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## Abstract

*Pressure distributions on three inlets having different cowl lengths were obtained in the Langley 16-Foot Transonic Tunnel. The cowl diameter ratio (highlight diameter to maximum diameter) was 0.85, and the cowl length ratios (cowl length to maximum diameter) were 0.337, 0.439, and 0.547. The cowls had identical nondimensionalized (with respect to cowl length) external geometry and identical internal geometry. The internal contraction ratio (highlight area to throat area) was 1.250. The inlets had longitudinal rows of static-pressure orifices on the top and bottom (external) surfaces and on the contraction (internal) and diffuser surfaces. The afterbody was cylindrical in shape, and its diameter was equal to the maximum diameter of the cowl. Depending on the cowl configuration and free-stream Mach number, the mass-flow ratio varied between 0.27 and 0.87 during the tests. Angle of attack varied from 0° to 4.1° at selected Mach numbers and mass-flow ratios, and the Reynolds number varied with the Mach number from $3.2 \times 10^6$ to $4.2 \times 10^6$ per foot.*

## Introduction

Jet-powered subsonic transport aircraft generally have engines installed in separate, essentially axisymmetric nacelles. Typically, the nacelle is pylon mounted (displaced from the airframe) to provide the inlet with flow that is not significantly distorted. This installation permits the nacelle cowl design to be developed independent of the rest of the airframe. This independence from the airframe geometry makes the data base for subsonic inlets directly usable (refs. 1 to 10).

Inlets for turbojet and turbofan subsonic aircraft must provide high-quality flow to the engine fan and compressor, produce low external drag, and be low in weight. Low weight implies shortening the internal flow path and cowl as much as possible while maintaining good internal and external performance. The internal flow path is shortened by selecting a large throat diameter and contouring the diffuser so that the flow is of high quality but near the limit for the onset of flow separation. Based on external flow consideration, the cowl drag is minimized by making the cowl maximum diameter and length as small as possible while still obtaining the desired drag-rise Mach number and critical mass-flow ratio. The critical mass-flow ratio occurs while operating below the compressibility drag-rise conditions and is defined as the point at which external drag increases rapidly because of separation or shocks on the cowl forebody when mass flow through the inlet is reduced. For commercial applications, noise suppression should also be considered during diffuser design because it may limit the minimum length of the nacelle forebody.

Many of the subsonic transport nacelle cowls used in the past have been based in part on the cowl contour of the NACA 1-series inlets, which were developed in the 1940's. The relatively small leading-edge radius of the NACA 1-series contour just aft of the highlight (most forward point on the inlet lip) results in good high-speed drag characteristics. The NACA 1-series contour was developed with emphasis on cowl external flow quality and performance with the assumption that internal performance (i.e., contraction section and diffuser shape) would be a separate design endeavor. References 1 to 10 contain some of the published experimental data obtained on the NACA 1-series contours. In practice, compromising the good high-speed external performance of the NACA 1-series contour by increasing the cowl leading-edge radius by blunting the lip has often been necessary to achieve acceptable internal performance at low-speed and static crosswind conditions.

In some investigations of cowls with elliptical longitudinal contours (e.g., ref. 9), flow separation on the cowl forebody was delayed to higher mass-flow ratios and Mach numbers than for comparable NACA 1-series contours because of the significantly blunter forward contour. However, the drag-rise Mach number was lower for a given mass-flow ratio. Based on data such as these, the cowl contour of the present investigation, though not as blunt as an elliptical contour, had a greatly increased nondimensionalized local radius of curvature over the forward 10 percent of the cowl relative to an NACA 1-series contour.

Three cowls having length ratios (cowl length to maximum diameter) of 0.337, 0.439, and 0.547 were investigated to determine the effect of length on cowl static-pressure distribution at various Mach numbers and mass-flow ratios. The cowls had identical nondimensionalized (with respect to cowl length) external geometry and identical internal geometry from the highlight to the end of the diffuser. The internal contraction ratio (highlight area to throat area) was 1.250, and the contraction section longitudinal contour was elliptical.

The investigation was conducted in the Langley 16-Foot Transonic Tunnel. Cowl pressures were obtained at Mach numbers from about 0.60 to 0.92, mass-flow ratios from 0.27 to 0.87, and angles of attack within the range of 0° to 4.1° at selected mass-flow ratios and Mach numbers. Cowl external static pressures were measured in rows on the top and bottom surfaces in the plane of vertical symmetry. Internal contraction section and diffuser wall static pressures were also measured.

## Symbols

Symbols in parentheses are used in computer-generated tables.

| | | |
|---|---|---|
| $A$ | | area normal to model centerline, in$^2$ |
| $C_p$ | (CP) | pressure coefficient, $(p - p_\infty)/q_\infty$ |
| $D_{\max}$ | (DMAX) | maximum diameter of model, 18.0 in. |
| $L$ | (L) | length of cowl from lip (highlight) to start of cylindrical portion of model, in. (see fig. 1) |
| $M$ | | free-stream Mach number |
| mfr | | mass-flow ratio based on inlet area at the highlight, $1/(\rho_\infty A_h V_\infty) \int \rho_r V_r \mathrm{d}A$ |
| $p$ | | local static pressure, psi |
| $p_\infty$ | | free-stream static pressure, psi |
| $q_\infty$ | | free-stream dynamic pressure, psi |
| $R_\infty$ | | free-stream Reynolds number, per foot |
| $r$ | | local radius from model axis of symmetry, in. |
| $r_w$ | | local radius from axis of symmetry to outer wall of model duct, 8.40 in. |
| $V$ | | velocity, ft/sec |
| $X$ | (X) | longitudinal distance measured aft of cowl lip (highlight), in. |
| $y$ | | local thickness of cowl, in. |
| $y_e$ | | local thickness of elliptical cowl, in. |
| $\alpha$ | | angle of attack with respect to forebody centerline, deg |
| $\rho$ | | density, slug/ft$^3$ |
| $\phi$ | (PHI) | meridian angle, measured from top of model in clockwise direction when looking upstream, deg |

Subscripts:

| | |
|---|---|
| $h$ | highlight, most forward point on cowl lip |
| max | maximum |
| $r$ | mass-flow rake pressure measuring station in duct |
| $\infty$ | free-stream conditions |

## Models

A complete model test installation consisted of an inlet attached to a cylindrical section ($D_{\max}$ = 18.0 in.) supported by a force balance and an afterbody (also cylindrical) supported by a rear sting upon which a remote-controlled mass-flow throttle plug was mounted. The throttle plug, which was driven by an internal electric motor, had a range of travel of about 10 in. The open area at the exit of the model (normal to the centerline) varied from 27.5 in$^2$ to 244.9 in$^2$ for the throttle plug in its two extreme positions. Figure 1 is a simplified cross-sectional sketch of the model assembly, and figure 2 is a photograph of a typical model installation in the wind tunnel test section.

Three inlets were tested that had cowls of identical nondimensionalized (with respect to cowl length) external geometry and identical internal geometry. The nondimensionalized external and internal coordinates for the cowl are presented in tables I and II. The cowl lengths ($L$) were 6.0655 in. for the short cowl, 7.8973 in. for the medium cowl, and 9.8420 in. for the long cowl, and the corresponding cowl length ratios ($L/D_{\max}$) were 0.337, 0.439, and

0.547. Figure 3 shows the dimensional differences among the three cowl contours. (Note, the radius scale is twice as large as the longitudinal scale.) Figure 4 shows the ratio of the local cowl thickness to the local thickness of an elliptical longitudinal contour having the same length and maximum thickness ($r_{\max} - r_h$). The cowls for the present investigation had a diameter ratio of 0.85 (i.e., highlight diameter to maximum diameter) and a contraction ratio of 1.250 (i.e., highlight area to throat area).

The total model length was 52.00 in. (fig. 1). The forebody had a fixed length of 27.50 in. and was comprised of the cowl and a cylindrical section. The forebody was supported by four struts that connected to a force-balance mounted centerbody. The afterbody had a length of 24.50 in. and a diameter of 18.0 in., and it was supported by four struts attached to the support sting. The 0.10 in. gap between the metric forebody and nonmetric afterbody was spanned by a free-floating flexible strip to inhibit flow leakage. The inlets had longitudinal rows of static-pressure orifices on the top and bottom external surfaces of the cowl and on the contraction (internal) and diffuser surfaces. Three of the four struts supporting the forebody were instrumented with pressure probes (fig. 5) to measure the internal mass flow. These struts were also used to route the tubes from the inlet surface static-pressure orifices to differential pressure-scanning units mounted in the nose of the centerbody. All pressure tubes associated with the afterbody were routed through the four rear support struts, into the sting, and out through the model support system to an externally mounted differential pressure-scanning unit.

## Wind Tunnel

The investigation was conducted in the Langley 16-Foot Transonic Tunnel, which is a single-return atmospheric wind tunnel with continuous air exchange. The test section is octagonal with 15.5 ft between opposite walls (equivalent in area to a circle 16 ft in diameter) and has axial slots at the wall vertices. The total width of the eight slots in the vicinity of the model is about 3.7 percent of the test section perimeter. The extreme limits of solid blockage of the model in the test section are between 0.88 percent for no flow through the model and 0.79 percent for the throttle plug area only (i.e., the throttle plug in its most rearward position). The tunnel sting support system pivots in such a manner that the model remains on or near the centerline through the angle-of-attack range. References 11 to 13 contain details of the operation of the tunnel and its flow qualities.

## Tests and Methods

Each cowl was tested at Mach numbers up to 0.92 at an angle of attack of 0° and over an angle-of-attack range up to 4.1° at selected Mach numbers and mass-flow ratios. Free-stream Reynolds number varied with Mach number from $3.2 \times 10^6$ to $4.2 \times 10^6$ (fig. 6). All the data presented herein are for artificially fixed boundary-layer transition on the internal and external surfaces of the model. Boundary-layer transition on the external surface was fixed by applying a 0.10-inch wide circumferential strip of No. 120 silicon carbide particles 0.6 in. aft (streamwise) of the cowl lip. Boundary-layer transition on the internal flow surface was fixed by applying a 0.10-inch wide circumferential strip of No. 120 silicon carbide particles at the geometric throat of each inlet.

Angle of attack of the forebody was computed by correcting the measured pitch angle of the support system for deflection of the sting and force balance (due to aerodynamic forces and moments) and for tunnel flow angularity. Although the test was conducted with the forebody mounted on a force balance, these data are not presented because the balance was damaged during the test and the data are considered inaccurate. Duct mass flow was calculated from the free-stream total temperature, the rake area-weighted stagnation pressures, and the static pressures from the rake, centerbody surface, and duct wall.

No corrections have been made to the pressure data for test section wall interference effects. The presence and geometry of the mass-flow plug did affect the afterbody external flow field. Therefore, the afterbody pressure data presented in the pressure tabulations are considered qualitative, especially for pressures near the model aft end and for large mass-flow ratios.

## Presentation of Results

The results of this investigation are presented primarily in tables III to V as local internal and external pressure coefficients. The tables also present the nondimensionalized orifice locations ($X/L$). The ratio $X/L$ is presented in percentage form in the tables. A negative value of $X/L$ indicates that the orifice is located on the internal surface (downstream of the highlight) of the inlet. The pressures are presented for three meridian angles ($\phi$) for the afterbody and forebody of each configuration. The afterbody is the portion of the model located aft of the metric break, and the forebody is the portion of the model located forward of the metric break. Inlet mass-flow ratio and angle of attack are given at the top of each table. In addition, some data are presented graphically (figs. 7 to 12) to illustrate the variation of pressure coefficient with $X/L$ over the forward portion of the model over a range of Mach numbers, mass-flow ratios, and angles of attack.

