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AEDC-TR-68-95 c.1

LIFT-TO-DRAG RATIOS OF SEMISPAN DELTA WING CONFIGURATIONS AT SUPERSONIC AND HYPERSONIC MACH NUMBERS

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May 1968

VON KÁRMÁN GAS DYNAMICS FACILITY
ARNOLD ENGINEERING DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
ARNOLD AIR FORCE STATION, TENNESSEE

NOTICES

LIFT-TO-DRAG RATIOS OF SEMISPAN DELTA WING CONFIGURATIONS AT SUPERSONIC AND HYPERSONIC MACH NUMBERS

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FOREWORD

The work reported herein was done at the request of the Air Force Office of Scientific Research (AFOSR) for Aerospace Research Associates (ARA) under Program Element 6244501F, Project 9781, Task 978101.

The results of tests presented were obtained by ARO, Inc. (a subsidiary of Sverdrup & Parcel and Associates, Inc.), contract operator of the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Arnold Air Force Station, Tennessee, under Contract AF40(600)-1200. The tests were conducted from January 6 to 11, May 2 to 6, December 29, 1966 to January 3, 1967, and December 6 to 13, 1967 under ARO Project No. VT0640. This report contains data, not previously published, obtained during the early stages of the test program. The manuscript was submitted for publication on March 29, 1968.

Further dissemination of this report is restricted because of disclosure considerations relating to preliminary concepts by contractor personnel which were a part of this test.

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This technical report has been reviewed and is approved.

Donald H. Meyer
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ABSTRACT

Tests were conducted in the 40-in. supersonic and 50-in. hypersonic tunnels of the von Kármán Gas Dynamics Facility (VKF) to determine the maximum lift-to-drag ratios of a series of blunt leading edge, semispan delta wings having a 70-deg leading-edge sweep angle. Each wing configuration was comprised of triangular forward and tip panels and a rectangular main wing panel. Data were obtained at Mach numbers from 3 to 8 over an angle-of-attack range from -2 to 14 deg. Testing was primarily at a Reynolds number, based on the maximum wing root chord (48 in.), of 14.4×10^6 with additional testing at Reynolds numbers of 9.6×10^6 and 3.4×10^6. Selected results are presented showing the effect of forward panel bluntness and deflection, and Mach number on the wing lift-to-drag ratios.

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I. ILLUSTRATIONS

NOMENCLATURE

c	Wing root chord (48 in.)
C_D	Forebody drag coefficient, drag/$q_\infty S$
C_L	Lift coefficient, lift/$q_\infty S$
L/D	Lift-to-drag ratio
M_∞	Free-stream Mach number
p_o	Tunnel stilling chamber pressure, psia
q_∞	Free-stream dynamic pressure, psia
Re_c	Free-stream Reynolds number based on wing root chord (48.00 in.)
S	Model reference area, see Fig. 1, in.^{2}
T_o	Tunnel stilling chamber temperature, °R
α	Model angle of attack, deg

MODEL NOMENCLATURE

F	Forward wing panel
T	Tip wing panel
W	Main wing panel

SECTION I
INTRODUCTION

Aerospace Research Associates, Inc. (ARA, Inc.) is engaged in a program to determine the maximum lift-to-drag ratios of delta wing configurations. In support of this program, a series of static force tests were conducted on configurations of a 70-deg, blunt leading-edge, semispan delta wing. The model consisted of a main rectangular panel and triangular forward and tip panels. Various configurations were obtained by varying the bluntness of the forward panel, by deflecting the forward panel nose down, and by varying the chordwise and spanwise gaps between the panels. Other results of this test program are reported in Refs. 1 to 3.

Data were obtained at Mach numbers 3, 4, 4.5, 5, 6, and 8 at angles of attack from -2 to 14 deg. The primary Reynolds number, based on the wing root chord of 48 in., was 14.40×10^6 with additional data being obtained at Reynolds numbers of 9.60×10^6 and 3.36×10^6.

SECTION II
APPARATUS

2.1 WIND TUNNELS

Tunnel A is a continuous, closed-circuit, variable density wind tunnel with an automatically driven flexible plate nozzle and a 40- by 40-in. test section. The tunnel operates at Mach numbers 1.5 to 6 at maximum stagnation pressures from 29 to 200 psia, respectively, and stagnation temperatures up to 760°R ($M_\infty = 6$). Minimum operating pressures range from about one-tenth to one-twentieth of the maximum pressures.

Tunnel B is a continuous, closed-circuit, variable density wind tunnel with axisymmetric contoured Mach 6 or 8 nozzles and a 50-in.-diam test section. The tunnel operates at stagnation pressures from 20 to 300 psia ($M_\infty = 6$) and from 50 to 900 psia ($M_\infty = 8$) and at stagnation temperatures up to about 1350°R. Additional information on both tunnels may be found in Ref. 4.

2.2 MODELS AND MODEL SUPPORT

The models, supplied by ARA (Fig. 1), were constant thickness (1.5 in.), semispan delta wings having hemispherical leading edges, 70-deg sweep angle, and a maximum root chord of 48 in. Wing configurations consisted of a triangular tip and rectangular main wing panel, and three different forward panels (Fig. 1). Additional configurations were obtained by deflecting the forward panel down 3 deg and by varying the gaps between the panels, as shown in Fig. 2.

Sectional views showing the sidewall mounted angle-of-attack mechanism and support for the three wing panels for Tunnels A and B are presented in Figs. 3a and b, respectively. A description of the angle-of-attack mechanism and support equipment is given in Ref. 1. An installation photograph of configuration 2 installed in Tunnel A is presented in Fig. 4a, and Fig. 4b is a photograph of the different nose shapes for the forward panel.

2.3 INSTRUMENTATION AND TECHNIQUES

Total wing forces and moments were measured with a six-component, force-type, strain-gage balance supplied and calibrated by the VKF. In addition, for selected runs, the forces and moments acting on the forward and tip wing panels were measured with five-component, moment-type, strain-gage balances also supplied and calibrated by the VKF. A different total wing balance was used for each tunnel.

Preceding the test, a range of static loadings was applied to the balances which simulated the range of model loadings obtained during the test. Listed below is the range of uncertainties, for the total wing balances, which correspond to the difference between the applied loads and the values calculated by the final data reduction balance equations. Since the balance was mounted perpendicular to the flow, the balance components listed correspond to the model component measured and are not necessarily the balance components normally used to obtain these forces and moments.

