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INVESTIGATION OF CAST-10-2/DOA 2 AIRFOIL IN NAE HIGH REYNOLDS NUMBER TWO-DIMENSIONAL TEST FACILITY

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Introduction

The NAE/NRC-NASA Langley Cooperative Program on Two-Dimensional Wind Tunnel Wall Interference Research was initiated in 1984. The objective of the program is to develop the technology for elimination of correction of wall interference in transonic two-dimensional tests using the Langley 0.3-m Transonic Cryogenic Tunnel with an adaptive wall test section and the NAE 1.5-m High Reynolds Number Two-Dimensional Test Facility. A common model with the CAST 10-2/DOA-2 profile and 228 mm (9 inches) chord length has been tested in both tunnels. The tests performed in NAE covered the Mach numbers from 0.3 to 0.8 and Reynolds numbers from 10 to 30 million. The model was tested with transition free and with transition fixed at 5 percent chord for both the upper and the lower surfaces.

The NAE facility consists of a two-dimensional test section inserted into the 1.5 m transonic test section of the Trisonic Wind Tunnel. The 2-D test section is 0.38 m (15 inches) wide, 1.5 m (60 inches) high and 3.6 m (141 inches) long. The side walls are solid and the top and the bottom walls are perforated with 21% porosity, the surfaces of which are covered by fine mesh screens for elimination of edge tone generated by the perforation. A static pressure tube is installed along the center-line of each wall for monitoring the pressure distribution at the wall. The model is situated at mid-height of the test section. A balance is housed at each side wall and the model is mounted on both balances. The side wall boundary layer in the vicinity of the model is controlled by normal suction. The suction area, 0.61 m × 0.46 m (24 in. × 18 in.), is covered by a porous plate and moderate suction is applied to control the adverse growth of the boundary layer. A pitot rake with four probes is mounted 0.41 m (16 in.) downstream from the model trailing edge for measuring the wake profiles. The tunnel is precisely controlled to give the required free stream Mach number and Reynolds number. The test results are available in tabulated and graphical forms immediately after the test run. The airfoil data are corrected for the top and bottom wall interference. The effect of sidewall boundary layer is being investigated.

Conclusions

The data obtained have been analysed for the effects of Reynolds number, transition fixing and Mach number. The role of the boundary layer on the displacement effect, the interaction with the shock wave and the trailing edge separation are examined. The results are summarized as follows.

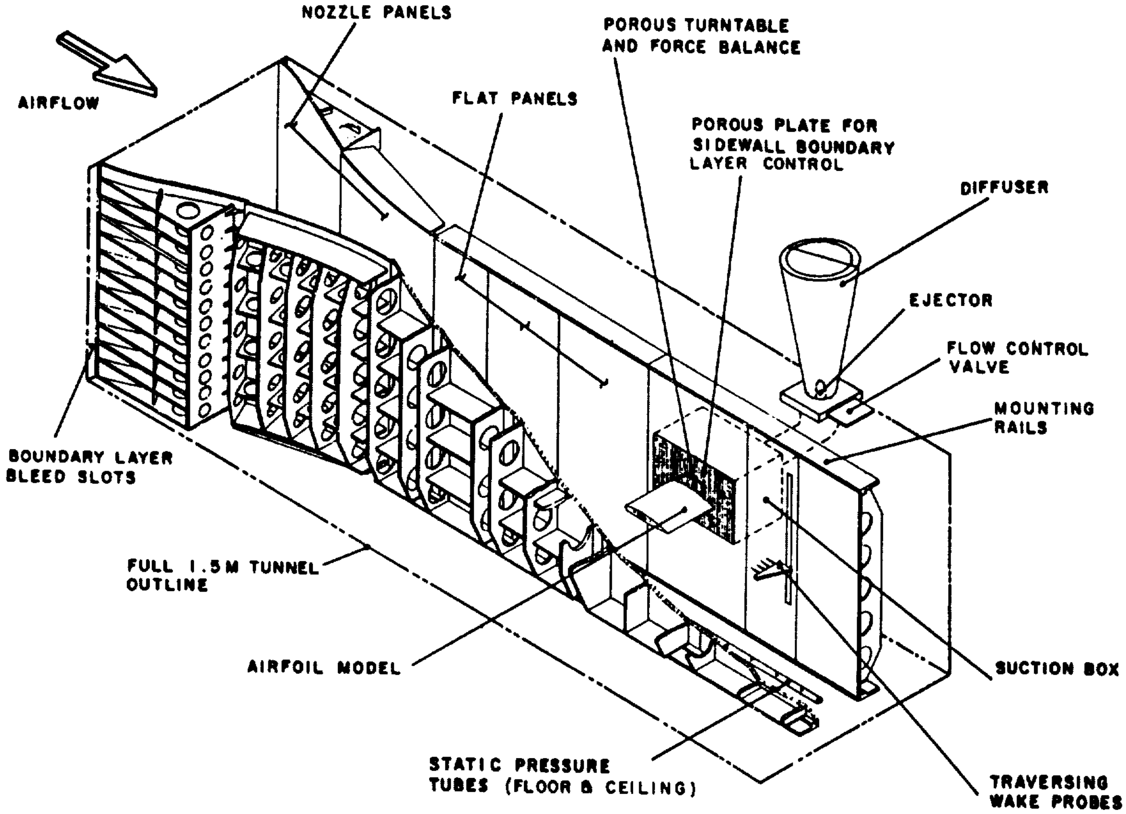
1. The airfoil performance depends strongly on Reynolds number and transition fixing.

2. With transition fixed, the aerodynamic quantities such as lift, pitching moment and drag show a monotonic variation with Reynolds number.

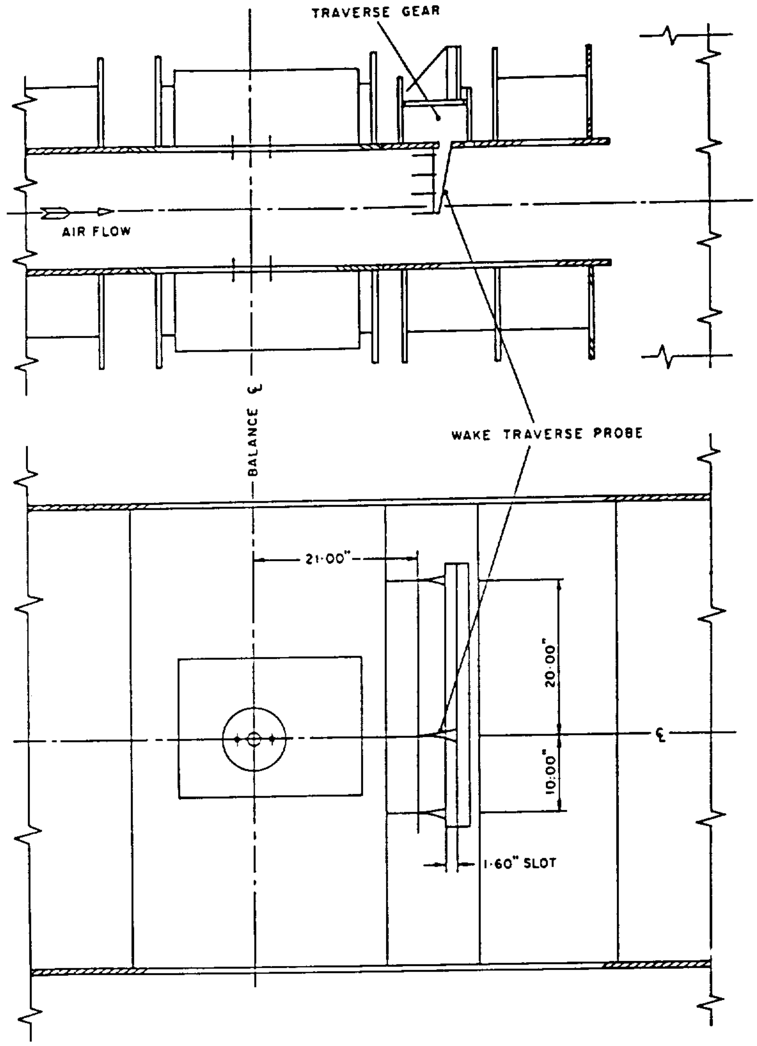
3. With transition free, the aerodynamic quantities vary less regularly with Reynolds number and a slight parametric dependency is shown. The weak dependency is due to the compensatory effect of the forward shift of the transition position and the thinning of the turbulent boundary layer as Reynolds number increases.

4. The shock Mach number and the shock position are weakly dependent on Reynolds number.

5. The long extent of the laminar boundary layer at transonic speeds reduces the drag appreciably at low Reynolds numbers. The drag bucket around the design Mach number can be observed below Reynolds number 15 million.