Summaries of the tabular and graphical data presentation are contained in the following listings for each cowl length. Each listing includes nominal test condition information and table and figure numbers for the pressure coefficient data.

## Discussion of Results

This investigation was conducted primarily to obtain cowl pressure distributions under conditions that isolate the nacelle cowl from the influence of a boat-tailed afterbody flow field. Therefore, the model downstream of the cowl was cylindrical with a diameter equal to the cowl maximum diameter (fig. 1). This portion of the model was also used in the tests of reference 10 where the range of mass flow through the model was limited because of the throttle plug geometry. To expand the mass-flow range of the model to encompass lower mass-flow rates, the throttle plug geometry was altered so that it had a larger maximum diameter. The results of reference 9 (last 14 in. of the afterbody boat tailed) and reference 10 (cylindrical afterbody) indicate that no significant effects fed forward to the cowl pressure distributions from the exit plume caused by the mass-flow plug for the range of Mach numbers and mass-flow ratios of this test.

In reference 14, an empirical study performed on the drag of several NACA 1-series inlets found that the drag-rise Mach number of the cowls correlated with the thickness ratio $({r_{\text{max}}}^2 - {r_h}^2)^{0.5}\ /L$ of an equivalent body of revolution. Thus, this thickness ratio can be used as a design tool to determine a first approximation of cowl length for a desired cruise Mach number. Analysis of wake pressure data in reference 15 indicated that the drag characteristics for the present cowl contour were almost as good as those for an NACA 1-series contour of the same thickness ratio. Therefore, the cowls in this investigation, because of their different lengths and identical nondimensionalized geometry, can be considered to be designs for three different cruise speeds, with the cowl length increasing as the design Mach number increases.

Reference 14 also presented a correlation for critical mass-flow ratio as a function of a cowl lip radius parameter. The critical mass-flow ratio is a measure of cowl performance when operating below the compressibility drag-rise design condition. That is, drag changes only gradually as mass flow is decreased until a critical mass-flow ratio is reached where drag abruptly increases. This drag increase results from flow separation caused by shocks or strong pressure gradients resulting from flow expansion around the initial cowl lip curvature. Relative to an NACA 1-series contour of the same length (fig. 4), the blunter forward portion of the present contour should provide the capability to sustain lower pressures on the cowl leading edge, without flow separation, to lower speeds and mass-flow ratios and yet have the potential to approach the drag-rise Mach number capabilities of the NACA 1-series contour.

The following discussion of results is based only on the graphical data presented in this report. Note the points in this discussion can be refined, if necessary, by examination of the pressure data in tables III to V, which include data for intermediate mass-flow ratios and angles of attack.

## Pressure Distributions at Angle of Attack of 0°

Because the internal geometry is identical for the three cowls, any differences in pressure distributions are caused by differences in the external geometry. The effect of cowl length on shock development and the ability to sustain negative pressure peaks without flow separation near the leading edge at low mass-flow ratios are shown by comparison of the data of figures 7, 9, and 11 at similar test conditions. For example, the pressure distribution peaks at the lowest Mach numbers and mass-flow ratios of figures 7(a), 9(a), and 11(a) show that the short cowl sustained the highest negative pressure peak. The data also show that the flow over the long cowl is separated (note the collapsed pressure peak) over the forward 20 percent of its length. Therefore, the long cowl is operating below its critical mass-flow ratio. This high-drag condition occurs at a mass-flow ratio that is typical for a windmilling (nonoperating) engine.

With attached flow near the leading edge, the pressure peaks became less negative, and the pressure distributions over the cowl became more nearly uniform (flat) as mass-flow ratio increased at the lower Mach numbers for all the cowls. (See figs. 7(a), 9(a), and 11(a).) A uniform cowl pressure distribution at large mass-flow ratios is desirable to delay the formation of shocks that can result at local supercritical flow conditions to higher Mach numbers. As Mach number was increased, the pressure distributions over the short cowl became rounded over the forward portion of the cowl at high mass-flow ratios (e.g., compare fig. 7(g) with 7(a)). Extensive areas with positive external pressure coefficients acting over the forward (projected) area of the cowl near the lip indicate pressure drag.

Flow was separated on the forward 20 percent of the medium cowl at Mach numbers of 0.64 and 0.69 (figs. 9(b) and 9(c)) at the lowest mass-flow ratio (0.28). On the long cowl, separated flow was observed at a mass-flow ratio of 0.28 at Mach numbers from 0.59 to 0.79 (figs. 11(a) to 11(g)). The short cowl sustained the most negative pressure peaks near the leading edge. The first evidence of a shock forming during recompression from the leading-edge suction peak occurred on the short cowl at about 30 percent of its length at a Mach number of 0.69 with a mass-flow ratio of 0.27 (fig. 7(c)). At the lowest mass-flow ratio, where flow separation occurred over the forward portion of the medium and long cowls at low Mach numbers, the data showed no evidence of a downstream shock. For example, the first evidence of a shock on the medium cowl was at a Mach number of 0.74 after a pressure peak was established (no flow separation) and pressure recovery from the pressure peak extended past 20 percent of the cowl length (fig. 9(d)). Likewise, at a mass-flow ratio of 0.27, the long cowl had a shock at about 50 percent of its length at a Mach number of 0.82 (fig. 11(h)). At a mass-flow ratio of 0.40, pressure distributions indicated that all three cowls had a shock at a Mach number of 0.74, and the short cowl had the shock located the farthest aft (compare figs. 7(e), 9(d), and 11(e)). The first signs of the pressure failing to recover to close to free-stream static pressure in the vicinity of the maximum cowl diameter ($X/L =$ 100 percent) occurred at the lowest mass-flow ratio. On the short cowl, this occurred at a Mach number of 0.79 (fig. 7(g)), on the medium cowl at a Mach number of 0.84 (fig. 9(h)), and on the long cowl at a Mach number of 0.89 (fig. 11(k)).

### Pressure Distributions at Small Angles of Attack

Pressure distributions over the three cowls at a Mach number of about 0.60 at an angle of attack of 2° at the lowest mass-flow ratio (compare figs. 8(a), 10(a), and 12(a)) showed that the short cowl had the most negative pressure peaks on the top and bottom of the cowl. At an angle of attack of 2° (fig. 8(a)), flow separation occurred on the top ($\phi = 0°$) of the short cowl between 5 and 10 percent of its length with pressure recovery downstream. The medium cowl also showed flow separation at an angle of attack of 2° (fig. 10(a)), but the separation occurred between 15 and 25 percent of the cowl length with pressure recovery downstream. On the long cowl at an angle of attack of 2° (fig. 12(a)), the flow separation extended over the forward 20 percent of the cowl length. In figure 12(a), the bottom row of pressure orifices ($\phi =$ 180°) at an angle of attack of 2° is, for aerodynamic purposes, at an angle of attack of −2°, and the pressures measured there showed no evidence of flow separation at this condition.

At a mass-flow ratio of about 0.50 at angles of attack up to 3° at the lowest Mach number (0.60), the cowls had similar pressure distributions with little indication of flow separation (figs. 8(e), 10(d), and 12(d)). When Mach number was increased to 0.69 at a mass-flow ratio of 0.50 at an angle of attack of 2°, a shock occurred on the top surface of the short and medium cowls (figs. 8(f) and 10(e)). The separation and shock were not evident on the long cowl (fig. 12(e)). At a Mach number of 0.79 and at an angle of attack of 2°, the shock occurred at about 60 percent on the short cowl length (fig. 8(h)), at 40 percent on the medium cowl length (fig. 10(f)), and at 30 percent on the long cowl length (fig. 12(g)). At a Mach number of 0.89 and at a mass-flow ratio of 0.50 only, the long cowl had pressure recovery over its aft portion that approached free-stream static pressure. (See figs. 8(k), 10(i), and 12(i).)

At a Mach number of 0.60 at an angle of attack of 2° at a mass-flow ratio of 0.69, the long cowl (compare figs. 8(m), 10(k), and 12(k)) had the most negative pressure peak, which was followed by a steep pressure recovery between 5 and 20 percent of the cowl length. As shown in figure 8(m), the short cowl had a small pressure peak and a considerable rounding off of the pressure distribution over the first 20 percent of the cowl length on the bottom ($\phi = 180°$). At a Mach number of 0.84 at an angle of attack of 2° at a mass-flow ratio of 0.68, the pressure peak on the short cowl occurred at 90 percent of its length and was followed by a shock and a rapid pressure recovery (fig. 8(o)). At these same conditions, the medium cowl had the most uniform pressure distribution of the three cowls on the top surface ($\phi = 0°$) over the forward 60 percent of the cowl length with a pressure recovery at that location due to a shock (fig. 10(l)). At a Mach number of 0.92, the medium and long cowls had the most uniform pressure distributions, but only the long cowl showed pressure recovery in the vicinity of the maximum cowl diameter. (See figs. 8(q), 10(m), and 12(n).)

At the lowest Mach number (0.60) at an angle of attack of 2° at a mass-flow ratio of 0.81, the short and medium cowls had the most uniform pressure distributions (compare figs. 8(r), 10(n), and 12(o)). However, the short cowl (fig. 8(r)) had positive pressure coefficients over the forward 7 percent of its length on the bottom surface ($\phi = 180°$) at an angle of attack of 2° and a smaller extent of positive pressure coefficients on the top surface.

## Concluding Remarks

An investigation has been conducted over a range of subsonic speeds to determine pressure distributions on three isolated cowls of different lengths having the same nondimensionalized geometry. The cowl diameter ratio (highlight diameter to maximum diameter) was 0.85, and the cowl length ratios (cowl length to maximum diameter) were 0.337, 0.439, and 0.547. Internal geometry was identical for all three cowls, and the contraction ratio was 1.250. Mass-flow ratio was varied at each Mach number, and angle of attack was varied over a small range (up to 4.1°) at selected Mach numbers and mass-flow ratios.

At an angle of attack of 0° at low Mach numbers at low mass-flow ratios, the short cowl sustained the most negative pressure peaks near the leading edge, and the flow was separated over the forward portion of the long cowl and remained so through a Mach number of 0.79. At high mass-flow ratios, the pressure coefficient distributions over the forward portion of the short cowl lost their uniformity (flatness) and became rounded as Mach number was increased. The first appearance of a shock occurred on the short cowl at 30 percent of its length at a Mach number of 0.69 at a mass-flow ratio of 0.27. By a Mach number of 0.74, shocks occurred on all three cowls at the low mass-flow ratios, with the short cowl having the shock located farthest aft at a mass-flow ratio of 0.40.

At small angles of attack (2°), the short cowl had the most negative pressure peaks on the top and bottom surfaces at a Mach number of 0.60 at the lowest mass-flow ratio (0.28). However, it had a short expanse of flow separation on the top surface between 5 and 10 percent of the cowl length, followed by a pressure recovery downstream. The medium cowl had flow separation farther downstream (between 15 and 25 percent of the cowl length), and the long cowl was separated over the forward 20 percent of its length.