TUNNEL A BALANCE

Balance Component	Design Load	Maximum Static Loads	Maximum Model Loads	Uncertainties
Normal Force, lb	600	250	325	±3.00
Axial Force, lb	600	50	35	±3.00

TUNNEL B BALANCE

Balance Component	Design Load	Maximum Static Loads	Maximum Model Loads	Uncertainties
Normal Force, lb	1500	300	250	±5.00
Axial Force, lb	750	50	34	±3.00

Model base pressures were measured with the standard pressure system of each tunnel. The Tunnel A system utilizes 15-psid transducers referenced to a near vacuum. These transducers are calibrated for ranges of 15, 5, and 1 psia, and the precision of the system is estimated to be within 0.25 percent of full scale of the range being used. The Tunnel B system incorporates differential pressure transducers of 15-psid capacity referenced to a vacuum, and the uncertainty of measurement is considered to be not more than ±0.003 psia or ±0.5 percent, whichever is greater.

For both tunnels, the angle of attack is considered to be correct to within ±0.1 deg, and the centerline flow uniformity is within ±0.5 percent in Mach number.

A summary of the test program is presented in Table I; listed below are the test conditions at each Mach number for the primary Reynolds number, $Re_c = 14.40 \times 10^6$.

M_∞	p_o, psia	T_o, °R	q_∞, psia
2.99	24.4	562	4.22
4.02	42.8	570	3.10
4.53	56.5	580	2.70
5.03	79.0	619	2.56
6.05	202.0	858	3.13
8.01	836.0	1351	3.81

SECTION III
RESULTS AND DISCUSSION

Selected results of the tests at M_∞ = 4.02 and 8.01 are presented in Figs. 5 through 8. In regard to these results, it should be noted that in many cases the data points shown are the result of fairings made through the test points to eliminate data scatter. This data scatter (primarily in drag) was the result of the method used to support the model wherein the balance had to be located a long distance away from the wing center-of-pressure and center-of-gravity positions and, consequently, a large capacity balance, relative to the model air loads, had to be used.

The data of Fig. 5 for configuration 1 at M_∞ = 4.02 and 8.01 typify the trends of C_L and C_D with angle of attack for all configurations and Mach numbers. The variation of the lift-to-drag ratio for various wing configurations at M_∞ = 4.02 and 8.01 is shown in Figs. 6 and 7. Figure 6 shows the decrease obtained in L/D with increasing bluntness of the forward panel; and comparing Figs. 6 and 7, it can be seen that deflecting the forward panel -3 deg also generally decreased L/D but that the same (or nearly so) maximum L/D value was obtained although at a higher angle of attack. For the basic configuration (1) at M_∞ = 4.02, there was little or no effect of the forward panel deflection at $\alpha \geq$ 6 deg.

No results are presented for the various gap configurations tested since the effect of the gaps on L/D were within the measurement precision.

Figure 8 presents the variation of $(L/D)_{max}$ with Mach number for various wing configurations. In general, $(L/D)_{max}$ decreased with increasing Mach number and with forward panel bluntness.

REFERENCES

1. Coats, Jack D. and Morgan, L. A. "Force Tests on Flat, Chambered, and Twisted Wings at Mach Numbers 3, 4, and 6." AEDC-TN-61-147 (AD326853), November 1961.

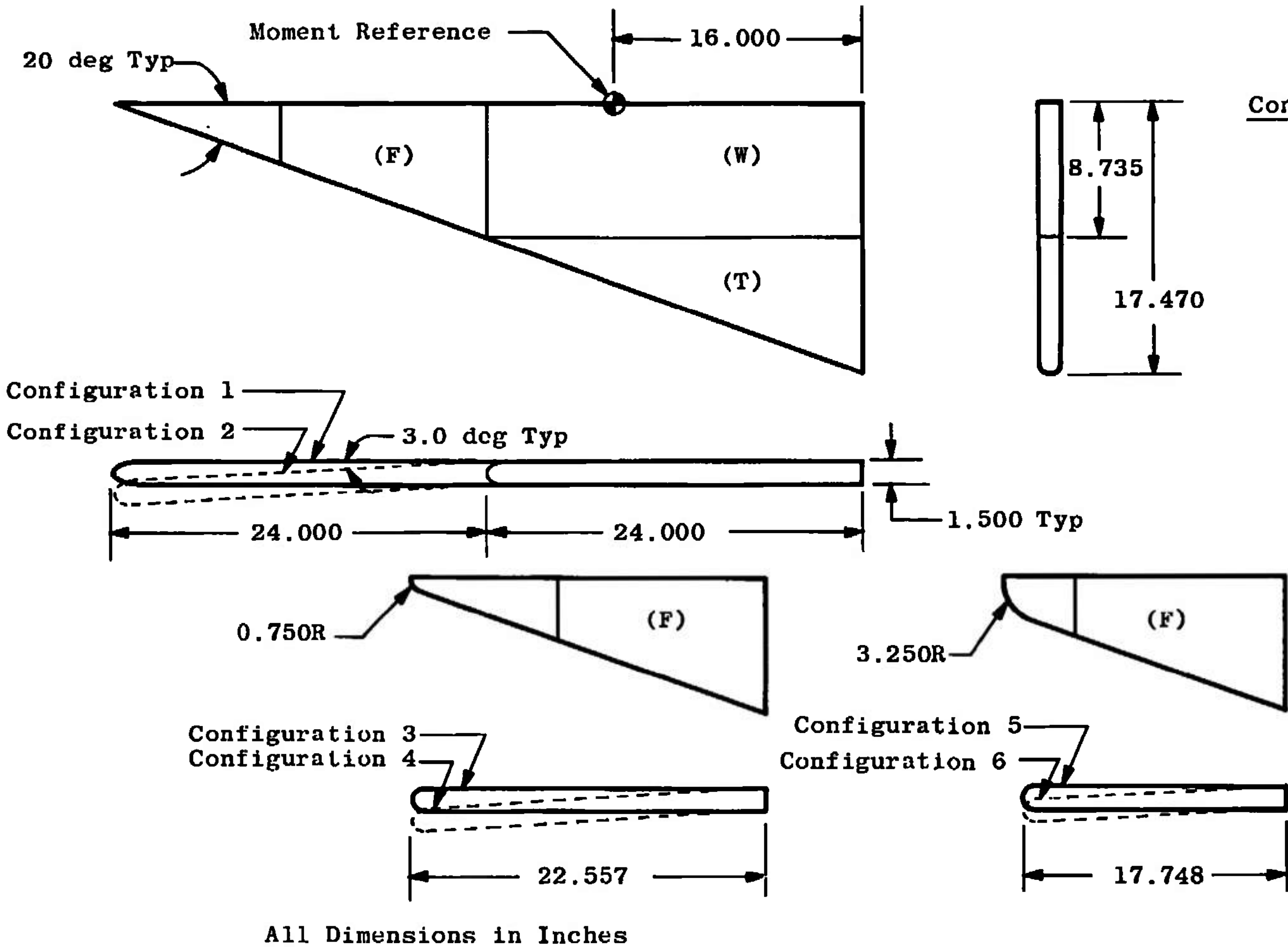
2. Pfaff, Larry J. "Force and Pressure Tests on a Semispan Delta Wing at Supersonic Speeds." AEDC-TR-65-165 (AD467448), August 1965.

