# AEDC-TR-69-51

ಯಾಯಾಯ

ANEINERINE INTO

**VEDC TECHNICAL LIBRAR** 

EDEI

Ē

# PRESSURE MEASUREMENTS IN THE NEAR FIELD OF A THREE-DIMENSIONAL DELTA WING MODEL

**ARCHIVE COPY** 

**DO NOT LOAN** 

. ....

ey i

Ernest J. Lucas

ARO, Inc.

This document has been app: oved for public release B72-19, its distribution is unlimited. PER TAB72-19, D+010ct., 72.

March 1969

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Air Force Office of Scientific Research (SREM), Arlington, Virginia 22209.

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

PROPERTY CF U. S. AIR FORCE ANDC LIDEARY F40600 - 69 - C - 0001



When U. S. Government drawings specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings. specifications, or other data, is not to be regarded by implication or otherwise, or in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Qualified users may obtain copies of this report from the Defense Documentation Center.

References to named commercial products in this report are not to be considered in any sense as an endorsement of the product by the United States Air Force or the Government.

# PRESSURE MEASUREMENTS IN THE NEAR FIELD OF A THREE-DIMENSIONAL DELTA WING MODEL

Ernest J. Lucas ARO, Inc.

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Air Force Office of Scientific Research (SREM), Arlington, Virginia 22209.

This document has been approved for public release  $\mathcal{R}$   $\mathcal{R}$   $\mathcal{R}$ ,  $\mathcal{R}$ ,  $\mathcal{R}$   $\mathcal{R}$ ,  $\mathcal{R}$   $\mathcal{R}$ ,  $\mathcal{R}$ 

#### FOREWORD

The work reported herein was done at the request of the Air Force Office of Scientific Research (AFOSR), Air Force Systems Command (AFSC), for Aerospace Research Associates (ARA, Inc.), West Covina, California, under Program Element 61102F, Project 9781.

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), AFSC, Arnold Air Force Station, Tennessee, under Contract F40600-69-C-0001. The test program was conducted from November 6 through December 9, 1968, under ARO Project No. VT0864, and the manuscript was submitted for publication on February 4, 1969.

Information in this report is embargoed under the Department of State International Traffic in Arms Regulations. This report may be released to foreign governments by departments or agencies of the U. S. Government subject to approval of the Air Force Office of Scientific Research (SREM), or higher authority within the Department of the Air Force. Private individuals or firms require a Department of State export license.

This technical report has been reviewed and is approved.

Eugene C. Fletcher Lt Colonel, USAF AF Representative, VKF Directorate of Test

÷.

Roy R. Croy, Jr. Colonel, USAF Director of Test

ii

## ABSTRACT

Tests were conducted to determine the near field static pressure signatures created by a 70-deg sweep delta wing model. The model was tested with three leading edges of 0-, 7-, and 11-deg camber and with three leading-edge slot width conditions (0, 0.03, and 0.10 in.). Static pressure signatures were measured with a traversing disk-type pressure probe. A 9-deg half-angle cone was used to generate a flow field through which the disk static pressure probe was traversed for the basic probe calibration. The tests were conducted at free-stream Mach numbers 1.76, 2.00, and 3.00 at model angles of attack of 0 and 6 deg and Reynolds numbers, based on the 10-in. model root chord, from 1.5 x  $10^6$  to 4.2 x  $10^6$ .

This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Air Force Office of Scientific Research (SREM), Arlington, Virginia 22209. This document has been approved for public release B12-19, DERTAB12, 10 Dt.J. (OCT.) its distribution is unlimited.

## CONTENTS

		Page
	ABSTRACT	iii
	NOMENCLATURE	vi
I.	INTRODUCTION	1
II.	APPARATUS	
	2.1 Wind Tunnel	1
	2.2 Model	2
	2.3 Survey Probe Instrumentation and Technique	3
III.	RESULTS AND DISCUSSION	
	3.1 Probe Calibration	3
	3.2 Delta Wing Surveys	4
	REFERENCES	4

## TABLE

I.	Test	Summary	•	•				•			•	•		•	•	•	•	•	•	•	•		2
----	------	---------	---	---	--	--	--	---	--	--	---	---	--	---	---	---	---	---	---	---	---	--	---

## APPENDIX

## Illustrations

## Figure

-

1.	Model Photographs	
	a. Basic Configuration (Zero Camber, Slot	
	Sealed) Installed in Tunnel A	9
	b. Centerbody with Leading Edges	10
2.	Model Geometry	11
3.	Probe and Survey System	
	a. Disk Probe Details	12
	b. Survey System Setup	13
4.	Probe Static Pressure Compared to Conical	
	Flow Theory	14
5.	Leading-Edge Effect for $\alpha = 0$	15
6.	Leading-Edge Effect for $\alpha = 6$ deg	
	a. Slot Sealed	16
	b. 0.03-in. Slot	17
	c. 0.10-in. Slot	18

.