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## References


1. Baals, Donald D.; Smith, Norman F.; and Wright, John B.: *The Development and Application of High-Critical-Speed Nose Inlets.* NACA Rep. 920, 1948. (Supersedes NACA ACR L5F30a.)
2. Nichols, Mark R.; and Keith, Arvid L., Jr.: *Investigation of a Systematic Group of NACA 1-Series Cowlings With and Without Spinners.* NACA Rep. 950, 1949. (Supersedes NACA RM L8A15.)
3. Pendley, Robert E.; and Robinson, Harold L.: *An Investigation of Several NACA 1-Series Nose Inlets With and Without Protruding Central Bodies at High-Subsonic Mach Numbers and at a Mach Number of 1.2.* NACA TN 3436, 1955. (Supersedes NACA RM L9L23a.)
4. Pendley, Robert E.; Robinson, Harold L.; and Williams, Claude V.: *An Investigation of Three Transonic Fuselage Air Inlets At Mach Numbers From 0.4 to 0.94 and at a Mach Number of 1.19.* NACA RM L50H24, 1950.
5. Nichols, Mark R.; and Pendley, Robert E.: *Performance of Air Inlets at Transonic and Low Supersonic Speeds.* NACA RM L52A07, 1952.
6. Pendley, Robert E.; Milillo, Joseph R.; and Fleming, Frank F.: *An Investigation of Three NACA 1-Series Nose Inlets at Subsonic and Transonic Speeds.* NACA RM L52J23, 1953.
7. Pendley, Robert E.; and Smith, Norman F.: *An Investigation of the Characteristics of Three NACA 1-Series Nose Inlets At Subcritical and Supercritical Mach Numbers.* NACA RM L8L06, 1949.
8. Pendley, Robert E.; Milillo, Joseph R.; Fleming, Frank F.; and Bryan, Carroll R.: *An Experimental Study of Five Annular-Air-Inlet Configurations at Subsonic and Transonic Speeds.* NACA RM L53F18a, 1953.
9. Re, Richard J.: *An Investigation of Several NACA 1-Series Axisymmetric Inlets at Mach Numbers From 0.4 to 1.29.* NASA TM X-2917, 1974.
10. Re, Richard J.: *An Investigation of Several NACA 1-Series Inlets at Mach Numbers From 0.4 to 1.29 for Mass-Flow Ratios Near 1.0.* NASA TM X-3324, 1975.
11. Corson, Blake W., Jr.; Runckel, Jack F.; and Igoe, William B.: *Calibration of the Langley 16-Foot Transonic Tunnel With Test Section Air Removal.* NASA TR R-423, 1974.
12. Couch, Lana M.; and Brooks, Cuyler W., Jr.: *Effect of Blockage Ratio on Drag and Pressure Distributions for Bodies of Revolution at Transonic Speeds.* NASA TN D-7331, 1973.
13. Dougherty, N. S., Jr.; and Steinle, Frank W., Jr.: Transition Reynolds Number Comparisons in Several Major Transonic Tunnels. AIAA Paper No. 74-627, July 1974.
14. Butler, S. F. J.: Aircraft Drag Prediction for Project Appraisal and Performance Estimation. *Aerodynamic Drag,* AGARD-CP-124, Apr. 1973, pp. 6-1–6-50. (Appendix on pp. 6-A1–6-A4; refs. on pp. 6-R1–6-R6.)
15. Krivec, D. K.; Ling, R. T.; and Vadyak, J.: Investigation of Transonic Inlet Drag Characteristics. SAE Paper 841539, Oct. 1984.

Inlet With Short Cowl ($L$ = 6.0655 in.)

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.60 | 0.28 | 0.0 | III(a) | 7(a), 8(a) |
| | .28 | 2.0 | | 8(a) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 7(a) |
| | .45 | 0.0 | | |
| | .49 | 0.0 | | 7(a), 8(e) |
| | .50 | 1.0 | | |
| | .50 | 2.0 | | 8(e) |
| | .50 | 3.0 | | 8(e) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 7(a) |
| | .69 | 0.0 | | 8(m) |
| | .69 | 2.0 | | 8(m) |
| | .75 | 0.0 | | 7(a) |
| | .81 | 0.0 | | 7(a), 8(r) |
| | .81 | 2.0 | | 8(r) |
| ↓ | .87 | 0.0 | ↓ | |
| 0.64 | 0.27 | 0.0 | III(b) | 7(b) |
| | .30 | 0.0 | | |
| | .40 | 0.0 | | 7(b) |
| | .45 | 0.0 | | |
| | .49 | 0.0 | | 7(b) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 7(b) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 7(b) |
| | .81 | 0.0 | | 7(b) |
| ↓ | .87 | 0.0 | ↓ | |
| 0.69 | 0.27 | 0.0 | III(c) | 7(c) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 7(c) |
| | .45 | 0.0 | | |
| | .49 | 0.0 | | 7(c), 8(f) |
| | .49 | 2.0 | | 8(f) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 7(c) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 7(c) |
| ↓ | .81 | 0.0 | ↓ | 7(c) |
| 0.72 | 0.27 | 0.0 | III(d) | 7(d) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 7(d) |
| | .45 | 0.0 | | |
| | .48 | 0.0 | | 7(d) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 7(d) |
| | .67 | 0.0 | | |
| | .74 | 0.0 | | 7(d) |
| ↓ | .81 | 0.0 | ↓ | 7(d) |

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.74 | 0.27 | 0.0 | III(e) | 7(e), 8(b) |
| | .28 | 1.0 | | |
| | .28 | 2.0 | | 8(b) |
| | .27 | 3.0 | | 8(b) |
| | .32 | 0.0 | | |
| | .40 | 0.0 | | 7(e) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 7(e), 8(g) |
| | .49 | 1.0 | | |
| | .49 | 2.0 | | 8(g) |
| | .49 | 3.1 | | |
| | .49 | 4.1 | | 8(g) |
| | .56 | 0.0 | | |
| | .62 | 0.0 | | 7(e) |
| | .68 | 0.0 | | 8(n) |
| | .68 | 1.0 | | |
| | .68 | 2.0 | | 8(n) |
| | .68 | 3.0 | | 8(n) |
| | .74 | 0.0 | | 7(e) |
| | .81 | 0.0 | | 7(e), 8(s) |
| | .81 | 1.0 | | |
| | .81 | 2.0 | | 8(s) |
| ↓ | .81 | 3.0 | ↓ | 8(s) |
| 0.77 | 0.27 | 0.0 | III(f) | 7(f) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 7(f) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 7(f) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 7(f) |
| | .68 | 0.0 | | |
| | .75 | 0.0 | | 7(f) |
| ↓ | .81 | 0.0 | ↓ | 7(f) |
| 0.79 | 0.28 | 0.0 | III(g) | 7(g) |
| | .32 | 0.0 | | |
| | .40 | 0.0 | | 7(g) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 7(g), 8(h) |
| | .49 | 2.0 | | 8(h) |
| | .54 | 0.0 | | |
| | .62 | 0.0 | | 7(g) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 7(g) |
| ↓ | .81 | 0.0 | ↓ | 7(g) |
| 0.82 | 0.27 | 0.0 | III(h) | 7(h) |
| | .32 | 0.0 | | |
| | .40 | 0.0 | | 7(h) |
| | .45 | 0.0 | | |
| ↓ | .49 | 0.0 | ↓ | 7(h) |

Inlet With Short Cowl ($L = 6.0655$ in.)—Concluded

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.82 | 0.56 | 0.0 | III(h) | |
| ↓ | .62 | 0.0 | ↓ | 7(h) |
| ↓ | .68 | 0.0 | ↓ | |
| ↓ | .74 | 0.0 | ↓ | 7(h) |
| ↓ | .81 | 0.0 | ↓ | 7(h) |
| 0.84 | 0.28 | 0.0 | III(i) | 7(i) |
| ↓ | .32 | 0.0 | ↓ | |
| ↓ | .40 | 0.0 | ↓ | 7(i) |
| ↓ | .45 | 0.0 | ↓ | |
| ↓ | .49 | 0.0 | ↓ | 7(i), 8(i) |
| ↓ | .49 | 2.1 | ↓ | 8(i) |
| ↓ | .55 | 0.0 | ↓ | |
| ↓ | .62 | 0.0 | ↓ | 7(i) |
| ↓ | .68 | 0.0 | ↓ | 8(o) |
| ↓ | .68 | 2.0 | ↓ | 8(o) |
| ↓ | .74 | 0.0 | ↓ | 7(i) |
| 0.87 | 0.27 | 0.0 | III(j) | 7(j), 8(c) |
| ↓ | .27 | 2.0 | ↓ | 8(c) |
| ↓ | .31 | 0.0 | ↓ | |
| ↓ | .40 | 0.0 | ↓ | 7(j) |
| ↓ | .45 | 0.0 | ↓ | |
| ↓ | .49 | 0.0 | ↓ | 7(j), 8(j) |
| ↓ | .49 | 1.0 | ↓ | |
| ↓ | .49 | 2.1 | ↓ | 8(j) |
| ↓ | .49 | 3.1 | ↓ | 8(j) |
| ↓ | .55 | 0.0 | ↓ | |
| ↓ | .62 | 0.0 | ↓ | 7(j) |
| ↓ | .68 | 0.0 | ↓ | 8(p) |
| ↓ | .68 | 2.1 | ↓ | 8(p) |
| ↓ | .74 | 0.0 | ↓ | 7(j) |
| 0.89 | 0.28 | 0.0 | III(k) | 7(k) |
| ↓ | .31 | 0.0 | ↓ | |
| ↓ | .40 | 0.0 | ↓ | 7(k) |
| ↓ | .45 | 0.0 | ↓ | |
| ↓ | .49 | 0.0 | ↓ | 7(k), 8(k) |
| ↓ | .49 | 2.1 | ↓ | 8(k) |
| ↓ | .55 | 0.0 | ↓ | |
| ↓ | .62 | 0.0 | ↓ | 7(k) |
| ↓ | .68 | 0.0 | ↓ | |
| ↓ | .74 | 0.0 | ↓ | 7(k) |
| 0.92 | 0.27 | 0.0 | III(l) | 7(l), 8(d) |
| ↓ | .27 | 2.1 | ↓ | 8(d) |
| ↓ | .31 | 0.0 | ↓ | |
| ↓ | .40 | 0.0 | ↓ | 7(l) |
| ↓ | .45 | 0.0 | ↓ | |
| ↓ | .49 | 0.0 | ↓ | 7(l), 8(l) |
| ↓ | .49 | 1.1 | ↓ | |
| ↓ | .49 | 2.1 | ↓ | 8(l) |
| ↓ | .49 | 3.1 | ↓ | 8(l) |
| ↓ | .55 | 0.0 | ↓ | |
| ↓ | .62 | 0.0 | ↓ | 7(l) |
| ↓ | .68 | 0.0 | ↓ | 8(q) |
| ↓ | .68 | 2.1 | ↓ | 8(q) |
| ↓ | .74 | 0.0 | ↓ | 7(l) |

Inlet With Medium Cowl ($L$ = 7.8973 in.)