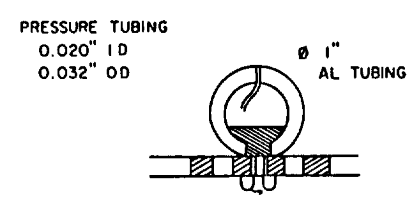


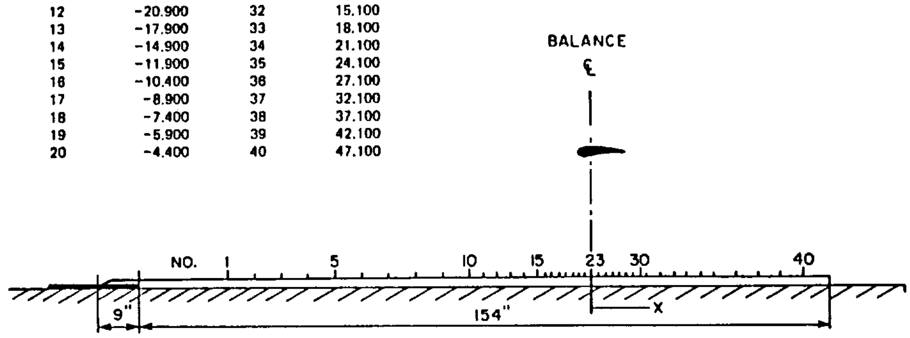
NAE 2-DIMENSIONAL
TEST SECTION



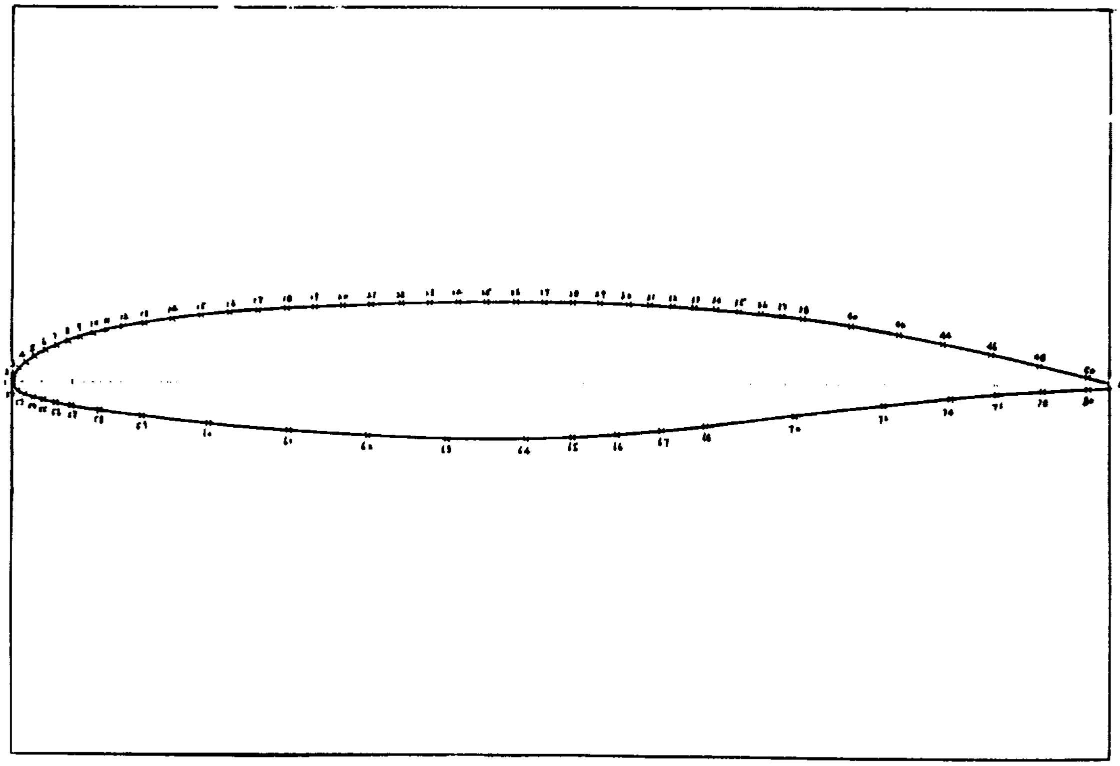
SIDEWALL MOUNTED WAKE TRAVERSE PROBE SYSTEM

HOLE NO.	X"	HOLE NO.	X"
1	-80.900	21	-2.900
2	-74.900	22	-1.400
3	-68.900	23	0.100
4	-62.900	24	1.600
5	-56.900	25	3.100
6	-50.900	26	4.600
7	-44.900	27	6.100
8	-38.900	28	7.600
9	-32.900	29	9.100
10	-26.900	30	10.600
11	-23.900	31	12.100
12	-20.900	32	15.100
13	-17.900	33	18.100
14	-14.900	34	21.100
15	-11.900	35	24.100
16	-10.400	36	27.100
17	-8.900	37	32.100
18	-7.400	38	37.100
19	-5.900	39	42.100
20	-4.400	40	47.100

