NASA Technical Memorandum 87602

WIND TUNNEL RESULTS FOR A HIGH-SPEED, NATURAL LAMINAR-FLOW AIRFOIL DESIGNED FOR GENERAL AVIATION AIRCRAFT

P-73

WILLIAM G. SEWALL

ROBERT J. McGHEE

JEFFERY K. VIKEN

EDGAR G. WAGGONER

BETTY S. WALKER

BETTY F. MILLARD

IN-02
117217
DATE OVERRIDE

(NASA-TM-87602) WIND TUNNEL RESULTS FOR A HIGH-SPEED, NATURAL LAMINAR-FLOW AIRFOIL DESIGNED FOR GENERAL AVIATION AIRCRAFT (NASA) 73 p CSCL 01A

N88-14078

Unclas
G3/02 0117217

NOVEMBER 1985

Date for general release November 30, 1987

National Aeronautics and Space Administration

Langley Research Center
Hampton, Virginia 23665

INTRODUCTION

During the past decade, several new advanced technology airfoils for general aviation have evolved from the research efforts at Langley Research Center. These new airfoils offer superior maximum lift and higher lift-to-drag ratios than the older general aviation airfoils. Reference 1 presents a summary of these airfoils.

Recent interest in viscous drag reduction has inspired airfoil design with laminar boundary layers on large segments of each surface. The laminar boundary layers are maintained by arranging favorable pressure gradients in the airfoil pressure distribution without any active boundary layer control. These types of airfoils have been designated natural laminar flow (NLF) airfoils. While these natural laminar flow airfoils attain minimum drag at the low-lift design condition, the high maximum lift of earlier airfoils is an additional requirement for general aviation applications.

This report presents wind tunnel test results on an NLF airfoil designed for the high speed applications of a business jet. The airfoil, designated as the HSNLF(1)-0213, is designed for a Mach number of 0.70 at a lift coefficient of 0.20 and Reynolds number of 11 million. At these conditions, the airfoil pressure distribution allows laminar boundary layers on 50 percent of the upper surface and 70 percent of the lower surface. In addition, a maximum lift coefficient of 1.60 at landing conditions, Mach number of 0.10, Reynolds number of 6 million, was a design condition.

The wind tunnel tests were conducted in two facilities, the Langley 6- by 28-Inch Transonic Tunnel for the high-speed conditions, and the Langley Low-Turbulence Pressure Tunnel for the low-speed maximum lift performance.

SYMBOLS

C_p	pressure coefficient, $\frac{p_\ell - p}{q}$
c	airfoil chord, 6 in. (6x28), 24 in. (LTPT)
c_c	section chord-force coefficients, $\int c_p \, d \frac{z}{c}$
c_d	section profile-drag coefficient, $\int_{wake} c'_d \, d \frac{h}{c}$
c'_d	point-drag coefficient
c_ℓ	section-lift coefficient
c_m	section pitching-moment coefficient about quarter-chord point $- \int c_p (x/c - 0.25) \, d \frac{x}{c} + \int c_p \frac{z}{c} \, d \frac{z}{c}$
c_n	section normal force coefficient, $- \int c_p \, d \frac{x}{c}$
h	vertical distance in wake profile, in.

M	free-stream Mach number
p	free-stream static pressure, lb/in^2 (6x28), lb/ft^2(LTPT)
q	free-stream dynamic pressure, lb/in^2(6x28), lb/ft^2(LTPT)
R	Reynolds number based on free-stream conditions and airfoil chord
x	airfoil abscissa, in.
y	spanwise station, in.
z	airfoil ordinate, in.
α	angle of attack, deg
δ_f	flap deflection, positive downward, deg

Subscripts:

corr	quantity from 6-by 28-inch transonic tunnel test with corrections including the sidewall boundary-layer interference
ℓ	local point on airfoil surface
max	maximum
meas.	measured quantity in test data that has some correction

Abbreviations:

HSNLF	high-speed natural laminar flow
LTPT	Low-Turbulence Pressure Tunnel
NTF	National Transonic Facility

AIRFOIL DESIGNATION

The airfoil shape is designated as the HSNLF(1)-0213 and is sketched in figure 1. The "HSNLF" denotes high-speed natural laminar flow, the (1) indicates the first in a series, and the 0213 denotes a lift coefficient of 0.2 and thickness ratio of 13 percent chord.

AIRFOIL DESIGN

This airfoil was designed jointly by Mr. Jeffrey Viken under contract to NASA Langley Research Center and the Applied Aerodynamics Group of the National Transonic Facility Aerodynamics Branch. The airfoil was specifically adapted for the wing design of a prototype business jet.

Initially. this airfoil consisted of a scale-down version of the NLF(1)-0414F airfoil described in references 2 and 3. The design conditions selected were a Reynolds number of 11 million, Mach number of 0.70, and lift coefficient of 0.25, which was provided by an optimum cruise flap setting on the NLF(1)-0414F airfoil.

The resulting contour yielded a pressure distribution shown in figure 2, which had some undesirable characteristics. First of all, since the minimum pressure on the upper surface had an aft location at 70 percent chord, the resulting pressure recovery had adverse gradients severe enough to cause boundary-layer separation near the trailing edge. Second, the lower surface leading edge region had a slightly excessive adverse pressure gradient that could cause boundary-layer transition at lift coefficients lower than the design condition. This would cause higher drag levels due to the loss in laminar bounbdary layers on the lower surface. In addition, there was an undesirable moment load on the trailing edge flap.

These problem areas were alleviated by first, recontouring the upper surface to move the minimum pressure location to 50 percent chord and thereby reduce the adverse pressure gradients in the pressure recovery. Second, the leading edge region of the lower surface was recontoured to provide favorable pressure gradients at the lower lift coefficients to maintain the laminar boundary layers. Figure 3 presents a comparison of the initial and final airfoil designs, where the final airfoil had minimum pressure located at 50 and 70 percent chord on the upper and lower surfaces respectively, thus allowing extensive regions of laminar flow. The airfoil shape is defined from the coordinates given in Table I.

MODELS, APPARATUS, AND PROCEDURE

Models

The airfoil was first tested in the Langley 6- by 28-Inch Transonic Tunnel to determine the high speed performance. Figure 4 is a photograph of the model, which had a 6-inch chord and width. The model spanned the tunnel with both ends mounted into endplates that fit turntables in the test section. Both upper and lower surfaces of the model were instrumented for static pressure orifices with their locations given in Table II. There were 51 orifices in the midspan region of the model, and 9 orifices 0.125 inches from the end of the model on the upper surface. The model was machined from a solid piece of 17-4 stainless steel to within 0.002 inches of the required shape. The tubes to the orifices are routed entirely in the lower surface and the passageways covered with metal filler. This allowed a smooth upper surface with minimal interruptions to disturb the laminar boundary layer.

Pressures measured on the model were integrated to give normal force and pitching moment coefficients. The model was tested with both smooth surfaces and with forced transition located at 0.05 chord on both surfaces. The forced transition consisted of a thin spanwise strip of clear spray adhesive.

After the high speed investigation, the airfoil was then tested at low speeds in the Langley Low-Turbulence Pressure Tunnel to determine the maximum lift. This model, shown in figure 5, had a 2-foot chord and was equipped with a split flap attachment to evaluate lift increments with a simple high-lift device. This model was not instrumented for pressures, as in the high speed test. Each end of the model attached to a unique external force balance system that was especially designed for high lift models in this facility. The model was fabricated by recontouring the surfaces of an existing model and wrapping fiberglass skin around the resulting shape. The final surfaces were hand-worked to accuracies with 0.002 inches of the required shape.

WIND TUNNELS

6- by 28-Inch Transonic Tunnel

The Langley 6- by 28-Inch Transonic Tunnel is a two-dimensional blowdown tunnel used primarily for testing airfoils at moderate Reynolds numbers with independent control of both Mach number and stagnation pressure. A detailed description of the facility is available in references 4 and 5 in addition to the following brief description.

The 6- by 28-Inch Transonic Tunnel operates on direct blowdown from a supply of dry, compressed air which is supplied from an offsite centrifugal compressor at 14,000 cfm and 300 psig. The compressor fills two reservoirs to obtain sufficient air volume for adequate run time. The main reservoir is the Langley Low-Turbulence Pressure Tunnel (LTPT), which has both high volume (approximately 65,000 cu. ft.) and a high pressure shell capable of 10 atmospheres. An additional reservoir consists of 4 storage tanks each having 2,000 cu ft. of volume at 300 psig, but the LTPT provides the majority of the air supply. For almost all test conditions, the LTPT is used as a reservoir for the 6- by 28-Inch Transonic Tunnel and therefore, both facilities cannot run simultaneously.

Normal test conditions for most models include Mach numbers ranging from 0.35 to 0.90 and stagnation pressures ranging from 1.5 to 6.0 atmospheres. Mach number is controlled by choker doors downstream of the test section while stagnation pressure is set by the valve that regulates the supply air. These ranges of conditions provide the best flow quality and permit adequate run time.

The test section has solid sidewalls and slotted top and bottom walls to alleviate the severe transonic wall interference problems. Reference 5 describes the slotted top and bottom walls in detail. The test section is 6 inches wide and actually 28.50 inches in height with all four walls undiverged over the entire test section length.

Figure 6 shows the test apparatus which consists of two opposing turntables in each sidewall that hold the model by the end plates and rotate to set angle of attack. In addition, a wake survey probe traverses the model wake vertically for drag measurements, and is sketched in figure 6.

Low Turbulence Pressure Tunnel

The Langley Low-Turbulence Pressure Tunnel is a closed-throat, single return tunnel which can be operated at stagnation pressures from 1 to 10 atmospheres at corresponding Mach numbers of 0.46 to 0.22. These combinations of conditions provide a maximum unit Reynolds number of 15 million per foot in the test section which is 3 feet wide and 7.5 feet high. The current configuration of the tunnel is described in detail in reference 6 and a brief description is given here.

The model and support system are shown in figures 7 and 8. The airfoil model is mounted between two endplates which are connected to inner drums. The inner drums are held in place by outer drums and a yoke-arm support system. The yoke support system is mounted to a force balance which is, in turn, connected to the tunnel through a balance platform. The yoke arm is fabricated from aluminum in a monocoque structure to minimize weight loads on the balance system. The balance provided direct lift force and pitching moments for this test.

Model angle of attack is controlled by a motor-driven, externally-mounted pitch mechanism that rotates the bearing-mounted inner drums. A multipath labyrinth seal is used to minimize air leakage from the test section into the outer tunnel plenum. An electrical fouling indicator is incorporated in the seal to detect any fouling at the seal components.

The wake survey rake, illustrated in figure 9, is used to measure the static and total pressure within the model's wake, as well as the mean wake flow angle. As shown in figure 9, several different types of probes are on this rake, and the rake itself is supported by a remote-controlled survey apparatus that can position the rake at different spanwise positions. The entire rake and survey apparatus appears in figure 10, and its capabilities are well documented in reference 6. For this test, the rake was used for drag measurements.

INSTRUMENTATION

6- by 28-Inch Transonic Tunnel

All test data were obtained by a high speed data acquisition system and recorded on magnetic tape. Each pressure measurement was made with a combination of a precision variable capacitance transducer coupled with a signed conditioner, as described in reference 7. Output signals from the wake total pressure measurements passed through 20-Hz low-pass filters before entering the data acquisition system. This range of filtered frequencies was reported in reference 4. Geometric angle of attack signals were provided by a digital shaft encoder attached to a rack and pinion mechanism on a test section turntable. A similar encoder arrangement provides the vertical position of the wake survey probe to the data acquisition system. Both the angle of attack and the wake survey probe can be pre-programed to operate automatically along with the stagnation pressure and Mach number.

Low-Turbulence Pressure Tunnel

The same data acquisition system mentioned above for the 6- by 28-inch transonic tunnel was used for the LTPT. In addition, the system was arranged for real-time display of lift force, pitching moment, and drag coefficients along with the wake total pressure profile. Pressure measurements for the wake were made with the same type of transducer-signal conditioner system used in the 6- by 28-inch transonic tunnel. Total and static freestream pressures were measured with precision quartz manometers. Geometric angle of attack was measured by a digital shaft encoder coupled to a rack and pinion mechanism attached to the inner drum of the model support system.

TEST AND METHODS

High-Speed Tests

The high-speed tests in the 6- by 28-inch transonic tunnel were conducted over Reynolds number ranges of 3.5 to 6.5 million at 0.35 Mach number and from 4 to 11 million at Mach numbers of 0.5 to 0.8.

Since the airfoil was designed for natural laminar flow, the model was first tested with smooth, clean metallic surfaces to allow the most rearward boundary-layer transition with the existing tunnel flow quality. Forced boundary-layer transition as indicated in the model description, was then applied and the model retested over the same range of conditions.

The data was recorded as surface pressure distributions which were integrated to give normal force, axial force and pitching-moment coefficients. Total pressure surveys of the model's wake and static pressures on the tunnel sidewall that were adjacent to the wake were used to calculate the drag coefficient by the method in reference 8.

The data was recorded as surface pressure distributions which were integrated to give normal force, axial force and pitching-moment coefficients. Total pressure surveys of the model's wake and static pressures on the tunnel sidewall that were adjacent to the wake were used to calculate the drag coefficient by the method in reference 8.

Corrections have been applied to the data that account for lift interference and some of the interference caused by the sidewall boundary layer. The lift interference was experimentally determined from unpublished data on a 3-inch and 6-inch chord model of the NACA 0012 airfoil. This correction looses validity in the transonic range, but appears valid up to a Mach number of 0.7. The correction deals with the angle of attack error at a given normal force coefficient and is given as:

$$\alpha_{corr.} = \alpha_{meas.} - \Delta\alpha$$

$$\Delta\alpha = (1.671M_{meas.} - .114) \times c_{n_{corr.}}$$

The sidewall boundary layer problem, discussed in detail in references 9 and 10, is a two-part problem. Historically, the primary concern was the interaction of trailing-edge boundary-layer separation on the model with boundary layer separation on the sidewall. This interaction destroys the two-dimensional character of the airfoil test and can severely compromise the maximum lift measurement. This problem is addressed by either having sufficient test section width as compared to the sidewall boundary-layer thickness or actively controlling the sidewall boundary layer with various devices. This problem has not been addressed for this facility and reference 9 indicates the facility limitations.

The second problem with the sidewall boundary layer concerns the effect of the model-induced pressure gradients in changing the displacement thickness of the sidewall boundary layer. The behavior, studied in detail in reference 10, affects the continuity equation for two-dimensional flow even though the sidewall boundary layer has experienced no separation. Reference 10 shows derived corrections that account for the sidewall boundary layer effects by using transonic similarity rules. These rules define an equivalent two-dimensional Mach number and pressure coefficient, where the Mach number correction has been calculated and curved-fitted against the measured Mach number:

$$M_{corr.} = 0.9731M_{meas.} - 0.01268 \quad \text{for} \quad M_{meas.} < 0.5916$$

and

$$M_{corr.} = 0.99366M_{meas.} - 0.02483 \quad \text{for} \quad M_{meas.} \quad 0.5916$$

The correction for pressure coefficient results in the following normal force and pitching moment corrections:

$$(c_{n,m})_{corr.} = (c_{n,m})_{meas.} \times \frac{B}{1-M^2_{corr.}}$$

where, for $M_{meas.} < .6323$, $B = -0.6675M^2_{meas.} + .0791M_{meas.} + 1.0406$

and for $M_{meas.}$ $.6323$, $B = -4.1123M^3_{meas.} + 7.7301M^2_{meas.} -5.7215M_{meas.} + 2.3905$

No correction has been applied to the drag coefficient from the 6-by 28-inch transonic tunnel. These corrections are based on small disturbance theory and do not address the separated sidewall boundary layer problem mentioned earlier in conjunction with the maximum lift measurement.

TEST AND METHODS

Low-Speed Test

The model was tested at Reynolds numbers based on chord of 3 million to 9 million and a Mach number range of 0.10 to 0.30. The model was tested both with smooth surfaces for natural transition and with fixed transition at 0.05 chord on both surfaces. For fixed transition, a strip of no. 100 carborundum particles was glued to the surfaces with clear lacquer and had a width of 0.05 inches.

For several test runs, thin hot-film gages were mounted on the model upper surface to determine the location of boundary-layer transition. These results are shown in figure 11.

Since the force and moment data were measured with a balance for the low speed test and calculated by integrating pressure distributions for the high speed test, some comparison of balance data and integrated pressure data would be useful. Figure 12 shows this comparison for a previous test in the LTPT on an NACA 4416 airfoil. The agreement between the balance-measured force data and the force data from integrated pressure distributions is considered excellent.

Section profile-drag coefficients were computed from the wake-rake total and static pressure by the method of reference 11.

Standard low-speed wind-tunnel boundary corrections given in reference 11 have been applied to the section data. Corrections were applied to the free-stream dynamic pressure due to solid and wake blockage. Also, the lift, pitching moment, and angle of atack were corrected due to the floor and ceiling boundaries. These corrections are as follows:

$$\alpha = \alpha_{meas.} + 0.133\ (c_{\ell_{meas.}} + 4\ c_{m_{meas.}})$$

$$c_{\ell_{corr.}} = (c_{\ell_{meas.}})(0.978 - 0.133\ c_{d_{meas.}})$$

$$c_m = (c_{m_{meas.}})(0.993 - 0.133\ c_{d_{meas.}}) + 0.0037\ c_{\ell_{meas.}}$$

$$c_d = (c_{d_{meas.}})(0.989 - 0.133\ c_{d_{meas.}})$$

No corrections have been made to the data that account for the sidewall boundary layer effect as in the high speed test because the boundary layer displacement thickness is a much smaller fraction of the tunnel width. The LTPT has approximately 1 percent of its width occupied by sidewall boundary layer displacement thickness compared to approximately 2.5 percent width for the 6- by 28-inch tunnel. The maximum lift measurements in LTPT consequently offer more accuracy than those in the 6- by 28-inch tunnel.

PRESENTATION OF RESULTS

Airfoil section data from the high- and low-speed tests are tabulated in Appendix A and B. Selected pressure distributions and section data are presented graphically in the following figures:

1. Measured chordwise pressure distributions from test in the 6- by 28-inch transonic tunnel presented with the corrected values of angle of attack, Mach number, normal-force coefficient, and pitching-moment coefficient.

Conditions	Figure
Model smooth, $M_{corr.} = 0.34$, $R = 3x10^6$ and $5x10^6$	13
Model smooth, $R = 4x10^6$, $M_{corr.} = .70, .74, .75, .77$	14
Fixed transition at 0.05c, $R = 11x10^6$, $M_{corr.} = .69, .73, .75, 77$	15

2. Effect of Mach number on section characteristics from test in 6- by 28-inch transonic tunnel.

8. Effect of Mach number and Reynolds number on maximum lift coefficient from test in LTPT.

Conditions	Figure
$M = 0.10$ to $.29$, $R = 3 \times 10^6$ to 6×10^6 model smooth..................	25

9. Variation of drag coefficient with Reynolds number from test in LTPT.

Conditions	Figure
$c_\ell = 0.2$, $M = .30$, $R = 3 \times 10^6$ to 9×10^6	
Model is both smooth and has fixed transition at 0.05c............	26

10. Variation of drag coefficient with Mach number from test in 6- by 28-inch transonic tunnel.

Conditions	Figure
$c_n = .26$, model smooth with $R = 4 \times 10^6$,	
fixed transition at 0.05c with $R = 11 \times 10^6$.........................	27

SUMMARY OF RESULTS

This investigation provided the following results:

1. Boundary-layer transition, measured in the LTPT, moved forward by approximately 0.10c at the design lift coefficient ($c_\ell \approx 0.25$) as the chord Reynolds number increased from 3 million to 9 million. The transition occurred between 0.50c to 0.70c on the lower surface.

2. The maximum lift coefficient measured in the LTPT was about 1.7 for the basic airfoil and about 2.5 with a 60-degree, 0.20c trailing-edge split-flap.

3. Increasing the Mach number from 0.10 to 0.30 at a fixed Reynolds number of 6 million reduced the maximum lift coefficient measured in the LTPT by only 10 percent.

4. Fixed boundary-layer transition near the leading edge of the airfoil decreased the maximum lift coefficient measured in the LTPT by approximately 0.04.

5. The minimum drag coefficient at the design lift coefficient was 0.0036 at a chord Reynolds number of 6 million, as measured in the LTPT for$M < 0.30$. For the high-speed test in the 6- by 28-inch transonic tunnel, the minimum drag at the design Mach number of 0.70 and chord Reynolds number of 4 million was 0.0072.

6. From the high-speed test, the drag-rise Mach number at a lift coefficient of 0.26 occurred at a Mach number of 0.725 for the smooth model at a chord Reynolds number of 4 million. With fixed boundary-layer transition at 0.05c, and chord Reynolds number of 11 million, the drag-rise Mach number dropped to 0.712

REFERENCES

1. McGhee, Robert J.; Beasley, William D.; and Whitcomb, Richard T.: NASA Low- and Medium-Speed Airfoil Development. NASA TM-78709, 1979.

2. Viken, Jeffrey K.: Aerodynamic Design Considerations and Theoretical Results for a High Reynolds Number Natural Laminar Airfoil. Master's Thesis, George Washington University, January 1983.

3. McGhee, Robert J.; Viken, Jeffrey K.; Pfenninger, Werner; Beasley, William D.; and Harvey, William D.: Experimental Results for a Flapped Natural-Laminar-Flow Airfoil With High Lift/Drag Ratio. NASA TM 85788, 1984.

4. Ladson, Charles L.: Description and Calibration of the Langley 6- by 28-Inch Transonic Tunnel. NASA TN D-8070, 1975.

5. Sewall, William G.: Description of Recent Changes to the Langley 6- by 28-Inch Transonic Tunnel. NASA TM 81947, May 1981.

6. McGhee, Robert J.; Beasley, William D.; and Foster, Jean M.: Recent Modifications and Calibration of the Langley Low-Turbulence Pressure Tunnel. NASA TP-2328, 1984.

7. Bynum, D. S.; Ledford, R. L.; and Smotherman, W. E.: Wind Tunnel Pressure Measuring Techniques. AGARD-AG-145-70, 1970.

8. Baals, Donald D.; and Mourhess, Mary J.: Numerical Evaluation of the Wake-Survey Equations for Subsonic Flow Including the Effect of Energy Addition. NACA WR L-5, 1945 (Formerly NACA ARR L5H27)

9. Bingham, Gene J.; Noonan, Kevin W.; and Sewall, William G.: Two-Dimensional Aerodynamic Characteristics of an Airfoil Designed for Rotorcraft Application. NASA TP-1965, 1981.

10. Sewall, William G.: Effects of Sidewall Boundary Layers in Two-Dimensional Subsonic and Transonic Wind Tunnels. AIAA Journal, Vol. 20, September 1982, pp. 1253-1256.

11. Pankhurst, R. C.; and Holder, D. W.: Wind-Tunnel Technique. Sir Issac Pitman and Sons, Ltd. (London), 1965.

TABLE 1: COORDINATES FOR THE HSNLF(1)-0213 AIRFOIL

* HSNLF(1)-0213 AIRFOIL *

LOWER SURFACE COORDINATES

X/C	Z/C
0.0	0.0
.00025	-.00159901
.00050	-.00230222
.00075	-.00286038
.0010	-.00334494
.0015	-.00419028
.0020	-.00492252
.0025	-.00556459
.005	-.00795793
.010	-.0112011
.020	-.0155117
.030	-.0187992
.040	-.0215501
.050	-.0239056
.060	-.0260205
.080	-.0297664
.090	-.0314631
.100	-.0330753
.125	-.0367325
.150	-.0399681
.175	-.0428315
.200	-.0453554
.225	-.0476378
.250	-.0497128
.275	-.0515824
.300	-.0532687
.325	-.0547767
.350	-.0561033
.375	-.0572318
.400	-.0581716
.425	-.0589204
.450	-.0594701
.475	-.0598050
.500	-.0599816
.525	-.0600226
.550	-.0598030
.575	-.0593236
.600	-.0585655
.625	-.0574839
.650	-.0559400
.675	-.0538433
.680	-.0533504
.700	-.0509298
.725	-.0463495
.750	-.0410619
.775	-.0367508
.780	-.0359926
.800	-.0331313
.820	-.0304965
.825	-.0298719
.850	-.0269506
.875	-.0243247
.900	-.0218780
.920	-.0200204
.925	-.0195751
.950	-.0175194
.975	-.0158287
.980	-.0155455
.990	-.0150271
1.0	-.0145600

TABLE 1: CONCLUDED.

* HSNLF(1)-0213 AIRFOIL *

UPPER SURFACE COORDINATES

X/C	Z/C	X/C	Z/C
0.0	0.0	.525	.0689648
.00025	.00301272	.550	.0667772
.00050	.00428352	.575	.0640790
.00075	.00526275	.600	.0607751
.0010	.00608870	.625	.0568193
.0015	.00746999	.650	.0521886
.0020	.00862628	.675	.0469746
.0025	.00963673	.680	.0458726
.005	.0135129	.700	.0413226
.010	.0186690	.725	.0354629
.020	.0252367	.750	.0295444
.030	.0300557	.775	.0238415
.040	.0340027	.780	.0227189
.050	.0374370	.800	.0182871
.060	.0404896	.820	.0140757
.080	.0457286	.825	.0130549
.090	.0480263	.850	.00810483
.100	.0501504	.875	.00350601
.125	.0548232	.900	-.00057777
.150	.0587791	.920	-.00358925
.175	.0621388	.925	-.00430936
.200	.0649785	.950	-.00761355
.225	.0673697	.975	-.0106563
.250	.0693627	.980	-.0112067
.275	.0709735	.990	-.0122354
.300	.0722353	1.0	-.013220
.325	.0731582		
.350	.0737502		
.375	.0740317		
.400	.0740003		
.425	.0736666		
.450	.0730084		
.475	.0720296		
.500	.0706895		

TABLE 2: ORIFICE LOCATIONS ON HSNLF(1)-0213 AIRFOIL MODEL TESTED IN THE 6- BY 28-INCH TRANSONIC TUNNEL

ORIFICE NO.	X/C	Y/C	Z/C
LOWER SURFACE			
1	0.0015	-.083	0.0002
2	0.0130		-.0129
3	0.0258		-.0177
4	0.0503		-.0241
5	0.0760		-.0292
6	0.1000		-.0333
7	0.1503		-.0401
8	0.2011		-.0457
9	0.2502		-.0499
10	0.3006		-.0535
11	0.3505		-.0562
12	0.4003		-.0583
13	0.4507		-.0596
14	0.5005		-.0601
15	0.5505		-.0599
16	0.6007		-.0587
17	0.6504		-.0559
18	0.6751		-.0540
19	0.7006		-.0509
20	0.7257		-.0465
21	0.7509		-.0412
22	0.8007		-.0333
23	0.8510		-.0271
24	0.9003		-.0221
25	0.9502		-.0177
26	0.9753		-.0159

TABLE 2: CONCLUDED.