| $M$ | mfr | $\alpha$ | Table | Figure |
|---|---|---|---|---|
| Pressure coefficients | | | | |
| 0.60 | 0.27 | 0.0 | IV(a) | 9(a), 10(a) |
| | .27 | 2.1 | | 10(a) |
| | .31 | 0.0 | | |
| | .41 | 0.0 | | 9(a) |
| | .46 | 0.0 | | |
| | .50 | 0.1 | | 9(a), 10(d) |
| | .50 | 1.1 | | |
| | .50 | 2.0 | | 10(d) |
| | .50 | 3.0 | | 10(d) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 9(a) |
| | .69 | 0.0 | | 10(k) |
| | .69 | 1.0 | | |
| | .69 | 2.0 | | 10(k) |
| | .75 | 0.0 | | 9(a) |
| | .82 | 0.0 | | 9(a), 10(n) |
| ↓ | .82 | 2.0 | ↓ | 10(n) |
| 0.64 | 0.28 | 0.0 | IV(b) | 9(b) |
| | .31 | 0.0 | | |
| | .41 | 0.0 | | 9(b) |
| | .46 | 0.0 | | |
| | .50 | 0.0 | | 9(b) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 9(b) |
| | .75 | 0.0 | | 9(b) |
| ↓ | .81 | 0.0 | ↓ | 9(b) |
| 0.69 | 0.28 | 0.0 | IV(c) | 9(c) |
| | .31 | 0.0 | | |
| | .41 | 0.0 | | 9(c) |
| | .46 | 0.0 | | |
| | .49 | 0.0 | | 9(c), 10(e) |
| | .50 | 2.0 | | 10(e) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 9(c) |
| | .75 | 0.0 | | 9(c) |
| ↓ | .81 | 0.0 | ↓ | 9(c) |
| 0.74 | 0.27 | 0.0 | IV(d) | 9(d) |
| | .31 | 0.0 | | |
| | .41 | 0.0 | | 9(d) |
| | .46 | 0.0 | | |
| | .50 | 0.0 | | 9(d) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 9(d) |
| | .75 | 0.0 | | 9(d) |
| ↓ | .82 | 0.0 | ↓ | 9(d) |

| $M$ | mfr | $\alpha$ | Table | Figure |
|---|---|---|---|---|
| Pressure coefficients | | | | |
| 0.77 | 0.27 | 0.0 | IV(e) | 9(e) |
| | .32 | 0.0 | | |
| | .41 | 0.0 | | 9(e) |
| | .46 | 0.0 | | |
| | .49 | 0.0 | | 9(e) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 9(e) |
| | .74 | 0.0 | | 9(e) |
| ↓ | .80 | 0.0 | ↓ | 9(e) |
| 0.79 | 0.27 | 0.0 | IV(f) | 9(f) |
| | .33 | 0.0 | | |
| | .41 | 0.0 | | 9(f) |
| | .45 | 0.0 | | |
| | .49 | 0.0 | | 9(f), 10(f) |
| | .49 | 2.1 | | 10(f) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 9(f) |
| | .74 | 0.0 | | 9(f) |
| ↓ | .80 | 0.0 | ↓ | 9(f) |
| 0.82 | 0.27 | 0.0 | IV(g) | 9(g) |
| | .32 | 0.0 | | |
| | .41 | 0.0 | | 9(g) |
| | .46 | 0.0 | | |
| | .50 | 0.0 | | 9(g) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 9(g) |
| | .74 | 0.0 | | 9(g) |
| ↓ | .80 | 0.0 | ↓ | 9(g) |
| 0.84 | 0.27 | 0.0 | IV(h) | 9(h), 10(b) |
| | .27 | 1.1 | | |
| | .32 | 0.0 | | |
| | .41 | 0.0 | | 9(h) |
| | .46 | 0.0 | | |
| | .50 | 0.1 | | 9(h), 10(g) |
| | .50 | 1.0 | | |
| | .49 | 2.1 | | 10(g) |
| | .49 | 3.1 | | 10(g) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 9(h) |
| | .68 | 0.0 | | 9(h), 10(l) |
| | .68 | 1.0 | | |
| | .68 | 2.0 | | 10(l) |
| | .68 | 3.1 | | 10(l) |
| ↓ | .74 | 0.0 | ↓ | 9(h) |

Inlet With Medium Cowl
($L$ = 7.8973 in.)—Concluded

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.87 | 0.27 | 0.1 | IV(i) | 9(i) |
| ↓ | .32 | 0.0 | ↓ | |
| | .40 | 0.0 | | 9(i) |
| | .46 | 0.1 | | |
| | .50 | 0.0 | | 9(i), 10(h) |
| | .50 | 2.1 | | 10(h) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 9(i) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 9(i) |
| 0.89 | 0.27 | 0.1 | IV(j) | 9(j) |
| ↓ | .32 | 0.0 | ↓ | |
| | .40 | 0.0 | | 9(j) |
| | .46 | 0.1 | | |
| | .50 | 0.1 | | 9(j), 10(i) |
| | .50 | 2.1 | | 10(i) |
| | .55 | 0.0 | | |
| | .62 | 0.0 | | 9(j) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 9(j) |
| 0.92 | 0.27 | 0.1 | IV(k) | 9(k), 10(c) |
| ↓ | .27 | 2.1 | ↓ | 10(c) |
| | .33 | 0.0 | | |
| | .40 | 0.0 | | 9(k) |
| | .46 | 0.1 | | |
| | .50 | 0.1 | | 9(k), 10(j) |
| | .49 | 1.1 | | |
| | .49 | 2.2 | | 10(j) |
| | .50 | 3.1 | | 10(j) |
| | .54 | 0.0 | | |
| | .62 | 0.0 | | 9(k) |
| | .68 | 0.0 | | 10(m) |
| | .68 | 2.0 | | 10(m) |
| | .74 | 0.0 | | 9(k) |

Inlet With Long Cowl ($L$ = 9.8420 in.)

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.60 | 0.28 | 0.0 | V(a) | 11(a), 12(a) |
| | .28 | 2.0 | | 12(a) |
| | .30 | 0.0 | | |
| | .40 | 0.0 | | 11(a) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(a), 12(d) |
| | .49 | 1.0 | | |
| | .49 | 2.0 | | 12(d) |
| | .50 | 3.0 | | 12(d) |
| | .56 | 0.0 | | |
| | .62 | 0.0 | | 11(a) |
| | .69 | 0.0 | | 12(k) |
| | .69 | 2.0 | | 12(k) |
| | .75 | 0.0 | | 11(a) |
| | .77 | 0.0 | | |
| | .81 | 0.0 | | 11(a), 12(o) |
| | .81 | 2.0 | | 12(o) |
| ↓ | .88 | 0.0 | ↓ | |
| 0.64 | 0.28 | 0.0 | V(b) | 11(b) |
| | .30 | 0.0 | | |
| | .40 | 0.0 | | 11(b) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(b) |
| | .55 | 0.0 | | |
| | .61 | 0.0 | | 11(b) |
| | .68 | 0.0 | | |
| | .75 | 0.0 | | 11(b) |
| | .81 | 0.0 | | 11(b) |
| ↓ | .87 | 0.0 | ↓ | |
| 0.69 | 0.28 | 0.0 | V(c) | 11(c) |
| | .30 | 0.0 | | |
| | .40 | 0.0 | | 11(c) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(c), 12(e) |
| | .49 | 2.0 | | 12(e) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(c) |
| | .68 | 0.0 | | |
| | .75 | 0.0 | | 11(c) |
| ↓ | .81 | 0.0 | ↓ | 11(c) |
| 0.72 | 0.28 | 0.0 | V(d) | 11(d) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(d) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(d) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(d) |
| | .68 | 0.0 | | |
| ↓ | .74 | 0.0 | ↓ | 11(d) |

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.72 | 0.81 | 0.0 | V(d) | 11(d) |
| 0.74 | 0.28 | 0.0 | V(e) | 11(e) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(e) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(e), 12(f) |
| | .49 | 2.0 | | 12(f) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(e) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 11(e) |
| ↓ | .80 | 0.0 | ↓ | 11(e) |
| 0.77 | 0.28 | 0.0 | V(f) | 11(f) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(f) |
| | .45 | 0.0 | | |
| | .49 | 0.0 | | 11(f) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(f) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 11(f) |
| ↓ | .80 | 0.0 | ↓ | 11(f) |
| 0.79 | 0.28 | 0.0 | V(g) | 11(g) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(g) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(g), 12(g) |
| | .49 | 2.0 | | 12(g) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(g) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 11(g) |
| ↓ | .80 | 0.0 | ↓ | 11(g) |
| 0.82 | 0.27 | 0.0 | V(h) | 11(h) |
| | .32 | 0.0 | | |
| | .40 | 0.0 | | 11(h) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(h) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(h) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 11(h) |
| ↓ | .80 | 0.0 | ↓ | 11(h) |
| 0.84 | 0.27 | 0.0 | V(i) | 11(i) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(i) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(i),12(h) |
| ↓ | .49 | 2.0 | ↓ | 12(h) |

Inlet With Long Cowl ($L$ = 9.8420 in.)—Concluded

| Pressure coefficients | | | | |
|---|---|---|---|---|
| $M$ | mfr | $\alpha$ | Table | Figure |
| 0.84 | 0.54 | 0.0 | V(i) | |
| ↓ | .61 | 0.0 | ↓ | 11(i) |
| | .68 | 0.0 | | 12(l) |
| | .68 | 2.1 | | 12(l) |
| | .74 | 0.0 | | 11(i) |
| 0.87 | 0.27 | 0.0 | V(i) | 11(j) |
| ↓ | .32 | 0.0 | ↓ | |
| | .40 | 0.0 | | 11(j) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(j) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(j) |
| | .68 | 0.0 | | |
| | .74 | 0.0 | | 11(j) |
| 0.89 | 0.27 | 0.0 | V(k) | 11(k), 12(b) |
| ↓ | .27 | 1.0 | ↓ | |
| | .27 | 2.1 | | 12(b) |
| | .27 | 3.1 | | 12(b) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(k) |
| | .44 | 0.0 | | |
| | .48 | 0.0 | | 11(k), 12(i) |
| | .49 | 1.0 | | |
| | .49 | 2.1 | | 12(i) |
| | .48 | 3.0 | | 12(i) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(k) |
| | .68 | 0.0 | | 12(m) |
| | .68 | 1.0 | | |
| | .68 | 2.1 | | 12(m) |
| | .68 | 3.1 | | 12(m) |
| | .74 | 0.0 | | 11(k) |
| 0.92 | 0.27 | 0.0 | V(l) | 11(l), 12(c) |
| ↓ | .27 | 2.1 | ↓ | 12(c) |
| | .31 | 0.0 | | |
| | .40 | 0.0 | | 11(l) |
| | .44 | 0.0 | | |
| | .49 | 0.0 | | 11(l), 12(j) |
| | .49 | 1.0 | | |
| | .49 | 2.1 | | 12(j) |
| | .49 | 3.1 | | 12(j) |
| | .54 | 0.0 | | |
| | .61 | 0.0 | | 11(l) |
| | .68 | 0.0 | | 12(n) |
| | .68 | 2.1 | | 12(n) |
| | .75 | 0.0 | | 11(l) |

Table I. Nondimensionalized Cowl Design Ordinates

[Nondimensional coordinates in percent]

| $X/L$ | $\frac{r - r_h}{r_{\max} - r_h}$ | $X/L$ | $\frac{r - r_h}{r_{\max} - r_h}$ |
|---|---|---|---|
| 0.00 | 0.000 | 21.54 | 59.609 |
| .02 | 1.996 | 23.16 | 61.800 |
| .08 | 3.984 | 24.87 | 63.910 |
| .18 | 5.949 | 26.68 | 66.034 |
| .32 | 7.892 | 28.59 | 68.174 |
| .50 | 9.797 | 30.60 | 70.322 |
| .72 | 11.671 | 32.74 | 72.477 |
| .98 | 13.515 | 35.01 | 74.640 |
| 1.29 | 15.321 | 37.42 | 76.810 |
| 1.63 | 17.097 | 40.00 | 78.988 |
| 2.02 | 18.850 | 43.00 | 81.348 |
| 2.45 | 20.595 | 46.00 | 83.533 |
| 2.92 | 22.333 | 49.00 | 85.559 |
| 3.44 | 24.078 | 52.00 | 87.426 |
| 4.00 | 25.854 | 55.00 | 89.133 |
| 4.61 | 27.667 | 58.00 | 90.704 |
| 5.26 | 29.542 | 61.00 | 92.138 |
| 5.96 | 31.446 | 64.00 | 93.436 |
| 6.71 | 33.381 | 67.00 | 94.605 |
| 7.50 | 35.332 | 70.00 | 95.652 |
| 8.35 | 37.297 | 73.00 | 96.578 |
| 9.25 | 39.270 | 76.00 | 97.397 |
| 10.20 | 41.266 | 79.00 | 98.103 |
| 11.21 | 43.269 | 82.00 | 98.710 |
| 12.27 | 45.280 | 85.00 | 99.211 |
| 13.40 | 47.306 | 88.00 | 99.605 |
| 14.58 | 49.340 | 91.00 | 99.856 |
| 15.83 | 51.389 | 94.00 | 99.970 |
| 17.15 | 53.445 | 97.00 | 100.00 |
| 18.54 | 55.517 | 100.00 | 100.00 |
| 20.00 | 57.604 | | |

