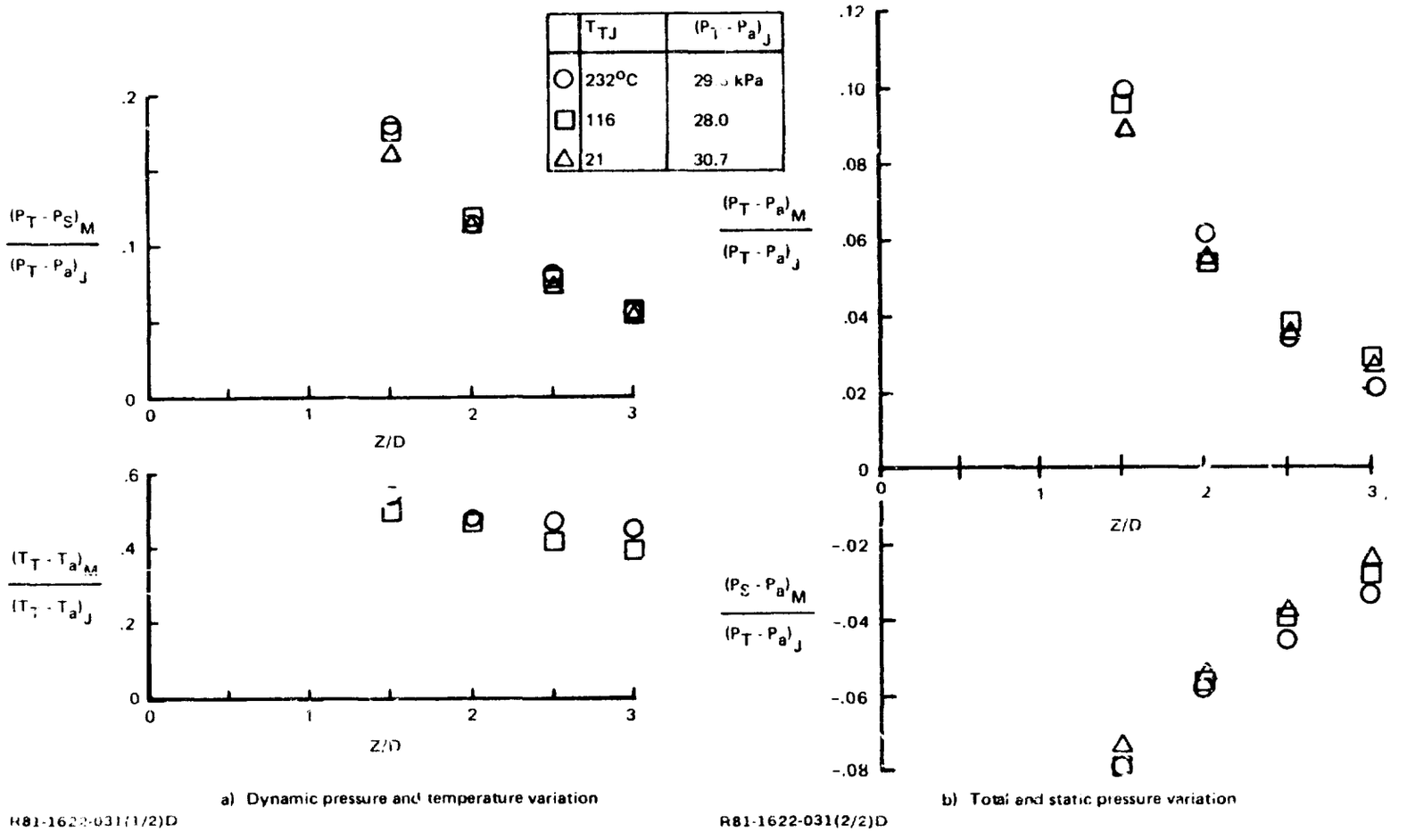

Figure 38 - Upwash properties between nozzle exit plane and ground, H/D = 3.

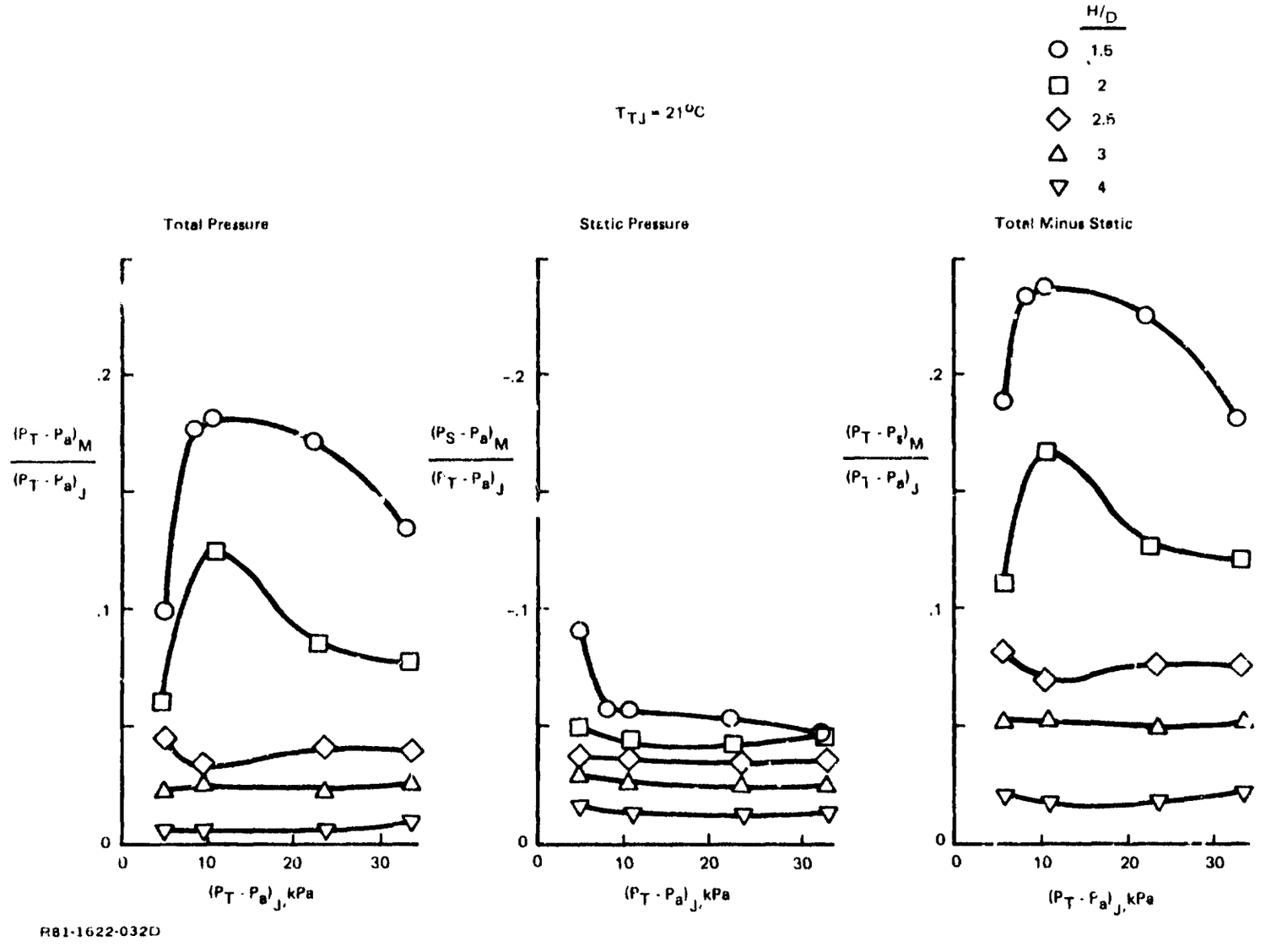

Figure 39 · Effect of settling chamber pressure on upwash properties at nozzle exit plane.

higher than this (somewhat arbitary) 5kPa level requires a compressible flow approach to determine dynamic pressure, since it cannot be found by subtracting static pressure from total pressure. Nozzle exit total pressure was greater than 5 kPa for almost all of our experimental work.

Therefore, for all of the data shown in Figure 39, the quantity (P_T-P_S) represents the upwash dynamic pressure on the centerline at the nozzle exit plane, and the flow velocity corresponding to this dynamic pressure can be evaluated with incompressible flow relations. Total pressures were measured with a Kiel probe and static pressures with a static probe aligned with the mean flow direction (probe dimensions are given in Subsection 4.7.3). Traversing both probes through the flow simultaneously (with fixed inter-probe distance, Y') provided direct plots of the total and static pressure profiles. When overlaid and shifted a distance, Y', one can trace a profile of (P_T-P_S). Data shown as $(P_T-P_S)_M$ in Figure 37, 38 and 39 were all obtained from the peak value of such tracings.

5.2.4 Effect of Model on Ground Flow. - Ground pressure measurements taken with and without the model in place showed that the model had little influence on the pressure close to the stagnation line but did change the pressure in the jet impingement region. Figure 40 shows the distribution of ground pressure in one of the jet impingement regions along a line connecting the two jet centerlines. The solid curve represents an empirical approximation for the ground pressure distribution for single jet impingement. Comparison with data taken at the same locations without the model (Figure 24) shows that the model reduces the pressure in this part of the impingement region. Data in Figure 40 for different jet temperatures show no significant temperature effect.

5.2.5 Effect of Model on Upwash. - Probe traverses were taken across the upwash with and without the model in place to determine the influence of the model on upwash properties. The temperature profiles across the upwash presented in Figure 41 show that the presence of the model raises the temperature of the upwash approaching the model. The increased upwash temperature with the model in place indicates a recirculating flow entrainment caused by model blockage.

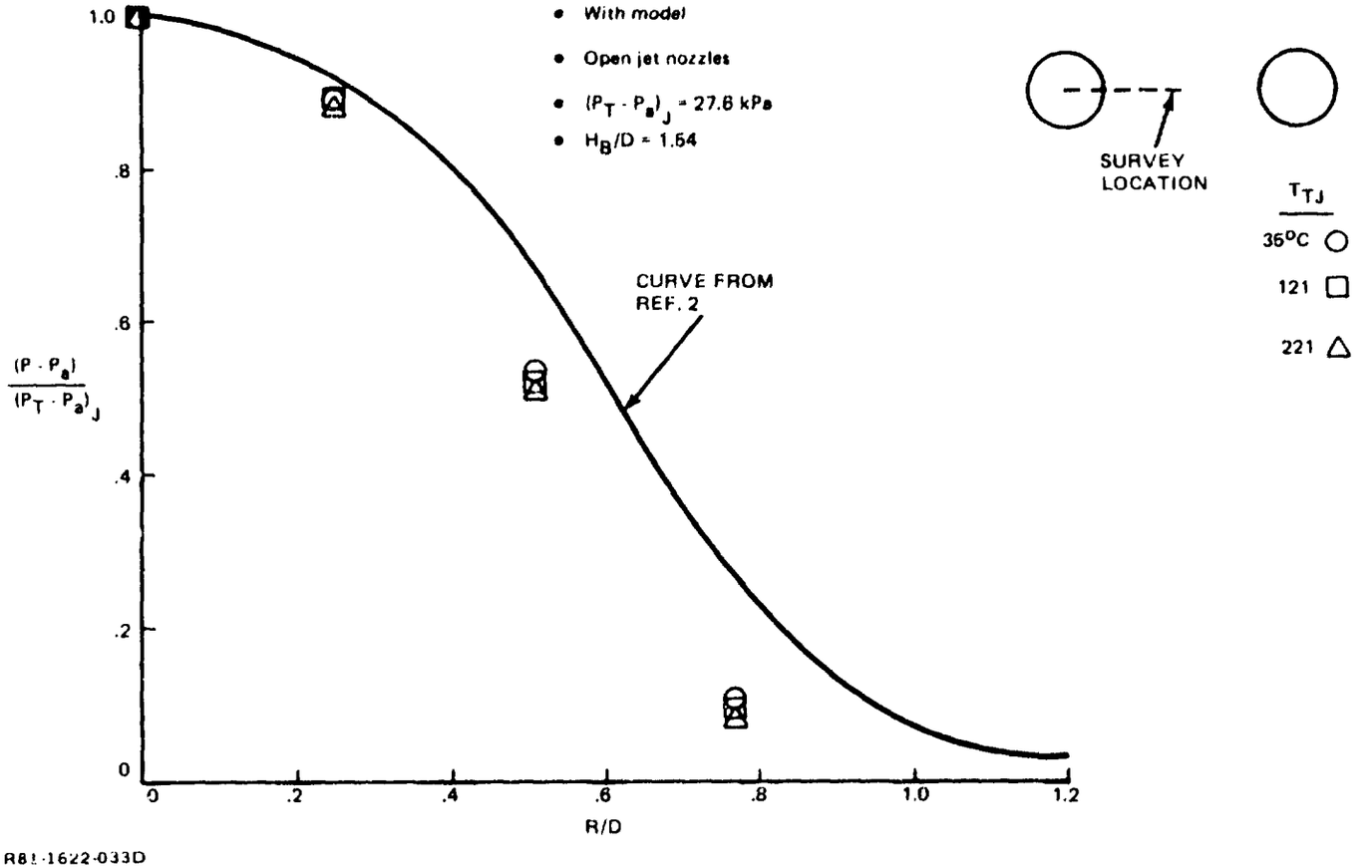

Figure 40 - Radial ground pressure distribution around one jet impingement center.

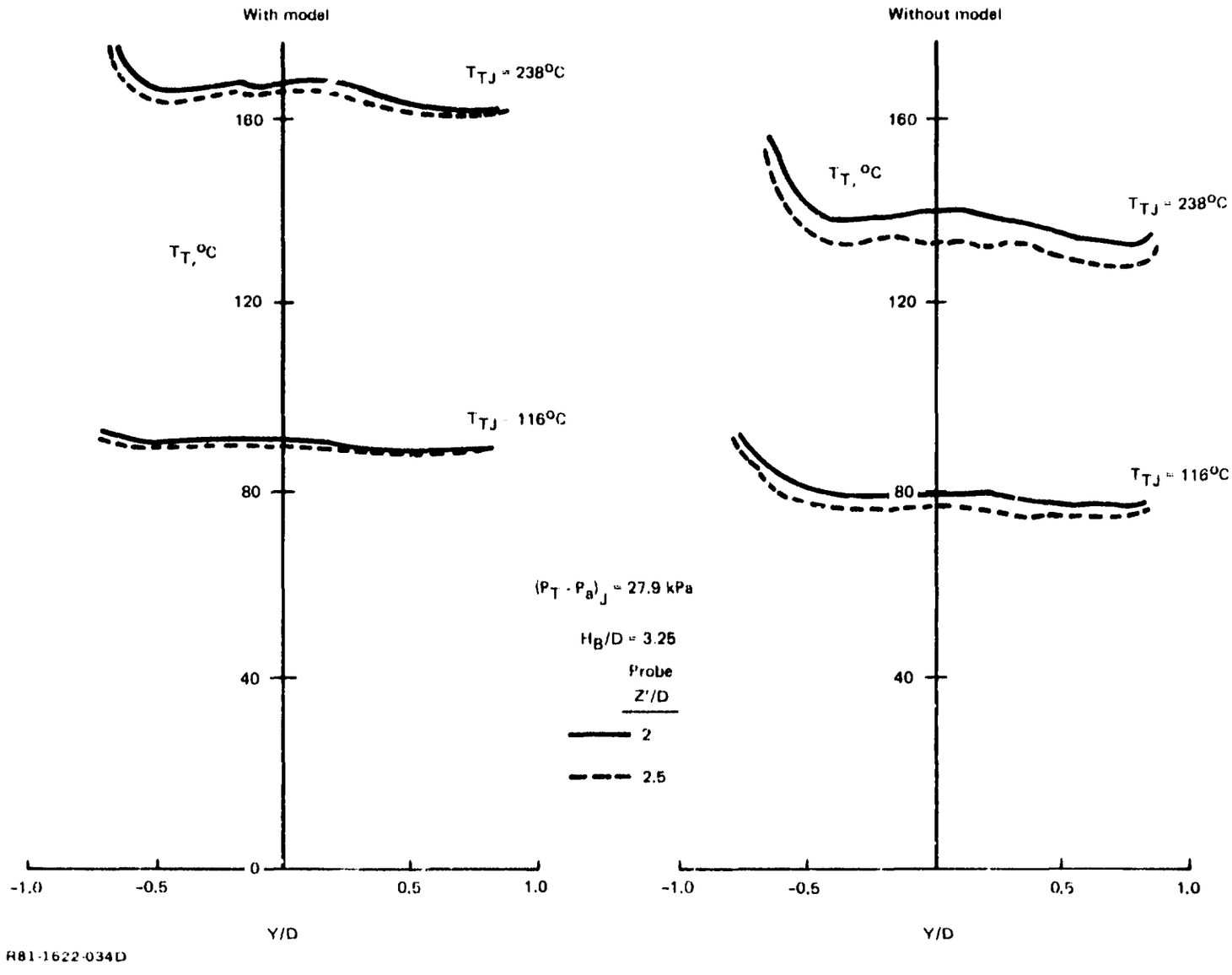

Figure 41 - Effect of presence of body on upwash temperatures.

Figure 42 shows pressure profiles taken across the upwash with and without the model for the same nozzle height above ground. These profiles were taken far enough from the model undersurface so that the increased upwash dynamic pressure caused by the presence of the model was not a local flow disturbance involving flow around the model. The dynamic pressure (and hence flow velocity) throughout the entire upwash was affected by model blockage. This change is significant for flow modelling. The cause of this change is not understood at present. The data in Figure 42 were taken with a jet exit temperature of 238°C. Data taken at temperatures of 116°C and 24°C showed almost identical profiles with and without the model, again illustrating that jet exit temperature has little influence on the pressure measurements in the upwash.

5.2.6 Model Forces. - The thrust of one of the open circular nozzles was determined from the relation

$$\text{Thrust} = 2\, q\, \eta\, A\ ,$$

where q is the dynamic pressure associated with the nozzle pressure ratio, A is the nozzle exit area and η is a thrust efficiency factor that accounts for momentum loss in the nozzle boundary layer. Based on thrust measurements made earlier on this 5-cm diameter nozzle, we found $\eta = .90$ for the open circular nozzles.

$$\text{Using } q = \frac{\gamma}{2} P M^2 \text{ and } M^2 = 5\left[\left(\frac{P_T}{P_S}\right)^{2/7} - 1\right] \quad \text{for air.}$$

the thrust developed by one circular nozzle can be found as a function of P_{TJ} (settling chamber pressure):

$$\text{Thrust} = 6.30\left[\left(\frac{P_{TJ}}{P_a}\right)^{2/7} - 1\right] A P_a$$

Force data taken with the open circular nozzles were normalized by twice the value of nozzle thrust.

Forces were measured on the model with 15° strakes for a range of settling-chamber temperatures and pressures. Figure 43 shows the variation of model interference force with height above ground for a settling chamber pressure of 27.6kPa gauge and jet temperatures of 24°C, 116°C and 240°C. These

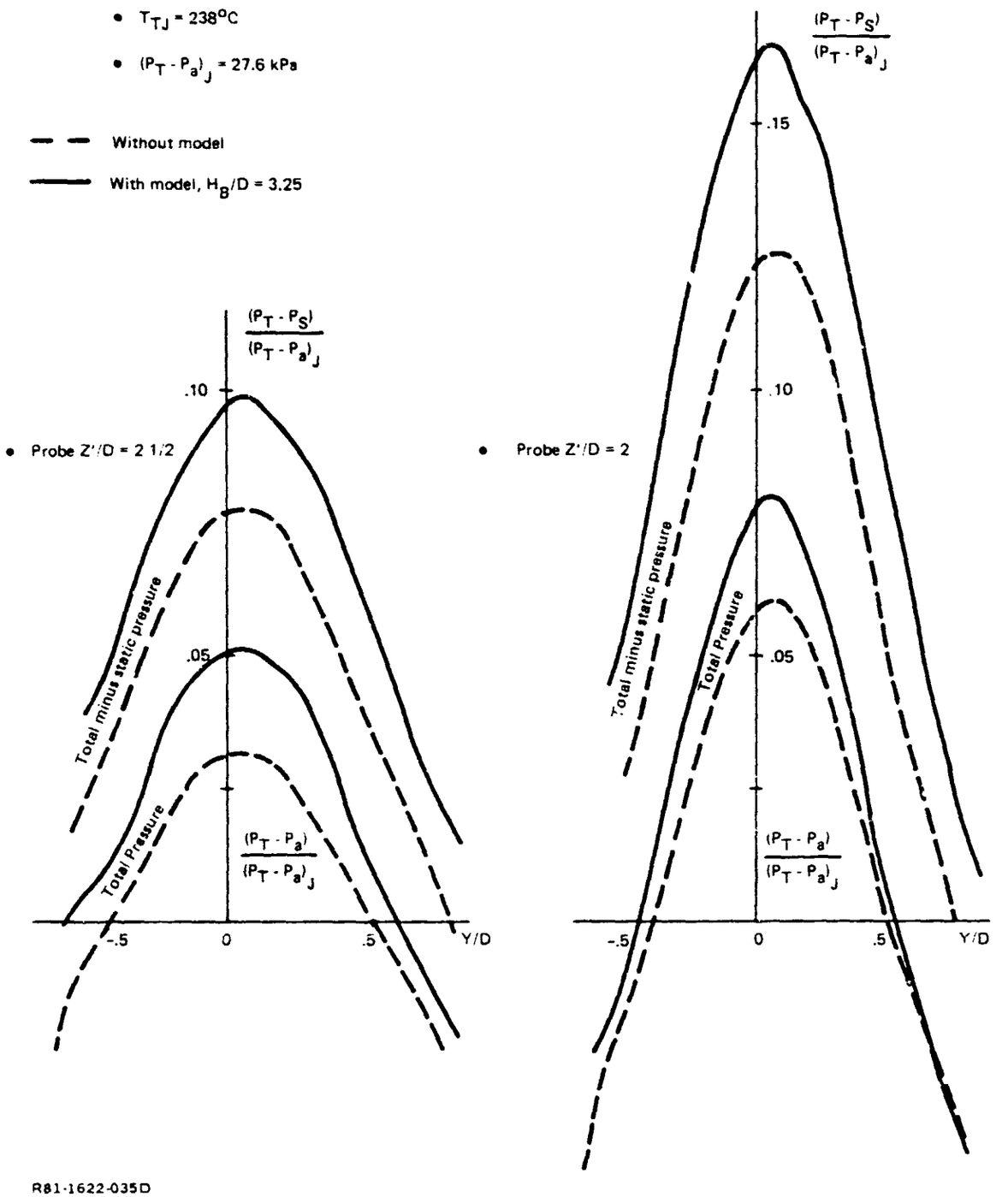

Figure 42 - Effect of presence of body on upwash pressures.

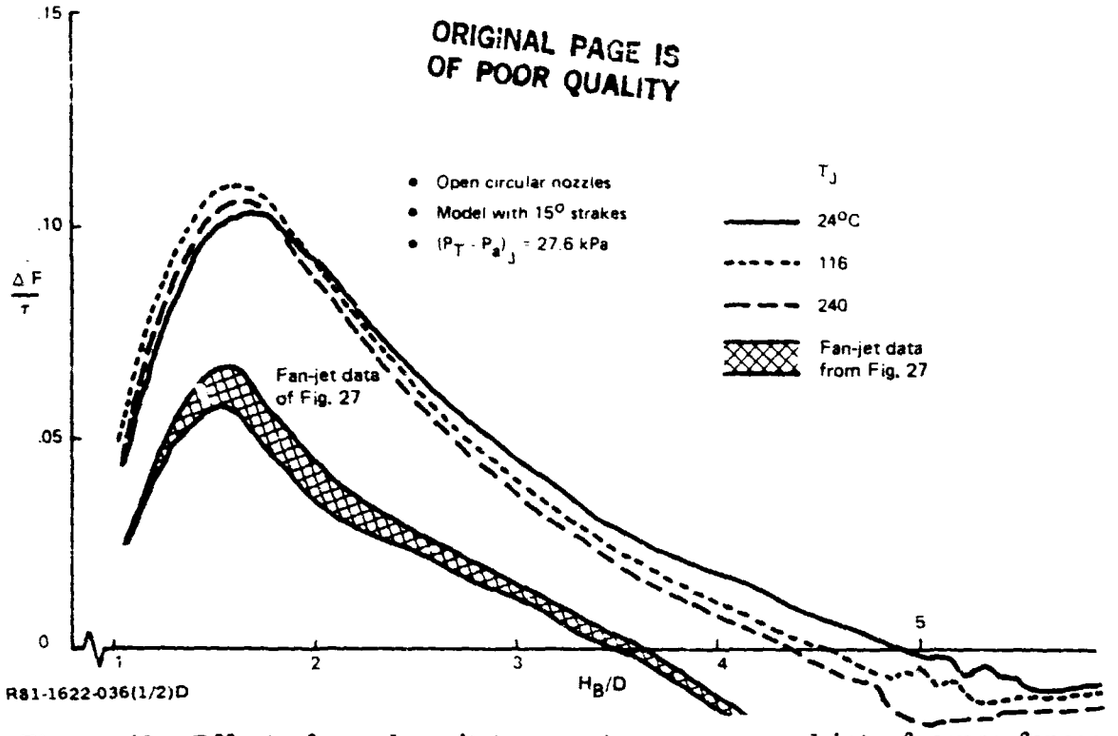

Figure 43 - Effect of nozzle exit temperature on ground interference forces.

three curves are quite similar, having small differences that appear to show a progression with temperature. Further investigation showed that differences in the force curves in Figure 43 are more likely to represent scatter attributable to slight differences in model alignment between runs. Subsequent measurements were taken at a fixed height above ground (H/D = 3.2) as the settling chamber temperature was raised from 24° to 221°C. Testing in this manner, essentially no change was found in interference force with jet exit temperature. The non-dimensional forces for the fan-jet simulation (Figure 27) are also shown and are much lower than those of the present section.

Figure 44 shows the variation of model force with height above ground for different settling chamber pressures and a jet exit temperature of 24°C. While these curves are qualitatively the same, they show some variation with settling chamber pressure. These data were all taken without disturbing alignment between tests.

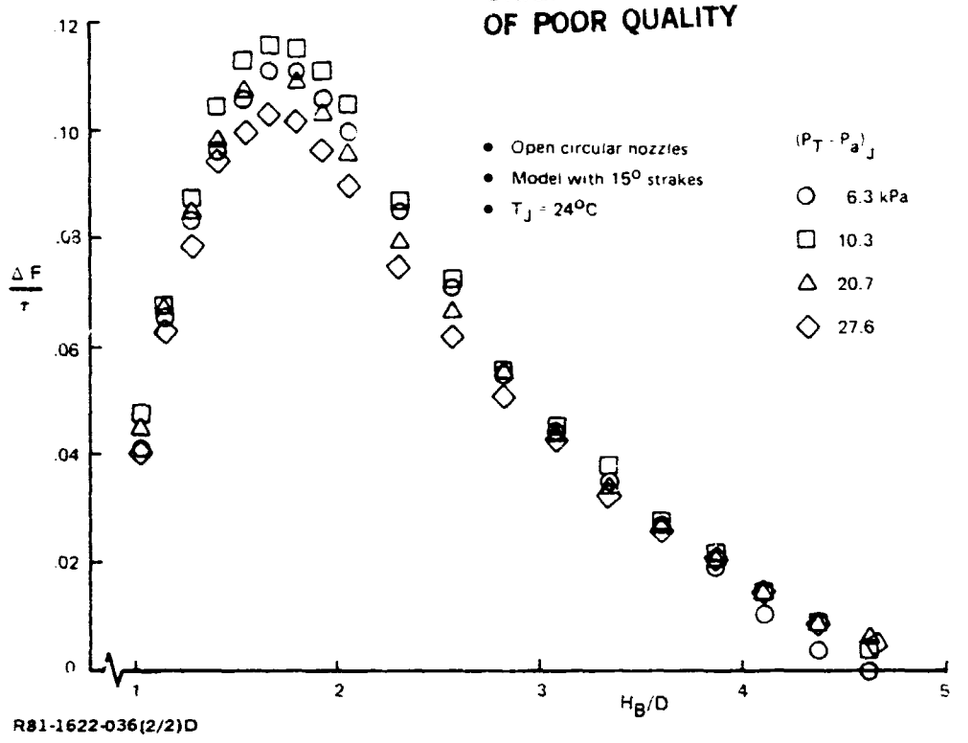

Figure 44 - Effect of nozzle stagnation pressure on ground interference forces.

5.2.7 Model Surface Pressure and Temperature. - Model surface pressures were measured with and without the 15° strakes for 24°C nozzle exit temperatures. At higher jet temperatures, the data were taken only with the strakes attached. Figure 45 shows the effect of the strakes on the pressure distribution along the fuselage undersurface. The pressure distribution across the model is shown in Figure 46. The presence of the strakes raises the surface pressure level and flattens the profile across the undersurface. Figure 47 shows the variation with height above ground of model pressure at three centerline taps for the model with strakes. The pressure on the fan nacelle centerline (from Figure 29) is shown for comparison, and is much lower. Figure 48 shows that the pressures along the model at a fixed height above ground are not significantly affected by jet temperature.

The temperature distribution along the model is shown in Figure 49. For H/D = 1.54, the temperature coefficient at a point between the nozzles was approximately 0.8, which is considerably higher than values measured with probes (range of 0.5) on the upwash centerline without the model (see Figures

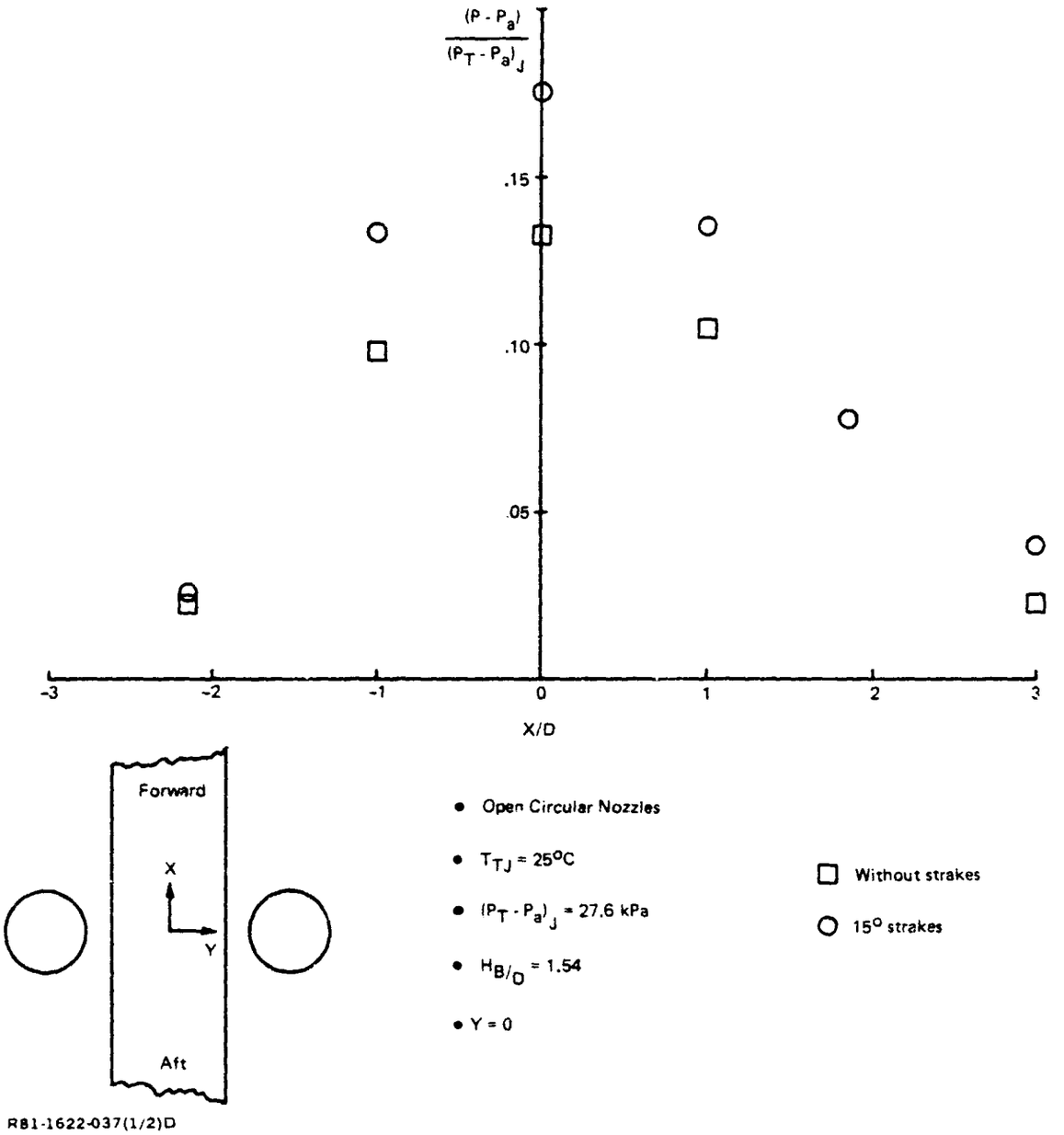

Figure 45 - Pressure distribution along fuselage underside.

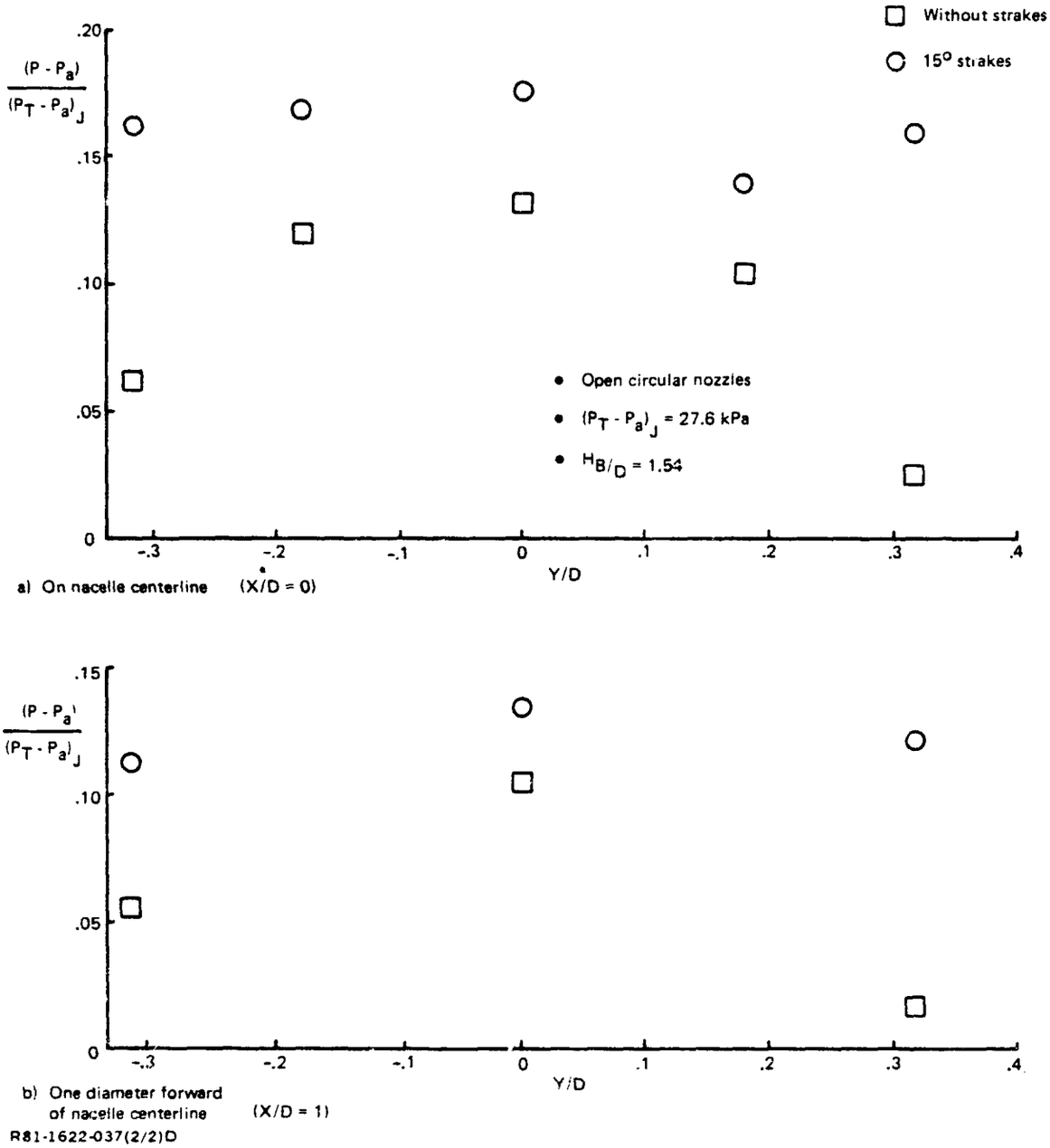

Figure 46 - Pressure distribution across fuselage underside.

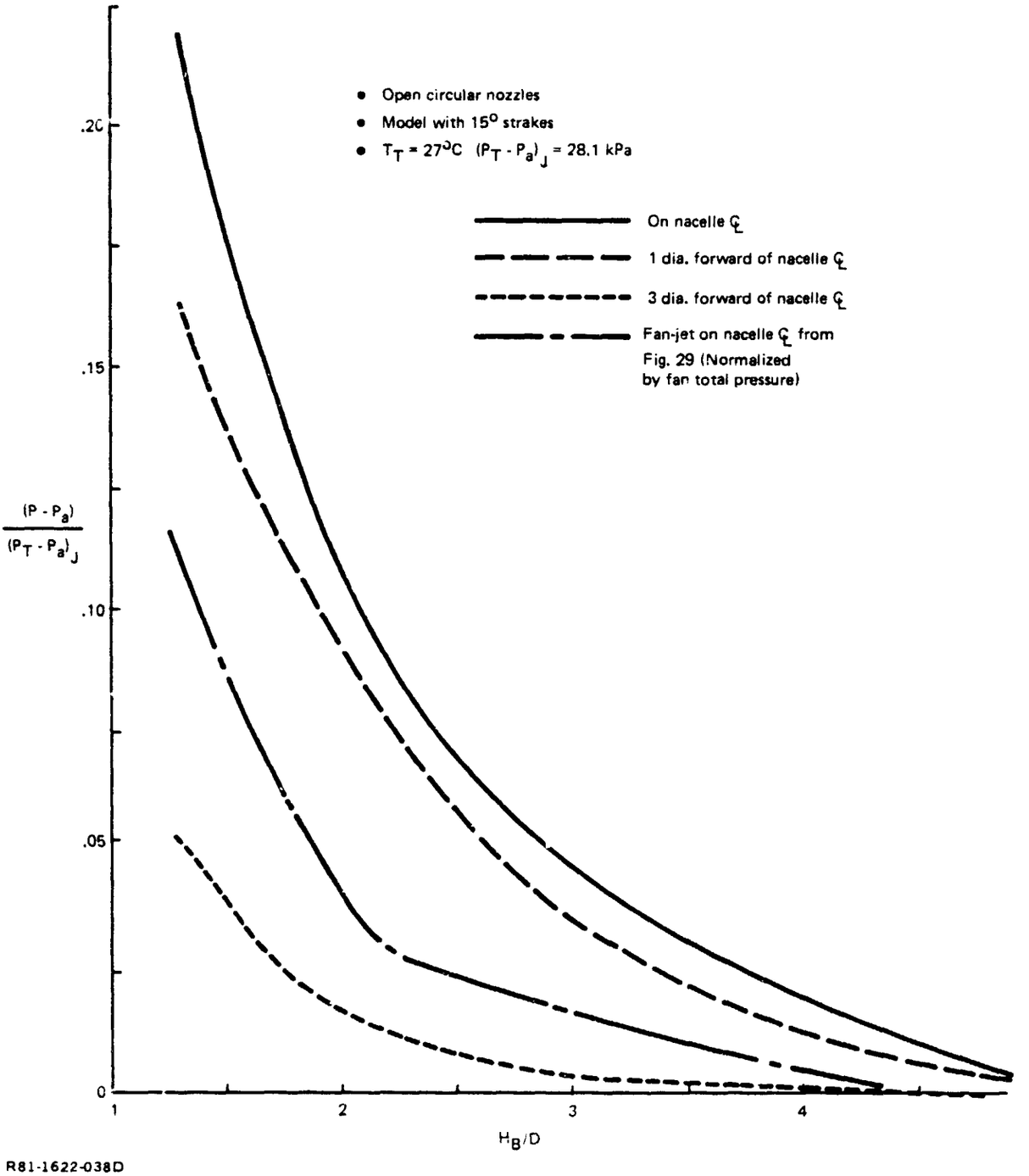

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Figure 47 - Variation of model pressure with height above ground.

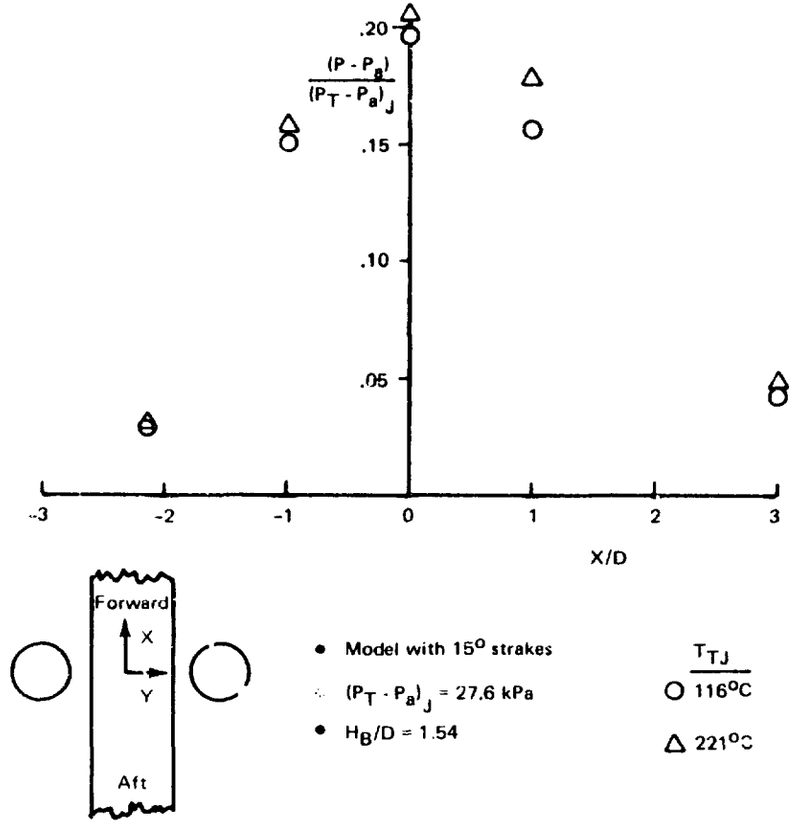


Figure 48 - Pressure distribution along fuselage underside.

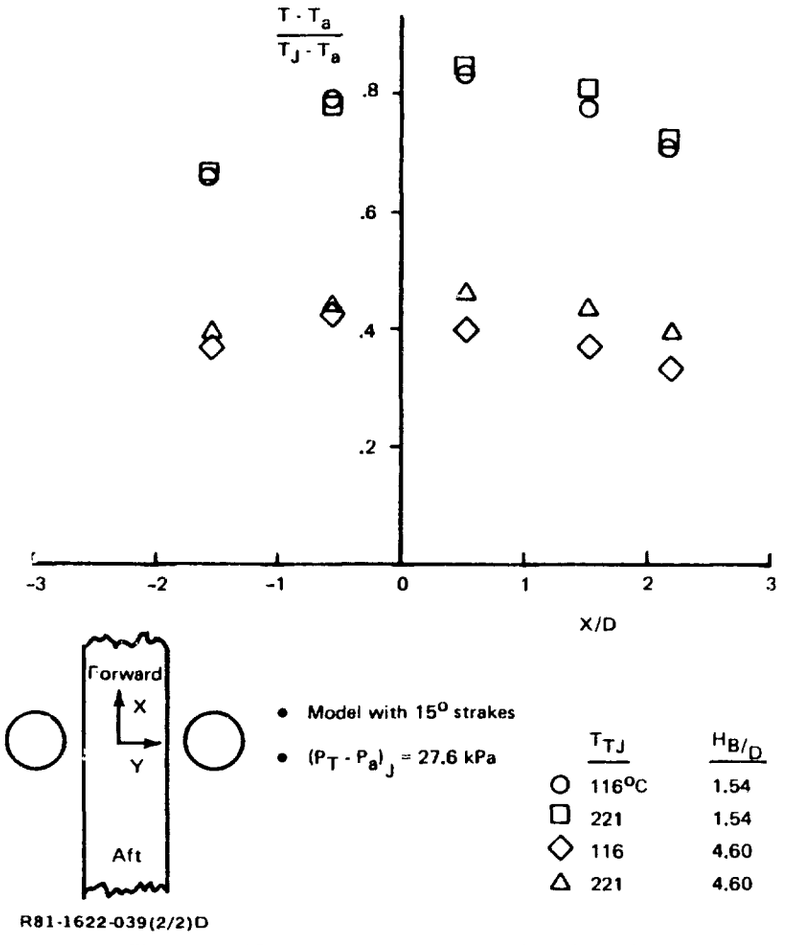


Figure 49 - Temperature distribution along fuselage underside

37b and 38a). The high model temperature appears to be caused by blockage of the entrainment flow brought about by the presence of the model. As discussed in Subsection 5.2.5, higher temperatures were measured in the upwash with the model in place than without it.