ORIFICE NO.	X/C	Y/C	Z/C
UPPER SURFACE			
27	0.0127	0.083	0.0213
28	0.0244		0.0281
29	0.0503		0.0381
30	0.0757		0.0453
31	0.0999		0.0507
32	0.1498		0.0593
33	0.2002		0.0656
34	0.2505		0.0700
35	0.3004		0.0728
36	0.3505		0.0743
37	0.4005		0.0746
38	0.4506		0.0736
39	0.5005		0.0712
40	0.5257		0.0695
41	0.5505		0.0673
42	0.5757		0.0646
43	0.6013		0.0612
44	0.6507		0.0526
45	0.7004		0.0418
46	0.7505		0.0302
47	0.8012		0.0188
48	0.8505		0.0086
49	0.9009		0.0000
50	0.9514		-.0072
51	0.9758		-.0101

ORIFICES NEAR SIDEWALL

ORIFICE NO.	X/C	Y/C	Z/C
UPPER SURFACE			
52	0.0000	0.4795	0.0000
53	0.0128		0.0215
54	0.0749		0.0451
55	0.0932		0.0507
56	0.5005		0.0713
57	0.6000		0.0614
58	0.7004		0.0419
59	0.8003		0.0188
60	0.9008		0.0000

APPENDIX A.

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115

MODEL SMOOTH RUNS 1-13

RUN 1

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-4.13	-4.03	.362	.339	-.1863	-.1945	-.0339	-.0354	***	2.75	2
-1.96	-1.98	.363	.341	.0317	.0331	-.0353	-.0368	***	2.75	3
.02	-.09	.359	.336	.2228	.2326	-.0201	-.0210	***	2.84	4
2.02	1.81	.354	.332	.4297	.4487	-.0253	-.0264	***	2.86	5
4.05	3.73	.360	.337	.6203	.6475	-.0258	-.0269	***	2.85	6
6.03	5.61	.353	.331	.8425	.8797	-.0378	-.0395	***	2.81	7
8.04	7.54	.356	.334	1.0040	1.0482	-.0322	-.0336	***	2.77	8
10.01	9.45	.359	.336	1.1083	1.1570	-.0232	-.0242	***	2.89	9
10.99	10.41	.357	.335	1.1497	1.2003	-.0216	-.0226	***	2.88	10
12.01	11.42	.352	.330	1.2019	1.2550	-.0142	-.0148	***	2.82	11
12.99	12.41	.357	.335	1.1578	1.2087	-.0110	-.0115	***	2.82	12
13.99	13.41	.354	.331	1.1576	1.2087	-.0132	-.0138	***	2.89	13
15.00	14.46	.356	.334	1.0856	1.1334	-.0181	-.0189	***	2.87	14

RUN 2

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-.09	-.19	.371	.348	.1947	.2032	-.0131	-.0137	.00530	2.77	17
.03	-.08	.367	.345	.2033	.2122	-.0138	-.0144	.00570	2.78	18
3.99	3.69	.351	.328	.6019	.6285	-.0198	-.0207	.00915	2.69	20
6.00	5.60	.355	.333	.7932	.8282	-.0205	-.0214	.01135	2.75	21
8.01	7.51	.364	.342	.9711	1.0135	-.0201	-.0210	.01480	2.76	22
9.95	9.39	.361	.339	1.1035	1.1519	-.0217	-.0227	***	2.70	23
11.99	11.40	.357	.335	1.1710	1.2225	-.0181	-.0189	***	2.71	24
13.95	13.38	.350	.328	1.1581	1.2093	-.0203	-.0212	***	2.70	25
15.97	15.43	.347	.325	1.1134	1.1628	-.0560	-.0585	***	2.70	26

RUN 3

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-4.12	-4.01	.356	.334	-.2257	-.2356	-.0065	-.0068	***	2.95	29
-1.97	-1.97	.358	.335	.0009	.0009	-.0116	-.0121	***	3.02	30
-.01	-.11	.362	.340	.2028	.2117	-.0138	-.0144	***	3.05	31
.00	-.10	.361	.339	.2032	.2121	-.0137	-.0143	***	2.95	28
2.04	1.83	.356	.334	.4136	.4318	-.0172	-.0180	***	2.96	32
3.96	3.66	.361	.339	.5939	.6199	-.0211	-.0220	***	3.10	33
5.99	5.58	.359	.337	.8132	.8489	-.0218	-.0228	***	3.04	34
8.02	7.52	.364	.341	.9693	1.0117	-.0234	-.0244	***	3.08	35
9.97	9.40	.362	.339	1.1054	1.1538	-.0215	-.0224	***	3.09	36
11.15	10.56	.358	.335	1.1720	1.2235	-.0203	-.0212	***	3.12	37
12.00	11.39	.353	.330	1.2244	1.2785	-.0253	-.0264	***	3.07	38
12.97	12.37	.357	.335	1.1935	1.2460	-.0163	-.0170	***	3.08	39
14.03	13.45	.356	.334	1.1660	1.2174	-.0134	-.0140	***	3.10	40
15.05	14.47	.355	.332	1.1589	1.2100	-.0323	-.0337	***	3.10	41
16.12	15.55	.359	.336	1.1203	1.1695	-.0563	-.0588	***	3.14	42

ORIGINAL PAGE IS
OF POOR QUALITY

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115-CONTINUED

RUN 4

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-4.02	-3.91	.360	.338	-.2196	-.2292	-.0072	-.0075	***	4.95	47
-1.97	-1.97	.360	.338	.0020	.0021	-.0113	-.0118	***	4.99	48
-.07	-.17	.359	.337	.1997	.2085	-.0143	-.0149	***	4.98	45
-.06	-.16	.353	.331	.2090	.2182	-.0141	-.0147	***	4.93	46
.03	-.08	.359	.337	.2208	.2305	-.0143	-.0149	***	4.94	49
1.97	1.75	.353	.331	.4361	.4554	-.0188	-.0196	***	4.84	50
4.03	3.71	.360	.338	.6384	.6664	-.0217	-.0227	***	4.99	51
5.99	5.56	.357	.334	.8574	.8951	-.0242	-.0253	***	4.93	52
8.01	7.48	.359	.336	1.0456	1.0915	-.0251	-.0262	***	4.96	53
9.98	9.38	.352	.330	1.2177	1.2715	-.0246	-.0257	***	4.86	54
10.97	10.33	.352	.329	1.2998	1.3573	-.0313	-.0327	***	4.90	55
11.98	11.35	.356	.333	1.2513	1.3064	-.0139	-.0145	***	4.93	56
12.97	12.34	.358	.335	1.2441	1.2988	-.0181	-.0189	***	4.98	57
13.99	13.36	.358	.336	1.2487	1.3036	-.0299	-.0312	***	4.95	58
14.97	14.37	.360	.337	1.1764	1.2280	-.0246	-.0257	***	5.01	59

RUN 5

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-.10	-.21	.360	.337	.2101	.2193	-.0147	-.0153	***	6.58	70
-.06	-.17	.360	.338	.2079	.2170	-.0151	-.0158	***	6.58	62
2.02	1.81	.357	.334	.4240	.4427	-.0181	-.0189	***	6.60	63
3.98	3.66	.353	.331	.6493	.6780	-.0228	-.0238	***	6.53	64
5.99	5.57	.360	.338	.8290	.8654	-.0242	-.0253	***	6.71	65
8.04	7.51	.355	.332	1.0577	1.1043	-.0261	-.0273	***	6.64	66
10.04	9.43	.357	.335	1.2014	1.2542	-.0227	-.0237	***	6.73	67
11.04	10.41	.358	.336	1.2406	1.2951	-.0206	-.0215	***	6.78	68
11.47	10.83	.351	.329	1.2970	1.3544	-.0192	-.0200	***	6.66	69
11.50	10.86	.348	.326	1.3081	1.3661	-.0220	-.0230	***	6.43	71
11.97	11.34	.353	.331	1.2675	1.3234	-.0235	-.0245	***	6.64	72
12.52	11.89	.351	.328	1.2752	1.3316	-.0172	-.0180	***	6.58	73
13.00	12.36	.350	.328	1.2985	1.3560	-.0319	-.0333	***	6.65	74

RUN 6

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.05	-2.05	.730	.700	-.0041	-.0042	-.0153	-.0157	.00757	4.21	81
-1.03	-1.18	.731	.702	.1280	.1316	-.0178	-.0183	.00691	4.26	82
-.07	-.36	.728	.699	.2575	.2647	-.0214	-.0220	.00743	4.26	80
-.01	-.31	.726	.697	.2660	.2734	-.0210	-.0216	.00702	4.27	83
.99	.54	.727	.697	.3968	.4078	-.0236	-.0243	.00650	4.32	84
1.47	.96	.725	.695	.4558	.4685	-.0239	-.0246	.00797	4.34	85
2.02	1.42	.728	.698	.5276	.5423	-.0238	-.0245	.00907	4.32	86
2.51	1.85	.723	.693	.5894	.6058	-.0247	-.0254	.00742	4.31	87
2.97	2.24	.722	.692	.6467	.6647	-.0235	-.0242	.01000	4.40	88

APPENDIX A.-

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115-CONTINUED

RUN 7

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.09	-2.09	.725	.695	-.0044	-.0045	-.0154	-.0158	.00737	4.37	91
-1.03	-1.18	.730	.700	.1279	.1315	-.0176	-.0181	.00657	4.28	92
-.03	-.32	.724	.695	.2597	.2669	-.0214	-.0220	.00657	4.24	90
-.02	-.32	.725	.696	.2620	.2693	-.0209	-.0215	.00644	4.34	93
.99	.55	.728	.698	.3909	.4018	-.0233	-.0239	.00699	4.28	94
1.48	.96	.725	.695	.4593	.4721	-.0240	-.0247	.00735	4.38	95
2.01	1.42	.722	.692	.5258	.5404	-.0241	-.0248	.00779	4.30	96
2.49	1.82	.723	.693	.5930	.6095	-.0242	-.0249	.00848	4.36	97
2.98	2.25	.723	.694	.6466	.6646	-.0241	-.0248	.00966	4.40	98

RUN 8

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.05	-2.05	.744	.715	-.0011	-.0011	-.0164	-.0169	.00714	4.27	101
-1.03	-1.19	.747	.717	.1352	.1389	-.0198	-.0203	.00647	4.25	102
-.53	-.77	.746	.716	.2049	.2106	-.0219	-.0225	.00703	4.19	103
-.04	-.35	.747	.717	.2678	.2752	-.0233	-.0239	.00687	4.25	104
-.03	-.34	.748	.718	.2677	.2751	-.0229	-.0235	.00686	4.18	100
.47	.08	.745	.715	.3356	.3449	-.0248	-.0255	.00728	4.27	105
.99	.52	.745	.716	.4009	.4120	-.0264	-.0271	.00794	4.24	106
1.48	.94	.744	.715	.4686	.4816	-.0280	-.0288	.00774	4.28	107
1.98	1.37	.743	.713	.5244	.5389	-.0280	-.0288	.00935	4.26	108

RUN 9

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.02	-2.03	.769	.740	.0093	.0096	-.0182	-.0187	.00796	3.86	111
-1.03	-1.20	.767	.738	.1435	.1474	-.0222	-.0228	.00749	3.95	112
-.07	-.39	.764	.734	.2680	.2754	-.0259	-.0266	.00927	3.92	110
-.02	-.35	.763	.734	.2729	.2804	-.0266	-.0273	.00865	3.89	114
.47	.07	.767	.737	.3302	.3393	-.0288	-.0296	.01123	3.87	115
.99	.52	.764	.734	.3926	.4034	-.0302	-.0310	.01259	3.95	116
1.48	.95	.762	.732	.4492	.4616	-.0317	-.0326	.01435	3.92	117
1.97	1.38	.765	.735	.4959	.5095	-.0333	-.0342	.01630	3.94	118

APPENDIX A.-

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115-CONTINUED

RUN 10

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.05	-2.05	.784	.754	.0023	.0024	-.0217	-.0223	.00916	3.97	121
-1.03	-1.20	.781	.751	.1378	.1416	-.0271	-.0278	.01000	3.94	122
-.54	-.78	.784	.754	.1920	.1972	-.0292	-.0300	.01260	3.94	123
-.07	-.37	.789	.759	.2445	.2511	-.0333	-.0342	.01662	3.92	120
-.02	-.34	.784	.754	.2569	.2639	-.0317	-.0326	.01412	3.91	124
.47	.09	.786	.756	.3076	.3160	-.0334	-.0343	.01839	3.91	125
.96	.52	.781	.752	.3617	.3716	-.0343	-.0352	.01936	3.96	126
1.48	.97	.782	.752	.4157	.4270	-.0365	-.0375	.02194	3.92	127
1.97	1.40	.779	.749	.4671	.4799	-.0368	-.0378	.02308	3.98	128

RUN 11

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.02	-2.00	.805	.775	-.0174	-.0179	-.0246	-.0253	***	3.86	131
-1.05	-1.19	.804	.774	.1087	.1116	-.0301	-.0309	.01791	3.85	132
-.51	-.72	.804	.774	.1688	.1733	-.0336	-.0345	.02054	3.80	133
-.03	-.30	.804	.774	.2172	.2230	-.0351	-.0360	.02224	3.84	134
-.01	-.29	.807	.777	.2175	.2233	-.0358	-.0368	.02256	3.89	130
.47	.12	.801	.771	.2792	.2867	-.0375	-.0385	***	3.85	135
.98	.57	.803	.773	.3228	.3315	-.0387	-.0397	***	3.87	136
1.48	1.00	.797	.767	.3813	.3916	-.0405	-.0416	***	3.84	137
2.00	1.47	.797	.767	.4256	.4371	-.0408	-.0419	***	3.90	138

RUN 12

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.02	-2.02	.731	.702	.0040	.0041	-.0155	-.0159	.00698	8.43	141
-1.07	-1.22	.724	.695	.1299	.1335	-.0183	-.0188	.00748	8.45	142
-.52	-.75	.724	.694	.2004	.2060	-.0197	-.0202	.00789	8.51	143
-.06	-.36	.729	.700	.2607	.2679	-.0217	-.0223	.00782	8.39	149
.52	.14	.725	.696	.3347	.3440	-.0223	-.0229	.00833	8.83	145
1.02	.56	.725	.695	.4044	.4156	-.0237	-.0244	.00849	8.89	146

RUN 13

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-1.04	-1.18	.725	.696	.1270	.1305	-.0179	-.0184	.00768	10.39	153
-.55	-.76	.723	.693	.1908	.1961	-.0193	-.0198	.00806	10.68	154
-.04	-.33	.720	.691	.2609	.2682	-.0207	-.0213	.00826	10.22	157
-.01	-.31	.716	.687	.2675	.2750	-.0209	-.0215	.00780	10.16	152
.47	.09	.724	.694	.3358	.3451	-.0230	-.0236	.00855	10.42	158
.98	.53	.724	.694	.4010	.4122	-.0241	-.0248	.00870	10.52	159

APPENDIX A.-

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115-CONTINUED

MODEL HAS FIXED TRANSITION AT 0.05C RUNS 16-37

RUN 16

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.03	-2.02	.517	.490	-.0104	-.0108	-.0118	-.0122	.00833	3.91	182
-1.02	-1.10	.517	.491	.1005	.1041	-.0131	-.0136	.00808	3.85	183
-.07	-.23	.513	.487	.2036	.2110	-.0153	-.0159	.00839	3.80	181
.02	-.15	.520	.493	.2137	.2214	-.0149	-.0154	.00843	3.95	184
.99	.74	.514	.488	.3217	.3334	-.0173	-.0179	.00836	3.92	185
2.02	1.69	.516	.489	.4295	.4451	-.0184	-.0191	.00864	3.90	186
2.97	2.55	.516	.490	.5360	.5555	-.0195	-.0202	.00890	3.86	187
4.01	3.51	.514	.488	.6506	.6743	-.0205	-.0212	.00846	3.94	188

RUNS 17,18

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.05	-2.04	.510	.484	-.0187	-.0194	-.0107	-.0111	.00686	8.42	191
-1.02	-1.10	.512	.485	.1005	.1042	-.0129	-.0134	.00794	8.55	192
-.06	-.22	.513	.486	.2099	.2176	-.0157	-.0163	.00682	8.49	199
-.03	-.19	.507	.481	.2142	.2221	-.0152	-.0158	.00726	8.44	204
-.03	-.19	.510	.484	.2093	.2170	-.0151	-.0157	.00754	8.29	190
.05	-.12	.512	.486	.2237	.2319	-.0154	-.0160	.00768	8.65	193
1.02	.76	.512	.485	.3325	.3446	-.0172	-.0178	.00826	8.77	194
2.02	1.68	.509	.483	.4510	.4675	-.0193	-.0200	.00765	8.48	200
2.03	1.69	.510	.483	.4484	.4648	-.0193	-.0200	.00859	8.81	195
3.00	2.57	.509	.482	.5610	.5816	-.0208	-.0216	.00832	8.54	201
3.01	2.58	.512	.485	.5607	.5812	-.0203	-.0210	.00778	8.61	205
3.01	2.58	.510	.484	.5577	.5781	-.0208	-.0216	.00859	8.63	196
4.02	3.51	.510	.483	.6733	.6980	-.0216	-.0224	.00935	8.67	206
4.05	3.53	.515	.488	.6776	.7022	-.0222	-.0230	.00890	8.69	202
5.01	4.41	.510	.483	.7849	.8137	-.0219	-.0227	.01010	8.86	207

RUNS 19,20

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.04	-2.02	.707	.678	-.0164	-.0169	-.0139	-.0143	.00787	11.02	210
-.99	-1.13	.703	.674	.1253	.1288	-.0169	-.0174	.00831	11.22	211
-.54	-.74	.705	.675	.1802	.1853	-.0182	-.0187	.00779	11.22	215
-.05	-.32	.704	.675	.2490	.2560	-.0194	-.0199	.00816	10.71	209
-.05	-.32	.707	.677	.2448	.2517	-.0196	-.0202	.00865	11.11	219
.03	-.25	.705	.675	.2590	.2663	-.0198	-.0204	.00809	11.37	216
.54	.19	.702	.673	.3261	.3353	-.0212	-.0218	.00909	11.10	217
1.49	1.00	.707	.677	.4502	.4629	-.0228	-.0234	.00885	11.50	221

APPENDIX A.-

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115-CONTINUED

RUNS 21,22

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.03	-2.01	.728	.698	-.0168	-.0173	-.0150	-.0154	.00841	11.11	225
-1.01	-1.15	.728	.699	.1221	.1255	-.0180	-.0185	.00836	11.30	226
-.05	-.34	.730	.701	.2532	.2602	-.0214	-.0220	.00833	10.97	224
.00	-.30	.724	.694	.2630	.2703	-.0212	-.0218	.00827	10.80	230
.49	.12	.720	.690	.3286	.3378	-.0223	-.0229	.00832	10.93	231
1.03	.58	.723	.694	.3986	.4097	-.0236	-.0243	.00904	11.12	232
2.03	1.44	.720	.690	.5306	.5454	-.0244	-.0251	.00951	11.09	236

RUNS 23,24

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.05	-2.03	.746	.716	-.0188	-.0193	-.0159	-.0163	.00867	11.15	239
-1.02	-1.17	.743	.714	.1318	.1354	-.0204	-.0210	.00896	11.19	240
-.52	-.75	.743	.714	.1988	.2043	-.0223	-.0229	.00870	11.35	241
-.09	-.39	.740	.710	.2578	.2649	-.0226	-.0232	.00865	10.87	238
.49	.10	.737	.707	.3411	.3505	-.0246	-.0253	.01004	10.42	243
.99	.52	.746	.716	.4016	.4127	-.0291	-.0299	.01174	10.64	244
1.49	.95	.744	.714	.4650	.4779	-.0315	-.0324	.01281	10.78	245
1.99	1.38	.742	.712	.5247	.5392	-.0328	-.0337	.01548	10.95	246

RUNS 25,26

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.08	-2.06	.760	.731	-.0179	-.0184	-.0179	-.0184	.00898	10.56	249
-1.05	-1.21	.759	.730	.1315	.1351	-.0236	-.0242	.00996	10.66	250
-.01	-.34	.754	.725	.2763	.2839	-.0280	-.0288	.01309	10.30	248
.53	.12	.760	.731	.3482	.3578	-.0352	-.0362	.01542	10.55	253
.99	.54	.762	.732	.3747	.3850	-.0363	-.0373	.02137	10.63	254
1.48	.99	.762	.732	.4118	.4231	-.0365	-.0375	***	10.78	255
2.02	1.48	.761	.731	.4538	.4663	-.0363	-.0373	***	10.93	256

RUNS 27,28

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.04	-2.03	.781	.751	-.0114	-.0117	-.0245	-.0252	.01309	10.45	259
-1.04	-1.18	.780	.750	.1171	.1203	-.0300	-.0308	.01715	10.57	260
-.55	-.76	.780	.750	.1692	.1738	-.0315	-.0324	.02149	10.74	261
-.14	-.40	.781	.751	.2101	.2158	-.0340	-.0349	.02219	10.32	258
.64	.28	.778	.748	.2984	.3066	-.0371	-.0381	***	10.39	263
1.00	.63	.783	.754	.3004	.3086	-.0342	-.0351	***	10.57	264
1.48	1.08	.785	.755	.3214	.3301	-.0320	-.0329	***	10.71	265
2.03	1.58	.783	.753	.3680	.3780	-.0318	-.0327	***	10.85	266

HSNLF(1)-0213 AIRFOIL, LANGLEY 6-BY 28-INCH TRANSONIC TUNNEL, TEST 115-CONCLUDED

RUNS 29,30

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.05	-1.99	.802	.772	-.0479	-.0492	-.0282	-.0290	.01912	10.73	269
-1.01	-1.10	.799	.769	.0690	.0709	-.0297	-.0305	***	10.89	270
-.51	-.65	.799	.769	.1140	.1171	-.0295	-.0303	***	11.11	271
-.06	-.25	.801	.771	.1488	.1528	-.0287	-.0295	***	10.56	268
.53	.27	.799	.769	.2114	.2171	-.0302	-.0310	***	10.66	273
.96	.70	.805	.775	.2028	.2082	-.0220	-.0226	***	10.82	274
1.49	1.16	.797	.767	.2675	.2747	-.0248	-.0255	***	10.96	275
2.00	1.61	.797	.767	.3108	.3192	-.0266	-.0273	***	11.14	276

RUNS 31,32

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.04	-2.03	.710	.681	-.0119	-.0122	-.0145	-.0149	.00817	11.13	281
-1.04	-1.17	.712	.682	.1221	.1255	-.0173	-.0178	.00757	11.27	282
-.51	-.72	.708	.679	.1939	.1993	-.0189	-.0194	.00841	11.42	283
-.05	-.33	.703	.673	.2531	.2602	-.0194	-.0199	.00796	10.71	280
.51	.15	.702	.672	.3302	.3395	-.0206	-.0212	.00883	10.70	285
1.13	.68	.702	.673	.4105	.4221	-.0224	-.0230	.00896	10.98	286
1.49	.99	.701	.672	.4585	.4715	-.0224	-.0230	.00917	11.22	287
2.03	1.46	.703	.673	.5265	.5414	.0227	.0233	.00950	11.39	288

RUNS 33,34

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-2.03	-2.02	.727	.697	-.0127	-.0131	-.0152	-.0156	.00804	11.23	291
-1.01	-1.16	.726	.697	.1310	.1346	-.0182	-.0187	.00826	11.37	292
-.51	-.73	.723	.694	.1972	.2027	-.0201	-.0207	.00875	11.45	293
-.05	-.35	.729	.699	.2614	.2687	-.0217	-.0223	.00862	10.97	290
.54	.16	.722	.692	.3422	.3517	-.0219	-.0225	.00891	11.08	295
1.03	.58	.721	.692	.4035	.4147	-.0232	-.0238	.00904	11.19	296
1.54	1.00	.727	.697	.4754	.4886	-.0249	-.0256	.00998	11.40	297
2.03	1.42	.725	.695	.5402	.5552	-.0258	-.0265	.01072	11.53	298

RUNS 35,36,37

ALPHA DEG	ALPHA,C DEG	MACH	MACH,C	CN	CN,C	CM	CM,C	CD	RN (X 10-6)	POINT
-.09	-.25	.517	.491	.2102	.2178	-.0154	-.0160	.00839	8.49	305
-.05	-.21	.513	.486	.2125	.2203	-.0155	-.0161	.00822	8.45	300
-.03	-.19	.513	.486	.2138	.2216	-.0152	-.0158	.00752	8.46	310
1.97	1.63	.517	.490	.4436	.4597	-.0187	-.0194	.00836	8.54	301
4.02	3.50	.514	.488	.6705	.6949	-.0215	-.0223	.00874	8.57	302
4.53	3.96	.512	.486	.7347	.7615	-.0217	-.0225	.00941	8.60	303
5.06	4.45	.514	.487	.7912	.8200	-.0220	-.0228	.01024	8.51	306
5.54	4.89	.512	.485	.8444	.8753	-.0215	-.0223	.01000	8.51	307
5.99	5.30	.514	.487	.8895	.9219	-.0201	-.0208	.01024	8.63	308
6.50	5.79	.509	.482	.9305	.9646	-.0195	-.0202	.01228	8.51	311
7.49	6.73	.509	.482	.9929	1.0293	-.0151	-.0157	.01705	8.68	313
8.02	7.23	.508	.481	1.0350	1.0730	-.0101	-.0105	.01740	8.74	314

ORIGINAL PAGE IS
OF POOR QUALITY

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313

MODEL SMOOTH   RUNS 3,5,6,9,10,12,13,15,17,19-22,29

RUNS 3,29   M = 0.22   R = 3.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.04	-.288	.0079	.0074
-4.01	-.229	.0079	.0162
-3.14	-.187	.0074	-.0001
-3.13	-.166	.0074	.0056
-2.03	-.053	.0051	.0046
-2.02	-.055	.0051	.0061
-1.00	.059	.0047	-.0075
-1.00	.049	.0048	-.0028
.03	.194	.0048	-.0167
.03	.204	.0048	-.0119
.04	.211	.0049	-.0166
.05	.216	.0048	-.0082
1.04	.282	.0049	-.0062
1.06	.330	.0049	.0123
2.07	.410	.0060	-.0027
2.08	.411	.0060	-.0216
2.10	.425	.0060	-.0159
3.09	.497	.0080	-.0114
3.09	.507	.0080	-.0095
4.01	.611	.0091	-.0201
4.03	.656	.0091	-.0006
4.11	.591	.0092	-.0184
6.11	.859	.0116	-.0069
6.12	.880	.0116	-.0057
8.37	1.045	.0157	-.0181
8.37	1.070	.0157	-.0177
10.20	1.176	****	-.0115
10.21	1.206	****	-.0052
12.18	1.312	****	-.0125
12.18	1.301	****	-.0084
14.19	1.366	****	-.0231
14.20	1.368	****	-.0179
15.28	1.409	****	-.0148
15.29	1.413	****	-.0129
16.20	1.394	****	-.0093
16.20	1.411	****	-.0093
17.16	1.216	****	-.0515
17.16	1.218	****	-.0416