Table II. Nondimensionalized Contraction Section and Diffuser Ordinates

[Nondimensional coordinates in percent]

| $X/D_{max}$ | $r/r_{max}$ | $X/D_{max}$ | $r/r_{max}$ |
|---|---|---|---|
| 0.00 | 85.36 | 12.01 | 76.36 |
| .01 | 85.00 | 12.43 | 76.38 |
| .04 | 84.64 | 12.91 | 76.40 |
| .08 | 84.28 | 13.42 | 76.44 |
| .14 | 83.92 | 13.99 | 76.49 |
| .23 | 83.56 | 14.62 | 76.55 |
| .33 | 83.20 | 15.31 | 76.64 |
| .45 | 82.83 | 16.07 | 76.74 |
| .59 | 82.47 | 16.90 | 76.88 |
| .76 | 82.11 | 17.82 | 77.04 |
| .94 | 81.75 | 18.83 | 77.23 |
| 1.15 | 81.39 | 19.94 | 77.46 |
| 1.38 | 81.03 | 21.16 | 77.74 |
| 1.64 | 80.67 | 22.50 | 78.07 |
| 1.93 | 80.31 | 23.98 | 78.46 |
| 2.25 | 79.95 | 25.61 | 78.92 |
| 2.61 | 79.59 | 27.39 | 79.46 |
| 3.00 | 79.23 | 29.36 | 80.07 |
| 3.45 | 78.87 | 31.52 | 80.78 |
| 3.94 | 78.51 | 33.90 | 81.59 |
| 4.51 | 78.15 | 36.52 | 82.49 |
| 5.18 | 77.77 | 39.40 | 83.51 |
| 5.86 | 77.45 | 42.57 | 84.62 |
| 6.53 | 77.18 | 46.05 | 85.83 |
| 7.21 | 76.95 | 49.89 | 87.12 |
| 7.88 | 76.76 | 54.10 | 88.46 |
| 8.56 | 76.61 | 58.74 | 89.81 |
| 9.24 | 76.49 | 63.84 | 91.09 |
| 9.91 | 76.41 | 69.45 | 92.21 |
| 10.59 | 76.36 | 75.62 | 93.02 |
| 11.26 | 76.35 | 82.25 | 93.33 |
| 11.62 | 76.35 | 89.72 | 93.33 |

Table III. Pressure Coefficients on Model With Short Cowl

(a) $M = 0.60$

$M = 0.594$; mfr = 0.275; $\alpha = 0°$

$M = 0.593$; mfr = 0.276; $\alpha = 2.0°$

Table III. Continued

(a) Continued

$M = 0.595$; mfr = 0.311; $\alpha = 0°$

$M = 0.595$; mfr = 0.403; $\alpha = 0°$

Table III. Continued

(a) Continued

$M = 0.596$; mfr = 0.448; $\alpha = 0°$

$M = 0.595$; mfr = 0.494; $\alpha = 0°$

Table III. Continued

(a) Continued

$M = 0.597$; mfr = 0.498; $\alpha = 1.0°$

$M = 0.595$; mfr = 0.498; $\alpha = 2.0°$

Table III. Continued

(a) Continued

$M = 0.594$; mfr = 0.498; $\alpha = 3.0°$

$M = 0.594$; mfr = 0.551; $\alpha = 0°$

Table III. Continued

(a) Continued

$M = 0.595$; mfr = 0.622; $\alpha = 0°$

$M = 0.595$; mfr = 0.685; $\alpha = 0°$

Table III. Continued

(a) Continued

$M = 0.596$; mfr = 0.687; $\alpha = 2.0°$

$M = 0.596$; mfr = 0.749; $\alpha = 0°$

Table III. Continued

(a) Continued

$M = 0.594$; mfr = 0.810; $\alpha = 0°$

$M = 0.596$; mfr = 0.809; $\alpha = 2.0°$

Table III. Continued

(a) Concluded

$M = 0.596;\ \text{mfr} = 0.874;\ \alpha = 0°$

Table III. Continued

(b) $M = 0.64$

$M = 0.644;\ \text{mfr} = 0.274;\ \alpha = 0°$

$M = 0.644;\ \text{mfr} = 0.305;\ \alpha = 0°$

Table III. Continued

(b) Continued

$M = 0.644;\ \text{mfr} = 0.401;\ \alpha = 0°$

$M = 0.644;\ \text{mfr} = 0.452;\ \alpha = 0°$

Table III. Continued

(b) Continued

$M = 0.643;\ \text{mfr} = 0.494;\ \alpha = 0°$

$M = 0.645;\ \text{mfr} = 0.546;\ \alpha = 0°$

Table III. Continued

(b) Continued

$M = 0.644;\ \text{mfr} = 0.619;\ \alpha = 0°$

$M = 0.646;\ \text{mfr} = 0.681;\ \alpha = 0°$

Table III. Continued

(b) Concluded

$M = 0.645;\ \text{mfr} = 0.741;\ \alpha = 0°$

$M = 0.645;\ \text{mfr} = 0.806;\ \alpha = 0°$

Table III. Continued

(b) Concluded

$M = 0.644;\ \text{mfr} = 0.874;\ \alpha = 0°$

$M = 0.;\ \text{mfr} = 0.;\ \alpha = 0°$

Table III. Continued

(c) $M = 0.69$

$M = 0.692;\ \text{mfr} = 0.274;\ \alpha = 0°$

TableIIIc

$M = 0.693;\ \text{mfr} = 0.309;\ \alpha = 0°$

Table III. Continued

(c) Continued

$M = 0.693;\ \text{mfr} = 0.401;\ \alpha = 0°$

$M = 0.692;\ \text{mfr} = 0.450;\ \alpha = 0°$

Table III. Continued

(c) Continued

$M = 0.692;\ \text{mfr} = 0.492;\ \alpha = 0°$

$M = 0.693;\ \text{mfr} = 0.489;\ \alpha = 0°$

Table III. Continued

(c) Continued

$M = 0.692;\ \text{mfr} = 0.546;\ \alpha = 0°$

$M = 0.693;\ \text{mfr} = 0.617;\ \alpha = 0°$

Table III. Continued

(c) Continued

$M = 0.693;\ \text{mfr} = 0.677;\ \alpha = 0°$

$M = 0.695;\ \text{mfr} = 0.744;\ \alpha = 0°$

Table III. Continued

(c) Concluded

$M = 0.693;\ \text{mfr} = 0.808;\ \alpha = 0°$

Table III. Continued

(d) $M = 0.72$

$M = 0.718;\ \text{mfr} = 0.272;\ \alpha = 0°$

$M = 0.718;\ \text{mfr} = 0.307;\ \alpha = 0°$

Table III. Continued

(d) Continued

$M = 0.719;\ \text{mfr} = 0.402;\ \alpha = 0°$

$M = 0.717;\ \text{mfr} = 0.447;\ \alpha = 0°$

Table III. Continued

(d) Continued

$M = 0.719;\ \text{mfr} = 0.485;\ \alpha = 0°$

$M = 0.720;\ \text{mfr} = 0.548;\ \alpha = 0°$

Table III. Continued

(d) $M = 0.72$

$M = 0.718;\ \text{mfr} = 0.615;\ \alpha = 0°$

$M = 0.718;\ \text{mfr} = 0.674;\ \alpha = 0°$

Table III. Continued

(d) Concluded

$M = 0.719;\ \text{mfr} = 0.742;\ \alpha = 0°$

$M = 0.720;\ \text{mfr} = 0.808;\ \alpha = 0°$

Table III. Continued

$M = 0.;\ \text{mfr} = 0.;\ \alpha = 0°$

$M = 0.;\ \text{mfr} = 0.;\ \alpha = 0°$

Table III. Continued

(e) $M = 0.74$

$M = 0.742;\ \text{mfr} = 0.273;\ \alpha = 0°$

Table IIIe

$M = 0.743;\ \text{mfr} = 0.277;\ \alpha = 1.0°$

Table III. Continued

(e) Continued

$M = 0.742;\ \text{mfr} = 0.276;\ \alpha = 2.0°$

$M = 0.744;\ \text{mfr} = 0.272;\ \alpha = 3.0°$

Table III. Continued

(e) Continued

$M = 0.743;\ \text{mfr} = 0.315;\ \alpha = 0°$

$M = 0.743;\ \text{mfr} = 0.402;\ \alpha = 0°$

Table III. Continued

(e) Continued

$M = 0.742;\ \text{mfr} = 0.445;\ \alpha = 0°$

$M = 0.741;\ \text{mfr} = 0.488;\ \alpha = 0°$

Table III. Continued

(e) Continued

$M = 0.742;\ \text{mfr} = 0.489;\ \alpha = 1.0°$

$M = 0.742;$ mfr $= 0.487;$ $\alpha = 2.0^\circ$

Table III. Continued

(e) Continued

$M = 0.743;$ mfr $= 0.491;$ $\alpha = 3.1^\circ$

$M = 0.744;$ mfr $= 0.489;$ $\alpha = 4.1^\circ$

Table III. Continued

(e) Continued

$M = 0.743;$ mfr $= 0.561;$ $\alpha = 0^\circ$

$M = 0.743;$ mfr $= 0.616;$ $\alpha = 0^\circ$

Table III. Continued

(e) Continued

$M = 0.745;$ mfr $= 0.677;$ $\alpha = 0^\circ$

$M = 0.744;$ mfr $= 0.675;$ $\alpha = 1.0^\circ$

Table III. Continued

(e) Continued

$M = 0.744;$ mfr $= 0.678;$ $\alpha = 2.0^\circ$

$M = 0.744;$ mfr $= 0.678;$ $\alpha = 3.0^\circ$

Table III. Continued

(e) Continued

$M = 0.742;$ mfr $= 0.744;$ $\alpha = 0^\circ$

$M = 0.744;$ mfr $= 0.810;$ $\alpha = 0^\circ$

Table III. Continued

(e) Continued

$M = 0.744;$ mfr $= 0.808;$ $\alpha = 1.0^\circ$

$M = 0.744;$ mfr $= 0.806;$ $\alpha = 2.0^\circ$

Table III. Continued

(e) Concluded

$M = 0.744;$ mfr $= 0.808;$ $\alpha = 3.0^\circ$

Table III. Continued

(f) $M = 0.77$

$M = 0.767;$ mfr $= 0.275;$ $\alpha = 0^\circ$

Table III(f)