The model temperature distributions in Figure 49 do not show a local temperature minimum just forward of the nacelle centerline that was found using the fan jet nozzles (Figure 31). In addition, comparison of Figure 49 with Figures 31 and 28 shows that the model temperature coefficients appear to scale better with jet exit temperature using the open circular nozzles than using the fan-jet nozzles, where only the core flow was heated. Temperature data taken in the upwash using the open circular nozzles (Figure 37b and 38a) also showed better temperature scaling than the fan-jet data (Figure 24).

5.3 Conclusions

5.3.1 Fan-Jet Simulation. - The primary conclusion of this experimental study is that a geometrically correct small-scale model testing program can predict V/STOL aircraft hover performance quite well. Interference force results of the 1/24-scale experiments matched full scale results closely. Pressure ratio changes (in this case with subsonic jet exit conditions) produced a neglibible effect. Core nozzle exit temperature produced a small effect, easily compensated for by empirical scaling. Aircraft lower surface temperatures did not scale well with core nozzle exit temperature.

5.3.2 Open Circular Nozzles. - The normalized interference forces resulting from operation with open circular nozzles were much larger (approximately a factor of two) than those found with the fan jets. The qualitative behavior with height above ground was the same. As with the fan-jet nozzles, there was a small change in the force with changes in stagnation temperature. There was also a small change in normalized force with total pressure in the region of highest forces ($H/D \sim 1\frac{1}{2}$), which did not occur for the fan-jet case. Aircraft lower surface temperature did scale well with nozzle exit temperature, a different result than that obtained with the fan-jet nozzles.

The presence of the model was found to raise significantly the temperature in the upwash. Unexpectedly, model presence also raised the total pressure in the upwash.

6 - PREDICTION METHODOLOGY

The establishment of a vertical jet impingement model is the basis for the prediction of the behavior of two jets impinging on a ground plane. A sketch of the flow problem is shown in Figure 50. Figure 50a shows the vertical plane containing the jet stagnation points and the ground plane. Each jet impinges on the ground plane and deflects to form radial-wall jets. The wall jets then interact and form an upwash deflection zone where the wall jets collide and are turned upward on leaving the ground plane. The stagnation line lies on the ground in the vertical plane of symmetry between the two impinging jets. The maximum upwash stagnation pressure occurs at the midpoint of the line connecting the two jet stagnation points on the ground. The ground pressure then drops off with lateral distance along the stagnation line. Figure 50b shows the radial streamline pattern that has been observed (Ref. 5, 6 & 7) both in the ground plane and in the vertical upwash plane of symmetry between the two jets. This flow situation only exists when the jets are spaced far enough

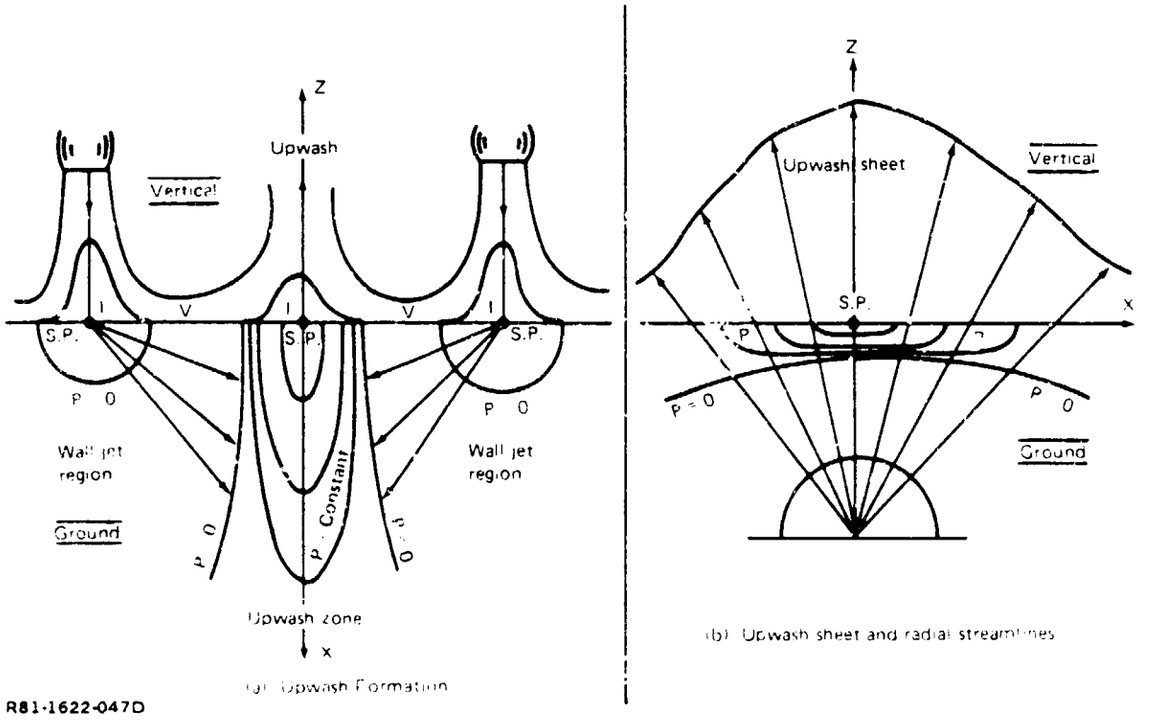


Figure 50 - Two-jet interacting flows - negligible deflection zone interaction.

apart so that the jet impingement zone does not interact or has a negligible affect on the upwash deflection zone. (Ref. 3).

6.1 Theoretical Models for Non-Isothermal Jet Impingement

In Ref. 3, semi-empirical analytical models were formulated to simulate the global behavior of two incompressible jets impinging on a ground plane. Models were generated for the behavior of the free and wall jets and, finally, the upwash sheet generated by the interaction of the opposing wall jets. The effect of jet proximity is considered in Ref. 3, leading to the development of upwash momentum models.

These incompressible models are extended, in the present study, to include temperature or density effects. The flowfield is divided into three major regions where viscous or turbulent mixing effects dominate, being:

- Free jet
- Wall jet
- Upwash.

Subdomains of these regions include the jet and upwash deflection zones. In these smaller regions, the flow changes from an inviscid behavior to a shear flow along with streamline deflections, causing a change in static pressure due to the stagnation and acceleration of the flow.

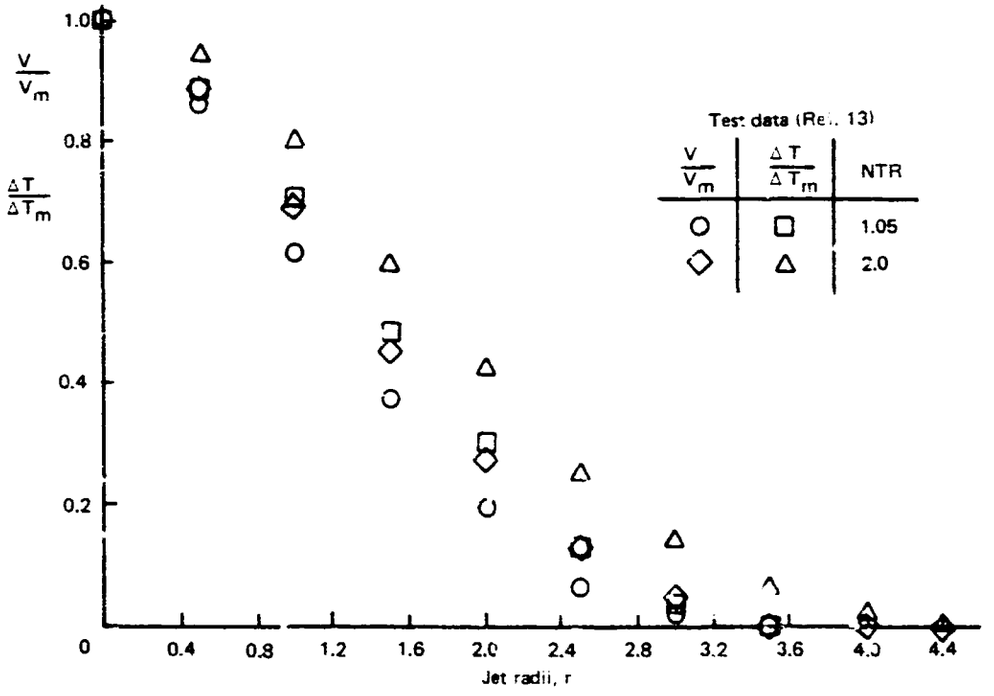
6.2 General Temperature and Velocity Equations

The transport or diffusion of heat in a free jet is much like the transport of momentum. The viscous mixing and entrainment of ambient air causes a shear layer of momentum (velocity) and heat to occur. Schlicting (Ref. 8), in quoting the experimental and theoretical observations of Reichardt (Ref. 9), implies that the temperature profile distribution of a two-dimensional jet behaves like the square root of the velocity distribution. Taylor's Free Turbulence Theory, as quoted by Abramovich (Ref. 10), arrives at this result for the thermal layer by a turbulence theory that is based on vorticity transfer rather than momentum. In Ref. 10, the temperature profile in a jet is obtained by a "New Prandtl-Gortler Theory of Turbulence". The following relationship is obtained between the temperature and velocity:

$$\frac{\Delta T}{\Delta T_M} = \left(\frac{V}{V_M} \right)^{\frac{1}{\delta}} \qquad (1)$$

where δ is some constant. If $\delta = 1$, the dimensionless temperature and velocity profile coincide. It has been observed experimentally that this behavior does not hold. For $\delta = 2$, Taylor's analytical result is obtained as well as Reichardt's experimental observations.

Experimental observations indicate that the thermal layer spreads faster than the dynamic (velocity) layer. In order to establish an empirical value for δ in eq. (1), some non-isothermal profile data are plotted in Figure 51a for a circular jet. Similarity is not obtained if the temperature data are related to the velocity half widths as shown in Figure 51b. In addition, the data do not seem to confirm the square root of the velocity relationship. If, on the other hand,



a) Related to jet radius.

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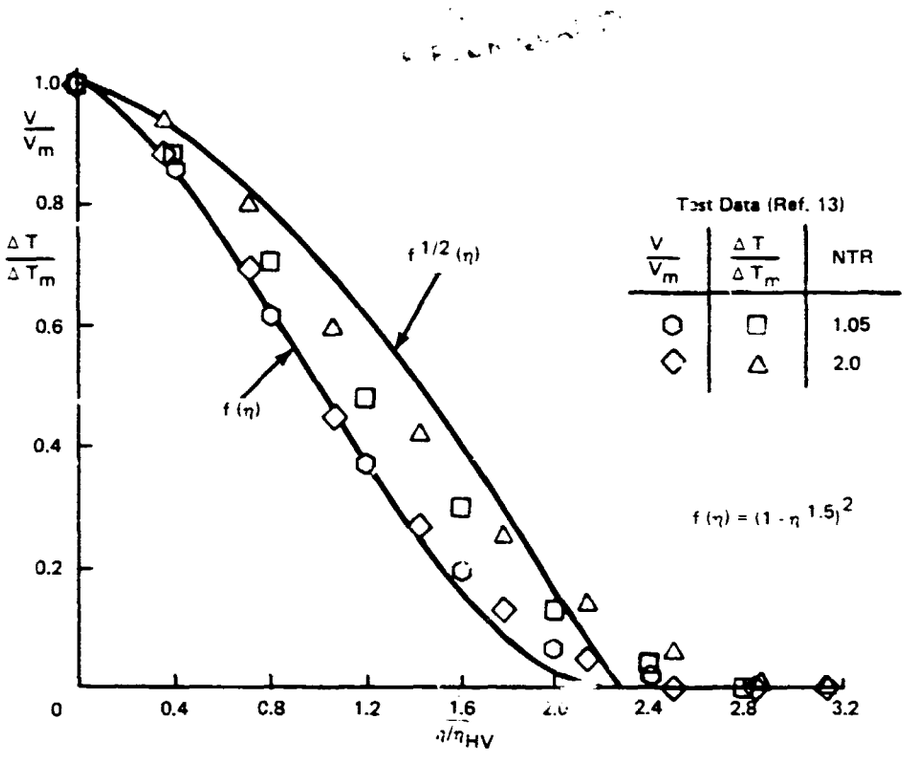
Figure 51 - Dimensionless velocity and temperature difference profile data.

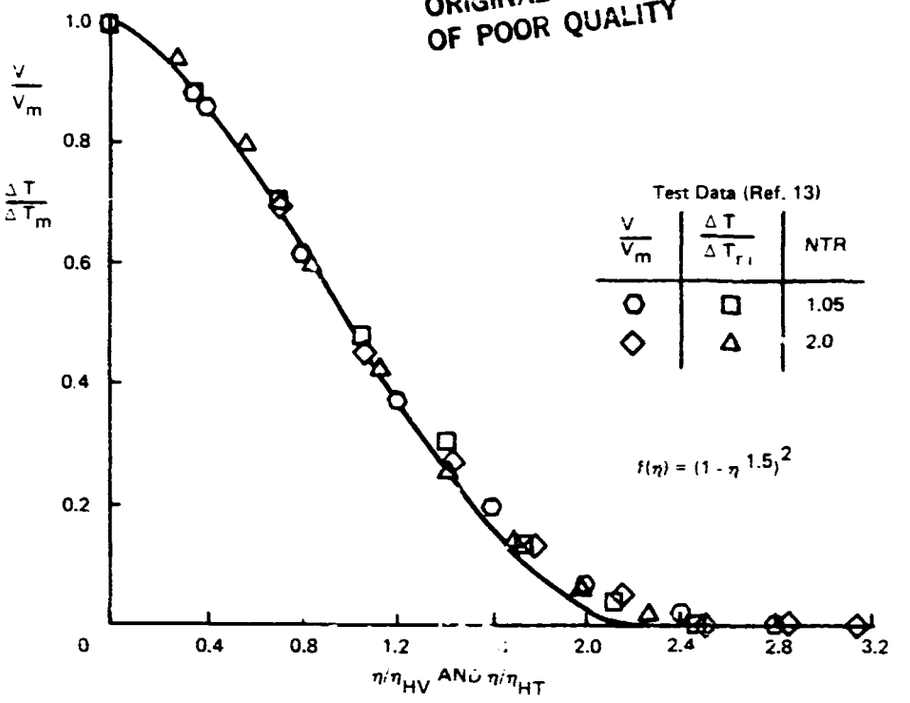


b) Related to jet radius non-dimensionalized by velocity half-width.
R81-1622-040(2/3)D

Figure 51 - (Continued).

the velocity and temperature difference data are plotted dimensionless to their respective half-velocity and half-temperature difference lengths, the data fall on one dimensionless curve as illustrated in Figure 51c. This result was also observed in Ref. 11 and in Ref. 12 for wall jets. It seems to be clear from the available data that the thermal layer persists beyond the point where a measurable velocity exists. The form of eq. (1) implies that the dynamic and thermal layers have the same scale length. If an exponential or infinite layer is assumed for the velocity profile and, hence, the thermal layer, then eq. (1) would yield results consistent with measured data. Indeed, if such a relationship as eq. (1) exists, the exponent may be a function of the nozzle thermal conditions.

In the models to be developed, it is more convenient to assume a finite thickness to the various layers to facilitate the various integrations involved in computing the velocity and temperature decay rates. Equation (1) is not



c) Related to jet radius non-dimensionalized by velocity and temperature half-widths.
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Figure 51 - (Concluded).

used in the following models but the relationship depicted by Figure 51c is used instead:

$$\frac{T-T_A}{T_M-T_A} = f_T(\eta_T)$$
$$\frac{V}{V_M} = f_V(\eta_V) \qquad (2)$$

where $\eta_T = \frac{r}{b_T}$, $\eta_V = \frac{r}{b_V}$ and $f = \left(1 - \eta^{\alpha}\right)^2$

The dimensionless forms (i.e., velocity and temperature each have their own scale lengths, b_V and b_T) of the velocity and temperature difference profiles as depicted in eq. (2) are assumed identical. The relationship between the thermal and dynamic (velocity) layers can be simply expressed by the ratio

of the half widths of the two layers:

$$\lambda = \frac{b_{HT}}{b_{NV}} > 1 \tag{3}$$

Hence, the thermal and dynamic layers do not have the same scale. The velocity goes to zero while the temperature persists beyond a measurable velocity.

6.3 Conservation Equations

The basic governing equation to model the behavior of jets is the conservation of momentum equation. To account for non-isothermal or temperature effects, an additional equation is required. The conservation of excess heat content is used as the governing equation to account for heat diffusion or temperature effects. These two integral equations can be expressed as:

Momentum -

$$M_J = \rho_N V_N^2 A_N = \int\int \rho V^2 dA \tag{4}$$

Heat Flux

$$H_F = \rho_N V_N (\Delta T_N) A_N = \iint \rho V \Delta T dA \tag{5}$$

where $\Delta T_N = T_N - T_A$, T_N is the nozzle temperature, and A_N is the nozzle area.

Equations (4) and (5) yield two expressions for the two unknowns, maximum centerline temperature and velocity. Unfortunately, more than two unknowns exist, namely, the profile shapes and growth rates of the various shear layers. These additional parameters must be given by empirical observations. The spreading models of Ref. 3 are used with the addition of eq. (5) and the further complication of the density or temperature occurring in eq. (4) which necessitates the simultaneous solution of eqs. (4) and (5).

6.4 Heated Free-Jet Model

The nozzle exit conditions of a free jet can be specified by two parameters, the nozzle exit stagnation pressure ratio (NPR) and temperature ratio (NTR). The exit Mach number of the jet is purely a function of NPR. A compressibility correction is included in the incompressible models, based upon an approximate Mach number computed using Bernoulli's equation.

$$M_N \sim \sqrt{\frac{2}{\gamma}(NPR-1)}$$

To be consistent with an incompressible approximation, the nozzle exit static temperature is assumed equal to the nozzle stagnation temperature,
or

$$T_N \sim NTR$$

The free jet is subdivided into three regions, as shown in Figure 52:

- Potential core, Region I
- Transition, Region II
- Fully developed, Region III.

In order to solve eqs. (4) and (5), some information about the half-velocity boundary growth behavior must be assumed to be known from experimental data. To be consistent with the models of Ref. 3, and for the sake of simplicity, the jet radius model assumes a simple linear boundary growth in each region.

Region I: $$\frac{b_{VH}}{r_N} = a_1\left(\frac{Z}{r_N}\right)+1$$

Region II: $$\frac{b_{VH}}{r_N} = a_2\left(\frac{Z}{r_N}\right)+b_2$$

Region III: $$\frac{b_{VH}}{r_N} = a_3\left(\frac{Z}{r_N}\right)$$

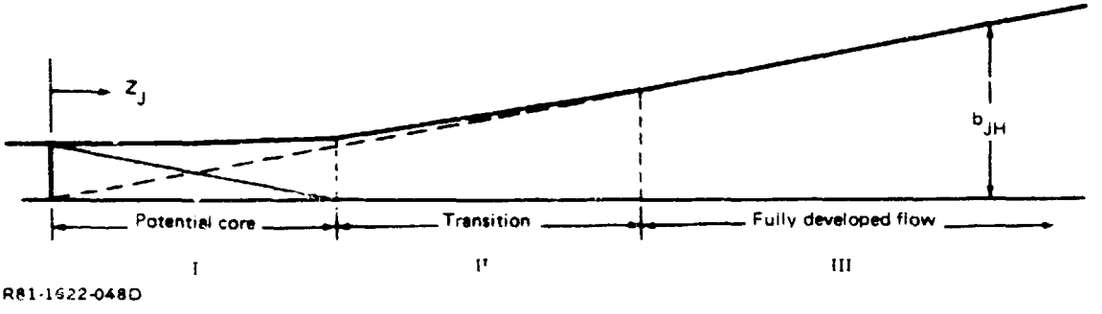


Figure 52 - Jet half-velocity width model.

The constants (a_1, a_2, a_3) governing the half-velocity boundary growth in the transition and fully-developed regions are determined empirically. The potential core length (Z_{PC}) and the exponent n_{FD} governing the shape of the shear profile in the fully developed region also must be specified. These constants vary slightly as functions of nozzle Mach number and temperature ratio. Suitable values have been determined as:

$$a_3 = .09 \left\{ 1 + \ln\left(\frac{2}{1 + \frac{1}{T_N}\beta_3} \right) \right\} \left\{ 1 - .16\, M_N \right\}$$

where $\beta_3 \sim 0.50$.

The potential core length is approximated by:

$$\frac{Z_{pc}}{D} = \frac{8.55}{2} \left[1 + \frac{1}{T_N} \beta_c \right]$$

where $\beta_c \sim 0.75$, and is also slightly a function of the nozzle temperature ratio.

The growth constant of the half-velocity boundary in the potential core region is determined by matching the boundaries at the end of the potential core, yielding,

$$a_1 = \frac{(b_2 - 1)}{(Z_{pc}/r_N)} + a_2$$

In addition, a linear decay in potential core radius r_c, is assumed:

$$\frac{r_c}{b_V} = 1 - \frac{Z_J}{Z_{Pc}}$$

The beginning of the fully developed region of flow, denoted by the length parameter Z_{FD}, is determined by matching the boundaries between the transition and fully developed regions,

$$\frac{Z_{FD}}{r_N} = \frac{b_2}{(a_3 - a_2)}$$

The momentum and heat flux equations become, for a circular jet,

$$M_J = \frac{2\pi P_A}{R_G} \int \frac{V^2 r \, dr}{T} \tag{6}$$

$$H_F = \frac{2\pi P_A}{R_G} \int \frac{V \Delta T \, r dr}{T} \tag{7}$$

using $P_A = \rho R_G T$ to eliminate density.

The velocity and temperature profiles are represented by the following dimensionless self-similar quantities:

$$\frac{V}{V_M} = f_V(\eta_V) \; ; \; \eta_V = \frac{r}{b_V} \tag{8}$$

$$\frac{\Delta T}{\Delta T_M} = f_T(\eta_T) \; ; \; \eta_T = \frac{r}{b_T} \tag{9}$$

Since finite profile functions will be used in the modeling, the velocity and temperature scale lengths, as represented by b_V and b_T, are not equal.

Substituting eqs. (8) and (9) into eqs. (6) and (7), and rearranging, yields,

Momentum

$$\frac{T_M}{T_N} = 2 \left(\frac{V_M}{V_N}\right)^2 \left(\frac{b_V}{r_N}\right)^2 \int_0^1 \frac{f_V^2 \eta_V d\eta_V}{\left[f_T \left(\frac{1-f_T}{\bar{T}_M}\right)\right]} \tag{10}$$

Heat -

$$\frac{T_M}{T_N} = 2 \left(\frac{V_M}{V_N}\right)\left(\frac{b_V}{r_N}\right)^2 \frac{\Delta T_M}{\Delta T_N} \int_0^1 \frac{f_V f_T \eta_V d\eta_V}{\left[f_T + (1-f_T)\left(\frac{1}{\bar{T}_M}\right)\right]} \tag{11}$$

where $\bar{T}_M = \frac{T_M}{T_A}$

Unfortunately, bringing the density into the integrands makes the profile integrals functions of the maximum centerline temperature ratio. Hence, simple

geometrical similarity does not exist for non-isothermal jets. The velocity scale length η_V is used in the integration since there can be no contribution to eq. (10) or eq. (11) beyond the dynamic (velocity) layer. The integrals in the above equations do not lend themselves necessarily to analytical integration, and are defined as:

$$C_M(\bar{T}_M) = \int_0^1 \frac{f_V{}^2 \eta_V d\eta_V}{\left[f_T + (1-f_T)\frac{}{\bar{T}_M}\right]} \tag{12}$$

$$C_T(\bar{T}_M) = \int_0^1 \frac{f_V f_T \eta_V d\eta_V}{\left[f_T + (1-f_T)\frac{}{\bar{T}_M}\right]} \tag{13}$$

Equations (10) and (11) can be rewritten simply as

$$\frac{T_M}{T_N} = 2\left(\frac{V_M}{V_N}\right)^2\left(\frac{b_V}{r_N}\right)^2 C_M(\bar{T}_M) \tag{14}$$

$$\frac{T_M}{T_N} = 2\left(\frac{V_M}{V_N}\right)\left(\frac{b_V}{r_N}\right)^2 \frac{\Delta T_M}{\Delta T_N} C_T(\bar{T}_M) \tag{15}$$

The values of the integrals C_M and C_T are also functions of the profile characteristics. In general, it is assumed that

$$\frac{V}{V_M} = f_V(\eta_v) = \left[1-\left(\frac{\eta_V-\eta_c}{1-\eta_c}\right)^{\alpha}\right]^2 \tag{16}$$

and

$$\frac{\Delta T}{\Delta T_M} = \left[1-\left(\frac{\eta_T-\eta_c}{1-\eta_c}\right)^{\alpha}\right]^2 = f_T(\eta_T) \tag{17}$$

where $\eta_C \quad r_{C/b_V}$.

Since the dimensionless velocity and temperature profile functions have the same form, then

$$\eta_T = \left(\frac{b_{VH}}{b_{TH}}\right) \eta_V \tag{18}$$

In general, it is assumed that

$$\lambda_T \equiv \frac{b_{TH}}{b_{VH}} > 1 \tag{19}$$

Hence:

$$\eta_T = \frac{\eta_V}{\lambda_T} \tag{20}$$

and the temperature scale length can be directly related to the scale length of the dynamic layer.

6.4.1 Potential core region - In the potential core region, the maximum temperature and velocity are known and are equal to the nozzle values. The momentum and heat equations, (14) and (15), can be reduced to,

$$\frac{1}{2} R_V^2(\alpha) - \left(\frac{b_{VH}}{r_N}\right)^2 C_M(\alpha, \lambda_T) = 0 \tag{21}$$

$$\frac{1}{2} R_V^2(\alpha) - \left(\frac{b_{VH}}{r_N}\right)^2 C_T(\alpha, \lambda_T) = 0 \tag{22}$$

where $R_V = \frac{b_{VH}}{b_v} = \eta_c - (1-\eta_c)\left(\frac{2-\sqrt{2}}{2}\right)^{\frac{1}{\alpha}}$

Equations (21) and (22) are solved simultaneously for the exponent α and the thermal-to-dynamic layer ratio λ_T. For simplicity, the thermal and dynamic cores are assumed identical.

6.4.2 Transition and fully-developed regions - The conservation equations can now be written as:

$$\frac{1}{2} R_V^2 \left(\frac{T_M}{T_N}\right) - \left(\frac{V_M}{V_N}\right)^2 \left(\frac{b_{VH}}{r_N}\right)^2 C_M(\bar{T}_M) = 0 \qquad (23)$$

$$\frac{1}{2} R_V^2 \left(\frac{T_M}{T_N}\right)\left(\frac{T_N}{T_A}-1\right) - \left(\frac{V_M}{V_N}\right)\left(\frac{T_M}{T_N}\cdot\frac{T_N}{T_A}-1\right)\left(\frac{b_{VH}}{r_N}\right)^2 C_T(\bar{T}_M) = 0 \qquad (24)$$

The above equations are solved simultaneously for the dimensionless maximum temperature ratio, $\frac{T_M}{T_N}$, and maximum velocity ratio, $\frac{V_M}{V_N}$, given values for the exponent α and λ_T. Suitable values based on empirical data are assigned to these parameters in the fully developed regions as

$$\alpha_{FD} = 1.5$$

$$\lambda_T = 1 + 0.185\ T_N^{\beta_\lambda} \text{ where } \beta_\lambda \sim 0.50,$$

and a linear variation from potential core values to the fully developed ones is assumed.

Some typical results are shown in Figures 53 through 57 and compared to the test data of Corrsin & Uberoi (Ref. 13) for low Mach number or basically incompressible jets. Figure 53 shows the relationship between the dimensionless velocity and temperature decay rates for a slightly-heated jet (NTR = 1.05) and a significantly-heated jet (NTR = 2.0). Both the velocity and temperature decay rates are enhanced due to an increase in heat content of the jet. The temperature decays faster than the velocity. Figure 54 shows the dynamic pressure or total pressure decay for the two different temperature ratios. The total pressure decays faster for the hotter jet. Figure 55 shows the relationship between the dynamic pressure and total temperature decay. Unlike the velocity and temperature, the pressure and temperature curves cross each other. The dynamic pressure is computed as $\left(\frac{V_M}{V_N}\right)^2 \Big/ (T_M/T_N)$. Figure 56a and b shows the relationship between the half dynamic pressure (q), half velocity (V_M/V_N) and half dimensionless temperature ($T_M - T_A / T_N - T_a$) boundaries for the two nozzle

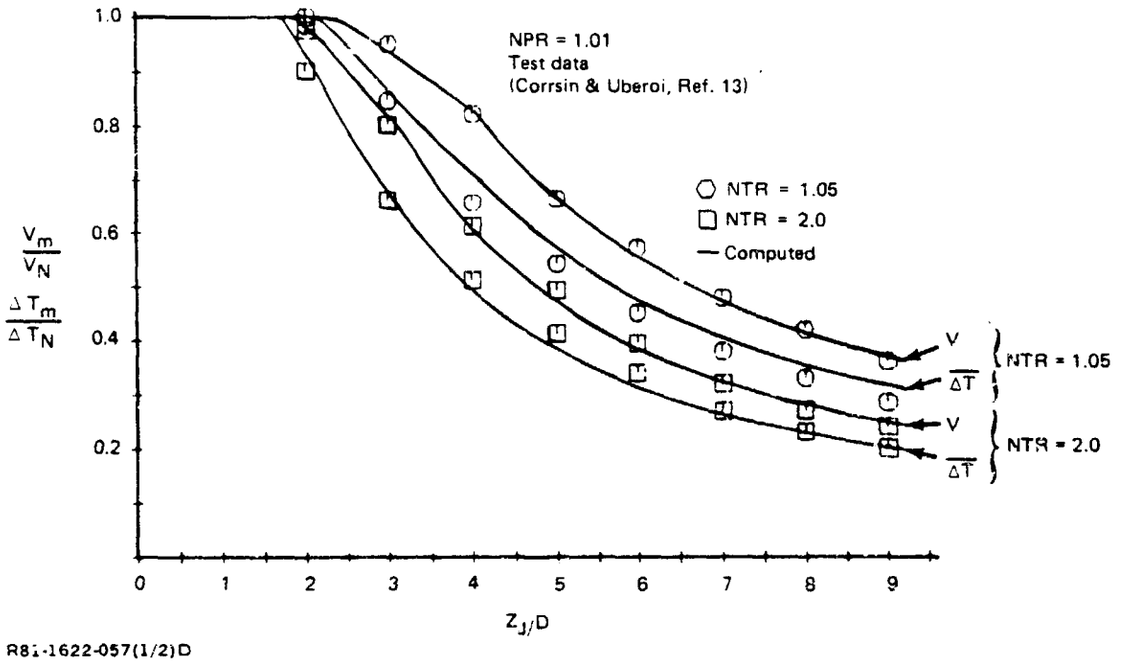


Figure 53 - Comparison of computed free-jet dimensionless velocity and temperature difference decay with test data.

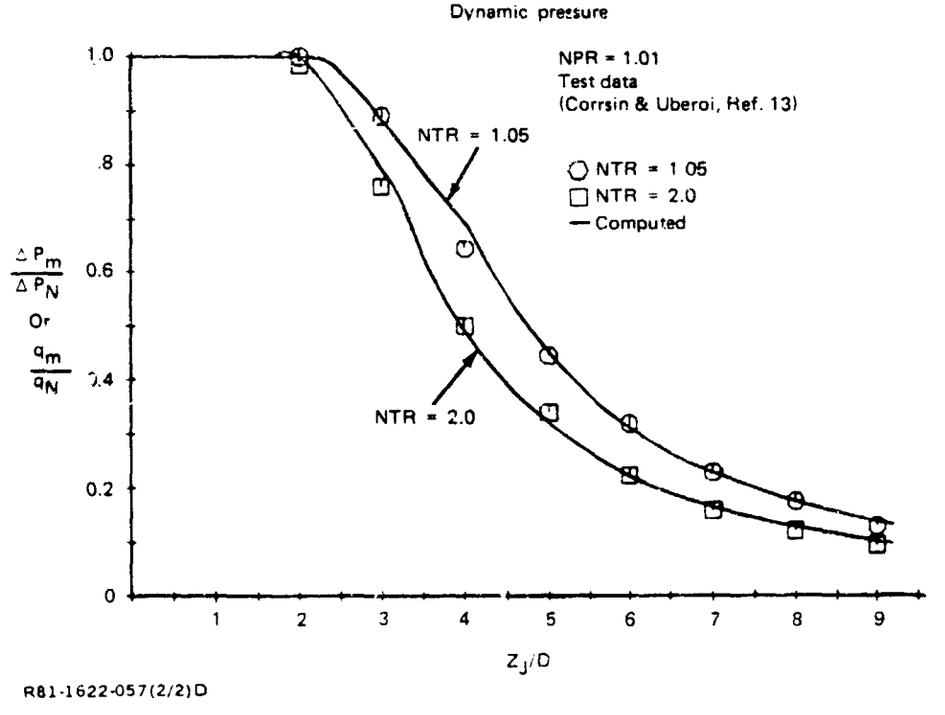
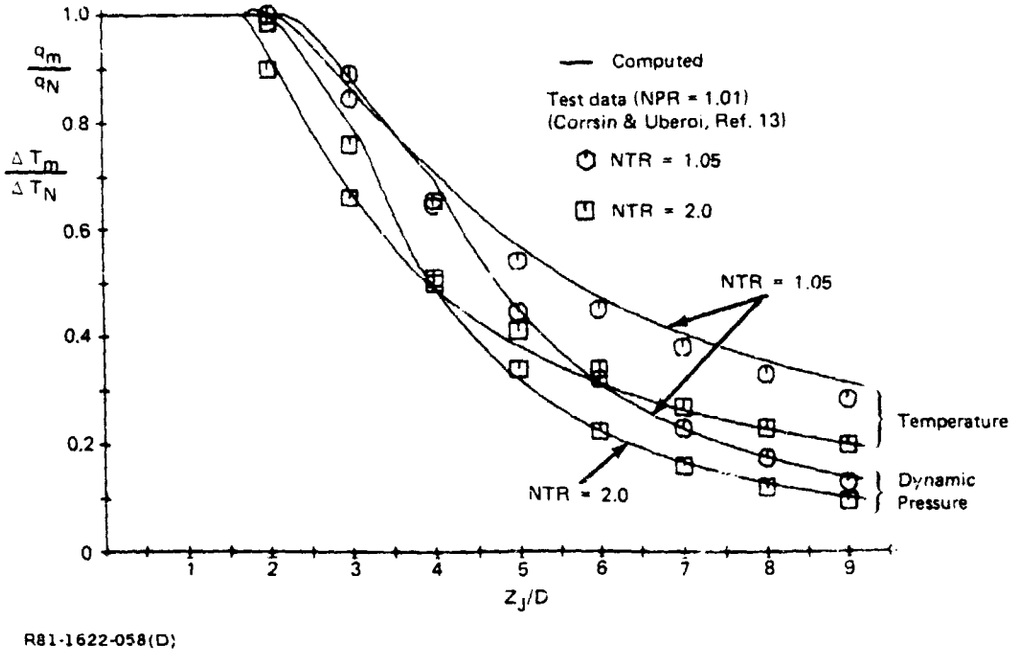


Figure 54 - Comparison of computed free-jet dimensionless dynamic pressure decay with test data.



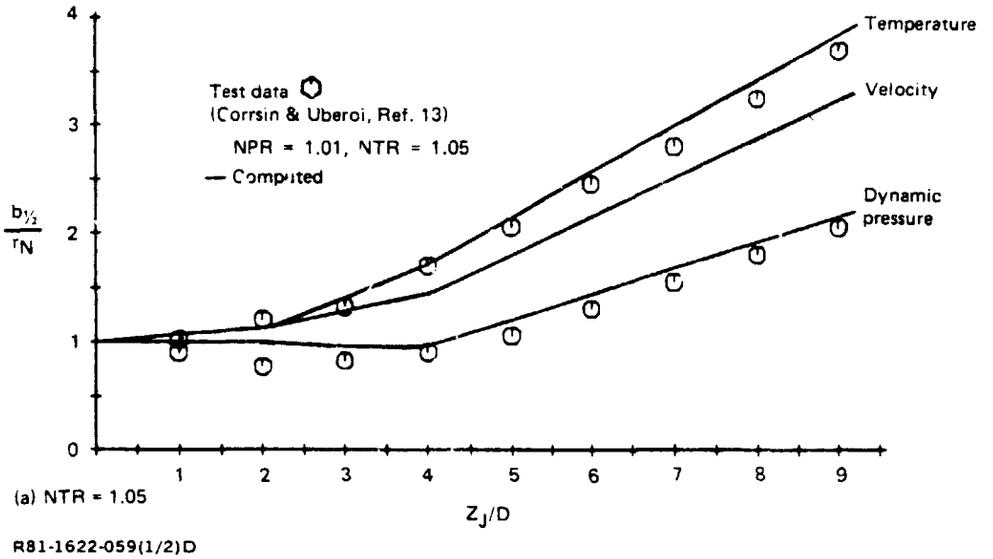
R81-1622-058(D)

Figure 55 - Comparison of computed free-jet dimensionless dynamic pressure and temperature difference decay with test data.

temperature ratios. The half dynamic pressure boundary exhibits a contraction in the potential core region ($Z_{PC} \sim 4D$). The half velocity boundary lies between the half dynamic pressure and temperature boundaries. The half temperature boundary being significantly wider than the half velocity boundary as the nozzle temperature is increased. Figure 57 shows a comparison of the half q and half temperature boundaries for the two nozzle temperature ratios. Hence, heating the jets causes an increase in the jet half boundaries, which is consistent with the higher decay rate exhibited by the hotter jet in the previous figures.

6.5 Jet Deflection Region

A schematic of the wall jet impingement model is shown in Figure 58. The jet begins to stagnate at some ground effect height given by Δ_J. Values for Δ_J are given in Ref. 14. The ground stagnation pressure and temperature is then determined by the jet properties at the ground effect height denoted by



(a) NTR = 1.05

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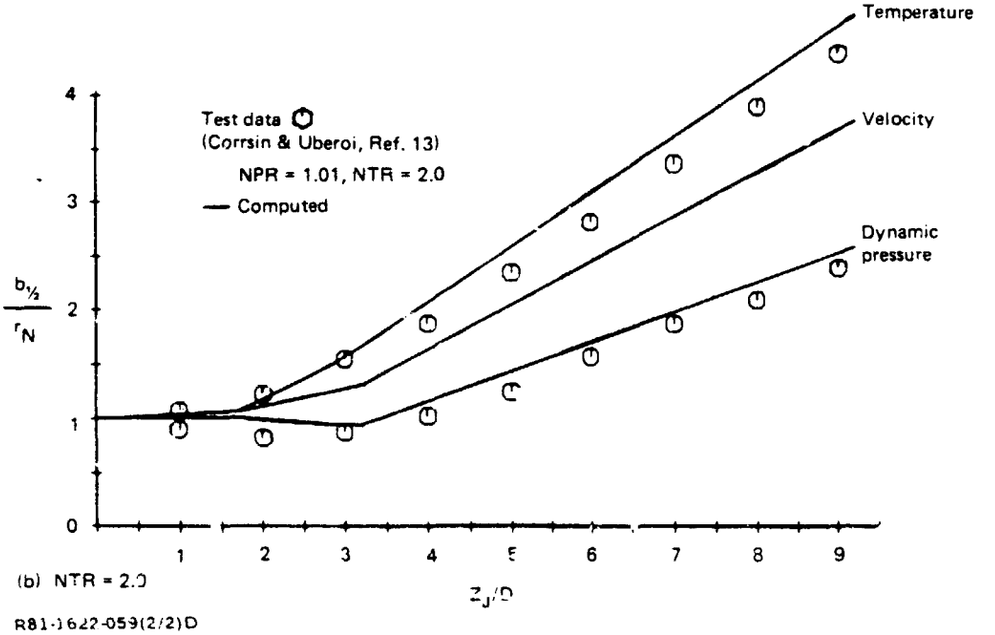

(b) NTR = 2.0

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Figure 56 - Heated free-jet boundary growth characteristics.

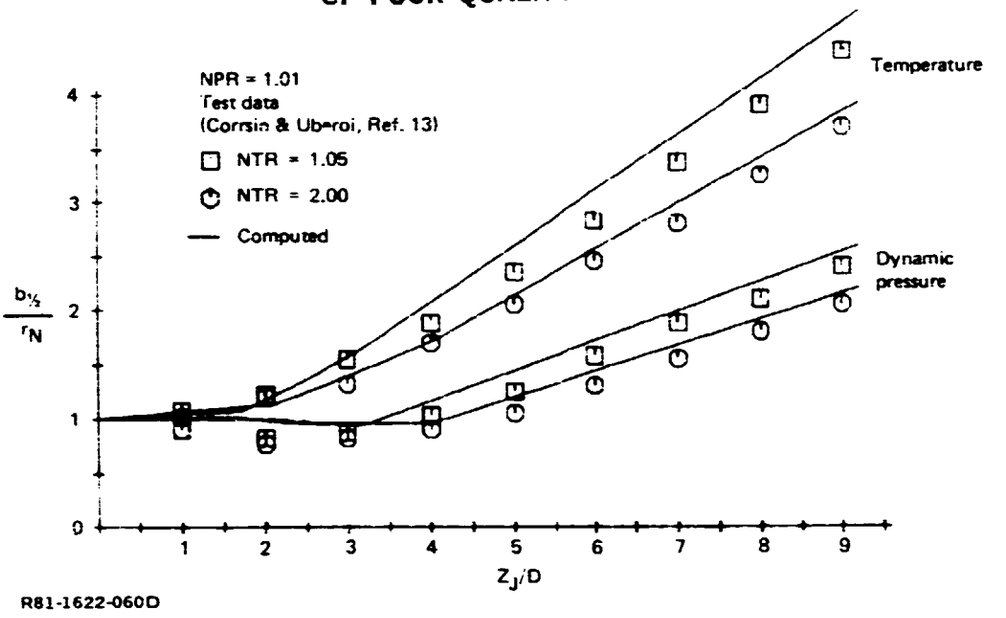


Figure 57 - Heated free-jet boundary growth characteristics.

the subscript (g), or:

$$\frac{\Delta P_S}{\Delta P_N} = \left(V_g/V_N\right)^2 \Big/ \left(T_g/T_N\right) : \qquad \frac{T_S}{T_A} = \frac{T_g}{T_A} \tag{25}$$

The ground pressure distribution in the impingement region is obtained in the same fashion as for an isothermal jet. A momentum balance is performed with the integral of the ground pressure equal to the momentum or thrust of the incident jet.

$$\frac{M_J}{4} = \int_0^{r_o} \int_0^{\pi/2} \Delta P r dr d\varphi \tag{26}$$

The ground pressure distribution is assumed to have the form:

$$\frac{\Delta P}{\Delta P_S} = f_g(r_W) = \left(1 - r_W^{2}{}_g\right)^4 \tag{27}$$

where $r_W = \frac{r}{r_o}$.

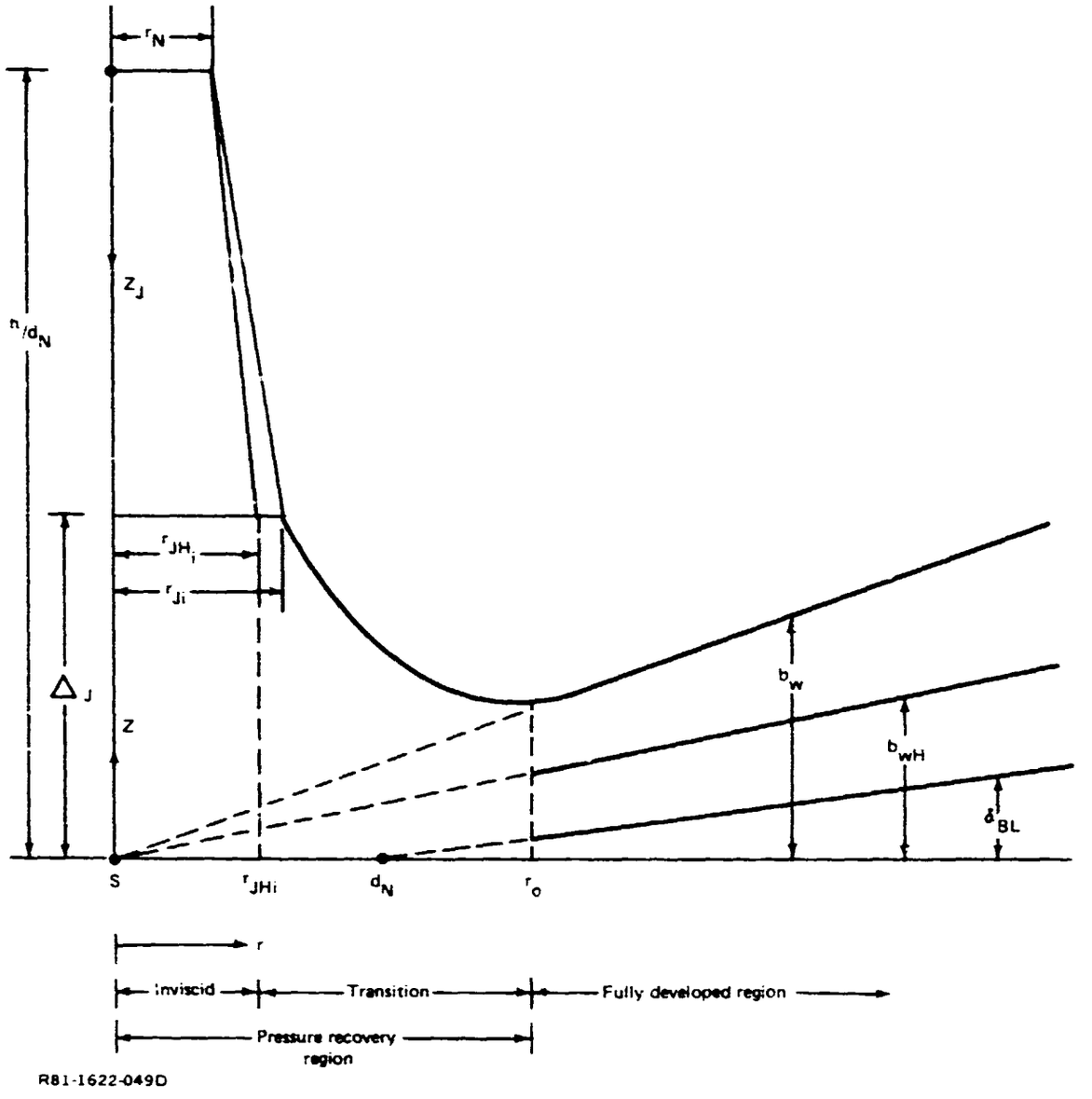


Figure 58 - Definition of scaling parameters for jet impingement and wall jet regions.