3. Merz, Glenn H. "Force Tests of a Slotted Semispan Delta Wing Model at Hypersonic Mach Numbers." AEDC-TR-68-47, February 1968.

4. <u>Test Facilities Handbook</u> (Sixth Edition). "von Kármán Gas Dynamics Facility, Vol. 4." Arnold Engineering Development Center, November 1966.

APPENDIXES

I. ILLUSTRATIONS
II. TABLE



Configuration	S, in.^{2}
1,2	419.293
3,4	418.864
5,6	411.236

Fig. 1 Model Details

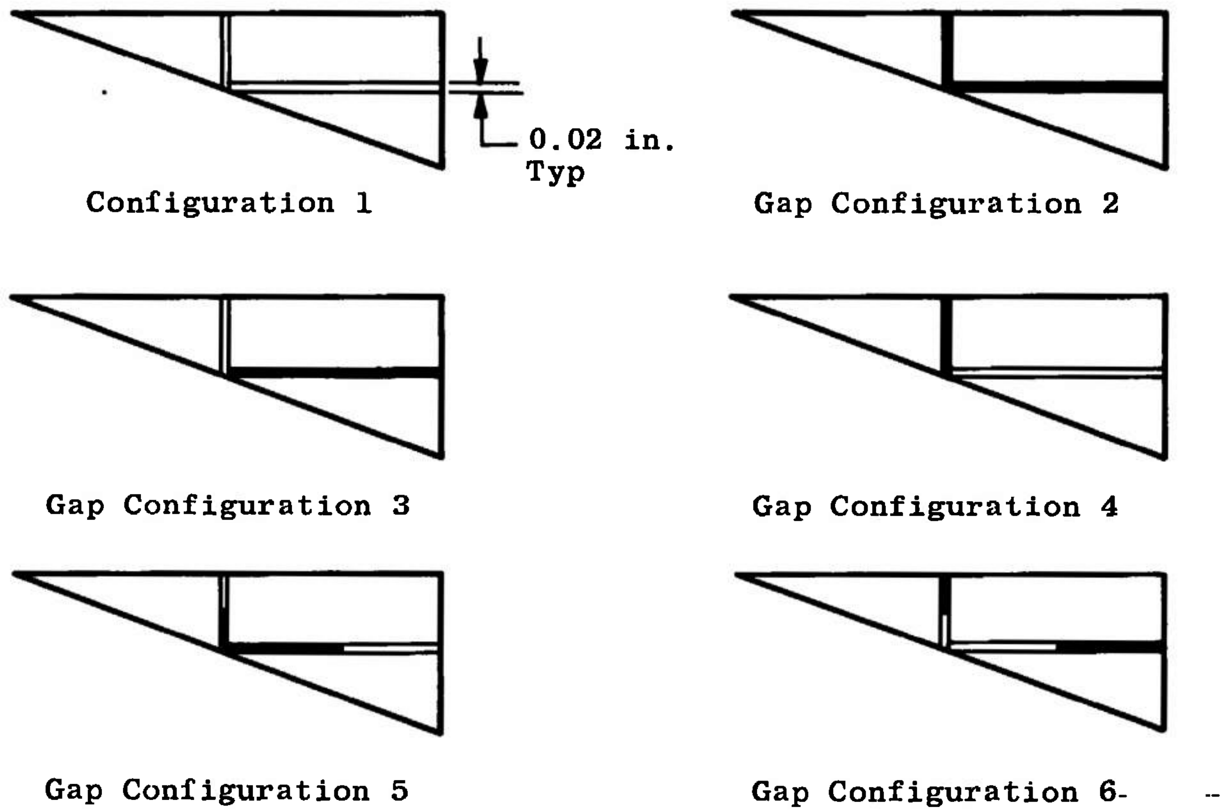
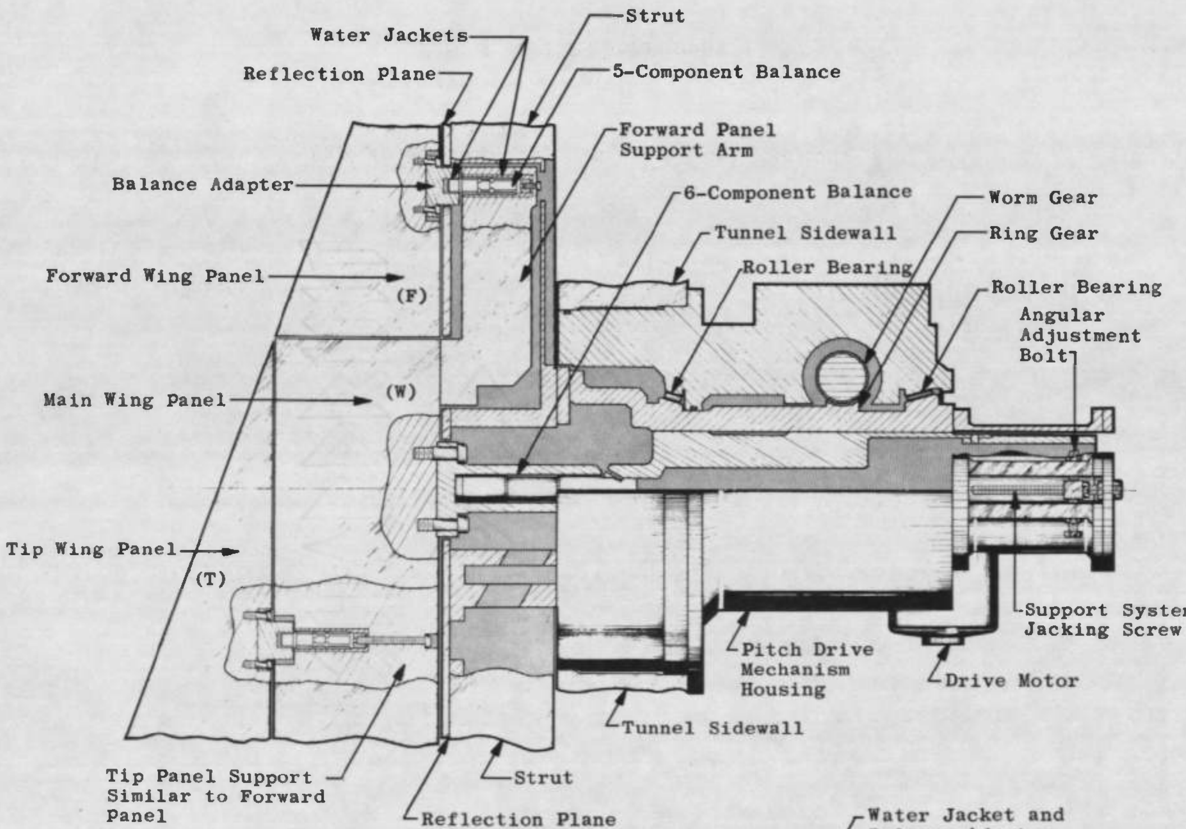
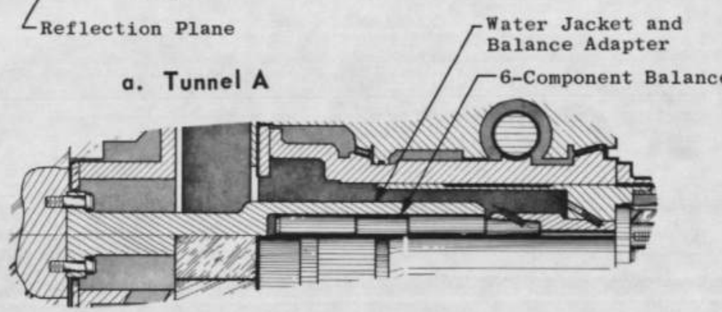


