Table regions justan for the contexts of information. Is estimated to average 1 hor per response, housing the methods in submit of any other space of contexts. Section 2 methods. Packer regions justan for the contexts of information. Is estimated in the detaining the statements registering the submit of any other space of advector. Sections Provide State of advector. I. AGENT USE ONLY (Leave blank) I. REPORT DATE Sections Provide State of Versions Provide State Oversions Provide State of Versions Provide State of Versions Provide State of Versions Provide State Oversions Provide State State Oversions Provide Oversions Proversions Proversions Proversions Provide Oversions Provide Overs	REPORT DOCUMENTATION PAGE			Form	Approved OMB No. 0704-0188	
1. ACENCY USE ONLY (Leave blank) 2. REPORT DATE 3. REPORT TYPE AND DATES COVERED 1984 Final Report 4. TITLE AND SUBTITLE Final Report Investigation of Temperature Factor Influence on Control Surface Effectiveness in Hyperronic 5. FUNDING NUMBERS Flows With Moderate Interacation 5. FUNDING NUMBERS 6. AUTHOR(S) Dr Yu Emak 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) 8. PERFORMING ORGANIZATION RAME(S) AND ADDRESS(ES) Carital Aerohydroghamics Institute N/A Zhikowsky N/A Modoow 140f00 RePORT NAME(S) PSC 802 EDX 14 FPO 05469 0200 PSC 802 EDX 14 FPO 05469 0200 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION CODE 12a. DISTRIBUTIONAVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. A 113. RESTRACT (Maximum 200 words) Ibit regot results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind funnet, the model, the test program, and the test results obtained. 114. SUBJECT TERMS 15. NUMBER OF PAGES 13. 15. SECURITY CLASSIFICATION 16. FILE ODE MA 14. SUBJECT TERMS 1	Public reporting burden for this collection of infor gathering and maintaining the data needed, and collection of information, including suggestions f Davis Highway, Suite 1204, Arlington, VA 22202-	mation is estimated to average 1 hour pe completing and reviewing the collection of or reducing this burden to Washington He 4302, and to the Office of Management and	r response, including t ' information. Send co adquarters Services, I d Budget, Paperwork F	he time for reviewir mments regarding Directorate for Infon Reduction Project (0	ng instructions, searching existing data sources, this burden estimate or any other aspect of this mation Operations and Reports, 1215 Jefferson 704-0188), Washington, DC 20503.	
1994 Find Report 4. TITLE AND SUBTITLE 5. FUNDING NUMBERS Flows With Moderale Interaction 5. FUNDING NUMBERS Flows With Moderale Interaction For Control Surface Effectiveness in Hypersonic F. AUTHOR(6) Dr Yu Ernak 7. PERFORMING ORGANIZATION NAME(5) AND ADDRESS(ES) 6. PERFORMING ORGANIZATION Central Aerolyticitymanics Institute N/A 21.McVorky NUMBER 8. SPONSORING/MONITORING AGENCY INAME(6) AND ADDRESS(ES) Contral Aerolyticitymanics Institute 21.McVorky NUMBER 956 202 BOX 14 FPC D9498-0200 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION CODE 12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE 12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE 13. ABSTRACT (Medianum 200 words) This report results from a contract tasking Central Aerolyticolynamics Institute as follows: The present report contains the description o the wind turnet, the model, the test program, and the test results obtained. 14. SUBJECT TERMS 15. NUMBER OF PAGES 15. NUMBER OF TRACE 16. PRICE CODE 14. SUBJECT TERMS 17. PRICE CODE 15. NUMBER OF TRACE <td colspa<="" th=""><th>1. AGENCY USE ONLY (Leave blank)</th><th>2. REPORT DATE</th><th>3. REPORT</th><th>TYPE AND DAT</th><th>TES COVERED</th></td>	<th>1. AGENCY USE ONLY (Leave blank)</th> <th>2. REPORT DATE</th> <th>3. REPORT</th> <th>TYPE AND DAT</th> <th>TES COVERED</th>	1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT	TYPE AND DAT	TES COVERED
4. TITLE AND SUBTITLE 6. FUNDING MUMBERS Investigation of Temperature Factor Influence on Control Surface Effectiveness in Hypersonic Flows With Moderate Interaction 6. FUNDING ORGANIZATION NAME(S) AND ADDRESS(ES) 6. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) 8. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) 10. SPONSORINGANONITORING AGENCY NAME(S) AND ADDRESS(ES) 11. SUPPLEMENTARY NOTES 11. SUPPLEMENTARY NOTES 12. DISTRIBUTION CODE A 13. ABSTRACT (Moximum 200 words) This report report contains the description o the wind tunne, the model, the test program, and the test results obtaine		1994			Final Report	