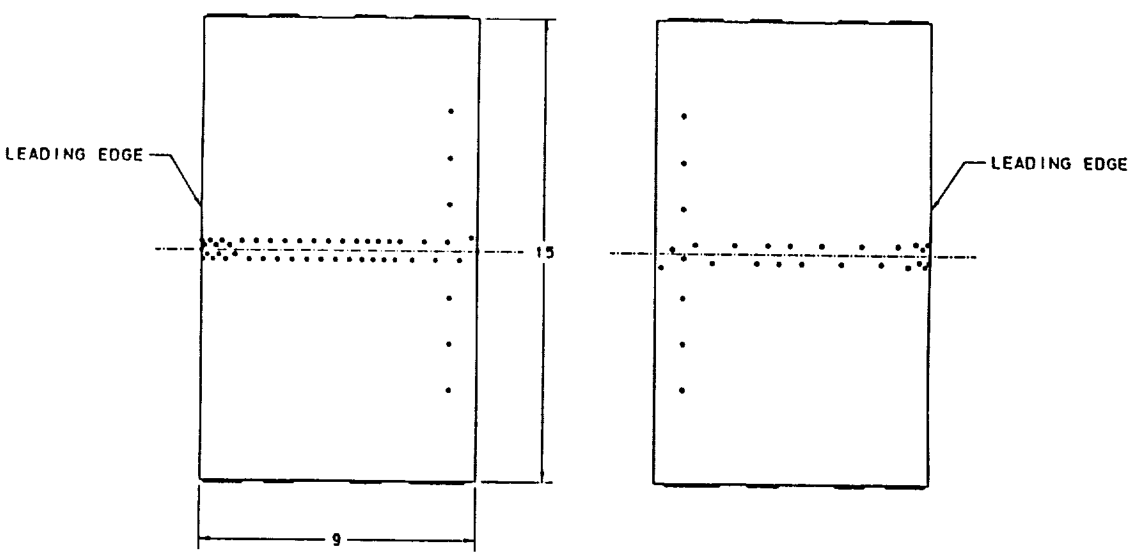




WALL STATIC TUBES



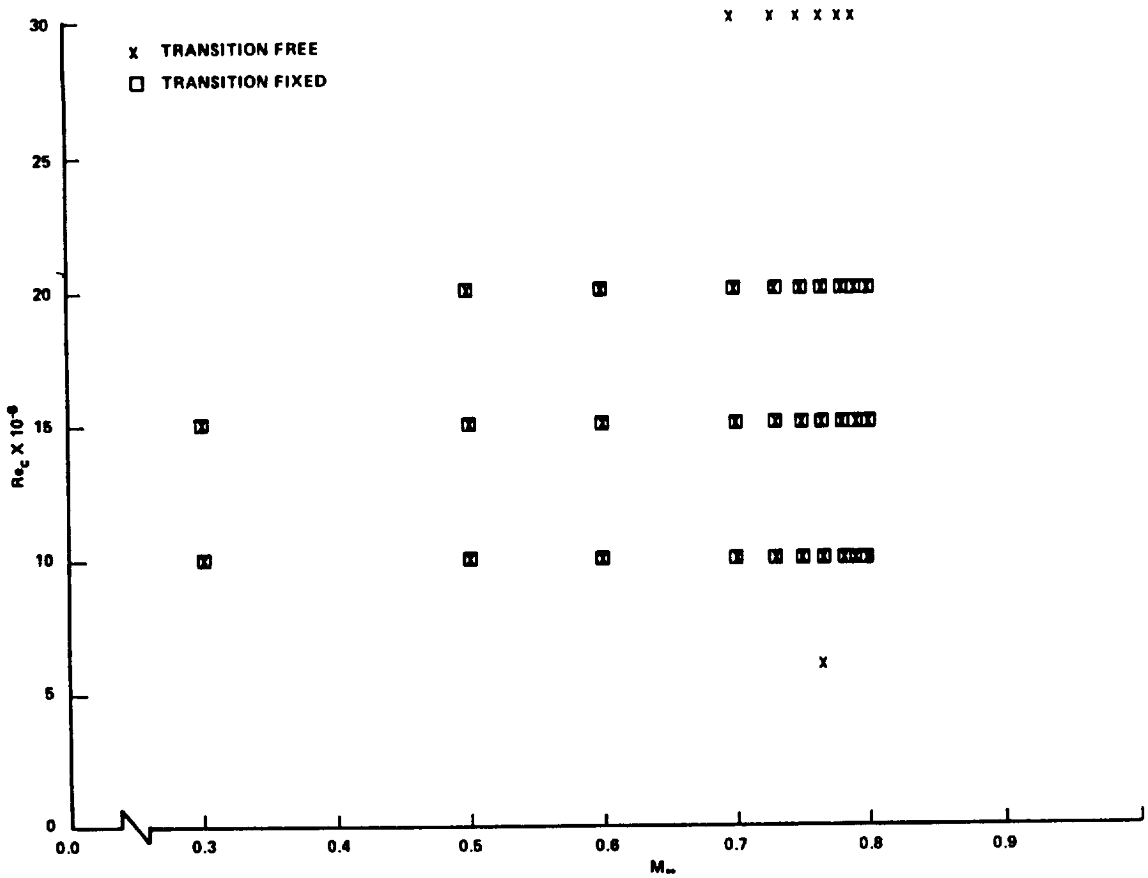
SECTION PROFILE OF CAST-10-2/DOA AIRFOIL
& PRESSURE ORIFICE LOCATION



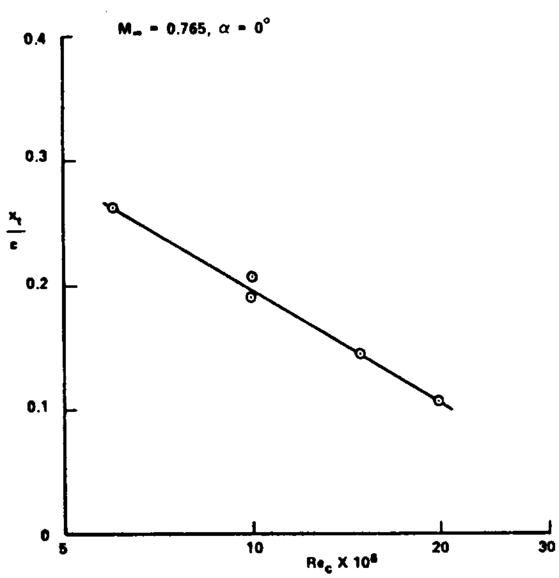
UPPER SURFACE

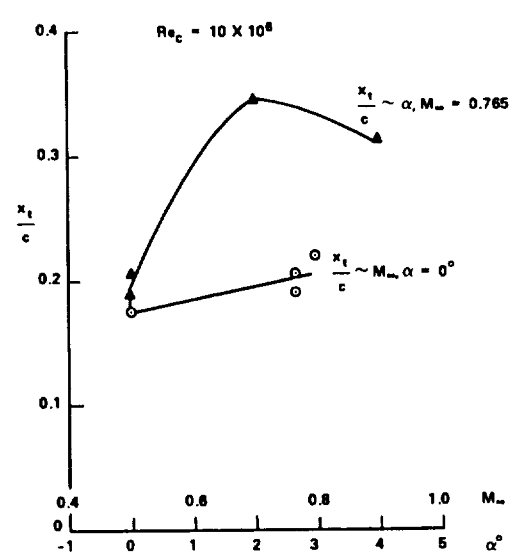
LOWER SURFACE

LOCATIONS OF PRESSURE ORIFICES AT UPPER AND LOWER
SURFACES PLANE VIEW

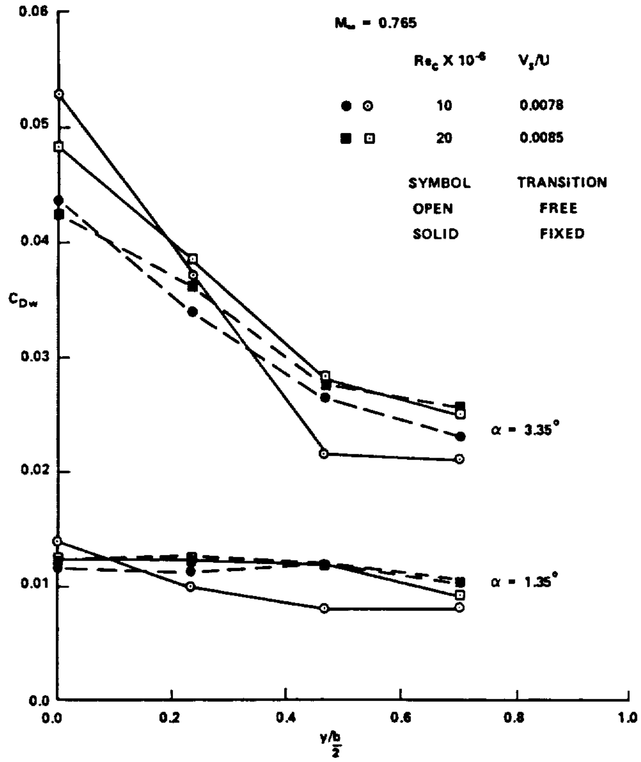


ENVELOPE OF TEST CONDITIONS

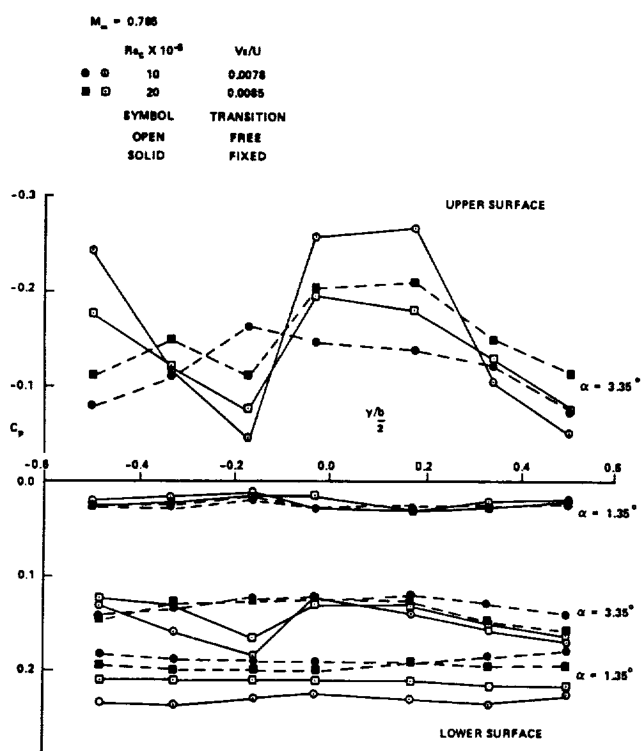




EFFECTS OF REYNOLDS NUMBER, MACH NUMBER AND INCIDENCE TO LOCATIONS OF BOUNDARY LAYER TRANSITION ON THE UPPER SURFACE OF THE MODEL



SPANWISE WAKE DRAG VARIATION AT VARIOUS REYNOLDS NUMBERS FOR TWO ANGLES OF ATTACK WITH FIXED OR FREE TRANSITION, M_∞ = 0.765



SPANWISE PRESSURE DISTRIBUTIONS AT X/C = 0.9 FOR TWO ANGLES OF ATTACK AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION, M_∞ = 0.765