Equation (26) can be rewritten as,

$$1 = \left(\frac{r_o}{r_N}\right)^2 \left(\frac{V_g}{V_N}\right)^2 C_{sp}\,(\alpha_g) \Big/ (T_g / T_N) \qquad (28)$$

where $C_{sp}(\alpha_g) = \int_0^1 f_g(\eta_W)\,\eta_W\,d\eta_W$.

Given the impingement radius r_o, equation (28) can be solved for the exponent α_g governing the shape of the ground pressure distribution. The deflection radius r_o is estimated empirically and is based upon the incident half velocity radius (b_{VH}:) of the jet:

$$2.9 \leq \frac{r_o}{b_{VHi}} \leq 3.6 \; ; \; 1.2 \leq \frac{h}{D} \leq 3.0$$

$$\frac{r_o}{b_{VHi}} = 3.6 \; ; \; \frac{h}{D} > 3.0$$

6.6 Heated Wall-Jet Transition Model

Figure 58 shows a schematic of the wall-jet model. The wall-jet transition model developed in Ref. 3 consists of three subregions:

i) Inviscid deflection region where the effects of viscosity are assumed to be negligible except in a region close to the wall and near the edge of the deflected flow. In this region, the inner boundary layer is established as governed by axially-symmetric stagnation flow.

ii) Transition region where the effects of viscosity are beginning to dominate and the inner boundary layer and outer shear flow changes to the fully-developed turbulent wall-jet.

iii) Fully-developed flow, where the effects of turbulent viscosity dominate and the static pressure through the wall layer is considered ambient, or fully recovered. In this region, the nearly similar wall-jet develops.

The addition of heat to the wall-jet requires the introduction of a radial

heat flux equation into the model of the isothermal wall-jet. The two conservation equations (assuming negligible losses) applied to the wall jet are:

Momentum -
$$M_F = \int_0^{b_W} (\rho V^2 + \Delta P)\, r dz \tag{29}$$

Heat -
$$H_F = \int_0^{b_W} \rho V \Delta T r dz \tag{30}$$

where b_W is the height or thickness of the dynamic (velocity) layer.

Before being able to apply eqs. (29) and (30) to the wall layer, the velocity, pressure and temperature profile behavior must be approximated. Two sublayers are assumed, an inner boundary layer and an outer shear layer. Adiabatic wall conditions are assumed and the thermal and dynamic boundary layers are also assumed to coincide.

Inner Boundary Layer

$$\frac{V}{V_M} = \left(\frac{\zeta_V}{K_\delta}\right)^{\frac{1}{N}} \quad \text{where } \zeta_V = \frac{Z}{b_w}, \; K_\delta = \frac{\delta_{bl}}{b_W} \tag{31}$$

$$\frac{\Delta P}{\Delta P_M} = 1 \qquad \text{(constant pressure through boundary layer)}$$

$$\frac{\Delta T}{\Delta T_M} = 1 \qquad \text{(adiabatic wall, constant temperature through boundary layer)}$$

where $7 \leqslant N \leqslant 15$.

Outer Shear Layer

$$\frac{V}{V_M} = f_V(\zeta_V) = \left[1 - \left(\frac{\zeta_V - K_\delta}{1 - K_\delta}\right)^{\alpha}\right]^2$$

$$\frac{\Delta P}{\Delta P_M} = f_p(\zeta_V) = f_v^2(\zeta_v) = \left[1 - \left(\frac{\zeta_V - K_\delta}{1 - K_\delta}\right)^{\alpha}\right]^4 \tag{32}$$

$$\frac{\Delta T}{\Delta T_M} = f_T(\zeta_T) = \left[1 - \left(\frac{\zeta_T - K_\delta}{1 - K_\delta}\right)^{\alpha}\right]^2$$

where $\zeta_T = \frac{Z}{b_T}$ and b_T is the height or thickness of the thermal layer. The dynamic and thermal layers are assumed to be related by:

$$\frac{b_{TH}}{b_{VH}} = \frac{b_T}{b_W} \equiv \lambda_T > 1 \tag{33}$$

The introduction of equations (30) and (31) into eqs. (28) and (29) lead to the development of several profile integral expressions.

The momentum integral has a velocity squared and a pressure term. The pressure term contributes to the momentum until pressure recovery occurs. Substitution of the profile expressions into the velocity term of the integral yields the following integrals for the two layers:

$$C_M\left(\overline{T}_M\right) = \int_0^{K_\delta} \left(\frac{\zeta_V}{K_\delta}\right)^{\frac{2}{N}} d\zeta_V + \int_{K_\delta}^{1} \frac{f_V{}^2\left(\zeta_V\right)\left[f_p\left(\zeta_V\right) + \left\langle 1 - \frac{f_p\left(\zeta_V\right)}{\overline{P}_M}\right\rangle\right]}{\left[f_T\left(\zeta_T\right) + \left(\frac{1-f_T\left(\zeta_T\right)}{\overline{T}_M}\right)\right]} d\zeta_V \tag{34}$$

where $\overline{T}_M = \frac{T_M}{T_A}$ and $\overline{P}_M = \frac{P_M}{P_A}$

The pressure term leads to a simpler expression:

$$C_p = K_\delta + \int_{K_\delta}^{1} f_p d\zeta_V \tag{35}$$

which can be integrated analytically.

The heat equation leads to integrals similar to eq. (34):

$$C_T\left(\bar{T}_M\right)=\int_0^{K_\delta}\left(\frac{\zeta_V}{K_\delta}\right)^{\frac{1}{N}}d\zeta_V+\int_{K_\delta}^{1}\frac{f_V\left(\zeta_V\right)f_T\left(\zeta_T\right)\left\langle f_p\left(\zeta_V\right)+\left[1-f_p\left(\zeta_V\right)\right]\right\rangle d\zeta_V}{\left[f_T\left(\zeta_T\right)+\left\langle 1-f_T\left(\zeta_T\right)\right\rangle\right]_{\bar{T}_M}} \tag{36}$$

The pressure distribution along the wall was defined previously as:

$$\Delta P_M = \Delta P_S f_g\left(\eta_W\right) \tag{37}$$

Equations (29) and (30) can now be expressed as

Momentum -

$$F_M\left(\eta_W\right)F_{VIS}(r)=\left(\frac{r}{r_N}\right)\left(\frac{b_W}{r_N}\right)\left[\frac{2\bar{P}_M\left(\frac{V_M}{V_A}\right)^2}{\frac{T_M}{T_N}}C_M+\frac{\Delta P_S}{\Delta P_N}f_g\left(\eta_W\right)C_p\right] \tag{38}$$

Heat Flux -

$$F_T\left(\eta_W\right)=2\left(\frac{r}{r_N}\right)\left(\frac{b_W}{r_N}\right)\bar{P}_M\left(\frac{V_M}{V_N}\right)\left(\frac{\Delta T_M}{\Delta T_N}\right)C_T\Big/\left(T_M/T_N\right) \tag{39}$$

The terms on the left side of eqs. (38) and (39), F_M and F_T, reflect the gain in radial momentum or heat flux as the jet deflects and becomes parallel to the wall. These functions are made proportional to the pressure recovery function, or

$$F_M\left(\eta_W\right)=F_T\left(\eta_N\right)=1\text{-}fg\left(\eta_W\right) \tag{40}$$

since little or no empirical data are available in the deflection region. Hence, the radial momentum and heat flux reach a maximum at pressure recovery, and for

$$\eta_W=\frac{r}{r_o}\geq 1\ ,\ F_M=F_T=1$$

The term $F_{VIS}(r)$ reflects the loss of momentum due to frictional loses at the

wall, and $$F_{VIS}(r) \sim \frac{1}{\left(\frac{r}{D}\right)^{\alpha_{VIS}}}, \text{ where } \alpha_{VIS} \sim 0.15\text{-}0.25. \tag{41}$$

Equations (38) and (39) represent two simultaneous equations for the two unknowns, V_M and T_M. The values of the integrals C_M, C_p and C_T, which arise from the profile functions, are determined numerically and are, in general, a function of the maximum temperature ratio $\left(\frac{T_M}{T_A}\right)$.

The inviscid deflection region is assumed to occur under the half velocity width (b_{VHi}) of the incident jet profile. Constant total pressure and total temperature is assumed throughout the inviscid layer to be equal to the incident jet values. The wall-jet properties at the beginning of the wall-jet transition region are obtained from the inviscid values. The initial velocity at the end of the inviscid region is defined from the static pressure and Bernoulli's equation.

Equations (38) and (39) are used to determine the initial values of the exponent α, governing the wall-jet profiles in the shear layer, and the initial ratio, λ_{T_i}, of the thermal-to-dynamic layer thickness. The wall layer is now completely initialized upon prescription of the initial boundary layer characteristics. Fully developed values for the exponent α and the ratio λ_T are now prescribed and a linear variation between the initial values at the beginning of the transition to the fully developed region is assumed. Equations (38) and (39) can then be solved simultaneously for the maximum temperature and velocity throughout the wall-jet, given a prescribed behavior for the half-velocity thickness.

For the fully developed wall-jet region, the boundary and shear layers are assumed to have a simple linear behavior:

$$\frac{b_{WH}}{r_N} = a_{W_3}\left(\frac{r}{r_N}\right) \tag{42}$$

$$\frac{\delta_{bL}}{D} = a_{bL_3}\left(\frac{r}{D} - \right)1 \tag{43}$$

where $a_{W_3} = 0.9\left[1 + \ln\left(\frac{2}{1 + \frac{1}{T_N \beta_W}}\right)\right]\left[1 - .16M_S\right]$; $\beta_W \sim 0.50$

$a_{bL_3} \cong 0.0175$

and M_s is the stagnation Mach number of the jet. The wall jet thickness in the transition region is obtained by a linear variation between the initial and fully developed values. Some total pressure and temperature decay data is shown in Figure 59 for single circular jet impingement into a radial wall-jet. The wall-jet pressure decay is only slightly influenced by the nozzle temperature ratio for the range tested. The temperature decay shows a greater dependence on the nozzle temperature. Both the temperature and pressure decays more rapidly with an increase in nozzle temperature.

6.7 Two-Jet Interaction Model

Figure 60 shows a sketch of the ground plane coordinate systems for the two jet impingement interaction problem. The jets stagnate on the ground, de-

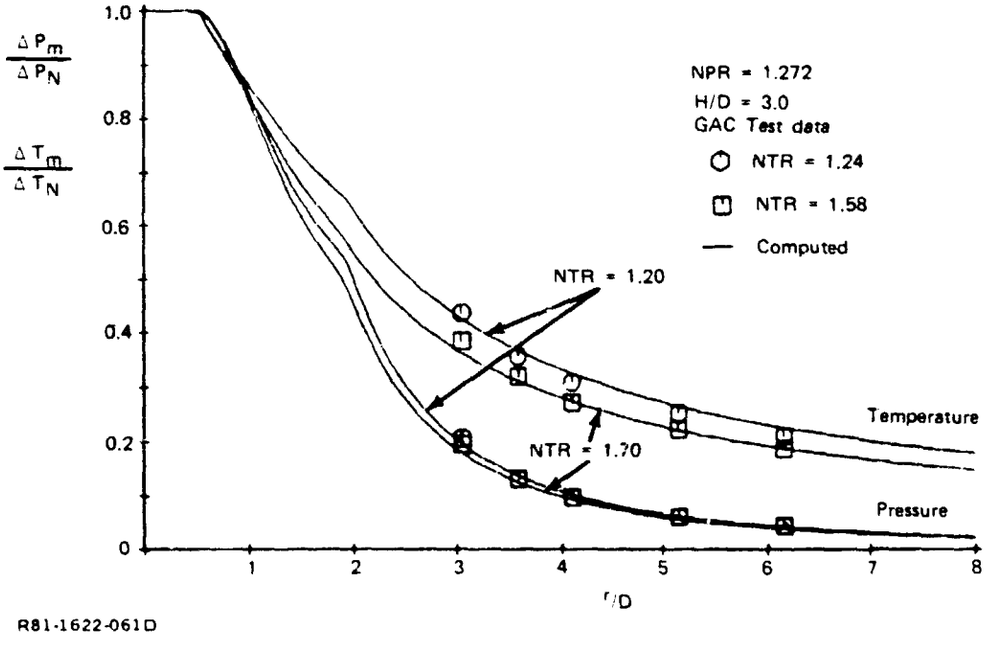


Figure 59 - Heated wall-jet dimensionless total pressure and temperature difference decay with ground radius.

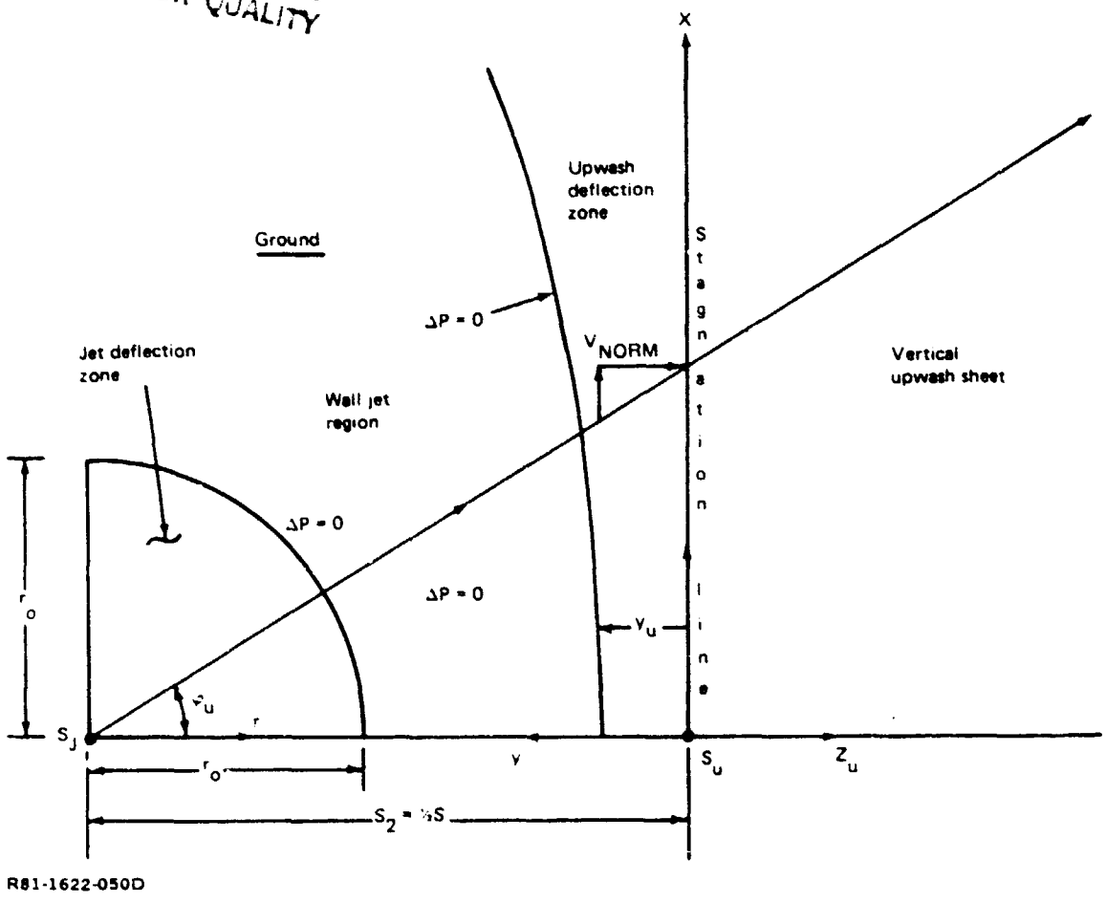


Figure 60 - Two-jet impingement without deflection zone interaction.

flect into radial wall jets and collide along their plane of symmetry. The formation of an upwash stagnation zone is a result of the upward deflection of the wall jet flow. The point S_u, on the line joining the jet centers, is the only true stagnation point where the flow comes to rest and deflects vertically. At points off of the center, the flow is deflected at an angle such that the pressure is representative of the stagnation of the normal component of the maximum wall jet velocity.

6.7.1 Maximum pressure and temperature distribution along the upwash stagnation line - To estimate the upwash stagnation line ground pressure and temperature distribution, the maximum velocity of the wall jet normal to the stagnation line is computed:

$$V_{NORM} = V_{MW} \cos \varphi_u \tag{44}$$

The maximum pressure along the stagnation line is computed from the static plus the contribution of the normal velocity of the wall jet.

Pressure -

$$\Delta P_{umg} = \Delta P_{MW} + \frac{1}{2} \frac{P_{MW}}{R_G T_{MW}} V_{MW}^2 \cos^2 \varphi_u \tag{45}$$

Dividing by the nozzle pressure given by

$$\frac{\Delta P_{SN}}{P_A} = NPR-1 = \frac{1}{2} \frac{V_N^2}{R_G T_N} \tag{46}$$

yields

$$\frac{\Delta P_{umg}}{\Delta P_{SN}} = \frac{\Delta P_{MW}}{\Delta P_{SN}} + \frac{\left(\frac{P_{MW}}{P_A}\right)\left(\frac{V_M}{V_N}\right)^2 \cos^2 \varphi_u}{\left(\frac{T_M}{T_N}\right)} \tag{47}$$

Temperature -

$$\frac{T_{umg}}{T_A} = \frac{T_{MW}}{T_A} \tag{48}$$

The maximum temperature along the stagnation line is then just equal to the maximum temperature of the wall-jet at the stagnation line location, $X = \frac{S}{2}$

The pressure along the stagnation line given by eq. (47) uses the maximum temperature, velocity, and static pressure of the wall-jet evaluated at the stagnation line location.

6.7.2 Upwash momentum models - The upwash momentum model, including the effects of close jet spacing, remains unchanged in principle due to temperature effects and are those described in Ref. 3. The addition of temperature effects has a slight effect on the ground pressure distribution since the addition of heat to the flow somewhat affects the overall decay rates of the various regions. The overall upwash momentum can then be related to the integral of the upwash ground pressure distribution as described in detail in Ref. 3.

6.7.3 Heated upwash decay model - Figure 61 shows a schematic of the upwash sheet model and the characteristic scaling parameters. The upwash sheet is assumed to be a reflection of the wall-jet flow into the vertical plane of symmetry lying between the jets. The radial streamline pattern of the wall layer is assumed to continue into the upwash sheet and, to a first approximation, be unperturbed by the turning region. The wall-jet flow is assumed to enter the upwash deflection region with a characteristic profile, half velocity width and maximum velocity or total pressure. The characteristic length scale in the upwash sheet is the half velocity width of the incident wall-jet layer estimated at the wall location. The pressure recovery region in the upwash sheet is assumed to be approximately three times the half velocity width of the incident wall jet profile. The magnitude of the momentum flux in the resulting upwash streamline is assumed equal to that of the incident wall-jet. Hence, the upwash sheet is treated in a similar fashion as the wall-jet with a few exceptions.

Due to the high turbulence levels typically measured in the upwash sheet, the flow is considered to be fully turbulent and similar. The upwash velocity profile is taken to be that of a free shear profile with no internal momentum defect due to the wall layer. The upwash sheet growth rate is assumed to be

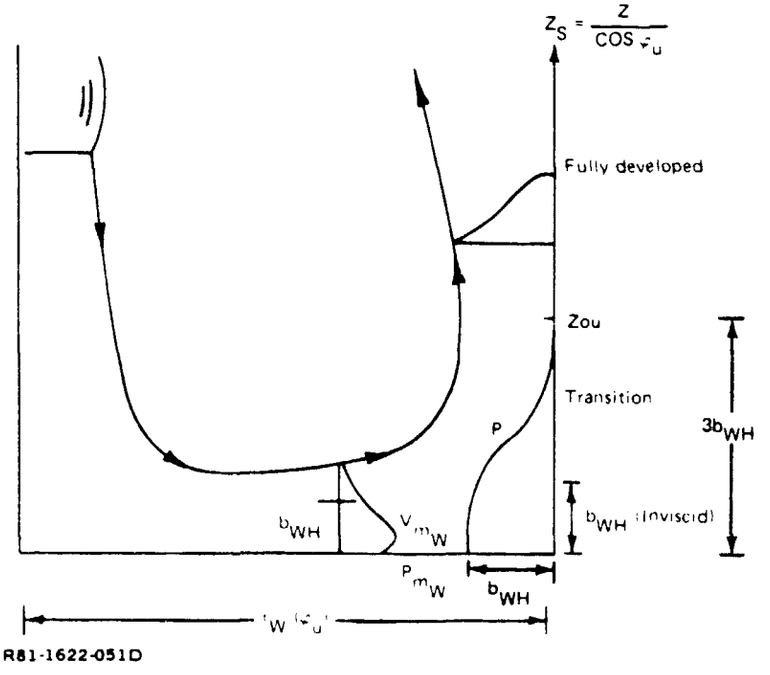


Figure 61 - Characteristic scaling parameters for upwash model.

constant without any initial transition phase. It is also assumed that the magnitude of the momentum flux distribution in the upwash sheet is given by the previously discussed momentum models. Expressions for the momentum and heat flux similar to those for the wall jet can be derived for the upwash flow:

Momentum -

$$f_{Mu}(\varphi)\left[1-f_{Pu}(\varphi)\right] = \left[\left(\frac{r_W + Z_S}{r_N}\right)\frac{b_u}{r_N}\right] \left[\frac{2\left(\frac{P_{uM}}{P_A}\right)\left(\frac{V_{Mu}}{V_N}\right)^2}{\left(\frac{T_{Mu}}{T_N}\right)} C_{Mu}\left(\overline{T}_{Mu}\right) + \frac{\Delta P_{uM}}{\Delta P_N} C_{Pu}\left(\overline{T}_{Mu}\right)\right] \quad (49)$$

where $\Delta P_{MU} = \Delta P_{MUG}(\varphi)\, f_{PU}(\varphi)$

Heat Flux -

$$f_{Mu}(\varphi)\left[1 - f_{Pu}(\varphi)\right] = 2\left(\frac{r_W + Z_s}{r_N}\right)\left(\frac{b_u}{r_N}\right)\left(\frac{P_{Mu}}{P_A}\right)\left(\frac{V_{Mu}}{V_N}\right)\left(\frac{\Delta T_{Mu}}{\Delta T_N}\right)\frac{C_{Tu}\ \overline{T}_{Mu}}{T_M / T_N} \quad (50)$$

where

$$C_{Mu} = \int_0^1 \frac{f_V^2\left[f_p + \frac{(1-f_p)}{\overline{P}_M}\right] d\eta_V}{\left[f_T + \frac{(1-f_T)}{\overline{T}_M}\right]} \quad (51)$$

$$C_{Pu} = \int_0^1 f_p\, d\eta_V \quad (52)$$

$$C_{Tu} = \int_0^1 \frac{f_V(\eta_V) f_T(\eta_T) \left[f_p + \frac{(1-f_p)}{\bar{P}_M} \right] d\eta_V}{\left[f_T + \frac{(1-f_T)}{\bar{T}_M} \right]} \qquad (53)$$

$$\zeta = \frac{z_s}{z_{so}} \; , \; \eta_V = \frac{Y}{b_u} \; , \; \eta_T = \frac{Y}{b_{ut}}$$

The pressure terms in eqs. (49) and (50) only have a contribution in the upwash deflection regions. The above integrals, as with the wall-jet and jet flows, are carried out over the width of the dynamic layer given by b_u. The thermal layer is considered to be somewhat wider and is given by:

$$b_{uT} = \lambda_T b_u$$

The growth rate of the upwash flow is assumed to be approximately three times the rate of the wall-jet due to the higher turbulence. Equations (49) and (50) are then solved simultaneously for the temperature and velocity. Initial application of this model to the heated upwash led to the results shown in Figure 62 for the pressure and temperature decay. The pressure correlates well with the test data but the temperature decays too rapidly. The wall-jet and upwash temperature behavior for two interacting impinging jets is significantly different from a single isolated jet impinging to form a wall-jet. Recirculation effects dominate for multi-jet impingement. These effects are due to several aspects of the two-jet problem. Hot upwash flow tends to recirculate back into the free jet and wall jet regions, altering their effective temperature decay. Confinement of the region between the free jet and upwash flow tends to heat the ambient flow or restrict the influx of cooler ambient air into this region to be entrained by the wall jet and upwash flow. As a result of these effects, in order to be able to estimate the temperature behavior of wall-jets and upwash flow, a recirculation model must be established.

6.7.4 Recirculation model - As a preliminary attempt at estimating recirculation effects, a model was generated for both the wall-jet and upwash flows. The

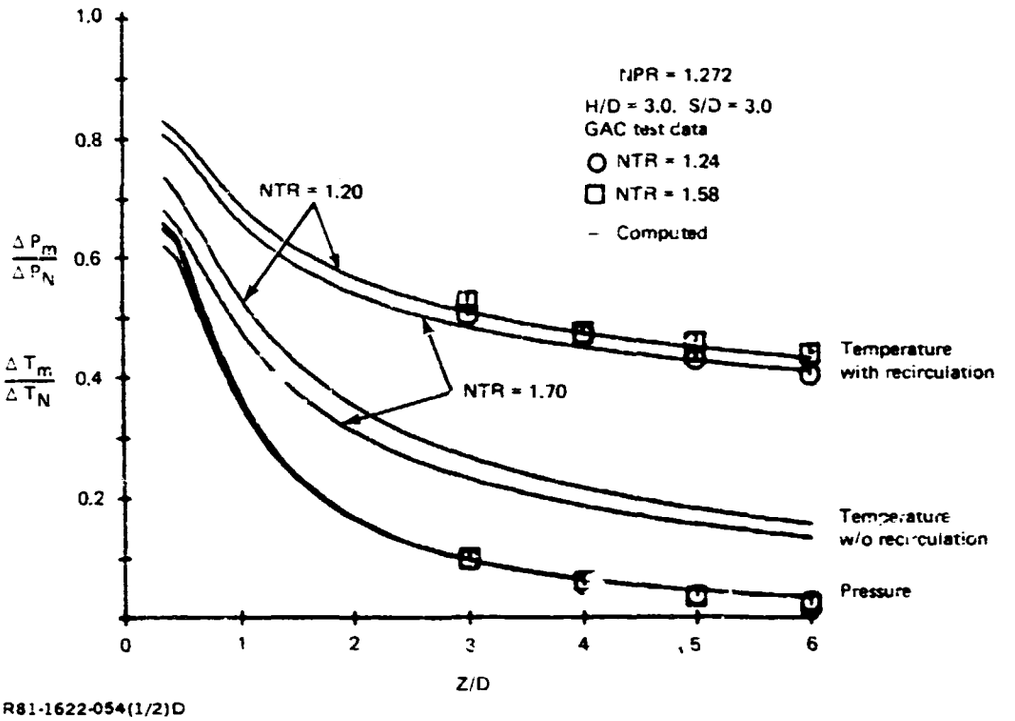


Figure 62 - Heated upwash centerline decay characteristics with recirculation effects.

basic principle of such a model is demonstrated in Figure 63. The model takes into account that the wall jet and upwash streamlines do not effectively entrain air at the reference ambient condition. This situation is most extreme along the inner wall-jet and upwash streamline ($\varphi=0^0$) and is enhanced as the jet spacing is reduced. The recirculation effect is also assumed to be negligible along the outermost ray ($\varphi=\pi$). In reality, the outermost ray may also be affected if the free jet decay has been altered. This is neglected in the present study. In order to quantify the recirculation effect, it is assumed that it results in a local change in ambient conditions represented by:

$$\frac{T}{T_A}_{Aeff} = 1 + A_{rec} \cos^2\left(\frac{\varphi}{2}\right) \Delta T_g \qquad (54)$$

where

$$A_{rec} = \left[\frac{r_g}{(S/2)}\right]^{\alpha_{rec}} , \quad \alpha_{rec} \sim 1.30$$

and ΔT_g is the ground stagnation temperature of the incident jet.

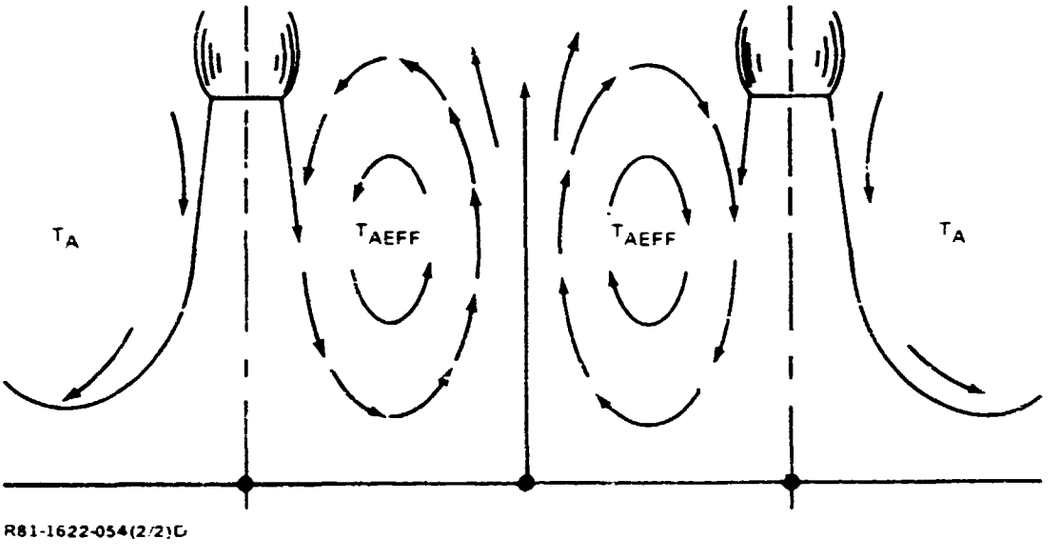


Figure 63 - Recirculation effects.

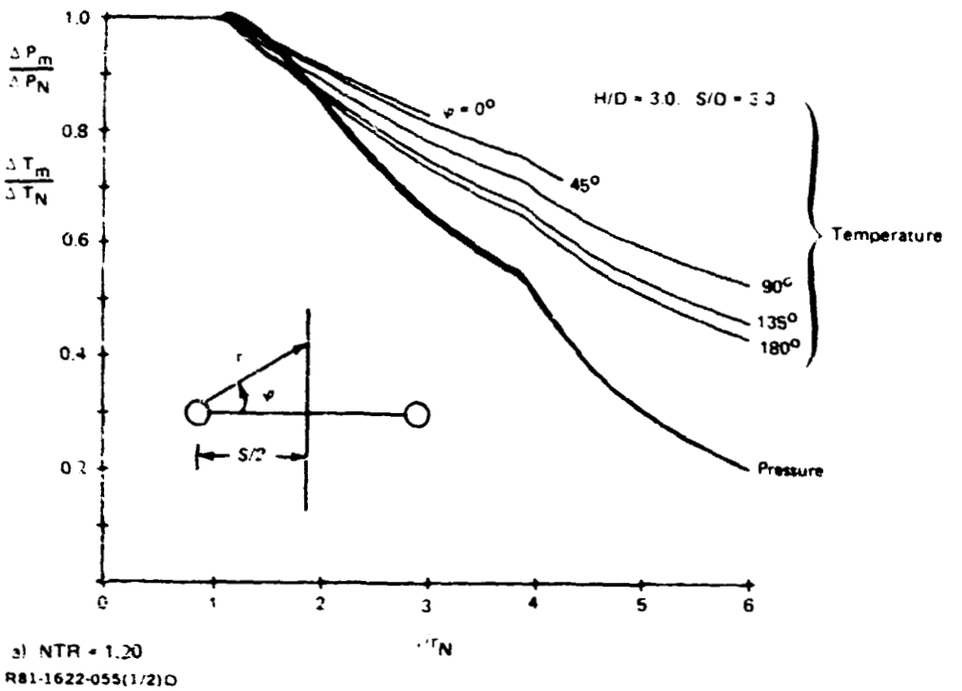
Essentially, the amount of excess heat flux in any given layer is then altered by the effective local ambient condition:

$$H_F \sim \Delta T_N = T_N - T_{Aeff}$$

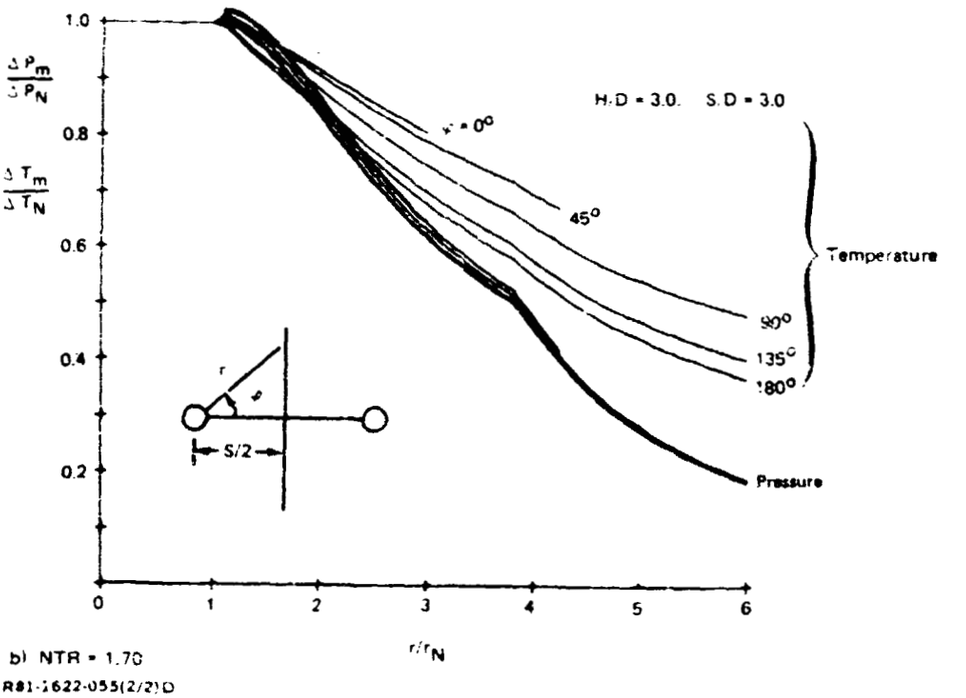
Hence, if the effective or local ambient temperature is equal to the nozzle temperature, the excess heat flux will be zero and no temperature decay will take place as a result of the heat equation.

If the incident radius (r_g) of the impinging jet is equal to the half spacing of the jets, then the effective ambient temperature (T_{Aeff}) becomes equal to the $\overline{T_A}$

incident temperature ratio of the jet along the stream e $\varphi = 0^\circ$ and no further temperature decay will occur. Figures 64a and 64b demonstrate the effect of this model on the wall jet decay rates for two jets with S/D = 3.0 and H/D = 3.0, and two different nozzle temperature ratios. In this figure, the decay is computed until the wall jet interacts with the stagnation line. For $\varphi > \pi/2$, the wall-jet decay is computed to a fixed radius of three diameters. The least temperature decay occurs along the inner ($\varphi = 0^0$) streamline. The wall-jet decays more rapidly as the outermost ray is approached and, at $\varphi = \pi$, the decay of the wall-jet becomes equal to the isolated impingement value.



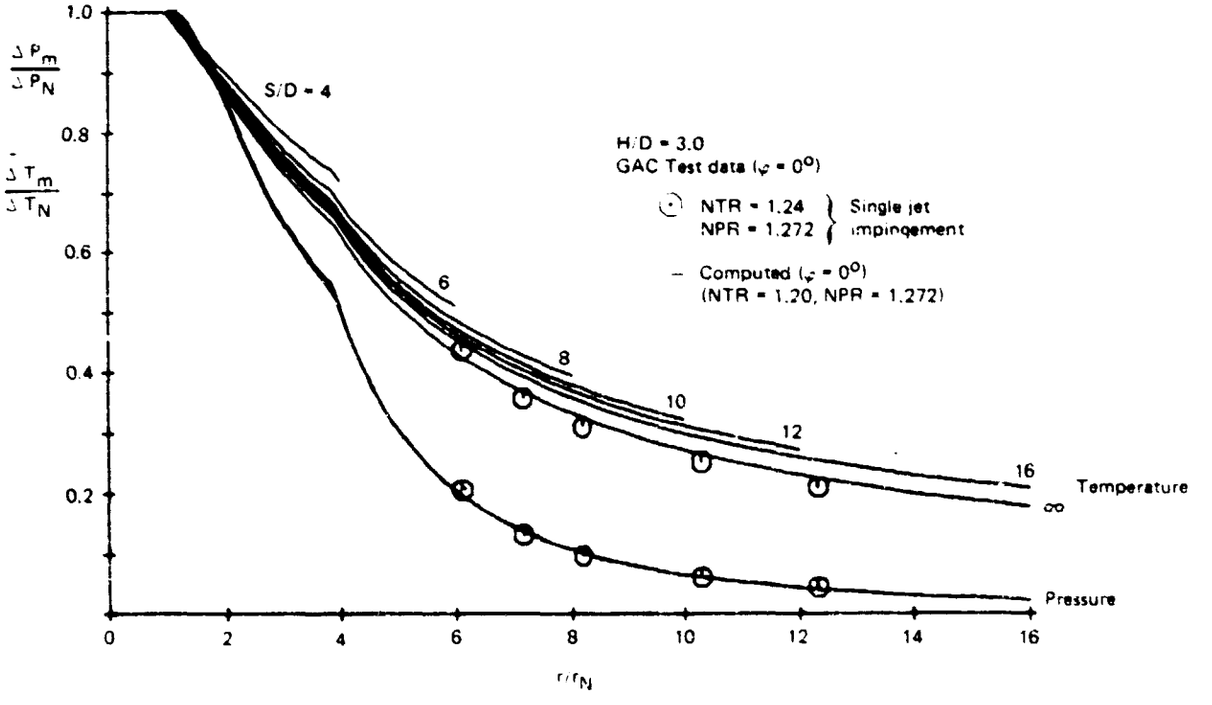
a) NTR = 1.20
R81-1622-055(1/2)D



b) NTR = 1.70
R81-1622-055(2/2)D

Figure 64 - Heated wall jet decay characteristics with azimuthal recirculation model.

A slight overshoot of the values occur at the end of the inviscid region due to a mismatch either in the radius of the inviscid region or in the thickness of the wall layer. Even though an effective change in ambient temperature conditions affects the temperature decay rate dramatically, it only affects the total pressure decay slightly as indicated by the figures. Figure 65 more clearly demonstrates the effect of the recirculation model as a function of jet spacing. The decay of the innermost streamline (ϕ=0) is plotted as a function of jet spacing. As the spacing increases, the wall-jet temperature decays more rapidly and, as $S/D \to \infty$, the decay rate of the interacting wall jet approaches the isolated or single jet impingement behavior. The recirculation effect on the wall-jet feeds into the upwash as an alteration of the initial upwash temperature as well as changing the upwash decay rate. Figure 66 shows the improved correlation in the upwash temperature decay with the implementation of the recirculation model in comparison with Figure 62. Obviously, more detailed correlation is required really to be able to quantify this effect. It is also expected that the presence of a confining plate or vehicle will significantly alter or enhance the recirculation effects.



R81-1622-056(1/2)D

Figure 65 - Heated-wall jet decay characteristics (φ = 0°) vs. jet spacing.

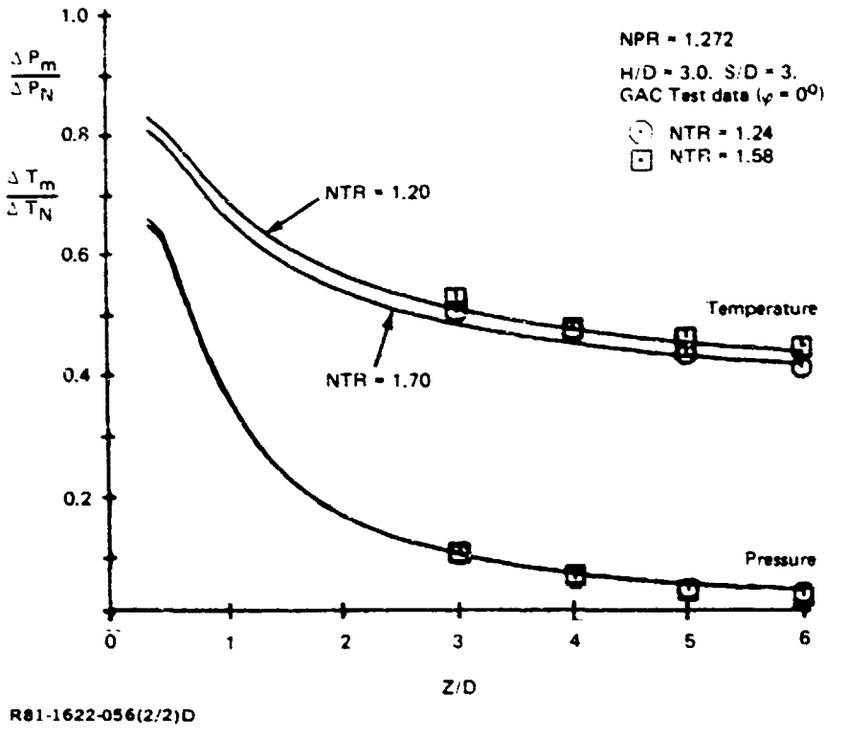


Figure 66 - Correleation of heated upwasn decay characteristics (φ = 0°) with recirculation model.

7 - CONCLUSIONS

For the configuration considered in this investigation, small-scale models can be used to predict full-scale induced forces. No scale effects were found, and jet temperature and pressure did not affect the nondimensionalized induced lift. The induced lift in-ground-effect was found to be higher for the uniform circular jets than for the simulated fan jets.

Modifications to an existing wall-jet transition model adequately predict the trends with height above ground of upwash temperatures and pressures. The addition of a recirculation model is necessary to predict upwash temperatures in the presence of an aircraft.

APPENDIX

COMPUTER PROGRAM DESCRIPTION

PROGRAM NAME: GRUMHOT2

PURPOSE: VTOL TWO-JET IMPINGEMENT INTERACTION PROBLEM

This program is designed to estimate the dynamic and thermal flow characteristics associated with two vertically-impinging and equal-strength hot jets. This program is specifically oriented towards the problem of closely-spaced jet interaction, where the deflection regions interact until eventually jet coalescence occurs.

Aside from the basic flow characteristics, the program assumes the symmetrical placement of a slender fuselage in the upwash flow. The upwash lift force is then computed for a cylindrical fuselage of constant cross-sectional shape. The body parameters, in terms of width and depth, do not vary longitudinally. The program estimates the force on the basis of a rectangular and a circular cross section. Two planes of symmetry are assumed and all output applies to one quadrant of the flow field (ie. equal jets and nozzles located at the midpoint of the fuselage). Jet entrainment effects may be significant but are neglected in this program. Hence, the force is only that due to upwash impingement. Some residual programming exists in the code for a parabolic body of revolution. These cards have been commented out but may be used if desired.

INPUT DESCRIPTION

Note: All input parameters are in terms of nozzle diameters.

Card No.	Code Names	Format
1	NPR, NTR	2F10.5

Name	Definition
NPR	Nozzle pressure ratio
NTR	Nozzle temperature ratio

Card No.	Code Names	Format
2	HD, SD, ZPLD, DZPL, ZFINAL	5F10.5

Name	Definition
HD	Nozzle height above ground
SD	Nozzle spacing

Note: The program will compute one or several positions of the fuselage relative to the ground for a fixed nozzle height above ground.

ZPLD	Initial fuselage height above ground
DZPL	Increment in fuselage ΔZ above ground
ZFINAL	Final Z coordinate of fuselage height relative to ground plane.

Card No.	Code Names	Format
3	XL2, WCON, ZCON	3F10.5

Names	Definition
XL2	Fuselage Length
WCON	Fuselage Width
ZCON	Fuselage Depth

Note: ZCON determines position of fuselage underside relative to its ZPLD location. Bottom of fuselage will be located at ZPLD-ZCON at first computed location. The upwash sheet properties are also computed at this Z location.

Card No.	Code Names	Format
4	IPBAR	I1

Name	Definition
IPBAR	Integer controlling the output of ground pressure pattern: IPBAR = 0, no pressure pattern output IPBAR = 1, pressure pattern output is desired

Note: Card No. 4 is not required if IPBAR = 0.

Card No.	Code Name	Format
5	NU	I2

Name	Definition
NU	Number of pressure values to be input for computation of ground isobar pattern NU < 25

Note: Card No. 5 is repeated NU times.

Card No.	Code Name	Format
6	PU	F10.5

Name	Definition
PU	Nondimensional pressure for isobar pattern $0.0 \leq PU < 1.0$

Figure 67 shows a typical input set.

```
TOF:
                                INPUT DATA
**********************************************************************************

1.007     2.00
4.00      3.000     2.00      1.00      4.00
8.00      1.00      0.0
1
10
.9
.8
.7
.60
.50
.4
.3
.2
.10
.05

**********************************************************************************
EOF:
.
R81-1622-062D
```

Figure 67 Typical program input

PRINTED OUTPUT DESCRIPTION

Figure 68 shows a typical computer printout. Most of the geometrical output quantities are nondimensionalized by the nozzle radius. All velocities and pressure are initially nondimensionalized by the nozzle exit velocity and stagnation pressure. All pressures are relative to ambient conditions.