Investigation of Temporature Factor Influence on Control Surface Effectiveness in Hypersonic Flows With Moderate Interacation F8170894W0088 6. AUTHOR(5) Dr Yu Emak PERFORMING ORGANIZATION NAME(5) AND ADDRESS(ES) Central Aerohydrodynamics Institute Zhukovsky Moscow 140160 SPONSORINGARONITORING AGENCY NAME(5) AND ADDRESS(ES) SPONSORINGARONITORING AGENCY NAME(5) ADDRESS(ES) SPONSORINGARONITORING AGENCY NAME(5) ADDRESS(ES)	4. TITLE AND SUBTITLE	•		5.	FUNDING NUMBERS	
6. AUTHOR(S) Dr Yu Ermak 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) 8. PERFORMING ORGANIZATION REPORT NUMBER 2. Distribution of the second status in the second status of the second status	Investigation of Temperature F Flows With Moderate Interacati	actor Influence on Control Surface Ef on	ffectiveness in Hype	ersonic	F6170894W0088	
Dr Yu Ermak Image: Second State Stat	6. AUTHOR(S)	···· ·································				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) 8. PERFORMING ORGANIZATION Central Aerohydrodynamics institute NA 2Tuktovsky NA B. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) 10. SPONSORING/MONITORING ECARD ECARD PSC 802 80X 14 SPC 94-4003 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS 15. NUMBER OF PAGES 14. SUBJECT TERMS 15. SECURITY CLASSIFICATION OF THIS PAGE 15. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT 20. LIMITATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT 21. INCLASSIFICATION 18. SECURITY CLASSIFICATION OF ABSTRACT 20. LIMITATION OF ABSTRACT 20. LIMITATION OF ABSTRACT	Dr Yu Ermak					
Zuktowsky Moscow 140160 Russia N/A 8. SPONSORINGMONITORING AGENCY NAME(S) AND ADDRESS(ES) 10. SPONSORINGMONITORING AGENCY NAME(S) AND ADDRESS(ES) E. GOARD PSC 802 BOX 14 FPO 09498-0200 10. SPONSORINGMONITORING AGENCY REPORT NUMBER 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION/AVAILABILITY STATEMENT 12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. 12b. DISTRIBUTION CODE 13. ABSTRACT (Maximum 200 words) A This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind turnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS DTIC QUALITY INSPECTED & 14. SUBJECT TERMS 12. NUMBER OF PAGES Nil 15. NUMBER OF PAGES Nil 16. PRICE CODE NA 17. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF THIS PAGE 20. LIMITATION OF ABSTRACT VI ASSELEED	7. PERFORMING ORGANIZATION NAM	E(S) AND ADDRESS(ES)		8.	PERFORMING ORGANIZATION	
ADDROVERY MOGEOUR 140160 Russia S. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) SPONSORING/MONITORING AGENCY NEPCORT NUMBER SPC 94-4003 SPC 94-403 SPC 94-4023 SPC 94-402	Central Aerohydrodynamics Ins	stitute			N/A	
Russia 10. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) 10. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) PSC 02407 PSC 02 802 14 SPC 94-4003 PSC 02 802 102 14 SPC 94-4003 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) 13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS DTIC QUALITY INSPECTED & Nil 15: NUMBER OF PAGES 14. SUBJECT TERMS 15: NUMBER OF PAGES Nil 18: SECURITY CLASSIFICATION OF THIS PAGE 17. SECURITY CLASSIFICATION OF THIS PAGE 19; SECURITY CLASSIFICATION OF ABSTRACT 18. NOV ASSIFIED 11: NOV ASSIFIED 11: NOV ASSIFIED	Znukovsky Moscow 140160				N/A	
8. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) 10. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) PSC 802 BOX 14 FPO 08499-0200 11. SUPPLEMENTARY NOTES 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. 12b. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) A This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS DTIC QUALITY INSPECTED & 14. SUBJECT TERMS 12b. NUMBER OF PAGES Nil 11. SECURITY CLASSIFICATION 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF THIS PAGE UNIX ASSIFICT UNIX ASSIFICATION 19. SECURITY CLASSIFICATION OF REPORT 11. NUMBER OF PAGES	Russia					