# FigurePage7. Slot Effects at $\alpha = 6 \deg$ 19b. 7-deg Camber20c. 11-deg Camber21

## NOMENCLATURE

Μ <sub>∞</sub>	Free-stream Mach number
р	Probe static pressure, psia
p <sub>∞</sub>	Free-stream static pressure, psia
Rel	Free-stream Reynolds number, based on model root chord length of 10.0 in.
Re <sub>w</sub>	Free-stream unit Reynolds number, in. $^{-1}$
х	Axial distance from model nose, positive downstream, in. (see Fig. 3b)
<sup>ж</sup> с	Axial distance from calibration cone nose, positive downstream, in.
z	Vertical distance from model nose, positive down, in. (see Fig. 3b)
α	Angle of attack, deg

1

p

# SECTION I

These tests constitute the second phase of a wind tunnel test program for sonic boom reduction studies on a three-dimensional delta wing model. Aerospace Research Associates (ARA, Inc.) is conducting a research program to investigate reduction of the sonic boom overpressure while maintaining or increasing the vehicle lift-to-drag ratio. The objective of the first-phase test program (Ref. 1) was to investigate the effect of various leading-edge slot widths and cambers on the vehicle lift-to-drag ratio. In the present test, the effect of leading-edge camber and slot width on the near field static pressure signatures was investigated. Three leading-edge configurations, cambered 0, 7, and 11 deg, were tested with nominal slot widths of 0, 0.03, and 0.10 in.

For the disk static pressure probe calibration, a 9-deg half-angle cone was used to generate a flow field through which the disk probe was traversed. These data were compared with theoretical results from a numerical solution of the nonlinear differential equations of Taylor and Maccoll described in Ref. 2.

The tests were conducted in the 40-in. supersonic tunnel (Gas Dynamic Wind Tunnel Supersonic (A)) of the von Karman Gas Dynamics Facility (VKF) at Mach numbers of 1.76, 2.00, and 3.00 at angles of attack of 0 and 6 deg and Reynolds numbers, based on the wing root chord of 10 in., from  $1.5 \times 10^6$  to  $4.2 \times 10^6$ .

# SECTION II

#### 2.1 WIND TUNNEL

Tunnel A is a continuous, closed-circuit, variable density wind tunnel with an automatically driven flexible-plate-type nozzle and a 40- by 40-in. test section. The tunnel is operated at Mach numbers from 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 onetwentieth of the maximum pressures. A more complete description of the tunnel and airflow calibration information may be found in Ref. 3.

## 2.2 MODEL

-1

The model, supplied by ARA, Inc., was a 70-deg sweep delta wing with a 10-deg included thickness angle (angle between upper and lower surfaces in a longitudinal cross section) and a 10-in. centerline chord length. Photographs of the basic model configuration (zero camber leading edge, slot sealed) installed in Tunnel A with the probe system and of the model with the three leading edges are presented in Figs. 1a and b (Appendix), respectively. The three leading edges were cambered 0, 7, and 11 deg in a plane parallel to the free-stream flow (see Fig. 2). The slot between the main body and the leading edge was measured normal to the centerbody-leading-edge junction as shown in Fig. 2.

It should be noted that the slot was not uniform (maximum deviation from the nominal values was  $\pm 0.01$  in.) along the leading edge. An epoxy was used to seal the slot for the closed slot configuration. Also, the leading edge was thicker than the centerbody at their junction such that a discontinuity (0.006 to 0.025 in.) existed in the model surface contour.

A 9-deg half-angle sharp cone 13.73 in. long was used as a flow field generator for the disk probe calibration. The cone was mounted in the tunnel at zero angle of attack in the same tunnel location as the delta wing (see Fig. 3). A summary of the delta wing model configurations and test conditions and cone calibration test conditions is given below.