Note: RN and D refer to nozzle exit radius and diameter. VN refers to nozzle exit velocity.

Input Parameters

The first set of output echoes the input parameters.

Output Titles	Definitions
NPR	Nozzle pressure ratio
NTR	Nozzle temperature ratio
Mach No.	Mach number computed from NPR and NTR
TN	Nozzle temperature ratio (NTR) relative to ambient or TN/TA
H/D	Nozzle height above ground
S/D	Nozzle spacing, distance between jet centerlines
Z/D	Initial fuselage height
DZ/D	Increment in fuselage position
ZFINAL/D	Final location of fuselage
L/D	Body Length
W/D	Body Width
ZB/D	Location of underside of body relative to specified fuselage location

Note: If ZB = 0, underside location is coincident with specified fuselage position.

Jet Decay Region

Output Titles	Definitions
DELG/D	Jet ground effect height relative to ground plane
ZPC/RN	Length of potential core
ZTD/RN	Length of potential core and transition regions
Z/RN	Jet axial location measured from nozzle exit

*** INPUT PARAMETERS ***

NPR= 1.0070 NTR= 2.0000
MACH NO.= 0.1000 TM/TA= 2.0000
H/D= 4.00000 S/D= 3.00000 Z/D= 2.00000

Z/D= 2.00000 DZ/D= 1.00000 ZFINAL/D= 4.00000

BODY LENGTH L/D= 8.00000 WIDTH W/D= 1.00000 DEPTH ZB/D= 0.0

***** JET DECAY REGION *****

JET DEFLECTION HEIGHT DELB/D = 1.19340
ZPC/RN= 6.81693 ZFD/RN= 12.78302

Z/RN	RJH/RN	RJ/RN	ALPV	VJ/VN	RC/RN	ALPT	RJHT/RN	TM/TN	TM/TA	DTM/DTN	RJHQ/RN	QJ/QN
0.0	1.0000	1.0000	0.0	1.0000	1.0000	1.5000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000
1.7016	1.0181	1.0673	6.0144	1.0000	0.8009	6.0144	1.0181	1.0000	2.0000	1.0000	1.0047	1.0000
3.4033	1.0363	1.1365	6.3209	1.0000	0.5491	6.3209	1.0363	1.0000	2.0000	1.0000	1.0088	1.0000
5.1049	1.0544	1.2085	6.5791	1.0000	0.3035	6.3791	1.0544	1.0000	2.0000	1.0000	1.0120	1.0000
6.8066	1.0726	1.2850	6.7837	1.0000	0.0019	6.7837	1.0726	1.0000	2.0000	1.0000	1.0138	1.0000

***** JET DEFLECTION REGION *****

RGH/RN= 1.07257 RG/RN= 1.28501 RO/RN= 3.86124 VG/VN= 1.00000

STAGNATION PRESSURE, DPS/DPTJ= 1.00000 GROUND MAX. TEMP., TGS/TA= 2.00000

STAGNATION MACH NUMBER OF JET= 0.10000

ALPG= 1.50462

SINGLE JET GROUND PRESSURES

R/RGH	DPS/DPTG	R/RN	DPS/DPTJ
0.0	1.00000	0.0	1.00000
0.15000	0.96689	0.16088	0.96689
0.30000	0.90821	0.32177	0.90821
0.45000	0.83608	0.48265	0.83608
0.60000	0.75619	0.64354	0.75619
0.75000	0.67257	0.80442	0.67257
0.90000	0.58832	0.96531	0.58832
1.05000	0.50592	1.12619	0.50592
1.20000	0.42734	1.28708	0.42734
1.35000	0.35409	1.44796	0.35409
1.50000	0.28731	1.60885	0.28731
1.65000	0.22775	1.76973	0.22775
1.80000	0.17586	1.93062	0.17586
1.95000	0.13175	2.09150	0.13175
2.10000	0.09528	2.25239	0.09528
2.25000	0.06606	2.41327	0.06606
2.40000	0.04350	2.57415	0.04350
2.55000	0.02685	2.73504	0.02685
2.70000	0.01524	2.89592	0.01524
2.85000	0.00771	3.05681	0.00771
3.00000	0.00331	3.21769	0.00331
3.14999	0.00110	3.37858	0.00110
3.29999	0.00023	3.53946	0.00023
3.44999	0.00001	3.70035	0.00001
3.59999	0.00000	3.86123	0.00000

***** WALL JET REGION *****

STAGNATION POINT BOUNDARY LAYER THICKNESS, DELS/RN= 0.03735
PMI/PA= 1.00373 (PTTOT/PA-1.)= 0.00700 (TOT/TA-1.)= 1.00000
TMI/TA= 2.00000 VMI/VN= 0.68210
VELOCITY AT START OF TURBULENT WALL JET, VM/VB= 0.68210
START OF WALL JET REGION, ALPWO= 0.60408 BWOH/RN= 0.34507 BWO/RN= 2.38600

R81-1622-063D(19 Sheets)

Figure 68 Typical program printout.

ISOLATED WALL JET PROPERTIES

R/RN	VM/VO	VM/VN	BWH/RN	BW/RN	DELRL/RN	DELPJ	KDEL	TM/TN	TM/TA	BWHT/RN	DTM/DTN
0.0	0.0	0.0	0.3451	2.3868	0.0374	1.0000	0.0156	1.0000	2.0000	0.3385	1.0000
0.2500	0.2512	0.2512	0.3451	2.3868	0.0374	1.0000	0.0156	1.0000	2.0000	0.3385	1.0000
0.5000	0.4138	0.4138	0.3451	2.3868	0.0374	1.0000	0.0156	1.0000	2.0000	0.3385	1.0000
0.7500	0.5455	0.5455	0.3451	2.3868	0.0374	1.0000	0.0156	1.0000	2.0000	0.3385	1.0000
1.0000	0.6542	0.6542	0.3451	2.3868	0.0374	1.0000	0.0156	1.0000	2.0000	0.3385	1.0000
1.2500	0.7258	0.7258	0.3483	2.0315	0.0370	0.9818	0.0183	0.9844	1.9687	0.3479	0.9687
1.5000	0.7622	0.7622	0.3529	1.6938	0.0366	0.9376	0.0216	0.9610	1.9219	0.3613	0.9219
1.7500	0.7764	0.7764	0.3575	1.4680	0.0362	0.8799	0.0247	0.9357	1.8715	0.3750	0.8715
2.0000	0.7741	0.7741	0.3620	1.3087	0.0358	0.8153	0.0273	0.9096	1.8193	0.3889	0.8193
2.2500	0.7597	0.7597	0.3664	1.1916	0.0353	0.7492	0.0297	0.8836	1.7673	0.4031	0.7673
2.5000	0.7367	0.7367	0.3712	1.1028	0.0349	0.6853	0.0316	0.8586	1.7173	0.4174	0.7173
2.7500	0.7081	0.7081	0.3758	1.0338	0.0345	0.6259	0.0333	0.8352	1.6704	0.4320	0.6704
3.0000	0.6764	0.6764	0.3803	0.9789	0.0340	0.5722	0.0348	0.8138	1.6276	0.4469	0.6276
3.2500	0.6439	0.6439	0.3849	0.9347	0.0336	0.5245	0.0360	0.7945	1.5889	0.4619	0.5889
3.5000	0.6123	0.6123	0.3895	0.8985	0.0332	0.4827	0.0369	0.7773	1.5545	0.4772	0.5545
3.7500	0.5830	0.5830	0.3941	0.8685	0.0328	0.4461	0.0377	0.7620	1.5239	0.4927	0.5239
4.0000	0.5476	0.5476	0.4103	0.8860	0.0350	0.4023	0.0395	0.7454	1.4907	0.5177	0.4907
4.2500	0.5071	0.5071	0.4360	0.9386	0.0394	0.3520	0.0419	0.7306	1.4612	0.5500	0.4612
4.5000	0.4718	0.4718	0.4616	0.9912	0.0437	0.3102	0.0441	0.7176	1.4352	0.5824	0.4352
4.7500	0.4409	0.4409	0.4873	1.0438	0.0481	0.2753	0.0461	0.7060	1.4120	0.6148	0.4120
5.0000	0.4135	0.4135	0.5129	1.0964	0.0525	0.2458	0.0479	0.6957	1.3913	0.6471	0.3913
5.2500	0.3892	0.3892	0.5386	1.1490	0.0569	0.2207	0.0495	0.6864	1.3727	0.6795	0.3727
5.5000	0.3674	0.3674	0.5642	1.2017	0.0613	0.1991	0.0510	0.6779	1.3558	0.7118	0.3558
5.7500	0.3477	0.3477	0.5899	1.2543	0.0656	0.1804	0.0523	0.6703	1.3405	0.7442	0.3405
6.0000	0.3300	0.3300	0.6155	1.3069	0.0700	0.1642	0.0536	0.6633	1.3265	0.7765	0.3265

***** TWO-JET INTERACTION PROBLEM *****

*** RECIRCULATION EFFECT ON WALL JETS ***

PHI= 0.0 DEGS.

TMEFF= 2.00000 TAEFF= 1.42834

R	VM/VN	TM/TN	TM/TA	DPM/DPN	DTM/DTN
0.0	0.0	1.00000	2.00000	1.00000	1.00000
0.12500	0.14993	1.00000	2.00000	1.00000	1.00000
0.25000	0.25116	1.00000	2.00000	1.00000	1.00000
0.37500	0.33728	1.00000	2.00000	1.00000	1.00000
0.50000	0.41383	1.00000	2.00000	1.00000	1.00000
0.62500	0.48281	1.00000	2.00000	1.00000	1.00000
0.75000	0.54548	1.00000	2.00000	1.00000	1.00000
0.87500	0.60245	1.00000	2.00000	1.00000	1.00000
1.00000	0.65416	1.00000	2.00000	1.00000	1.00000
1.12300	0.69741	0.99760	1.99520	0.99569	0.99520
1.25000	0.72787	0.99185	1.98369	0.98077	0.98369
1.37500	0.75098	0.98587	1.97175	0.96012	0.97175
1.50000	0.76785	0.97962	1.95925	0.93487	0.95925
1.62500	0.77938	0.97312	1.94623	0.90638	0.94623
1.75000	0.78629	0.96641	1.93281	0.87539	0.93281
1.87500	0.78918	0.95956	1.91913	0.84284	0.91913
2.00000	0.78859	0.95265	1.90530	0.80935	0.90530
2.12500	0.78458	0.94574	1.89147	0.77554	0.89147
2.25000	0.77877	0.93888	1.87776	0.74205	0.87776
2.37500	0.77036	0.93213	1.86425	0.70933	0.86425
2.50000	0.76008	0.92553	1.85106	0.67744	0.85106
2.62500	0.74829	0.91913	1.83825	0.64696	0.83825
2.75000	0.73528	0.91294	1.82589	0.61777	0.82589
2.87500	0.72135	0.90701	1.81402	0.59025	0.81402
3.00000	0.70679	0.90133	1.80266	0.56423	0.80266

Figure 68 - Continued

PHI= 45.0000 DEGS

TNEFF= 2.00000 TAEFF= 1.36561

R	VM/VN	TM/TN	TM/TA	DPM/DPN	DTM/DTN
0.0	0.0	1.00000	2.00000	1.00000	1.00000
0.17678	0.19461	1.00000	2.00000	1.00000	1.00000
0.35355	0.32347	1.00000	2.00000	1.00000	1.00000
0.53033	0.43124	1.00000	2.00000	1.00000	1.00000
0.70711	0.52440	1.00000	2.00000	1.00000	1.00000
0.88388	0.60628	1.00000	2.00000	1.00000	1.00000
1.06066	0.67759	1.00000	2.00000	1.00000	1.00000
1.23744	0.72490	0.99149	1.98298	0.98262	0.98298
1.41421	0.75632	0.98195	1.96390	0.95298	0.96390
1.59099	0.77578	0.97180	1.94360	0.91485	0.94360
1.76776	0.78556	0.96117	1.92233	0.87140	0.92233
1.94454	0.78744	0.95026	1.90051	0.82496	0.90051
2.12132	0.78287	0.93928	1.87857	0.77746	0.87857
2.29809	0.77309	0.92844	1.85688	0.73037	0.85688
2.47487	0.75920	0.91788	1.83577	0.68473	0.83577
2.65164	0.74215	0.90775	1.81550	0.64164	0.81550
2.82842	0.72284	0.89813	1.79626	0.60132	0.79626
3.00519	0.70210	0.88909	1.77818	0.56415	0.77818
3.18197	0.68068	0.88066	1.76132	0.53008	0.76132
3.35875	0.65927	0.87285	1.74570	0.49919	0.74570
3.53552	0.63844	0.86564	1.73128	0.47101	0.73128
3.71230	0.61861	0.85898	1.71796	0.44550	0.71796
3.88907	0.59812	0.85242	1.70484	0.41969	0.70484
4.06585	0.56866	0.84472	1.68944	0.38281	0.68944
4.24263	0.54030	0.83824	1.67648	0.34826	0.67648

PHI= 89.9999 DEGS.

TNEFF= 2.00000 TAEFF= 1.21417

R	VM/VN	TM/TN	TM/TA	DPM/DPN	DTM/DTN
0.0	0.0	1.00000	2.00000	1.00000	1.00000
0.25000	0.25114	1.00000	2.00000	1.00000	1.00000
0.50000	0.41383	1.00000	2.00000	1.00000	1.00000
0.75000	0.54548	1.00000	2.00000	1.00000	1.00000
1.00000	0.65414	1.00000	2.00000	1.00000	1.00000
1.25000	0.72690	0.98828	1.97656	0.98127	0.97656
1.50000	0.76518	0.97072	1.94144	0.93617	0.94144
1.75000	0.78159	0.95177	1.90354	0.87750	0.90354
2.00000	0.78170	0.93210	1.86419	0.81215	0.86419
2.25000	0.76971	0.91246	1.82472	0.74536	0.82492
2.50000	0.74898	0.89349	1.78699	0.68107	0.78699
2.75000	0.72238	0.87567	1.75135	0.62150	0.75135
3.00000	0.69239	0.85929	1.71858	0.56789	0.71858
3.25000	0.66122	0.84449	1.68897	0.52032	0.68897
3.50000	0.63070	0.83124	1.66249	0.47881	0.66249
3.75000	0.60214	0.81944	1.63888	0.44249	0.63888
4.00000	0.56726	0.80654	1.61307	0.39897	0.61307
4.25000	0.52658	0.79499	1.58998	0.34880	0.58998
4.50000	0.49105	0.78476	1.56952	0.30726	0.56952
4.75000	0.45976	0.77564	1.55128	0.27252	0.55128
5.00000	0.43202	0.76746	1.53491	0.24319	0.53491
5.25000	0.40726	0.76007	1.52014	0.21822	0.52014
5.50000	0.38504	0.75336	1.50673	0.19679	0.50673
5.75000	0.36499	0.74725	1.49450	0.17828	0.49450
6.00000	0.34682	0.74166	1.48331	0.16219	0.48331

Figure 68 - Continued

PHI=134.9999 DEGS.

TNEFF= 2.00000 TAEFF= 1.06273

R	VM/VN	TM/TN	TM/TA	DPM/DPN	DTM/DTN
0.0	0.0	1.00000	2.00000	1.00000	1.00000
0.25000	0.25116	1.00000	2.00000	1.00000	1.00000
0.50000	0.41383	1.00000	2.00000	1.00000	1.00000
0.75000	0.54548	1.00000	2.00000	1.00000	1.00000
1.00000	0.65416	1.00000	2.00000	1.00000	1.00000
1.25000	0.72616	0.98555	1.97111	0.98166	0.97111
1.50000	0.76313	0.96392	1.92784	0.93718	0.92764
1.75000	0.77798	0.94060	1.88119	0.87914	0.88119
2.00000	0.77641	0.91642	1.83285	0.81436	0.83285
2.25000	0.76272	0.89235	1.78470	0.74799	0.78470
2.50000	0.74041	0.86916	1.73833	0.68397	0.73833
2.75000	0.71242	0.84743	1.69486	0.62450	0.69486
3.00000	0.68128	0.82750	1.65501	0.57087	0.65501
3.25000	0.64917	0.80954	1.61908	0.52317	0.61908
3.50000	0.61792	0.79351	1.58702	0.48147	0.58702
3.75000	0.58883	0.77925	1.55850	0.44494	0.55850
4.00000	0.56361	0.76375	1.52750	0.40128	0.52750
4.25000	0.51303	0.74993	1.49987	0.35097	0.49987
4.50000	0.47768	0.73774	1.47547	0.30930	0.47547
4.75000	0.44663	0.72688	1.45376	0.27443	0.45376
5.00000	0.41915	0.71716	1.43433	0.24497	0.43433
5.25000	0.39467	0.70840	1.41681	0.21988	0.41681
5.50000	0.37274	0.70047	1.40095	0.19835	0.40095
5.75000	0.35299	0.69325	1.38651	0.17974	0.38651
6.00000	0.33512	0.68666	1.37331	0.16355	0.37331

PHI=179.9999 DEGS.

TNEFF= 2.00000 TAEFF= 1.00000

R	VM/VN	TM/TN	TM/TA	DPM/DPN	DTM/DTN
0.0	0.0	1.00000	2.00000	1.00000	1.00000
0.25000	0.25116	1.00000	2.00000	1.00000	1.00000
0.50000	0.41383	1.00000	2.00000	1.00000	1.00000
0.75000	0.54548	1.00000	2.00000	1.00000	1.00000
1.00000	0.65416	1.00000	2.00000	1.00000	1.00000
1.25000	0.72583	0.98437	1.96874	0.98183	0.96874
1.50000	0.76224	0.96097	1.92194	0.93752	0.92194
1.75000	0.77641	0.93575	1.87149	0.87987	0.87149
2.00000	0.77409	0.90963	1.81925	0.81533	0.81925
2.25000	0.75967	0.88364	1.76727	0.74917	0.76727
2.50000	0.73667	0.85863	1.71726	0.68527	0.71726
2.75000	0.70807	0.83522	1.67044	0.62585	0.67044
3.00000	0.67641	0.81378	1.62755	0.57222	0.62755
3.25000	0.64390	0.79447	1.58893	0.52447	0.58893
3.50000	0.61233	0.77725	1.55450	0.48268	0.55450
3.75000	0.58299	0.76196	1.52392	0.44606	0.52392
4.00000	0.54763	0.74536	1.49073	0.40235	0.49073
4.25000	0.50710	0.73061	1.46121	0.35197	0.46121
4.50000	0.47183	0.71759	1.43518	0.31024	0.43518
4.75000	0.44088	0.70602	1.41205	0.27531	0.41205
5.00000	0.41352	0.69567	1.39135	0.24580	0.39135
5.25000	0.38916	0.68636	1.37271	0.22066	0.37271
5.50000	0.36736	0.67792	1.35585	0.19907	0.35585
5.75000	0.34774	0.67026	1.34051	0.18042	0.34051
6.00000	0.33000	0.66325	1.32651	0.16419	0.32651

Figure 68 - Continued

MAXIMUM GROUND PRESSURE AND TEMPERATURE ALONG UPWASHGROUND STAGNATION LINE

XW/RN	XW/S	DPMAX/DPJ	PMAX/PMAXO	DTMAX/DTJ	TMAX/TMAXO
0.0	0.0	0.56423	1.00000	0.50266	1.00000
0.17473	0.02912	0.56128	0.99478	0.80208	0.99927
0.35065	0.05844	0.55263	0.97944	0.80031	0.99707
0.52698	0.08816	0.53852	0.95443	0.79734	0.99337
0.71101	0.11850	0.51902	0.91987	0.79315	0.98815
0.89814	0.14969	0.49383	0.87701	0.78771	0.98137
1.09191	0.18198	0.46621	0.82629	0.78096	0.97296
1.29407	0.21568	0.43380	0.76884	0.77286	0.96287
1.50665	0.25111	0.39862	0.70648	0.76335	0.95104
1.73205	0.28867	0.36127	0.64028	0.75241	0.93739
1.97313	0.32885	0.32275	0.57202	0.73994	0.92186
2.23341	0.37224	0.28402	0.50337	0.72591	0.90438
2.51770	0.41955	0.24582	0.43636	0.70873	0.88298
2.83035	0.47172	0.19617	0.34768	0.68737	0.85636
3.17981	0.52997	0.15246	0.27198	0.66516	0.82869
3.57525	0.59588	0.11645	0.20639	0.64119	0.79882
4.02969	0.67162	0.08535	0.15127	0.61545	0.76675
4.56127	0.76021	0.06009	0.10650	0.58796	0.73251
5.19614	0.86602	0.04024	0.07149	0.55874	0.69611
5.97346	0.99558	0.0255	0.04531	0.52781	0.65757
6.95473	1.15912	0.01506	0.02673	0.49520	0.61694
8.24235	1.37372	0.00811	0.01438	0.46093	0.57425
10.02056	1.67009	0.00385	0.00683	0.42503	0.52952
12.65775	2.10962	0.00153	0.00272	0.38750	0.48277
17.01334	2.83556	0.00046	0.00082	0.34829	0.43392

UPWASH MOMENTUM FUNCTION: JET RADIUS, INTERACTION CONSTANT, VERTICAL UPWASH SHEET MOMENTUM, AND COALES

RG/RN= 1.29501 ACON= 0.81453 XMOMZ= 0.93884 PHIO(DEGS)= 0.0

UPWASH WIDTH CONSTANT ESTIMATE , CU= 0.29758

*** CALL INTERG ***

SOLUTION OF GROUND PRESSURE DISTRIBUTION HAS BEEN FOUND
ITERATION CYCLE= 15 EPS= 0.03691 SIGMA= 0.91425
EPI= 0.03491 CUI= 0.29758 PHIUO= 49.43231 PHIO= 63.52774 DEGREES
PHI=0.0, DELPWO= 0.67723
PHI=0.0, PMIN= 0.11929
PHI=0.0, ALFUO= 2.73835
UPWASH THICKNESS CONSTANT, (CU) X (SIGMA)= 0.27206

*** COMPUTATION OF TWO-JET GROUND ISOBAR PATTERN ***

10 VALUES OF PRESSURE SPECIFIED FOR PATTERN

PBAR= 0.0 0.80000 0.70000 0.60000 0.50000 0.40000 0.30000 0.20000 0.10000 0.05000

Figure 68 - Continued

GROUND PATTERN IN JET CENTERED COORDINATE SYSTEM

FBAR= 0.90000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 0

XISOJ	YISOJ	XISOU	YISOU
0.34791	0.0		
0.34760	0.01472		
0.34665	0.02941		
0.34509	0.04402		
0.34291	0.05852		
0.34012	0.07289		
0.33673	0.08707		
0.33277	0.10105		
0.32823	0.11479		
0.32316	0.12827		
0.31755	0.14145		
0.31144	0.15431		
0.30485	0.16683		
0.29780	0.17899		
0.29031	0.19076		
0.28242	0.20214		
0.27414	0.21310		
0.26551	0.22363		
0.25655	0.23374		
0.24729	0.24339		
0.23774	0.25260		
0.22795	0.26135		
0.21792	0.26965		
0.20769	0.27748		
0.19729	0.28486		
0.18672	0.29178		
0.17601	0.29824		
0.16520	0.30425		
0.15428	0.30981		
0.15428	0.30981		
0.13132	0.31999		
0.10769	0.32846		
0.08353	0.33519		
0.05894	0.34013		
0.03411	0.34328		
0.00911	0.34461		
-0.01590	0.34413		
-0.04079	0.34184		
-0.06544	0.33775		
-0.08970	0.33189		
-0.11347	0.32429		
-0.13660	0.31501		
-0.15859	0.30408		
-0.18052	0.29157		
-0.20108	0.27755		
-0.22056	0.26209		
-0.23887	0.24527		
-0.25591	0.22719		
-0.27160	0.20794		
-0.28585	0.18761		
-0.29860	0.16633		
-0.30978	0.14418		
-0.31934	0.12130		
-0.32722	0.09779		
-0.33339	0.07379		
-0.33783	0.04941		
-0.34049	0.02477		
-0.34139	0.00000		

Figure 68 - Continued

PBAR= 0.80000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 0

XISOJ	YISOJ	XISOU	YISOU
0.56735	0.0		
0.56684	0.02401		
0.56530	0.04795		
0.56275	0.07178		
0.55919	0.09543		
0.55464	0.11886		
0.54912	0.14199		
0.54265	0.16479		
0.53526	0.18720		
0.52698	0.20917		
0.51784	0.23067		
0.50788	0.25164		
0.49712	0.27206		
0.48563	0.29188		
0.47342	0.31108		
0.46055	0.32963		
0.44705	0.34751		
0.43298	0.36469		
0.41837	0.38116		
0.40326	0.39691		
0.38770	0.41193		
0.37172	0.42620		
0.35537	0.43973		
0.33869	0.45250		
0.32172	0.46453		
0.30449	0.47581		
0.28703	0.48635		
0.26939	0.49615		
0.25159	0.50522		
0.25159	0.50522		
0.21415	0.52182		
0.17562	0.53563		
0.13621	0.54660		
0.09614	0.55467		
0.05562	0.55980		
0.01485	0.56197		
-0.02593	0.56119		
-0.06652	0.55744		
-0.10671	0.55078		
-0.14628	0.54122		
-0.18503	0.52884		
-0.22276	0.51369		
-0.25928	0.49587		
-0.29439	0.47547		
-0.32791	0.45261		
-0.35968	0.42740		
-0.38954	0.39997		
-0.41732	0.37049		
-0.44290	0.33909		
-0.46615	0.30595		
-0.48694	0.27123		
-0.50517	0.23512		
-0.52075	0.19781		
-0.53361	0.15948		
-0.54368	0.12033		
-0.55090	0.08057		
-0.55526	0.04039		
-0.55671	0.00001		

Figure 68 - Continued

ORIGINAL PAGE IS
OF POOR QUALITY

PBAR= 0.70000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 0

XISOJ	YISOJ	XISOU	YISOU
0.76642	0.0		
0.76573	0.03243		
0.76365	0.06478		
0.76020	0.09697		
0.75540	0.12892		
0.74925	0.16056		
0.74179	0.19181		
0.73306	0.22261		
0.72307	0.25288		
0.71189	0.28257		
0.69954	0.31160		
0.68608	0.33994		
0.67155	0.36751		
0.65602	0.39429		
0.63953	0.42023		
0.62214	0.44529		
0.60392	0.46944		
0.58490	0.49265		
0.56516	0.51490		
0.54475	0.53618		
0.52373	0.55646		
0.50215	0.57574		
0.48007	0.59401		
0.45753	0.61127		
0.43460	0.62752		
0.41133	0.64276		
0.38775	0.65700		
0.36391	0.67024		
0.33987	0.68250		
0.33987	0.68250		
0.28929	0.70491		
0.23724	0.72357		
0.18401	0.73839		
0.12988	0.74929		
0.07513	0.75622		
0.02007	0.75916		
-0.03503	0.75809		
-0.08987	0.75304		
-0.14415	0.74403		
-0.19761	0.73112		
-0.24996	0.71439		
-0.30093	0.69393		
-0.35025	0.66986		
-0.39768	0.64230		
-0.44297	0.61141		
-0.48589	0.57736		
-0.52622	0.54032		
-0.56375	0.50048		
-0.59831	0.45807		
-0.62971	0.41330		
-0.65779	0.36640		
-0.68242	0.31762		
-0.70347	0.26721		
-0.72084	0.21543		
-0.73444	0.16255		
-0.74420	0.10884		
-0.75008	0.05456		
-0.75204	0.00001		

Figure 68 - Continued

FBAR= 0.60000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 11

XISOJ	YISOJ	XISOU	YISOU
0.96092	0.0	2.75420	0.0
0.96005	0.04066	2.75724	0.09247
0.95745	0.08122	2.76042	0.18511
0.95313	0.12157	2.76592	0.27811
0.94710	0.16164	2.77408	0.37164
0.93939	0.20131	2.78552	0.46588
0.93004	0.24049	2.80128	0.56104
0.91909	0.27910	2.82348	0.65729
0.90657	0.31706	2.85749	0.75486
0.89254	0.35428	2.93572	0.85395
0.87706	0.39068	3.00000	0.86662
0.86018	0.42620		
0.84198	0.46078		
0.82250	0.49435		
0.80183	0.52687		
0.78003	0.55829		
0.75717	0.58857		
0.73333	0.61767		
0.70859	0.64557		
0.68300	0.67225		
0.65664	0.69768		
0.62958	0.72185		
0.60189	0.74476		
0.57364	0.76640		
0.54489	0.78677		
0.51571	0.80588		
0.48615	0.82373		
0.45626	0.84033		
0.42612	0.85570		
0.42612	0.85570		
0.36270	0.88380		
0.29744	0.90720		
0.23070	0.92577		
0.16283	0.93944		
0.09420	0.94813		
0.02516	0.95181		
-0.04392	0.95048		
-0.11267	0.94414		
-0.18074	0.93285		
-0.24776	0.91666		
-0.31339	0.89569		
-0.37729	0.87004		
-0.43914	0.83985		
-0.49860	0.80530		
-0.55538	0.76658		
-0.60919	0.72388		
-0.65976	0.67743		
-0.70682	0.62749		
-0.75014	0.57432		
-0.78951	0.51818		
-0.82472	0.45939		
-0.85560	0.39823		
-0.88199	0.33503		
-0.90377	0.27011		
-0.92082	0.20380		
-0.93306	0.13645		
-0.94043	0.06841		
-0.94289	0.00001		

Figure 68 - Continued

ORIGINAL PAGE IS
OF POOR QUALITY

PBAR= 0.50000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 16

XISOJ	YISOJ	XISOU	YISOU
1.15977	0.0	2.65969	0.0
1.15872	0.04907	2.66023	0.09247
1.15558	0.09802	2.66189	0.18511
1.15036	0.14673	2.66471	0.27811
1.14308	0.19509	2.66877	0.37164
1.13379	0.24296	2.67421	0.46588
1.12250	0.29026	2.68121	0.56104
1.10928	0.33686	2.69003	0.65729
1.09417	0.38267	2.70102	0.75486
1.07724	0.42759	2.71472	0.85395
1.05856	0.47153	2.73192	0.95479
1.03819	0.51440	2.75392	1.05763
1.01621	0.55613	2.78312	1.16274
0.99271	0.59665	2.82518	1.27038
0.96775	0.63590	2.90661	1.38087
0.94144	0.67382	3.00000	1.40836
0.91386	0.71036		
0.88509	0.74549		
0.85522	0.77916		
0.82433	0.81136		
0.79252	0.84205		
0.75986	0.87123		
0.72645	0.89888		
0.69235	0.92500		
0.65765	0.94958		
0.62243	0.97265		
0.58675	0.99419		
0.55068	1.01422		
0.51430	1.03277		
0.51430	1.03277		
0.43775	1.06669		
0.35900	1.09493		
0.27844	1.11735		
0.19653	1.13384		
0.11369	1.14433		
0.03036	1.14878		
-0.05301	1.14716		
-0.13599	1.13951		
-0.21814	1.12588		
-0.29903	1.10635		
-0.37824	1.08103		
-0.45537	1.05008		
-0.53001	1.01365		
-0.60178	0.97195		
-0.67031	0.92521		
-0.73525	0.87367		
-0.79628	0.81762		
-0.85308	0.75734		
-0.90537	0.69316		
-0.95289	0.62541		
-0.99538	0.55445		
-1.03265	0.48063		
-1.06451	0.40435		
-1.09079	0.32600		
-1.11137	0.24598		
-1.12615	0.16469		
-1.13504	0.08257		
-1.13801	0.00002		

Figure 68 - Continued

ORIGINAL PAGE IS
OF POOR QUALITY

PBAR= 0.40000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 20

XISOJ	YISOJ	XISOU	YISOU
1.37135	0.0	2.58414	0.0
1.37011	0.05802	2.58449	0.09247
1.36639	0.11590	2.58558	0.18511
1.36022	0.17350	2.58741	0.27811
1.35162	0.23067	2.59003	0.37164
1.34062	0.28729	2.59350	0.46588
1.32728	0.34321	2.59791	0.56104
1.31164	0.39832	2.60337	0.65729
1.29378	0.45248	2.61003	0.75486
1.27376	0.50559	2.61807	0.85395
1.25167	0.55753	2.62774	0.95479
1.22758	0.60824	2.63938	1.05763
1.20160	0.65759	2.65343	1.16274
1.17381	0.70550	2.67051	1.27038
1.14430	0.75191	2.69146	1.38087
1.11319	0.79675	2.71766	1.49454
1.08058	0.83996	2.75146	1.61174
1.04656	0.88149	2.79778	1.73292
1.01123	0.92131	2.87355	1.85848
0.97472	0.95937	3.00000	1.92118
0.93710	0.99567		
0.89849	1.03017		
0.85897	1.06286		
0.81866	1.09374		
0.77763	1.12282		
0.73598	1.15009		
0.69379	1.17556		
0.65114	1.19925		
0.60812	1.22118		
0.60812	1.22118		
0.51761	1.26129		
0.42449	1.29468		
0.32924	1.32119		
0.23238	1.34069		
0.13443	1.35309		
0.03590	1.35835		
-0.06268	1.35644		
-0.16079	1.34740		
-0.25793	1.33128		
-0.35358	1.30819		
-0.44725	1.27825		
-0.53844	1.24164		
-0.62670	1.19857		
-0.71156	1.14926		
-0.79259	1.09399		
-0.86939	1.03306		
-0.94155	0.96678		
-1.00871	0.89551		
-1.07054	0.81962		
-1.12672	0.73951		
-1.17697	0.65560		
-1.22104	0.56832		
-1.25871	0.47812		
-1.28979	0.38547		
-1.31412	0.29085		
-1.33159	0.19474		
-1.34211	0.09763		
-1.34562	0.00002		

Figure 68 - Continued

PBAR= 0.30000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 24

XISOJ	YISOJ	XISOU	YISOU
1.60708	0.0	2.51121	0.0
1.60563	0.06800	2.51147	0.09247
1.60128	0.13583	2.51225	0.18511
1.59405	0.20333	2.51357	0.27811
1.58397	0.27033	2.51543	0.37164
1.57108	0.33667	2.51789	0.46588
1.55544	0.40221	2.52099	0.56104
1.53712	0.46679	2.52477	0.65729
1.51619	0.53026	2.52933	0.75484
1.49273	0.59251	2.53476	0.85395
1.46684	0.65339	2.54119	0.95479
1.43861	0.71280	2.54877	1.05763
1.40816	0.77063	2.55770	1.16274
1.37553	0.82678	2.56828	1.27038
1.34101	0.88114	2.58079	1.38087
1.30455	0.93371	2.59566	1.49454
1.26633	0.98435	2.61347	1.61174
1.22646	1.03302	2.63497	1.73292
1.18507	1.07968	2.66119	1.85848
1.14227	1.12429	2.69366	1.98892
1.09819	1.16682	2.73482	2.12481
1.05294	1.20725	2.78971	2.26676
1.00663	1.24557	2.87664	2.41548
0.95939	1.28176	3.00000	2.48979
0.91131	1.31583		
0.86249	1.34779		
0.81305	1.37764		
0.76308	1.40540		
0.71266	1.43110		
0.71266	1.47110		
0.60659	1.47810		
0.49746	1.51723		
0.38584	1.54830		
0.27233	1.57116		
0.15754	1.58569		
0.04208	1.59185		
-0.07345	1.58962		
-0.18843	1.57902		
-0.30227	1.56013		
-0.41436	1.53306		
-0.52413	1.49798		
-0.63100	1.45508		
-0.73443	1.40461		
-0.83388	1.34682		
-0.92884	1.28205		
-1.01884	1.21064		
-1.10340	1.13297		
-1.18211	1.04945		
-1.25457	0.96051		
-1.32041	0.86663		
-1.37930	0.76830		
-1.43094	0.66601		
-1.47509	0.56031		
-1.51151	0.45174		
-1.54002	0.34085		
-1.56049	0.22821		
-1.57282	0.11441		
-1.57694	0.00002		

Figure 68 - Continued

PBAR= 0.20000

JET IMPINGEMENT REGION, IJET= 58 UPWASH DEFLECTION REGION, IU= 27

XISOJ	YISOJ	XISOU	YISOU
1.88819	0.0	2.42495	0.0
1.88648	0.07989	2.42521	0.09247
1.88137	0.15959	2.42596	0.18511
1.87287	0.23889	2.42722	0.27811
1.86103	0.31761	2.42898	0.37144
1.84589	0.39556	2.43124	0.46508
1.82751	0.47256	2.43399	0.56104
1.80598	0.54844	2.43725	0.65729
1.78139	0.62302	2.44103	0.75486
1.75382	0.69615	2.44538	0.85395
1.72341	0.76768	2.45034	0.95479
1.69024	0.83748	2.45600	1.05763
1.65446	0.90542	2.46244	1.16274
1.61620	0.97139	2.46983	1.27038
1.57557	1.03529	2.47830	1.38087
1.53274	1.09703	2.48809	1.49454
1.48783	1.15652	2.49947	1.61174
1.44099	1.21371	2.51281	1.73292
1.39235	1.26853	2.52855	1.85848
1.34207	1.32095	2.54727	1.98892
1.29028	1.37092	2.56971	2.12481
1.23711	1.41842	2.59680	2.26676
1.18271	1.46344	2.62976	2.41548
1.12720	1.50596	2.67830	2.57178
1.07071	1.54599	2.74376	2.73653
1.01336	1.58354	2.83529	2.91086
0.95527	1.61841	3.00000	3.07394
0.89655	1.65123		
0.83731	1.68142		
0.83731	1.68142		
0.71270	1.73665		
0.58447	1.78262		
0.45333	1.81912		
0.31997	1.84598		
0.18510	1.86306		
0.04944	1.87029		
-0.08630	1.86767		
-0.22140	1.85521		
-0.35514	1.83302		
-0.48684	1.80122		
-0.61581	1.76000		
-0.74137	1.70960		
-0.86289	1.65029		
-0.97974	1.58241		
-1.09131	1.50631		
-1.19705	1.42240		
-1.29640	1.33114		
-1.38888	1.23301		
-1.47401	1.12852		
-1.55137	1.01822		
-1.62056	0.90268		
-1.68124	0.78251		
-1.73310	0.65832		
-1.77589	0.53075		
-1.80940	0.40047		
-1.83345	0.26813		
-1.84793	0.13442		
-1.85277	0.00003		

Figure 68 - Continued

PBAR= 0.10000

JET IMPINGEMENT REGION, IJET= 50 UPWASH DEFLECTION REGION, IU= 50

XISOJ	YISOJ	XISOU	YISOU
2.14366	0.74971	2.25500	0.75486
2.11049	0.83772	2.28283	0.85395
2.07389	0.92380	2.30026	0.95479
2.03398	1.00779	2.31383	1.05763
1.99092	1.08955	2.32540	1.16274
1.94487	1.16894	2.33585	1.27038
1.89599	1.24584	2.34567	1.38087
1.84444	1.32013	2.35527	1.49454
1.79040	1.39172	2.36495	1.61174
1.73403	1.46054	2.37505	1.73292
1.67551	1.52651	2.38589	1.85848
1.61500	1.58958	2.39785	1.98892
1.55268	1.64971	2.41139	2.12481
1.48870	1.70688	2.42704	2.26676
1.42323	1.76105	2.44549	2.41548
1.35643	1.81222	2.47136	2.57178
1.28845	1.86039	2.50457	2.73655
1.21944	1.90557	2.54675	2.91086
1.14953	1.94778	2.59936	3.09591
1.07888	1.98703	2.66421	3.29313
1.00759	2.02337	2.74253	3.50416
1.00759	2.02337	2.74253	3.50416
0.85763	2.08982	2.74722	3.52268
0.70333	2.14515	2.75205	3.54132
0.54552	2.18907	2.75702	3.56008
0.38504	2.22138	2.76214	3.57895
0.22274	2.24193	2.76742	3.59793
0.05949	2.25064	2.77285	3.61704
-0.10385	2.24748	2.77847	3.63627
-0.26642	2.23250	2.78426	3.65562
-0.42736	2.20579	2.79024	3.67509
-0.58585	2.16753	2.79644	3.69469
-0.74104	2.11793	2.80284	3.71441
-0.89214	2.05727	2.80949	3.73426
-1.03837	1.98590	2.81638	3.75424
-1.17898	1.90421	2.82354	3.77435
-1.31325	1.81263	2.83100	3.79459
-1.44048	1.71167	2.83877	3.81497
-1.56005	1.60185	2.84690	3.83548
-1.67133	1.48376	2.85541	3.85613
-1.77378	1.35802	2.86436	3.87691
-1.86686	1.22529	2.87379	3.89784
-1.95012	1.08626	2.88380	3.91891
-2.02314	0.94164	2.89446	3.94013
-2.08555	0.79220	2.90592	3.96149
-2.13704	0.63869	2.91838	3.98299
-2.17736	0.48191	2.93216	4.00465
-2.20631	0.32266	2.94785	4.02645
-2.22373	0.16176	2.96686	4.04841
-2.22955	0.00003	2.99881	4.07053

Figure 68 - Continued

PBAR= 0.05000

JET IMPINGEMENT REGION, IJET= 43 UPWASH DEFLECTION REGION, IU= 43

XISOJ	YISOJ	XISOU	YISOU
2.08715	1.49384	2.14019	1.49454
2.02600	1.57486	2.22838	1.61176
1.96221	1.65273	2.25469	1.73292
1.89599	1.72738	2.27276	1.85848
1.82752	1.79875	2.28751	1.98892
1.75699	1.86680	2.30084	2.12481
1.68460	1.93148	2.31384	2.26676
1.61051	1.99278	2.32739	2.41548
1.53492	2.05069	2.34467	2.57178
1.45800	2.10520	2.36596	2.73655
1.37990	2.15633	2.39259	2.91084
1.30080	2.20409	2.42590	3.09591
1.22084	2.24851	2.46759	3.29313
1.14018	2.28962	2.51904	3.50416
1.14018	2.28962	2.51904	3.50416
0.97049	2.36482	2.52380	3.55007
0.79588	2.42742	2.52886	3.59469
0.61730	2.47713	2.53426	3.64403
0.43570	2.51369	2.54001	3.69212
0.25205	2.53695	2.54615	3.74097
0.06732	2.54680	2.55269	3.79062
-0.11752	2.54323	2.55967	3.84107
-0.30148	2.52627	2.56712	3.89234
-0.48360	2.49605	2.57508	3.94452
-0.66294	2.45275	2.58360	3.99756
-0.83855	2.39662	2.59270	4.05152
-1.00954	2.32799	2.60246	4.10642
-1.17501	2.24723	2.61291	4.16230
-1.33412	2.15479	2.62414	4.21918
-1.48606	2.05116	2.63621	4.27710
-1.63004	1.93691	2.64922	4.33609
-1.76533	1.81264	2.66325	4.39619
-1.89126	1.67901	2.67844	4.45743
-2.00719	1.53672	2.69493	4.51985
-2.11252	1.38652	2.71290	4.58349
-2.20674	1.22920	2.73257	4.64839
-2.28936	1.06555	2.75423	4.71460
-2.35999	0.89644	2.77828	4.78215
-2.41826	0.72273	2.80529	4.85107
-2.46388	0.54532	2.83615	4.92149
-2.49664	0.36512	2.87247	4.99339
-2.51635	0.18305	2.91795	5.06683
-2.52294	0.00004	2.99761	5.14190

UPWASH DEFLECTION ZONE LINE, PBAR=0 OUTSIDE INTERACTION REGION

XUP	YUP
2.18381	0.0
2.17864	0.33802
2.17211	0.50972
2.16282	0.68473
2.15061	0.86428
2.13528	1.04974
2.11656	1.24264
2.09410	1.44472
2.06745	1.65804
2.03606	1.88502
1.99923	2.12861
1.95605	2.39247
1.90539	2.68096
1.84573	3.00000
1.77513	3.35700
1.69093	3.76187
1.58954	4.22810
1.46590	4.77446
1.31268	5.42806
1.11888	6.22952

Figure 68 - Continued

***** COMPUTATION OF UPWASH FLOW FIELD *****

COMPUTATION OF UPWASH STREAMLINE PROPERTIES

PHID= 0.0 DEGS

INV.VEL.= 0.54015 TMI/TA= 1.80266 DELPWJ= 0.56423 DELTWJ= 0.80266 BWGH/RN= 0.38034
ZOU/RN= 1.14102 BUO/RN= 0.46750 BUOHN/RN= 0.20618 TLAMI= 1.22919

Z/RN	VMU/VN	TM/TN	TM/TA	BUH/RN	BU/RN	DPU/DPJ	DTM/DTN
0.38034	0.54015	0.90133	1.80266	0.20618	0.46750	0.56417	0.80266
0.53116	0.60399	0.89130	1.78261	0.25143	0.57009	0.53185	0.78241
0.68198	0.60919	0.87896	1.75791	0.29668	0.67268	0.46950	0.75791
0.83280	0.58224	0.86563	1.73125	0.34192	0.77527	0.40296	0.73125
0.98362	0.54169	0.85313	1.70625	0.38717	0.87786	0.34477	0.70625
1.13443	0.50113	0.84234	1.68467	0.43241	0 98045	0.29814	0.68467
1.28525	0.46613	0.83340	1.66679	0.47766	1.08304	0.26071	0.66679
1.43607	0.43608	0.82573	1.65146	0.52290	1.18563	0.23030	0.65145
1.58689	0.40994	0.81906	1.63812	0.56815	1.28822	0.20517	0.63812
1.73771	0.38696	0.81319	1.62639	0.61340	1.39081	0.18414	0.62639
1.88853	0.36659	0.80799	1.61598	0.65864	1.49340	0.16632	0.61598
2.03935	0.34837	0.80334	1.60668	0.70389	1.59599	0.15107	0.60668
2.19017	0.33198	0.79915	1.59830	0.74913	1.69858	0.13791	0.59830
2.34099	0.31713	0.79536	1.59071	0.79438	1.80117	0.12645	0.59071
2.49180	0.30362	0.79190	1.58381	0.83962	1.90376	0.11641	0.58381
2.64262	0.29126	0.78875	1.57749	0.88487	2.00635	0.10755	0.57749
2.79344	0.27991	0.78584	1.57169	0.93012	2.10894	0.09970	0.57169
2.94426	0.26944	0.78317	1.56634	0.97536	2.21153	0.09270	0.56634
3.09508	0.25976	0.78069	1.56139	1.02061	2.31411	0.08643	0.56139
3.24590	0.25077	0.77839	1.55679	1.06585	2.41670	0.08079	0.55679
3.39672	0.24240	0.77626	1.55251	1.11110	2.51929	0.07570	0.55251
3.54754	0.23459	0.77426	1.54852	1.15634	2.62188	0.07108	0.54852
3.69835	0.22729	0.77239	1.54478	1.20159	2.72447	0.06688	0.54478
3.84917	0.22043	0.77064	1.54127	1.24683	2.82706	0.06305	0.54127
3.99999	0.21399	0.76899	1.53798	1.29208	2.92965	0.05955	0.53798