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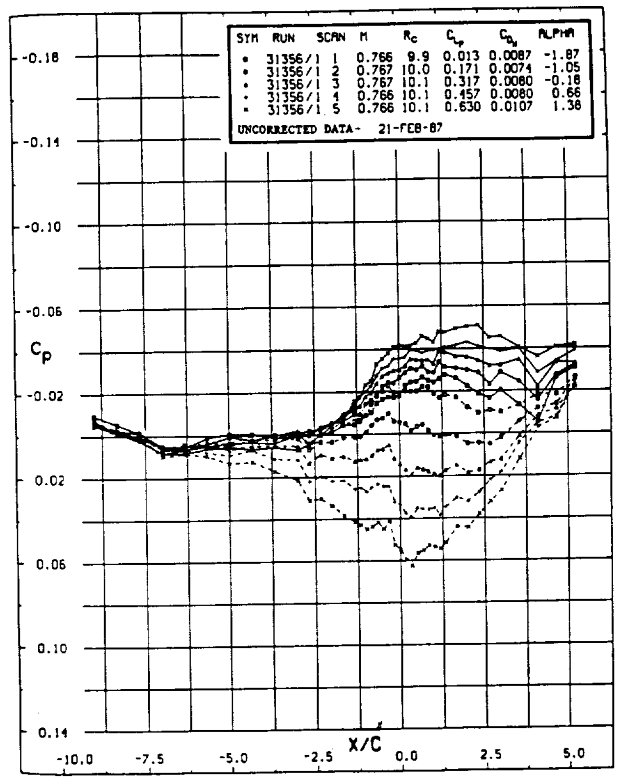
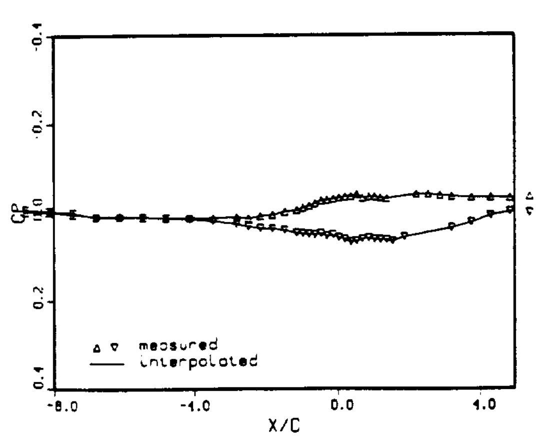


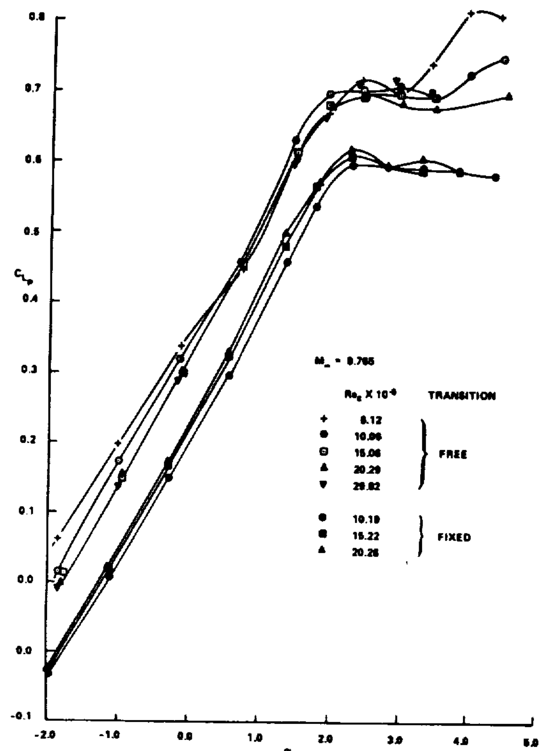
TYPICAL STATIC PRESSURE DISTRIBUTIONS ALONG TOP AND BOTTOM WALLS OF TEST SECTION.

RUN 29812/6

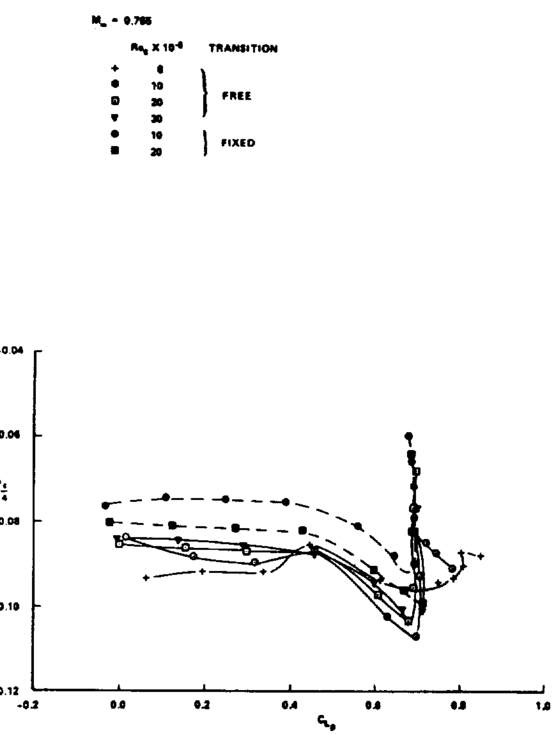
	ΔM = -0.0073
R_c = 10.23×10^6	$\Delta\alpha$ = -0.663°
M = 0.7724	$c \times \delta\Delta M/\delta x$ = 0.0010
α = 2.441°	$c \times \delta\Delta\alpha/\delta x$ = -0.008°
CN = 0.6276	
CX = -0.0026	M_{cor} = 0.7651
CM = -0.0826	α_{cor} = 1.778°
A = 0.0850	
c/h = 0.1500	



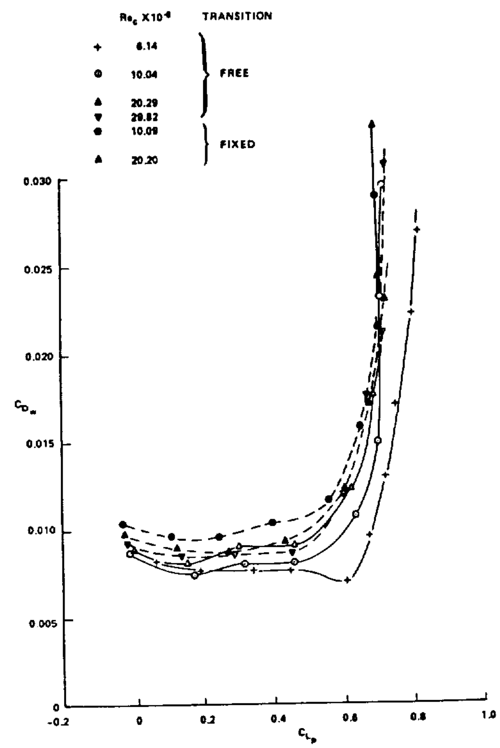
TYPICAL INTERFERENCE CALCULATION FOR SPECIFIC MODEL CONDITION.



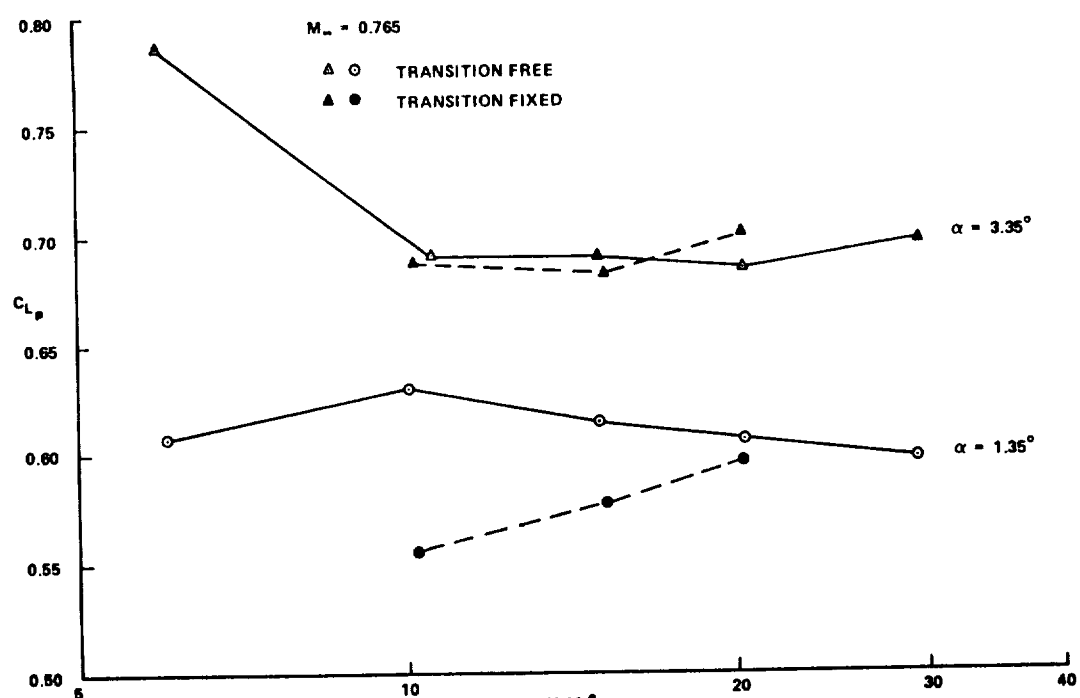
LIFT VERSUS ANGLE OF ATTACK AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION AT NOMINAL M∞ = 0.765