Fig. 2 Sketch of Gap Variation Configurations

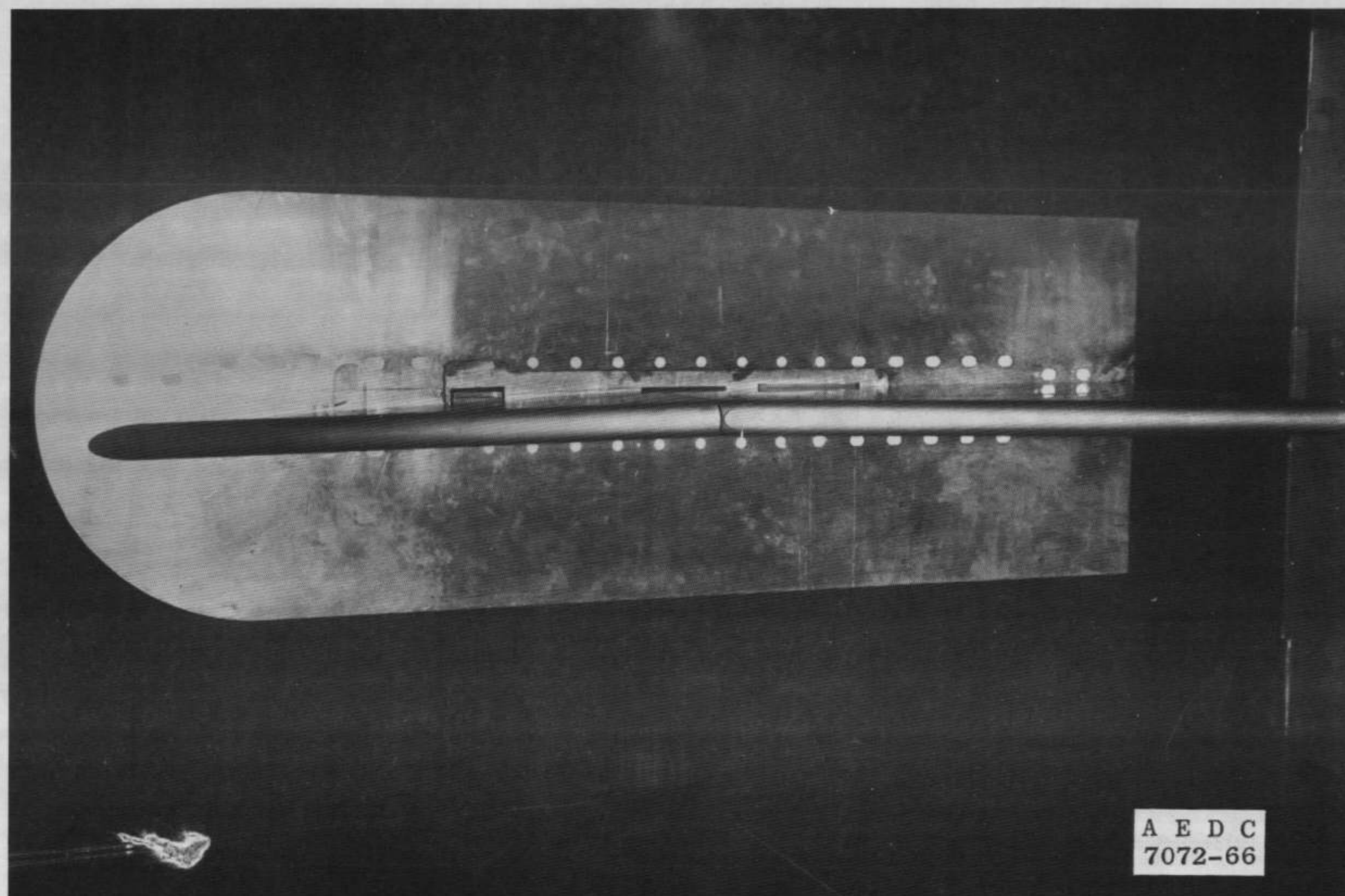


a. Tunnel A



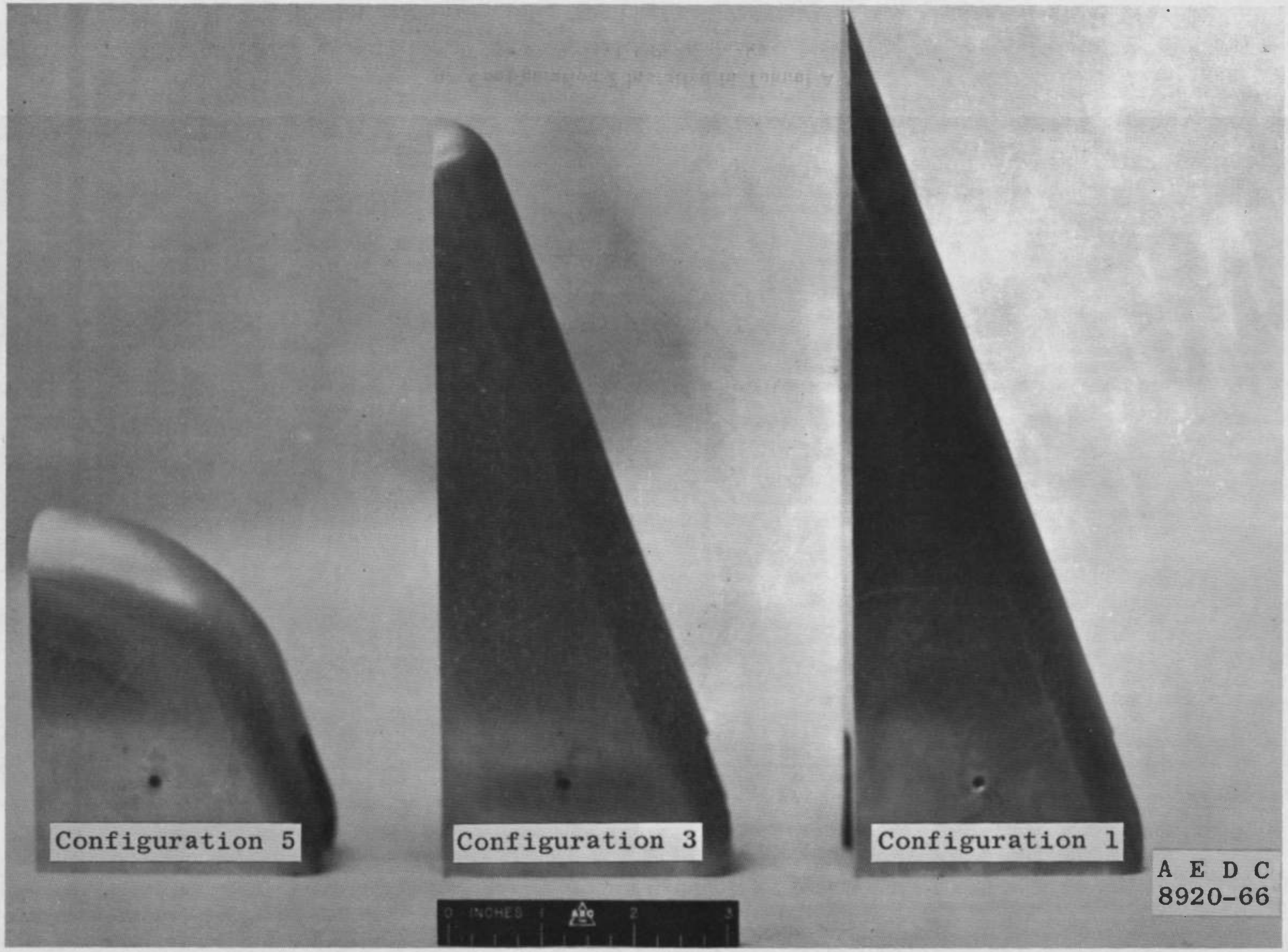
b. Tunnel B

Fig. 3 General Arrangement of the Sidewall Angle-of-Attack Mechanism and Model Support Details