PHID= 60.0000 DEGS

INV.VEL.= 0.26871 TMI/TA= 1.55874 DELPWJ= 0.16135 DELTWJ= 0.55874 BWGH/RN= 0.61550
ZOU/RN= 1.84649 BUO/RN= 1.11853 BUOHN/RN= 0.49331 TLAMI= 1.05924

Z/RN	VMU/VN	TM/TN	TM/TA	BUH/RN	BU/RN	DPU/DPJ	DTM/DTN
0.61550	0.26871	0.77937	1.55874	0.49331	1.11853	0.16122	0.55874
0.92319	0.32788	0.77604	1.55207	0.55858	1.26653	0.16662	0.55207
1.23087	0.33782	0.76938	1.53876	0.62385	1.41452	0.15529	0.53876
1.53856	0.32358	0.76089	1.52178	0.68912	1.56251	0.13801	0.52178
1.84625	0.30302	0.75283	1.50566	0.75439	1.71051	0.12197	0.50566
2.15393	0.28421	0.74712	1.49424	0.81966	1.85850	0.10812	0.49424
2.46162	0.26772	0.74211	1.48422	0.88493	2.00649	0.09658	0.48422
2.76931	0.25312	0.73768	1.47536	0.95020	2.15449	0.08685	0.47536
3.07699	0.24009	0.73372	1.46744	1.01547	2.30248	0.07857	0.46744
3.38468	0.22840	0.73017	1.46033	1.08074	2.45047	0.07144	0.46033
3.69237	0.21782	0.72695	1.45391	1.14601	2.59846	0.06527	0.45391
4.00005	0.20822	0.72403	1.44807	1.21128	2.74646	0.05988	0.44807
4.30774	0.19946	0.72137	1.44274	1.27655	2.89445	0.05515	0.44274
4.61543	0.19142	0.71893	1.43785	1.34182	3.04244	0.05097	0.43785
4.92311	0.18402	0.71668	1.43335	1.40709	3.19044	0.04725	0.43335
5.23080	0.17719	0.71460	1.42920	1.47237	3.33843	0.04394	0.42920
5.53849	0.17086	0.71267	1.42534	1.53763	3.48642	0.04096	0.42534
5.84617	0.16497	0.71088	1.42176	1.60291	3.63442	0.03829	0.42176
6.15386	0.15949	0.70921	1.41843	1.66818	3.78241	0.03587	0.41843
6.46155	0.15437	0.70765	1.41531	1.73345	3.93040	0.03367	0.41531
6.76923	0.14957	0.70619	1.41239	1.79872	4.07840	0.03168	0.41239
7.07692	0.14506	0.70482	1.40965	1.86399	4.22639	0.02986	0.40965
7.38461	0.14083	0.70353	1.40707	1.92926	4.37438	0.02819	0.40707
7.69230	0.13683	0.70232	1.40464	1.99453	4.52238	0.02666	0.40464
7.99998	0.13307	0.70117	1.40235	2.05980	4.67037	0.02523	0.40235

Figure 68 - Continued

UPWASH PROPERTIES COMPUTED AT Z LOCATION OF UNDERSIDE OF BODY

BODY CENTERLINE LOCATION AT Z/RN= 4.00000

ZU/RN	RW/RN	PHIB	X/RN	VMU/VN	DPU/PN	RUH/RN	DPU/PUO	DPU/PJS	TM/TA	DTSM/DTN	PBB/PN
4.0000	3.0000	0.0	0.0	0.2140	0.0595	1.2921	1.0000	0.0595	1.5380	0.5380	0.05955
4.0000	3.0024	2.7263	0.3333	0.2139	0.0595	1.2931	0.9991	0.0595	1.5377	0.5377	0.05934
4.0000	3.0136	5.4403	0.6667	0.2136	0.0593	1.2960	0.9965	0.0593	1.5370	0.5370	0.05881
4.0000	3.0305	8.1301	1.0000	0.2130	0.0591	1.3009	0.9923	0.0591	1.5357	0.5357	0.05791
4.0000	3.0539	10.7843	1.3333	0.2122	0.0587	1.3076	0.9863	0.0587	1.5340	0.5340	0.05668
4.0000	3.0[illegible]	13.3925	1.6667	0.2113	0.0583	1.3161	0.9785	0.0583	1.5319	0.5319	0.05515
4.0000	3.1[illegible]	15.9454	2.0000	0.2101	0.0577	1.3263	0.9692	0.0577	1.5293	0.5293	0.05334
4.0000	3.1623	18.4349	2.3333	0.2087	0.0571	1.3379	0.9582	0.0571	1.5263	0.5263	0.05135
4.0000	3.2103	20.8544	2.6667	0.2071	0.0563	1.3512	0.9456	0.0563	1.5230	0.5230	0.04917
4.0000	3.2639	23.1986	3.0000	0.2053	0.0555	1.3656	0.9316	0.0555	1.5194	0.5194	0.04687
4.0000	3.3228	25.4633	3.3333	0.2033	0.0546	1.3813	0.9163	0.0546	1.5155	0.5155	0.04448
4.0000	3.3866	27.6460	3.6667	0.2012	0.0536	1.3981	0.8997	0.0536	1.5114	0.5114	0.04204
4.0000	3.4553	29.7448	4.0000	0.1990	0.0525	1.4157	0.8822	0.0525	1.5071	0.5071	0.03960
4.0000	3.5283	31.7594	4.3333	0.1966	0.0514	1.4344	0.8636	0.0514	1.5027	0.5027	0.03718
4.0000	3.6055	33.6900	4.6667	0.1941	0.0503	1.4536	0.8445	0.0503	1.4981	0.4981	0.03482
4.0000	3.6867	35.5376	5.0000	0.1915	0.0491	1.4735	0.8248	0.0491	1.4935	0.4935	0.03252
4.0000	3.7715	37.3039	5.3333	0.1889	0.0479	1.4938	0.8047	0.0479	1.4888	0.4888	0.03032
4.0000	3.8598	38.9910	5.6667	0.1862	0.0467	1.5147	0.7843	0.0467	1.4840	0.4840	0.02821
4.0000	3.9512	40.6013	6.0000	0.1833	0.0454	1.5384	0.7626	0.0454	1.4792	0.4792	0.02618
4.0000	4.0457	42.1376	6.3333	0.1803	0.0441	1.5631	0.7407	0.0441	1.4744	0.4744	0.02425
4.0000	4.1429	43.6028	6.6667	0.1773	0.0428	1.5892	0.7185	0.0428	1.4696	0.4696	0.02243
4.0000	4.2426	45.0000	7.0000	0.1743	0.0415	1.6157	0.6966	0.0415	1.4648	0.4648	0.02074
4.0000	4.3448	46.3322	7.3333	0.1713	0.0402	1.6427	0.6750	0.0402	1.4601	0.4601	0.01916
4.0000	4.4493	47.6025	7.6667	0.1683	0.0389	1.6701	0.6538	0.0389	1.4554	0.4554	0.01770
4.0000	4.5558	48.8140	8.0000	0.1654	0.0377	1.6979	0.6331	0.0377	1.4509	0.4509	0.01635

FLAT BOTTOM VEHICLE WITH SHARP CORNERS

UPWASH LIFT FORCE LU/2TJ= 0.08718

BODY WITH CIRCULAR CROSS SECTION

UPWASH LIFT FORCE LU/2TJ= 0.02366

Figure 68 - Continued

UPWASH PROPERTIES COMPUTED AT Z LOCATION OF UNDERSIDE OF BODY

BODY CENTERLINE LOCATION AT Z/RN= 6.00000

ZU/RN	RW/RN	PHIR	Y/RN	VMU/VN	DPU/PN	BUH/RN	DPU/PUO	DPU/PJS	TM/TA	DTSM/DTN	PBS/PN
6.0000	3.0000	0.0	0.0	0.1546	0.0317	1.8921	1.0000	0.0317	1.5076	0.5076	0.03170
6.0000	3.0021	2.1211	0.3333	0.1545	0.0317	1.8928	0.9995	0.0317	1.5074	0.5074	0.03165
6.0000	3.0082	4.2364	0.6667	0.1544	0.0316	1.8953	0.9981	0.0316	1.5070	0.5070	0.03147
6.0000	3.0185	6.3402	1.0000	0.1542	0.0316	1.8992	0.9957	0.0316	1.5062	0.5062	0.03118
6.0000	3.0327	8.4270	1.3333	0.1539	0.0315	1.9047	0.9923	0.0315	1.5052	0.5052	0.03078
6.0000	3.0510	10.4915	1.6667	0.1535	0.0313	1.9118	0.9879	0.0313	1.5039	0.5039	0.03028
6.0000	3.0732	12.5288	2.0000	0.1530	0.0312	1.9203	0.9826	0.0312	1.5023	0.5023	0.02969
6.0000	3.0992	14.5344	2.3333	0.1524	0.0310	1.9302	0.9763	0.0310	1.5005	0.5005	0.02900
6.0000	3.1289	16.5043	2.6667	0.1517	0.0307	1.9414	0.9690	0.0307	1.4985	0.4985	0.02824
6.0000	3.1623	18.4349	3.0000	0.1510	0.0305	1.9539	0.9608	0.0305	1.4962	0.4962	0.02741
6.0000	3.1992	20.3231	3.3333	0.1501	0.0302	1.9677	0.9516	0.0302	1.4938	0.4938	0.02653
6.0000	3.2394	22.1663	3.6667	0.1492	0.0299	1.9826	0.9416	0.0299	1.4911	0.4911	0.02560
6.0000	3.2830	23.9625	4.0000	0.1482	0.0295	1.9984	0.9308	0.0295	1.4883	0.4883	0.02464
6.0000	3.3296	25.7099	4.3333	0.1471	0.0291	2.0153	0.9191	0.0291	1.4854	0.4854	0.02365
6.0000	3.3793	27.4075	4.6667	0.1460	0.0287	2.0330	0.9067	0.0287	1.4823	0.4823	0.02266
6.0000	3.4319	29.0546	5.0000	0.1448	0.0283	2.0515	0.8937	0.0283	1.4791	0.4791	0.02165
6.0000	3.4871	30.6506	5.3333	0.1435	0.0279	2.0709	0.8801	0.0279	1.4758	0.4758	0.02065
6.0000	3.5451	32.1957	5.6667	0.1422	0.0275	2.0908	0.8659	0.0275	1.4725	0.4725	0.01966
6.0000	3.6055	33.6900	6.0000	0.1408	0.0270	2.1114	0.8511	0.0270	1.4691	0.4691	0.01869
6.0000	3.6683	35.1342	6.3333	0.1394	0.0265	2.1325	0.8364	0.0265	1.4657	0.4657	0.01774
6.0000	3.7334	36.5288	6.6667	0.1380	0.0260	2.1541	0.8212	0.0260	1.4622	0.4622	0.01681
6.0000	3.8006	37.8749	7.0000	0.1365	0.0255	2.1761	0.8057	0.0255	1.4588	0.4588	0.01592
6.0000	3.8698	39.1736	7.3333	0.1350	0.0250	2.1988	0.7901	0.0250	1.4553	0.4553	0.01505
6.0000	3.9409	40.4260	7.6667	0.1334	0.0245	2.2234	0.7737	0.0245	1.4518	0.4518	0.01421
6.0000	4.0139	41.6335	8.0000	0.1319	0.0240	2.2486	0.7573	0.0240	1.4483	0.4483	0.01341

FLAT BOTTOM VEHICLE WITH SHARP CORNERS

UPWASH LIFT FORCE LU/2TJ= 0.05623

BODY WITH CIRCULAR CROSS SECTION

UPWASH LIFT FORCE LU/2TJ= 0.01440

Figure 68 - Continued .

UPWASH PROPERTIES COMPUTED AT Z LOCATION OF UNDERSIDE OF BODY

BODY CENTERLINE LOCATION AT Z/RN= 8.0000C

ZU/RN	RW/RN	PHIB	X/RN	VMU/VN	DFU/FN	BUH/RN	DFU/PUO	DFU/PJS	TM/TA	DTSM/DTN	FBS/FN
8.0000	3.0000	0.0	0.0	0.1212	0.0197	2.4921	1.0000	0.0197	1.4905	0.4905	0.01972
8.0000	3.0014	1.7357	0.3333	0.1212	0.0197	2.4928	0.9997	0.0197	1.4904	0.4904	0.01970
8.0000	3.0055	3.4682	0.6667	0.1211	0.0197	2.4947	0.9988	0.0197	1.4901	0.4901	0.01962
8.0000	3.0124	5.1944	1.0000	0.1210	0.0197	2.4981	0.9972	0.0197	1.4896	0.4896	0.01950
8.0000	3.0220	6.9112	1.3333	0.1209	0.0196	2.5028	0.9951	0.0196	1.4889	0.4889	0.01934
8.0000	3.0342	8.6156	1.6667	0.1207	0.0196	2.5088	0.9922	0.0196	1.4880	0.4880	0.01913
8.0000	3.0492	10.3048	2.0000	0.1204	0.0195	2.5160	0.9888	0.0195	1.4870	0.4870	0.01888
8.0000	3.0668	11.9761	2.3333	0.1201	0.0194	2.5245	0.9847	0.0194	1.4858	0.4858	0.01858
8.0000	3.0869	13.6270	2.6667	0.1198	0.0193	2.5342	0.9800	0.0193	1.4844	0.4844	0.01825
8.0000	3.1096	15.2551	3.0000	0.1194	0.0192	2.5451	0.9747	0.0192	1.4828	0.4828	0.01788
8.0000	3.1347	16.8584	3.3333	0.1189	0.0191	2.5570	0.9687	0.0191	1.4811	0.4811	0.01750
8.0000	3.1623	18.4349	3.6667	0.1185	0.0190	2.5699	0.9622	0.0190	1.4793	0.4793	0.01708
8.0000	3.1922	19.9831	4.0000	0.1179	0.0188	2.5840	0.9550	0.0189	1.4773	0.4773	0.01663
8.0000	3.2244	21.5014	4.3333	0.1174	0.0187	2.5990	0.9472	0.0187	1.4752	0.4752	0.01617
8.0000	3.2588	22.9887	4.6667	0.1168	0.0185	2.6150	0.9388	0.0183	1.4730	0.4730	0.01569
8.0000	3.2954	24.4439	5.0000	0.1161	0.0183	2.6318	0.9299	0.0183	1.4707	0.4707	0.01520
8.0000	3.3340	25.8663	5.3333	0.1154	0.0182	2.6494	0.9205	0.0182	1.4683	0.4683	0.01470
8.0000	3.3747	27.2553	5.6667	0.1147	0.0180	2.6678	0.9105	0.0180	1.4658	0.4658	0.01419
8.0000	3.4173	28.6104	6.0000	0.1140	0.0178	2.6868	0.9002	0.0178	1.4633	0.4633	0.01368
8.0000	3.4617	29.9315	6.3333	0.1132	0.0175	2.7065	0.8894	0.0175	1.4607	0.4607	0.01317
8.0000	3.5080	31.2184	6.6667	0.1124	0.0173	2.7268	0.8783	0.0173	1.4581	0.4581	0.01267
8.0000	3.5559	32.4712	7.0000	0.1115	0.0171	2.7478	0.8668	0.0171	1.4554	0.4554	0.01217
8.0000	3.6055	33.6900	7.3333	0.1107	0.0169	2.7691	0.8550	0.0169	1.4527	0.4527	0.01167
8.0000	3.6568	34.8753	7.6667	0.1098	0.0166	2.7910	0.8430	0.0166	1.4500	0.4500	0.01119
8.0000	3.7095	36.0273	8.0000	0.1089	0.0164	2.8134	0.8307	0.0164	1.4472	0.4472	0.01071

FLAT BOTTOM VEHICLE WITH SHARP CORNERS

UPWASH LIFT FORCE LU/2TJ= 0.03891

BODY WITH CIRCULAR CROSS SECTION

UPWASH LIFT FORCE LU/2TJ= 0.00970

Figure 68 - Concluded.

Output Titles	Definitions
RJH/RN	Half-velocity radius of jet measured from jet center-line
RJ/RN	Half width of jet
ALPV	Exponent of velocity profile
VJ/VN	Centerline velocity
RC/RN	Potential core radius
ALPT	Exponent of temperature profile
RJNT/RN	Half temperature radius
TM/TN	Center line temperature non-dimensionalized by nozzle temperature
TM/TA	Centerline temperature nondimensionalized by ambient temperature
DTM/DTN	(TM-TA)/(TN-TA)
RJHQ/RN	Half dynamic pressure radius
QJ/QN	Centerline dynamic pressure

Note: RN, VN, TN, and QN denote nozzle radius, velocity, temperature, and dynamic pressure. TA denotes ambient temperature.

Jet Deflection Region

Single jet impingement characteristics are printed.

Output Titles	Definitions
RGH/RN	Half-velocity radius of jet at ground-effect height
RG/RN	Jet half width at ground-effect height
RO/RN	Deflection zone or pressure recovery radius
VG/VN	Square root of jet ground stagnation pressure
DPS/DPTJ	Jet ground stagnation pressure nondimensionalized by nozzle stagnation pressure
TGS/TA	Stagnation temperature of incident jet at ground-effect height.
ALPG	Exponent of ground pressure distribution
R/RGH	Radial location in deflection region relative to ground stagnation point. Nondimensionalized by ground-effect half-velocity radius of jet

DPS/DPTG	Ground pressure nondimensionalized by ground stagnation pressure
R/RN	Radial location in deflection region nondimensionalized by nozzle radius
DPS/DPTJ	Ground pressure nondimensionalized by nozzle stagnation pressure

Wall Jet Region

Isolated wall jet properties are printed in this set of output.

Output Titles	Definitions
DELS/RN	Boundary layer thickness at stagnation point
VMI/VG, VMI/VN	Inviscid maximum velocity at jet half width (RGH) radial location or start of transition to turbulent wall jet
ALPWO	Exponent of velocity profile at start of wall jet
BWOH/RN	Half velocity thickness at start of wall jet
BWO/RN	Initial thickness of wall layer
PMI/PR	Initial static pressure in wall layer
TMI/TA	Initial temperature of wall layer
(PTTOT/PR-1.)	Initial total pressure of wall layer
(TOT/TA-1.)	Initial total temperature of wall layer
R/RN	Radial location in wall jet measured from ground stagnation point
VM/VG	Maximum velocity in wall layer nondimensionalized by square root of ground stagnation pressure
VM/VN	Maximum velocity in wall layer referenced to nozzle exit velocity.
BWH/RN	Half velocity thickness of wall layer
BW/RN	Thickness of wall layer
DELBL/RN	Boundary layer thickness
DELPJ	Maximum stagnation pressure in wall layer
KDEL	Ratio of boundary layer to total wall layer thickness
TM/TN, TM/TA	Maximum temperature in wall layer profile
BWNT/RN	Half temperature thickness of wall layer
DTM/DTN	(TM-TA)/(TN-TA)

TWO-JET IMPINGEMENT INTERACTION OUTPUT

Recirculation Effect on Wall Jets

Note: This set of output recomputes the wall jet properties accounting for the interaction of two hot jets.

Output Titles	Definitions
PHI	Azimuthal angle in jet-centered ground polar coordinate system
TNEFF, TAEFF	Effective nozzle and ambient temperature ratios with recirculation effects taken into account.
R	Radial location in wall jet, measured from ground stagnation point
VM/VN	Maximum velocity in wall layer
TM/TN, TM/TA	Maximum temperature in wall layer
DPM/DPN	(PM-PA)/(PN-PA) or (PM-1.)/(NPR-1.)
DTM/DTN	(TM-TA)/(TN-TA) or (TM-1.)/(NTR-1.)

Maximum Ground Pressures along Upwash Ground Stagnation Line

Output Titles	Definitions
XW/RN, XW/S	Coordinate along stagnation line measured from upwash stagnation point
DPMAX/DPJ	Stagnation line pressure nondimensionalized by nozzle stagnation pressure $(P_{MAX}-P_A)/(P_N-P_A)$
PMAX/PMAXO	Stagnation line pressure nondimensionalized by upwash stagnation point pressure
DTMAX/DTJ	Stagnation line temperature nondimensionalized by nozzle stagnation temperature
TMAX/TMAXO	Stagnation line temperature nondimensionalized by upwash stagnation point temperature

Upwash Momentum Function

Output Titles	Definitions
RG/RN	Radius of jet at ground effect height
ACON	Constant in momentum function

XMOMZ	Total vertical momentum in upwash sheet non-dimensionalized by the optimum value of $M_J/2\pi$
PHIO	Coalescence angle used in upwash momentum model If PHIO = 0 jets are not coalesced If PHIO > 0 jets have begun to coalesce

Note: Depending on the value of PHIO (i.e. zero or non-zero) the constant ACON applies to the appropriate upwash momentum model.

CU	Nondimensional upwash deflection region width constant

Note: There are two possible outputs that can occur at this point. If the jets are spaced far enough apart the comment:

JET AND UPWASH DEFLECTION REGIONS DO NOT

INTERACT, CU ESTIMATE IS CORRECT

In this case the value of CU is correct and the jet impingement and upwash deflection regions are independent. The perturbation parameters are then defined as:

EPS = 0.0
SIG = 1.0
PHIUO = 0.0
PHIO = 0.0
PMIN = 0.0 along upwash line
ALPUG = 1.50

If the nozzle spacing and height above ground are such that the deflection regions interact, the subroutine INTERG will be called and

CALL INTERG

will be displayed. The following output will be printed.

Note: The ground pressure distributions are computed without temperature effects.

Output Titles	Definitions
Iteration cycle	Number of iterations required to find solution using Newton's method

EPS or EPI	Perturbation parameter for jet impingement pressure distribution
SIGMA or SIG	Perturbation parameter for upwash deflection region pressure distribution
CU or CUI	Upwash width estimate prior to iterative solution
PHIUO PHIO	Angles defining the intersection of jet and upwash deflection regions

Note: The following values apply along the line connecting the jet stagnation points on the ground (i.e. x = 0).

DELPWO	Pressure at upwash stagnation point nondimensionalized by nozzle stagnation pressure
PMIN	Minimum pressure between jet and upwash deflection regions nondimensionalized by nozzle stagnation pressure
ALPUG	Exponent of upwash ground pressure distribution function
(CU) x (SIGMA)	Final value of upwash thickness constant

Note: If IPBAR = 0, the following output will occur.

Computation of Two-Jet Ground Isobar Pattern

Output Titles	Definitions
PBAR	Input values of pressure, nondimensionalized by nozzle stagnation pressures, will be echoed.

Note: The following will be repeated NU times.

Output Titles	Definitions
IJET	Number of points on jet impingement region isobar
IU	Number of points on upwash deflection region isobar

If IJET = 0 or IU = 0, the specified value of PBAR was not found in ground pressure distribution.

Note: The following coordinates are referenced to the jet stagnation point on the ground.

Output Titles	Definitions
XISOJ	X coordinate of jet isobar
YISOJ	Y coordinate of jet isobar

XISOU	X coordinate upwash region isobar
YISOU	Y coordinate of upwash region isobar

The final set of output in this section is the upwash deflection zone line. If the deflection zones do not interact, ambient conditions exist along this line.

XUP	X coordinate of upwash line
YUP	Y coordinate of upwash line

COMPUTATION OF UPWASH FLOW FIELD

Upwash Streamline Properties

Note: Two streamlines are printed

Output Titles	Definitions
PHID	Azimuthal angle of upwash streamline referenced to jet ground coordinate system
INV. VEL.	Inviscid turning region maximum velocity
TMI/TA	Inviscid turning region maximum temperature
DELPWJ	Maximum pressure on upwash stagnation line on the ground where upwash streamline orginated
BWGH/RN	Half velocity width of incident wall jet streamline
ZOU/RN	Upwash turning region height above ground
BUO/RN	Initial upwash width
BUOHN/RN	Initial upwash half velocity width

Upwash Streamline Decay Properties

Output Titles	Definitions
Z/RN	Upwash Streamline coordinate (ZS)
VMU/VN	Upwash maximum or centerline velocity
TM/TN TM/TA	Upwash maximum or centerline temperature
BUH/RN	Half velocity width
BU/RN	Half width of upwash
DPU/DPJ	Upwash maximum or centerline total pressure non-dimensionalized by nozzle stagnation pressure or $(P_{MU}-P_A)/(P_N-P_A)$

Upwash Properties Computed At Z Location of Underside of Body

If ZB = 0, the output will yield the upwash properties at Z = constant plane above ground.

Output Titles	Definitions
ZU/RN	Upwash coordinate measured from ground plane
RW/RN	Radial coordinate from jet ground stagnation point to upwash stagnation line
PHIB	Azimuthal location of upwash streamline referenced to jet coordinate system
X/RN	X coordinate in upwash sheet or X coordinate on fuselage
VMU/VN	Maximum or centerline upwash velocity
DPU/PN	Maximum or centerline upwash total pressure nondimensionalized by nozzle stagnation pressure $(P_{MU}-P_A)/(P_N-P_A)$
BUH/RN	Half-velocity width of upwash
DPU/PUO	Upwash total pressure nondimensionalized by total pressure on streamline originating from upwash stagnation point (X = 0, Y = 0)
DPU/PJS	Upwash total pressure nondimensionalized by jet ground stagnation pressure
TM/TA	Maximum or centerline upwash temperature
DTSM/DTN	(TM-TA)/(TN-TA)
PBS/PN	Stagnation pressure on underside of fuselage placed in upwash sheet

Upwash Lift Force

Two values are printed:

FLAT BOTTOM VEHICLE WITH SHARP CORNERS

BODY WITH CIRCULAR CROSS SECTION

Output Title	Definition
LU/2TJ	Upwash lift force nondimensionalized by the total thrust of the two jets

COMPUTER PROGRAM LISTING

Figure 69 shows a Fortran listing of the computer program

```
C*************************************************************************JET00010
C                                                                         JET00020
C     VTOL TWO-JET IMPINGEMENT INTERACTION COMPUTER PROGRAM               JET00030
C                FOR CLOSELY SPACED JETS                                  JET00040
C                  BY M.J.SIGLARI                                         JET00050
C                   516 575-2207                                          JET00060
C            GRUMMAN AEROSPACE CORPORATION                                JET00070
C             BETHPAGE,NEW YORK 11714                                     JET00080
C                                                                         JET00090
C*************************************************************************JET00100
C                                                                         JET00110
C   PROGRAM GRUMHOT2                                                      JET00120
C                                                                         JET00130
      REAL KDELFD,KDELO,NFD,NO,N,KDEL                                     JET00140
      REAL MACH,NPR,NTR                                                   JET00150
      COMMON/WALL/DELS,NO,KDELO,ALFG,ALFWO,ALFWFD,RO,RGH,VG,BWHO          JET00160
      COMMON/WALLT/ TLAMI,DELPS,DELTSB,PSBAR                              JET00170
      COMMON/NOZZLE/NPR,NTR,TN,GAM,MACH,ACHS,TAEFF,TNEFF                  JET00180
      COMMON/JET/SD,RGU                                                   JET00190
      COMMON/HEIGHT/ HD,IPBAR                                             JET00200
      FETAWB(ETA,A)=ETA-(4./(A+1.))*ETA**(A+1.)+(6./(2.*A+1.))*ETA**(2.*AJET00210
     1A+1.)-(4./(3.*A+1.))*ETA**(3.*A+1.)+(1./(4.*A+1.))*ETA**(4.*A+1.) JET00220
C                                                                         JET00230
C   BODY SHAPE FUNCTIONS FOR FORCE PREDICTION                             JET00240
C     W2...HALF-WIDTH IN NOZZLE RADII                                     JET00250
C     ZBODY...HALF DEPTH IN NOZZLE RADII                                  JET00260
C     DZDXB...AXIAL SLOPES                                                JET00270
C     THNOSE...NOSE ANGLE OF PARABOLIC BODY                               JET00280
C                                                                         JET00290
C                                                                         JET00300
C  PARABOLIC BODY WITH CONSTANT CROSS SECTIONAL SHAPE                     JET00310
C                                                                         JET00320
C     W2(XB)=.5*TAN(THNOSE)*(XL2**2-XB**2)/XL2                            JET00330
C     ZBODY(XB)=.5*TAN(THNOSE)*(XL2**2-XB**2)/XL2                         JET00340
C     DZDXB(XB)=TAN(THNOSE)*XB/XL2                                        JET00350
C                                                                         JET00360
C  CYLINDRICAL BODY WITH CONSTANT CROSS SECTIONAL SHAPE                   JET00370
C                                                                         JET00380
      W2(XB)=WCON                                                         JET00390
      ZBODY(XB)=ZCON                                                      JET00400
      DZDXB(XB)=ZSCON                                                     JET00410
C                                                                         JET00420
C  CYLINDRICAL BODY PARAMETERS IN TERMS OF NOZZLE DIAMTERS                JET00430
C                                                                         JET00440
C                                                                         JET00450
      ZSCON=0.0                                                           JET00460
      THNOSE=14.0362*PI/180.                                              JET00470
C                                                                         JET00480
C  CIRCULAR CROSS SECTION                                                 JET00490
C     POINT OF FLOW SEPARATION                                            JET00500
C                                                                         JET00510
      PI=3.14159265                                                       JET00520
      GAM=1.4                                                             JET00530
      PHISEP=135.*PI/180.                                                 JET00540
      READ (5,1) NPR,NTR                                                  JET00550
      READ (5,1) HD,SD,ZPLD,DZPL,ZFINAL                                   JET00560
    1 FORMAT (5F10.5)                                                     JET00570
      READ (5,1) XL2,WCON,ZCON                                            JET00580
      WRITE (6,21)                                                        JET00590
   21 FORMAT ('1',///30X,'***   INPUT PARAMETERS   ***'//)                JET00600
      MACH=SQRT(2.*(NPR-1.)/GAM)                                          JET00610
      TN=NTR                                                              JET00620
      WRITE (6,17) NPR,NTR                                                JET00630
   17 FORMAT (20X,'NPR=',F8.4,2X,'NTR=',F8.4)                             JET00640
      WRITE (6,27) MACH,TN                                                JET00650
   27 FORMAT (20X,'MACH NO.=',F10.4,2X,'TN/TA=',F10.4)                    JET00660
      WRITE (6,9) HD,SD,ZFLD                                              JET00670
    9 FORMAT (20X,'H/D=',F10.5,2X,'S/D=',F10.5,2X,'Z/D=',F10.5)           JET00680
      WRITE (6,907) ZPLD,DZPL,ZFINAL                                      JET00690
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```

Figure 69 Program FORTRAN Listing

```
  907 FORMAT (/20X,'Z/D=',F10.5,2X,'DZ/D=',F10.5,2X,'ZFINAL/D=',F10.5/) JET00700
      WRITE (6,908) XL2,WCON,ZCON                                      JET00710
  908 FORMAT (/20X,'BODY LENGTH L/D=',F10.5,2X,'WIDTH W/D=',F10.5,2X,'DEJET00720
     1PTH ZB/D=',F10.5/)                                               JET00730
      ZPLANE=2.*ZPLD                                                   JET00740
C                                                                      JET00750
C  COMPUTE JET STANDOFF DISTANCE AND EFFECTIVE JET DECAY HEIGHT        JET00760
C  (GIRALT ET AL)                                                      JET00770
C                                                                      JET00780
      IF (HD.LE.6.8) DELG=0.153*7.8                                    JET00790
      IF (HD.GT.6.8) DELG=0.153*(1.+HD)                                JET00800
      ZEND=(HD-.50*DELG)*2.                                            JET00810
      WRITE (6,22)                                                     JET00820
   22 FORMAT (///30X,'*****     JET DECAY REGION     *****'//)         JET00830
      WRITE (6,7) DELG                                                 JET00840
    7 FORMAT (10X,'JET DEFLECTION HEIGHT DELG/D =',F10.5)              JET00850
C                                                                      JET00860
C  COMPUTE JET DECAY                                                   JET00870
C                                                                      JET00880
C  ALL DIMENSIONS NONDIMENSIALIZED BY NOZZLE RADIUS                    JET00890
C                                                                      JET00900
C   SET EMPIRICAL CONSTANTS FOR HALF-WIDTH BEHAVIOR AND LENGTH OF      JET00910
C  POTENTIAL CORE (HRYCAN,ET AL)                                       JET00920
C                                                                      JET00930
      A2=.040                                                          JET00940
      B2=.800                                                          JET00950
      FM=1.                                                            JET00960
      A3=.09*(1.+ALOG(2./(1.+1./TN**.5)))*(1.0-.16*FM*MACH)            JET00970
      B3=0.                                                            JET00980
      ZPCO=8.55                                                        JET00990
      FM=0.0                                                           JET01000
      ZPC=.5*ZPCO*(1.+1./(TN**.75))*(1.0+.16*FM*MACH)                  JET01010
      A1=A2+(B2-1.)/ZPC                                                JET01020
      ZFD=B2/(A3-A2)                                                   JET01030
      ALPFD=1.5                                                        JET01040
      WRITE (6,23) ZPC,ZFD                                             JET01050
   23 FORMAT (10X,'ZPC/RN=',F10.5,2X,'ZFD/RN=',F10.5)                  JET01060
      WRITE (6,12)                                                     JET01070
   12 FORMAT (//3X,'Z/RN',3X,'RJH/RN',3X,'RJ/RN',2X,'ALPV',4X,'UJ/UN',4XJET01080
     1,'RC/RN',3X,'ALPT',3X,'RJHT/RN',2X,'TM/TN',2X,'TM/TA',4X,'DTM/DTN'JET01090
     2,2X,'RJHQ/RN',2X,'QJ/QN')                                        JET01100
C                                                                      JET01110
C  REGION 1...POTENTIAL CORE REGION OF JET..                           JET01120
C                                                                      JET01130
      NJPC=5                                                           JET01140
      DNPC=NJPC-1                                                      JET01150
      IF (ZEND.GE.ZPC) DZPC=ZPC/DNPC                                   JET01160
      IF (ZEND.LT.ZPC) DZPC=ZEND/DNPC                                  JET01170
      Z=0.                                                             JET01180
      DO 100 I=1,NJPC                                                  JET01190
      IF (I.EQ.1) GO TO 102                                            JET01200
      GO TO 103                                                        JET01210
  102 UJ=1.                                                            JET01220
      RJH=1.                                                           JET01230
      RJHT=1.                                                          JET01240
      RJ=1.                                                            JET01250
      ALPVC=0.                                                         JET01260
      ALPTC=1.5                                                        JET01270
      CV2=.5                                                           JET01280
      RJPC=1.                                                          JET01290
      TM=1.                                                            JET01300
      DELPMN=1.                                                        JET01310
      TMB=TN                                                           JET01320
      DELTMN=1.0                                                       JET01330
      RC=1.                                                            JET01340
      RJHQ=1.                                                          JET01350
      GO TO 104                                                        JET01360
  103 ETAC=1.-Z/ZPC                                                    JET01370
      RJH=A1*Z+1.                                                      JET01380
      CALL JETPCT (TN,ETAC,RJH,ALPVC,TLAM,CV2,CT,RV,RT)                JET01390
      TLAMPC=TLAM                                                      JET01400
      RJ=RJH/RV                                                        JET01410
      RJHT=TLAM*RJH                                                    JET01420
      TM=1.                                                            JET01430
      TMB=TN                                                           JET01440
      DELTMN=1.                                                        JET01450
      DELPMN=1.                                                        JET01460
```

Figure 69 - Continued

```
      RJPC=RJ                                                          JET01470
      RJHTPC=RJHT                                                      JET01480
      VJ=1.                                                            JET01490
      RC=ETAC*RJ                                                       JET01500
      ALPTC=ALPVC                                                      JET01510
      CALL QHALF (TMB,ETAC,ALPVC,TLAM,RQ)                              JET01520
      RJHQ=RJ*RQ                                                       JET01530
      VQ=1.                                                            JET01540
      TQ=1.                                                            JET01550
      TMSTAG=TMB+VJ*VJ*(NTR-TN)                                        JET01560
      DTSTAG=(TMSTAG-1.)/(NTR-1.)                                      JET01570
  104 WRITE (6,11) Z,RJH,RJ,ALPVC,VJ,RC,ALPTC,RJHT,TM,TMB,DELTMN,RJHQ, JET01580
     1DELPMN                                                           JET01590
   11 FORMAT (1X,4(F7.4,1X),6(F7.4,1X),4(F8.4,1X))                     JET01600
      Z=Z+DZPC                                                         JET01610
  100 CONTINUE                                                         JET01620
C                                                                      JET01630
C  TRANSITION REGION II AND FULLY DEVELOPED REGION OF JET              JET01640
C                                                                      JET01650
      IF (ZEND.LE.ZPC) GO TO 998                                       JET01660
      NJFD=25                                                          JET01670
      DNFD=NJFD-1                                                      JET01680
      ALPVFD=1.5                                                       JET01690
      ALPTFD=1.50                                                      JET01700
      TLAMFD=1.+.185*TN**.5                                            JET01710
      RCON=(2.-SQRT(2.))/2.                                            JET01720
      RVFD=RCON**(1./ALPVFD)                                           JET01730
      RJFD=(A3*ZFD+B3)/RVFD                                            JET01740
      RTFD=RVFD                                                        JET01750
      RJHTFD=TLAMFD*(A3*ZFD+B3)                                        JET01760
      DZ=(ZEND-ZPC)/DNFD                                               JET01770
      Z=ZPC+DZ                                                         JET01780
      DO 200 I=2,NJFD                                                  JET01790
      IF (Z.GT.ZFD) GO TO 201                                          JET01800
      RJ=RJPC+((RJFD-RJPC)/(ZFD-ZPC))*(Z-ZPC)                          JET01810
      RJH=A2*Z+B2                                                      JET01820
      RV=RJH/RJ                                                        JET01830
      ALPV=ALOG(RCON)/ALOG(RV)                                         JET01840
      ALPT=ALPV                                                        JET01850
      TLAM=TLAMPC+((TLAMFD-TLAMPC)/(ZFD-ZPC))*(Z-ZPC)                  JET01860
      GO TO 202                                                        JET01870
  201 ALPV=ALPVFD                                                      JET01880
      ALPT=ALPTFD                                                      JET01890
      RJH=A3*Z+B3                                                      JET01900
      TLAM=TLAMFD                                                      JET01910
  202 CALL VTSOLV(TN,RJH,ALPV,TLAM,VJ,TM,RV,RT)                        JET01920
      RJ=RJH/RV                                                        JET01930
      RJHT=TLAM*RJH                                                    JET01940
      TMB=TM*TN                                                        JET01950
      IF (ABS(TN-1.).LT.1.E-5) DELTMN=1.0                              JET01960
      IF (ABS(TN-1.).GT.1.E-5) DELTMN=(TMB-1.)/(TN-1.)                 JET01970
      DELPMN=VJ*VJ/TM                                                  JET01980
      CALL QHALF (TMB,0.,ALPV,TLAM,RQ)                                 JET01990
      RJHQ=RQ*RJ                                                       JET02000
      TQ=TM                                                            JET02010
      VQ=VJ                                                            JET02020
      TMSTAG=TMB+VJ*VJ*(NTR-TN)                                        JET02030
      DTSTAG=(TMSTAG-1.)/(NTR-1.)                                      JET02040
      WRITE (6,11) Z,RJH,RJ,ALPV,VJ,RC,ALPT,RJHT,TM,TMB,DELTMN,RJHQ    JET02050
     1,DELPMN                                                          JET02060
      Z=Z+DZ                                                           JET02070
  200 CONTINUE                                                         JET02080
C                                                                      JET02090
C  JET DEFLECTION REGION                                               JET02100
C  JET IMPINGEMENT PRESSURES                                           JET02110
C                                                                      JET02120
  998 AOCON=-.032026                                                   JET02130
      BOCON=.3354248                                                   JET02140
      COCON=2.8                                                        JET02150
      IF (HD.GT.3.) AO=3.6                                             JET02160
      AOSLH=(3.6-2.9)/(3.-1.2)                                         JET02170
      IF (HD.LE.3.) AO=2.9+AOSLH*(HD-1.2)                              JET02180
      WRITE (6,79)                                                     JET02190
   79 FORMAT (///30X,'*****     JET DEFLECTION REGION     *****')      JET02200
   80 FORMAT (10X,'RQH/RN=',F10.5,2X,'RQ/RN=',F10.5,2X,'PO/RN=',F10.5,2XJET02210
     1,'VQ/VN=',F10.5/)                                                JET02220
C                                                                      JET02230
```

Figure 69 - Continued

```
C  SET CHARACTERISTIC SCALE LENGTHS FOR IMPINGEMENT REGION                JET02240
C                                                                         JET02250
      RGH=RJH                                                             JET02260
      RG=RJ                                                               JET02270
      RO=AO*RGH                                                           JET02280
      ETAWG=RGH/RO                                                        JET02290
      IF (2.*HD.LE.ZPC) GO TO 454                                         JET02300
C                                                                         JET02310
C  DETERMINE STAGNATION POINT PRESSURE                                    JET02320
C                                                                         JET02330
  454 WRITE (6,80) RGH,RG,RO,VG                                           JET02340
C                                                                         JET02350
C  STAGNATION PRESSURE NONDIMENSIONALIZED BY JET TOTAL PRESSURE           JET02360
C                                                                         JET02370
      RGU=RG                                                              JET02380
      DELPS=(VG**2)/TG                                                    JET02390
      PSBAR=1.+DELPS*(NPR-1.)                                             JET02400
      ACHS=SQRT(2.*(PSBAR-1.)/GAM)                                        JET02410
      TGB=TG*TN                                                           JET02420
      TGBS=TGB+(NTR-TN)*VG*VG                                             JET02430
      WRITE (6,81) DELPS,TGBS                                             JET02440
   81 FORMAT (10X,'STAGNATION PRESSURE, DPS/DPTJ=',F10.5,2X,2X,'GROUND MJET02450
     1AX. TEMP., TGS/TA=',F10.5)                                          JET02460
      WRITE (6,801) ACHS                                                  JET02470
  801 FORMAT (/10X,'STAGNATION MACH NUMBER OF JET=',F10.5/)               JET02480
      CALL OPREST(RO,VG,TG,ALPG,R,CV2)                                    JET02490
      WRITE (6,82) ALPG                                                   JET02500
   82 FORMAT (10X,'ALPG=',F10.5)                                          JET02510
      NG=25                                                               JET02520
      RNGM=NG-1                                                           JET02530
      DR=RO/(RNGM*RGH)                                                    JET02540
      DETA=1./(RNGM)                                                      JET02550
      ETA=0.                                                              JET02560
      R=0.                                                                JET02570
      WRITE (6,83)                                                        JET02580
   83 FORMAT (30X,'SINGLE JET GROUND PRESSURES'//25X,'R/ROH',6X,'DPS/DPTJET02590
     1G',8X,'R/RN',7X,'DPS/DPTJ'/)                                        JET02600
      DO 300 I=1,NG                                                       JET02610
      DPTG=(1.-ETA**ALPG)**4.                                             JET02620
      DPTJ=DPTG*DELPS                                                     JET02630
      RRN=R*RGH                                                           JET02640
      WRITE (6,84) R,DPTG,RRN,DPTJ                                        JET02650
   84 FORMAT (20X,4(F10.5,5X))                                            JET02660
      R=R+DR                                                              JET02670
      ETA=ETA+DETA                                                        JET02680
  300 CONTINUE                                                            JET02690
C                                                                         JET02700
C  INITIALIZE WALL JE  REGION                                             JET02710
C                                                                         JET02720
      AWJ=.09*(1.+ALOG(2./(1.+1./TN**.5)))*(1.-.16*ACHS)                  JET02730
      TLAMFD=1.+.185*TN**.5                                               JET02740
      ALPWFD=1.5                                                          JET02750
      KDELFD=.0962                                                        JET02760
      ALPUG=1.5                                                           JET02770
      NFD=7.                                                              JET02780
      CALL SIMW(KDELFD,NFD,ALPWFD,RATW,CSV2W,CPW)                         JET02790
      CALL SIMUG(ALPUG,RATUG,CSPUG)                                       JET02800
      CU=2.*AWJ*CSV2W/(RATW*CSPUG)                                        JET02810
      AS1=.015638                                                         JET02820
      AS2=.128035                                                         JET02830
      DELS=2.*AS1*(HD)**AS2                                               JET02840
      WRITE (6,26)                                                        JET02850
   26 FORMAT (///30X,'*****     WALL JET REGION     *****'//)             JET02860
      WRITE (6,86) DELS                                                   JET02870
   86 FORMAT (5X,'STAGNATION POINT BOUNDARY LAYER THICKNESS, DELS/RN=',    JET02880
     1F10.5)                                                              JET02890
      NO=14                                                               JET02900
      KDELO=DELS/(2.*DELG)                                                JET02910
      FETAG=(1.-ETAWG**ALPG)**4                                           JET02920
      PMBI=1.+(NPR-1.)*DELPS*FETAG                                        JET02930
      DELPSB=(NPR-1.)*DELPS                                               JET02940
      ACHI=SQRT(2.*(PSBAR/PMBI-1.)/GAM)                                   JET02950
      TMBI=TGBS                                                           JET02960
      VMI=(ACHI/MACH)*SQRT(TMBI/TN)                                       JET02970
      DELTSB=TGBS-1.0                                                     JET02980
      WRITE (6,89) PMBI,DELPSB,DELTSB                                     JET02990
```

Figure 69 - Continued