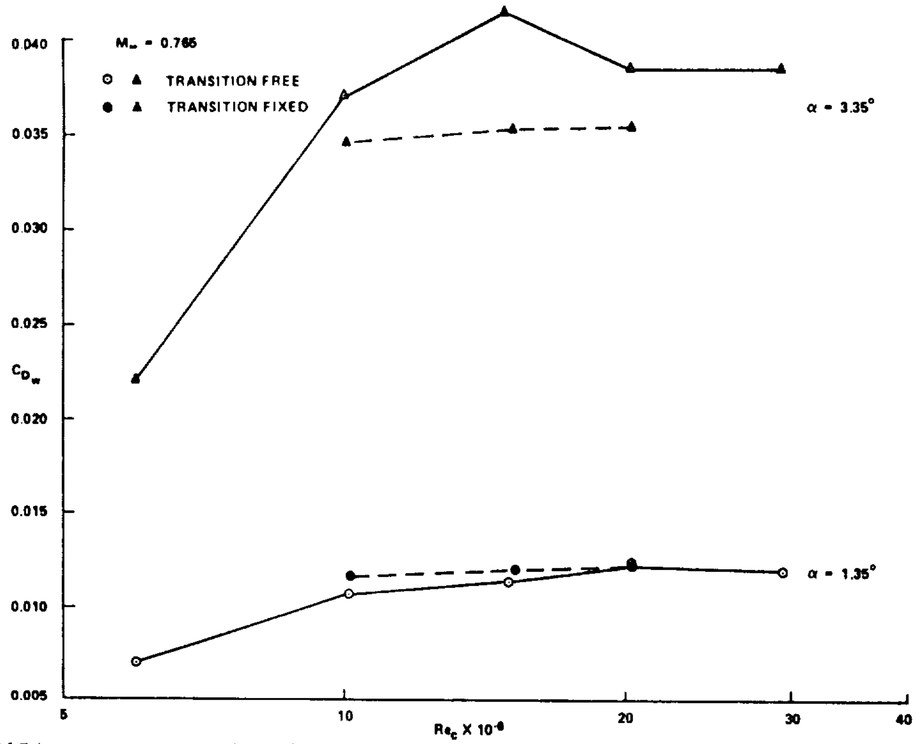
PITCHING MOMENT VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION AT NOMINAL M∞ = 0.765



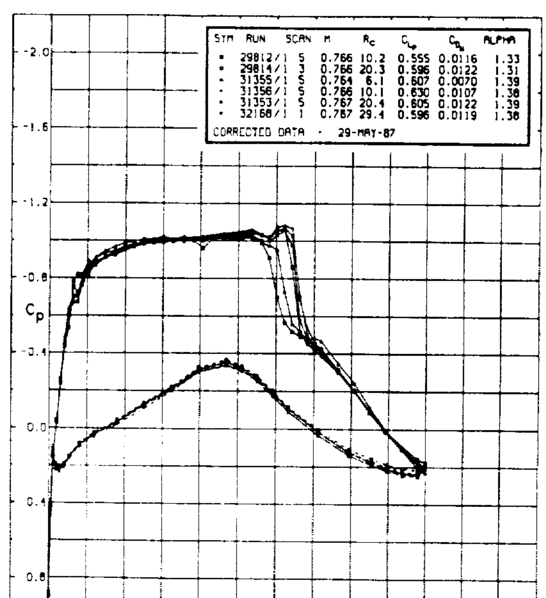
DRAG VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION AT NOMINAL M_∞ = 0.765



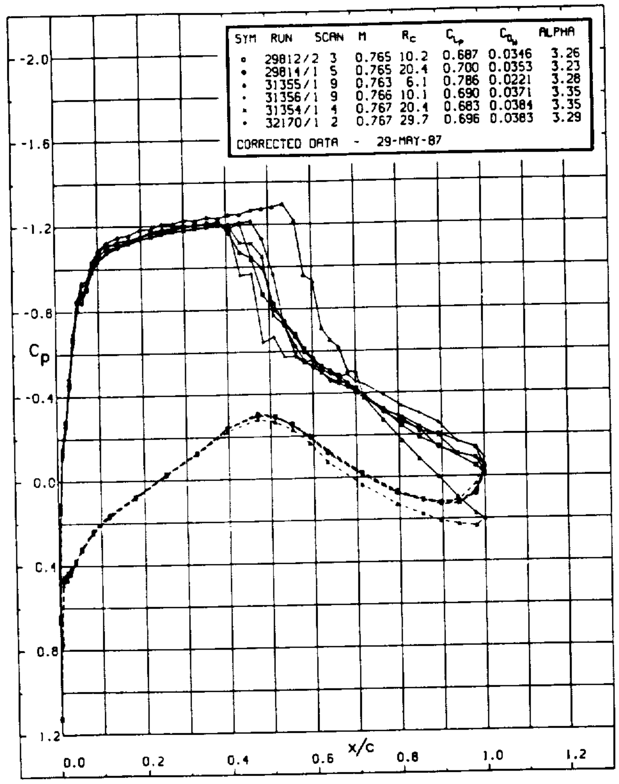
REYNOLDS NUMBER DEPENDENCE OF LIFT FOR TWO ANGLES OF ATTACK WITH FIXED OR FREE TRANSITION



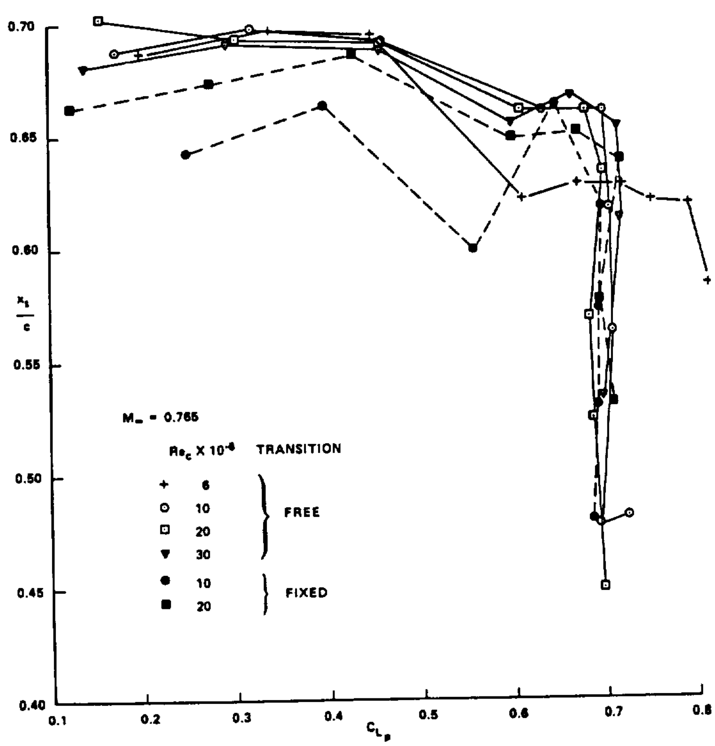
REYNOLDS NUMBER DEPENDENCE OF DRAG FOR TWO ANGLES OF ATTACK WITH FIXED OR FREE TRANSITION



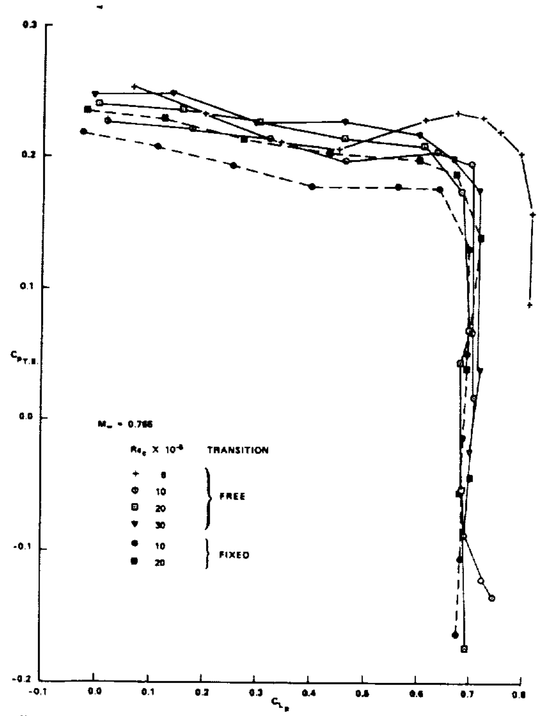
REYNOLDS NUMBER EFFECTS ON SURFACE PRESSURE DISTRIBUTIONS AT NOMINAL α = 3.35°, M_∞ = 0.765. THE FIRST TWO CASES ARE WITH TRANSITION FIXED, THE REST ARE TRANSITION FREE