a. Configuration 2 Installed in Tunnel A

Fig. 4 Model Photographs



b. Forward Panel Sections
Fig. 4 Concluded

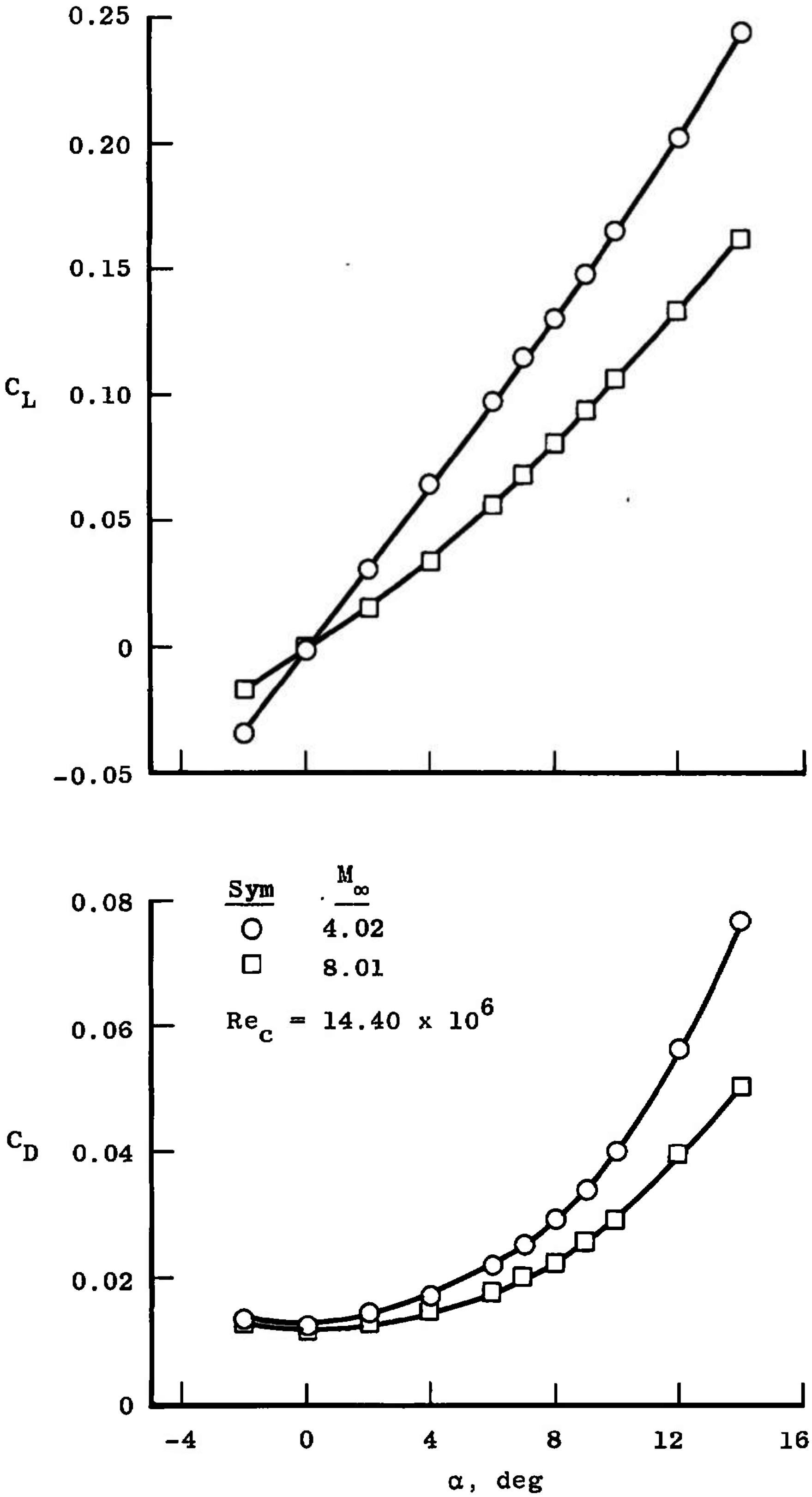


Fig. 5 Variation of C_L and C_D with Angle of Attack for Configuration 1

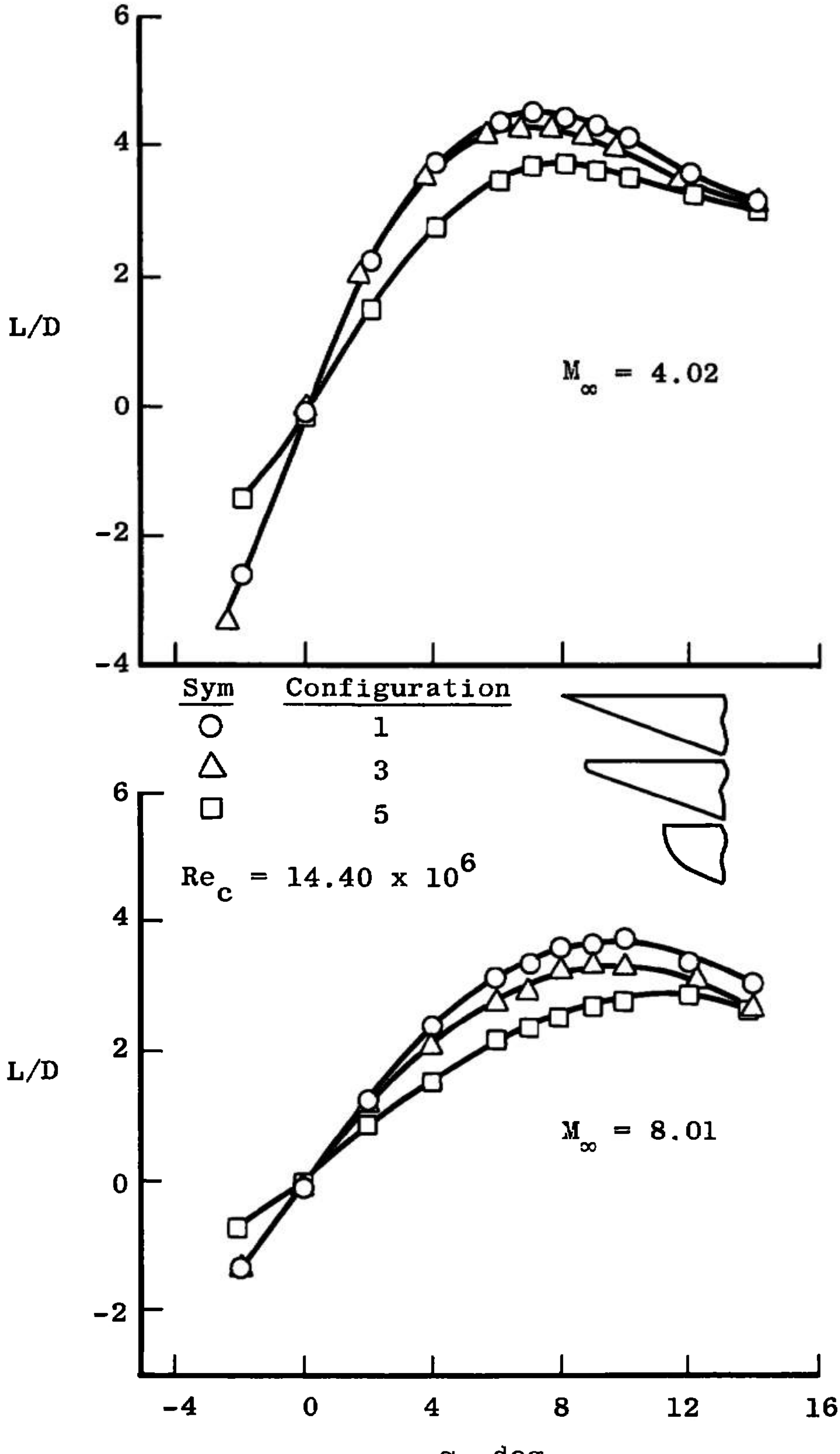


Fig. 6 Effect of Forward Panel Bluntness on L/D at M_∞ = 4.02 and 8.01

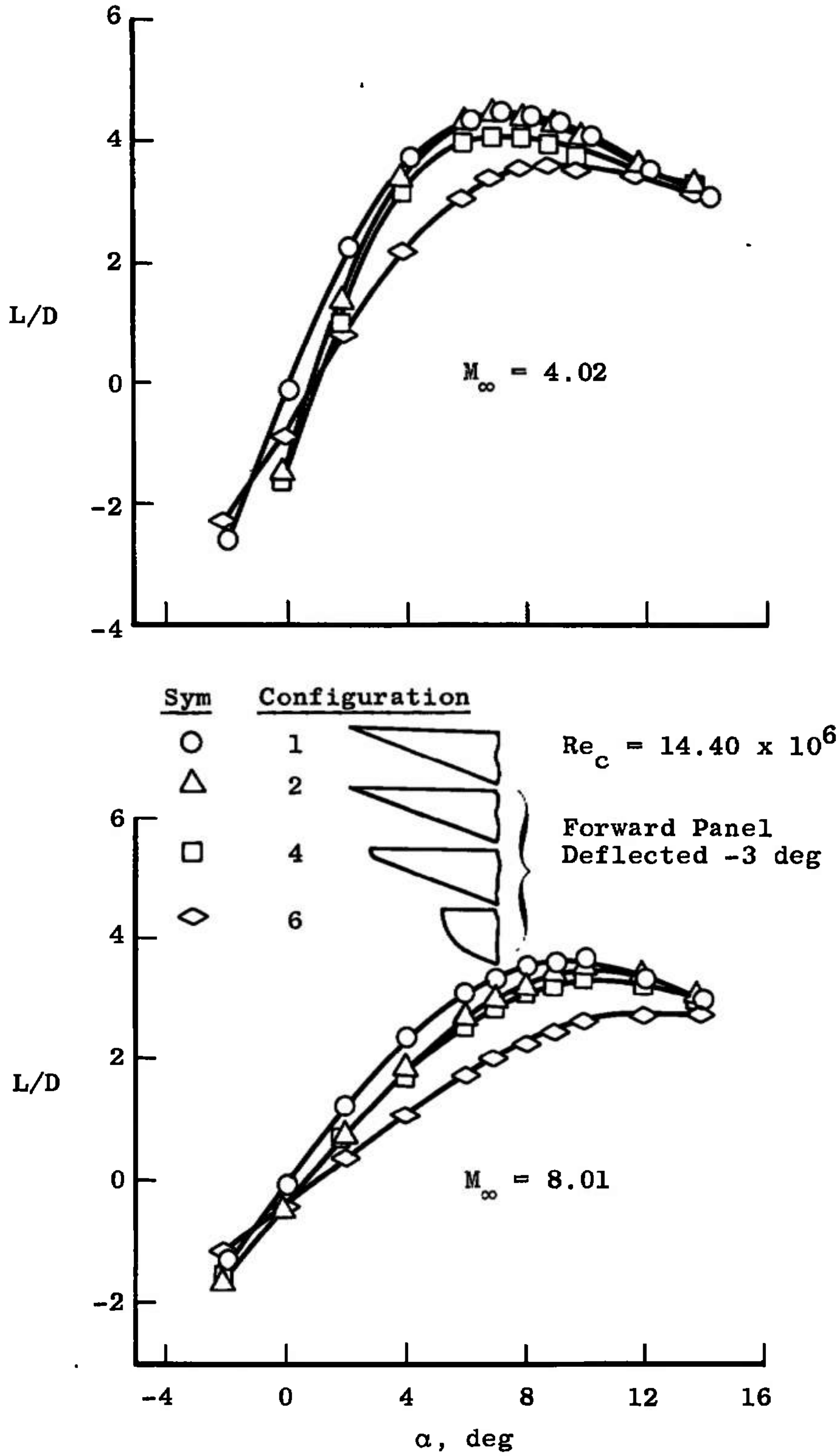


Fig. 7 Effect of Forward Panel Deflection on L/D at M_∞ = 4.02 and 8.01

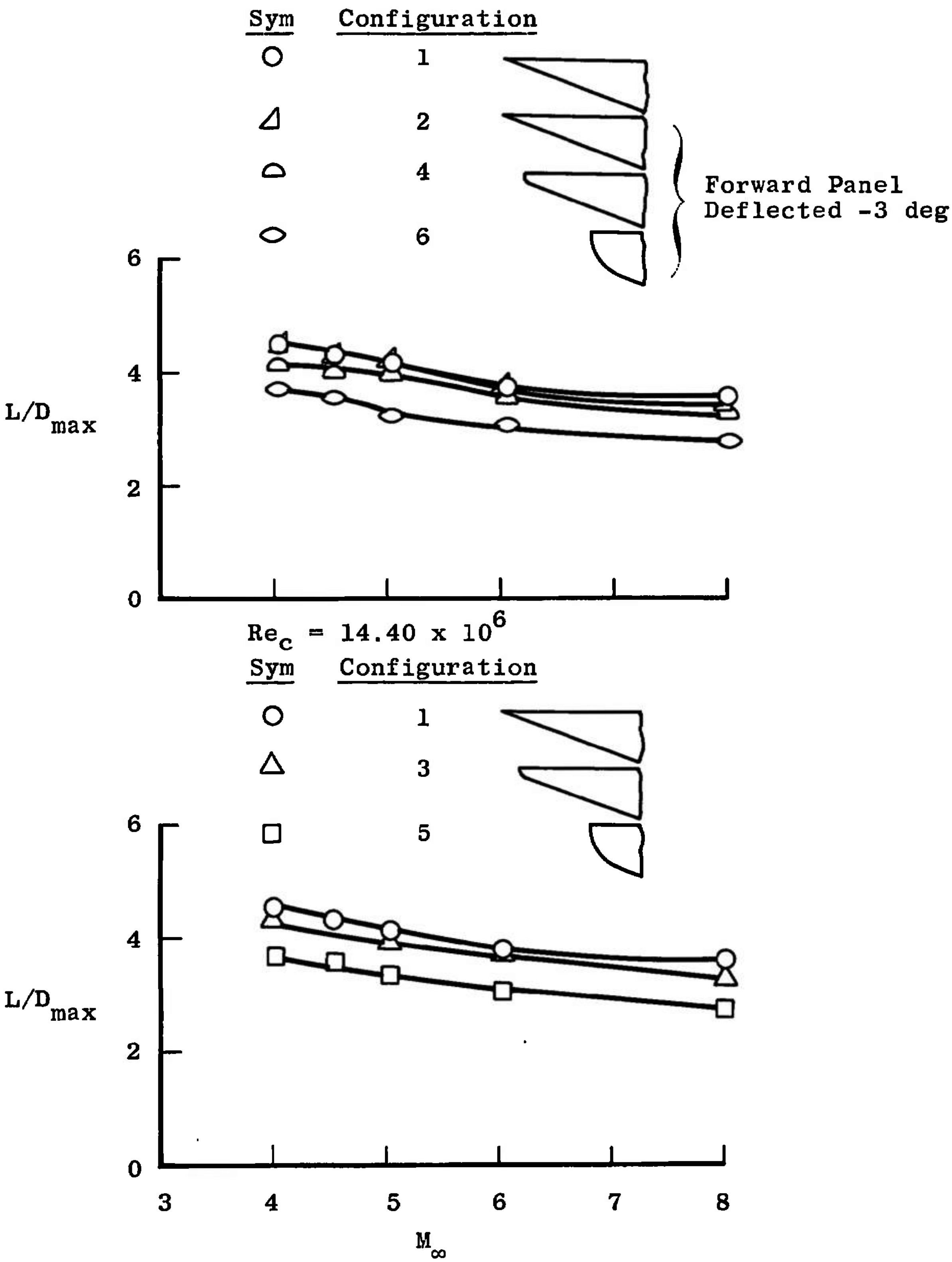


Fig. 8 Variation of $(L/D)_{max}$ with Mach Number

TABLE I
TEST SUMMARY

M_∞	$Re_c \times 10^{-6}$	Configuration					
		1	2	3	4	5	6
2.99	14.40	α_1 and A_1	α_1 and A_1	α_1 and A_1	α_1 and A_1	α_1 and A_1	α_1 and A_1
2.98	3.36	α_2 and A_1		α_2 and A_1		α_2 and A_2	
4.02	14.40	α_2, A_1 and A_2***	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1
4.53	14.40	α_2, A_1 and A_2***	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1
4.50	3.36	α_2 and A_1		α_2 and A_1		α_2 and A_1	
5.03	14.40	α_2, A_1, A_2,*** and A_3	α_2 and A_1	α_2, A_1, and A_3	α_2 and A_1	α_2 and A_1	α_2 and A_1
5.02	9.60	α_2 and A_3		α_2 and A_3			
4.95	3.36	α_2, A_1 and A_3		α_2, A_1, and A_3		α_2 and A_1	
5.95*	14.40	α_2, A_1 and A_3	α_2 and A_1	α_2, A_1, and A_3	α_2 and A_1	α_2 and A_1	α_2 and A_1
5.93*	9.60	α_2 and A_3		α_2 and A_3			
5.82*	3.36	α_2, A_1 and A_3		α_2, A_1, and A_3		α_2 and A_1	