```
   89 FORMAT (1X,'PMI/PA=',F10.5,2X,'(PTTOT/PA-1.)=',F10.5,2X,'(TOT/TA-JET03000
     11.)=',F10.5)                                                    JET03010
        WRITE (6,92) TMI,VMI                                          JET03020
   92 FORMAT (2X,'TMI /A=',F10.5,2X,'VMI/VN=',F10.5)                  JET03030
        TMI=TMBI/TN                                                   JET03040
        CALL GMATT(TN,RGH,DELPS,PMBI,TMI,VMI,ALPG,KDELO,NO,ETAWG,DELS,JET03050
       1ALPWO,R,BWO,BWHO,TLAMI)                                       JET03060
        RATWO=R                                                       JET03070
        DELSM=BWO*KDELO                                               JET03080
        VMG1=VMI/VG                                                   JET03090
        WRITE (6,91) VMG1                                             JET03100
   91 FORMAT (5X,'VELOCITY AT START OF TURBULENT WALL JET, VM/VG=',F10.5JET03110
       1)                                                             JET03120
C       WRITE (6,87) TLAMFD                                           JET03130
   87 FORMAT (5X,'TLAMFD=',F10.5)                                     JET03140
        WRITE (6,85) ALPWO,BWHO,BWO                                   JET03150
   85 FORMAT (10X,'START OF WALL JET REGION, ALPWO=',F10.5,2X,'BWOH/RN='JET03160
       1,F10.5,2X,'BWO/RN=',F10.5)                                    JET03170
C                                                                     JET03180
C  MAXIMUM VELOCITY DISTRIBUTION IN DEFLECTION REGION                 JET03190
C                                                                     JET03200
        NWPT=25                                                       JET03210
        XNWPT=NWPT-1                                                  JET03220
        REND=2*SD                                                     JET03230
        DR=REND/XNWPT                                                 JET03240
        BW3HO=AW3*RO                                                  JET03250
        DELBRH=(BW3HO-BWHO)/(RO-RGH)                                  JET03260
        DELNR=(NFD-NO)/(RO-RGH)                                       JET03270
        DELAR=(ALPWFD-ALPWO)/(RO-RGH)                                 JET03280
        ADELBT=.0175                                                  JET03290
        ADELBL=(ADELBT*(RO-2.)-DELS)/(RO-RGH)                         JET03300
        R=0.                                                          JET03310
        TLAMSL=(TLAMFD-TLAMI)/(RO-RGH)                                JET03320
        WRITE (6,107)                                                 JET03330
  107 FORMAT(//40X,'ISOLATED WALL JET PROPERTIES'//)                  JET03340
        WRITE (6,97)                                                  JET03350
   97 FORMAT (//5X,'R/RN',5X,'VM/VG',5X,'VM/VN',5X,'BWH/RN',3X,       JET03360
       1'BW/RN',3X,'DELBL/PN',3X,'DELPJ',3X,'KDEL',3X'TM/TN'          JET03370
       2,1X,'TM/TA',1X,'BWHT/PN',1X,'DTM/DTN'/)                       JET03380
        DO 400 I=1,NWPT                                               JET03390
        IF (R.GE.RGH) TLAM=TLAMI+TLAMSL*(R-RGH)                       JET03400
        IF (R.LT.RGH) TLAM=TLAMI                                      JET034
        IF (R.LE.RO) FETA=(1.-(R/RO)**ALPG)**4                        JET034
        IF (R.GT.RO) FETA=0.0                                         JET03430
        IF (R.GT.RO) TLAM=TLAMFD                                      JET03440
        PMB=1.+(NPR-1.)*DELPS*FETA                                    JET03450
        IF (R.GT.RGH) GO TO 402                                       JET03460
        ACH=SQRT(2.*(PSBAR/PMB-1.)/GAM)                               JET03470
        TMB=TOBS                                                      JET03480
        VMN=(ACH/MACH)*SQRT(TMB/TN)                                   JET03490
        TM=TMB/TN                                                     JET03500
        DELPJ=DELPS                                                   JET03510
        DELTA=KDELO*BWO                                               JET03520
        N=14                                                          JET03530
        KDEL=KDELO                                                    JET03540
        BW=BWO                                                        JET03550
        BWH=RATWO*BWO                                                 JET03560
        VMG=VMN/VG                                                    JET03570
        BWHT=TLAMI*BWH                                                JET03580
        DELTMN=(TMB-1.)/(TN-1.)                                       JET03590
        TMSTAG=TMB+VMN*VMN*(NTR-TN)                                   JET03600
        DTSTAG=(TMSTAG-1.)/(NTR-1.)                                   JET03610
        GO TO 401                                                     JET03620
  402 IF (R.GT.RO) GO TO 403                                          JET03630
        BWH=BWHO+DELBRH*(R-RGH)                                       JET03640
        ALPW=ALPWO+DELAR*(R-RGH)                                      JET03650
        DELBL=DELS+ADELBL*(R-RGH)                                     JET03660
        N=NO+DELNR*(R-RGH)                                            JET03670
        GO TO 405                                                     JET03680
  403 BWH=AW3*R                                                       JET03690
        DELBL=ADELBT*(R-2.)                                           JET03700
        N=NFD                                                         JET03710
        ALPW=ALPWFD                                                   JET03720
```

Figure 69 - Continued

```
  405 ALAM=((2.-SQRT(2.))/2.)**(1./ALPW)                                    JET03720
      KDEL=DELBL/(DELBL+(BWH-DELBL)/ALAM)                                   JET03740
      IF (R.LE.4.) FVIS=1.0                                                 JET03750
      IF (R.GT.4.) FVIS=1./(R/4.)**.24                                      JET03760
      FMOM=1.-FETA                                                          JET03770
      DELPM=DELPS*FETA                                                      JET03780
      TAEFF=1.                                                              JET03790
      TNEFF=TN                                                              JET03800
      CALL VTWALL (R,BWH,FVIS,FMOM,DELPM,TN,TLAM,PMB,KDEL,N,ALPW,           JET03810
     1VMN,TM,TNEFF,TAEFF)                                                   JET03820
      VMG=VMN/VG                                                            JET03830
      DELPJ=(PMB-1.)/(NPR-1.)+PMB*VMN*VMN/TM                                JET03840
      RCON=(2.-SQRT(2.))/2.                                                 JET03850
      RAT=KDEL+(1.-KDEL)*RCON**(1./ALPW)                                    JET03860
      BW=BWH/RAT                                                            JET03870
      DELTA=KDEL*BW                                                         JET03880
      TMB=TM*TN                                                             JET03890
      BWHT=TLAM*BWH                                                         JET03900
      DELTMN=(TMB-1.)/(TN-1.)                                               JET03910
      TMSTAG=TMB+VMN*VMN*(NTR-TN)                                           JET03920
      DTSTAG=(TMSTAG-1.)/(NTR-1.)                                           JET03930
  401 WRITE (6,95) R,VMG,VMN,BWH,BW,DELTA,DELPJ,KDEL,TM,TMB                 JET03940
     1,BWHT,DELTMN                                                          JET03950
      R=R+DR                                                                JET03960
   95 FORMAT (1X,5(F8.4,2X),8(F7.4,1X))                                     JET03970
  400 CONTINUE                                                              JET03980
C                                                                           JET03990
C   UPWASH GROUND MAXIMUM PRESSURE DISTRIBUTION                             JET04000
C                                                                           JET04010
      WRITE (6,24)                                                          JET04020
   24 FORMAT (////30X,'*****     TWO-JET INTERACTION PROBLEM     *****'//  JET04030
     1//)                                                                   JET04040
C                                                                           JET04050
C   WALL JET RECIRCULATION EFFECTS                                          JET04060
C                                                                           JET04070
      IRAY=5                                                                JET04080
      AREC=1.                                                               JET04090
      OMEG=(TGRS-1.)*((RG/SD)**AREC)                                        JET04100
      IF (RG.GT.SD) OMEG=TGRS-1.                                            JET04110
      DRAY=IRAY-1                                                           JET04120
      DPHI=PI/DRAY                                                          JET04130
      PHI=0.                                                                JET04140
      WRITE (6,710)                                                         JET04150
  710 FORMAT (//30X,'***  RECIRCULATION EFFECT ON WALL JETS  ***'///)       JET04160
      DO 750 IW=1,IRAY                                                      JET04170
      PHID=PHI*180./PI                                                      JET04180
      WRITE (6,711) PHID                                                    JET04190
  711 FORMAT (/50X,'PHI=',F8.4,' DEGS.'/)                                   JET04200
      CPHI2=COS(.5*PHI)                                                     JET04210
      TAEFF=1.+OMEG*CPHI2*CPHI2                                             JET04220
      TNEFF=TN+(TAEFF-1.)*(TGRS-TN)/(TGRS-1.)                               JET04230
      WRITE (6,740) TNEFF,TAEFF                                             JET04240
  740 FORMAT (/40X,'TNEFF=',F10.5,2X,'TAEFF=',F10.5/)                       JET04250
      IF (PHI.GE..5*PI) GO TO 761                                           JET04260
      XW=SD*TAN(PHI)                                                        JET04270
      RW=SQRT(XW**2+SD**2)                                                  JET04280
      IF (RW.GT.2.*SD) RW=2.*SD                                             JET04290
      GO TO 702                                                             JET04300
  701 RW=2.*SD                                                              JET04310
  702 NWPT=25                                                               JET04320
      XNWPT=NWPT-1                                                          JET04330
      DR=RW/XNWPT                                                           JET04340
      R=0.                                                                  JET04350
      WRITE (6,713)                                                         JET04360
  713 FORMAT (/37X,'R',7X,'VM/VN',7X,'TM/TN',7X,'TM/TA',7X,'DPM/DPN',5X,    JET04370
     1'DTM/DTN'/)                                                           JET04380
      DO 703 IR=1,NWPT                                                      JET04390
      CALL WALLJT (R,VMN,BWH,DELPW,TM,TMB,PMB,DELTMN,DTSTAG)                JET04400
      WRITE (6,704) R,VMN,TM,TMB,DELPW,DTSTAG                               JET04410
  704 FORMAT (30X,6(F10.5,2X))                                              JET04420
      R=R+DR                                                                JET04430
  703 CONTINUE                                                              JET04440
      PHI=PHI+DPHI                                                          JET04450
  750 CONTINUE                                                              JET04460
      WRITE (6,460)                                                         JET04470
```

Figure 69 - Continued

```
  460 FORMAT (//5X,'MAXIMUM GROUND PRESSURE AND TEMPERATURE ALONG UPWASH JET04480
     1GROUND STAGNATION LINE'//)                                          JET04490
      WRITE (6,470)                                                       JET04500
  470 FORMAT (14X,'XW/RN',6X,'XW/S',6X,'DPMAX/DPJ',3X,'PMAX/PMAXO',3X,'DJET04510
     1TMAX/DTJ',3X,'TMAX/TMAXO'/)                                         JET04520
      PHI=0.                                                              JET04530
      PHIM=80.*PI/180.                                                    JET04540
      DPHI=PHIM/24.                                                       JET04550
      DO 450 IL=1,25                                                      JET04560
      XW=SD*TAN(PHI)                                                      JET04570
      RW=SQRT(XW**2+SD**2)                                                JET04580
      XWS=XW/(2.*SD)                                                      JET04590
      CPHI2=COS(.5*PHI)                                                   JET04600
      TAEFF=1.+OMEG*CPHI2*CPHI2                                           JET04610
      TMEFF=TM+(TAEFF-1.)*(TGBS-TM)/(TGBS-1.)                             JET04620
      CALL WALLJT (RW,VMM,BWH,DELPW,TM,TMB,PMB,DELTMM,DTSTAG)             JET04630
      PMAXG=(PMB-1.)/(NPR-1.)+PMB*VMM*VMM*COS(PHI)*COS(PHI)/TM            JET04640
      TSG=TMB+(NTR-TM)*VMM*VMM*COS(PHI)*COS(PHI)                          JET04650
      TMAXG=(TSG-1.)/(NTR-1.)                                             JET04660
      IF (IL.EQ.1) DELPWO=PMAXG                                           JET04670
      IF (IL.EQ.1) DELTWO=TMAXG                                           JET04680
      PMAXND=PMAXG/DELPWO                                                 JET04690
      TMAXND=TMAXG/DELTWO                                                 JET04700
      WRITE (6,455) XW,XWS,PMAXG,PMAXND,TMAXG,TMAXND                      JET04710
  455 FORMAT (10X,8(F10.5,2X))                                            JET04720
      PHI=PHI+DPHI                                                        JET04730
  450 CONTINUE                                                            JET04740
      ACON=1.-(RO/SD)**2                                                  JET04750
      PHIOD=0.0                                                           JET04760
      IF (ACON.GE.0.) PHIO=0.0                                            JET04770
      IF (ACON.GE.0.) GO TO 667                                           JET04780
      PHIO=ARCOS((SD/RO)**.20)                                            JET04790
      PHIOD=PHIO*180./PI                                                  JET04800
      ACON=2./(SIN(.5*PI-PHIO)**2)                                        JET04810
      XMOMZ=ACON*(1.0+SIN(PHIO)*(SIN(PHIO)-2.0))/3.                       JET04820
      GO TO 668                                                           JET04830
  667 XMOMZ=ACON+2.*(1.-ACON)/3.                                          JET04840
  668 WRITE (6,553)                                                       JET04850
  553 FORMAT (//5X,'UPWASH MOMENTUM FUNCTION: JET RADIUS, INTERACTION     JET04860
     1CONSTANT, VERTICAL UPWASH SHEET MOMENTUM, AND COALESCENCE ANGLE'/)  JET04870
      WRITE (6,551) RO,ACON,XMOMZ,PHIOD                                   JET04880
  551 FORMAT (15X,'RO/RN=',F10.5,2X,'ACON=',F10.5,2X,'XMOMZ=',F10.5,2X,'JET04890
     1PHIO(DEGS)=',F10.5/)                                                JET04900
      CPHI2=1.                                                            JET04910
      TAEFF=1.+OMEG*CPHI2*CPHI2                                           JET04920
      TMEFF=TM+(TAEFF-1.)*(TGBS-TM)/(TGBS-1.)                             JET04930
      CALL WALLJT(SD,VMM,BWH,DELPW,TM,TMB,PMB,DELTMM,DTSTAG)              JET04940
      CALL PGUMST(CU,DELPS,DELPW,RO,SD,ALPG,ALPUG)                        JET04950
      CALL SIMW(KDELFI,NFD,ALPWFD,RATW,CSV2W,CFW)                         JET04960
      CALL SIMUG(ALPUG,RATUG,CSPUG)                                       JET04970
      CU=2.*4W3*CSV2W/(RATW*CSPUG)                                        JET04980
      WRITE (6,557) CU                                                    JET04990
  557 FORMAT (25X,'UPWASH WIDTH CONSTANT ESTIMATE , CU=',F10.5)           JET05000
      READ (5,661) IPBAR                                                  JET05010
  661 FORMAT (I1)                                                         JET05020
C                                                                         JET05030
C   TEST FOR INTERACTION OF DELFLECTION REGIONS                           JET05040
C                                                                         JET05050
      IF (CU*SD+RO.LE.SD) GO TO 222                                       JET05060
C                                                                         JET05070
C  COMPUTATION OF DEFLECTION REGION INTERACTION                           JET05080
C                                                                         JET05090
      CALL INTERG(XMOMZ,DELPS,SD,RO,ALPG,EPS,CU,SIG)                      JET05100
C                                                                         JET05110
      GO TO 223                                                           JET05120
  222 EPS=0.0                                                             JET05130
      SIG=1.0                                                             JET05140
      PHIUO=0.                                                            JET05150
      PHIO=0.0                                                            JET05160
      WRITE (6,28) EPS,SIG,PHIUO,PHIO                                     JET05170
   28 FORMAT (//20X,'JET AND UPWASH DEFLECTION REGIONS DO NOT INTERACT,   JET05180
     1 CU ESTIMATE IS CORRECT'/                                           JET05190
     1/35X,'EPS=',F10.5,2X,'SIG=',F10.5,2X,'PHIUO=',F10.5,2X,'PHIO=',F10JET05200
     1.5)                                                                 JET05210
      WRITE (6,25) ALPUG                                                  JET05220
```

Figure 69 - Continued

```
   29 FORMAT (30X,'PHIN=0.0 ALONG UPWASH  LINE, ALPHG=',F8.4,1X,' IN UPWJET05230
     1ASH REFLECTION REGION'/)                                          JET05240
      IF (IPBAR.NE.0) CALL GPLOT (ALPG,DELPS,SD,RO,EPS,CU,SIG,PHIUO,PHIGJET05250
     1)                                                                 JET05260
C                                                                       JET05270
C                                                                       JET05280
  223 WRITE (6,111)                                                     JET05290
  111 FORMAT (//30X,'*****      COMPUTATION OF UPWASH FLOW FIELD      ****JET05300
     1*'//)                                                             JET05310
      WRITE (6,112)                                                     JET05320
  112 FORMAT (//35X,'COMPUTATION OF UPWASH STREAMLINE PROPERTIES'/)      JET05330
      DPHI=5.* PI/180.                                                  JET05340
      PHI=0.                                                            JET05350
  113 FORMAT (//30X,'PHID=',F8.4,' DEGS'//)                             JET05360
      DO 600 I=1,2                                                      JET05370
      PHID=PHI*180./PI                                                  JET05380
      WRITE (6,114) PHID                                                JET05390
      ZEND=ZPLANE/COS(PHI)                                              JET05400
      Y=SD*TAN(PHI)                                                     JET05410
      RW=SQRT(SD**2+Y**2)                                               JET05420
      IF (RW.LE.RO) BWH=BWHO+DELBRH*(RW-RGH)                            JET05430
      IF (RW.GT.RO) BWH=AW3*RW                                          JET05440
      CPHI2=COS(.5*PHI)                                                 JET05450
      TAEFF=1.+OMEG*CPHI2*CPHI2                                         JET05460
      TNEFF=TN+(TAEFF-1.)*(TGBS-TN)/(TGBS-1.)                           JET05470
      CALL WALLJT(RW,VMN,BWHG,DELPWS,TM,TMB,PMB,DELTMN,DELTWS)          JET05480
      IWR=1                                                             JET05490
      CALL UPWAST(RO,RW,PHI,ZEND,BWHG,DELPS,DELPWS,DELTWS,VUN,DELPUJ    JET05500
     1,TM,TMB,DELTMN,DSTAG,BUH,ZOUS,IWR)                                JET05510
      PHI=PHI+DPHI                                                      JET05520
  600 CONTINUE                                                          JET05530
      NUPT=25                                                           JET05540
      XNUPT=NUPT-1                                                      JET05550
      ALPU=1.5                                                          JET05560
C                                                                       JET05570
C  CIRCULAR CYLINDER DRAG FUNCTION                                      JET05580
C                                                                       JET05590
      DRAG=SIN(PHISEP)*(1.-(4./3.)*(SIN(PHISEP)**2))                    JET05600
      DO 700  J=1,23                                                    JET05610
      SUMF=0.0                                                          JET05620
      SUMFC=0.0                                                         JET05630
      XB=0.                                                             JET05640
      DXB=XL2/XNUPT                                                     JET05650
      WRITE (6,116)                                                     JET05660
  116 FORMAT (/////30X,'UPWASH PROPERTIES COMPUTED AT Z LOCATION OF UNDEJET05670
     1RSIDE OF BODY'//)                                                 JET05680
      WRITE (6,118) ZPLANE                                              JET05690
  118 FORMAT (/35X,'BODY CENTERLINE LOCATION AT Z/RN=',F10.5//)          JET05700
      WRITE (6,78)                                                      JET05710
   78 FORMAT (//1X,'ZU/RN',5X,'RW/RN',5X,'PHIB',5X,'X/RN',5X,'VMU/VN',  JET05720
     13X,'DPU/PN',4X,'BUH/RN',2X,'DPU/PUO',1X,'DPU/PJS',3X,'TM/TA',3X,'DJET05730
     2TSM/DTN',1X,'PBS/PN'/)                                            JET05740
      IWR=0                                                             JET05750
      DO 500 I=1,NUPT                                                   JET05760
      FACT=2.0                                                          JET05770
      IF (I.EQ.1) FACT=1.0                                              JET05780
      IF (I.EQ.NUPT) FACT=1.                                            JET05790
      ZB=ZBODY(XB)                                                      JET05800
      PHIB=ATAN(XB/(SD+ZPLANE-ZB))                                      JET05810
      XW=SD*TAN(PHIB)                                                   JET05820
      RW=SQRT(SD**2+XW**2)                                              JET05830
      CPHI2=COS(.5*PHIB)                                                JET05840
      TAEFF=1.+OMEG*CPHI2*CPHI2                                         JET05850
      TNEFF=TN+(TAEFF-1.)*(TGBS-TN)/(TGBS-1.)                           JET05860
      CALL WALLJT(RW,VMN,BWHG,DELPWS,TM,TMB,PMB,DELTMN,DELTWS)          JET05870
      ZU=ZPLANE-ZB                                                      JET05880
      ZEND=ZU/COS(PHIB)                                                 JET05890
      CALL UPWAST (RO,RW,PHIB,ZEND,BWHG,DELPS,DELPWS,DELTWS,VUN,        JET05900
     1DELPUJ,TM,TMB,DELTMN,DTSTAG,BUH,ZOUS,IWR)                         JET05910
      THETB=ATAN(DZDXB(XB))                                             JET05920
      ETAWB=W2(XB)/(3.6*BUH)                                            JET05930
      IF (ETAWB.GT.1.) ETAWB=1.                                         JET05940
      FB=FETAWB(ETAWB,ALPU)                                             JET05950
      DCYL=W2(XB)*DRAG                                                  JET05960
      DFLAT=3.6*BUH*FB                                                  JET05970
      SUMF=SUMF+.5*DXB*FACT*DFLAT*(VUN**2)*(COS(PHIB+THETB)**2)/TM      JET05980
```

Figure 69 - Continued

```
      SUMFC=SUMFC+.5*DXB*FACT*DCYL*(VUN**2)*(COS(PHIB+THETB)**2)/TM      JET05990
      ZOU=ZOUS*COS(PHIB)                                                 JET06000
      PHID=PHIB*180./PI                                                  JET06010
      IF (ABS(PHID).LT.1.E-4) DELPM=DELPUJ                               JET06020
      IF (DELPM.NE.0.) DELPB=DELPUJ/DELPM                                JET06030
       IF (DELPM.EQ.0.) DELPB=DELPUJ                                     JET06040
      DELPUS=DELPUJ/DELPS                                                JET06050
      PBS=((VUN*COS(PHIB+THETB))**2)/TM                                  JET06060
      WRITE (6,77) ZU,RW,PHID,XB,VUN,DELPUJ,BUH,DELPB,DELPUS,TMB,DTSTAG,JET06070
     1PBS                                                                JET06080
   77 FORMAT (1X,11(F8.4,1X),F8.5)                                       JET06090
      XB=XB+DXB                                                          JET06100
  500 CONTINUE                                                           JET06110
C                                                                        JET06120
C  FLAT BOTTOM LIFT FORCE                                                JET06130
C                                                                        JET06140
      XLUT=(1./PI)*SUMF                                                  JET06150
      WRITE (6,778)                                                      JET06160
  778 FORMAT (//30X,'FLAT BOTTOM VEHICLE WITH SHARP CORNERS'/)           JET06170
      WRITE (6,771) XLUT                                                 JET06180
  771 FORMAT (35X,'UPWASH LIFT FORCE',5X,'LU/2TJ=',F10.5//)              JET06190
C                                                                        JET06200
C  UPWASH LIFT FORCE FOR CIRCULAR CROSS SECTION                          JET06210
C                                                                        JET06220
      XLUT=(1./PI)*SUMFC                                                 JET06230
      WRITE (6,773)                                                      JET06240
  773 FORMAT (//30X,'BODY WITH CIRCULAR CROSS SECTION'/)                 JET06250
      WRITE (6,771) XLUT                                                 JET06260
      ZPLANE=ZPLANE+2.*DZPL                                              JET06270
      IF (ZPLANE.GT.2.*ZFINAL) STOP                                      JET06280
  700 CONTINUE                                                           JET06290
      END                                                                JET06300
                                                                         JET06310
                                                                         JET06320
                                                                         JET06330
                                                                         JET06340
      SUBROUTINE VTSOLV (TN,BVH,ALPV,TLAM,VM,TM,RV,RT)                   JET06350
      RCON=(2.-SQRT(2.))/2.                                              JET06360
C     WRITE (6,200) TN,BVH,ALPV,ALPT                                     JET06370
  200 FORMAT (1X,'TN=',F10.5,2X,'BVH=',F10.3,2X,'ALPV=',F10.5,2X,'ALPT='JET06380
     1,F10.5)                                                            JET06390
      DTN=TN-1.                                                          JET06400
      REL=.5                                                             JET06410
      DELMIN=1.E-5                                                       JET06420
      RV=(RCON)**(1./ALPV)                                               JET06430
      RT=RV                                                              JET06440
      ALPT=ALPV                                                          JET06450
      VM=1.                                                              JET06460
      TM=1.                                                              JET06470
      DO 100 I=1,500                                                     JET06480
      CALL SIMTV(TN,TM,ALPV,TLAM,CM,CT,CNTM,CTTM)                        JET06490
C     WRITE (6,203) CM,CT,CNTM,CTTM                                      JET06500
  203 FORMAT (1X,'CM=',F10.5,2X,'CT=',F10.5,2X,'CNTM=',F10.5,2X,         JET06510
     1'CTTM=',F10.5)                                                     JET06520
      F=RV*RV*TM-2.*VM*BVH*BVH*CM                                        JET06530
      G=DTN*TM*RV*RV-2.*VM*(TM*TN-1.)*BVH*BVH*CT                         JET06540
      FTM=TM-2.*VM*BVH*BVH*CNTM                                          JET06550
      FVM=-4.*VM*BVH*BVH*CM                                              JET06560
      GTM=DTN*RV*RV-2.*VM*(TM*TN-1.)*BVH*BVH*CTTM-2.*VM*BVH*BVH*CT*TN    JET06570
      GVM=-2.*(TM*TN-1.)*BVH*BVH*CT                                      JET06580
      DET=FVM*GTM-GVM*FTM                                                JET06590
      DELVM=(G*FTM-F*GTM)/DET                                            JET06600
      DELTM=(F*GVM-G*FVM)/DET                                            JET06610
      VM=VM+REL*DELVM                                                    JET06620
      TM=TM+REL*DELTM                                                    JET06630
C     WRITE (6,505) VM,DELVM,TM,DELTM,F,G                                JET06640
  505 FORMAT (1X,'VM=',F10.5,1X,'DELV=',F10.5,1X,'TM=',F10.5,2X,'DTM=',FJET06650
     110.5,1X,'F=',F10.5,1X,'G=',F10.5)                                  JET06660
      IF (ABS(F).LT.DELMIN.AND.ABS(G).LT.DELMIN) GO TO 101               JET06670
  100 CONTINUE                                                           JET06680
      STOP                                                               JET06690
  101 RETURN                                                             JET06700
      END                                                                JET06710
                                                                         JET06720
                                                                         JET06730
                                                                         JET06740
                                                                         JET06750
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Figure 69 - Continued

```
      SUBROUTINE WALLJT (R,VMN,BWH,DELPJ,TM,TMB,PMB,DELTMN,DTSTAG)        JET06760
      REAL KDELO,NO,KDELFD,NFD,N,KDEL,NPR,NTR,MACH                       JET06770
      COMMON/WALL/ DELS,NO,KDELO,ALPG,ALPWO,ALPWFD,RO,RGH,VG,BWHO        JET06780
      COMMON/WALLT/TLAMI,DELPS,DELTSB,PSBAR                              JET06790
      COMMON /NOZZLE/ NPR,NTR,TM,GAM,MACH,ACHS,TAEFF,TNEFF               JET06800
      RCON=(2.-SQRT(2.))/2.                                              JET06810
      NFD=7.0                                                            JET06820
      KDELFD=1./9.                                                       JET06830
      BW3HO=AW3*RO                                                       JET06840
      AW=.09*(1.+ALOG(2./(1.+1./TM**.5)))*(1.-.16*ACHS)                  JET06850
      BWHO=AW3*RO                                                        JET06860
      DELBRH=(BW3HO-BWHO)/(RO-RGH)                                       JET06870
      DELNR=(NFD-NO)/(RO-RGH)                                            JET06880
      DELAR=(ALPWFD-ALPWO)/(RO-RGH)                                      JET06890
      ADELBT=.0175                                                       JET06900
      ADELBL=(ADELBT*(RO-2.)-DELS)/(RO-RGH)                              JET06910
      TLAMFD=1.+.185*TM**.5                                              JET06920
      TLAMSL=(TLAMFD-TLAMI)/(RO-RGH)                                     JET06930
      IF (R.GE.RGH) TLAM=TLAMI+TLAMSL*(R-RGH)                            JET06940
      IF (R.LT.RGH) TLAM=TLAMI                                           JET06950
      IF (R.LE.RO) FETA=(1.-(R/RO)**ALPG)**4                             JET06960
      IF (R.GT.RO) FETA=0.0                                              JET06970
      IF (R.GT.RO) TLAM=TLAMFD                                           JET06980
      PMB=1.+(NPR-1.)*DELPS*FETA                                         JET06990
      IF (R.GT.RGH) GO TO 402                                            JET07000
      TMB=1.+DELTSB                                                      JET07010
      TM=TMB/NTR                                                         JET07020
      ACHI=SQRT(2.*(PSBAR/PMB-1.)/GAM)                                   JET07030
      VMN=(ACHI/MACH)*SQRT(TMB/NTR)                                      JET07040
      DELPJ=DELPS                                                        JET07050
      DELTA=KDELO*BWO                                                    JET07060
      N=14                                                               JET07070
      KDEL=KDELO                                                         JET07080
      BW=BWO                                                             JET07090
      BWH=RATWO*BWO                                                      JET07100
      VMG=VMN/VG                                                         JET07110
      BWHT=TLAMI*BWH                                                     JET07120
      DELTMN=(TMB-1.)/(NTR-1.)                                           JET07130
      TMSTAG=TMB                                                         JET07140
      DTSTAG=(TMSTAG-1.)/(NTR-1.)                                        JET07150
      GO TO 401                                                          JET07160
  402 IF (R.GT.RO) GO TO 403                                             JET07170
      BWH=BWHO+DELBRH*(R-RGH)                                            JET07180
      ALPW=ALPWO+DELAR*(R-RGH)                                           JET07190
      DELBL=DELS+ADELBL*(R-RGH)                                          JET07200
      N=NO+DELNR*(R-RGH)                                                 JET07210
      GO TO 405                                                          JET07220
  403 BWH=AW3*R                                                          JET07230
      DELBL=ADELBT*(R-2.)                                                JET07240
      N=NFD                                                              JET07250
      ALPW=ALPWFD                                                        JET07260
  405 ALAM=((2.-SQRT(2.))/2.)**(1./ALPW)                                 JET07270
      KDEL=DELBL/(DELBL+(BWH-DELBL)/ALAM)                                JET07280
      IF (R.LE.4.) FVIS=1.0                                              JET07290
      IF (R.GT.4.) FVIS=1./(R/4.)**.24                                   JET07300
      FMOM=1.-FETA                                                       JET07310
      DELPM=DELPS*FETA                                                   JET07320
      CALL VTWALL (R,BWH,FVIS,FMOM,DELPM,TM,TLAM,PMB,KDEL,N,ALPW,        JET07330
     1VMN,TM,TNEFF,TAEFF)                                                JET07340
      VMG=VMN/VG                                                         JET07350
      RCON=(2.-SQRT(2.))/2.                                              JET07360
      RAT=KDEL+(1.-KDEL)*RCON**(1./ALPW)                                 JET07370
      BW=BWH/RAT                                                         JET07380
      DELTA=KDEL*BW                                                      JET07390
      DELPJ=(PMB-1.)/(NPR-1.)+PMB*VMN*VMN/TM                             JET07400
      TMB=TM*NTR                                                         JET07410
      BWHT=TLAM*BWH                                                      JET07420
      DELTMN=(TMB-1.)/(NTR-1.)                                           JET07430
      TMSTAG=TMB                                                         JET07440
      DTSTAG=(TMSTAG-1.)/(NTR-1.)                                        JET07450
C 401 WRITE (6,95) R,VMG,VMN,BWH,BW,DELTA,DELPJ,KDEL,TM,TMB              JET07460
C    1,BWHT,DELTMN,DTSTAG                                                JET07470
  401 CONTINUE                                                           JET07480
      R=R+DR                                                             JET07490
   95 FORMAT (1X,5(F8.4,2X),6(F7.4,1X))                                  JET07500
      RETURN                                                             JET07510
      END                                                                JET07520
```

Figure 69 - Continued

```
                                                                        JET07530
                                                                        JET07540
                                                                        JET07550
                                                                        JET07560
      SUBROUTINE VTWALL (R,BWH,FVIS,FMOM,DPM,TM,TLAM,PMB,KDEL,N,ALPV,VM,JET07570
     1TM,TNEFF,TAEFF)                                                   JET07580
      REAL KDEL,N                                                       JET07590
      VM=1.                                                             JET07600
      TM=1.                                                             JET07610
      DELMIN=1.E-5                                                      JET07620
      REL=.5                                                            JET07630
      DO 100 I=1,500                                                    JET07640
      TMB=TM*TM                                                         JET07650
      CALL SIMUTV (TM,TM,TLAM,PMB,KDEL,N,ALPV,CV2,CP,CT,CV2TM,CTTM,     JET07660
     1RV)                                                               JET07670
      F=RV*FMOM*FVIS-R*BWH*(2.*PMB*VM*VM*CV2/TM+DPM*CP)                 JET07680
      G=RV*FMOM*(TNEFF-TAEFF)*TM-2.*PMB*VM*(TMB-TAEFF)*R*BWH*CT         JET07690
      FVM=-4.*R*BWH*(PMB*VM*CV2/TM)                                     JET07700
      FTM=2.*R*BWH*PMB*VM*VM*(CV2/(TM*TM)-CV2TM/TM)                     JET07710
      GVM=-2.*PMB*(TMB-TAEFF)*R*BWH*CT                                  JET07720
      GTM=RV*FMOM*(TNEFF-TAEFF)-2.*PMB*VM*R*BWH*(CT*TM+(TMB-TAEFF)*CTTM)JET07730
      DET=FVM*GTM-GVM*FTM                                               JET07740
      DELVM=(G*FTM-F*GTM)/DET                                           JET07750
      DELTM=(F*GVM-G*FVM)/DET                                           JET07760
      VM=VM+REL*DELVM                                                   JET07770
      TM=TM+REL*DELTM                                                   JET07780
C     WRITE (6,705) F,G,VM,TM                                           JET07790
  705 FORMAT (1X,'F=',F10.5,2X,'G=',F10.5,1X,'VM=',F10.5,1X,'TM=',F10.5)JET07800
      IF (ABS(F) .LT. DELMIN.AND.ABS(G).LT.DELMIN) GO TO 101            JET07810
  100 CONTINUE                                                          JET07820
      STOP                                                              JET07830
  101 CONTINUE                                                          JET07840
      RETURN                                                            JET07850
      END                                                               JET07860
                                                                        JET07870
                                                                        JET07880
                                                                        JET07890
                                                                        JET07900
      SUBROUTINE UPWAST (RO,RWALL,PHI,ZEND,BWGH,DELPS,DELPWS,DELTWS,    JET07910
     1VMUN,DELPUJ,TM,TMB,DELTMN,DTSTAG,BGH,ZOU,IWR)                     JET07920
      REAL NPR,NTR,MOMU                                                 JET07930
      COMMON /JET/ SD,RGH                                               JET07940
      COMMON/NOZZLE/NPR,NTR,TN,GAM,MACH,ACHS,TAEFF,TNEFF                JET07950
      REAL MACH                                                         JET07960
C                                                                       JET07970
C THIS ROUTINE COMPUTES THE UPWASH STREAMLINE PROPERTIES                 JET07980
C                                                                       JET07990
      AOU=3.                                                            JET08000
      PI=3.14159265                                                     JET08010
      ALPUP=1.5                                                         JET08020
      ALPUM=1.5                                                         JET08030
      ACON=1.-(RGH/SD)**2                                               JET08040
      IF (ACON.GE.0.) GO TO 907                                         JET08050
      PHIO=ARCOS((SD/RGH)**.20)                                         JET08060
      ACON=2./(SIN(.5*PI-PHIO)**2)                                      JET08070
      PHIOD=PHIO*180./PI                                                JET08080
      IF (PHI.GE.PHIO) MOMU=ACON*SIN(PHI-PHIO)**2                       JET08090
      IF (PHI.LT.PHIO) MOMU=0.                                          JET08100
      GO TO 909                                                         JET08110
  907 MOMU=ACON+2.*(1.-ACON)*SIN(PHI)**2                                JET08120
  909 CONTINUE                                                          JET08130
  773 FORMAT (1X,'ACON=',F10.5,2X,'MOMU=',F10.5)                        JET08140
      AU3=.30                                                           JETC8150
      ALU1=.5                                                           JET08160
      ALU2=.8                                                           JET08170
      ZOU=AOU*BWGH                                                      JET08180
C     WRITE (6,108) SD,RGH,ZOU                                          JET08190
  108 FORMAT (1X,'JET',3F10.5)                                          JET08200
      ZV=ZOU*COS(PHI)                                                   JET08210
      ALU=.5                                                            JET08220
      ALPU=1.5                                                          JET08230
      CALL SIMU(ALPU,RAT,CV2U)                                          JET08240
C     WRITE (6,111) CV2U                                                JET08250
  111 FORMAT (1X,'SIMU',F10.5)                                          JET08260
C                                                                       JET08270
C   DETERMINE DEPATURE FROM INVISCID DEFLECTION                         JET08280
```

Figure 69 - Continued

```
C  DETERMINE INITIAL UPWASH WIDTH                                        JET06290
C                                                                        JET08300
      DELPWJ=DELPWS                                                      JET08310
      ZETAG=BWGH/ZOU                                                     JET08320
      FETAGP=(1.-ZETAG**ALPUP)**4                                        JET08330
C     WRITE (6,117) ZETAG,FETAGP                                         JET08340
  117 FORMAT (1X,'ZETAG=',F10.5,2X,'FETAGP=',F10.5)                      JET08350
      FETAGM=(1.-ZETAG**ALPUM)**4                                        JET08360
      FMOMU=MOMU*(1.-FETAGM)                                             JET08370
      PMBI=1.+(NPR-1.)*DELPWJ*FETAGP                                     JET08380
      DELPWB=(NPR-1.)*DELPWJ                                             JET08390
      PSB=1.+DELPWB                                                      JET08400
      DELTSB=(NTR-1.)*DELTWS                                             JET08410
C     WRITE (6,107) DELPWB,DELTSB                                        JET08420
  107 FORMAT (1X,'DTS=',F10.5,2X,'DTT=',F10.5)                           JET08430
      ACHI=SQRT(2.*(PSB/PMBI-1.)/GAM)                                    JET08440
      TMBI=1.+DELTSB                                                     JET08450
      VMNUI=(ACHI/MACH)*SQRT(TMBI/NTR)                                   JET08460
      TMI=TMBI/NTR                                                       JET08470
      IF (IWR.NE.0) WRITE (6,55) VMNUI,TMBI,DELPWJ,DELTWS,BWGH           JET08480
   55 FORMAT (1X,'INV.VEL.=',F10.5,3X,'TMI/TA=',F10.5,2X,'DELPWJ=',F10.5JET08490
     1,2X,'DELTWJ=',F10.5,2X,'BWGH/RN=',F10.5)                           JET08500
      RAY=RWALL+BWGH                                                     JET08510
      CALL SIMUM (TN,TMI,TLAMI,PMBI,ALPU,FETAGP,DELPWJ,VMNUI,BUON,RAY,   JET08520
     1RAT,FMOMU,TNEFF,TAEFF)                                             JET08530
      BUOHN=RAT*BUON                                                     JET08540
      IF (ABS(MOMU).LT.1.E-5) BUON=1.E-5                                 JET08550
      IF (ABS(MOMU).LT.1.E-5) BUOHN=1.E-5                                JET08560
      IF (IWR.NE.0) WRITE (6,10) ZOU,BUON,BUOHN,TLAMI                    JET08570
   10 FORMAT (1X,'ZOU/RN=',F10.5,2X,'BUO/RN=',F10.5                      JET08580
     1,2X,'BUOHN/RN=',F10.5,2X,'TLAMI=',F10.5//)                         JET08590
      NUPT=25                                                            JET08600
      XNUPT=NUPT-1                                                       JET08610
      DZ=(ZEND-BWGH)/XNUPT                                               JET08620
      Z=BWGH                                                             JET08630
      IF (IWR.NE.0) WRITE (6,12)                                         JET08640
   12 FORMAT (3X,'Z/RN',7X,'VMU/VN',7X,'TM/TN',7X,'TM/TA',7X,'BUH/RN',6 JET08650
     1X,'BU/RN',6X,'DPU/DPJ',6X,'DTM/DTN',/)                             JET08660
      TLAMFD=1.+.185*TN**.5                                              JET08670
      TLAMSL=(TLAMFD-TLAMI)/(ZOU-BWGH)                                   JET08680
      TM=TMI                                                             JET08690
      VMUN=VMNUI                                                         JET08700
      DO 100 I=1,NUPT                                                    JET08710
      BUH=BUOHN+AU3*(Z-BWGH)*(COS(PHI)**ALU1)                            JET08720
      BU=BUH/RAT                                                         JET08730
      ZETA=Z/ZOU                                                         JET08740
      IF (Z.GE.ZOU) ZETA=1.                                              JET08750
      IF (Z.GT.ZOU) TLAM=TLAMFD                                          JET08760
      IF (Z.LE.ZOU) TLAM=TLAMI+TLAMSL*(Z-BWGH)                           JET08770
      FETAP=(1.-ZETA**ALPUP)**4                                          JET08780
      FETAM=(1.-ZETA**ALPUM)**4                                          JET08790
      RAY=RWALL+Z                                                        JET08800
      FMOM=MOMU*(1.-FETAM)                                               JET08810
      DPM=DELPWJ*FETAP                                                   JET08820
      PMB=1.+(NPR-1.)*DPM                                                JET08830
      CALL VTUPW (RAY,BUH,FMOM,DPM,TN,TLAM,PMB,ALPU,VMUN,TM,TNEFF,TAEFF) JET08840
  905 DELPUJ=(PMB-1.)/(NPR-1.)+PMB*VMUN*VMUN/TM                          JET08850
      TMB=TM*NTR                                                         JET08860
      DELTMN=(TMB-1.)/(NTR-1.)                                           JET08870
      TMSTAG=TMB                                                         JET08880
      DTSTAG=(TMSTAG-1.)/(NTR-1.)                                        JET08890
      IF (IWR.EQ.0) DELPUJ=DELPUJ/DELPS                                  JET08900
      IF (IWR.NE.0) WRITE (6,11) Z,VMUN,TM,TMB,BUH,BU,DELPUJ,DELTMN      JET08910
   11 FORMAT (2X,9(F10.5,2X))                                            JET08920
      Z=Z+DZ                                                             JET08930
  100 CONTINUE                                                           JET08940
      RETURN                                                             JET08950
      END                                                                JET08960
                                                                         JET08970
                                                                         JET08980
                                                                         JET08990
                                                                         JET09000
```