$M = 0.767$; mfr = 0.314; $\alpha = 0°$

Table III. Continued

(f) Continued

$M = 0.768$; mfr = 0.402; $\alpha = 0°$

$M = 0.768$; mfr = 0.444; $\alpha = 0°$

Table III. Continued

(f) Continued

$M = 0.766$; mfr = 0.488; $\alpha = 0°$

$M = 0.767$; mfr = 0.553; $\alpha = 0°$

Table III. Continued

(f) Continued

$M = 0.768$; mfr = 0.618; $\alpha = 0°$

$M = 0.769$; mfr = 0.677; $\alpha = 0°$

Table III. Continued

(f) Concluded

$M = 0.767$; mfr = 0.746; $\alpha = 0°$

$M = 0.767$; mfr = 0.809; $\alpha = 0°$

Table III. Continued

(g) $M = 0.79$

$M = 0.793$; mfr = 0.278; $\alpha = 0°$

Table III(g)

$M = 0.792$; mfr = 0.317; $\alpha = 0°$

Table III. Continued

(g) Continued

$M = 0.792$; mfr = 0.405; $\alpha = 0°$

$M = 0.792$; mfr = 0.445; $\alpha = 0°$

Table III. Continued

(g) Continued

$M = 0.793$; mfr = 0.487; $\alpha = 0°$

$M = 0.794$; mfr = 0.488; $\alpha = 2.0°$

Table III. Continued

(g) Continued

$M = 0.795$; mfr = 0.544; $\alpha = 0°$

$M = 0.791$; mfr = 0.620; $\alpha = 0°$

Table III. Continued

(g) Continued

$M = 0.791$; mfr = 0.677; $\alpha = 0°$

$M = 0.792$; mfr = 0.739; $\alpha = 0°$

Table III. Continued

(g) Concluded

$M = 0.792$; mfr = 0.806; $\alpha = 0°$

Table III. Continued

(h) $M = 0.82$

$M = 0.816$; mfr = 0.272; $\alpha = 0°$

Table III(h)

$M = 0.817$; mfr = 0.316; $\alpha = 0°$

Table III. Continued

(h) Continued

$M = 0.817$; mfr = 0.403; $\alpha = 0°$

$M = 0.816$; mfr = 0.447; $\alpha = 0°$

Table III. Continued

(h) Continued

$M = 0.817$; mfr = 0.489; $\alpha = 0°$

$M = 0.819$; mfr = 0.561; $\alpha = 0°$

Table III. Continued

(h) Continued

$M = 0.817$; mfr = 0.619; $\alpha = 0°$

$M = 0.817$; mfr = 0.678; $\alpha = 0°$

Table III. Continued

(h) Concluded

$M = 0.818$; mfr = 0.744; $\alpha = 0°$

$M = 0.817$; mfr = 0.806; $\alpha = 0°$

Table III. Continued

(i) $M = 0.84$

$M = 0.842;$ mfr $= 0.278;$ $\alpha = 0°$

$M = 0.843;$ mfr $= 0.316;$ $\alpha = 0°$

Table III. Continued

(i) Continued

$M = 0.840;$ mfr $= 0.403;$ $\alpha = 0°$

$M = 0.842;$ mfr $= 0.448;$ $\alpha = 0°$

Table III. Continued

(i) Continued

$M = 0.843;$ mfr $= 0.487;$ $\alpha = 0°$

$M = 0.842;$ mfr $= 0.490;$ $\alpha = 2.1°$

Table III. Continued

(i) Continued

$M = 0.841;$ mfr $= 0.552;$ $\alpha = 0°$

$M = 0.842;$ mfr $= 0.616;$ $\alpha = 0°$

Table III. Continued

(i) Continued

$M = 0.841;$ mfr $= 0.681;$ $\alpha = 0°$

$M = 0.843;$ mfr $= 0.680;$ $\alpha = 2.0°$

Table III. Continued

(i) Concluded

$M = 0.843;$ mfr $= 0.741;$ $\alpha = 0°$

Table III

(j) $M = 0.87$

$M = 0.867;$ mfr $= 0.271;$ $\alpha = 0°$

Table III(j)

$M = 0.868;$ mfr $= 0.267;$ $\alpha = 2.0°$

Table III. Continued

(j) Continued

$M = 0.865;$ mfr $= 0.314;$ $\alpha = 0°$

$M = 0.866;$ mfr $= 0.404;$ $\alpha = 0°$

Table III. Continued

(j) Continued

$M = 0.866$; mfr = 0.449; $\alpha = 0°$

$M = 0.865$; mfr = 0.490; $\alpha = 0°$

Table III. Continued

(j) Continued

$M = 0.868$; mfr = 0.491; $\alpha = 1.0°$

$M = 0.866$; mfr = 0.489; $\alpha = 2.1°$

Table III. Continued

(j) Continued

$M = 0.867$; mfr = 0.490; $\alpha = 3.1°$

$M = 0.867$; mfr = 0.553; $\alpha = 0°$

Table III. Continued

(j) Continued

$M = 0.867$; mfr = 0.618; $\alpha = 0°$

$M = 0.866$; mfr = 0.681; $\alpha = 0°$

Table III. Continued

(j) Concluded

$M = 0.866$; mfr = 0.682; $\alpha = 2.1°$

$M = 0.866$; mfr = 0.741; $\alpha = 0°$

Table III. Continued

(k) $M = 0.89$

$M = 0.891$; mfr = 0.276; $\alpha = 0°$

Table III(k)

$M = 0.890$; mfr = 0.314; $\alpha = 0°$

i

Table III. Continued

(k) Continued

$M = 0.890$; mfr = 0.404; $\alpha = 0°$

$M = 0.891$; mfr = 0.449; $\alpha = 0°$

Table III. Continued

(k) Continued

$M = 0.890$; mfr = 0.493; $\alpha = 0°$

$M = 0.890$; mfr = 0.495; $\alpha = 2.1°$

Table III. Continued

(k) Continued

$M = 0.892$; mfr $= 0.555$; $\alpha = 0°$

$M = 0.892$; mfr $= 0.619$; $\alpha = 0°$

Table III. Continued

(k) Concluded

$M = 0.889$; mfr $= 0.683$; $\alpha = 0°$

$M = 0.891$; mfr $= 0.739$; $\alpha = 0°$

Table III. Continued

(l) $M = 0.92$

$M = 0.915$; mfr $= 0.267$; $\alpha = 0°$

Table III(l)

$M = 0.917$; mfr $= 0.268$; $\alpha = 2.1°$

Table III. Continued

(l) Continued

$M = 0.915$; mfr $= 0.314$; $\alpha = 0°$

$M = 0.915$; mfr $= 0.401$; $\alpha = 0°$

Table III. Continued

(l) Continued

$M = 0.914$; mfr $= 0.448$; $\alpha = 0°$

$M = 0.914$; mfr $= 0.492$; $\alpha = 0°$

Table III. Continued

(l) Continued

$M = 0.916$; mfr $= 0.492$; $\alpha = 1.1°$

$M = 0.915$; mfr $= 0.491$; $\alpha = 2.1°$

Table III. Continued

(l) Continued

$M = 0.916$; mfr $= 0.492$; $\alpha = 3.1°$

$M = 0.916$; mfr $= 0.550$; $\alpha = 0°$

Table III. Continued

(l) Continued

$M = 0.915$; mfr $= 0.622$; $\alpha = 0°$

$M = 0.915$; mfr $= 0.682$; $\alpha = 0°$

Table III. Concluded

(l) Concluded

$M = 0.918$; mfr $= 0.682$; $\alpha = 2.1°$

$M = 0.916$; mfr $= 0.741$; $\alpha = 0°$

Table IV. Pressure Coefficients on Model With Medium Cowl

(a) $M = 0.60$

$M = 0.597$; mfr $= 0.270$; $\alpha = 0°$

Table Iv(a)

$M = 0.595$; mfr $= 0.269$; $\alpha = 2.1°$

Table IV. Continued

(a) Continued

$M = 0.596$; mfr $= 0.313$; $\alpha = 0°$

$M = 0.594$; mfr $= 0.411$; $\alpha = 0°$

Table IV. Continued

(a) Continued

$M = 0.598$; mfr $= 0.491$; $\alpha = 0°$

$M = 0.595$; mfr $= 0.502$; $\alpha = 0.1°$

Table IV. Continued

(a) Continued

$M = 0.595$; mfr $= 0.503$; $\alpha = 1.1°$

$M = 0.597$; mfr $= 0.502$; $\alpha = 2.0°$

Table IV. Continued

(a) Continued

$M = 0.597$; mfr $= 0.504$; $\alpha = 3.0°$

$M = 0.594$; mfr $= 0.553$; $\alpha = 0°$

Table IV. Continued

(a) Continued

$M = 0.596$; mfr $= 0.623$; $\alpha = 0°$

$M = 0.595$; mfr $= 0.687$; $\alpha = 0°$

Table IV. Continued

(a) Continued

$M = 0.597$; mfr $= 0.687$; $\alpha = 1.0°$

$M = 0.598$; mfr $= 0.686$; $\alpha = 2.0°$

Table IV. Continued

(a) Continued

$M = 0.597$; mfr $= 0.749$; $\alpha = 0°$

$M = 0.598$; mfr $= 0.816$; $\alpha = 0°$

Table IV. Continued

(a) Concluded

$M = 0.598$; mfr $= 0.816$; $\alpha = 2.0°$

Table IV. Continued

(b) $M = 0.64$

$M = 0.644$; mfr $= 0.278$; $\alpha = 0°$

Table IV(b)

$M = 0.645$; mfr $= 0.314$; $\alpha = 0°$

Table IV. Continued

(b) Continued

$M = 0.645$; mfr $= 0.414$; $\alpha = 0°$

$M = 0.645$; mfr $= 0.462$; $\alpha = 0°$

Table IV. Continued

(b) Continued

$M = 0.643$; mfr $= 0.501$; $\alpha = 0°$

$M = 0.646$; mfr $= 0.549$; $\alpha = 0°$

Table IV. Continued

(b) Continued

$M = 0.645$; mfr $= 0.617$; $\alpha = 0°$

$M = 0.644$; mfr $= 0.746$; $\alpha = 0°$

Table IV. Continued

(b) Concluded

$M = 0.645$; mfr $= 0.812$; $\alpha = 0°$

Table IV. Continued

(c) $M = 0.69$

$M = 0.692$; mfr $= 0.275$; $\alpha = 0°$

Table IV(c)

$M = 0.694;\ \mathrm{mfr} = 0.308;\ \alpha = 0°$

Table IV. Continued

(c) Continued

$M = 0.695;\ \mathrm{mfr} = 0.412;\ \alpha = 0°$

$M = 0.692;\ \mathrm{mfr} = 0.459;\ \alpha = 0°$

Table IV. Continued

(c) Continued

$M = 0.695;\ \mathrm{mfr} = 0.495;\ \alpha = 0°$

$M = 0.694;\ \mathrm{mfr} = 0.498;\ \alpha = 2.0°$

Table IV. Continued

(c) Continued

$M = 0.696;\ \mathrm{mfr} = 0.545;\ \alpha = 0°$

$M = 0.696;\ \mathrm{mfr} = 0.613;\ \alpha = 0°$

Table IV. Continued

(c) Concluded

$M = 0.694;\ \mathrm{mfr} = 0.745;\ \alpha = 0°$

$M = 0.694;\ \mathrm{mfr} = 0.812;\ \alpha = 0°$

Table IV. Continued

(d) $M = 0.74$

$M = 0.742;\ \mathrm{mfr} = 0.272;\ \alpha = 0°$

Table IV(d)