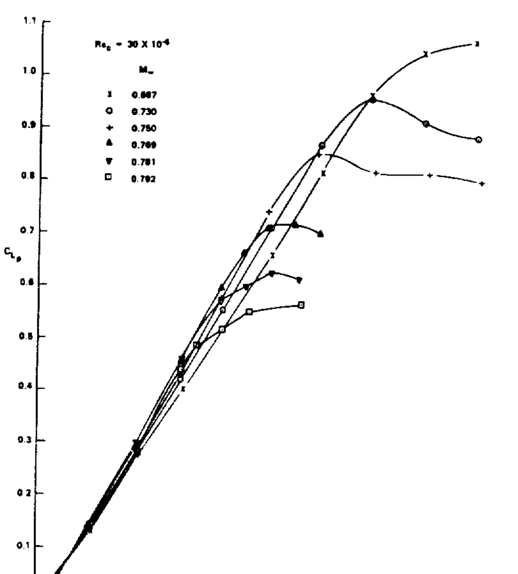
REYNOLDS NUMBER EFFECTS ON SURFACE PRESSURE DISTRIBUTIONS AT NOMINAL α = 1.35°, M_∞ = 0.765. THE FIRST TWO CASES ARE WITH TRANSITION FIXED, THE REST ARE TRANSITION FREE



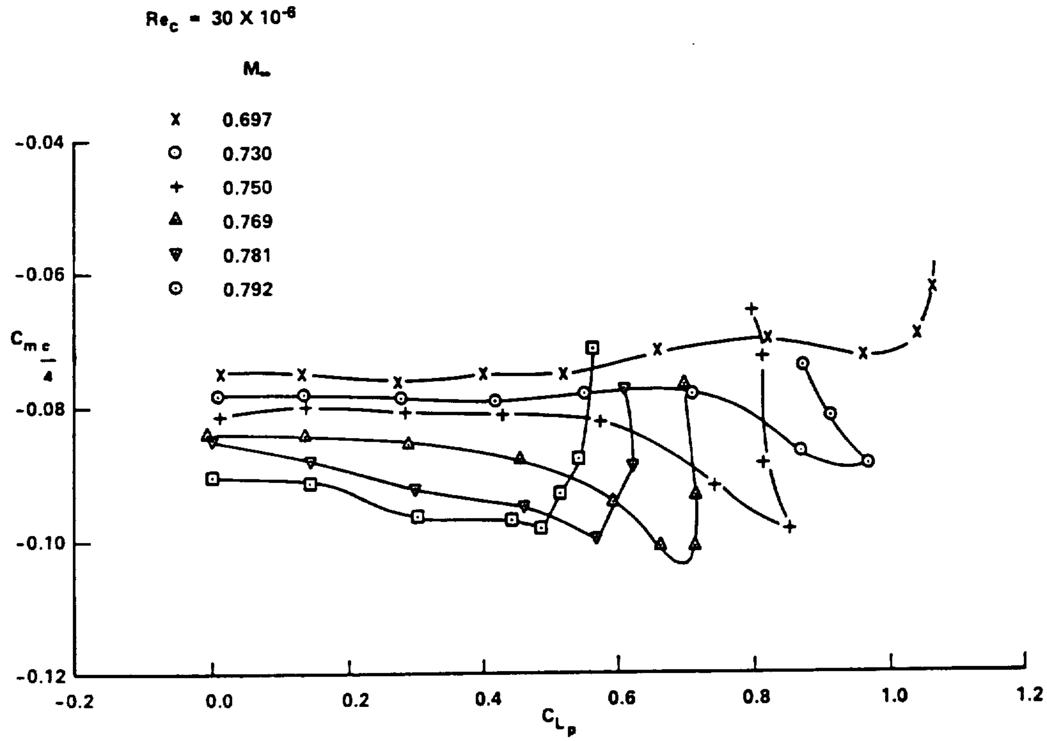
SHOCK LOCATION VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION AT NOMINAL M_∞ = 0.765



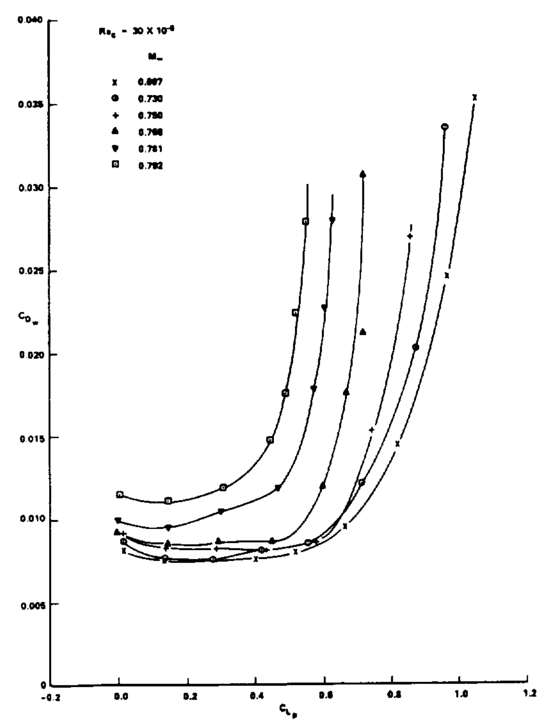
TRAILING EDGE PRESSURE VERSUS LIFT AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION AT NOMINAL M_∞ = 0.765



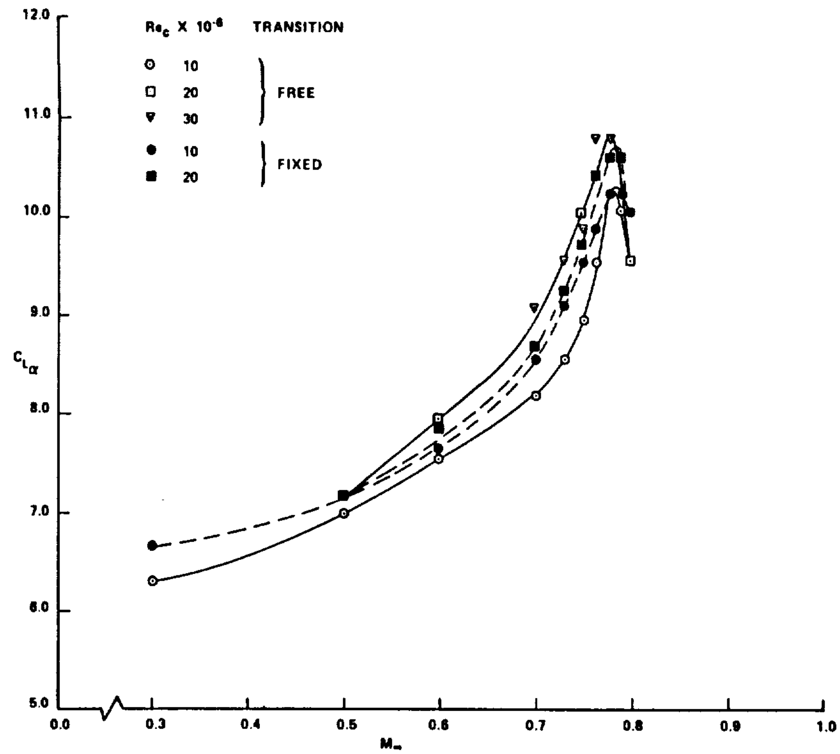
LIFT VERSUS ANGLE OF ATTACK AT VARIOUS MACH NUMBERS AT NOMINAL Re_c = 30 X 10^6 WITH FREE TRANSITION