Figure 69 - Continued

```
      SUBROUTINE VTUPW (R,BUH,FMOM,DFM,TN,TLAM,FMB,ALPV,VM,TM,TMEFF,     JET09010
     1TAEFF)                                                             JET09020
      DELMIN=1.E-5                                                       JET09030
      REL=.5                                                             JET09040
      DO 100 I=1,500                                                     JET09050
      TMB=TM*TN                                                          JET09060
      CALL SIMUTV (TN,TM,TLAM,FMB,ALPV,CV2,CF,CT,CV2TM,CTTM,RV)          JET09070
      F=RV*FMOM-R*BUH*(2.*FMB*VM*VM*CV2/TM+DFM*CP)                       JET09080
      G=RV*FMOM*(TMB-1.)*TM-2.*FMB*VM*(TMB-1.)*R*BUH*CT                  JET09090
C     WRITE (6,111) F,G,TM,VM                                            JET09100
  111 FORMAT (1X,'F=',F10.5,2X,'G=',F10.5,2X,'TM=',F10.5,2X,'VM=',F10.5)JET09110
      FVM=-4.*R*BUH*(FMB*VM*CV2/TM)                                      JET09120
      FTM=2.*R*BUH*FMB*VM*VM*(CV2/(TM*TM)-CV2TM/TM)                      JET09130
      GVM=-2.*FMB*(TMB-1.)*R*BUH*CT                                      JET09140
      GTM=RV*FMOM*(TN-1.)-2.*FMB*VM*R*BUH*(CT*TN+(TMB-1.)*CTTM)          JET09150
      DET=FVM*GTM-GVM*FTM                                                JET09160
      DELVM=(G*FTM-F*GTM)/DET                                            JET09170
      DELTM=(F*GVM-G*FVM)/DET                                            JET09180
      VM=VM+REL*DELVM                                                    JET09190
      TM=TM+REL*DELTM                                                    JET09200
C     WRITE (6,705) F,G,VM,TM                                            JET09210
  705 FORMAT (1X,'F=',F10.3,2X,'G=',F10.5,1X,'VM=',F10.5,1X,'TM=',F10.5)JET09220
      IF (ABS(F).LT.DELMIN.AND.ABS(G).LT.DELMIN) GO TO 101               JET09230
  100 CONTINUE                                                           JET09240
      STOP                                                               JET09250
  101 CONTINUE                                                           JET09260
      RETURN                                                             JET09270
      END                                                                JET09280
                                                                         JET09290
                                                                         JFT09300
                                                                         JET09310
                                                                         JET09320
      SUBROUTINE INTERG (XLAM,DELPS,SD,RO,ALPB,EPS,CU,SIG)               JET09330
C                                                                        JET09340
C  MAIN ROUTINE FOR COMPUTING GROUND PRESSURE DISTRIBUTION               JET09350
C   THIS ROUTINE FINDS THE SOLUTION FOR THE UPWASH THICKNESS AND         JET09360
C   JET IMPINGEMENT PERTURBATION PARAMETERS SIGMA AND EPS BY             JET09370
C   MATCHING PRESSURE INTEGRALS                                          JET09380
C                                                                        JET09390
      COMMON /HEIGHT/ HD,IPBAR                                           JET09400
      DIMENSION EP(200),C(200),PHIU(200),PHI(200),CSJ(200),FUI(4),FJI(4)JET09410
      CSPJ(ETA,A)=.5*ETA**2-(4./(A+2.))*ETA**(A+2)+(3./(A+1.))*ETA**(2.JET09420
     1*A+2.)-(4./(3.*A+2.))*ETA**(3.*A+2.)+(1./(4.*A+2.))*ETA**(4.*A+2.)JET09430
      FETA(ETA,A)=(1.-ETA**A)**34                                        JET09440
      EP(1)=.0                                                           JET09450
      WRITE (6,777)                                                      JET09460
  777 FORMAT (///1X,'*** CALL INTERG ***'//)                             JET09470
      IFLAG=0                                                            JET09480
      C(1)=1.                                                            JET09490
      PI=3.14159265                                                      JET09500
      SIGI=1.0                                                           JET09510
      CUI=CU                                                             JET09520
      ALU=1.0                                                            JET09530
      PARM=.01                                                           JET09540
      DO 900 J=1,100                                                     JET09550
      EPI=EP(J)                                                          JET09560
      SIGI=C(J)                                                          JET09570
      DO 1000 ITR=1,4                                                    JET09580
      IF (ITR.EQ.2) EPI=EP(J)+PARM                                       JET09590
      IF (ITR.EQ.3) EPI=EP(J)                                            JET09600
      IF (ITR.EQ.4) SIGI=C(J)+PARM                                       JET09610
C                                                                        JET09620
C   SOLVE FOR INTERSECTION OF PRESSURE BOUNDARIES                        JET09630
C                                                                        JET09640
      DO 100 I=1,99                                                      JET09650
      IF (I.EQ.1) PHIU(1)=1.42                                           JET09660
      YU=SD*TAN(PHIU(I))                                                 JET09670
      XUP=SD/(COS(PHIU(I))**2)                                           JET09680
      YU=CUI*SIGI*SD/(COS(PHIU(I))**ALU)                                 JET09690
      YUP=-CUI*SIGI*SD*ALU/(COS(PHIU(I))**(ALU+1.))                      JET09700
      RUSQ=XU**2+(SD-YU)**2                                              JET09710
      RU=SQRT(RUSQ)                                                      JET09720
      ROP=RO+EPI*(1.+((SD-YU)/RU))                                       JET09730
      ROPSQ=ROP**2                                                       JET09740
      F=RUSQ-ROPSQ                                                       JET09750
      FP=2.*XU*XUP-2.*(SD-YU)*YUP-2.*EPI*ROP*(SD-YU)*                    JET09760
     1(YUP/RU+(2.*XU*XUP-2.*(SD-YU)*YUP)/RUSQ)                           JET09770
      PHIU(I+1)=PHIU(I)-F/FP                                             JET09780
      IF (ABS(PHIU(I+1)-PHIU(I)).LT.1.E-5) GO TO 101                     JET09790
```

Figure 69 - Continued

ORIGINAL PAGE IS
OF POOR QUALITY

```
  100 CONTINUE                                                          JET09800
      STOP                                                              JET09810
  101 PHIUO=PHIU(I+1)                                                   JET09820
      PHIUOD=PHIUO*180./PI                                              JET09830
      YUO=CUI*SIGI*SD/(COS(PHIUO)**ALU)                                 JET09840
      PHIO=ATAN2(SD*TAN(PHIUO),SD-YUO)                                  JET09850
      PHIOD=PHIO*180./PI                                                JET09860
      IF (IFLAG.EQ.1) WRITE (6,10) EPI,CUI,PHIUOD,PHIOD                 JET09870
   10 FORMAT (15X,'EPI=',F10.5,2X,'CUI=',F10.5,2X,'PHIUO=',F10.5        JET09880
     1,2X,'PHIO=',F10.5,2X,'DEGREES')                                   JET09890
C                                                                       JET09900
C DETERMINE MOMENTUM INTEGRAL FOR IMPINGEMENT REGION                    JET09910
C                                                                       JET09920
      NUPTS=99                                                          JET09930
      IF (J.GT.20) NUPTS=198                                            JET09940
      XPTS=NUPTS-1.                                                     JET09950
      DPHIU=PHIUO/XPTS                                                  JET09960
      PHIU(1)=0.                                                        JET09970
      SUMU1=0.                                                          JET09980
      DO 200 IJ=1,NUPTS                                                 JET09990
      FACT=2.0                                                          JET10000
      IF (IJ.EQ.1) FACT=1.0                                             JET10010
      IF (IJ.EQ.NUPTS) FACT=1.0                                         JET10020
      RW=SD/COS(PHIU(IJ))                                               JET10030
      CALL WALLJ (RW,VMN,DUM2,DUM3,DUM4,DELPW)                          JET10040
      IF (IJ.EQ.1.AND.IFLAG.EQ.1) WRITE (6,111) DELPW                   JET10050
  111 FORMAT (35X,'PHI=0.0, DELPWO=',F10.5)                             JET10060
      YU=CUI*SIGI*SD/COS(PHIU(IJ))                                      JET10070
      XU=SD*TAN(PHIU(IJ))                                               JET10080
      PHI(IJ)=ATAN2(XU,SD-YU)                                           JET10090
      RU=(SD-YU)/COS(PHI(IJ))                                           JET10100
      ROP=RO+EPI*(1.+COS(PHI(IJ)))                                      JET10110
      ETAM=RU/ROP                                                       JET10120
      IF (ETAM.GT.1.) FETAG=0.0                                         JET10130
      IF (ETAM.GT.1.) GO TO 1011                                        JET10140
      FETAG=FETA(ETAM,ALPG)                                             JET10150
 1011 PMIN=DELPS*FETAG                                                  JET10160
      IF (IJ.EQ.1.AND.IFLAG.EQ.1) WRITE (6,775) PMIN                    JET10170
  775 FORMAT (35X,'PHI=0.0, PMIN=',F10.5)                               JET10180
      PMAX=DELPW-VMN**2+(VMN*COS(PHIU(IJ)))**2                          JET10190
      CALL PMATCH (PMIN,PMAX,ALPUG)                                     JET10200
      IF (IJ.EQ.1.AND.IFLAG.EQ.1) WRITE (6,1055) ALPUG                  JET10210
 1055 FORMAT (35X,'PHI=0.0, ALPUO=',F10.5)                              JET10220
      CALL SIMUO(ALPUO,RATU,CSPUO)                                      JET10230
      PMAX=DELPW-VMN**2+(VMN*COS(PHIU(IJ)))**2                          JET10240
      FU=DELPS*FETAG+CSPUO*(PMAX-DELPS*FETAG)                           JET10250
      FUT=SIGI*FU/(COS(PHIU(IJ))**3)                                    JET10260
      SUMU1=SUMU1+.5*DPHIU*FACT*FUT                                     JET10270
      IF (ETAM.GT.1.) ETAM=1.0                                          JET10280
      CSJ(IJ)=CSPJ(ETAM,ALPG)                                           JET10290
      PHIU(IJ+1)=PHIU(IJ)+DPHIU                                         JET10300
  200 CONTINUE                                                          JET10310
      XI1UG=CUI*SUMU1*SD**2                                             JET10320
      SUMI=0.                                                           JET10330
      NUPTSM=NUPTS-1                                                    JET10340
      DO 300 IJ=1,NUPTSM                                                JET10350
      ROPP=RO+EPI*(1.+COS(PHI(IJ+1)))                                   JET10360
      ROPPSQ=ROPP**2                                                    JET10370
      ROPM=RO+EPI*(1.+COS(PHI(IJ)))                                     JET10380
      ROPMSQ=ROPM**2                                                    JET10390
      FM=ROPMSQ*CSJ(IJ)                                                 JET10400
      FP=ROPPSQ*CSJ(IJ+1)                                               JET10410
      DPHI=PHI(IJ+1)-PHI(IJ)                                            JET10420
      SUMI=SUMI+.5*DPHI*(FM+FP)                                         JET10430
  300 CONTINUE                                                          JET10440
      XI1JG=DELPS*SUMI                                                  JET10450
      CALL SIM(0.0,ALPG,R[illegible]3,CSPJG)                            JET10460
      XI2JG=CSPJG*DELPS*((PI-PHIO)*(RO*(RO+2.*EPI)+1.5*EPI**2)          JET10470
     1-2.*EPI*(RO+EP1)*SIN(PHIO)-.25*SIN(2.*PHIO)*EPI**2)               JET1048[illegible]
      XJI=XI1JG+XI2JG                                                   JET10490
      FJI(ITR)=XJI-PI                                                   JET10500
      DPHIU=(.5*PI-PHIUO)/XPTS                                          JET10510
      SUMU2=0.0                                                         JET10520
      PH=PHIUO                                                          JET10530
      XI2UG=SIGI*(1.-SIN(PHIUO))                                        JET10540
      FUI(ITR)=XI1UG+XI2UG-XLAM                                         JET10550
```

Figure 69 - Continued

```
      IF (IFLAG.EQ.1) GO TO 907                                          JET10560
      IF (ITR.EQ.1) GO TO 1000                                           JET10570
      RELAX=.5                                                           JET10580
      DEPI=PARM                                                          JET10590
      DCUI=PARM                                                          JET10600
      IF (ITR.EQ.2) FUIE=(FUI(ITR)-FUI(ITR-1))/DEPI                      JET10610
      IF (ITR.EQ.4) FUIC=(FUI(ITR)-FUI(ITR-1))/DCUI                      JET10620
      IF (ITR.EQ.2) FJIE=(FJI(ITR)-FJI(ITR-1))/DEPI                      JET10630
      IF (ITR.EQ.4) FJIC=(FJI(ITR)-FJI(ITR-1))/DEPI                      JET10640
 1000 CONTINUE                                                           JET10650
      DET=FUIE*FJIC-FJIE*FUIC                                            JET10660
      DELE=(FJI(1)*FUIC-FUI(1)*FJIC)/DET                                 JET10670
      DELC=(FUI(1)*FJIE-FJI(1)*FUIE)/DET                                 JET10680
      EP(J+1)=EP(J)+RELAX*DELE                                           JET10690
      C(J+1)=C(J)+RELAX*DELC                                             JET10700
  905 FORMAT (15X,'ITERATION CYCLE=',I3,2X,'EPS=',F10.5,2X,'SIGMA=',F10.JET10710
     15)                                                                 JET10720
      IF (ABS(DELE).LT.1.E-5)AND.ABS(DELC).LT.1.E-5) IFLAG=1             JET10730
      IF (IFLAG.EQ.1) WRITE (6,909)                                      JET10740
  909 FORMAT (20X,'SOLUTION OF GROUND PRESSURE DISTRIBUTION HAS BEEN FOUJET10750
     1ND')                                                               JET10760
      IF (IFLAG.EQ.1) WRITE (6,905) J,EP(J+1),C(J+1)                     JET10770
  900 CONTINUE                                                           JET10780
      STOP                                                               JET10790
  907 SIG=C(J)                                                           JET10800
      EPS=EP(J)                                                          JET10810
      CUU=SIG*CUI                                                        JET10820
      WRITE (6,13) CUU                                                   JET10830
   13 FORMAT (20X,'UPWASH THICKNESS CONSTANT, (CU) X (SIGMA)=',F10.5)    JET10840
      IF (IPBAR.NE.0) CALL GPLOT(ALPG,DELPS,SD,RO,EPS,CUI,SIG,PHIUO,PHIOJET10850
     1)                                                                  JET10860
      RETURN                                                             JET10870
      END                                                                JET10880
                                                                         JET10890
                                                                         JET10900
                                                                         JET10910
                                                                         JET10920
      SUBROUTINE GPLOT (ALPG,DELPS,SD,RO,EPS,CUI,SIGI,PHIUO,PHIO)        JET10930
      DIMENSION PU(25),RWALL(102),ERR(102),XPLOTU(202),YPLOTU(           JET10940
     1202),XPLOTJ(202),YPLOTJ(202),XAXIS(30),YAXIS(30),XDATA(10),YDATA(1JET10950
     20)                                                                 JET10960
      COMMON /HEIGHT/ HD,IPBAR                                           JET10970
C                                                                        JET10980
C  THIS ROUTINE COMPUTES THE GROUND ISOBAR PATTERN FOR THE TWO-JET       JET10990
C   IMPINGEMENT FLOW FIELD                                               JET11000
C                                                                        JET11010
      FETA(ETA,A)=(1.-ETA**A)**4                                         JET11020
C                                                                        JET11030
C   INPUT NUMBER OF ISOBAR VALUES                                        JET11040
C                                                                        JET11050
      READ(5,51) NU                                                      JET11060
   51 FORMAT (I2)                                                        JET11070
      WRITE (6,53) NU                                                    JET11080
   53 FORMAT ('1',//30X,'***  COMPUTATION OF TWO-JET GROUND ISOBAR PATTEJET11090
     1RN ***'///32X,I2,' VALUES OF PRESSURE SPECIFIED FOR PATTERN'       JET11100
     2//)                                                                JET11110
C                                                                        JET11120
C   INPUT NU ISOBAR VALUES FOR GROUND PATTERN                            JET11130
C                                                                        JET11140
      READ(5,1) (PU(I),I=1,NU)                                           JET11150
    1 FORMAT (F10.5)                                                     JET11160
      WRITE (6,112) (PU(I),I=1,NU)                                       JET11170
  112 FORMAT (10X,'PBAR=',8(F10.5,2X))                                   JET11180
      WRITE (6,121)                                                      JET11190
  121 FORMAT (//25X,'GROUND PATTERN IN JET CENTERED COORDINATE SYSTEM'//JET11200
     1)                                                                  JET11210
      NUPTS=29                                                           JET11220
C     CALL PLOT(6.,0.,-3)                                                JET11230
      XLMAX=RO+SD                                                        JET11240
C     XSC=XLMAX/8.                                                       JET11250
      XSC=1.0                                                            JET11260
      XMIN=0.                                                            JET11270
      DXMIN=-1.                                                          JET11280
      DO 801 IP=1,100                                                    JET11290
      IF (XMIN.LT.-RO) GO TO 802                                         JET11300
      XMIN=XMIN+DXMIN                                                    JET11310
  801 CONTINUE                                                           JET11320
```

Figure 69 - Continued

```
  802 XMAX=SD                                                          JET11330
      DXAXIS=SD-XMIN                                                   JET11340
      NAPTS=DXAXIS+1                                                   JET11350
      XAXIS(1)=XMIN/XSC                                                JET11360
      YAXIS(1)=0.                                                      JET11370
      DO 809 IP=2,NAPTS                                                JET11380
      XAXIS(IP)=XAXIS(IP-1)+1./XSC                                     JET11390
      YAXIS(IP)=YAXIS(IP-1)                                            JET11400
  809 CONTINUE                                                         JET11410
      DYAX=1./XSC                                                      JET11420
      XAXIS(NAPTS+1)=SD/XSC                                            JET11430
      YAXIS(NAPTS+1)=0.                                                JET11440
      DO 805 IP=2,NAPTS                                                JET11450
      XAXIS(NAPTS+IP)=SD/XSC                                           JET11460
      YAXIS(NAPTS+IP)=YAXIS(NAPTS+IP-1)+DYAX                           JET11470
  805 CONTINUE                                                         JET11480
      NPLOT=2*NAPTS                                                    JET11490
C     CALL LINE (XAXIS,YAXIS,NPLOT,1,1,-3,1,.1)                        JET11500
C     CALL SYMBL4 (-3.,8.,.2,'H/D=14.0, S/D=2.00',0.,18)               JET11510
      PI=3.14159265                                                    JET11520
      XPTS=NUPTS-1.                                                    JET11530
      RELAX=.5                                                         JET11540
      DO 500 I=1,NU                                                    JET11550
      WRITE (6,66) PU(I)                                               JET11560
   66 FORMAT (///45X,'PBAR=',F10.5)                                    JET11570
      IFLAG=1                                                          JET11580
      XPUF=0.                                                          JET11590
      IJET=1                                                           JET11600
      IU=1                                                             JET11610
      RW=SD                                                            JET11620
      ALPUG=1.5                                                        JET11630
      CALL WALLJ (RW,VMN,DUM2,DUM3,DUM4,DELPW)                         JET11640
      PMAXO=DELPW                                                      JET11650
      IF (PMAXO.LT.PU(I)) IFLAG=0                                      JET11660
      RW=SD/COS (PHIUO)                                                JET11670
      CALL WALLJ (RW,VMN,DUM2,DUM3,DUM4,DELPW)                         JET11680
      PMAXF=DELPW-VMN**2+(VMN*COS(PHIUO))**2                           JET11690
      IF (IFLAG.EQ.0) GO TO 502                                        JET11700
      RWALL(1)=SD                                                      JET11710
      RWALL(2)=SD+.1                                                   JET11720
      DO 400 K=1,100                                                   JET11730
      CALL WALLJ(RWALL(K),VMN,DUM2,DUM3,DUM4,DELPW)                    JET11740
      XU=SQRT(RWALL(K)**2-SD**2)                                       JET11750
      PHIU=ATAN2(XU,SD)                                                JET11760
      PMAX=DELPW-VMN**2+(VMN*COS(PHIU))**2                             JET11770
      ERR(K)=PU(I)-PMAX                                                JET11780
      IF (K.EQ.1) GO TO 400                                            JET11790
      IF (ABS(ERR(K)).LT.1.E-5) GO TO 501                              JET11800
      DRDE=(RWALL(K)-RWALL(K-1))/(ERR(K)-ERR(K-1))                     JET11810
      RWALL(K+1)=RWALL(K)-RELAX*DRDE*ERR(K)                            JET11820
  400 CONTINUE                                                         JET11830
      STOP                                                             JET11840
  501 RW=RWALL(K)                                                      JET11850
      YPUF=SQRT(RW**2-SD**2)                                           JET11860
      PUF=ATAN2(XPUF,SD)                                               JET11870
      YUF=CUI*SIGI*SD/COS(PUF)                                         JET11880
      PUFD=PUF*180./PI                                                 JET11890
  502 DPHIU=PHIUO/XPTS                                                 JET11900
      IF (PHIUO.EQ.0.) GO TO 201                                       JET11910
      PHIU=0.                                                          JET11920
      DO 200 IJ=1,NUPTS                                                JET11930
      RW=SD/COS(PHIU)                                                  JET11940
      CALL WALLJ (RW,VMN,DUM2,DUM3,DUM4,DELPW)                         JET11950
      YU=CUI*SIGI*SD/COS(PHIU)                                         JET11960
      XU=SD*TAN(PHIU)                                                  JET11970
      PHI=ATAN2(XU,SD-YU)                                              JET11980
      RU=(SD-YU)/COS(PHI)                                              JET11990
      ROP=RO+EPS*(1.+COS(PHI))                                         JET12000
      ETAM=RU/ROP                                                      JET12010
      IF (ETAM.GT.1.) FETAG=0.0                                        JET12020
      IF (ETAM.GT.1.) GO TO 1011                                       JET12030
      FETAG=FETA(ETAM,ALPG)                                            JET12040
 1011 PMIN=DELPS*FETAG                                                 JET12050
      PMAX=DELPW-VMN**2+(VMN*COS(PHIU))**2                             JET12060
      CALL PMATCH (PMIN,PMAX,ALPUG)                                    JET12070
      PBAR=(PU(I)-PMIN)/(PMAX-PMIN)                                    JET12080
```

Figure 69 - Continued

```
      IF (PMIN.GT.PU(I)) GO TO 509                                          JET12090
      PBARJ=PU(I)/DELPS                                                     JET12100
      IF (PBARJ.GT.1.) GO TO 509                                            JET12110
      ETAJ=(1.-PBARJ**.25)**(1./ALPG)                                       JET12120
      XPLOTJ(IJET)=ROP*ETAJ*COS(PHI)                                        JET12130
      YPLOTJ(IJET)=ROP*ETAJ*SIN(PHI)                                        JET12140
      XPLOTJ(IJET)=XPLOTJ(IJET)/XSC                                         JET12150
      YPLOTJ(IJET)=YPLOTJ(IJET)/XSC                                         JET12160
      IJET=IJET+1                                                           JET12170
  509 IF (PBAR.GT.1..OR.PBAR.LT.0.) GO TO 506                               JET12180
      ETAU=(1.-PBAR**.25)**(1./ALPUG)                                       JET12190
      XPLOTU(IU)=SD-YU*ETAU                                                 JET12200
      YPLOTU(IU)=XU                                                         JET12210
      XPLOTU(IU)=XPLOTU(IU)/XSC                                             JET12220
      YPLOTU(IU)=YPLOTU(IU)/XSC                                             JET12230
      IU=IU+1                                                               JET12240
  506 PHIU=PHIU+DPHIU                                                       JET12250
  200 CONTINUE                                                              JET12260
  201 DPHI=(PI-PHIO)/XPTS                                                   JET12270
      PHI=PHIO                                                              JET12280
      DO 600 IK=1,NUPTS                                                     JET12290
      PBARJ=PU(I)/DELPS                                                     JET12300
      IF (PBARJ.GT.1.) GO TO 600                                            JET12310
      ETAJ=(1.-PBARJ**.25)**(1./ALPG)                                       JET12320
      ROP=RO+EPS*(1.+COS(PHI))                                              JET12330
      XPLOTJ(IJET)=ROP*ETAJ*COS(PHI)                                        JET12340
      YPLOTJ(IJET)=ROP*ETAJ*SIN(PHI)                                        JET12350
      XPLOTJ(IJET)=XPLOTJ(IJET)/XSC                                         JET12360
      YPLOTJ(IJET)=YPLOTJ(IJET)/XSC                                         JET12370
      IJET=IJET+1                                                           JET12380
      PHI=PHI+DPHI                                                          JET12390
  600 CONTINUE                                                              JET12400
      IF (IFLAG.EQ.0) GO TO 513                                             JET12410
      IF (PU(I).EQ.0.) GO TO 513                                            JET12420
      IF(PUF.LT.PHIUO) GO TO 510                                            JET12430
      GO TO 511                                                             JET12440
  510 XPLOTU(IU)=SD                                                         JET12450
      YPLOTU(IU)=XPUF                                                       JET12460
      XPLOTU(IU)=XPLOTU(IU)/XSC                                             JET12470
      YPLOTU(IU)=YPLOTU(IU)/XSC                                             JET12480
      GO TO 800                                                             JET12490
  511 DPHIU=(PUF-PHIUO)/XPTS                                                JET12500
      PHIU=PHIUO                                                            JET12510
      DO 700 IJ=1,NUPTS                                                     JET12520
      YU=CUI*SIGI*SD/COS(PHIU)                                              JET12530
      XU=SD*TAN(PHIU)                                                       JET12540
      RW=SD/COS(PHIU)                                                       JET12550
      CALL WALLJ(RW,VMN,DUM2,DUM3,DUM4,DELPW)                               JET12560
      PMAX=DELPW-VMN**2+(VMN*COS(PHIU))**2                                  JET12570
      PBAR=PU(I)/PMAX                                                       JET12580
      ETAU=(1.-PBAR**.25)**(1./ALPUG)                                       JET12590
      XPLOTU(IU)=SD-YU*ETAU                                                 JET12600
      YPLOTU(IU)=XU                                                         JET12610
      XPLOTU(IU)=XPLOTU(IU)/XSC                                             JET12620
      YPLOTU(IU)=YPLOTU(IU)/XSC                                             JET12630
      IU=IU+1                                                               JET12640
      PHIU=PHIU+DPHIU                                                       JET12650
  700 CONTINUE                                                              JET12660
  513 IU=IU-1                                                               JET12670
  800 IJET=IJET-1                                                           JET12680
      WRITE (6,11) IJET,IU                                                  JET12690
   11 FORMAT (//15X,'JET IMPINGEMENT REGION,  IJET=',I4,10X,'UPWASH DEFL   JET12700
     1ECTION REGION, IU=',I4//)                                             JET12710
      IF (IJET.GT.0.OR.IU.GT.0) WRITE (6,552)                               JET12720
  552 FORMAT (//34X,'XISOJ',6X,'YISOJ',8X,'XISOU',8X,'YISOU'/)              JET12730
      IMIN=IU                                                               JET12740
      IMAX=IJET                                                             JET12750
      IF (IU.GT.IJET) IMAX=IU                                               JET12760
      IF (IU.GT.IJET) IMIN=IJET                                             JET12770
      DO 803 IM=1,IMAX                                                      JET12780
      IF (IM.LE.IMIN) WRITE(6,12) XPLOTJ(IM),YPLOTJ(IM),XPLOTU(IM),YPLOT    JET12790
     1U(IM)                                                                 JET12800
   12 FORMAT (30X,4(F10.5,2X))                                              JET12810
      IF (IM.GT.IMIN.AND.IMIN.EQ.IU) WRITE (6,15) XPLOTJ(IM),YPLOTJ(IM)     JET12820
   15 FORMAT (30X,2(F10.5,2X))                                              JET12830
      IF (IM.GT.IMIN.AND.IMIN.EQ.IJET) WRITE (6,16) XPLOTU(IM),YPLOTU(IM    JET12840
     1)                                                                     JET12850
   16 FORMAT (54X,2(F10.5,2X))                                              JET12860
```

Figure 69 - Continued

```
  803 CONTINUE                                                          JET12870
C     CALL LINE (XPLOTU,YPLOTU,IU,1,1,1,.1)                           JET12880
C     CALL LINE (XPLOTJ,YPLOTJ,IJET,1,1,1,.1)                         JET12890
  500 CONTINUE                                                          JET12900
      DPHIU=.5*PI/XPTS                                                JET12910
      PHIU=0.                                                         JET12920
      DO 900 IJ=1,NUPTS                                               JET12930
      YU=CUI*SIGI*SD/COS(PHIU)                                        JET12940
      XU=SD*TAN(PHIU)                                                 JET12950
      IF (XU.GT.XLMAX) GO TO 901                                      JET12960
      XPLOTU(IJ)=SD-YU                                                JET12970
      YPLOTU(IJ)=XU                                                   JET12980
      XPLOTU(IJ)=XPLOTU(IJ)/XSC                                       JET12990
      YPLOTU(IJ)=YPLOTU(IJ)/XSC                                       JET13000
      PHIU=PHIU+DPHIU                                                 JET13010
  900 CONTINUE                                                          JET13020
  901 IU=IJ-1                                                           JET13030
      WRITE (6,807)                                                   JET13040
  807 FORMAT (///15X,'UPWASH DEFLECTION ZONE LINE, PBAR=0 OUTSIDE INTERAJET13050
     1CTION REGION'//)                                                JET13060
      WRITE (6,808)                                                   JET13070
  808 FORMAT (35X,'XUP',8X,'YUP'//)                                   JET13080
      DO 813 IM=1,IU                                                  JET13090
      WRITE (6,811) XPLOTU(IM),YPLOTU(IM)                             JET13100
  813 CONTINUE                                                          JET13110
  811 FORMAT (30X,2(F10.5,2X))                                        JET13120
C     CALL LINE (XPLOTU,YPLOTU,IU,1,1,1,.1)                           JET13130
C     CALL ADRAW                                                      JET13140
C     CALL PLOT (-99.,-99., 3)                                        JET13150
C     READ (5,101) PAUSE                                              JET13160
  101 FORMAT (1X,F10.5)                                               JET13170
      RETURN                                                          JET13180
      END                                                             JET13190
                                                                      JET13200
                                                                      JET13210
                                                                      JET13220
                                                                      JET13230
      SUBROUTINE WALLJ(R,VMN,BWH,BW,CV2,DELPW)                        JET13240
      REAL KDELO,NO,KDELFD,NFD,N,KDEL                                 JET13250
C                                                                     JET13260
C   THIS COMPUTES THE WALL JET PROPERTIES GIVEN A WALL RADIUS          JET13270
C                                                                     JET13280
      COMMON/WALL/ DELS,NO,KDELO,ALPG,ALPWO,ALPWFD,RO,RGH,VG,BWHO     JET13290
C                                                                     JET13300
C  MAXIMUM VELOCITY DISTRIBUTION IN DEFLECTION REGION                 JET13310
C                                                                     JET13320
      AW3=.09                                                         JET13330
      NFD=7.                                                          JET13340
      KDELFD=1./9.                                                    JET13350
      BW3HO=AW3*RO                                                    JET13360
      DELBRH=(BW3HO-BWHO)/(RO-RGH)                                    JET13370
      ALPWFD=1.5                                                      JET13380
      DELAR=(ALPWFD-ALPWO)/(RO-RGH)                                   JET13390
      DELNR=(NFD-NO)/(RO-RGH)                                         JET13400
      ADELBT=.0175                                                    JET13410
      ADELBL=(ADELBT*(RO-2.)-DELS)/(RO-RGH)                           JET13420
      DKDELR=(KDELFD-KDELO)/(RO-RGH)                                  JET13430
      IF (R.LE.RO) FETA=(1.-(R/RO)**ALPG)**4                          JET13440
      IF (R.GT.RO) FETA=0.0                                           JET13450
      IF (R.LE.RGH) VMG=SQRT(1.-FETA)                                 JET13460
      IF (R.LE.RGH) VMN=VMG*VG                                        JET13470
      IF (R.LE.RGH) GO TO 401                                         JET13480
      IF (R.LE.RO) BWH=BWHO+DELBRH*(R-RGH)                            JET13490
      IF (R.GT.RO) BWH=AW3*R                                          JET13500
      IF (R.LE.RO) ALPW=ALPWO+DELAR*(R-RGH)                           JET13510
      IF (R.GT.RO) ALPW=ALPWFD                                        JET13520
      IF (R.LE.RO) N=NO+DELNR*(R-RGH)                                 JET13530
      IF (R.GT.RO) N=NFD                                              JET13540
      IF (R.LE.RO) DELBL=DELS+ADELBL*(R-RGH)                          JET13550
      IF (R.GT.RO) DELBL=ADELBT*(R-2.)                                JET13560
      ALAM=((2.-SQRT(2.))/2.)**(1./ALPW)                              JET13570
      KDEL=DELBL/(DELBL+(BWH-DELBL)/ALAM)                             JET13580
      CALL SIMW(KDEL,N,ALPW,RAT,CV2,CP)                               JET13590
      IF (R.LE.4.) VISMOM=1.0                                         JET13600
      IF (R.GT.4.) VISMOM=1./(R/4.)**.24                              JET13610
      F1=VISMOM*RAT*(1.-FETA)/(R*BWH)                                 JET13620
      F2=CP*FETA*VG**2                                                JET13630
```

Figure 69 - Continued

```
      VMN=SQRT((F1-F2)/(2.*CV2))                                        JET13640
      VMG=VMN/VG                                                        JET13650
      DELPW=FETA*VG**2+VMN**2                                           JET13660
      PW=BWH/RAT                                                        JET13670
      DELTA=ADEL*BW                                                     JET13680
  401 CONTINUE                                                          JET13690
      IF (R.LT.RGH) DELPW=VG**2                                         JET13700
      IF (R.LT.RGH) BWH=BWHO                                            JET13710
      RETURN                                                            JET13720
      END                                                               JET13730
                                                                        JET13740
                                                                        JET13750
                                                                        JET13760
                                                                        JET13770
      SUBROUTINE JETPCT (TM,ETAC,BVH,ALPV,TLAM,CM,CT,RV,RT)             JET13780
      DELMIN=1.E-5                                                      JET13790
      CALL JETPCN(ETAC,BVH,ALPVI,RVI,CV2)                               JET13800
C     WRITE (6,555) CV2,ALPVI                                           JET13810
C     CALL JETPC (ETAC,BVH,ALPVI,RVI,CV2)                               JET13820
C     WRITE (6,555) CV2,ALPVI                                           JET13830
  555 FORMAT (1X,'CV2=',F10.6,2X,'ALPVI=',F10.6)                        JET13840
C     WRITE (6,123) TM,ETAC,BVH                                         JET13850
  123 FORMAT (1X,3F10.6)                                                JET13860
      ALPV=1.*ALPVI                                                     JET13870
      TLAM=1.                                                           JET13880
      R2=(SQRT(2.)-1.)/SQRT(2.)                                         JET13890
      REL=.1000000                                                      JET13900
      DO 100 I=1,999                                                    JET13910
      RV=ETAC+(1.-ETAC)*R2**(1./ALPV)                                   JET13920
      RVAV=(ETAC-1.)*((RV-ETAC)/(1.-ETAC))*ALOG((RV-ETAC)/(1.-ETAC))/   JET13930
     1ALPV                                                              JET13940
      CALL SIMTPC(TM,ETAC,ALPV,TLAM,CM,CT,CMAV,CMAT,CTAV,CTAT)          JET13950
      F=2.*BVH*BVH*CT-RV*RV                                             JET13960
      G=2.*BVH*BVH*CM-RV*RV                                             JET13970
      FAV=2.*BVH*BVH*CTAV-2.*RV*RVAV                                    JET13980
      FAT=2.*BVH*BVH*CTAT                                               JET13990
      GAV=2.*BVH*BVH*CMAV-2.*RV*RVAV                                    JET14000
      GAT=2.*BVH*BVH*CMAT                                               JET14010
      DET=FAV*GAT-GAV*FAT                                               JET14020
      DALPV=(G*FAT-F*GAT)/DET                                           JET14030
      DLAM=(F*GAV-G*FAV)/DET                                            JET14040
C     WRITE (6,800) BVH,CT,RV,CM,ALPV,ALPT,F,G                          JET14050
  800 FORMAT (1X,8F14.6)                                                JET14060
C     WRITE (6,700) I,DALPV,DALPT                                       JET14070
  700 FORMAT (1X,I3,2X,2F15.6)                                          JET14080
      ALPV=ALPV+REL*DALPV                                               JET14090
      TLAM=TLAM+REL*DLAM                                                JET14100
      IF (ABS(F).LT.DELMIN.AND.ABS(G).LT.DELMIN) GO TO 200              JET14110
  100 CONTINUE                                                          JET14120
      STOP                                                              JET14130
C 200 WRITE (6,500) I,ALPV,ALPT                                         JET14140
  200 CONTINUE                                                          JET14150
  500 FORMAT (1X,I3,2X,'ALPV=',F10.6,2X,'ALPT=',F10.6)                  JET14160
      RT=RV                                                             JET14170
      RETURN                                                            JET14180
      END                                                               JET14190
                                                                        JET14200
                                                                        JET14210
                                                                        JET14220
      SUBROUTINE JETPCN (ETAC,RJH,ALPC,R,CV2)                           JET14230
C                                                                       JET14240
C     THIS ROUTINE COMPUTES THE EXPONENT OF THE JET VELOCITY PROFILE    JET14250
C     IN THE POTENTIAL CORE REGION                                      JET14260
C                                                                       JET14270
      ALP=4.0                                                           JET14280
      DELMIN=1.E-5                                                      JET14290
      REL=.50                                                           JET14300
      DO 100 I=1,500                                                    JET14310
      CALL SIMN(ETAC,ALP,R,CV2,CV2A,RALP)                               JET14320
      FUNC=CV2-.5*(R/RJH)**2                                            JET14330
      FUNCD=CV2A-(R*RALP)/(RJH**2)                                      JET14340
      ALPN=ALP-FUNC/FUNCD                                               JET14350
C     WRITE (6,700) ALPN,FUNC                                           JET14360
  700 FORMAT (1X,'ALP=',F10.5,2X,'FUNC=',F10.5)                         JET14370
      ALP=ALP+REL*(ALPN-ALP)                                            JET14380
      IF (ABS(FUNC).LT.DELMIN) GO TO 101                                JET14390
```

Figure 69 - Continued

```
  100 CONTINUE                                                          JET14400
      STOP                                                              JET14410
  101 ALPC=ALPN                                                         JET14420
      RETURN                                                            JET14430
      END                                                               JET14440
                                                                        JET14450
                                                                        JET14460
                                                                        JET14470
      SUBROUTINE SIMN(ETAC,ALP,R,CV2,CV2A,RALP)                         JET14480
C                                                                       JET14490
C   INTEGRAL OF JET VELOCITY PROFILE FUNCTION=CV2                       JET14500
C    R=RATIO OF RJH TO RJ                                             JET14510
C                                                                       JET14520
      A1=.5-4./((ALP+2.)+3./(ALP+1.)-4./(3.*ALP+2.)+1./(4.*ALP+2)      JET14530
      A2=1.-4./(ALP+1.)+6./(2.*ALP+1.)-4./(3.*ALP+1.)+1./(4.*ALP+1.)   JET14540
      CV2=.5*ETAC**2+A1*(1.-ETAC)**2+ETAC*(1.-ETAC)*A2                  JET14550
      A1ALP=4./((ALP+2.)**2)-3./((ALP+1)**2)+12./((3.*ALP+2.)**2)       JET14560
     1-4./((4.*ALP+2.)**2)                                              JET14570
      A2ALP=4./((ALP+1)**2)-12./((2.*ALP+1.)**2)+12./((3.*ALP+1.)**2)   JET14580
     1-4./((4.*ALP+1.)**2)                                              JET14590
      ETAB1=(1.-ETAC)**2                                                JET14600
      ETAB2=ETAC*(1.-ETAC)                                              JET14610
      CV2A=ETAB1*A1ALP+ETAB2*A2ALP                                      JET14620
      R=ETAC+(1.-ETAC)*((2.-SQRT(2.))/2.)**(1./ALP)                     JET14630
      RALP=((ETAC-R)/ALP)*ALOG((R-ETAC)/(1.-ETAC))                      JET14640
      RETURN                                                            JET14650
      END                                                               JET14660
                                                                        JET14670
                                                                        JET14680
                                                                        JET14690
      SUBROUTINE SIKTFC (TM,ETAC,ALPV,TLAM,CM,CT,CMALP,CMTLAM,CTALP,    JET14700
     1CTTLAM)                                                           JET14710
      FVP(ETAP)=(1.-ETAP**ALPV)**2                                      JET14720
      FTP(ETAPT)=(1.-ETAPT**ALPT)**2                                    JET14730
      FVAVP(ETAP,FV)=2.*SQRT(FV)*(SQRT(FV)-1.)*ALOG(ETAP)               JET14740
      FTATP(ETAPT,FT)=2.*SQRT(FT)*(SQRT(FT)-1.)*ALOG(ETAPT)             JET14750
      FTLAM(ETAPT,ETAP,TLAM)=2.*ALPT*(1.-ETAPT**ALPT)*(ETAPT**(ALPT-1.  JET14760
     1))*(ETAP-TLAM*TLAM))                                              JET14770
      FUNC(FV,FT)=FV/(FT+(1.-FT)/TM)                                    JET14780
      FUN(FT)=FT/(FT+(1.-FT)/TM)                                        JET14790
      FUNCT(FV,FT)=FV/((FT+(1.-FT)/TM)**2)                              JET14800
      N=24                                                              JET14810
C     WRITE (6,800) TM,ETAC,ALPV,TLAM                                   JET14820
  800 FORMAT (5X,4F11.5)                                                JET14830
      DTM=(1.-TM)/TM                                                    JET14840
      N1=N-1                                                            JET14850
      ALPT=ALPV                                                         JET14860
      N2=N-2                                                            JET14870
      DETA=(1.-ETAC)/N1                                                 JET14880
      ETA=ETAC+DETA                                                     JET14890
      SUMOM=0.                                                          JET14900
      SUMOMA=0.                                                         JET14910
      SUMOMT=0.                                                         JET14920
      SUMOTA=0.                                                         JET14930
      SUMOTT=0.                                                         JET14940
      SUMOT=0.                                                          JET14950
      DO 100 I=1,N1,2                                                   JET14960
      ETAP=(ETA-ETAC)/(1.-ETAC)                                         JET14970
      ETAPT=ETAP/TLAM                                                   JET14980
      FV=FVP(ETAP)                                                      JET14990
      FT=FTP(ETAPT)                                                     JET15000
      FVAV=FVAVP(ETAP,FV)                                               JET15010
      FTAT=FTATP(ETAPT,FT)                                              JET15020
      FTTLAM=FTLAM(ETAPT,ETAP,TLAM)                                     JET15030
      SUMOM=SUMOM+FV*ETA*FUNC(FV,FT)                                    JET15040
      SUMOT=SUMOT+FT*ETA*FUNC(FV,FT)                                    JET15050
      SUMOMA=SUMOMA+2.*FVAV*ETA*FUNC(FV,FT)+FV*FTAT*ETA*DTM*FUNCT(FV,FT)JET15060
      SUMOMT=SUMOMT+FV*FTTLAM*ETA*FUNCT(FV,FT)                          JET15070
      SUMOTA=SUMOTA+FVAV*ETA*FUN(FT)+FTAT*ETA*FUNC(FT,FV)+FTAT*DTM*FUNCTJET15080
     1(FV,FT)*ETA                                                       JET15090
      SUMOTT=SUMOTT+FTTLAM*ETA*(FUNC(FV,FT)+DTM*FUNCT(FV,FT))           JET15100
      ETA=ETA+2.*DETA                                                   JET15110
```

Figure 69 - Continued

```
  100 CONTINUE                                                          JET15120
      ETA=ETAC+2.*DETA                                                  JET15130
      SUMEM=0.                                                          JET15140
      SUMET=0.                                                          JET15150
      SUMEMA=0.                                                         JET15160
      SUMEMT=0.                                                         JET15170
      SUMETA=0.                                                         JET15180
      SUMETT=0.                                                         JET15190
      DO 200 I=3,N2,2                                                   JET15200
      ETAP=(ETA-ETAC)/(1.-ETAC)                                         JET15210
      ETAPT=ETAP/TLAM                                                   JET15220
      FV=FVP(ETAP)                                                      JET15230
      FT=FTP(ETA                                                        JET15240
      FVAV=FVAVP(ETAP,FV)                                               JET15250
     *TAT=FTATP(ETAPT,FT)                                               JET15260
      FTTLAM=FTLAM(ETAPT,ETAP,TLAM)                                     JET15270
      SUMEM=SUMEM+FV*ETA*FUNC(FV,FT)                                    JET15280
      SUMET=SUMET+FT*ETA*FUNC(FV,FT)                                    JET15290
      SUMEMA=SUMEMA+2.*FVAV*ETA*FUNC(FV,FT)+FV*FTAT*ETA*DTM*FUNCT(FV,FT)JET15300
      SUMEMT=SUMEMT+FV*FTTLAM*ETA*FUNCT(FV,FT)                          JET15310
      SUMETA=SUMETA+FVAV*ETA*FUN(FT)+FTA*ETA*FU(FT,FV)+FTAT*DTM*FUNCTJET15320
     1(FV,FT)*ETA                                                       JET15330
      SUMETT=SUME    :TTLAM*ETA*(FUNC(FV,FT)+DTM*FUNCT(FV,FT))          JET15340
      ETA=ETA+2.*DETA                                                   JET15350
  200 CONTINUE                                                          JET15360
      CM=.5*ETAC*ETAC+(DETA/3.)*(ETAC+4.*SUMOM+2.*SUMEM)                JET15370
      CT=.5*ETAC*ETAC+(DETA/3.)*(ETAC+4.*SUMOT+2.*SUMET)                JET15380
      CMALP=(DETA/3.)*(4.*SUMOMA+2.*SUMEMA)                             JET15390
      CMTLAM=(DETA/3.)*(4.*SUMOMT+2.*SUMEMT)*DTM                        JET15400
      CTALP=(DETA/3.)*(4.*SUMOTA+2.*SUMETA)                             JET15410
      CTTLAM=(DETA/3.)*(4.*SUMOTT+2.*SUMETT)                            JET15420
C     WRITE (6,700) TM,ETAC,ALPV,TLAM,CM,CT,CMALP,CMTLAM,CTALP,CTTLAM   JET15430
  700 FORMAT (1X,10F11.5)                                               JET15440
      RETURN                                                            JET15450
      END                                                               JET15460
                                                                        JET15470
                                                                        JET15480
                                                                        JET15490
      SUBROUTINE QHALF (TMB,ETAC,ALPV,TLAM,Q0)                          JET15500
      FVP(ETAP)=(1.-ETAP**ALPV)**2                                      JET15510
      FTP(ETAP)=(1.-(ETAP/TLAM)**ALPT)**2                               JET15520
      FVETAP(ETAP)=-2.*(1.-ETAP**ALPV)*ALPV*ETAP**(ALPV-1.)             JET15530
      FTETAP(ETAP)=-2.*(1.-(ETAP/TLAM)**ALPT)*ALPT*((ETAP/TLAM)**(ALPT-1JET15540
     1.))*(1./TLAM)                                                     JET15550
      REL=.5                                                            JET15560
      ALPT=ALPV                                                         JET15570
C     WRITE (6,700) TMB,ETAC,ALPV,ALPT                                  JET15580
  700 FORMAT (1X,'TMB=',F10.5,2X,'ETAC=',F10.5,2X,'ALPV=',F10.5,2X,'ALPTJET15590
     1=',F10.5)                                                         JET15600
      ETAP=0.                                                           JET15610
      DETAP=1./24.                                                      JET15620
      DO 300 I=1,25                                                     JET15630
      FV=FVP(ETAP)                                                      JET15640
      FT=FTP(ETAP)                                                      JET15650
      QOLD=Q                                                            JET15660
      Q=FV*FV*TMB/(1.+FT*(TMB-1.))                                      JET15670
      IF (Q.LT..5.AND.QOLD.GT..5) GO TO 367                             JET15680
      ETAP=ETAP+DETAP                                                   JET15690
  300 CONTINUE                                                          JET15700
      STOP                                                              JET15710
C 367 WRITE (6,557) QOLD,Q                                              JET15720
  557 FORMAT (2X,'QO=',F10.5,2X,'Q=',F10.5)                             JET15730
  367 DEDQ=DETAP/(Q-QOLD)                                               JET15740
      ETAP=ETAP+DEDQ*(.5-Q)                                             JET1575
C     WRITE (6,375) ETAP                                                JET15760
  375 FORMAT (2X,'ETAP=',F10.5)                                         JET15770
      DELMIN=1.E-5                                                      JET15780
      DO 100 I=1,500                                                    JET15790
      FV=FVP(ETAP)                                                      JET1580C
      FT=FTP(ETAP)                                                      JET15810
      FVETA=FVETAP(ETAP)                                                JET15820
      FTETA=FTETAP(ETAP)                                                JET15830
      DEN=1.+FT*(TMB-1.)                                                JET15840
      FUNC=.5-FV*FV*TMB/DEN                                             JET15850
      FUNCD=-FV*FV*TMB*(TMB-1.)*FTETA/(DEN*DEN)-2.*FV*FVETA*TMB/DEN     JET15860
      ETAN=ETAP-FUNC/FUNCD                                              JET15870
      ETAP=ETAP+REL*(ETAN-ETAP)                                         JET15880
C     WRITE (6,500) ETAP,FUNC                                           JET15890
```