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUNS 5,6   M = 0.17   R = 4.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.56	-.326	.0074	-.0155
-4.02	-.209	.0072	.0086
-3.03	-.126	.0068	-.0152
-3.01	-.105	.0068	-.0005
-2.57	-.018	.0064	.0080
-2.02	-.041	.0052	-.0186
-2.01	-.021	.0052	-.0088
-1.50	.046	.0047	-.0053
-1.49	.046	.0047	.0031
-1.01	.091	.0039	-.0148
-1.00	.103	.0039	-.0092
.03	.174	.0040	-.0236
.04	.216	.0040	-.0159
.05	.225	.0038	-.0110
.06	.244	.0038	-.0032
1.07	.332	.0046	-.0182
1.07	.348	.0046	-.0051
1.23	.325	.0043	-.0198
1.24	.332	.0043	-.0156
1.56	.339	.0053	-.0314
1.57	.378	.0053	-.0130
2.05	.422	.0063	-.0247
2.06	.420	.0063	-.0084
2.57	.480	.0070	-.0086
3.07	.503	.0078	-.0197
3.07	.519	.0078	-.0145
4.34	.622	.0090	-.0256
4.34	.636	.0090	-.0216
5.09	.676	.0097	-.0204
5.10	.727	.0097	-.0188
6.10	.812	.0107	-.0326
6.11	.844	.0107	-.0168
8.29	1.034	.0136	-.0244
8.29	1.053	.0136	-.0217
10.23	1.160	.0178	-.0308
10.24	1.203	.0178	-.0291
12.20	1.309	****	-.0361
12.20	1.327	****	-.0281
12.21	1.347	****	-.0205
14.19	1.439	****	-.0283
14.19	1.430	****	-.0274
15.20	1.488	****	-.0261
15.21	1.505	****	-.0129
16.22	1.510	****	-.0238
16.22	1.516	****	-.0206
17.21	1.507	****	-.0310
17.22	1.540	****	-.0167
17.72	1.518	****	-.0246
18.14	1.165	****	-.0874
18.16	1.253	****	-.0767

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUNS 9,10   M = 0.14   R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.08	-.266	.0068	-.0092
-4.08	-.274	.0068	-.0023
-3.09	-.187	.0064	-.0192
-3.08	-.154	.0064	-.0124
-2.57	-.103	.0061	-.0180
-2.57	-.105	.0061	-.0158
-2.08	-.088	.0056	-.0183
-2.08	-.054	.0056	-.0175
-1.51	-.003	.0037	-.0171
-1.51	.008	.0037	-.0173
-1.03	.028	.0038	-.0266
-1.02	.052	.0038	-.0190
-.01	.170	.0037	-.0152
.04	.152	.0038	-.0265
.04	.180	.0038	-.0228
.04	.183	.0038	-.0203
.05	.172	.0038	-.0151
1.04	.260	.0045	-.0271
1.05	.285	.0045	-.0177
2.05	.382	.0059	-.0215
2.05	.386	.0059	-.0192
2.06	.367	.0059	-.0290
2.07	.388	.0059	-.0221
3.07	.514	.0070	-.0377
3.08	.508	.0070	-.0213
4.06	.595	.0077	-.0354
4.07	.633	.0077	-.0251
5.09	.718	.0083	-.0252
5.10	.743	.0083	-.0226
6.15	.842	.0091	-.0284
6.15	.839	.0091	-.0236
8.15	1.038	.0113	-.0328
8.15	1.053	.0113	-.0320
10.17	1.215	.0146	-.0279
10.18	1.252	.0146	-.0234
12.19	1.364	.0190	-.0327
12.19	1.382	.0190	-.0304
14.19	1.480	****	-.0337
14.20	1.509	****	-.0207
16.22	1.585	****	-.0238
16.22	1.593	****	-.0211
17.21	1.589	****	-.0321
17.22	1.637	****	-.0171
18.22	1.652	****	-.0205
18.23	1.660	****	-.0145
18.71	1.613	****	-.0292
18.72	1.643	****	-.0244
19.17	1.181	****	-.1068
19.19	1.318	****	-.0954
19.22	1.413	****	-.0678

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 12 M = 0.20 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-1.00	.091	.0037	-.0113
-1.00	.092	.0037	-.0083
.05	.208	.0039	-.0132
.05	.217	.0039	-.0108
1.06	.326	.0047	-.0167
1.06	.324	.0047	-.0125
2.06	.427	.0061	-.0195
2.06	.434	.0061	-.0170
3.06	.520	.0071	-.0258
3.06	.547	.0071	-.0191
4.05	.642	.0079	-.0201
4.05	.652	.0079	-.0242
6.13	.872	.0098	-.0274
6.14	.881	.0098	-.0237
8.10	1.070	.0120	-.0299
8.10	1.084	.0119	-.0218
10.18	1.267	.0150	-.0263
10.18	1.277	.0150	-.0198
12.21	1.418	.0224	-.0249
12.21	1.436	.0224	-.0199
14.30	1.527	****	-.0205
14.30	1.526	****	-.0196
15.31	1.586	****	-.0143
15.31	1.592	****	-.0128
16.22	1.624	****	-.0174
16.23	1.635	****	-.0122
16.70	1.640	****	-.0166
16.71	1.637	****	-.0130
17.21	1.622	****	-.0187
17.21	1.647	****	-.0183
17.63	1.489	****	-.0405
17.64	1.524	****	-.0434
18.19	1.339	****	-.0833
18.22	1.436	****	-.0495

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 13 M = 0.14 R = 4.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
.01	.142	.0042	-.0452
.02	.178	.0042	-.0274
2.03	.393	.0057	-.0504
2.03	.362	.0057	-.0401
4.04	.538	.0085	-.0530
4.06	.566	.0085	-.0397
6.10	.823	.0106	-.0331
6.10	.833	.0106	-.0336
8.12	.945	.0132	-.0597
8.12	.961	.0132	-.0600
10.14	1.178	.0171	-.0461
10.15	1.202	.0171	-.0420
12.16	1.285	****	-.0594
12.17	1.315	****	-.0459
14.17	1.399	****	-.0537
14.17	1.398	****	-.0514
15.18	1.459	****	-.0451
15.19	1.485	****	-.0325
16.17	1.449	****	-.0651
16.19	1.496	****	-.0431
16.69	1.542	****	-.0383
16.69	1.551	****	-.0335
17.16	1.549	****	-.0503
17.17	1.521	****	-.0399
17.68	1.492	****	-.0602
17.68	1.502	****	-.0565
18.22	1.446	****	-.0489
18.24	1.527	****	-.0417
18.63	1.258	****	-.1152
18.67	1.404	****	-.0740

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 15 M = 0.11 R = 5.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
.01	.149	.0040	-.0370
.02	.186	.0040	-.0259
2.06	.385	.0058	-.0362
2.07	.401	.0058	-.0321
4.07	.584	.0081	-.0426
4.08	.634	.0081	-.0276
6.13	.811	.0100	-.0513
6.15	.841	.0100	-.0300
8.13	1.023	.0121	-.0423
8.13	1.034	.0121	-.0445
10.16	1.188	.0150	-.0509
10.17	1.218	.0150	-.0410
12.18	1.375	.0221	-.0396
12.19	1.390	.0221	-.0290
14.18	1.466	****	-.0490
14.19	1.480	****	-.0455
15.21	1.523	****	-.0445
15.22	1.535	****	-.0373
16.20	1.547	****	-.0412
16.21	1.589	****	-.0347
17.26	1.596	****	-.0535
17.26	1.577	****	-.0445
17.70	1.611	****	-.0505
17.71	1.603	****	-.0400
18.29	1.593	****	-.0548
18.30	1.595	****	-.0400
18.70	1.611	****	-.0324
18.72	1.631	****	-.0283
19.11	.986	****	-.1436
19.14	1.135	****	-.1313

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 17 M = 0.10 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-1.01	.114	.0037	-.0124
-1.00	.156	.0037	.0079
.04	.225	.0037	-.0077
.04	.242	.0037	-.0065
1.07	.325	.0044	-.0363
1.09	.334	.0044	-.0127
2.05	.387	.0059	-.0352
2.06	.426	.0059	-.0238
3.07	.552	.0069	-.0261
3.07	.560	.0069	-.0212
4.08	.661	.0078	-.0308
4.09	.672	.0078	-.0249
6.14	.882	.0094	-.0237
6.14	.878	.0094	-.0202
8.13	1.058	.0115	-.0368
8.14	1.100	.0115	-.0252
10.19	1.237	.0139	-.0425
10.22	1.322	.0139	-.0199
12.19	1.439	.0181	-.0241
12.19	1.454	.0181	-.0244
14.21	1.552	****	-.0205
14.21	1.548	****	-.0176
16.24	1.609	****	-.0328
16.25	1.663	****	-.0204
17.25	1.674	****	-.0204
17.25	1.688	****	-.0136
17.74	1.675	****	-.0224
17.74	1.691	****	-.0158
18.24	1.642	****	-.0353
18.27	1.715	****	-.0105
18.73	1.670	****	-.0206
18.74	1.714	****	-.0065
18.93	1.053	****	9.9000
18.93	1.377	****	9.9000
19.22	1.425	****	9.9000
19.23	1.415	****	9.9000

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 19 M = 0.14 R = 9.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.06	-.261	.0063	-.0040
-4.05	-.256	.0063	.0008
-3.57	-.207	.0062	-.0059
-3.57	-.192	.0062	-.0027
-3.08	-.151	.0060	-.0047
-3.08	-.131	.0060	-.0036
-2.62	-.091	.0058	-.0070
-2.62	-.088	.0058	-.0057
-2.04	-.044	.0055	-.0168
-2.03	-.025	.0055	-.0093
-1.54	.016	.0049	-.0152
-1.53	.036	.0049	-.0098
-.99	.082	.0040	-.0167
-.98	.095	.0040	-.0105
.05	.187	.0040	-.0187
.05	.203	.0040	-.0195
1.07	.300	.0048	-.0103
1.07	.320	.0048	-.0098
1.55	.357	.0053	-.0175
1.55	.370	.0053	-.0127
2.12	.428	.0059	-.0117
3.06	.522	.0066	-.0197
4.08	.633	.0073	-.0176
4.08	.624	.0073	-.0150
5.10	.750	.0080	-.0203
5.10	.753	.0080	-.0163
6.22	.868	.0090	-.0150
6.22	.890	.0090	-.0100
7.12	.970	.0098	-.0188
7.12	.972	.0098	-.0169
8.16	1.060	.0107	-.0224
8.17	1.099	.0107	-.0134
10.28	1.282	.0129	-.0211
10.29	1.311	.0129	-.0159
12.21	1.449	.0161	-.0169
12.21	1.450	.0161	-.0150
14.23	1.569	****	-.0119
14.23	1.577	****	-.0087
16.23	1.636	****	-.0119
16.23	1.654	****	-.0093
17.23	1.672	****	-.0092
17.23	1.666	****	-.0061
18.24	1.631	****	.0077
18.24	1.660	****	.0021
18.72	1.678	****	-.0104
18.73	1.705	****	-.0005
19.24	1.686	****	-.0004
19.24	1.683	****	.0070
19.62	1.150	****	-.0991
19.63	1.169	****	-.0860

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 20 M = 0.25 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
.04	.181	.0039	-.0268
.05	.198	.0039	-.0190
1.04	.307	.0048	-.0236
1.04	.308	.0048	-.0220
2.09	.424	.0062	-.0266
2.10	.430	.0062	-.0214
4.08	.632	.0080	-.0289
4.08	.653	.0080	-.0290
6.11	.859	.0099	-.0374
6.11	.867	.0099	-.0264
8.15	1.074	.0123	-.0331
8.15	1.098	.0123	-.0261
10.17	1.263	.0158	-.0365
10.17	1.272	.0158	-.0323
12.19	1.420	****	-.0290
12.19	1.425	****	-.0290
14.25	1.537	****	-.0266
14.25	1.518	****	-.0211
15.20	1.558	****	-.0323
15.21	1.568	****	-.0255
16.21	1.591	****	-.0237
16.22	1.596	****	-.0210
16.68	1.428	****	-.0538
16.68	1.457	****	-.0456
17.21	1.418	****	-.0650
17.21	1.397	****	-.0580
17.64	1.315	****	-.0792
17.65	1.366	****	-.0635

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 21 M = 0.29 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
.03	.200	.0041	-.0176
.03	.205	.0041	-.0183
1.05	.314	.0050	-.0160
1.06	.330	.0050	-.0156
2.07	.427	.0063	-.0199
2.07	.431	.0063	-.0168
4.08	.645	.0082	-.0261
4.09	.656	.0082	-.0230
6.12	.880	.0101	-.0282
6.13	.885	.0101	-.0202
8.18	1.088	.0127	-.0306
8.19	1.103	.0127	-.0240
10.17	1.269	.0167	-.0269
10.17	1.279	.0167	-.0263
12.19	1.404	****	-.0230
12.19	1.412	****	-.0198
14.20	1.496	****	-.0155
14.21	1.504	****	-.0155
15.20	1.466	****	-.0196
15.21	1.493	****	-.0140
16.23	1.406	****	-.0270
16.24	1.414	****	-.0253
16.66	1.350	****	-.0392
16.67	1.356	****	-.0368
17.17	1.269	****	-.0629
17.17	1.238	****	-.0547

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 22 M = 0.20 R = 3.7 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.06	-.266	.0076	-.0089
-4.05	-.236	.0076	-.0017
-3.08	-.149	.0071	-.0137
-3.08	-.154	.0071	-.0103
-2.04	-.051	.0055	-.0190
-2.03	-.056	.0055	-.0100
-1.00	.099	.0044	-.0132
-1.00	.116	.0044	-.0067
.03	.177	.0045	-.0187
.04	.231	.0044	-.0164
1.03	.283	.0045	-.0281
1.05	.337	.0045	-.0056
2.05	.405	.0060	-.0217
2.06	.407	.0060	-.0134
4.12	.626	.0088	-.0228
4.13	.655	.0088	-.0187
6.14	.859	.0111	-.0198
6.14	.864	.0111	-.0141
8.16	1.074	.0138	-.0102
8.16	1.100	.0138	-.0114
10.16	1.217	.0194	-.0195
10.17	1.241	.0194	-.0104
12.19	1.344	****	-.0239
12.20	1.373	****	-.0064
14.19	1.445	****	-.0189
14.19	1.446	****	-.0163
15.22	1.500	****	-.0146
16.16	1.515	****	-.0231
16.21	1.522	****	-.0186
16.21	1.537	****	-.0137
17.21	1.495	****	-.0253
17.21	1.501	****	-.0208
17.64	1.292	****	-.0495
17.66	1.362	****	-.0387
18.13	1.177	****	-.0789
18.15	1.249	****	-.0669

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

MODEL HAS FIXED TRANSITION AT 0.05C RUNS 26-28

RUN 26 M = 0.14 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.06	-.289	.0089	-.0230
-4.05	-.267	.0089	-.0117
-3.06	-.177	.0087	-.0239
-3.05	-.153	.0087	-.0177
-2.09	-.032	.0084	-.0124
-2.09	-.036	.0084	-.0118
-1.54	-.010	.0083	-.0328
-1.53	.023	.0083	-.0172
-1.01	.076	.0082	-.0216
-1.00	.092	.0082	-.0082
.03	.178	.0081	-.0190
.04	.203	.0081	-.0231
1.03	.284	.0081	-.0303
1.04	.303	.0081	-.0252
2.05	.406	.0083	-.0250
2.06	.433	.0083	-.0215
3.10	.524	.0087	-.0278
3.10	.538	.0087	-.0294
4.07	.617	.0092	-.0400
4.07	.602	.0092	-.0364
5.09	.726	.0100	-.0281
5.10	.753	.0100	-.0269
6.10	.822	.0108	-.0430
6.11	.840	.0108	-.0310
8.13	1.030	.0127	-.0431
8.14	1.063	.0127	-.0318
10.15	1.224	.0152	-.0460
10.16	1.253	.0152	-.0345
12.19	1.388	.0190	-.0427
12.20	1.400	.0190	-.0371
14.18	1.462	****	-.0557
14.19	1.508	****	-.0390
16.21	1.561	****	-.0342
16.22	1.595	****	-.0257
17.22	1.609	****	-.0389
17.22	1.617	****	-.0334
17.70	1.602	****	-.0456
17.71	1.627	****	-.0360
18.18	1.427	****	-.0541
18.19	1.517	****	-.0526

APPENDIX B.-

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 27   M = 0.17   R = 4.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.06	-.268	.0095	-.0159
-4.04	-.259	.0095	.0127
-3.10	-.168	.0093	-.0169
-3.10	-.157	.0093	-.0155
-2.10	-.050	.0090	-.0151
-2.09	-.036	.0090	-.0165
-1.06	.043	.0088	-.0223
-1.05	.049	.0088	-.0183
.02	.181	.0087	-.0216
.03	.198	.0087	-.0079
1.03	.286	.0088	-.0263
1.04	.302	.0088	-.0181
2.04	.365	.0091	-.0388
2.06	.421	.0091	-.0177
3.06	.496	.0094	-.0334
3.07	.520	.0094	-.0259
4.07	.604	.0100	-.0368
4.08	.634	.0100	-.0287
6.10	.815	.0118	-.0340
6.11	.840	.0119	-.0314
6.11	.812	.0119	-.0522
6.12	.829	.0119	-.0345
8.16	1.052	.0143	-.0511
8.17	1.022	.0143	-.0382
10.15	1.193	.0180	-.0383
10.16	1.209	.0180	-.0269
12.18	1.355	****	-.0274
12.18	1.355	****	-.0240
14.19	1.443	****	-.0424
14.21	1.498	****	-.0205
16.20	1.537	****	-.0287
16.20	1.535	****	-.0272
17.20	1.547	****	-.0363
17.21	1.546	****	-.0236
17.71	1.514	****	-.0413
17.72	1.518	****	-.0337
18.16	1.144	****	-.0755
18.20	1.397	****	-.0599
18.61	1.168	****	-.0927
18.62	1.248	****	-.0874

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 28 M = 0.20 R = 3.7 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-4.10	-.262	.0097	-.0101
-4.10	-.251	.0097	-.0053
-2.10	-.052	.0093	-.0117
-2.10	-.025	.0093	-.0042
-1.02	.040	.0090	-.0245
-1.01	.074	.0090	-.0095
.03	.187	.0089	-.0152
.04	.226	.0089	-.0009
1.04	.278	.0090	-.0259
1.05	.288	.0090	-.0195
2.05	.367	.0092	-.0357
2.07	.406	.0092	-.0170
4.06	.590	.0101	-.0474
4.07	.588	.0101	-.0272
6.11	.860	.0121	-.0240
6.11	.862	.0120	-.0221
8.13	1.020	.0148	-.0362
8.13	1.029	.0148	-.0303
10.15	1.185	.0199	-.0327
10.16	1.216	.0199	-.0263
12.18	1.325	****	-.0385
12.18	1.325	****	-.0333
14.19	1.457	****	-.0276
14.20	1.465	****	-.0145
15.22	1.475	****	-.0241
15.22	1.485	****	-.0191
16.22	1.521	****	-.0226
16.23	1.554	****	-.0190
17.21	1.503	****	-.0295
17.22	1.513	****	-.0168
17.63	1.238	****	-.0708
17.65	1.337	****	-.0531
18.16	1.130	****	-.0923
18.17	1.159	****	-.0735

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

MODEL HAS TRAILING-EDGE SPLIT FLAP(0.20C) AT 60 DEG RUNS 30-32

RUN 30 M = 0.17 R = 4.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-.97	1.336	****	-.2518
-.96	1.374	****	-.2546
.08	1.480	****	-.2473
.08	1.489	****	-.2417
2.10	1.627	****	-.2599
2.12	1.669	****	-.2402
4.13	1.846	****	-.2466
4.14	1.885	****	-.2407
6.15	2.023	****	-.2500
6.16	2.049	****	-.2465
8.19	2.217	****	-.2608
8.20	2.243	****	-.2500
9.20	2.305	****	-.2552
9.20	2.311	****	-.2528
10.21	2.402	****	-.2639
10.21	2.415	****	-.2518
11.19	2.255	****	-.2643
11.20	2.342	****	-.2700
12.17	2.142	****	-.2824
12.18	2.132	****	-.2647
13.13	1.962	****	-.2935
13.15	2.010	****	-.2720

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONTINUED

RUN 31 M = 0.14 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-.96	1.364	****	-.2377
-.94	1.438	****	-.2213
.11	1.480	****	-.2410
.12	1.495	****	-.2355
2.11	1.676	****	-.2441
2.11	1.690	****	-.2384
4.15	1.869	****	-.2423
4.16	1.876	****	-.2270
6.17	2.063	****	-.2416
6.18	2.073	****	-.2365
8.24	2.220	****	-.2442
8.26	2.290	****	-.2294
9.20	2.317	****	-.2493
9.21	2.323	****	-.2379
10.22	2.405	****	-.2391
10.22	2.426	****	-.2360
10.48	2.439	****	-.2458
10.48	2.432	****	-.2386
10.72	2.443	****	-.2393
10.72	2.461	****	-.2354
11.20	2.355	****	-.2529
11.20	2.382	****	-.2526
12.17	2.169	****	-.2593
12.18	2.186	****	-.2446
13.15	2.093	****	-.2805
13.16	2.124	****	-.2642

HSNLF(1)-0213 AIRFOIL, LANGLEY LOW TURBULENCE PRESSURE TUNNEL, TEST 313-CONCLUDED

RUN 32 M = 0.10 R = 6.0 MILLION

ALPHA, DEG	LIFT COEFFICIENT	DRAG COEFFICIENT	PITCHING-MOMENT COEFFICIENT
-.97	1.425	****	-.2082
-.96	1.439	****	-.2037
.11	1.487	****	-.2154
.11	1.509	****	-.2151
2.13	1.670	****	-.2267
2.13	1.705	****	-.2248
4.15	1.834	****	-.2318
4.15	1.850	****	-.2253
6.20	2.060	****	-.2249
6.21	2.052	****	-.2128
7.22	2.116	****	-.2385
7.24	2.159	****	-.2186
8.20	2.218	****	-.2269
8.21	2.233	****	-.2087
9.22	2.294	****	-.2268
9.23	2.339	****	-.2168
10.22	2.383	****	-.2231
10.22	2.437	****	-.2301
10.23	2.402	****	-.2193
10.23	2.407	****	-.2172
10.71	2.448	****	-.2287
10.72	2.506	****	-.2194
11.13	2.498	****	-.2277
11.13	2.501	****	-.2210
11.23	2.518	****	-.2121
11.23	2.542	****	-.2170
11.69	2.288	****	-.2415
11.70	2.320	****	-.2487
12.04	2.252	****	-.2553
12.05	2.311	****	-.2604
12.16	2.079	****	-.2472
12.20	2.295	****	-.2444
13.14	1.956	****	-.2684
13.17	2.094	****	-.2508

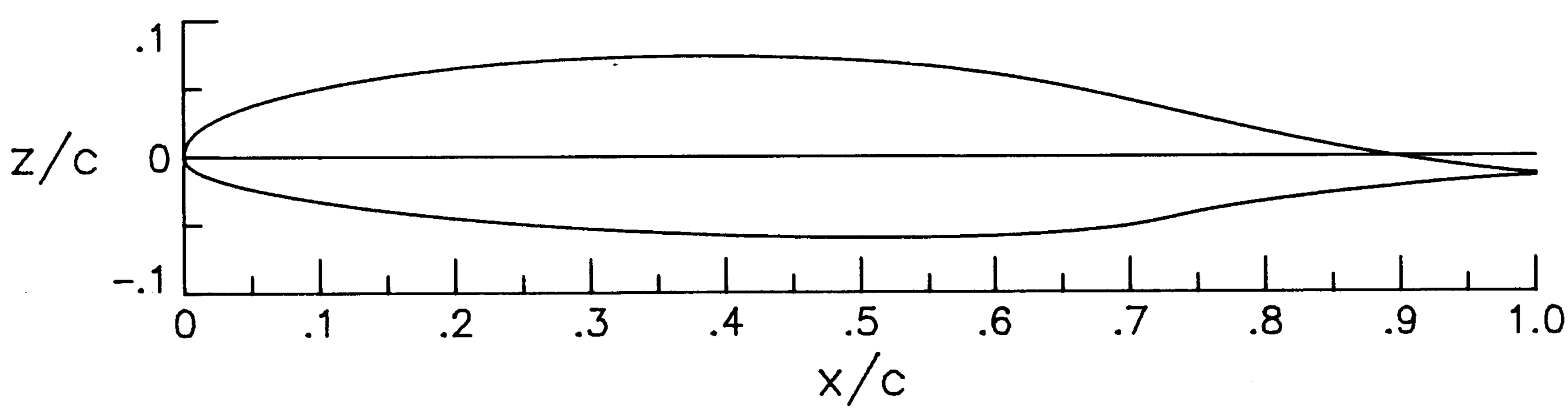


Figure 1.- Section shape HSNLF(1)-0213 airfoil.