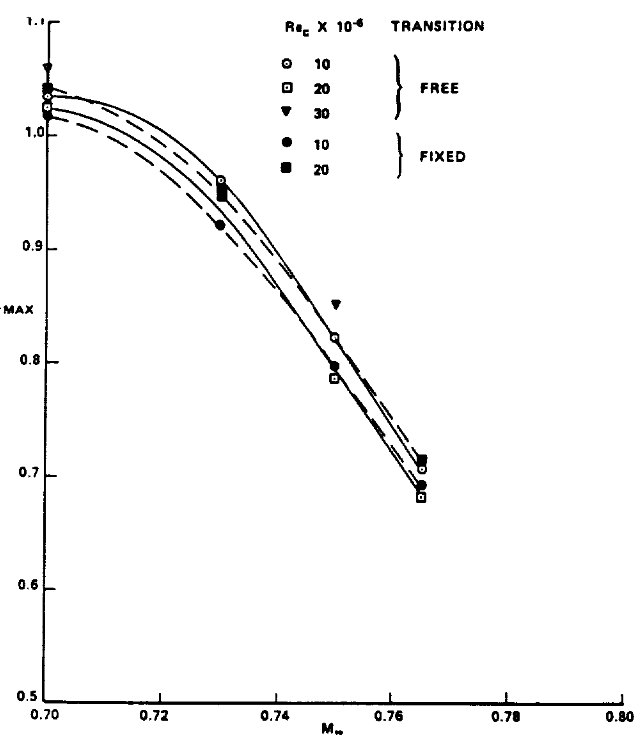
PITCHING MOMENT VERSUS LIFT AT VARIOUS MACH NUMBERS AT NOMINAL Re_c = 30 X 10^6 WITH FREE TRANSITION



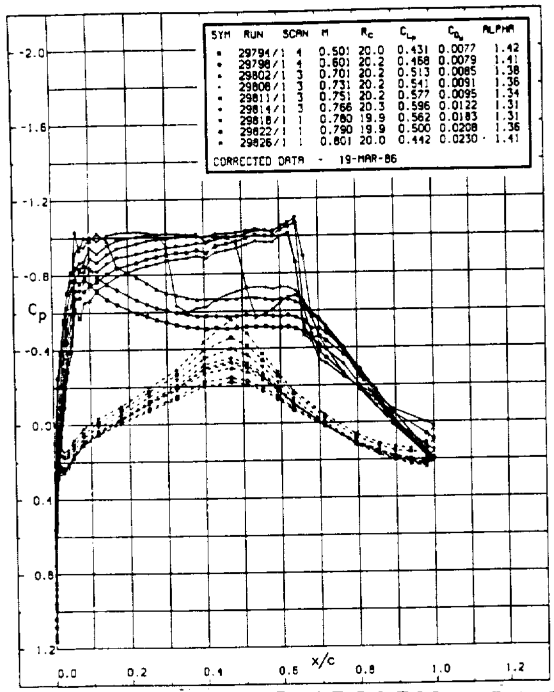
DRAG VERSUS LIFT AT VARIOUS MACH NUMBERS AT NOMINAL Re_c = 30 X 10^6 WITH FREE TRANSITION



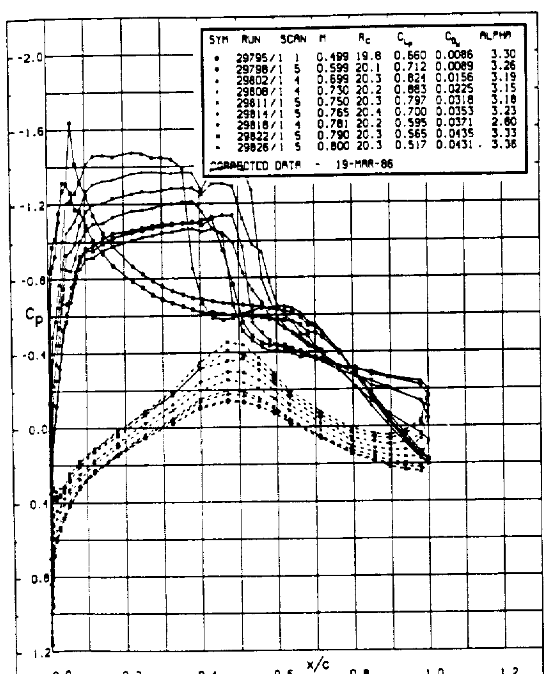
LIFT CURVE SLOPE AT ZERO LIFT VERSUS MACH NUMBER AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION



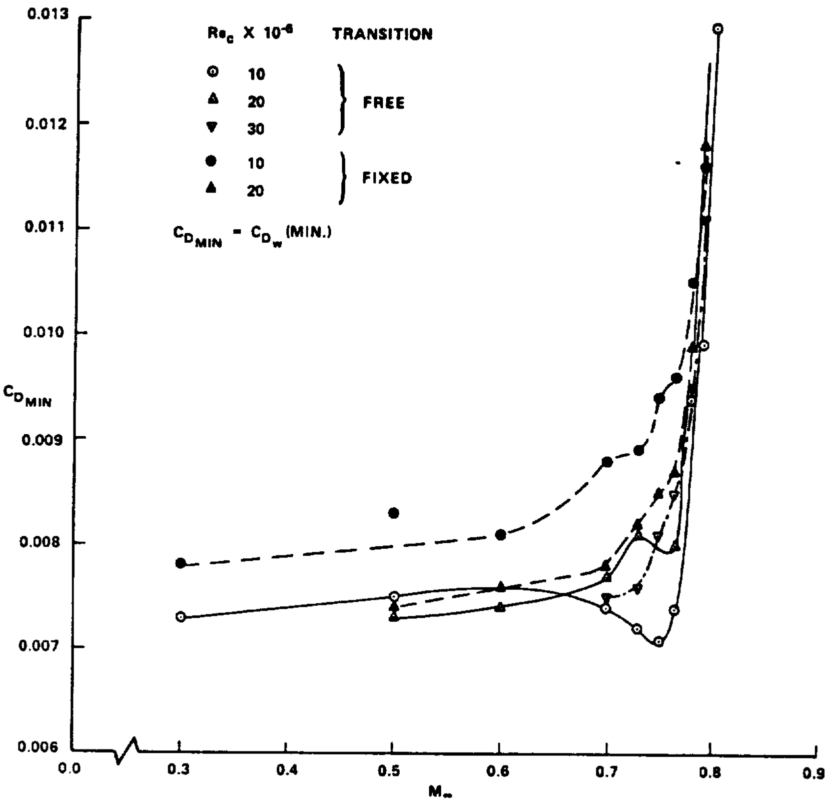
MAXIMUM LIFT VERSUS MACH NUMBER AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION



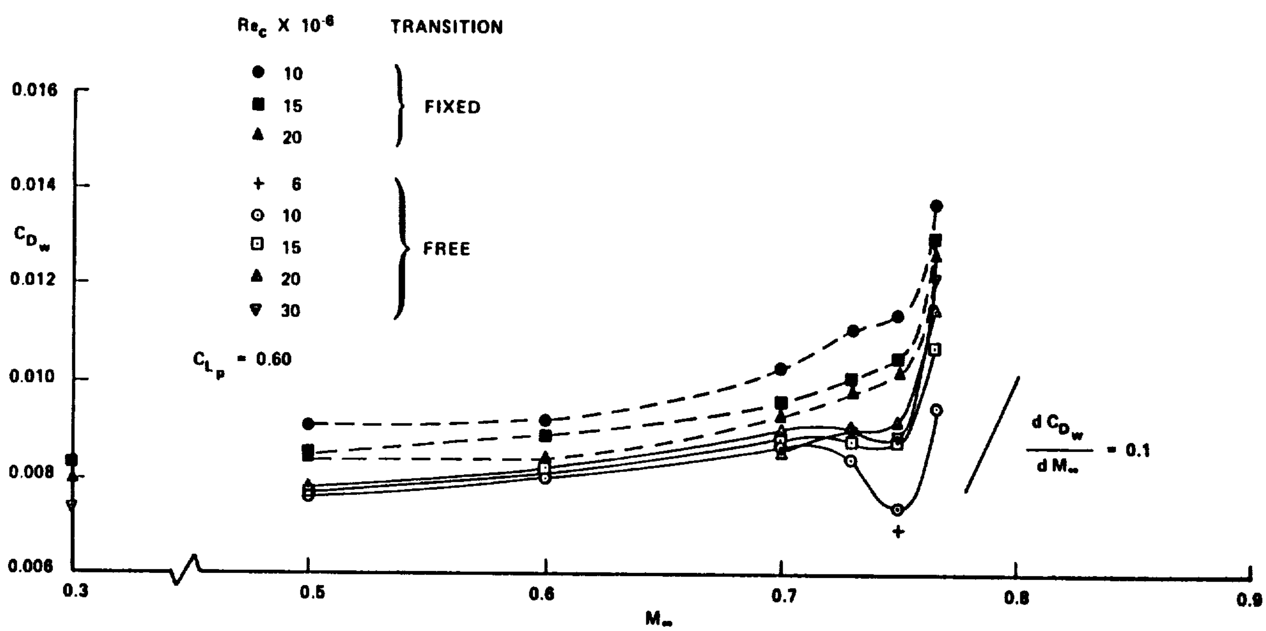
MACH NUMBER EFFECTS ON SURFACE PRESSURE DISTRIBUTIONS AT NOMINAL α = 1.35°, Re_c = 20 X 10^6 WITH FIXED TRANSITION