ECARD PSC 802 BOX 14 FPO 09499-0200 SPC 94-4003 11. SUPPLEMENTARY NOTES 12b. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. 12b. DISTRIBUTION CODE A 12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. 12b. DISTRIBUTION CODE A 13. ABSTRACT (Maximum 200 words) 13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 199980312 0666 DTIC QUALITY INSPECTED & 14. SUBJECT TERMS 15. NUMBER OF PAGES NII 15. NUMBER OF PAGES NII 12. ECURITY CLASSIFICATION OF THIS PAGE 17. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF THIS PAGE 18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF THIS PAGE	9. SPONSORING/MONITORING AGENC	Y NAME(S) AND ADDRESS(ES)		10.	SPONSORING/MONITORING AGENCY REPORT NUMBER	
IN SUPPLEMENTARY NOTES 12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. 1 13. ABSTRACT (Maximum 200 words) A This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. DTIC QUALITY INSPECTED & 14. SUBJECT TERMS NII 15. NUMBER OF PAGES NII 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICATION 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICE UNCLASSIFICE	EOARD PSC 802 BOX 14				SPC 94-4003	
11. SUPPLEMENTARY NOTES 12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited. 13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS NII 14. SUBJECT TERMS NII 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICATION 19. SECURITY CLASSIFICATION 19. SECURITY CLASSIFICATION 19. MICLASSIFICATION 11. MICLASSIFICATION	FPO 09499-0200					
12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) A This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnet, the model, the test program, and the test results obtained. DTIC QUALITY INSPECTED a 14. SUBJECT TERMS DTIC QUALITY INSPECTED a 15. NUMBER OF PAGES 32 16. PRICE CODE NII 17. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT 18. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF ABSTRACT 19. UNCLASSIFICATION 18. SECURITY CLASSIFICATION 19. MICLASSIFICATION 19. SECURITY CLASSIFICATION 19. MICLASSIFICATION 11. MICLASSIFICATION	11 SUPPLEMENTARY NOTES	····				
12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. DTTIC QUALITY INSPECTED & 14. SUBJECT TERMS NI 15. NUMBER OF PAGES 14. SUBJECT TERMS 15. NUMBER OF PAGES NI 16. PRICE CODE NI 17. SECURITY CLASSIFICATION OF THIS PAGE 19, SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED 18. SECURITY CLASSIFICATION OF ABSTRACT 19, SECURITY CLASSIFICATION OF ABSTRACT						
12a. DISTRIBUTION/AVAILABILITY STATEMENT 12b. DISTRIBUTION CODE Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) In this report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS DTIC QUALITY INSPECTED & 14. SUBJECT TERMS 15. NUMBER OF PAGES Nil 15. NUMBER OF PAGES Nil 16. PRICE CODE Nil 17. SECURITY CLASSIFICATION OF THIS PAGE I18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED UNCLASSIFICATION						
Approved for public release; distribution is unlimited. Approved for public release; distribution is unlimited. A 13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description of the wind tunnel, the model, the test program, and the test results obtained. DTTIC QUALITY INSPECTED & 14. SUBJECT TERMS Nil 15. NUMBER OF PAGES Nil 16. PRICE CODE Nil 18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED UNCLASSIFIED	12a. DISTRIBUTION/AVAILABILITY STA	TEMENT		12t	D. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 14. SUBJECT TERMS 14. SUBJECT TERMS 15. NUMBER OF PAGES 16. PRICE CODE NII 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT 10. LIMITATION OF ABSTR	Approved for public release; di	stribution is unlimited.			Α	
13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description of the wind tunnel, the model, the test program, and the test results obtained. DTIC QUALITY INSPECTED & 19980312 066 14. SUBJECT TERMS NI 15. NUMBER OF PAGES 16. PRICE CODE NI 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE 19, SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICATION INCLASSIFICATION I						
13. ABSTRACT (Maximum 200 words) This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description o the wind tunnel, the model, the test program, and the test results obtained. 19. DTIC QUALITY INSPECTED ≥ 14. SUBJECT TERMS Nil 15. NUMBER OF PAGES 16. PRICE CODE Nil 17. SECURITY CLASSIFICATION OF THIS PAGE 18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF THIS PAGE 19. NICLASSIFIED						