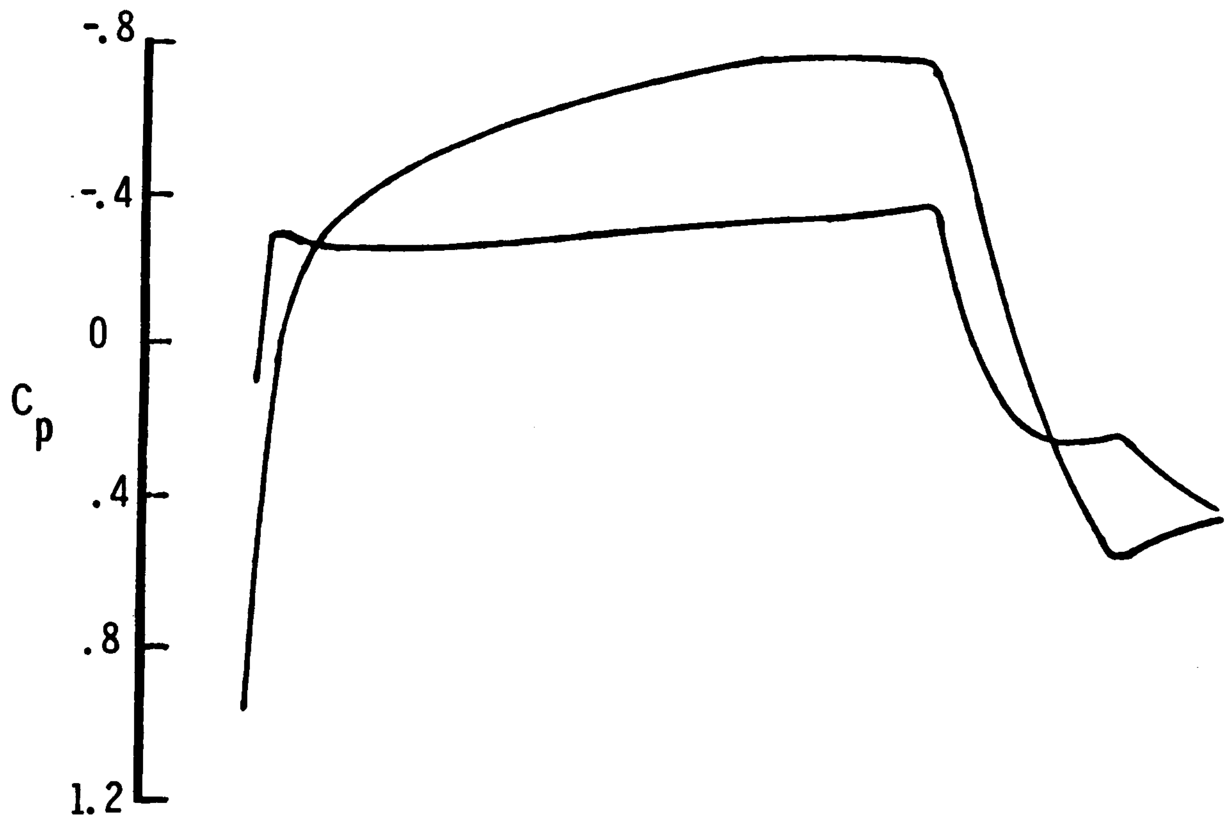


Figure 2.- Initial theoretical pressure distribution of the HSNLF(1)-0213 airfoil provided by scaling down the NLF(1)-0414F airfoil.

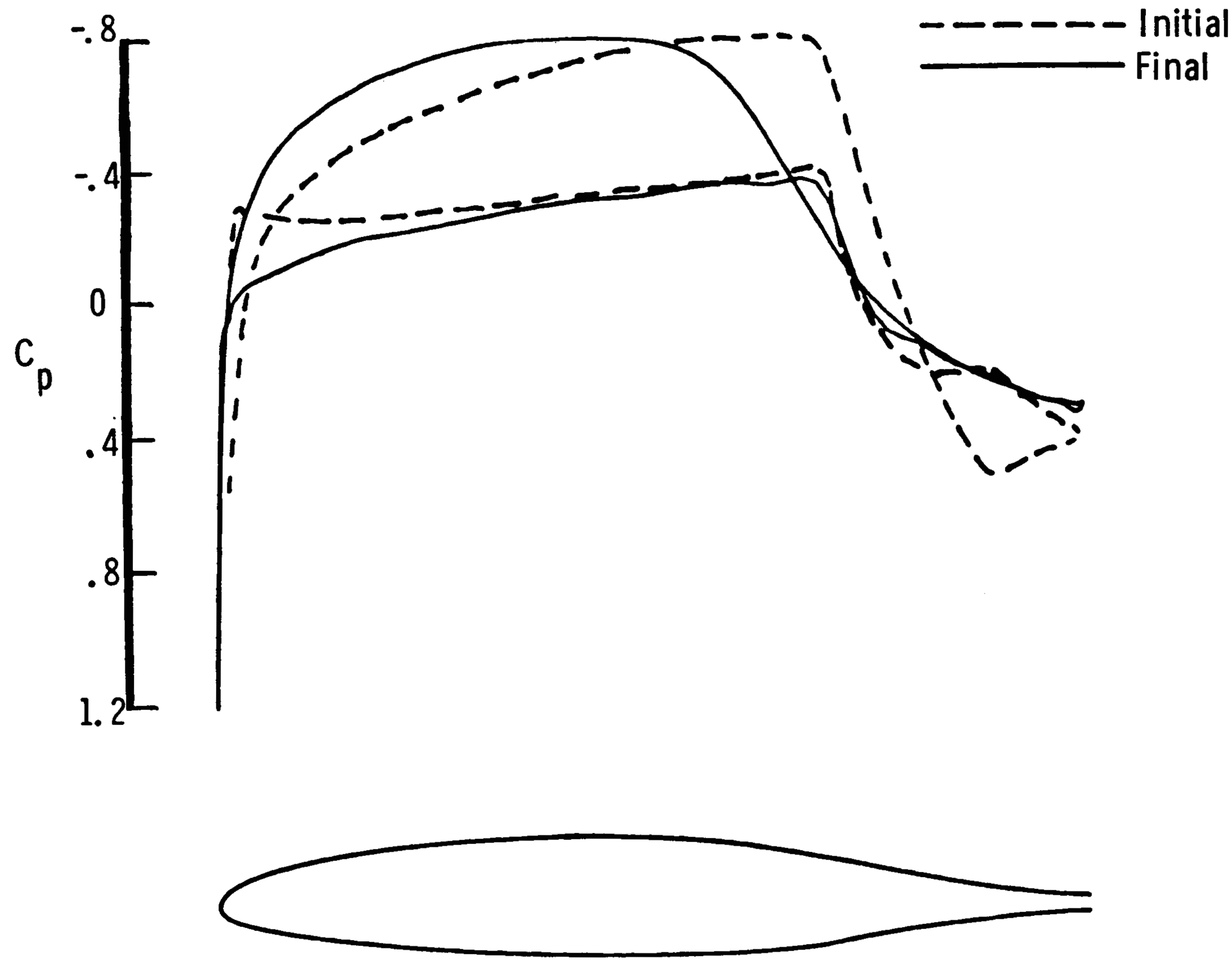
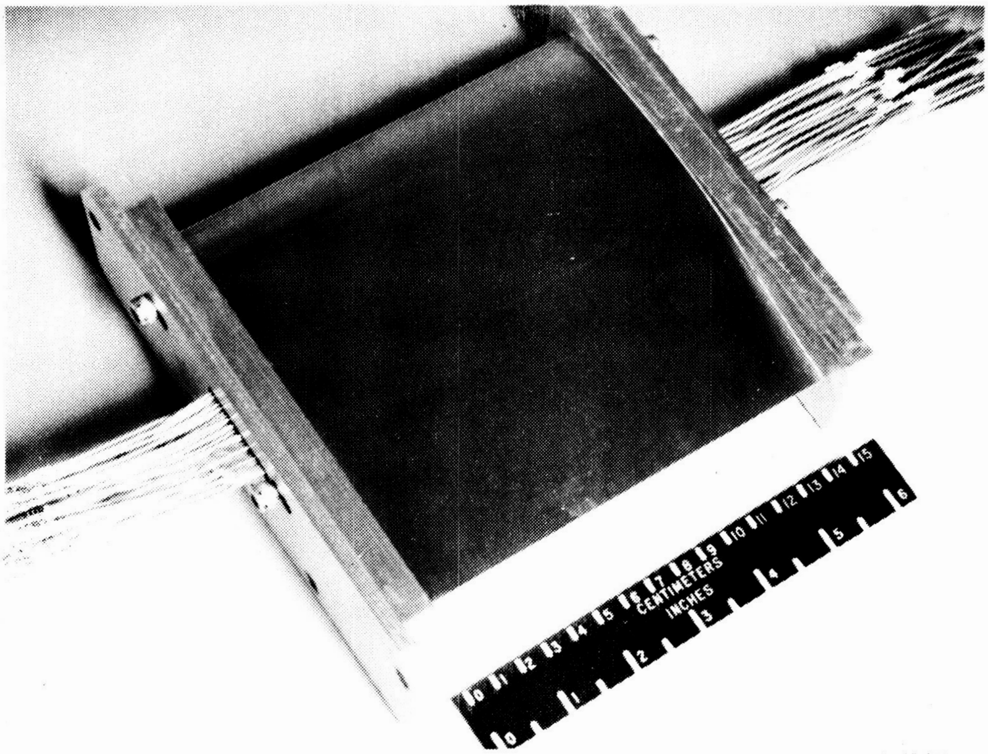
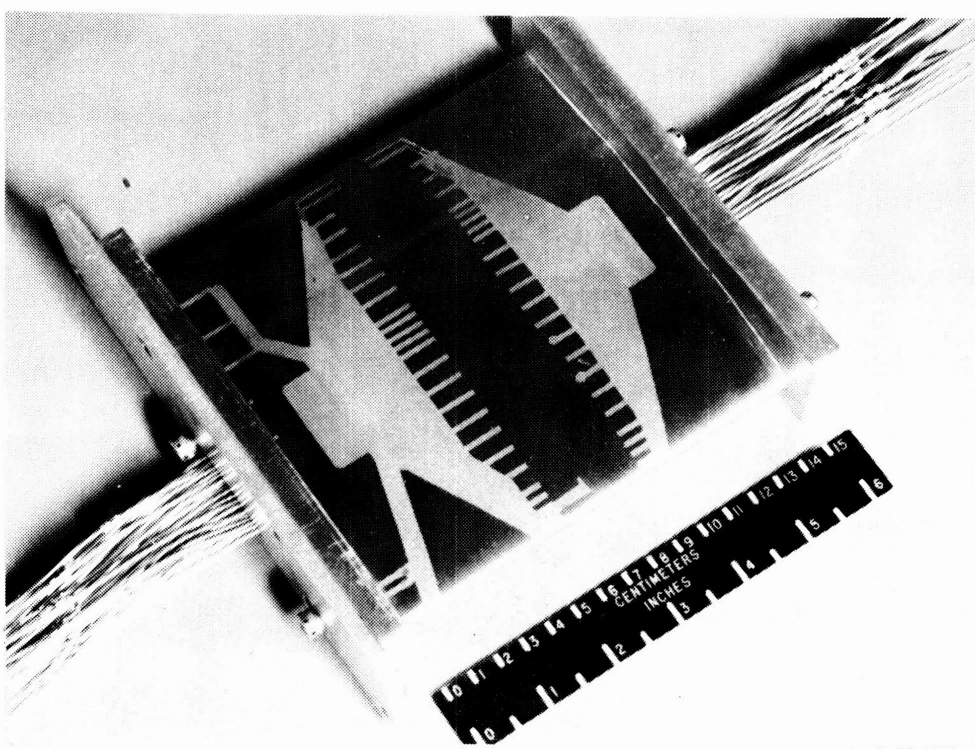


Figure 3.- Final design of the HSNLF(1)-0213 airfoil after modification of the upper and lower surfaces to reduce the adverse pressure gradients in the original design.

ORIGINAL PAGE IS
OF POOR QUALITY



(a) Upper surface.



L-85-2184

(b) Lower surface, showing routing of tubes.

Figure 4.- Photograph of HSNLF(1)-0213 airfoil model tested in the 6- by 28-Inch Transonic Tunnel.

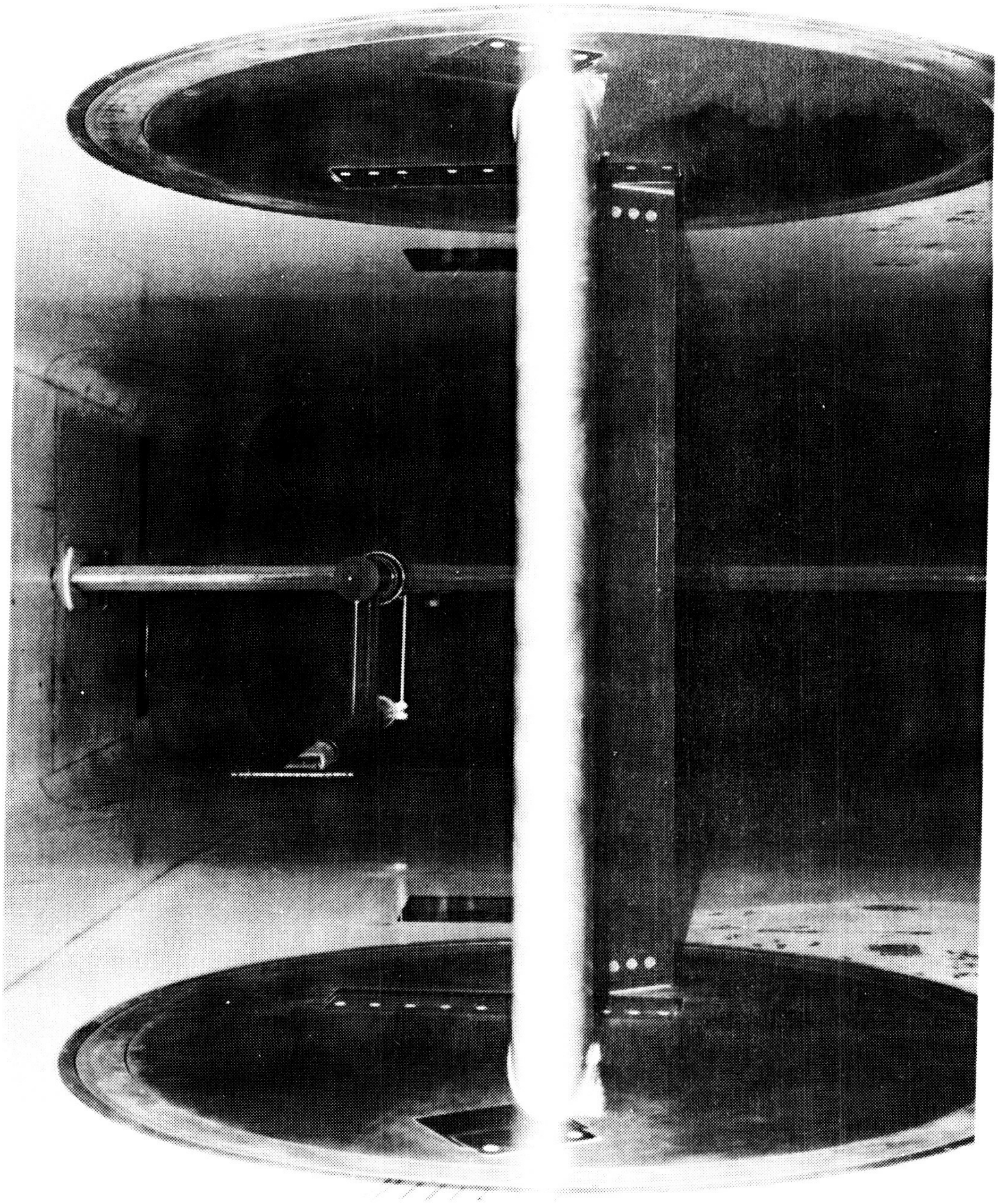


Figure 5.- Photograph of HSNLF(1)-0213 airfoil model tested in the Low-Turbulence Pressure Tunnel (LTPT). Model has a simulated trailing-edge split flap deflected 60 degrees.

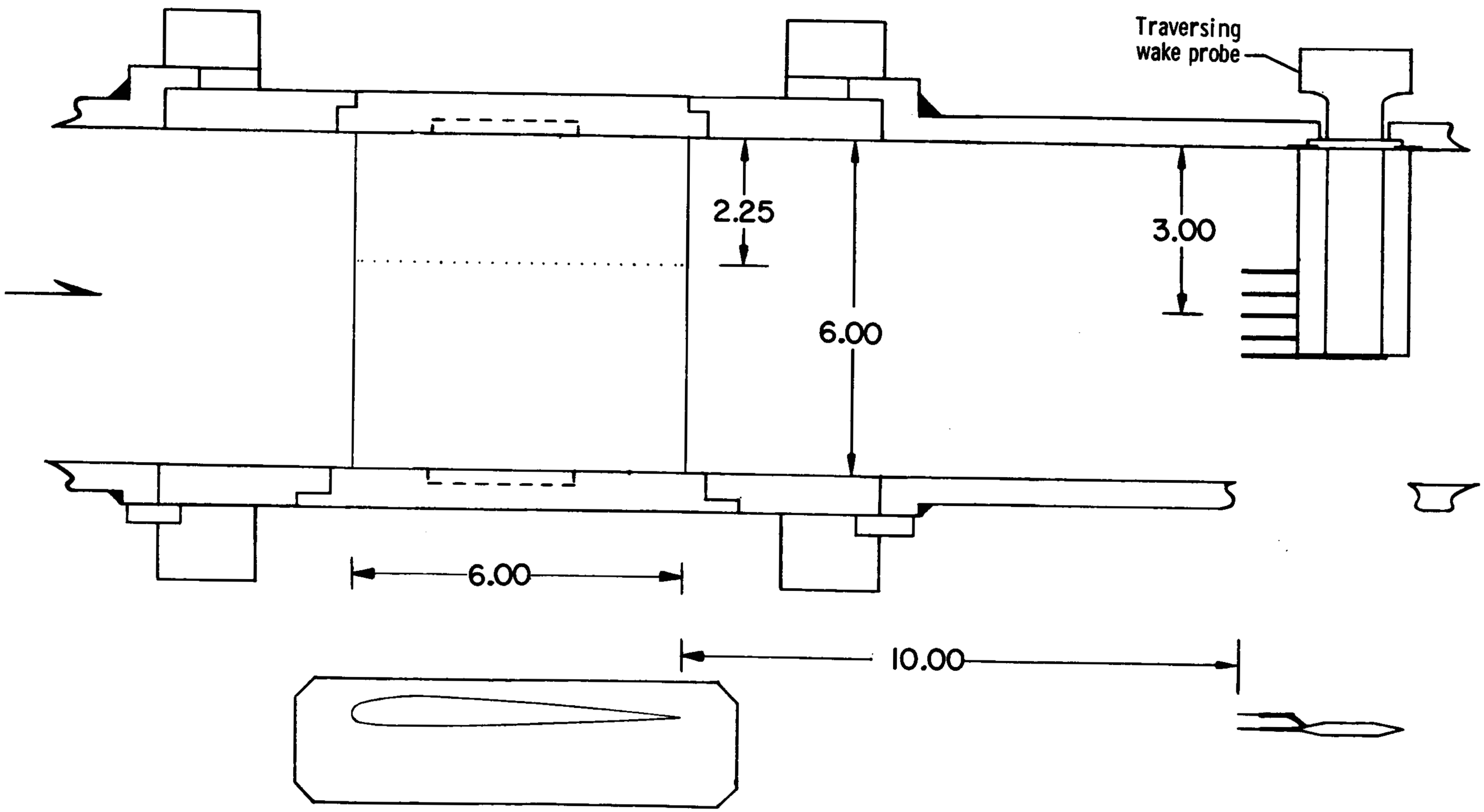


Figure 6.- Model and wake-survey probe installation in Langley 6- by 28-Inch Transonic Tunnel. All dimensions are in inches.

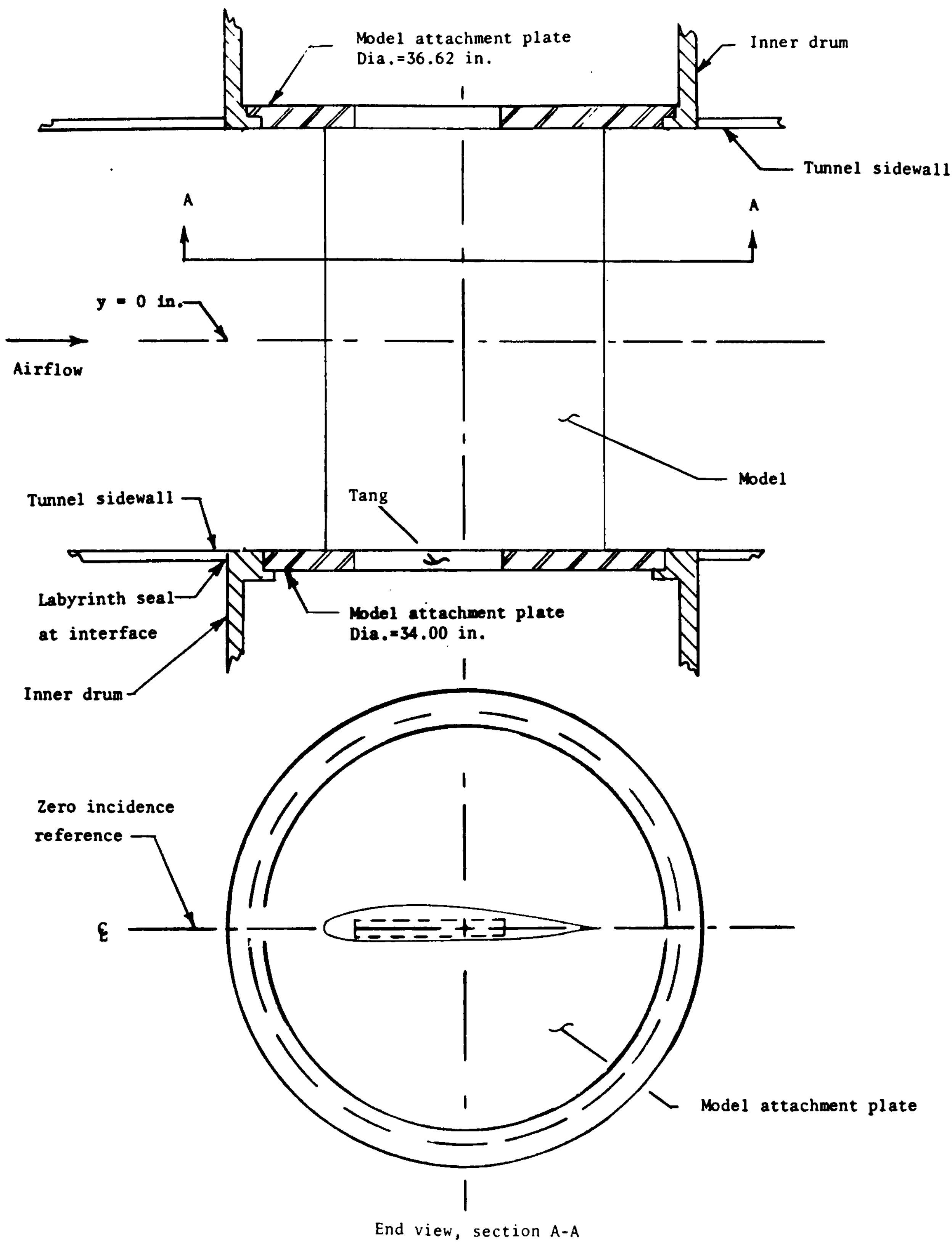


Figure 7.- Airfoil model mounted in wind tunnel.

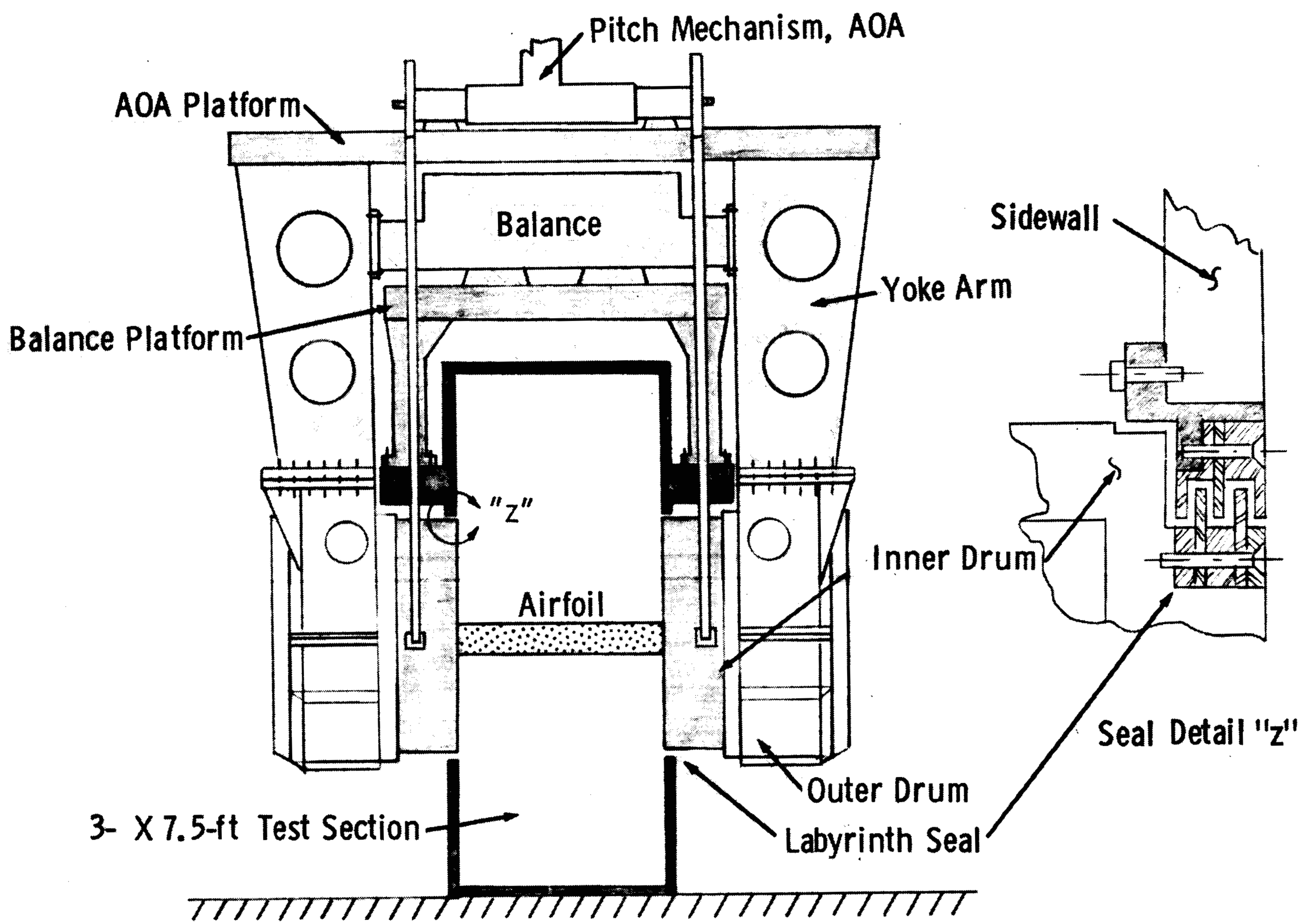


Figure 8.- Model support and force balance system for the Langley Low-Turbulence Pressure Tunnel (looking upstream).