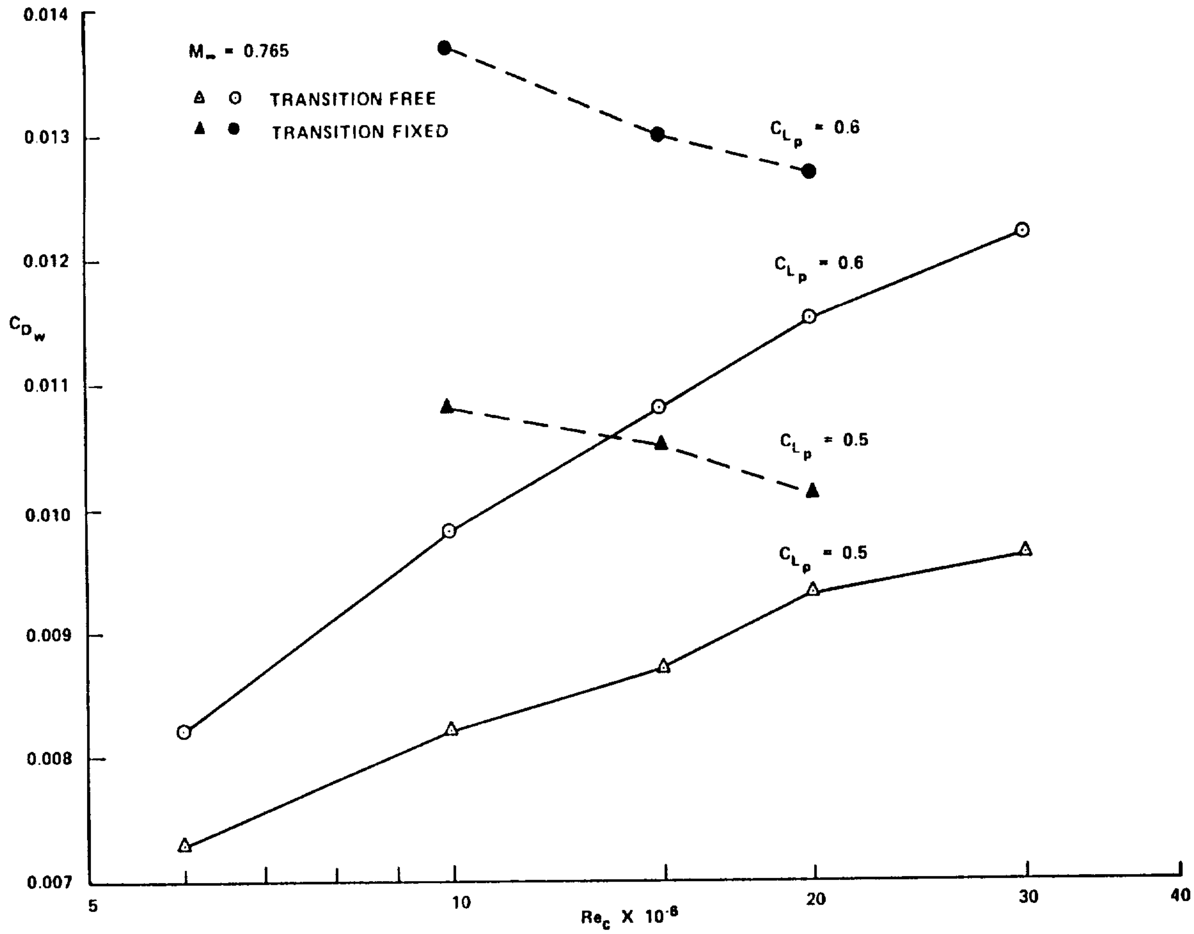
MACH NUMBER EFFECTS ON SURFACE PRESSURE DISTRIBUTIONS AT NOMINAL α = 3.35°, Re_c = 20 X 10^6 WITH FIXED TRANSITION



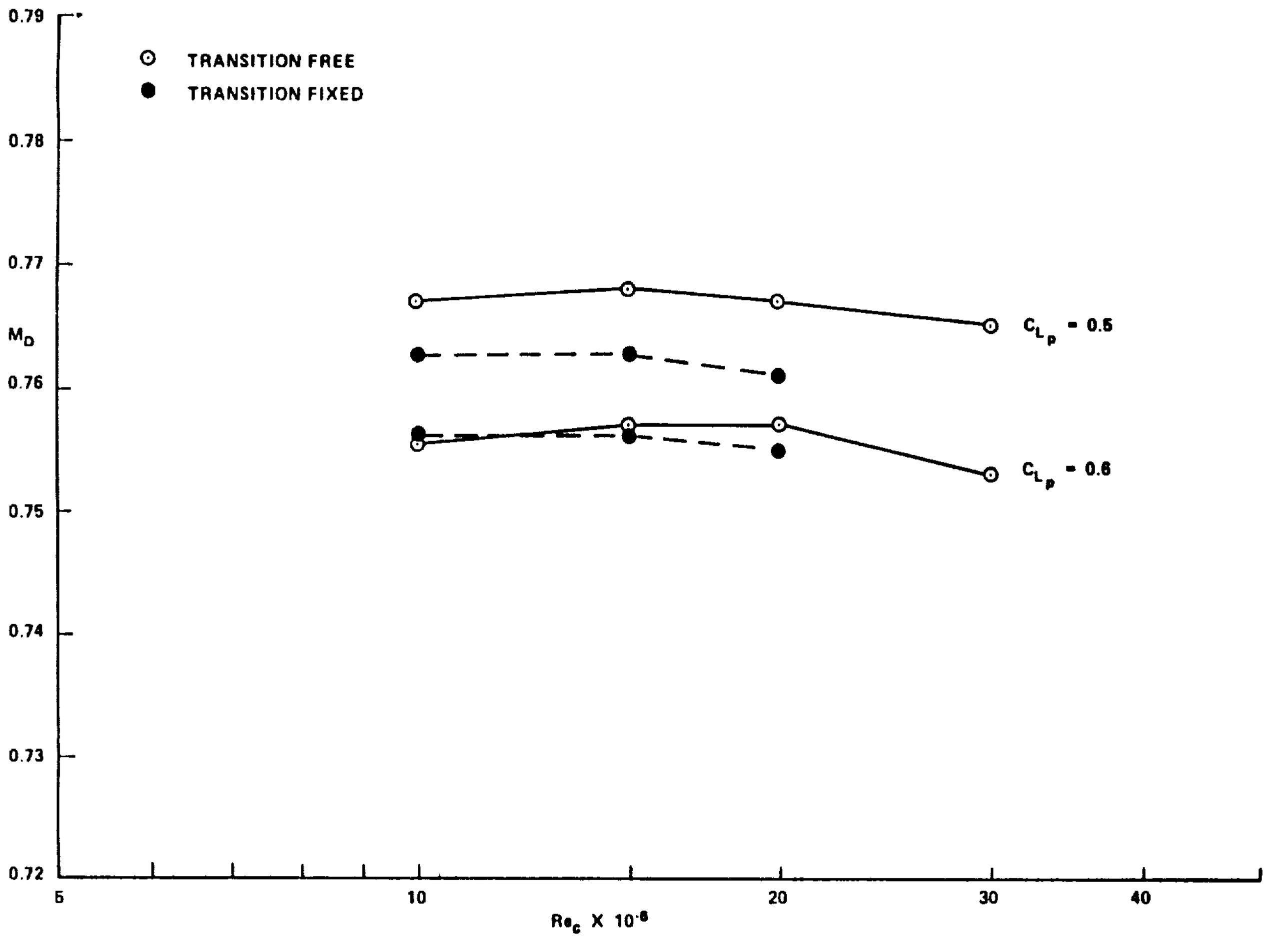
MINIMUM DRAG VERSUS MACH NUMBER AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION



DRAG AT $C_{L_p} = 0.6$ VERSUS MACH NUMBER AT VARIOUS REYNOLDS NUMBERS WITH FIXED OR FREE TRANSITION



REYNOLDS NUMBER DEPENDENCE OF DRAG AT M_∞ = 0.765, C_{L_p} = 0.5, 0.6 WITH FIXED OR FREE TRANSITION



REYNOLDS NUMBER DEPENDENCE OF DRAG WITH MACH NUMBER FOR TWO LIFT CONDITIONS WITH FIXED AND FREE TRANSITION