Configu	ration	Angle of		
Leading-Edge Camber, deg	Slot Width, in.	Attack, α, deg	$Re_{\infty} \times 10^{-6}$ , in. <sup>-1</sup>	$\mathbf{M}_{\omega}$
0	0	0, 6	0.15 and 0.34	1.76, 2.0, 3.0
0	0.03 and 0.10	6	0.34	ľ
7	0	0,6	0.15 and 0.34	
7	0.03 and 0.10	6	0.34 and 0.42	
11	0	0,6	0.15 and 0.34	+
11	0.03 and 0.10	6	0.34	1.76, 2.0, 3.0
Calibration		0	0.34	1.76, 2.0, 3.0
<u>Cone</u>				

## TABLE I TEST SUMMARY

#### 2.3 SURVEY PROBE INSTRUMENTATION AND TECHNIQUE

The static pressure probe used for these surveys was a 1-in. diam disk (Fig. 3a). The probe was oriented such that the probe face was aligned with and parallel to the model vertical centerline plane, which was coincident with the wind tunnel x-z plane (see Fig. 3b). With this orientation, and traversing axially along the model centerline plane only, the probe surface was always in the plane of the flow direction. To reduce the effect of variations in free-stream static pressure created by small fluctuations in the tunnel supply pressure, a test section sidewall static pressure measurement was used to electrically cancel these effects, pressure measurement was used to electrically cancel these effects, as suggested by Ref. 4. No effort was made to correct the pressure signatures for the test section axial static pressure gradient (maximum  $\Delta p_{\phi}/p_{\phi} = \pm 3$  percent over  $\Delta x = 53$  in.). The probe system provided a remotely controlled longitudinal traverse of 53 in.

Miniature transducers used to measure the probe static pressures were developed at VKF primarily for use in the VKF hotshot tunnels. The transducers were calibrated for 3.0-psid full scale, and a variable reference pressure was utilized to stay within this limit. The transducers are considered accurate to within  $\pm 2$  percent of the calibrated range.

The data were recorded on analog (x-y) plotters, which provided a continuous trace of the probe static pressure with axial position (x), and on tape for computer computation of discrete points for tabulated data.

## SECTION III RESULTS AND DISCUSSION

## 3.1 PROBE CALIBRATION

Results of the probe calibration in a conical flow field are compared in Fig. 4 with an inviscid theoretical prediction (using Ref. 2) for the 9-deg half-angle cone. The agreement between the measured pressure rise across the shock and the inviscid calculation is observed to be good at Mach numbers 2.0 and 3.0, although the flow field pressures behind the shock were lower than theory. The measured pressures were consistently lower than theoretical at Mach number 1.76.

The disk probe was traversed ahead of the conical calibration body and the delta wing model leading-edge shocks. The probe's ability tomeasure free-stream static pressure was thereby determined and is shown in the data traces (Figs. 4 to 7). The maximum deviation from the calculated free-stream static pressure, which is based on an average test section Mach number from tunnel calibration, was  $\pm 5$  percent. A portion of this deviation can also be attributed to test section axial free-stream pressure gradients and to small misalignments of the probe relative to the free-stream flow direction.

## 3.2 DELTA WING SURVEYS

The leading-edge slots were expected to be effective only at angle of attack, so only the slot-sealed configurations were tested at  $\alpha = 0$ . The static pressure signatures for the three leading-edge cambers are presented in Fig. 5 for the three Mach numbers tested.

Data were obtained at  $\alpha = 6$  deg for the three leading-edge cambers at slot widths of 0, 0.03, and 0.10 in., and the results are presented in Figs. 6a, b, and c, respectively. These data have also been plotted to show the effect of varying the slot width for the three wing leading edges in Figs. 7a, b, and c. There was no apparent reduction in the shock pressure rise with camber, but the maximum slot width (0.10-in.) changed the shape of the pressure signature at the z = 5-in. station in Figs. 7a and c (dashed curve). This was apparently a local disturbance, and the effect on the far field signature may be negligible since the effect was less prominent at the z = 17-in. station.

It should be noted that because of the model size and limited downstream probe travel, the complete typical "N"-type static pressure signatures could not be obtained at  $M_{\infty} = 3.0$ . The irregularities in the "plateau" region of the three-dimensional flow field signatures are attributed to the model slot or the step which existed when the slot was sealed. The final analysis of the data with respect to sonic boom reduction will be accomplished by ARA, Inc.

#### REFERENCES

 Lucas, E. J. and Martindale, W. R. "Force Tests on a Slotted Delta Wing with Varying Leading-Edge Camber at Supersonic Mach Numbers." AEDC-TR-68-257 (AD844666), December 1968.