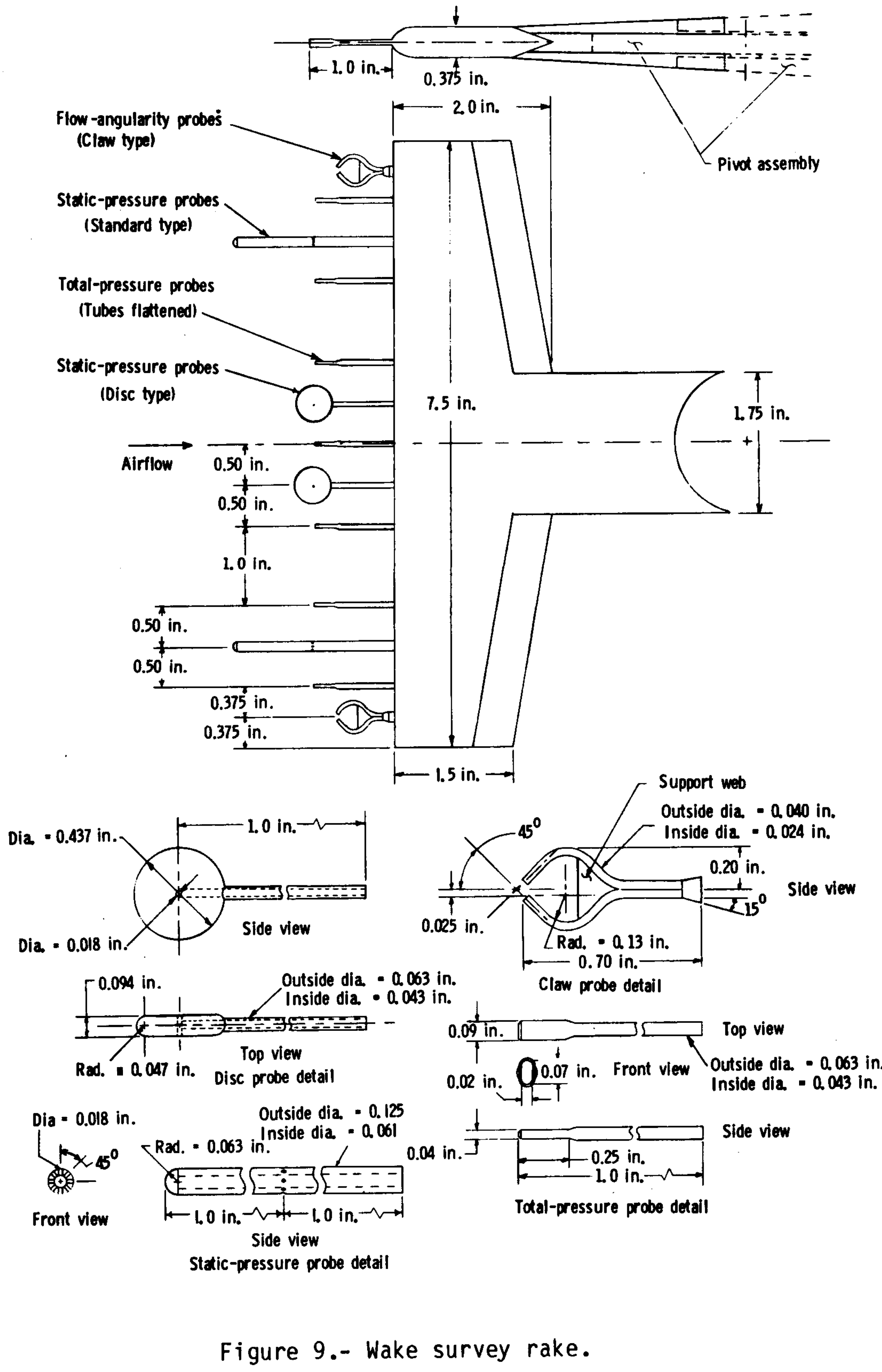


Figure 9.- Wake survey rake.

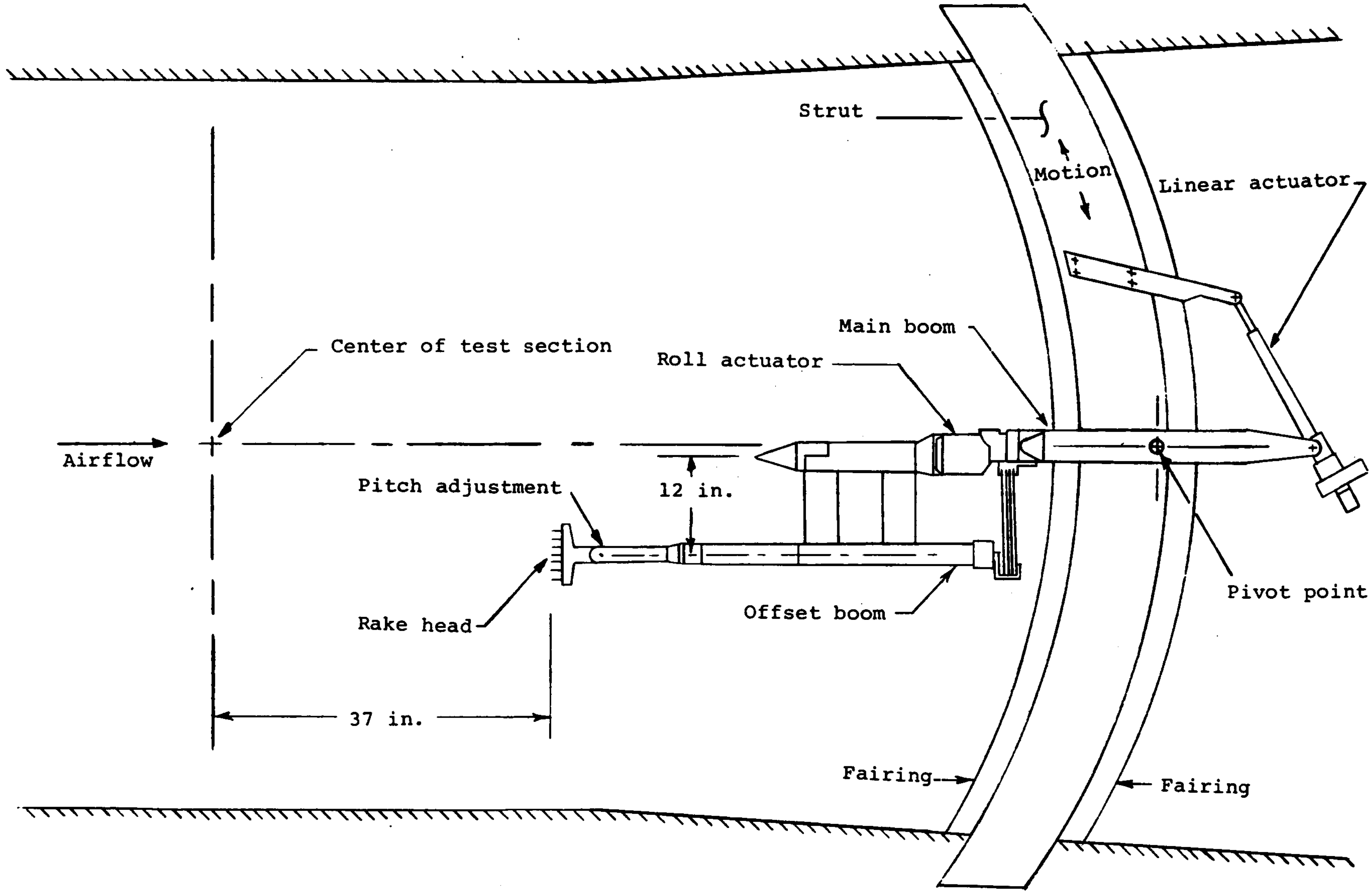
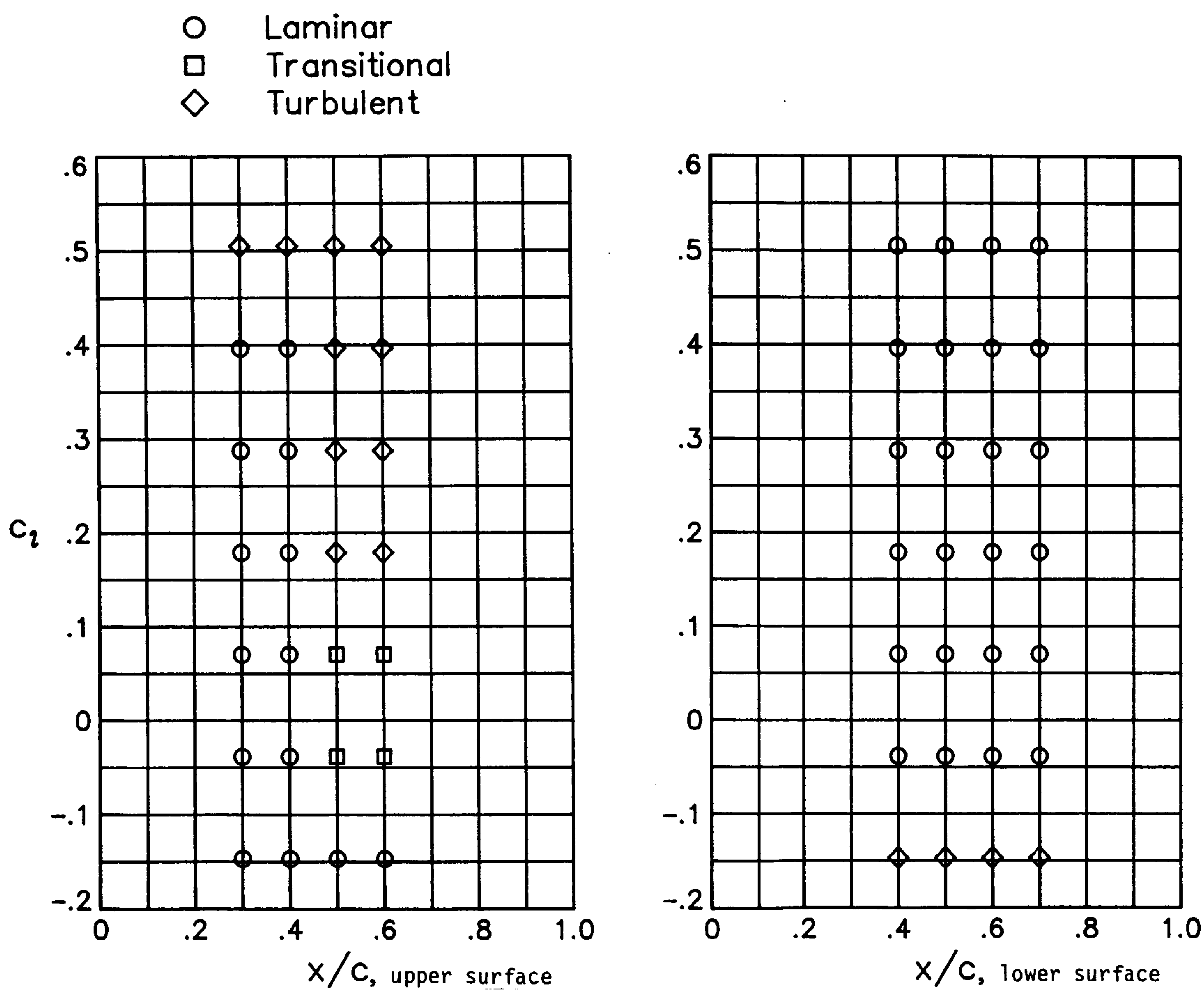
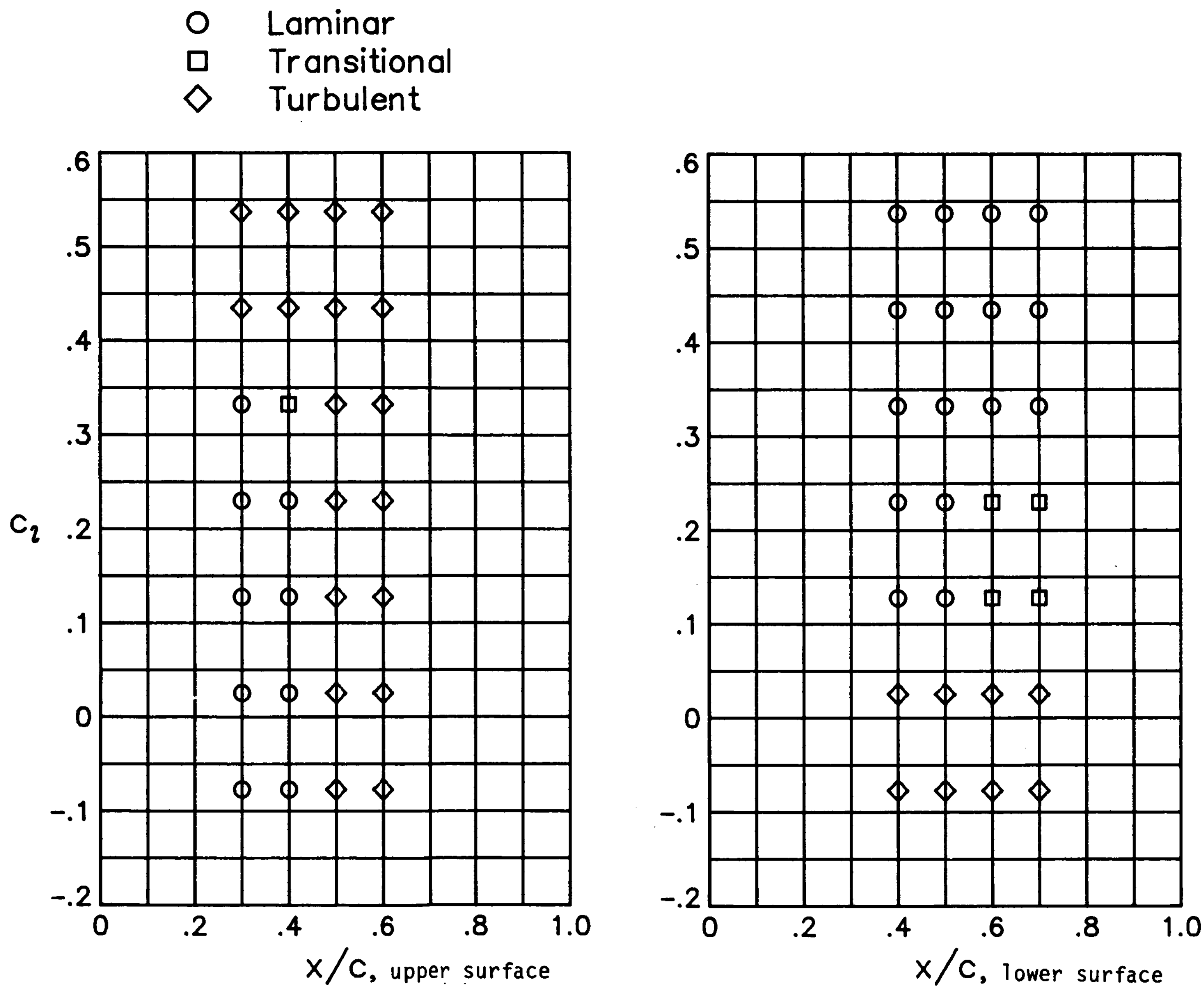


Figure 10.- Sketch of remote controlled survey apparatus for the Langley Low-Turbulence Pressure Tunnel.

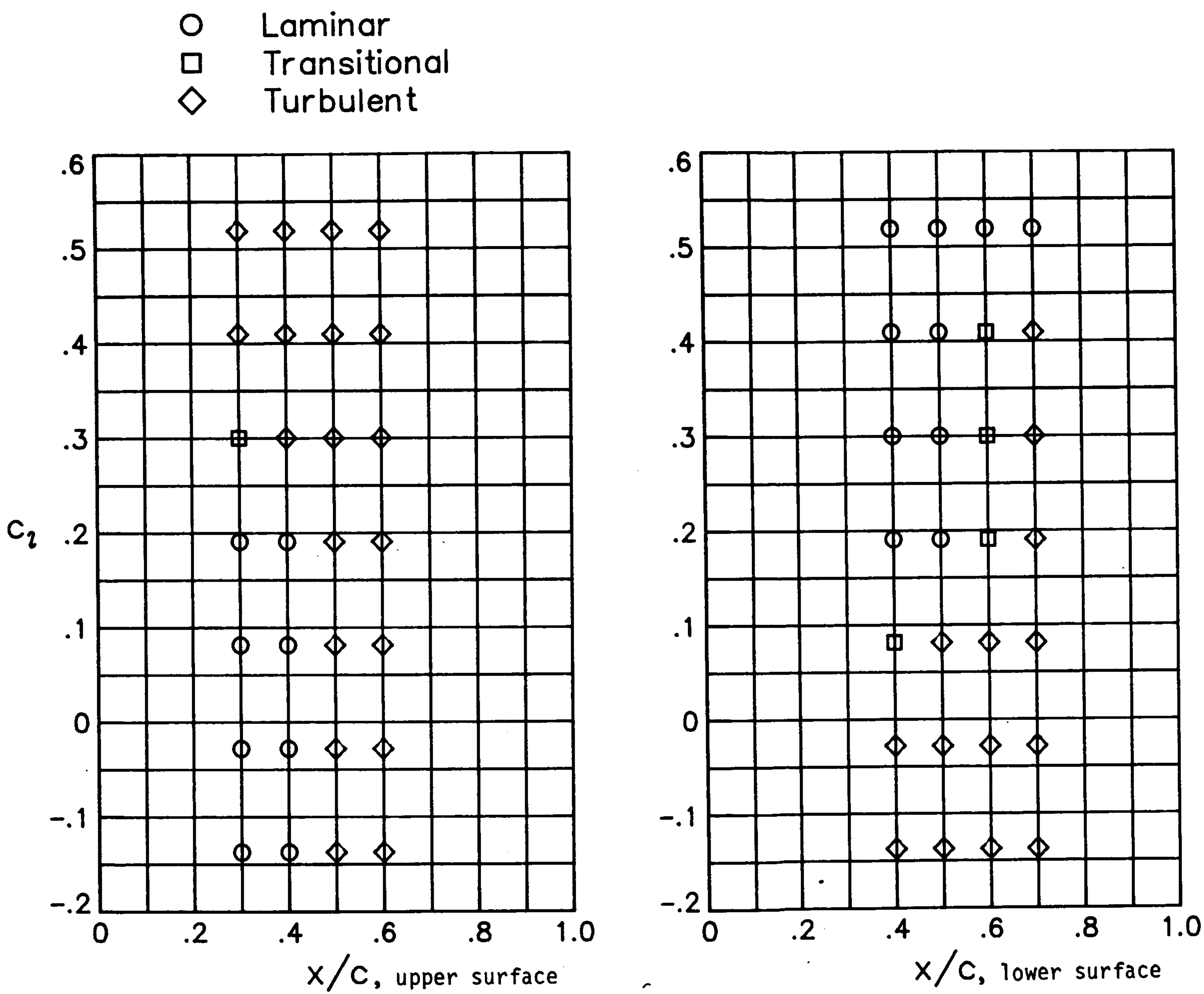


(a) $R = 3 \times 10^6$, $M = 0.047$.

Figure 11.- Results from hot-film sensors for laminar and turbulent boundarylayer assessment from test in LTPT.



(b) $R = 6 \times 10^6$, $M = 0.093$.
Figure 11.- Continued.



(c) R = 9 x 10 , M = 0.139.

Figure 11.- Concluded.

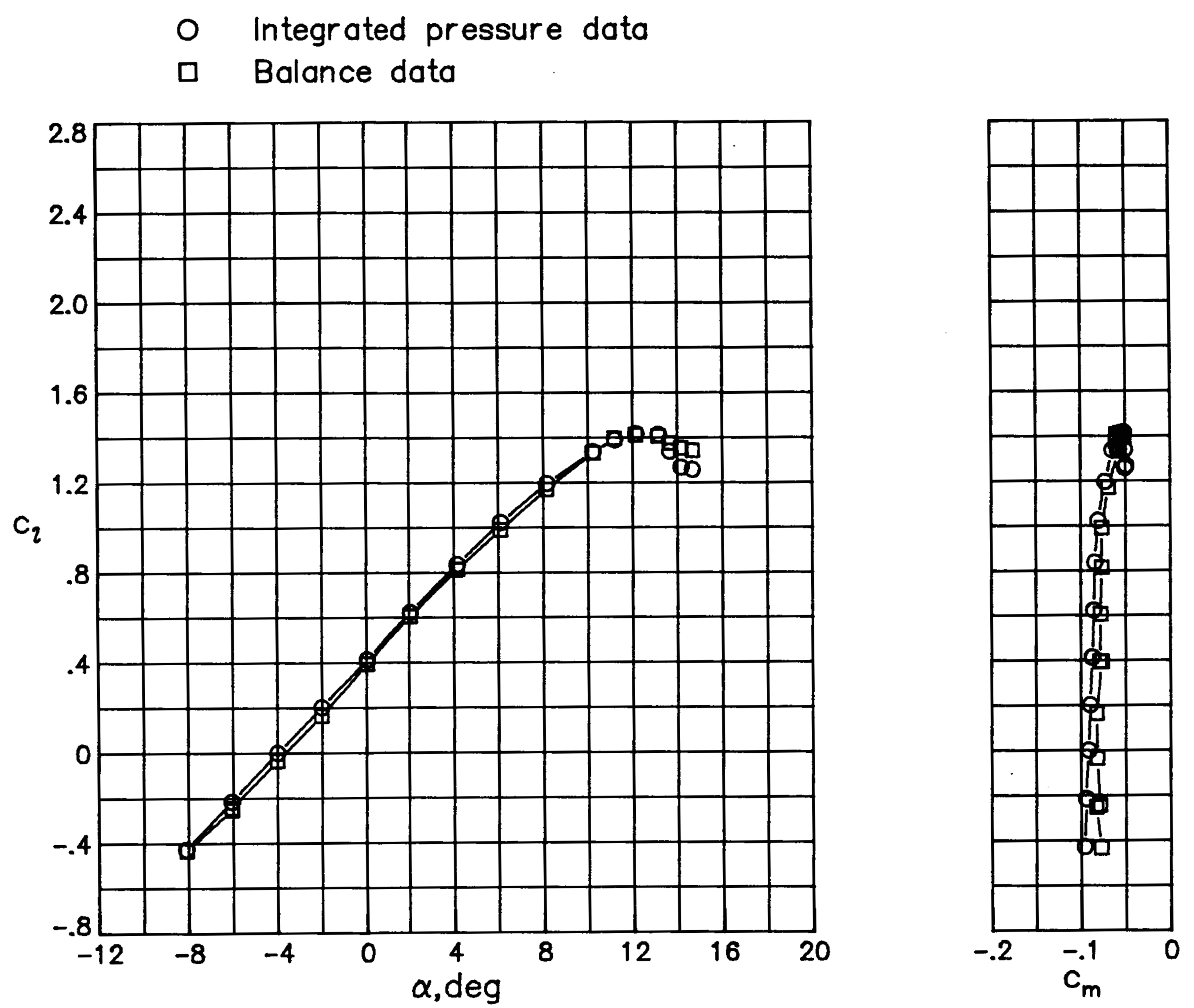
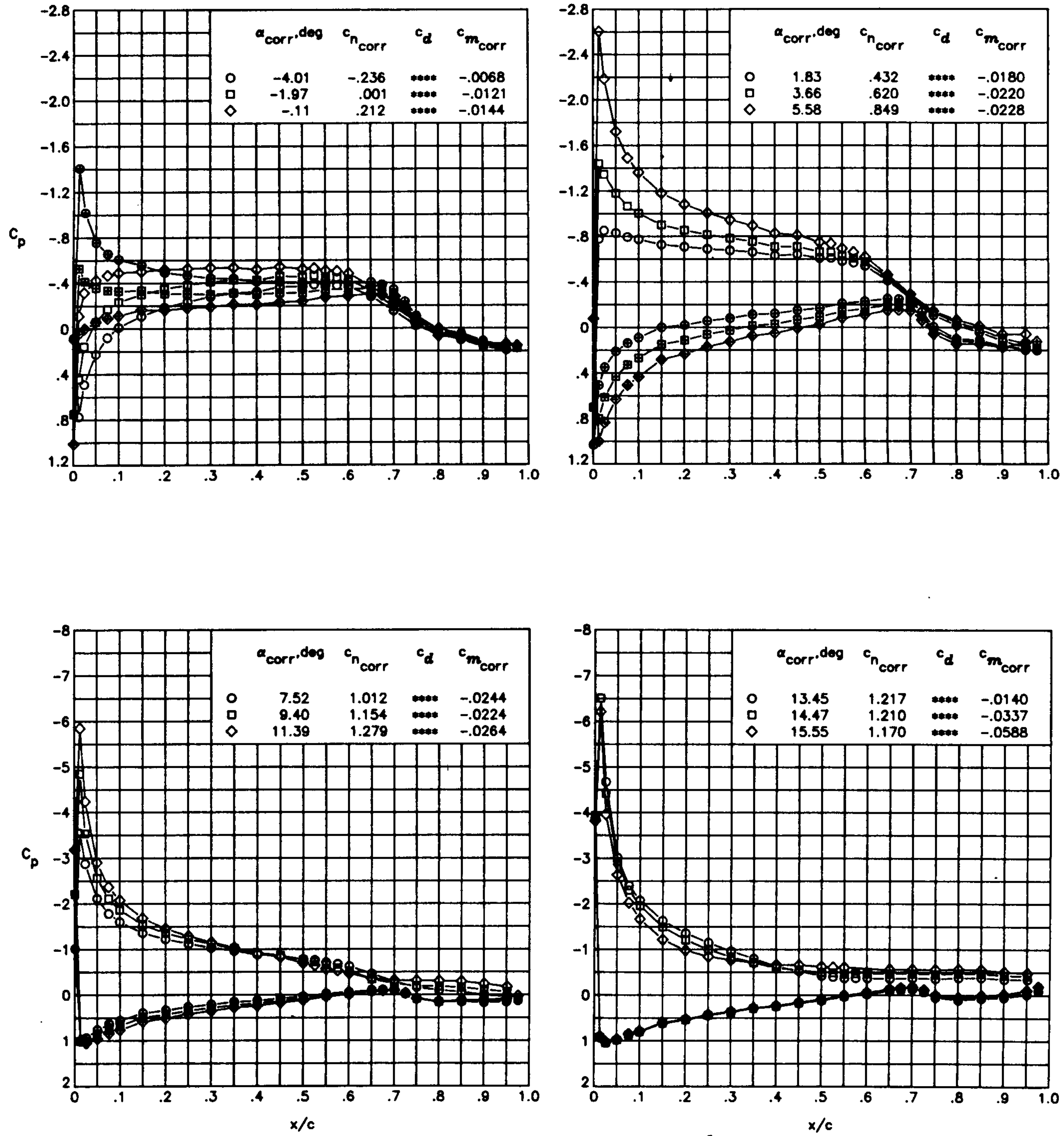
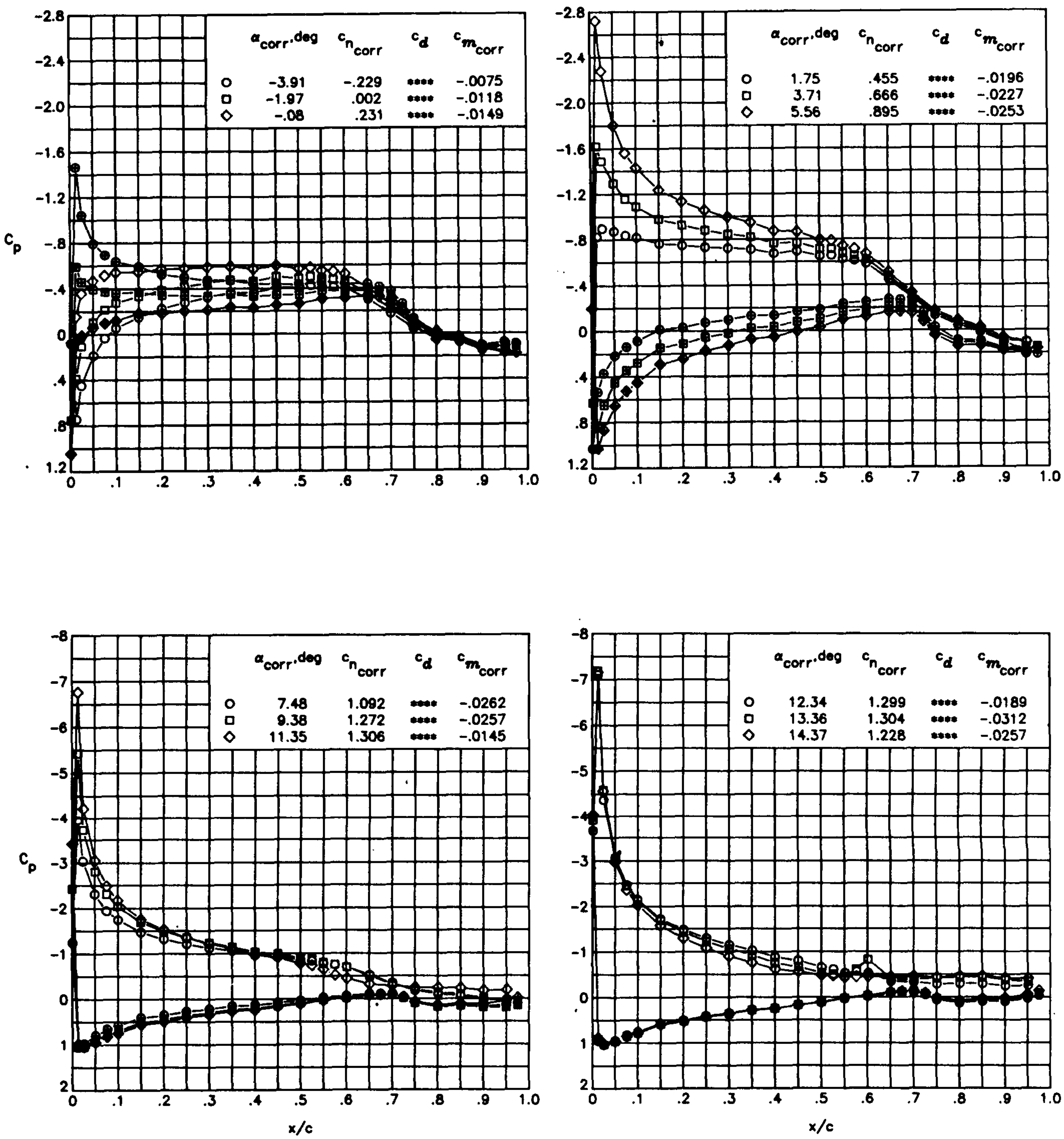