$M = 0.744;\ \mathrm{mfr} = 0.313;\ \alpha = 0°$

Table IV. Continued

(d) Continued

$M = 0.744;\ \mathrm{mfr} = 0.411;\ \alpha = 0°$

$M = 0.744;\ \mathrm{mfr} = 0.456;\ \alpha = 0°$

Table IV. Continued

(d) Continued

$M = 0.744;\ \mathrm{mfr} = 0.495;\ \alpha = 0°$

$M = 0.743;\ \mathrm{mfr} = 0.544;\ \alpha = 0°$

Table IV. Continued

(d) Continued

$M = 0.744$; mfr = 0.612; $\alpha = 0°$

$M = 0.744$; mfr = 0.747; $\alpha = 0°$

Table IV. Continued

(d) Concluded

$M = 0.744$; mfr = 0.816; $\alpha = 0°$

Table IV. Continued

(e) $M = 0.77$

$M = 0.768$; mfr = 0.274; $\alpha = 0°$

Table IV(e)

$M = 0.769$; mfr = 0.322; $\alpha = 0°$

Table IV. Continued

(e) Continued

$M = 0.769$; mfr = 0.408; $\alpha = 0°$

$M = 0.767$; mfr = 0.459; $\alpha = 0°$

Table IV. Continued

(e) Continued

$M = 0.768$; mfr = 0.494; $\alpha = 0°$

$M = 0.770$; mfr = 0.545; $\alpha = 0°$

Table IV. Continued

(e) Continued

$M = 0.770$; mfr = 0.613; $\alpha = 0°$

$M = 0.767$; mfr = 0.740; $\alpha = 0°$

Table IV. Continued

(e) Concluded

$M = 0.768$; mfr = 0.799; $\alpha = 0°$

Table IV. Continued

(f) $M = 0.79$

$M = 0.792$; mfr = 0.269; $\alpha = 0°$

Table IV(f)

$M = 0.795$; mfr = 0.329; $\alpha = 0°$

Table IV. Continued

(f) Continued

$M = 0.794$; mfr = 0.408; $\alpha = 0°$

$M = 0.794$; mfr = 0.453; $\alpha = 0°$

Table IV. Continued

(f) Continued

$M = 0.794$; mfr = 0.492; $\alpha = 0°$

$M = 0.794$; mfr = 0.493; $\alpha = 2.1°$

Table IV. Continued

(f) Continued

$M = 0.795$; mfr = 0.546; $\alpha = 0°$

$M = 0.794$; mfr = 0.615; $\alpha = 0°$

Table IV. Continued

(f) Concluded

$M = 0.793$; mfr = 0.737; $\alpha = 0°$

$M = 0.793$; mfr = 0.802; $\alpha = 0°$

Table IV. Continued

(g) $M = 0.82$

$M = 0.817$; mfr = 0.270; $\alpha = 0°$

Table IV(g)

$M = 0.818$; mfr = 0.324; $\alpha = 0°$

Table IV. Continued

(g) Continued

$M = 0.819$; mfr = 0.406; $\alpha = 0°$

$M = 0.819$; mfr = 0.456; $\alpha = 0°$

Table IV. Continued

(g) Continued

$M = 0.820$; mfr = 0.495; $\alpha = 0°$

$M = 0.819$; mfr = 0.544; $\alpha = 0°$

Table IV. Continued

(g) Continued

$M = 0.819$; mfr = 0.615; $\alpha = 0°$

$M = 0.818$; mfr = 0.737; $\alpha = 0°$

eject

Table IV. Continued

(g) Concluded

$M = 0.820$; mfr = 0.800; $\alpha = 0°$

Table IV. Continued

(h) $M = 0.84$

$M = 0.843$; mfr = 0.266; $\alpha = 0°$

TAble IV(h)

$M = 0.841$; mfr = 0.273; $\alpha = 1.1°$

Table IV. Continued

(h) Continued

$M = 0.844$; mfr = 0.323; $\alpha = 0°$

$M = 0.844$; mfr = 0.406; $\alpha = 0°$

Table IV. Continued

(h) Continued

$M = 0.844$; mfr = 0.456; $\alpha = 0°$

$M = 0.843$; mfr = 0.497; $\alpha = 0.1°$

Table IV. Continued

(h) Continued

$M = 0.842$; mfr = 0.495; $\alpha = 1.0°$

$M = 0.841$; mfr = 0.494; $\alpha = 2.1°$

Table IV. Continued

(h) Continued

$M = 0.842$; mfr = 0.494; $\alpha = 3.1°$

$M = 0.843$; mfr = 0.545; $\alpha = 0°$

Table IV. Continued

(h) Continued

$M = 0.844$; mfr = 0.615; $\alpha = 0°$

$M = 0.842$; mfr = 0.680; $\alpha = 0°$

Table IV. Continued

(h) Continued

$M = 0.842$; mfr = 0.677; $\alpha = 1.0°$

$M = 0.844$; mfr = 0.679; $\alpha = 2.0°$

Table IV. Continued

(h) Concluded

$M = 0.843$; mfr $= 0.681$; $\alpha = 3.1°$

$M = 0.843$; mfr $= 0.738$; $\alpha = 0°$

Table IV. Continued

(i) $M = 0.87$

$M = 0.867$; mfr $= 0.273$; $\alpha = 0.1°$

Table IV(i)

$M = 0.867$; mfr $= 0.322$; $\alpha = 0°$

Table IV. Continued

(i) Continued

$M = 0.868$; mfr $= 0.404$; $\alpha = 0°$

$M = 0.870$; mfr $= 0.456$; $\alpha = 0.1°$

Table IV. Continued

(i) Continued

$M = 0.867$; mfr $= 0.496$; $\alpha = 0°$

$M = 0.867$; mfr $= 0.495$; $\alpha = 2.1°$

Table IV. Continued

(i) Continued

$M = 0.867$; mfr $= 0.546$; $\alpha = 0°$

$M = 0.868$; mfr $= 0.616$; $\alpha = 0°$

Table IV. Continued

(i)Concluded

$M = 0.869$; mfr $= 0.680$; $\alpha = 0°$

$M = 0.868$; mfr $= 0.739$; $\alpha = 0°$

Table IV. Continued

(j) $M = 0.89$

$M = 0.893$; mfr $= 0.269$; $\alpha = 0.1°$

Table IV(i)

$M = 0.892$; mfr $= 0.322$; $\alpha = 0°$

Table IV. Continued

(j) Continued

$M = 0.891$; mfr = 0.404; $\alpha = 0°$

$M = 0.891$; mfr = 0.456; $\alpha = 0.1°$

Table IV. Continued

(j) Continued

$M = 0.892$; mfr = 0.492; $\alpha = 0.1°$

$M = 0.892$; mfr = 0.498; $\alpha = 2.1°$

Table IV. Continued

(j) Continued

$M = 0.893$; mfr = 0.547; $\alpha = 0°$

$M = 0.895$; mfr = 0.617; $\alpha = 0°$

Table IV. Continued

(j) Concluded

$M = 0.893$; mfr = 0.682; $\alpha = 0°$

$M = 0.894$; mfr = 0.741; $\alpha = 0°$

Table IV. Continued

(k) $M = 0.92$

$M = 0.917$; mfr = 0.274; $\alpha = 0.1°$

Table IV(k)

$M = 0.916$; mfr = 0.272; $\alpha = 2.1°$

Table IV. Continued

(k) Continued

$M = 0.918$; mfr = 0.326; $\alpha = 0°$

$M = 0.918$; mfr = 0.403; $\alpha = 0°$

Table IV. Continued

(k) Continued

$M = 0.917$; mfr = 0.457; $\alpha = 0.1°$

$M = 0.916$; mfr = 0.497; $\alpha = 0.1°$

Table IV. Continued

(k) Continued

$M = 0.915$; mfr = 0.493; $\alpha = 1.1°$

$M = 0.918$; mfr = 0.494; $\alpha = 2.2°$

Table IV. Continued

(k) Continued

$M = 0.915$; mfr = 0.496; $\alpha = 3.1°$

$M = 0.915$; mfr = 0.543; $\alpha = 0°$

Table IV. Continued

(k) Continued

$M = 0.917$; mfr = 0.618; $\alpha = 0°$

$M = 0.918$; mfr = 0.681; $\alpha = 0°$

Table IV. Concluded

(k) Concluded

$M = 0.916$; mfr = 0.683; $\alpha = 2.0°$

$M = 0.918$; mfr = 0.741; $\alpha = 0°$

Table V. Pressure Coefficients on Model With Long Cowl

(a) $M = 0.60$

$M = 0.594$; mfr = 0.282; $\alpha = 0°$

Table V(a)

$M = 0.594$; mfr = 0.283; $\alpha = 2.0°$

Table V. Continued

(a) Continued

$M = 0.595$; mfr = 0.295; $\alpha = 0°$

$M = 0.595$; mfr = 0.397; $\alpha = 0°$

Table V. Continued

(a) Continued

$M = 0.594$; mfr = 0.441; $\alpha = 0°$

$M = 0.594$; mfr = 0.495; $\alpha = 0°$

Table V. Continued

(a) Continued

$M = 0.595$; mfr = 0.494; $\alpha = 1.0°$

$M = 0.597$; mfr = 0.494; $\alpha = 2.0°$

Table V. Continued

(a) Continued

$M = 0.595$; mfr = 0.498; $\alpha = 3.0°$

$M = 0.594$; mfr = 0.557; $\alpha = 0°$

Table V. Continued

(a) Continued

$M = 0.594$; mfr $= 0.615$; $\alpha = 0°$

$M = 0.594$; mfr $= 0.688$; $\alpha = 0°$

Table V. Continued

(a) Continued

$M = 0.596$; mfr $= 0.688$; $\alpha = 2.0°$

$M = 0.596$; mfr $= 0.752$; $\alpha = 0°$

Table V. Continued

(a) Continued

$M = 0.595$; mfr $= 0.772$; $\alpha = 0°$

$M = 0.596$; mfr $= 0.814$; $\alpha = 0°$

Table V. Continued

(a) Concluded

$M = 0.595$; mfr $= 0.815$; $\alpha = 2.0°$

$M = 0.595$; mfr $= 0.878$; $\alpha = 0°$

Table V. Continued

(b) $M = 0.64$

$M = 0.644$ mfr $= 0.277$; $\alpha = 0°$

Table V(b)

$M = 0.645$; mfr $= 0.304$; $\alpha = 0°$

Table V. Continued

(b) Continued

$M = 0.645$; mfr $= 0.400$; $\alpha = 0°$

$M = 0.644$; mfr $= 0.438$; $\alpha = 0°$

Table V. Continued

(b) Continued

$M = 0.645$; mfr $= 0.492$; $\alpha = 0°$

$M = 0.644$; mfr $= 0.547$; $\alpha = 0°$

Table V. Continued

(b) Continued

$M = 0.646$; mfr $= 0.612$; $\alpha = 0°$

$M = 0.644$; mfr = 0.682; $\alpha = 0°$

Table V. Continued

(b) Continued

$M = 0.645$; mfr = 0.750; $\alpha = 0°$

$M = 0.644$; mfr = 0.810; $\alpha = 0°$

Table V. Continued

(b) Concluded

$M = 0.645$; mfr = 0.873; $\alpha = 0°$

Table V. Continued

(c) $M = 0.69$

$M = 0.693$; mfr = 0.280; $\alpha = 0°$

$M = 0.695$; mfr = 0.304; $\alpha = 0°$

Table V. Continued

(c) Continued

$M = 0.694$; mfr = 0.398; $\alpha = 0°$

$M = 0.693$; mfr = 0.436; $\alpha = 0°$

Table V. Continued

(c) Continued

$M = 0.692$; mfr = 0.490; $\alpha = 0°$

$M = 0.694$; mfr = 0.491; $\alpha = 2.0°$

Table V. Continued

(c) Continued

$M = 0.694$; mfr = 0.543; $\alpha = 0°$

$M = 0.693$; mfr = 0.607; $\alpha = 0°$

Table V. Continued

(c) Continued

$M = 0.694$; mfr = 0.682; $\alpha = 0°$

$M = 0.694$; mfr = 0.750; $\alpha = 0°$

Table V. Continued

(c) Concluded

$M = 0.692$; mfr = 0.813; $\alpha = 0°$

Table V. Continued

(d) $M = 0.72$

$M = 0.719$; mfr = 0.276; $\alpha = 0°$

Table V(d)