- Taylor, G. I. and Maccoll, J. W. "The Air on a Cone Moving at High Speeds." <u>Proceedings of the Royal Society of</u> London (Series A), Vol. 139, March 1933.
- 3. <u>Test Facilities Handbook</u> (Seventh Edition). "von Karman Gas Dynamics Facility, Vol. 4." Arnold Engineering Development Center, July 1968.
- 4. Pate, S. R. "Pressure Measurements in the Near Field of a Supersonic Two-Dimensional Wing-Jet Configuration." AEDC-TR-68-131 (AD834772), June 1968.

.

# APPENDIX ILLUSTRATIONS

.

•



a. Basic Configuration (Zero Camber, Slot Sealed) Installed in Tunnel A Fig. 1 Model Photographs



b. Centerbody with Leading Edges
Fig. 1 Concluded









.



b. Survey System Setup

Fig. 3 Concluded

AEDC-TR-69-51



Fig. 4 Probe Static Pressure Compared to Conical Flow Theory



Fig. 5 Leading-Edge Effect for  $\alpha = 0$ 

•



a. Slot Sealed Fig. 6 Leading-Edge Effect for a = 6 deg

.



Fig. 6 Continued



Fig. 6 Concluded

18

AEDC-TR-69-51



<u>Sym</u>	Ma	Re <sub>L</sub> x 10 <sup>-6</sup>	p <sub>co</sub> , psia
Solid	1.76	3.4	2.78
Flagged	2.00	3.4 .	2.17
upen	3.00	3.4	U. 76

Data Fairing from Continuous Data Trace



b. 7-deg Camber Fig. 7 Continued

۰

.



AEDC-TR-69-51

UNCLASSIFIED								
Security Classification								
Security classification of title, body of abstract and indexing a	NUL VAIA - K & V mnotation must be entered when the	overall report is classified)						
I. ORIGINATING ACTIVITY (Corporate author) Annold Engineening Development Conte	28. REPORT SE	CURITY CLASSIFICATION						
ARO. Inc., Operating Contractor	26. GROUP							
Arnold Air Force Station, Tennessee		N/A						
3. REPORT TITLE PRESSURE MEASUREMENTS IN THE NEAR FI WING MODEL	ELD OF A THREE-DI	MENSIONAL DELTA						
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) November 6. through December 9, 1968	- Final Report							
5- AUTHOR(S) (First name, middle initial, last name)								
Ernest J. Lucas, ARO, Inc.								
March 1969	78. TOTAL NO. OF PAGES	76. NO. OF REFS 4						
58. CONTRACT OR GRANT NO. F40600-69-C-0001	Sa. ORIGINATOR'S REPORT NUM	BER(S)						
6. PROJECT NO 9781	AEDC-TI	R-69-51						
•Program Element 61102F	95. OTHER REPORT NO(5) (Any of this report)	ther numbers that may be assigned						
d								
each transmittal to foreign governme only with prior approval of Air Fore (SREM), Arlington, Virginia 22209.	oject to special ex ents or <del>foreign na</del> ce Office of Scient	kport <u>controls</u> and tionals may be made tific Research						
17. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTI							
Available in DDC.	Research (SREM)	Scientific						
	Arlington, Virgin:	La 22209						
Tests were conducted to determine the near field static pressure signatures created by a 70-deg sweep delta wing model. The model was tested with three leading edges of 0-, 7-, and 11-deg camber and with three leading-edge slot width conditions (0, 0.03, and 0.10 in.). Static pressure signatures were measured with a traversing disk-type pressure probe. A 9-deg half-angle cone was used to generate a flow field through which the disk static pressure probe was traversed for the basic probe calibration. The tests were conducted at free-stream Mach numbers 1.76, 2.00, and 3.00 at model angles of attack of 0 and 6 deg and Reynolds numbers, based on the 10-in. model root chord, from 1.5 x 10 <sup>6</sup> to 4.2 x 10 <sup>6</sup> . This document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of Air Force office of Scientific Research (SRPM), Arlington, Virginia 22209.								
DD FORM 1473	UNCI	ASSIFIED						
	Securit	y Classification						

## UNCLASSIFIED

Security Classification

4. KEY WORDS		LINK A		LINKB		ĸc
	ROLE	WT	ROLE	WT	ROLE	WT
delta wings swept wings wind tunnel models static pressure pressure signatures aircraft noise aerodynamic configurations supersonic flow I. Wingp 2 July 3 July 3 July	LIN ROLE Press 17 17	X A WT Suc	LIN ROLE	WT WT	LIN	
AFS4 Arrus AFS Trav						

UNCLASSIFIED

Security Classification

••