Figure 12.- Comparison of force-balance measurements to integrated pressure measurements for a NACA 4416 airfoil tested in the Low-Turbulence Pressure Tunnel.



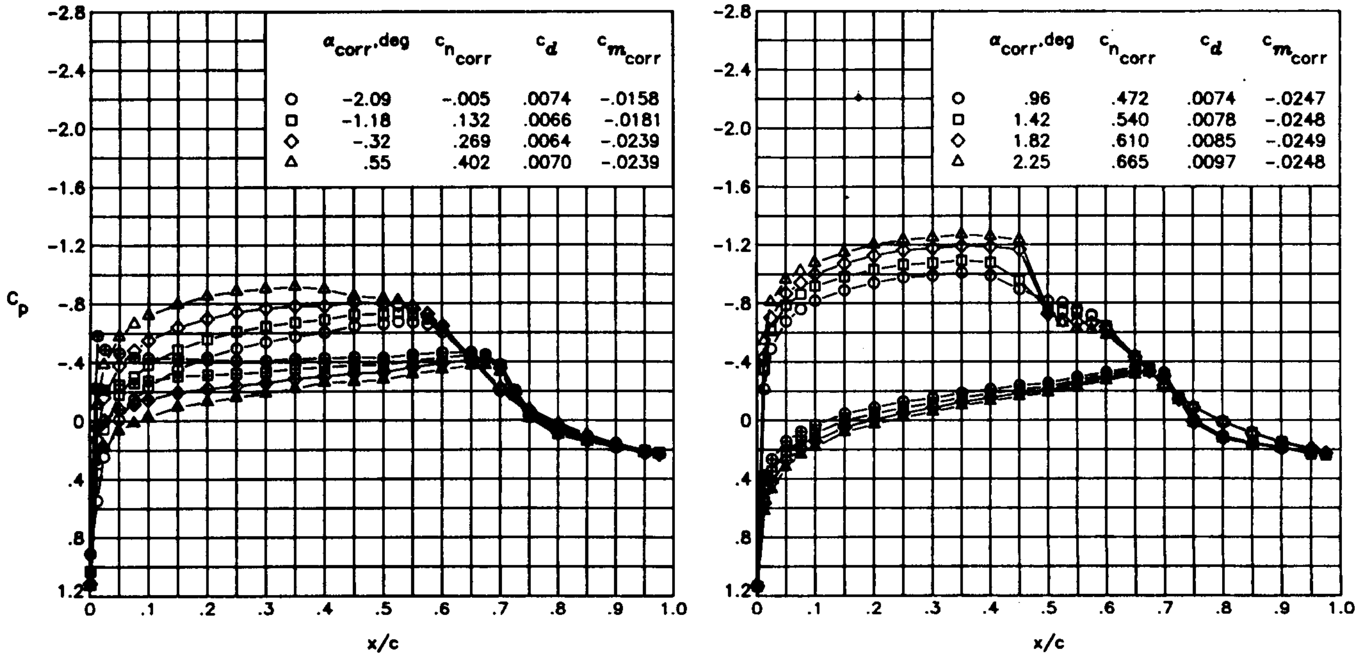
(a) $M_{corr} = 0.34$, $R = 3 \times 10^6$.

Figure 13.- Measured chordwise pressure distributions from test in 6- by 28-Inch Transonic Tunnel presented with corrected values of angle of attack, Mach number, normal force coefficient, and pitching-moment coefficient. Model smooth, $R = 3 \times 10^6$ and 5×10^6. Open symbols denote upper surface; centered symbols denote lower surface.

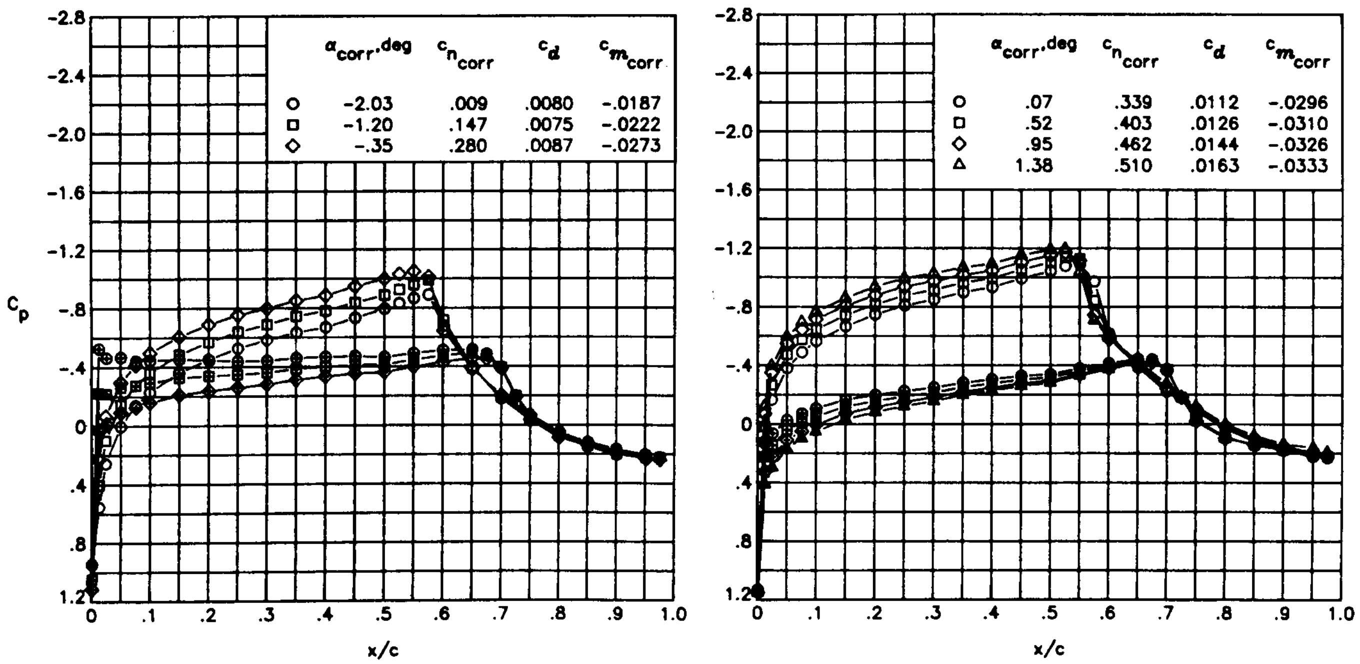


(b) $M_{corr} = 0.34$, $R = 5 \times 10^6$.

Figure 13.- Concluded.

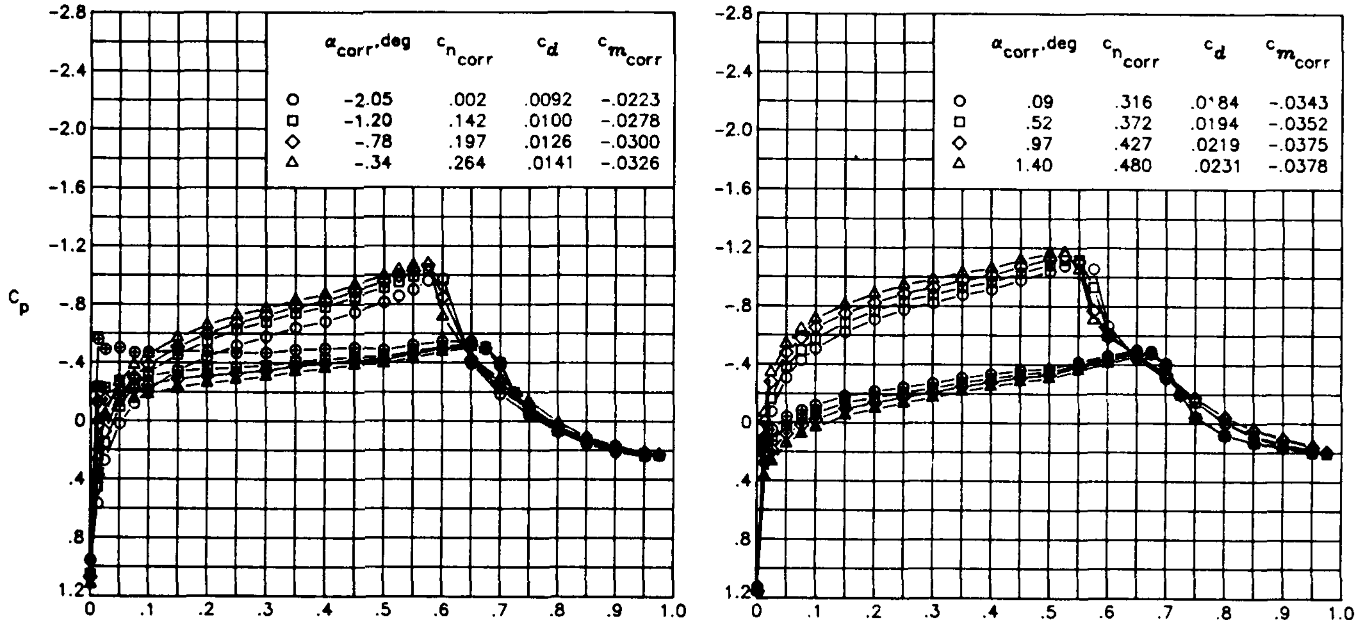


(a) M_{corr} = 0.70.

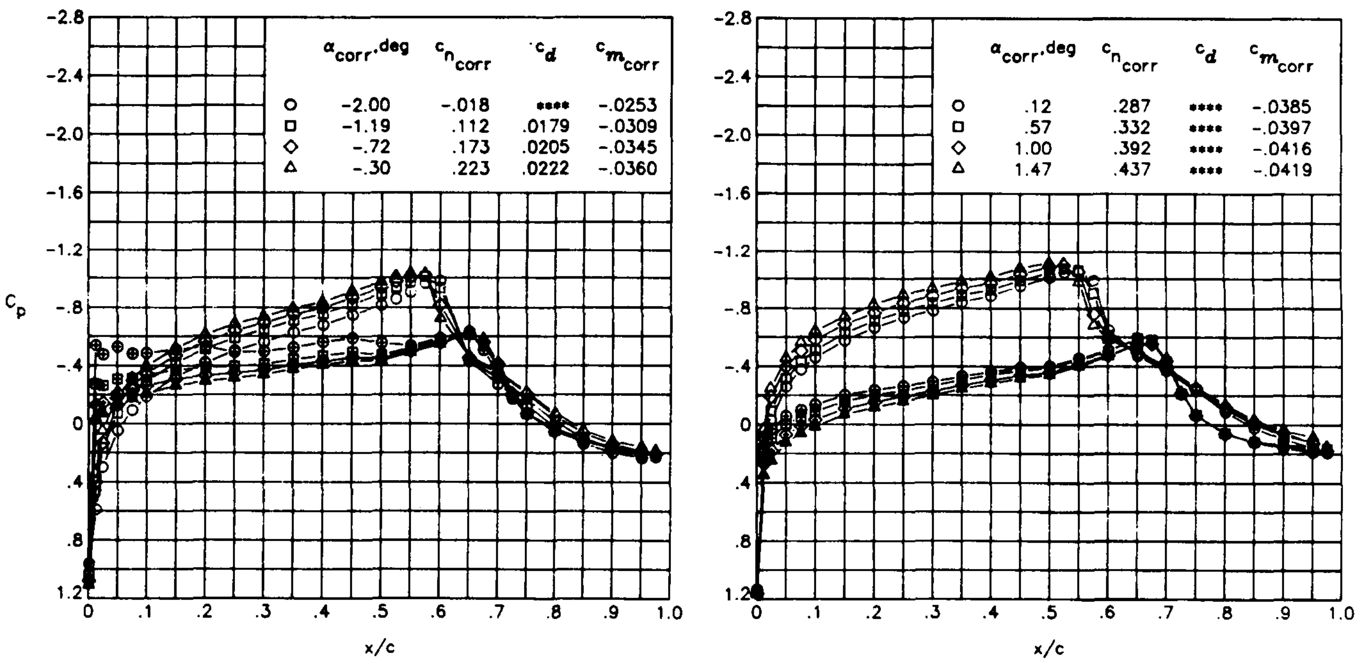


(b) M_{corr} = 0.74.

Figure 14.- Measured chordwise pressure distributions from test in 6- by 28-Inch Transonic Tunnel presented with corrected values of angle of attack, Mach number, normal force coefficient, and pitching-moment coefficient. Model smooth, R = 4 × 10^6. Open symbols denote upper surface; centered symbols denote lower surface.

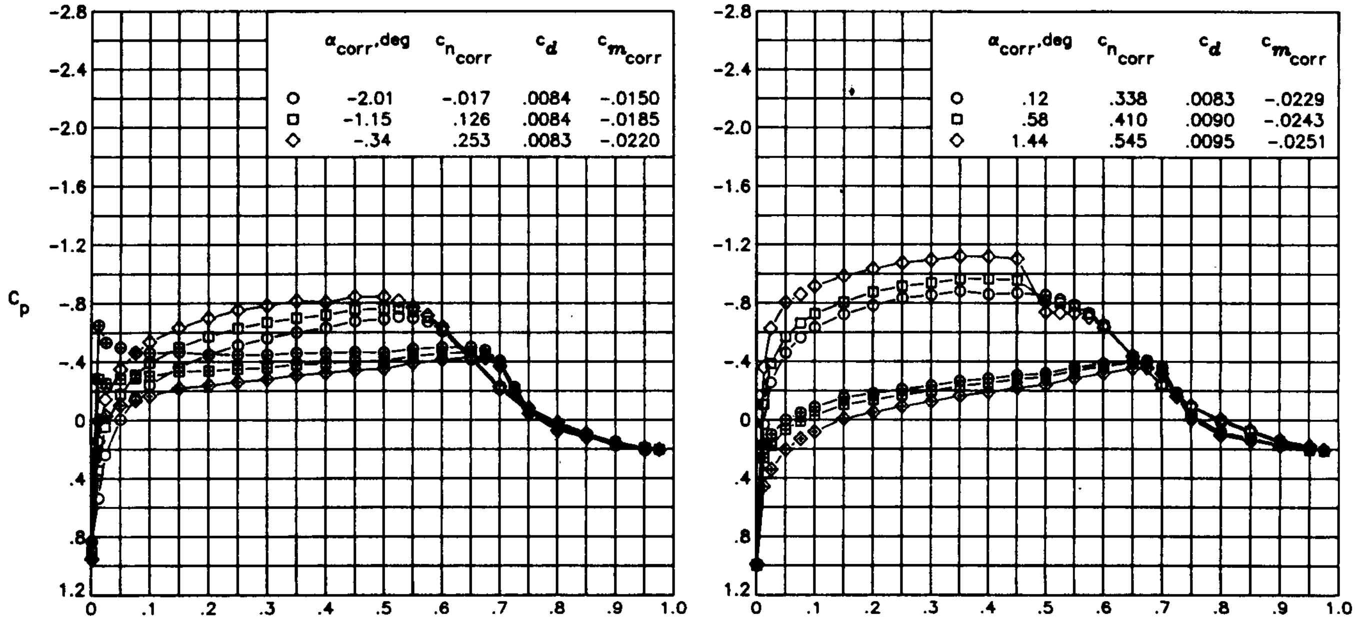


(c) M_{corr} = 0.75.

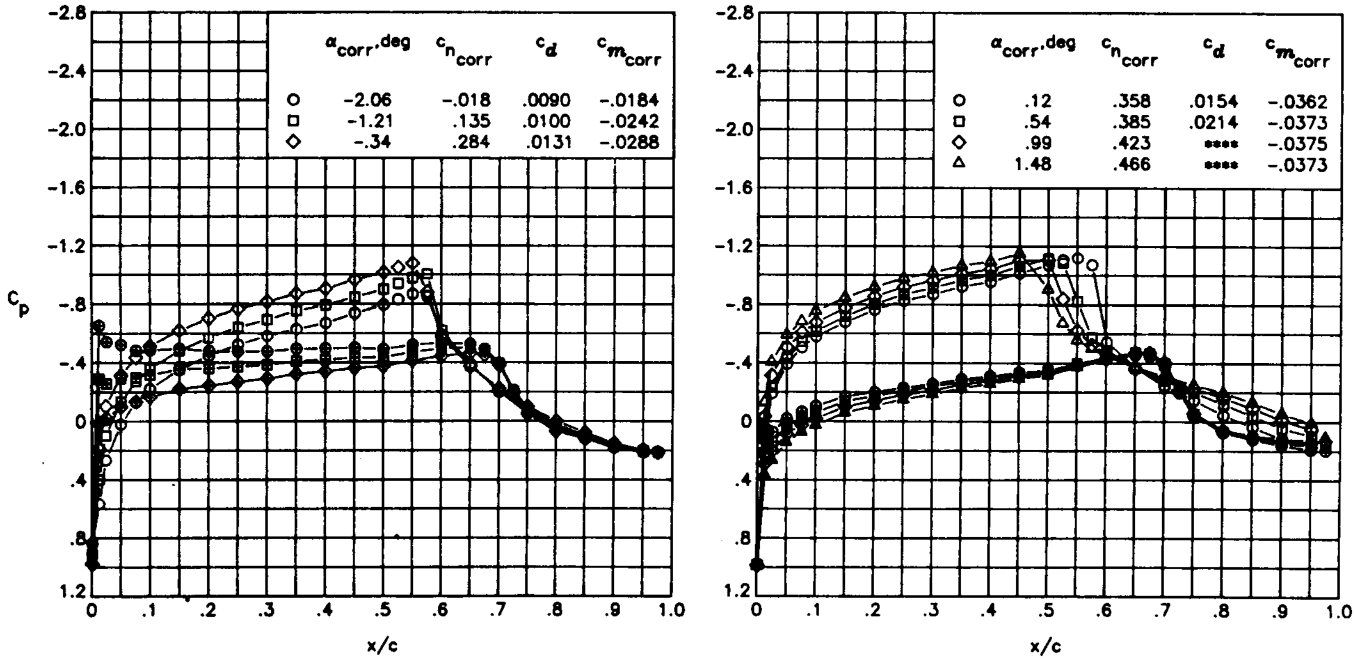


(d) M_{corr} = 0.77.

Figure 14.- Concluded.



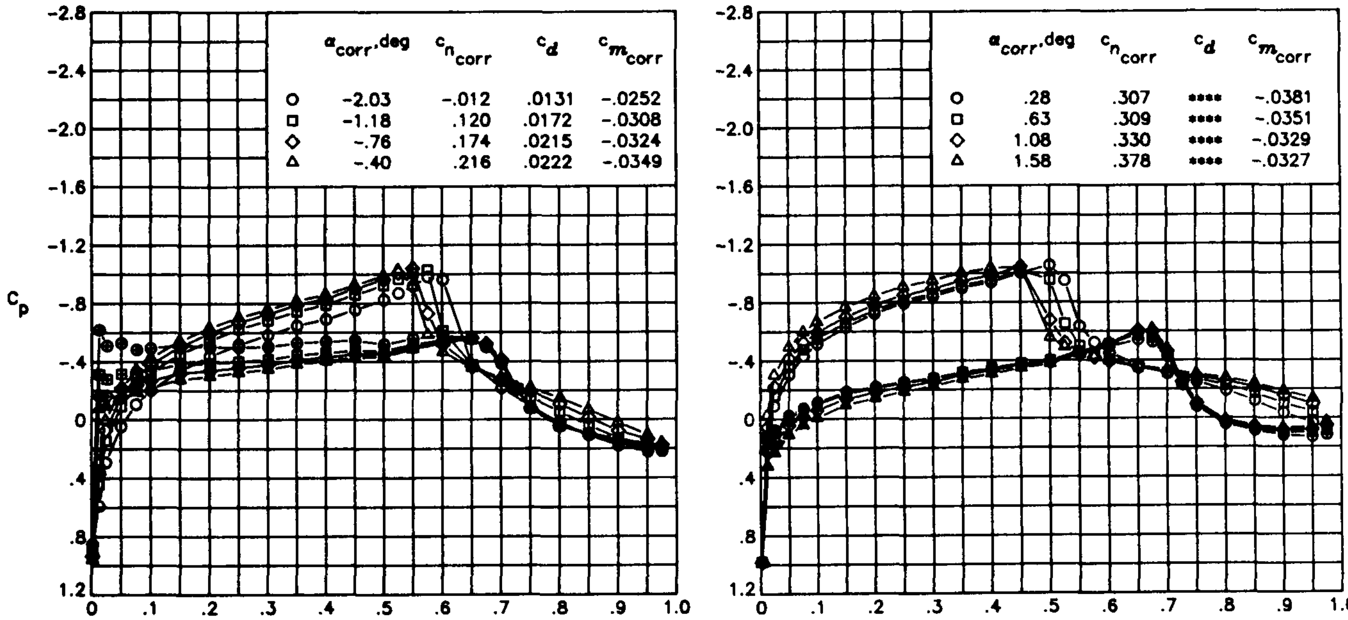
(a) M_{corr} = 0.69.



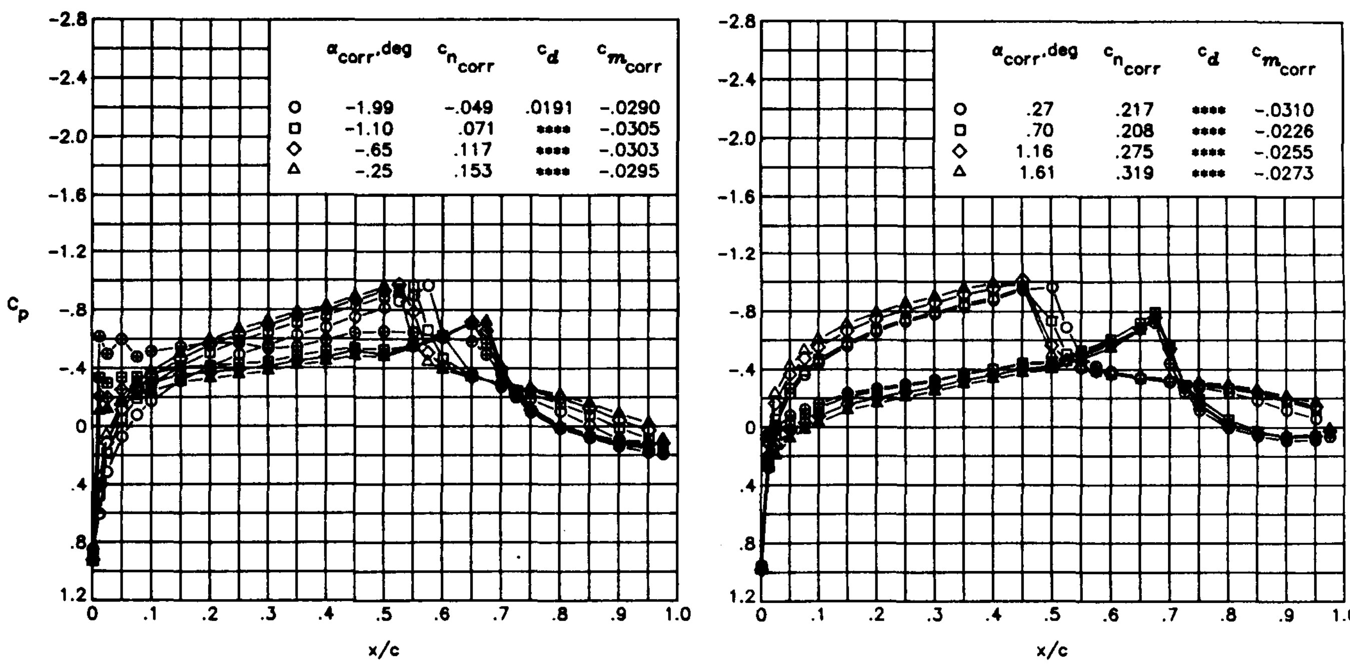
(b) M_{corr} = 0.73.