$M = 0.718$; mfr = 0.309; $\alpha = 0°$

Table V. Continued

(d) Continued

$M = 0.717$; mfr = 0.396; $\alpha = 0°$

$M = 0.719$; mfr = 0.438; $\alpha = 0°$

Table V. Continued

(d) Continued

$M = 0.718$; mfr = 0.490; $\alpha = 0°$

$M = 0.717$; mfr = 0.543; $\alpha = 0°$

Table V. Continued

(d) Continued

$M = 0.721$; mfr = 0.609; $\alpha = 0°$

$M = 0.718$; mfr = 0.682; $\alpha = 0°$

Table V. Continued

(d) Concluded

$M = 0.717$; mfr = 0.742; $\alpha = 0°$

$M = 0.717$; mfr = 0.812; $\alpha = 0°$

Table V. Continued

(e) $M = 0.74$

$M = 0.741$; mfr = 0.280; $\alpha = 0°$

Table V(e)

$M = 0.745$; mfr = 0.311; $\alpha = 0°$

Table V. Continued

(e) Continued

$M = 0.743$; mfr = 0.396; $\alpha = 0°$

$M = 0.744$; mfr = 0.442; $\alpha = 0°$

Table V. Continued

(e) Continued

$M = 0.743$; mfr $= 0.489$; $\alpha = 0°$

$M = 0.742$; mfr $= 0.491$; $\alpha = 2.0°$

Table V. Continued

(e) Continued

$M = 0.744$; mfr $= 0.541$; $\alpha = 0°$

$M = 0.743$; mfr $= 0.607$; $\alpha = 0°$

Table V. Continued

(e) Continued

$M = 0.744$; mfr $= 0.684$; $\alpha = 0°$

$M = 0.745$; mfr $= 0.744$; $\alpha = 0°$

Table V. Continued

(e) Concluded

$M = 0.743$; mfr $= 0.803$; $\alpha = 0°$

Table V. Continued

(f) $M = 0.77$

$M = 0.766$; mfr $= 0.277$; $\alpha = 0°$

Table V(f)

$M = 0.768$; mfr $= 0.310$; $\alpha = 0°$

Table V. Continued

(f) Continued

$M = 0.766$; mfr $= 0.399$; $\alpha = 0°$

$M = 0.768$; mfr $= 0.448$; $\alpha = 0°$

Table V. Continued

(f) Continued

$M = 0.767$; mfr $= 0.487$; $\alpha = 0°$

$M = 0.767$; mfr $= 0.543$; $\alpha = 0°$

Table V. Continued

(f) Continued

$M = 0.768$; mfr $= 0.607$; $\alpha = 0°$

$M = 0.767$; mfr $= 0.684$; $\alpha = 0°$

Table V. Continued

(f) Concluded

$M = 0.767$; mfr = 0.743; $\alpha = 0°$

$M = 0.767$; mfr = 0.805; $\alpha = 0°$

Table V. Continued

(g) $M = 0.79$

$M = 0.792$; mfr = 0.278; $\alpha = 0°$

Table V(g)

$M = 0.791$; mfr = 0.314; $\alpha = 0°$

Table V. Continued

(g) Continued

$M = 0.792$; mfr = 0.400; $\alpha = 0°$

$M = 0.792$; mfr = 0.443; $\alpha = 0°$

Table V. Continued

(g) Continued

$M = 0.793$; mfr = 0.489; $\alpha = 0°$

$M = 0.793$; mfr = 0.489; $\alpha = 2.0°$

Table V. Continued

(g) Continued

$M = 0.792$; mfr = 0.542; $\alpha = 0°$

$M = 0.794$; mfr = 0.607; $\alpha = 0°$

Table V. Continued

(g) Continued

$M = 0.793$; mfr = 0.683; $\alpha = 0°$

$M = 0.792$; mfr = 0.744; $\alpha = 0°$

Table V. Continued

(g) Concluded

$M = 0.793$; mfr = 0.802; $\alpha = 0°$

Table V. Continued

(h) $M = 0.82$

$M = 0.818$; mfr = 0.274; $\alpha = 0°$

Table V(h)

$M = 0.818$; mfr = 0.316; $\alpha = 0°$

Table V. Continued

(h) Continued

$M = 0.817$; mfr $= 0.396$; $\alpha = 0°$

$M = 0.818$; mfr $= 0.445$; $\alpha = 0°$

Table V. Continued

(h) Continued

$M = 0.818$; mfr $= 0.488$; $\alpha = 0°$

$M = 0.816$; mfr $= 0.543$; $\alpha = 0°$

Table V. Continued

(h) Continued

$M = 0.817$; mfr $= 0.609$; $\alpha = 0°$

$M = 0.817$; mfr $= 0.676$; $\alpha = 0°$

Table V. Continued

(h) Concluded

$M = 0.815$; mfr $= 0.741$; $\alpha = 0°$

$M = 0.817$; mfr $= 0.800$; $\alpha = 0°$

Table V. Continued

(i) $M = 0.84$

$M = 0.844$; mfr $= 0.273$; $\alpha = 0°$

Table V(i)

$M = 0.841$; mfr $= 0.314$; $\alpha = 0°$

Table V. Continued

(i) Continued

$M = 0.840$; mfr $= 0.400$; $\alpha = 0°$

$M = 0.842$; mfr $= 0.445$; $\alpha = 0°$

Table V. Continued

(i) Continued

$M = 0.840$; mfr $= 0.487$; $\alpha = 0°$

$M = 0.841$; mfr $= 0.490$; $\alpha = 2.0°$

Table V. Continued

(i) Continued

$M = 0.842$; mfr $= 0.542$; $\alpha = 0°$

$M = 0.843$; mfr $= 0.609$; $\alpha = 0°$

Table V. Continued

(i) Continued

$M = 0.840$; mfr $= 0.678$; $\alpha = 0°$

$M = 0.841$; mfr $= 0.678$; $\alpha = 2.1°$

Table V. Continued

(i) Concluded

$M = 0.841$; mfr $= 0.741$; $\alpha = 0°$

Table V. Continued

(j) $M = 0.87$

$M = 0.869$; mfr $= 0.271$; $\alpha = 0°$

Table V(j)

$M = 0.868$; mfr $= 0.316$; $\alpha = 0°$

Table V. Continued

(j) Continued

$M = 0.865$; mfr $= 0.397$; $\alpha = 0°$

$M = 0.866$; mfr $= 0.443$; $\alpha = 0°$

Table V. Continued

(j) Continued

$M = 0.867$; mfr $= 0.488$; $\alpha = 0°$

$M = 0.867$; mfr $= 0.543$; $\alpha = 0°$

Table V. Continued

(j) Continued

$M = 0.868$; mfr $= 0.611$; $\alpha = 0°$

$M = 0.867$; mfr $= 0.680$; $\alpha = 0°$

Table V. Continued

(j) Concluded

$M = 0.867$; mfr $= 0.743$; $\alpha = 0°$

Table V. Continued

(k) $M = 0.89$

Table V. Continued

(k) Continued

$M = 0.891$; mfr $= 0.273$; $\alpha = 0°$

$M = 0.892$; mfr = 0.273; $\alpha = 1.0°$

Table V. Continued

(k) Continued

$M = 0.892$; mfr = 0.274; $\alpha = 2.1°$

$M = 0.892$; mfr = 0.268; $\alpha = 3.1°$

Table V. Continued

(k) Continued

$M = 0.891$; mfr = 0.311; $\alpha = 0°$

$M = 0.893$; mfr = 0.398; $\alpha = 0°$

Table V. Continued

(k) Continued

$M = 0.890$; mfr = 0.443; $\alpha = 0°$

$M = 0.891$; mfr = 0.485; $\alpha = 0°$

Table V. Continued

(k) Continued

$M = 0.890$; mfr = 0.488; $\alpha = 1.0°$

$M = 0.891$; mfr = 0.488; $\alpha = 2.1°$

Table V. Continued

(k) Continued

$M = 0.890$; mfr = 0.485; $\alpha = 3.0°$

$M = 0.893$; mfr = 0.544; $\alpha = 0°$

Table V. Continued

(k) Continued

$M = 0.891$; mfr = 0.611; $\alpha = 0°$

$M = 0.890$; mfr = 0.681; $\alpha = 0°$

Table V. Continued

(k) Continued

$M = 0.891$; mfr = 0.680; $\alpha = 1.0°$

$M = 0.892$; mfr = 0.681; $\alpha = 2.1°$

Table V. Continued

(k) Concluded

$M = 0.890$; mfr $= 0.682$; $\alpha = 3.1°$

$M = 0.893$; mfr $= 0.744$; $\alpha = 0°$

Table V. Continued

(l) $M = 0.92$

$M = 0.917$; mfr $= 0.273$; $\alpha = 0°$

$M = 0.917$; mfr $= 0.272$; $\alpha = 2.1°$

Table V. Continued

(l) Continued

$M = 0.917$; mfr $= 0.314$; $\alpha = 0°$

$M = 0.918$; mfr $= 0.395$; $\alpha = 0°$

Table V. Continued

(l) Continued

$M = 0.917$; mfr $= 0.443$; $\alpha = 0°$

$M = 0.917$; mfr $= 0.485$; $\alpha = 0°$

Table V. Continued

(l) Continued

$M = 0.917$; mfr $= 0.488$; $\alpha = 1.0°$

$M = 0.916$; mfr $= 0.488$; $\alpha = 2.1°$

Table V. Continued

(l) Continued

$M = 0.917$; mfr $= 0.488$; $\alpha = 3.1°$

$M = 0.916$; mfr $= 0.544$; $\alpha = 0°$

Table V. Continued

(l) Continued

$M = 0.917$; mfr $= 0.612$; $\alpha = 0°$

$M = 0.916$; mfr $= 0.681$; $\alpha = 0°$

Table V. Concluded

(l) Concluded

$M = 0.915$; mfr $= 0.681$; $\alpha = 2.1°$

$M = 0.915$; mfr $= 0.746$; $\alpha = 0°$

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Pressure distributions on three inlets having different cowl lengths were obtained in the Langley 16-Foot Transonic Tunnel. The cowl diameter ratio (highlight diameter to maximum diameter) was 0.85, and the cowl length ratios (cowl length to maximum diameter) were 0.337, 0.439, and 0.547. The cowls had identical nondimensionalized (with respect to cowl length) external geometry and identical internal geometry. The internal contraction ratio (highlight area to throat area) was 1.250. The inlets had longitudinal rows of static-pressure orifices on the top and bottom (external) surfaces and on the contraction (internal) and diffuser surfaces. The afterbody was cylindrical in shape, and its diameter was equal to the maximum diameter of the cowl. Depending on the cowl configuration and free-stream Mach number, the mass-flow ratio varied between 0.27 and 0.87 during the tests. Angle of attack varied from 0° to 4.1° at selected Mach numbers and mass-flow ratios, and the Reynolds number varied with the Mach number from $3.2 \times 10^6$ to $4.2 \times 10^6$ per foot.

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