Figure 69 - Continued

```
  500 FORMAT (1X,2F10.5)                                                    JET15900
      IF (ABS(FUNC).LT.1.E-5) GO TO 200                                     JET15910
  100 CONTINUE                                                              JET15920
      STOP                                                                  JET15930
  200 RO=ETAC+(1.-ETAC)*ETAP                                                JET15940
      RETURN                                                                JET15950
      END                                                                   JET15960
                                                                            JET15970
                                                                            JET15980
                                                                            JET15990
      SUBROUTINE SIMTV (TN,TM,ALPV,TLAM,CM,CT,CMTM,CTTM)                    JET16000
      FVP(ETA)=(1.-ETA**ALPV)**2                                            JET16010
      FTP(ETA)=(1.-(ETA/TLAM)**ALPT)**2                                     JET16020
      FUNC(ETA,FV,FT)=FV*ETA/(FT+(1.-FT)/TMB)                               JET16030
      FUNCD(ETA,FV,FT)=FV*ETA*((1.-FT)/(TMB*TM))/((FT+(1.-FT)/TMB)**2)      JET16040
      N=24                                                                  JET16050
      ALPT=ALPV                                                             JET16060
C     WRITE (6,777) TN,TM,ALPV,ALPT,CM,CT                                   JET16070
      TMB=TM*TN                                                             JET16080
      N1=N-1                                                                JET16090
      N2=N-2                                                                JET16100
      DETA=1./N1                                                            JET16110
      ETA=DETA                                                              JET16120
      SUMOM=0.                                                              JET16130
      SUMOT=0.                                                              JET16140
      SUMOTM=0.                                                             JET16150
      SUMOCM=0.                                                             JET16160
      DO 100 I=1,N1,2                                                       JET16170
      FV=FVP(ETA)                                                           JET16180
      FT=FTP(ETA)                                                           JET16190
      SUMOM=SUMOM+FV*FUNC(ETA,FV,FT)                                        JET16200
      SUMOT=SUMOT+FT*FUNC(ETA,F ,FT)                                        JET16210
      SUMOCM=SUMOCM+FV*FUNCD(ETA,FV,FT)                                     JET16220
      SUMOTM=SUMOTM+FT*FUNCD(ETA,FV,FT)                                     JET16230
      ETA=ETA+2.*DETA                                                       JET16240
  100 CONTINUE                                                              JET16250
      ETA=2.*DETA                                                           JET16260
      SUMEM=0.                                                              JET16270
      SUMET=0.                                                              JET16280
      SUMECM=0.                                                             JET16290
      SUMETM=0.                                                             JET16300
      DO 200 I=3,N2,2                                                       JET16310
      FV=FVP(ETA)                                                           JET16320
      FT=FTP(ETA)                                                           JET16330
      SUMEM=SUMEM+FV*FUNC(ETA,FV,FT)                                        JET16340
      SUMET=SUMET+FT*FUNC(ETA,FV,FT)                                        JET16350
      SUMECM=SUMECM+FV*FUNCD(ETA,FV,FT)                                     JET16360
      SUMETM=SUMETM+FT*FUNCD(ETA,FV,FT)                                     JET16370
      ETA=ETA+2.*DETA                                                       JET16380
  200 CONTINUE                                                              JET16390
      CM=(DETA/3.)*(4.*SUMOM+2.*SUMEM)                                      JET16400
      CT=(DETA/3.)*(4.*SUMOT+2.*SUMET)                                      JET16410
      CMTM=(DETA/3.)*(4.*SUMOCM+2.*SUMECM)                                  JET16420
      CTTM=(DETA/3.)*(4.*SUMOTM+2.*SUMETM)                                  JET16430
C     WRITE (6,777) TN,TM,ALPV,ALPT,CM,CT                                   JET16440
  777 FORMAT (1X,6F10.5)                                                    JET16450
      RETURN                                                                JET16460
      END                                                                   JET16470
                                                                            JET16480
                                                                            JET16490
                                                                            JET16500
      SUBROUTINE GPREST (RO,VG,THG,ALPG,R,CPG)                              JET16510
      FUNC(ALP)=.5-4./(ALP+2.)+3./(ALP+1.)-4./(3.*ALP+2.)+1./(4.*ALP        JET16520
     1+2.)                                                                  JET16530
      FUNCD(ALP)=4./((ALP+2.)**2)-3./((ALP+1.)**2)+12./((3.*ALP+2.)**2)     JET16540
     1-4./((4.*ALP+2.)**2)                                                  JET16550
C                                                                           JET16560
C  THIS ROUTINE SOLVES GROUND PRESSURE INTEGRAL FOR GROUND PRESSURE         JET16570
C   EXPONENT                                                                JET16580
C                                                                           JET16590
      ALPG=1.5                                                              JET16600
      REL=.5                                                                JET16610
      DELMIN=1.E-5                                                          JET16620
      DO 100 I=1,99                                                         JET16630
      CPG=FUNC(ALPG)                                                        JET16640
      CPGP=FUNCD(ALPG)                                                      JET16650
      F=THG-RO*RO*VG*VG*CPG                                                 JET16660
      FP=-RO*RO*VG*VG*CPGP                                                  JET16670
      ALPG=ALPG-REL*F/FP                                                    JET16680
C     WRITE (6,500) ALPG,CPG,CPGP,                                          JET16690
```

Figure 69 - Continued

```
  500 FORMAT (1X,4F15.5)                                                    JET16700
      IF (ABS(F).LT.DELMIN) GO TO 101                                       JET16710
  100 CONTINUE                                                              JET16720
      STOP                                                                  JET16730
  101 RETURN                                                                JET16740
      END                                                                   JET16750
                                                                            JET16760
                                                                            JET16770
                                                                            JET16780
      SUBROUTINE SIMW(KDEL,N,ALPW,R,CV2,CP)                                 JET16790
C                                                                           JET16800
C   THIS ROUTINE COMPUTES THE INTEGRAL OF THE VELOCITY SQUARED PROFILE      JET16810
C   AND STATIC PRESSURE PROFILE FOR WALL JET FUNCTIONS                      JET16820
C     CV2=VELOCITY SQUARED INTEGRAL                                         JET16830
C     CP=STAIC PRESSURE INTEGRAL                                            JET16840
C     R=RATIO OF DWH TO DW                                                  JET16850
C                                                                           JET16860
      REAL KDEL,N                                                           JET16870
      XN=N                                                                  JET16880
      XI1=1.-4./(ALPW+1.)+6./(2.*ALPW+1.)-4./(3.*ALPW+1.)+1./(4.*ALPW+1.JET16890
     1)                                                                     JET16900
      CV2=(XN/(2.+XN))*KDEL+(1.-KDEL)*XI1                                   JET16910
      CP=KDEL+(1.-KDEL)*XI1                                                 JET16920
      F=((2.-SQRT(2.))/2.)**(1./ALPW)                                       JET16930
      R=KDEL+(1.-KDEL)*F                                                    JET16940
C     WRITE (6,500) CV2,CP                                                  JET16950
  500 FORMAT (1X,'CV2=',F10.5,2X,'CP=',F10.5)                               JET16960
      RETURN                                                                JET16970
      END                                                                   JET16980
                                                                            JET16990
                                                                            JET17000
                                                                            JET17010
      SUBROUTINE SIMUG(ALPU,R,CV2U)                                         JET17020
C                                                                           JET17030
C   THIS ROUTINE COMPUTES VELOCITY  QUARED INTEGRAL FOR UPWASH              JET17040
C                                                                           JET17050
      CV2U=1.-4./(ALPU+1.)+6./(2.*ALPU+1.)-4./(3.*ALPU+1.)+1./(4.*ALPU+1JET17060
     1.)                                                                    JET17070
      F=(SQRT(2.)-1.)/SQRT(2.)                                              JET17080
      R=F**(1./ALPU)                                                        JET17090
      RETURN                                                                JET17100
      END                                                                   JET17110
                                                                            JET17120
                                                                            JET17130
                                                                            JET17140
      SUBROUTINE GMATT (TN,RG,DELPS,PMBI,TMI,VMI,ALPG,KDEL,N,ETAWG,DELS JET17150
     1,ALPW,R,BWO,BWOH,TLAM)                                                JET17160
C                                                                           JET17170
C   THIS ROUTINE IS USED FOR INITIATING WALL JET REGION                     JET17180
C     COMPUTES THE INTIAL INVISCID EXPONENT FOR WALL JET PROFILE            JET17190
C                                                                           JET17200
      REAL KDEL,N                                                           JET17210
      BWO=DELS/KDEL                                                         JET17220
      TLAM=1.1                                                              JET17230
      ALPW=.5                                                               JET17240
      CALL SIMWM (TN,TMI,TLAM,PMBI,KDEL,N,ALPW,ALPG,ETAWG,DELPS,VMI,        JET17250
     1BWO,RG)                                                               JET17260
      RCON=(2.-SQRT(2.))/2.                                                 JET17270
      R=KDEL+(1.-KDEL)*RCON**(1./ALPW)                                      JET17280
      BWOH=R*BWO                                                            JET17290
C     WRITE (6,709) TLAM,ALPW,BWO,BWOH                                      JET17300
  709 FORMAT (1X,'TLAM=',F10.5,2X,'ALPW=',F10.5,2X,'BWO=',F10.5,2X,'BWOH JET17310
     1=',F10.5)                                                             JET17320
      RETURN                                                                JET17330
      END                                                                   JET17340
                                                                            JET17350
                                                                            JET17360
                                                                            JET17370
      SUBROUTINE SIMWM(TN,TM,TLAM,PMB,KDEL,N,ALPW,ALPG,ETAWG,DELPS,VM,      JET17380
     1BW,RG)                                                                JET17390
      REAL KDEL,N                                                           JET17400
      TMB=TM*TN                                                             JET17410
      REL=.5                                                                JET17420
      DELMIN=1.E-5                                                          JET17430
      FETAG=(1.-ETAWG**ALPG)**4                                             JET17440
      FMOM=1.-FETAG                                                         JET17450
C     WRITE (6,400) FETAG,FMOM,BW,RG                                        JET17460
```

Figure 69 - Continued

```
  400 FORMAT (1X,'FETAG',4F10.5)                                          JET17470
      DO 100 I=1,200                                                      JET17480
      CALL SIMUTI (TN,TM,TLAM,PMB,KDEL,N,ALPW,CV2,CP,CT,CV2A,CV2L         JET17490
     1,CPA,CTA,CTL,R,RALP)                                                JET17500
C     WRITE (6,740) CV2,CP,CT,CV2A,CV2L,CPA,CTA,CTL,R                     JET17510
  740 FORMAT (1X,9F10.5)                                                  JET17520
      F=FMOM-RG*BW*(2.*PMB*VM*VM*CV2/TM+DELPS*FETAG*CP)                   JET17530
      G=FMOM*TM*(TN-1.)-2.*PMB*VM*(TMB-1.)*RG*BW*CT                       JET17540
      FALP=-RG*BW*(2.*PMB*VM*VM*CV2A/TM+DELPS*FETAG*CPA)                  JET17550
      FLAM=-RG*BW*(2.*PMB*VM*VM*CV2L/TM)                                  JET17560
      GALP=-2.*PMB*VM*(TMB-1.)*RG*BW*CTA                                  JET17570
      GLAM=-2.*PMB*VM*(TMB-1.)*RG*BW*CTL                                  JET17580
C     WRITE (6,750) FALP,FLAM,GALP,GLAM                                   JET17590
  750 FORMAT (1X,'FA=',F10.5,1X,'FL=',F10.5,1X,'GA=',F10.5,1X,'GL=',F10.  JET17600
     15)                                                                  JET17610
      DET=FALP*GLAM-FLAM*GALP                                             JET17620
      DALP=(G*FLAM-F*GLAM)/DET                                            JET17630
      DLAM=(F*GALP-G*FALP)/DET                                            JET17640
      ALPW=ALPW+REL*DALP                                                  JET17650
      TLAM=TLAM+REL*DLAM                                                  JET17660
C     WRITE (6,500) F,G,ALPW,TLAM                                         JET17670
      IF (ABS(F).LT.DELMIN.AND.ABS(G).LT.DELMIN) GO TO 101                JET17680
  500 FORMAT (1X,4F15.5)                                                  JET17690
  100 CONTINUE                                                            JET17700
      STOP                                                                JET17710
  101 CONTINUE                                                            JET17720
      RETURN                                                              JET17730
      END                                                                 JET17740
                                                                          JET17750
                                                                          JET17760
                                                                          JET17770
      SUBROUTINE SIMUTI (TN,TM,TLAM,PMB,KDEL,N,ALPW,CV2,CP,CT,CV2A,CV2L   JET17780
     1,CPA,CTA,CTL,R,RALP)                                                JET17790
      REAL KDEL,N                                                         JET17800
      FVP(ETAP)=(1.-ETAP**ALPV)**2                                        JET17810
      FTP(ETAP)=(1.-(ETAP/TLAM)**ALPT)**2                                 JET17820
      FVA(ETAP)=-2.*(ETAP**ALPV)*(1.-ETAP**ALPV)*ALOG(ETAP)               JET17830
      FTA(ETAPT)=-2.*(ETAPT**ALPT)*(1.-ETAPT**ALPT)*ALOG(ETAPT)           JET17840
      FPA(ETAP)=-4.*(ETAP**ALPV)*((1.-ETAP**ALPV)**3)*ALOG(ETAP)          JET17850
      FTL(ETAPT)=2.*(1.-ETAPT**ALPT)*ALPT*(ETAPT**ALPT)/TLAM              JET17860
      FUNC(FV,FT,FP)=FV*(FP+(1.-FP)/PMB*FT+(1.-FT)/TMB)                   JET17870
      FUNCD(FV,FT,FP)=FV*(FP+(1.-FP)       ((FT+(1.-FT)/TMB)**2)          JET17880
      FUN(FV,FT)=FT*(FP+(1.-FP)/PMB)/(FP+(1.-FT)/TMB)                     JET17890
      FUNT(FV,FT)=FV*FT/(FT+(1.-FT)/TMB)                                  JET17900
      NPTS=24                                                             JET17910
      ALPT=ALPV                                                           JET17920
C     WRITE (6,777) TN,TM,ALPV,ALPT,CM,CT                                 JET17930
      TMB=TM*TN                                                           JET17940
      DTM=(1.-TMB)/TMB                                                    JET17950
      DPM=(PMB-1.)/PMB                                                    JET17960
      N1=NPTS-1                                                           JET17970
      N2=NPTS-2                                                           JET17980
      XN1=N1                                                              JET17990
      DETA=(1.-KDEL)/XN1                                                  JET18000
      ETA=KDEL+DETA                                                       JET18010
      SUMOM=0.                                                            JET18020
      SUMOT=0.                                                            JET18030
      SCV2AO=0.                                                           JET18040
      SCV2LO=0.                                                           JET18050
      SCTAO=0.                                                            JET18060
      SCTLO=0.                                                            JET18070
      DO 100 I=1,N1,2                                                     JET18080
      ETAP=(ETA-KDEL)/(1.-KDEL)                                           JET18090
      ETAPT=ETAP/TLAM                                                     JET18100
      IF (ETAPT.GT.1.) ETAPT=1.                                           JET18110
      FV=FVP(ETAP)                                                        JET18120
      FT=FTP(ETAP)                                                        JET18130
      FP=FV*FV                                                            JET18140
      FVALP=FVA(ETAP)                                                     JET18150
      FTALP=FTA(ETAPT)                                                    JET18160
      FPALP=FPA(ETAP)                                                     JET18170
      FTLAM=FTL(ETAPT)                                                    JET18180
      SUMOM=SUMOM+FV*FUNC(FV,FT,FP)                                       JET18190
      SUMOT=SUMOT+FT*FUNC(FV,FT,FP)                                       JET18200
```

Figure 69 - Continued

```
      SCV2A0=SCV2A0+FUNC(FV,FT,FP)*(2.*FVALP+FV*FPALP*DPM)                JET18210
     1+FUNCD(FV,FT,FP)*FV*FTALP*DTM                                       JET18220
      SCV2L0=SCV2L0+FUNCD(FV,FT,FP)*FV*FTLAM*DTM                          JET18230
      SCTA0=SCTA0+FVALP*FUN(FT,FP)+FUNC(FV,FT,FP)*FTALP                   JET18240
     1+FUNT(FV,FT)*FPALP*DPM+FUNCD(FV,FT,FP)*FT*FTALP*DTM                 JET18250
      SCTL0=SCTL0+FUNC(FV,FT,FP)*FTLAM+FUNCD(FV,FT,FP)*FT*FTLAM*DTM       JET18260
      ETA=ETA+2.*DETA                                                     JET18270
  100 CONTINUE                                                            JET18280
      ETA=KDEL+2.*DETA                                                    JET18290
      SUMEM=0.                                                            JET18300
      SUMET=0.                                                            JET18310
      SCV2AE=0.                                                           JET18320
      SCV2LE=0.                                                           JET18330
      SCTAE=0.                                                            JET18340
      SCTLE=0.                                                            JET18350
      DO 200 I=3,N2,2                                                     JET18360
      ETAP=(ETA-KDEL)/(1.-KDEL)                                           JET18370
      ETAPT=ETAP/TLAM                                                     JET18380
      IF (ETAPT.GT.1.) ETAPT=1.                                           JET18390
      FV=FVP(ETAP)                                                        JET18400
      FT=FTP(ETAP)                                                        JET18410
      FP=FV*FV                                                            JET18420
      FVALP=FVA(ETAP)                                                     JET18430
      FTALP=FTA(ETAPT)                                                    JET18440
      FPALP=FPA(ETAP)                                                     JET18450
      FTLAM=FTL(ETAPT)                                                    JET18460
      SUMEM=SUMEM+FV*FUNC(FV,FT,FP)                                       JET18470
      SUMET=SUMET+FT*FUNC(FV,FT,FP)                                       JET18480
      SCV2AE=SCV2AE+FUNC(FV,FT,FP)*(2.*FVALP+FV*FPALP*DPM)                JET18490
     1+FUNCD(FV,FT,FP)*FV*FTALP*DTM                                       JET18500
      SCV2LE=SCV2LE+FUNCD(FV,FT,FP)*FV*FTLAM*DTM                          JET18510
      SCTAE=SCTAE+FVALP*FUN(FT,FP)+FUNC(FV,FT,FP)*FTALP                   JET18520
     1+FUNT(FV,FT)*FPALP*DPM+FUNCD(FV,FT,FP)*FT*FTALP*DTM                 JET18530
      SCTLE=SCTLE+FUNC(FV,FT,FP)*FTLAM+FUNCD(FV,FT,FP)*FT*FTLAM*DTM       JET18540
      ETA=ETA+2.*DETA                                                     JET18550
  200 CONTINUE                                                            JET18560
      CV2=N*KDEL/(2.*N)+(DETA/3.)*(1.*4.*SUMOM+2.*SUMEM)                  JET18570
      CT=N*KDEL/(1.*N)+(DETA/3.)*(1.*4.*SUMOT+2.*SUMET)                   JET18580
      CV2A=(DETA/3.)*(4.*SCV2A0+2.*SCV2AE)                                JET18590
      CV2L=(DETA/3.)*(4.*SCV2L0+2.*SCV2LE)                                JET18600
      CTA=(DETA/3.)*(4.*SCTA0+2.*SCTAE)                                   JET18610
      CTL=(DETA/3.)*(4.*SCTL0+2.*SCTLE)                                   JET18620
      CPF=1.-4./(ALPV+1.)+6./(2.*ALPV+1.)-4./(3.*ALPV+1.)+1./(4.*ALPV+1.JET18630
     1)                                                                   JET18640
      CPFD=4./((ALPV+1.)**2)-12./((2.*ALPV+1.)**2)+12./((3.*ALPV+1.)**2)JET18650
     1-4./((4.*ALPV+1.)**2)                                               JET18660
      CP=KDEL+(1.-KDEL)*CPF                                               JET18670
      CPA=(1.-KDEL)*CPFD                                                  JET18680
      RCON=(2.-SQRT(2.))/2.                                               JET18690
      R=KDEL+(1.-KDEL)*RCON**(1./ALPV)                                    JET18700
      RP=(R-KDEL)/(1.-KDEL)                                               JET18710
      RALP=(KDEL-1.)*RP*ALOG(RP)/ALPV                                     JET18720
C     WRITE (6,777) TN,TM,ALPV,ALPT,CV2,CP,CT                             JET18730
  777 FORMAT (1X,7F10.5)                                                  JET18740
      RETURN                                                              JET18750
      END                                                                 JET18760
                                                                          JET18770
                                                                          JET18780
                                                                          JET18790
      SUBROUTINE SIMWTV (TN,TM,TLAM,FMB,KDEL,N,ALPV,CV2,CP,CT,CV2TM,CTTMJET18800
     1,R)                                                                 JET18810
      REAL KDEL,N                                                         JET18820
      FVP(ETAP)=(1.-ETAP**ALPV)**2                                        JET18830
      FTP(ETAP)=(1.-(ETAP/TLAM)**ALPT)**2                                 JET18840
      FUNC(FV,FT,FP)=FV*(FP+(1.-FP)/FMB)/(FT+(1.-FT)/TMB)                 JET18850
      FUNCD(FV,FT,FP)=FV*((1.-FT)/(TMB*TM))*(FP+(1.-FP)/FMB)/((FT+(1.-FTJET18860
     1)/TMB)**2)                                                          JET18870
      NPTS=24                                                             JET18880
      ALPT=ALPV                                                           JET18890
C     WRITE (6,777) TN,TM,ALPV,ALPT,CM,CT                                 JET18900
      TMB=TM*TN                                                           JET18910
      DTM=(1.-TMB)/TMB                                                    JET18920
      DPM=(FMB-1.)/FMB                                                    JET18930
      N1=NPTS-1                                                           JET18940
      N2=NPTS-2                                                           JET18950
      XN1=N1                                                              JET18960
      DETA=(1.-KDEL)/XN1                                                  JET18970
      ETA=KDEL+DETA                                                       JET18980
      SUMOM=0.                                                            JET18990
```

Figure 69 - Continued

```
      SUMOT=0.                                                          JET19000
      SCV2TO=0.                                                         JET19010
      SCTMO=0.                                                          JET19020
      DO 100 I=1,N1,2                                                   JET19030
      ETAP=(ETA-KDEL)/(1.-KDEL)                                         JET19040
      ETAPT=ETAP/TLAM                                                   JET19050
      IF (ETAPT.GT.1.) ETAPT=1.                                         JET19060
      FV=FVP(ETAP)                                                      JET19070
      FT=FTP(ETAP)                                                      JET19080
      FP=FV*FV                                                          JET19090
      SUMOM=SUMOM+FV*FUNC(FV,FT,FP)                                     JET19100
      SUMOT=SUMOT+FT*FUNC(FV,FT,FP)                                     JET19110
      SCV2TO=SCV2TO+FUNCD(FV,FT,FP)*FV                                  JET19120
      SCTMO=SCTMO+FUNCD(FV,FT,FP)*FT                                    JET19130
      ETA=ETA+2.*DETA                                                   JET19140
  100 CONTINUE                                                          JET19150
      ETA=KDEL+2.*DETA                                                  JET19160
      SUMEM=0.                                                          JET19170
      SUMET=0.                                                          JET19180
      SCV2TE=0.                                                         JET19190
      SCTME=0.                                                          JET19200
      DO 200 I=3,N2,2                                                   JET19210
      ETAP=(ETA-KDEL)/(1.-KDEL)                                         JET19220
      ETAPT=ETAP/TLAM                                                   JET19230
      IF (ETAPT.GT.1.) ETAPT=1.                                         JET19240
      FV=FVP(ETAP)                                                      JET19250
      FT=FTP(ETAP)                                                      JET19260
      FP=FV*FV                                                          JET19270
      SUMEM=SUMEM+FV*FUNC(FV,FT,FP)                                     JET19280
      SUMET=SUMET+FT*FUNC(FV,FT,FP)                                     JET19290
      SCV2TE=SCV2TE+FUNCD(FV,FT,FP)*FV                                  JET19300
      SCTME=SCTME+FUNCD(FV,FT,FP)*FT                                    JET19310
      ETA=ETA+2.*DETA                                                   JET19320
  200 CONTINUE                                                          JET19330
      CV2=M*KDEL/(2.+N)+(DETA/3.)*(1.+4.*SUMOM+2.*SUMEM)                JET19340
      CT=M*KDEL/(1.+N)+(DETA/3.)*(1.+4.*SUMOT+2.*SUMET)                 JET19350
      CV2TM=(DETA/3.)*(4.*SCV2TO+2.*SCV2TE)                             JET19360
      CTTM=(DETA/3.)*(4.*SCTMO+2.*SCTME)                                JET19370
      CPF=1.-4./(ALPV+1.)+4./(2.*ALPV+1.)-4./(3.*ALPV+1.)+1./(4.*ALPV+1.JET19380
     1)                                                                 JET19390
      CP=KDEL+(1.-KDEL)*CPF                                             JET19400
      RCON=(2.-SQRT(2.))/2.                                             JET19410
      R=KDEL+(1.-KDEL)*RCON**(1./ALPV)                                  JET19420
C     WRITE (6,777) TM,TM,ALPV,ALPT,CV2,CP,CT                           JET19430
  777 FORMAT (1X,7F10.5)                                                JET19440
      RETURN                                                            JET19450
      END                                                               JET19460
                                                                        JET19470
                                                                        JET19480
                                                                        JET19490
      SUBROUTINE PGUNAT(CUFD,DELPS,DELPW,RO,SD,ALPG,ALPUG)              JET19500
      DIMENSION ERR(101),SIG(101)                                       JET19510
C                                                                       JET19520
C   THIS ROUTINE COMPUTES EXPONENT OF UPWASH GROUND PRESSURE PROFILE    JET19530
C                                                                       JET19540
      SIG(1)=.10                                                        JET19550
       SIG(2)=1.0                                                       JET19560
      ALPUFD=1.5                                                        JET19570
      DO 100 I=1,100                                                    JET19580
      FB=(DELPS/DELPW)**(.25)                                           JET19590
      ETAG=SD*(1.-SIG(I))/RO                                            JET19600
      ETAU=SIG(I)/CUFD                                                  JET19610
      F1=FB*(1.-ETAG**ALPG)                                             JET19620
      F2=1.-ETAU**ALPUFD                                                JET19630
      ERR(I)=F1-F2                                                      JET19640
      IF (I.EQ.1) GO TO 100                                             JET19650
      S=(SIG(I)-SIG(I-1))/(ERR(I)-ERR(I-1))                             JET19660
      IF (ABS(ERR(I)).LT.1.E-5) GO TO 101                               JET19670
      SIG(I+1)=SIG(I)-S*ERR(I)                                          JET19680
  100 CONTINUE                                                          JET19690
      STOP                                                              JET19700
  101 SIGUO=SIG(I)                                                      JET19710
      ETAM=SIGUO/CUFD                                                   JET19720
      IF (ETAM.GT.1.0) ETAM=1.0                                         JET19730
      PMIN=DELPW*(1.-ETAM**ALPUFD)**4                                   JET19740
      CALL PMATCH (PMIN,DELPW,ALPUG)                                    JET19750
      RETURN                                                            JET19760
      END                                                               JET19770
```

Figure 69 - Continued

```
                                                                      JET19780
                                                                      JET19790
                                                                      JET19800
      SUBROUTINE PMATCH (PMIN,PMAX,ALPUG)                             JET19810
      DIMENSION ERR(101),AL(101)                                      JET19820
C                                                                     JET19830
C     THIS ROUTINE COMPUTES THE EXPONENT OF THE PRESSURE PROFILE FOR   JET19840
C     THE UPWASH DEFLECTION ZONE                                      JET19850
C                                                                     JET19860
      ALPUFD=1.                                                       JET19870
      PB=PMIN/PMAX                                                    JET19880
      ETAM=(1.-PB**.25)**(1./ALPUFD)                                  JET19890
      CALL SIMUF(ALPUFD,ETAM,CSPUFD)                                  JET19900
      AL(1)=1.5                                                       JET19910
      AL(2)=3.0                                                       JET19920
      DO 100 I=1,100                                                  JET19930
      CALL SIMUF(AL(I),1.0,CSPU)                                      JET19940
      X1=ETAM*(PB+(1.-PB)*CSPU)                                       JET19950
      X2=CSPUFD                                                       JET19960
      ERR(I)=X1-X2                                                    JET19970
      IF (ABS(ERR(I)).LT.1.E-5) GO TO 101                             JET19980
      IF (I.EQ.1) GO TO 100                                           JET19990
      S=(AL(I)-AL(I-1))/(ERR(I)-ERR(I-1))                             JET20000
      AL(I+1)=AL(I)-S*ERR(I)                                          JET20010
  100 CONTINUE                                                        JET20020
      STOP                                                            JET20030
  101 ALPUG=AL(I)                                                     JET20040
      RETURN                                                          JET20050
      END                                                             JET20060
                                                                      JET20070
                                                                      JET20080
                                                                      JET20090
      SUBROUTINE SIMUF(ALPU,ETA,CSPU)                                 JET20100
      A1=ETA                                                          JET20110
      A2=-(4./(ALPU+1.))*ETA**(ALPU+1.)                               JET20120
      A3=(6./(2.*ALPU+1.))*ETA**(2.*ALPU+1.)                          JET20130
      A4=-(4./(3.*ALPU+1.))*ETA**(3.*ALPU+1.)                         JET20140
      A5=(1./(4.*ALPU+1.))*ETA**(4.*ALPU+1.)                          JET20150
      CSPU=A1+A2+A3+A4+A5                                             JET20160
      RETURN                                                          JET20170
      END                                                             JET20180
                                                                      JET20190
                                                                      JET20200
                                                                      JET20210
      SUBROUTINE SIM(ETAC,ALP,R,CV2)                                  JET20220
C                                                                     JET20230
C    INTEGRAL OF JET VELOCITY PROFILE FUNCTION=CV2                    JET20240
C     R=RATIO OF BJH TO BJ                                            JET20250
C                                                                     JET20260
      A1=.5-4./(ALP+2.)+3./(ALP+1.)-4./(3.*ALP+2.)+1./(4.*ALP+2)      JET20270
      A2=1.-4./(ALP+1.)+6./(2.*ALP+1.)-4./(3.*ALP+1.)+1./(4.*ALP+1.)  JET20280
      CV2=.5*ETAC**2+A1*(1.-ETAC)**2+ETAC*(1.-ETAC)*A2                JET20290
      R=ETAC+(1.-ETAC)*((2.-SQRT(2.))/2.)**(1./ALP)                   JET20300
      RETURN                                                          JET20310
      END                                                             JET20320
                                                                      JET20330
                                                                      JET20340
                                                                      JET20350
      SUBROUTINE SIMU(ALPU,R,CV2U)                                    JET20360
      CV2U=1.-4./(ALPU+1.)+6./(2.*ALPU+1.)-4./(3.*ALPU+1.)+1./(4.*ALPU+1JET20370
     1.)                                                              JET20380
      F=(SQRT(2.)-1.)/SQRT(2.)                                        JET20390
      R=F**(1./ALPU)                                                  JET20400
      RETURN                                                          JET20410
      END                                                             JET20420
                                                                      JET20430
                                                                      JET20440
                                                                      JET20450
      SUBROUTINE SIMUM(TN,TM,TLAM,PMB,ALPU,FETAG,DELPWS,VM,BU,RG,R,FM )  460
     1TNEFF,TAEFF)                                                      470
C     WRITE (6,111) PMB,VM                                            480
  111 FORMAT (1X,'PMB=',F10.5,2X, VM=',F10.5)                         490
      TMB=TM*TN                                                       500
      REL=.5                                                          510
      IFLAG=0                                                         520
      DELMIN=1.E-5                                                    530
      TLAM=1.0                                                        540
      TLAMI=TLAM                                                      JET20550
C     WRITE (6,400) FETAG,FMOM,BU,RG                                  JET20560
```

Figure 69 - Continued

```
  400 FORMAT (1X,'FETAG',4F10.5)                                        JET20570
      DO 100 I=1,50                                                     JET20580
      CALL SIMUTI (TN,TM,TLAM,PMB,ALPV,CV2,CP,CT,CV2L,CTL,R)            JET20590
      IF (I.EQ.1) BU=FMOM/(RG*CV2*(2.                                   JET20600
     1*VM**2+DELPWS*FETAG))                                             JET20610
      IF (I.EQ.1) BUI=BU                                                JET20620
C     WRITE (6,740) CV2,CP,CT,CV2L,CTL,R                                JET20630
  740 FORMAT (1X,6F10.5)                                                JET20640
C     IF (I.EQ.1) WRITE (6,103) BU                                      JET20650
  103 FORMAT (1X,'BU EST.=',F10.5)                                      JET20660
      F=FMOM-RG*(2.*PMB*VM*VM*CV2/TM+DELPWS*FETAG*CP)                   JET20670
      G=FMOM*TM*(TM-1.)-2.*PMB*VM*(TMB-1.)*RG*BU*CT                     JET20680
      FBU=-RG*(2.*PMB*VM*VM*CV2/TM+DELPWS*FETAG*CP)                     JET20690
      FLAM=-RG*BU*(2.*PMB*VM*VM*CV2L/TM)                                JET20700
      GBU=-2.*PMB*VM*(TMB-1.)*RG*CT                                     JET20710
      GLAM=-2.*PMB*VM*(TMB-1.)*RG*BU*CTL                                JET20720
C     WRITE (6,750) FBU,FLAM,GBU,GLAM                                   JET20730
  750 FORMAT (1X,'FA=',F10.5,1X,'FL=',F10.5,1X,'GA=',F10.5,1X,'GL=',F10.JET20740
     15)                                                                JET20750
      DET=FBU*GLAM-FLAM*GBU                                             JET20760
      IF (ABS(DET).LT.1.E-10) IFLAG=1                                   JET20770
      IF (ABS(DET).LT.1.E-10) GO TO 101                                 JET20780
      DBU=(G*FLAM-F*GLAM)/DET                                           JET20790
      DLAM=(F*GBU-G*FBU)/DET                                            JET20800
      BU=BU+REL*DBU                                                     JET20810
      TLAM=TLAM+REL*DLAM                                                JET20820
      IF (TLAM.LT.0.) IFLAG=1                                           JET20830
      IF (TLAM.LT.0.) GO TO 101                                         JET20840
C     WRITE (6,500) F,G,BU,TLAM                                         JET20850
      IF (ABS(F).LT.DELMIN.AND.ABS(G).LT.DELMIN) GO TO 101              JET20860
  500 FORMAT (1X,4F15.5)                                                JET20870
  100 CONTINUE                                                          JET20880
      STOP                                                              JET20890
  101 IF (IFLAG.EQ.1) BU=BUI                                            JET20900
      IF (IFLAG.EQ.1) TLAM=TLAMI                                        JET20910
      RETURN                                                            JET20920
      END                                                               JET20930
                                                                        JET20940
                                                                        JET20950
                                                                        JET20960
      SUBROUTINE SIMUTI (TN,TM,TLAM,PMB,ALPV,CV2,CP,CT,CV2L,CTL,R)      JET20970
      FVP(ETAP)=(1.-ETAP**ALPV)**2                                      JET20980
      FTP(ETAP)=(1.-(ETAP/TLAM)**ALPT)**2                               JET20990
      FTL(ETAPT)=2.*(1.-ETAPT**ALPT)*ALPT*(ETAPT**ALPT)/TLAM            JET21000
      FUNC(FV,FT,FP)=FV*(FP+(1.-FP)/PMB)/(FT+(1.-FT)/TMB)               JET21010
      FUNCD(FV,FT,FP)=FV*(FP+(1.-FP)/PMB)/((FT+(1.-FT)/TMB)**2)         JET21020
      NPTS=24                                                           JET21030
      ALPT=ALPV                                                         JET21040
C     WRITE (6,777) TN,TM,ALPV,ALPT,CM,CT                               JET21050
      TMB=TM*TN                                                         JET21060
      DTM=(1.-TMB)/TMB                                                  JET21070
      DPM=(PMB-1.)/PMB                                                  JET21080
      N1=NPTS-1                                                         JET21090
      N2=NPTS-2                                                         JET21100
      XN1=N1                                                            JET21110
      DETA=1./XN1                                                       JET21120
      ETA=DETA                                                          JET21130
      SUMOM=0.                                                          JET21140
      SUMOT=0.                                                          JET21150
      SCV2LO=0.                                                         JET21160
      SCTLO=0.                                                          JET21170
      DO 100 I=1,N1,2                                                   JET21180
      ETAP=ETA                                                          JET21190
      ETAPT=ETAP/TLAM                                                   JET21200
      IF (ETAPT.GT.1.) ETAPT=1.                                         JET21210
      FV=FVP(ETAP)                                                      JET21220
      FT=FTP(ETAP)                                                      JET21230
      FP=FV*FV                                                          JET21240
      FTLAM=FTL(ETAPT)                                                  JET21250
      SUMOM=SUMOM+FV*FUNC(FV,FT,FP)                                     JET21260
      SUMOT=SUMOT+FT*FUNC(FV,FT,FP)                                     JET21270
      SCV2LO=SCV2LO+FUNCD(FV,FT,FP)*FV*FTLAM*DTM                        JET21280
      SCTLO=SCTLO+FUNC(FV,FT,FP)*FTLAM+FUNCD(FV,FT,FP)*FT*FTLAM*DTM     JET21290
      ETA=ETA+2.*DETA                                                   JET21300
```

Figure 69 - Continued

```
  100 CONTINUE                                                          JET21310
      ETA=2.*DETA                                                       JET21320
      SUMEM=0.                                                          JET21330
      SUMET=0.                                                          JET21340
      SCV2LE=0.                                                         JET21350
      SCTLE=0.                                                          JET21360
      DO 200 I=3,N2,2                                                   JET21370
      ETAP=ETA                                                          JET21380
      ETAPT=ETAP/TLAM                                                   JET21390
      IF (ETAPT.GT.1.) ETAPT=1.                                         JET21400
      FV=FVP(ETAP)                                                      JET21410
      FT=FTP(ETAP)                                                      JET21420
      FP=FV*FV                                                          JET21430
      FTLAM=FTL(ETAPT)                                                  JET21440
      SUMEM=SUMEM+FV*FUNC(FV,FT,FP)                                     JET21450
      SUMET=SUMET+FT*FUNC(FV,FT,FP)                                     JET21460
      SCV2LE=SCV2LE+FUNCD(FV,FT,FP)*FV*FTLAM*DTM                        JET21470
      SCTLE=SCTLE+FUNC(FV,FT,FP)*FTLAM+FUNCD(FV,FT,FP)*FT*FTLAM*DTM     JET21480
      ETA=ETA+2.*DETA                                                   JET21490
  200 CONTINUE                                                          JET21500
      CV2=(DETA/3.)*(1.+4.*SUMOM+2.*SUMEM)                              JET21510
      CT=(DETA/3.)*(1.+4.*SUMOT+2.*SUMET)                               JET21520
      CV2L=(DETA/3.)*(4.*SCV2LO+2.*SCV2LE)                              JET21530
      CTL=(DETA/3.)*(4.*SCTLO+2.*SCTLE)                                 JET21540
      CP=1.-4./(ALPV+1.)+6./(2.*ALPV+1.)-4./(3.*ALPV+1.)+1./(4.*ALPV+1. JET21550
     1)                                                                 JET21560
      RCON=(2.-SQRT(2.))/2.                                             JET21570
      R=RCON**(1./ALPV)                                                 JET21580
C     WRITE (6,777) TN,TM,ALPV,ALPT,CV2,CP,CT                           JET21590
  777 FORMAT (1X,7F10.5)                                                JET21600
      RETURN                                                            JET21610
      END                                                               JET21620
                                                                        JET21630
                                                                        JET21640
                                                                        JET21650
      SUBROUTINE SIMUTV (TN,TM,TLAM,PMB,ALPV,CV2,CP,CT,CV2TM,CTTM,R)    JET21660
      FVP(ETAP)=(1.-ETAP**ALPV)**2                                      JET21670
      FTP(ETAP)=(1.-(ETAP/TLAM)**ALPT)**2                               JET21680
      FUNC(FV,FT,FP)=FV*(FP+(1.-FP)/PMB)/(FT+(1.-FT)/TMB)               JET21690
      FUNCD(FV,FT,FP)=FV*((1.-FT)/(TMB*TM))*(FP+(1.-FP)/PMB)/((FT+(1.-FTJET21700
     1)/TMB)**2)                                                        JET21710
      NPTS=24                                                           JET21720
      ALPT=ALPV                                                         JET21730
C     WRITE (6,777) TN,TM,ALPV,ALPT,CM,CT                               JET21740
      TMB=TM*TN                                                         JET21750
      DTM=(1.-TMB)/TMB                                                  JET21760
      DPM=(PMB-1.)/PMB                                                  JET21770
      N1=NPTS-1                                                         JET21780
      N2=NPTS-2                                                         JET21790
      XN1=N1                                                            JET21800
      DETA=1./XN1                                                       JET21810
      ETA=DETA                                                          JET21820
      SUMOM=0.                                                          JET21830
      SUMOT=0.                                                          JET21840
      SCV2TO=0.                                                         JET21850
      SCTMO=0.                                                          JET21860
      DO 100 I=1,N1,2                                                   JET21870
      ETAP=ETA                                                          JET21880
      ETAPT=ETAP/TLAM                                                   JET21890
      IF (ETAPT.GT.1.) ETAPT=1.                                         JET21900
      FV=FVP(ETAP)                                                      JET21910
      FT=FTP(ETAP)                                                      JET21920
      FP=FV*FV                                                          JET21930
      SUMOM=SUMOM+FV*FUNC(FV,FT,FP)                                     JET21940
      SUMOT=SUMOT+FT*FUNC(FV,FT,FP)                                     JET21950
      SCV2TO=SCV2TO+FUNCD(FV,FT,FP)*FV                                  JET21960
      SCTMO=SCTMO+FUNCD(FV,FT,FP)*FT                                    JET21970
      ETA=ETA+2.*DETA                                                   JET21980
```

Figure 69 - Continued

```
  100 CONTINUE                                                          JET21990
      ETA=2.*DETA                                                       JET22000
      SUMEM=0.                                                          JET22010
      SUMET=0.                                                          JET22020
      SCV2TE=0.                                                         JET22030
      SCTME=0.                                                          JET22040
      DO 200 I=3,N2,2                                                   JET22050
      ETAP=ETA                                                          JET22060
      ETAPT=ETAP/TLAM                                                   JET22070
      IF (ETAPT.GT.1.) ETAPT=1.                                         JET22080
      FV=FVP(ETAP)                                                      JET22090
      FT=FTP(ETAP)                                                      JET22100
      FP=FV*FV                                                          JET22110
      SUMEM=SUMEM+FV*FUNC(FV,FT,FP)                                     JET22120
      SUMET=SUMET+FT*FUNC(FV,FT,FP)                                     JET22130
      SCV2TE=SCV2TE+FUNCD(FV,FT,FP)*FV                                  JET22140
      SCTME=SCTME+FUNCD(FV,FT,FP)*FT                                    JET22150
      ETA=ETA+2.*DETA                                                   JET22160
  200 CONTINUE                                                          JET22170
      CV2=(DETA/3.)*(1.+4.*SUMOM+2.*SUMEM)                              JET22180
      CT=(DETA/3.)*(1.+4.*SUMOT+2.*SUMET)                               JET22190
      CV2TM=(DETA/3.)*(4.*SCV2TO+2.*SCV2TE)                             JET22200
      CTTM=(DETA/3.)*(4.*SCTMO+2.*SCTME)                                JET22210
      CPF=1.-4./(ALPV+1.)+6./(2.*ALPV+1.)-4./(3.*ALPV+1.)+1./(4.*ALPV+1.JET22220
     1)                                                                 JET22230
      CP=CPF                                                            JET22240
      RCON=(2.-SQRT(2.))/2.                                             JET22250
      R=RCON**(1./ALPV)                                                 JET22260
C     WRITE (6,777) TN,TM,ALPV,ALPT,CV2,CP,CT                           JET22270
  777 FORMAT (1X,7F10.5)                                                JET22280
      RETURN                                                            JET22290
      END                                                               JET22300
                                                                        JET22310
                                                                        JET22320
                                                                        JET22330
```

Figure 69 - Concluded.

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