Figure 15.- Measured chordwise pressure distributions from test in 6- by 28-Inch Transonic Tunnel presented with corrected values of angle of attack, Mach number, normal force coefficient, and pitching-moment coefficient. Model has fixed transition at 0.05c, $R = 11 \times 10^6$. Open symbols denote upper surface; centered symbols denote lower surface.

ORIGINAL PAGE IS
OF POOR QUALITY



(c) M_{corr} = 0.75.



(d) M_{corr} = 0.77.

Figure 15.- Concluded.

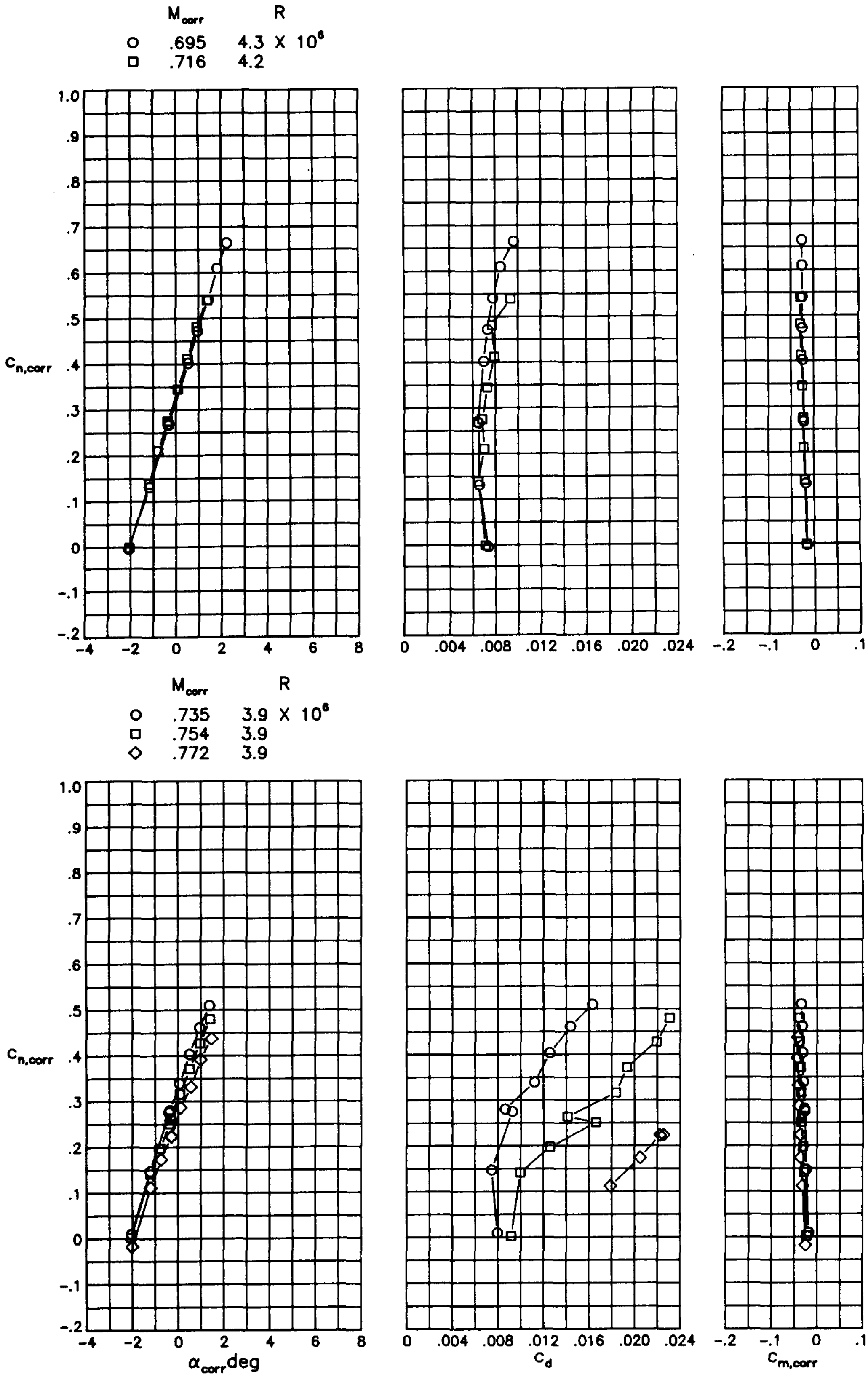


Figure 16.- Effect of Mach number on section characteristics from test in 6- by 28-Inch Transonic Tunnel. Model smooth, $R = 4 \times 10^6$.

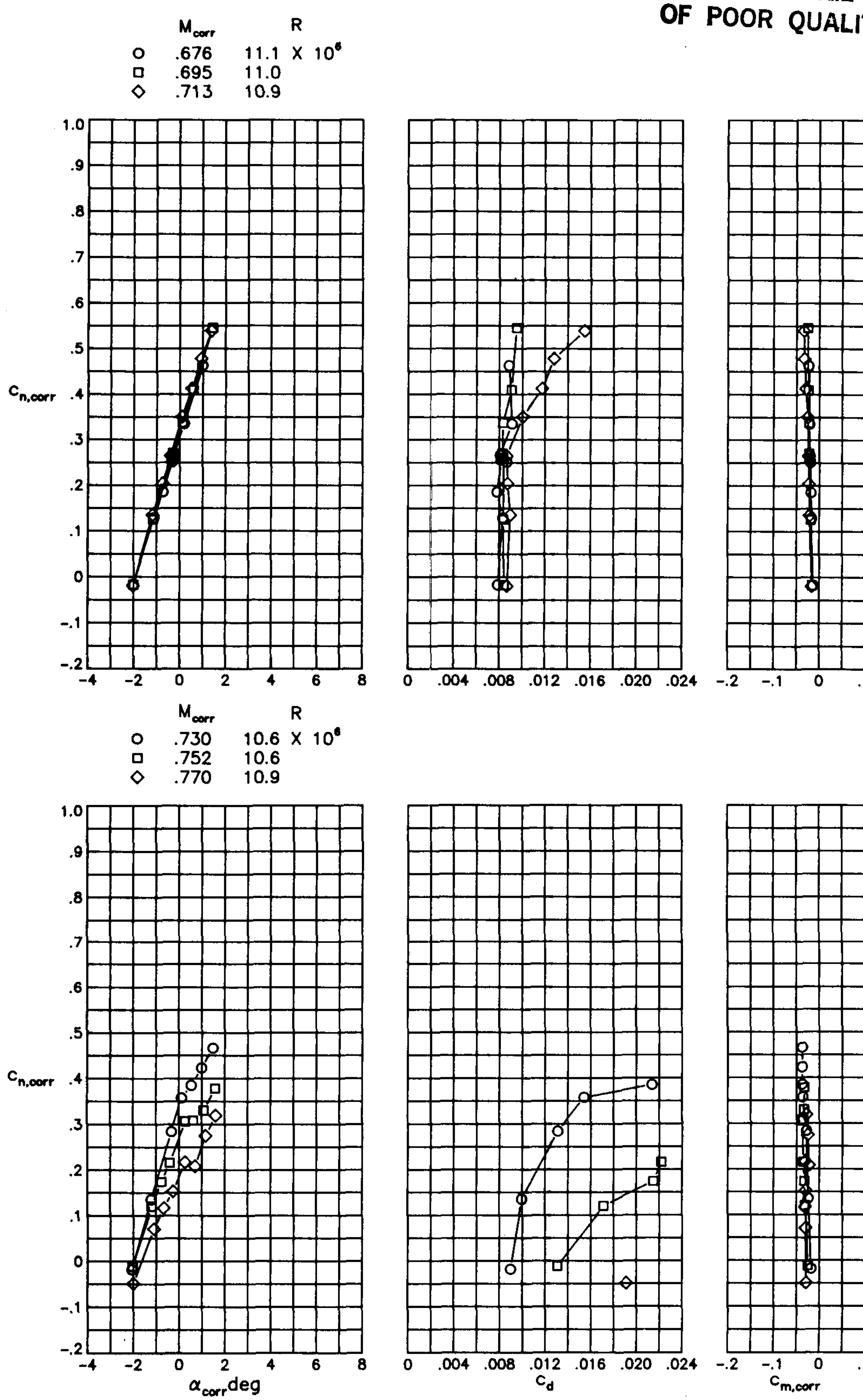


Figure 17.- Effect of Mach number on section characteristics from test in 6- by 28-Inch Transonic Tunnel. Model has fixed transition at 0.05c, R = 11 × 10^6.

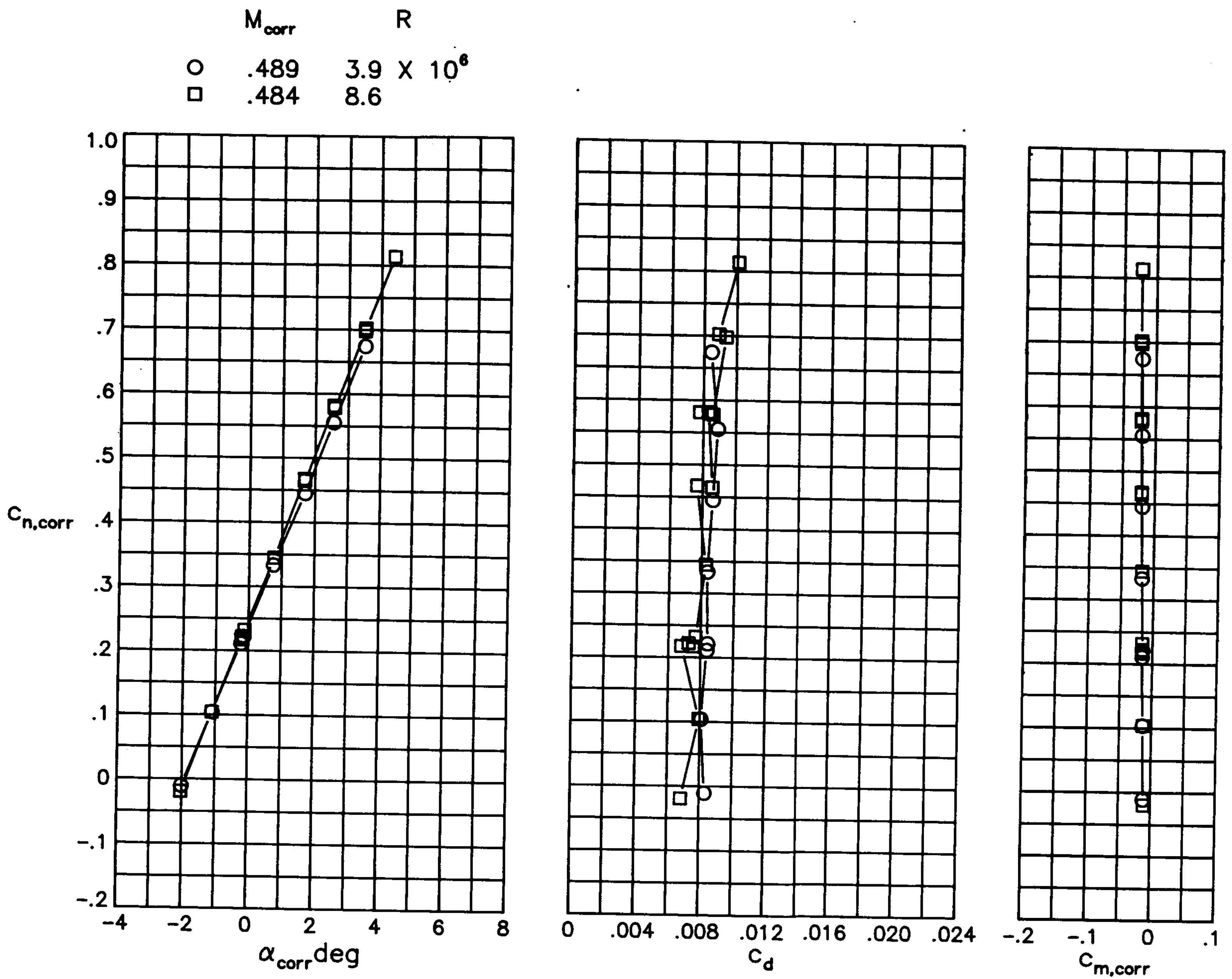
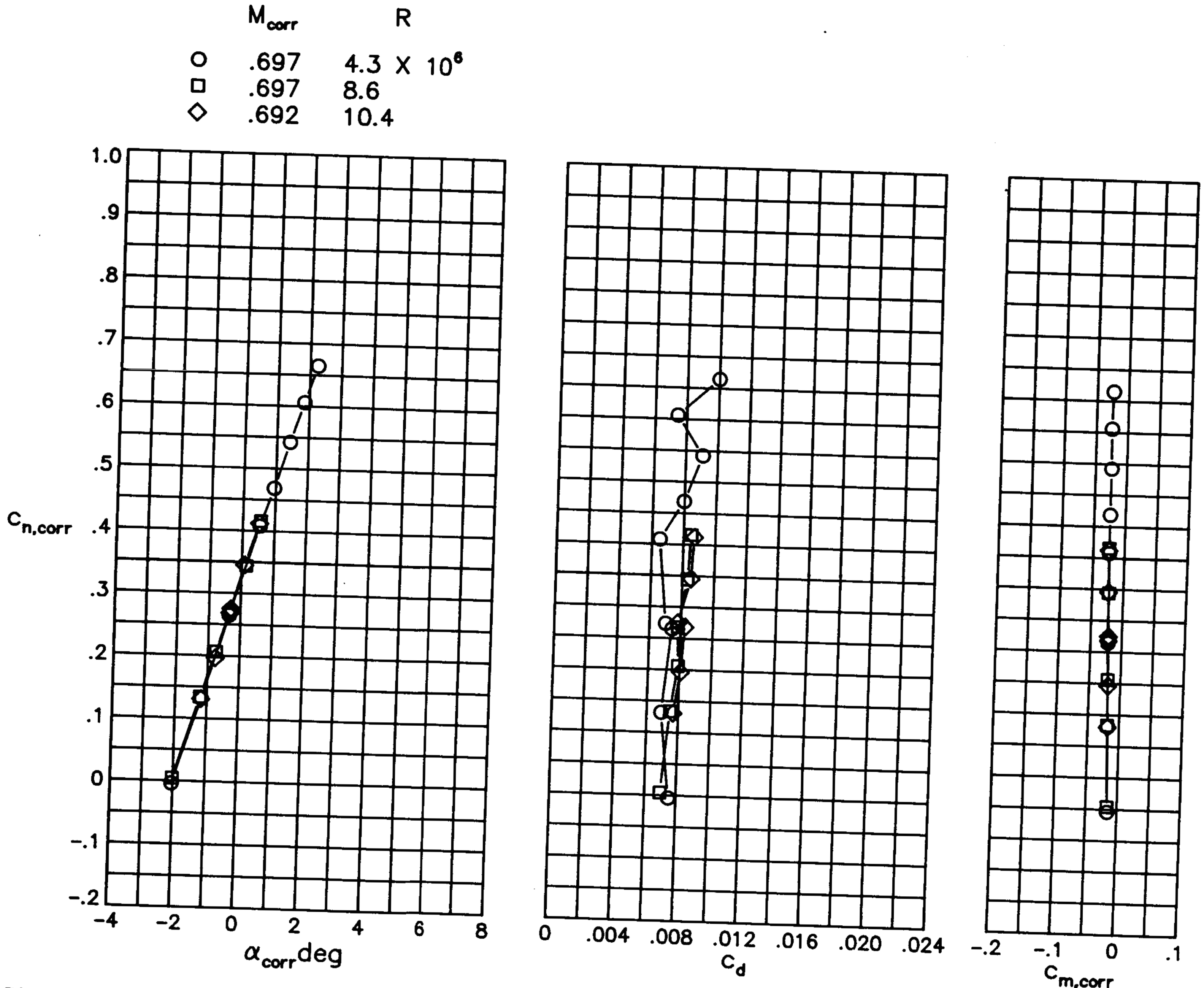


Figure 18.- Effect of Reynolds number on section characteristics from test in 6- by 28-Inch Transonic Tunnel. Model has fixed transition at 0.05c.



ORIGINAL PAGE IS
OF POOR QUALITY

Figure 19.- Effect of Reynolds number on section characteristics from test in 6- by 28-Inch Transonic Tunnel. Model smooth.

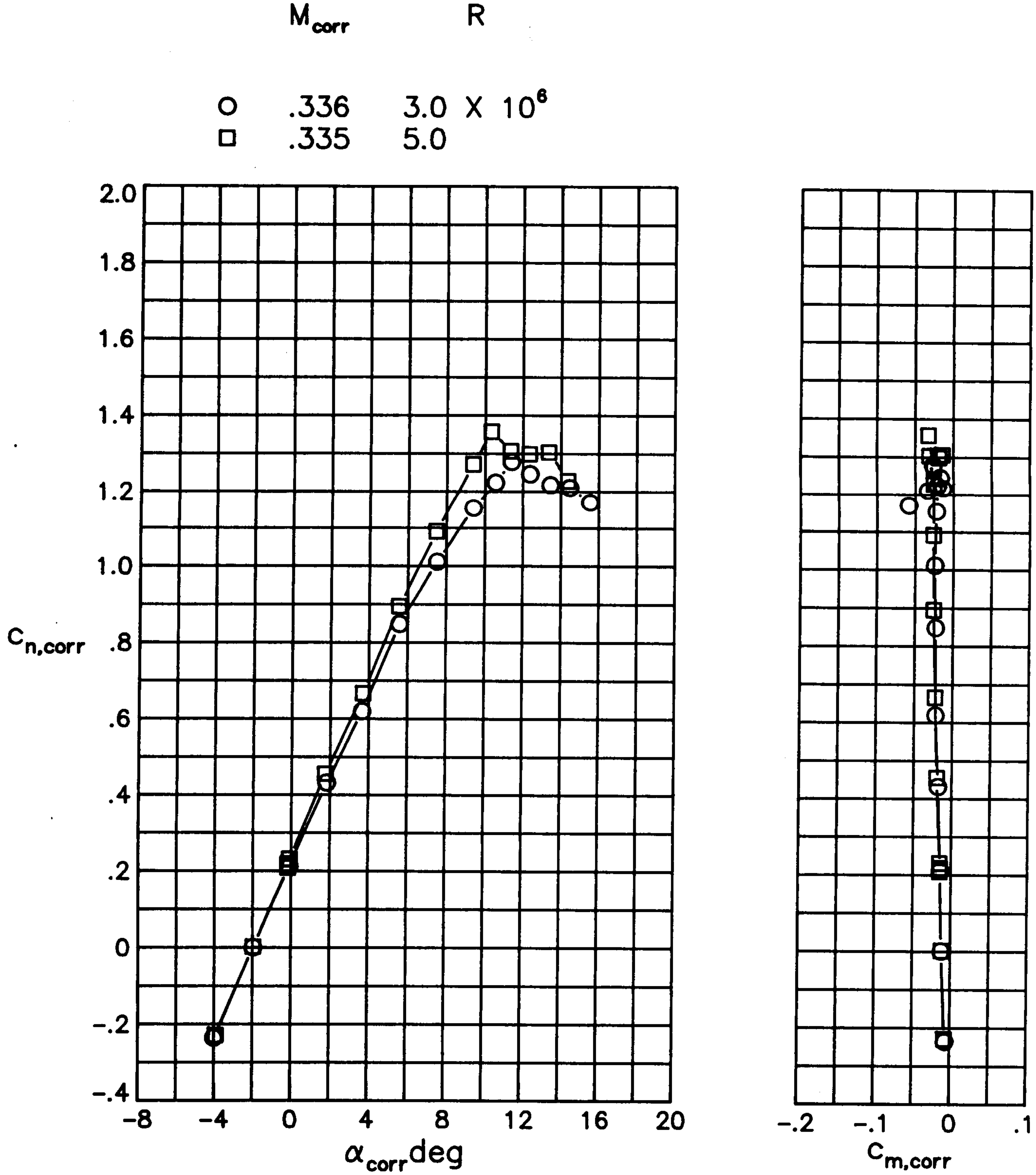


Figure 20.- Effect of Reynolds number on normal-force and pitching-moment coefficients from test in 6- by 28-Inch Transonic Tunnel. M_{corr} = 0.34, model smooth.