6.05**	14.40	α_2 and A_1		α_2 and A_1		α_2 and A_1	
8.01	14.40	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1
7.91	3.36	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1	α_2 and A_1

M_∞	$Re_c \times 10^{-6}$	Gap Configuration				
		2	3	4	5	6
4.02	14.40	α_2 and A_2	α_2 and A_2	α_2 and A_2	α_2 and A_2	α_2 and A_2
4.53	↓	↓	↓	↓	↓	↓
5.03						
8.01						

Gap between panels = 0.020 in. except as noted

α_1 = -2 to 9 deg

α_2 = -2 to 14 deg

A_1 - Measured forces and moments on total wing and forward and tip panels

A_2 - Measured forces and moments on total wing only

A_3 - Configuration consisted of forward panel only

*Tunnel A

**Tunnel B

***Configuration tested with gaps between panels equal to 0.015, 0.020, and 0.030 in.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Arnold Engineering Development Center ARO, Inc., Operating Contractor Arnold Air Force Station, Tennessee	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
	2b. GROUP N/A

3. REPORT TITLE
LIFT-TO-DRAG RATIOS OF SEMISPAN DELTA WING CONFIGURATIONS AT SUPERSONIC AND HYPERSONIC MACH NUMBERS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Jan. 6-11, May 2-6, Dec. 29, 1966 - Jan. 3, 1967; Dec. 6-13, 1967-Final

5. AUTHOR(S) (First name, middle initial, last name)
Larry J. Pfaff, ARO, Inc.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
May 1968	22	4

8a. CONTRACT OR GRANT NO. AF 40(600)-1200	9a. ORIGINATOR'S REPORT NUMBER(S) AEDC-TR-68-95
b. PROJECT NO. 9781	
c. Program Element 6244501F	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A
d. Task 978101	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
Available in DDC	Air Force Office of Scientific Research (SREM), Washington, D.C.

13. ABSTRACT

Tests were conducted in the 40-in. supersonic and 50-in. hypersonic tunnels of the von Kármán Gas Dynamics Facility (VKF) to determine the maximum lift-to-drag ratios of a series of blunt leading edge, semispan delta wings having a 70-deg leading-edge sweep angle. Each wing configuration was comprised of triangular forward and tip panels and a rectangular main wing panel. Data were obtained at Mach numbers from 3 to 8 over an angle-of-attack range from -2 to 14 deg. Testing was primarily at a Reynolds number, based on the maximum wing root chord (48 in.), of 14.4×10^6 with additional testing at Reynolds numbers of 9.6×10^6 and 3.4×10^6. Selected results are presented showing the effect of forward panel bluntness and deflection, and Mach number on the wing lift-to-drag ratios.

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DD FORM 1 NOV 65 1473

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
supersonic flow						
hypersonic flow						
lift						
drag						
Delta Wing Configurations						

1-2

1. Triangular wings - - Lift

2 " " - - Drag -

Security Classification