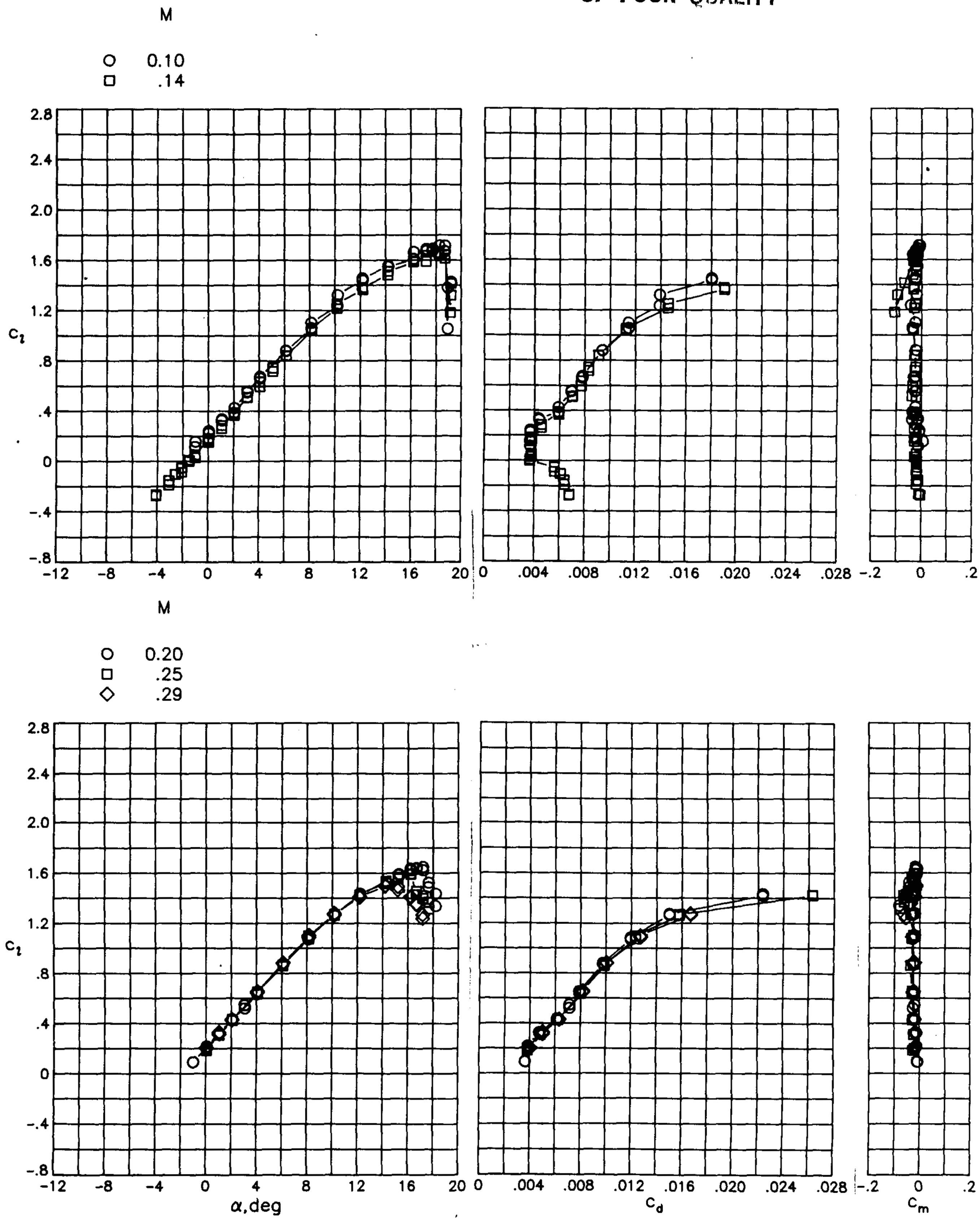
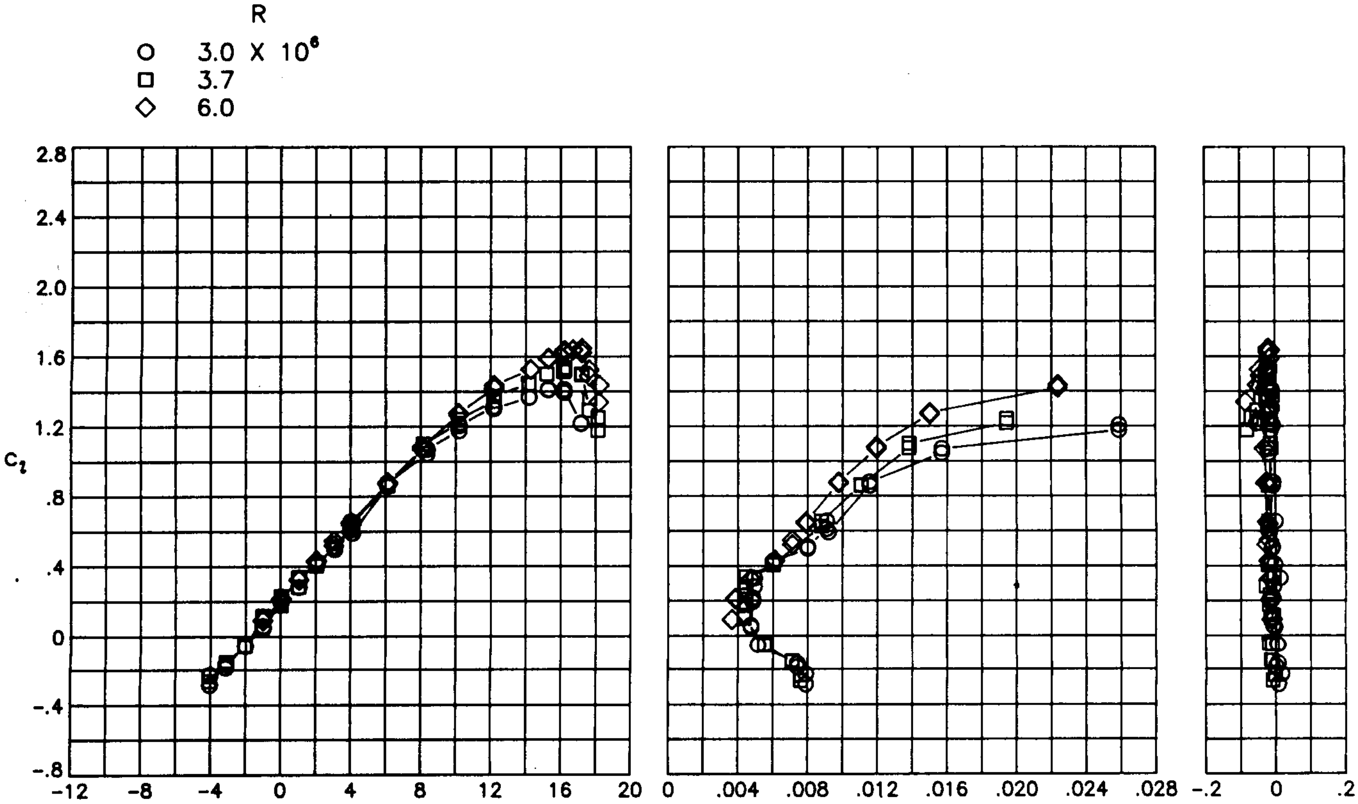
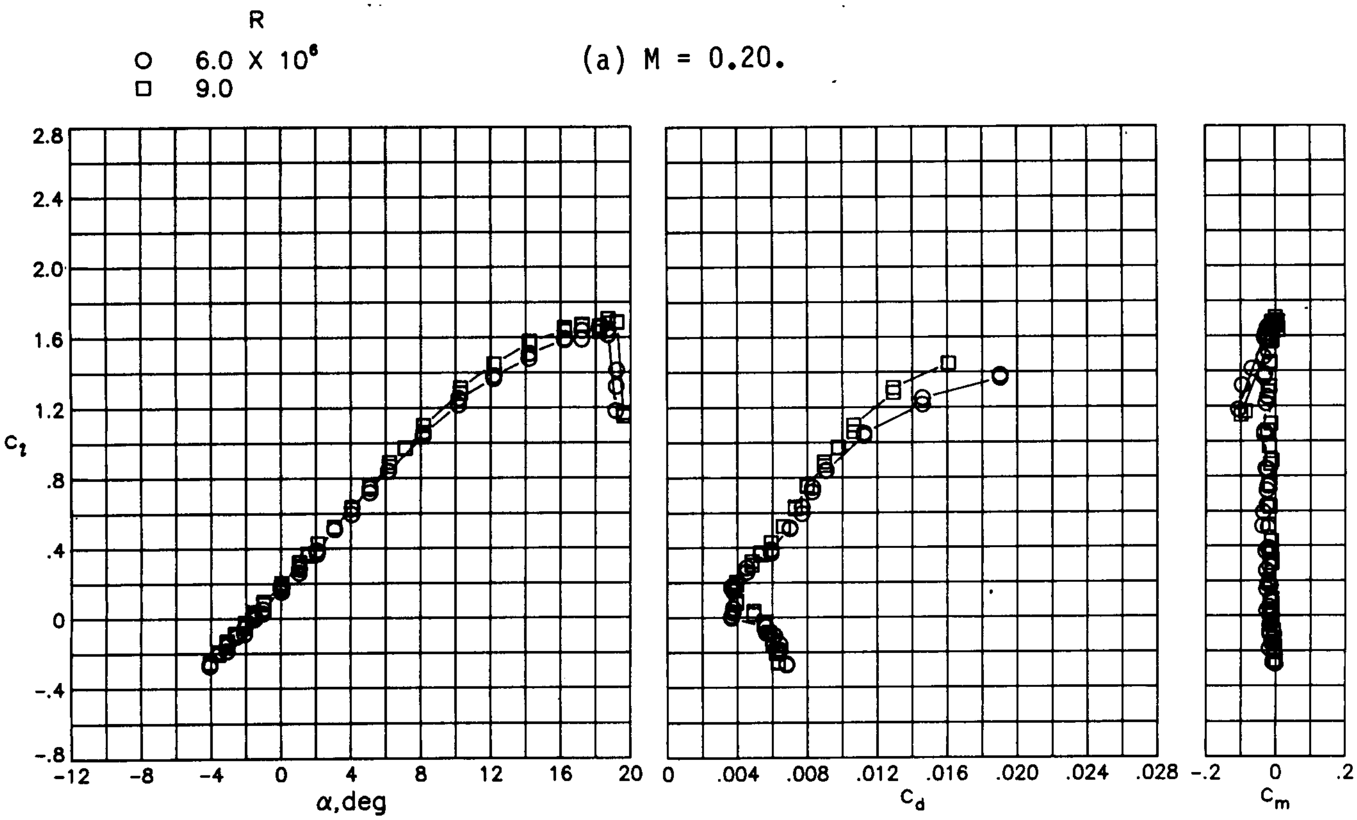


Figure 21.- Effect of Mach number on section characteristics from test in LTPT. Model smooth, $R = 6 \times 10^6$.

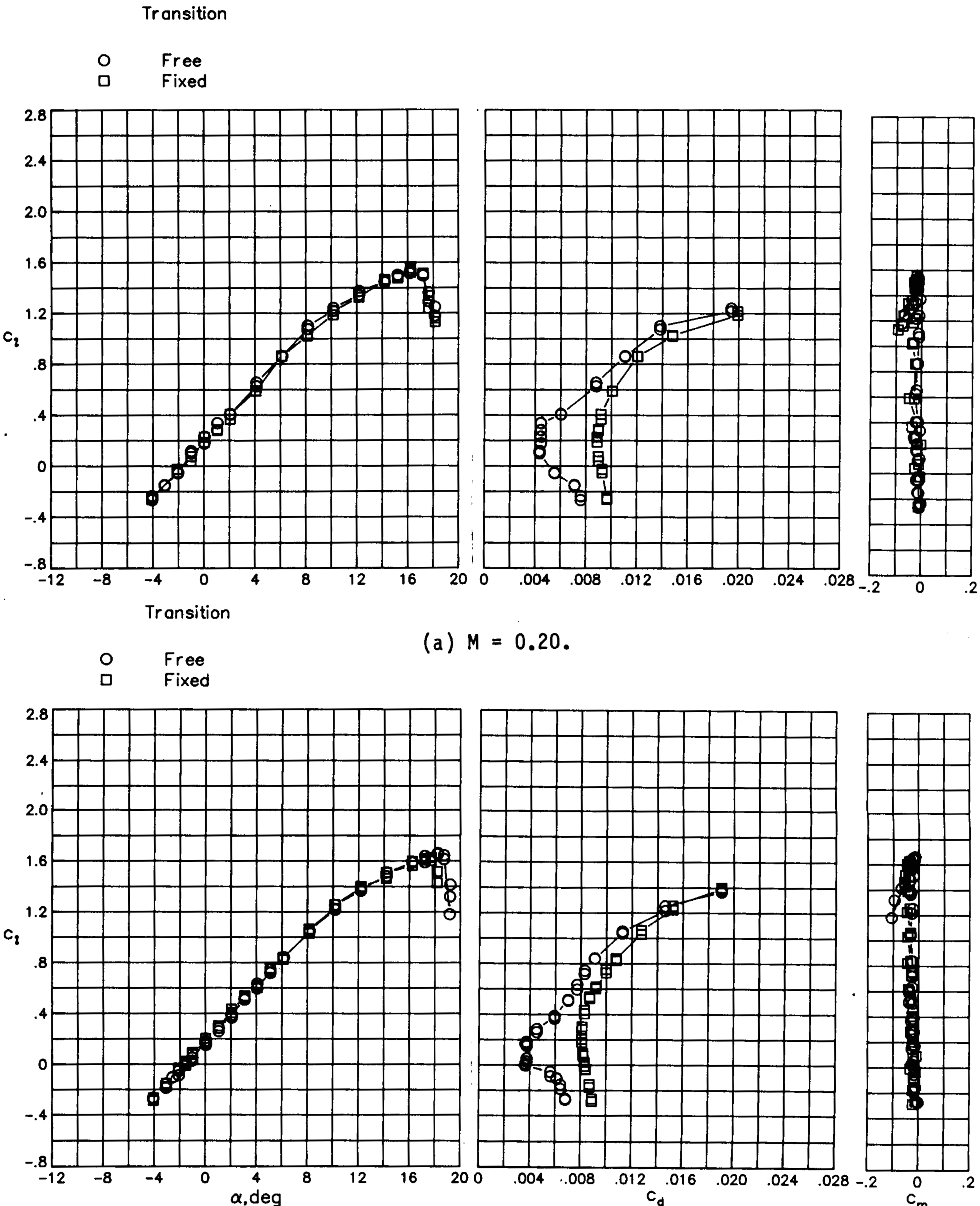


(a) M = 0.20.



(b) M = 0.14.

Figure 22.- Effect of Reynolds number on section characteristics from test in LTPT. Model smooth.



(a) M = 0.20.

(b) M = 0.14.

Figure 23.- Effect of fixed transition on section characteristics from test in LTPT.

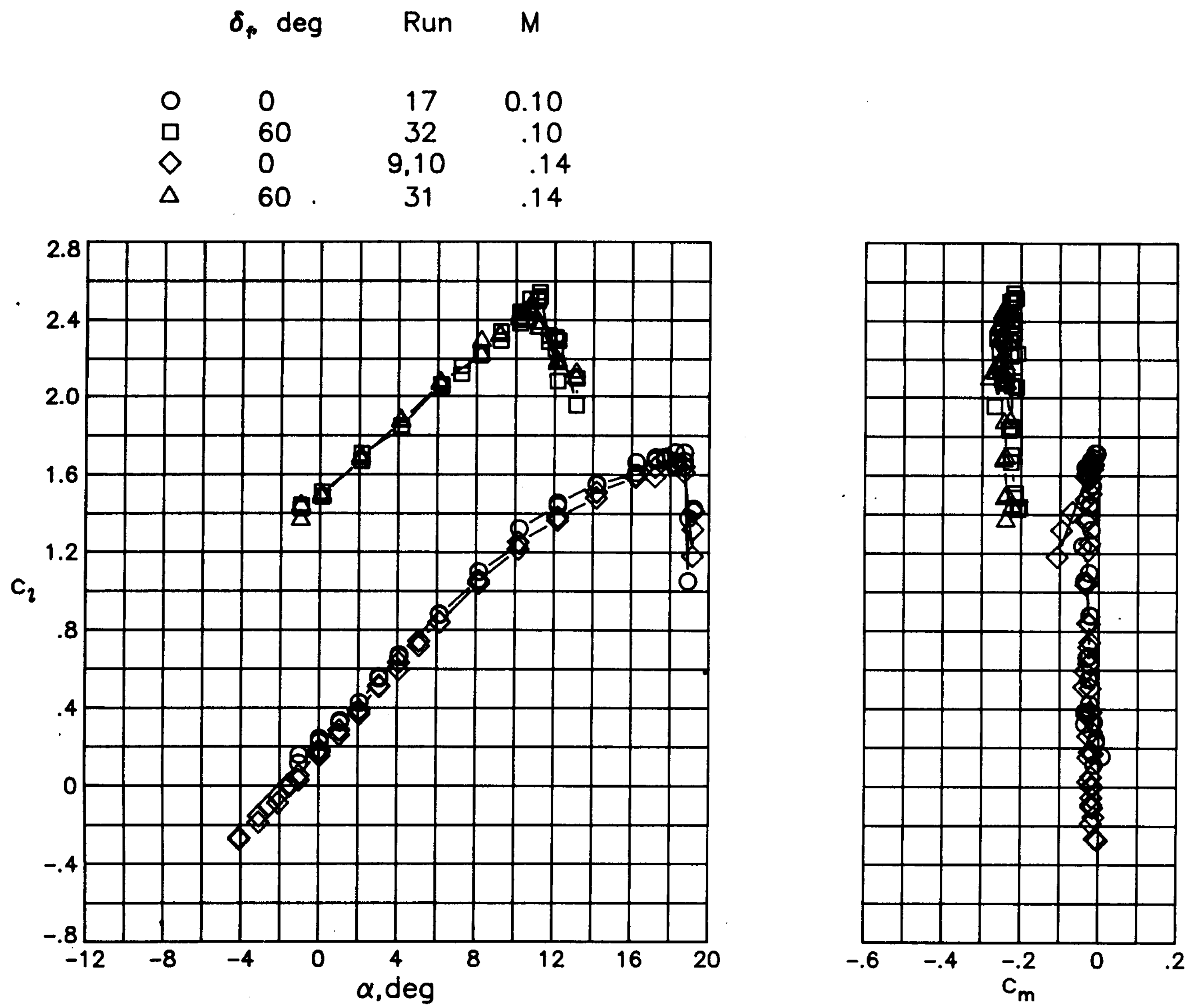


Figure 24.- Effect of trailing-edge split flap on section lift and pitching-moment coefficients from test in LTPT. Flap is 0.20c in length, $R = 6 \times 10^6$, model smooth.

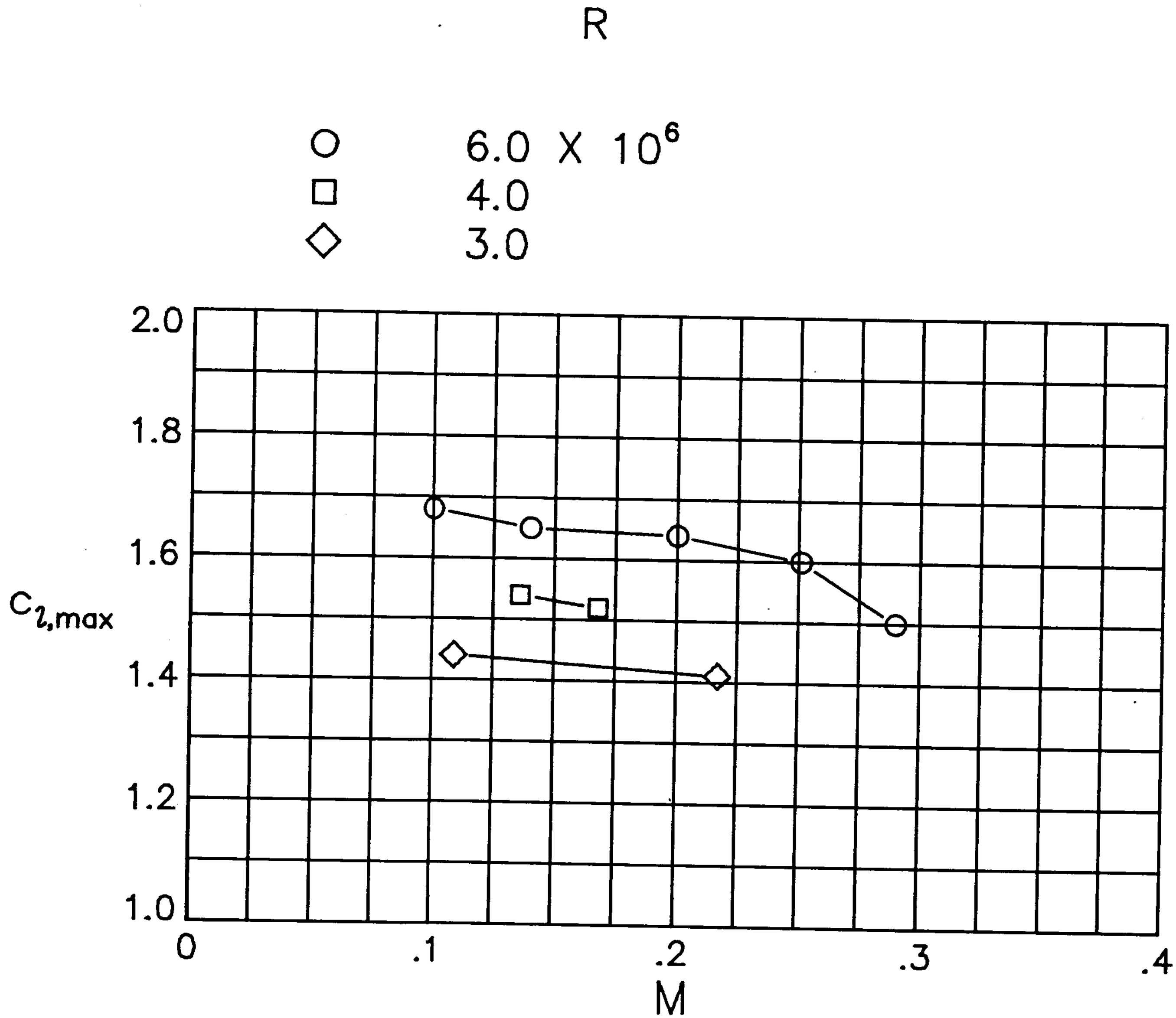


Figure 25.- Effect of Mach number and Reynolds number on maximum lift coefficient from test in LTPT.

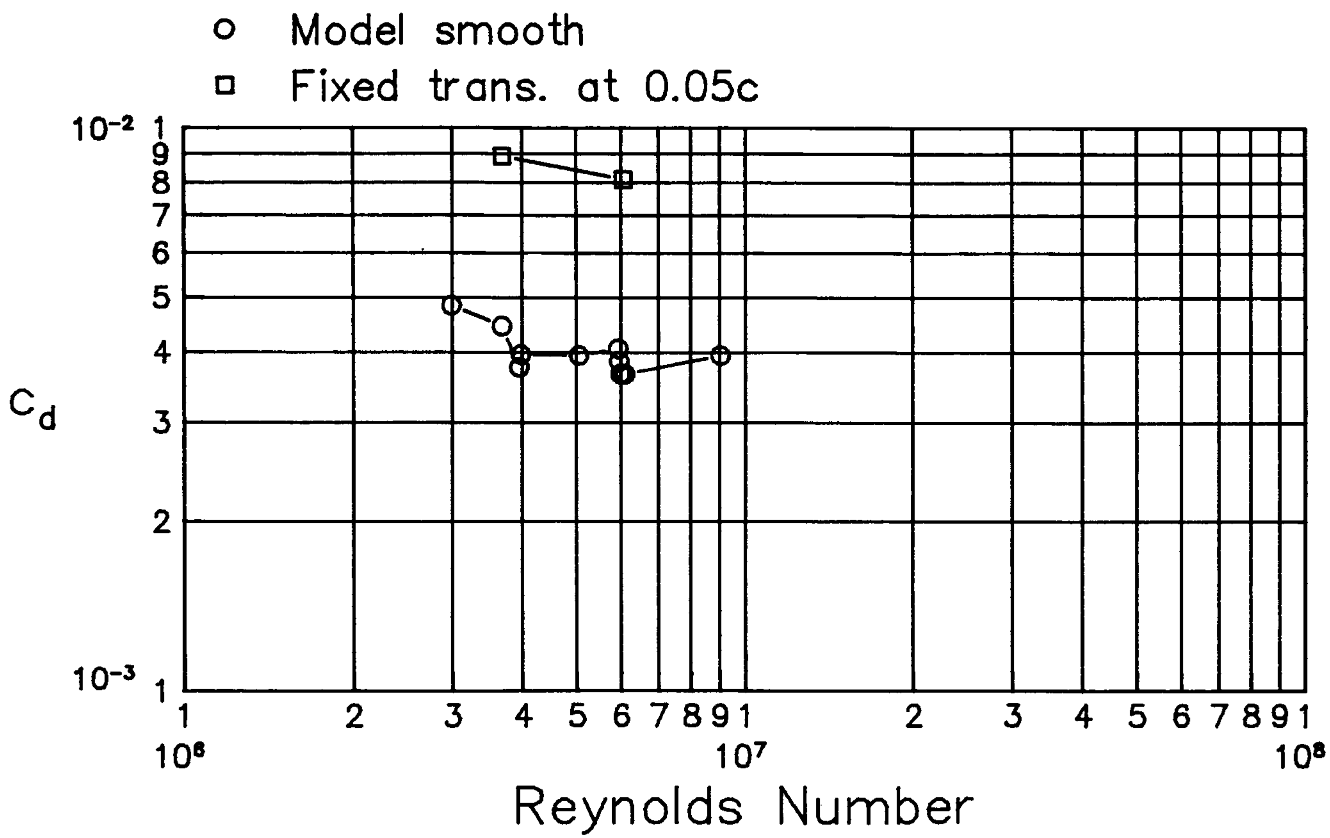
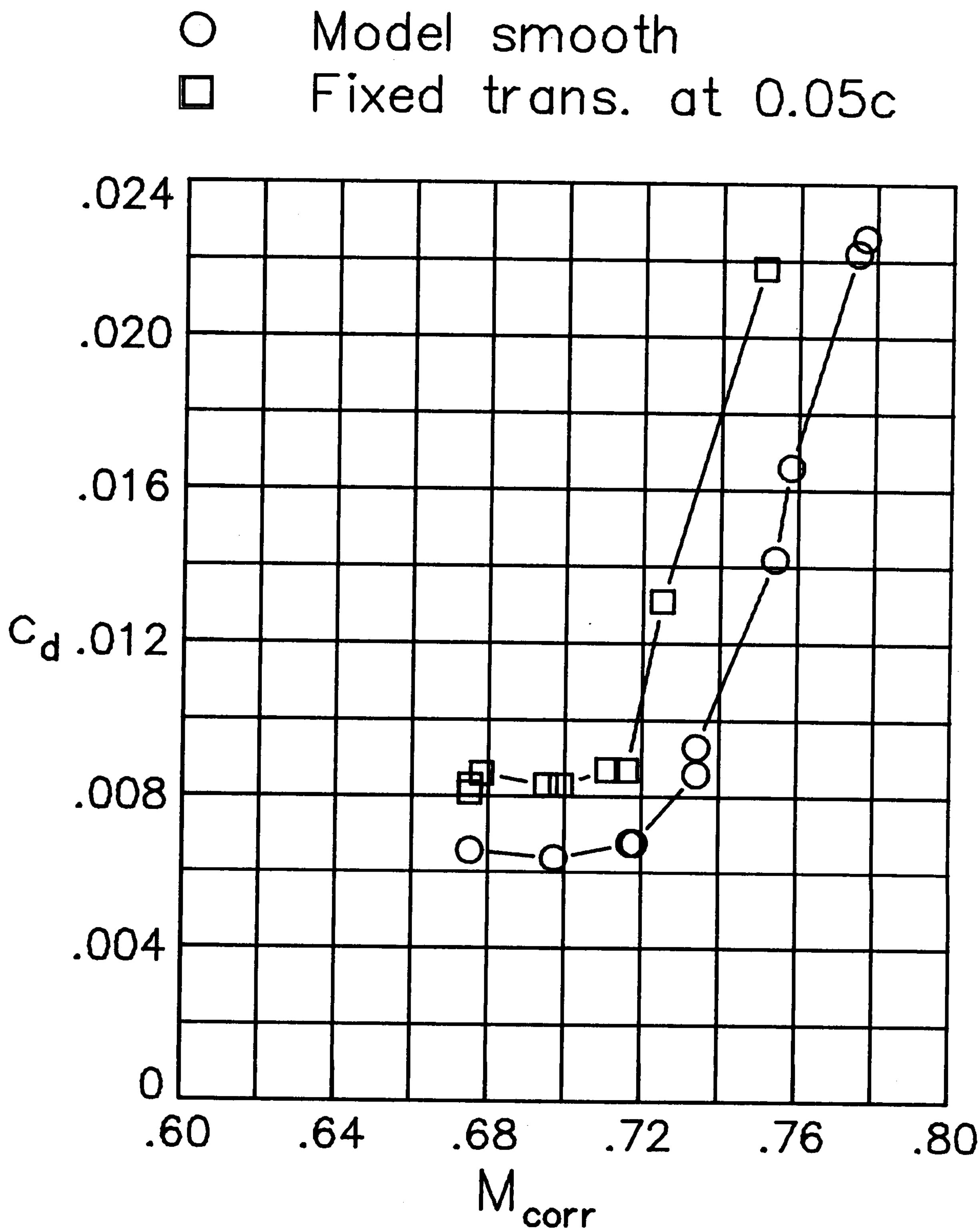


Figure 26.- Variation of drag coefficient with Reynolds number from test in LTPT.
$\alpha = 0$; $M < 0.30$.



[redacted]

Figure 27.- Variation of section drag coefficient with Mach number. $c_n = 0.26$.

[redacted]

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
NASA TM-87602		

4. Title and Subtitle	5. Report Date
Wind Tunnel Results for a High-Speed, Natural Laminar-Flow Airfoil Designed for General Aviation Aircraft	November 1985
	6. Performing Organization Code: 505-60-21-01
7. Author(s) W. G. Sewall, R. J. McGhee, J. K. Viken,* E. G. Waggoner, B. S. Walker, and B. F. Millard	8. Performing Organization Report No.
	10. Work Unit No.
9. Performing Organization Name and Address: National Aeronautics and Space Administration, Langley Research Center, Hampton, VA 23665-5225	11. Contract or Grant No.
	13. Type of Report and Period Covered: Technical Memorandum
12. Sponsoring Agency Name and Address: National Aeronautics and Space Administration, Washington, DC 20546	14. Sponsoring Agency Code

15. Supplementary Notes

*ESCON, Hampton, VA

16. Abstract

Two dimensional wind-tunnel tests have been conducted on a high-speed natural laminar-flow airfoil, the HSNLF(1)-0213, in both the Langley 6- by 28-inch Transonic Tunnel and the Langley Low Turbulence Pressure Tunnel. The test conditions consisted of Mach numbers ranging from 0.10 to 0.77 and Reynolds numbers ranging from 3 X 10^6 to 11 X 10^6. The airfoil was designed for a lift coefficient of 0.20 at a Mach number of 0.70 and Reynolds number of 11 X 10^6. At these conditions, laminar flow would extend back to 50 percent chord of the upper surface and 70 percent chord of the lower surface. Low-speed results were also obtained with a 0.20 chord trailing-edge split-flap deflected 60^o.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
HSNLF(1)-0213 Airfoils Low-speed characteristics Laminar flow General aviation	[redacted] Subject Category 02

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	72	

[redacted]