This report results from a contract tasking Central Aerohydrodynamics Institute as follows: The present report contains the description of the wind tunnel, the model, the test program, and the test results obtained. DTIC QUALITY INSPECTED & 14. SUBJECT TERMS Nil 15. NUMBER OF PAGES Nil 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT	13. ABSTRACT (Maximum 200 words)		10 CECU	Ł		
the wind tunnel, the model, the test program, and the test results obtained. DTIC QUALITY INSPECTED & DTIC QUALITY INSPECTED & 14. SUBJECT TERMS Nil 14. SUBJECT TERMS Nil 15. NUMBER OF PAGES 32 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE INCLASSIFICATION OF THIS PAGE INCLASSIFICATION OF ABSTRACT III	This report results from a cont	ract tasking Central Aerohydrodyna	mics Institute as fo	llows: The prese	ent report contains the description of	
DTIC QUALITY INSPECTED & 19980312 066 14. SUBJECT TERMS 15. NUMBER OF PAGES 14. SUBJECT TERMS 15. NUMBER OF PAGES 32 16. PRICE CODE NA 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF ABSTRACT 20. LIMITATION OF ABSTR 11. INCLASSIFIED 11. INCLASSIFIE	the wind tunnel, the model, the	test program, and the test results of	tained.			
DTIC QUALITY INSPECTED & 19980312 066 14. SUBJECT TERMS 15. NUMBER OF PAGES 14. SUBJECT TERMS 15. NUMBER OF PAGES 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION OF THIS PAGE 19. SECURITY CLASSIFICATION OF THIS PAGE 10. CLASSIFICATION OF THIS PAGE 10. CLASSIFICATION 11. CLASSIFICATION 12. LIMITATION OF ABSTR 13. SECURITY CLASSIFICATION 14. SUBJECT 14. LIMITATION OF ABSTR 14. LIMITATIO						
DTIC QUALITY INSPECTED & 19980312 066 14. SUBJECT TERMS Ni 15. NUMBER OF PAGES 32 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICATION OF THIS PAGE UNCLASSIFICATION UNCLASSIF						
DTIC QUALITY INSPECTED & DTIC QUALITY INSPECTED & 19980312 066 14. SUBJECT TERMS NII 15. NUMBER OF PAGES 32 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION OF THIS PAGE INCLASSIFICATION OF THIS PAGE INCLASSIFICATION INCLASSIFICE INCLASIFICE INCLASSIFICE INCLASIFICE INCLASSIFICE						
19980312 066 15. NUMBER OF PAGES 14. SUBJECT TERMS 15. NUMBER OF PAGES NI 15. NUMBER OF PAGES 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE 19, SECURITY CLASSIFICATION OF ABSTRACT 20. LIMITATION OF ABSTR	· · · · · · ·		DETC OTALT	TV TRIODER		
14. SUBJECT TERMS 15. NUMBER OF PAGES Nil 32 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICATION 18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFICATION 18. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED UNCLASSIFIED	1000001/	<u> </u>	Dire down	LI INDERO		
14. SUBJECT TERMS 15. NUMBER OF PAGES Nil 32 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION UNCLASSIFIED UNCLASSIFIED	33902 4					
14. SUBJECT TERMS 15. NUMBER OF PAGES Nil 32 Nil 16. PRICE CODE N/A N/A 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION UNCLASSIFIED UNCLASSIFIED						
14. SUBJECT TERMS 15. NUMBER OF PAGES Nil 32 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE 19, SECURITY CLASSIFICATION 20. LIMITATION OF ABSTR						
Nil 32 Nil 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF REPORT 18. SECURITY CLASSIFICATION OF THIS PAGE OF ABSTRACT	14. SUBJECT TERMS				15. NUMBER OF PAGES	
Nil 16. PRICE CODE N/A 17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION OF REPORT 0F THIS PAGE UNCLASSIFIED UNCLASSIFIED					32	
17. SECURITY CLASSIFICATION 18. SECURITY CLASSIFICATION 19, SECURITY CLASSIFICATION 20. LIMITATION OF ABSTR OF REPORT OF THIS PAGE OF ABSTRACT 20. LIMITATION OF ABSTR	Nil				16. PRICE CODE N/A	
	17. SECURITY CLASSIFICATION 1	8. SECURITY CLASSIFICATION	19, SECURITY C		20. LIMITATION OF ABSTRACT	
		UP THIS PAGE	UF ABSTRAC			
NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89	UNCLASSIFIED	UNCLASSIFIED	UNCL	ASSIFIED	UL Standard Form 298 (Rev. 2-89)	

•

•

²⁹⁸⁻¹⁰²



INVESTIGATION OF TEMPERATURE FACTOR INFLUENCE ON CONTROL SURFACE EFFECTIVENESS IN HYPERSONIC FLOWS WITH MODERATE INTERACTION

(Final report)

Project Supervisor:

Juaie

Dr.Yuri Yermak

CONTENTS

	paye
Introduction	3
Nomenclature	4
1. Wind tunnel VAT-3	6
1.1. Technical characteristicsof VAT-3	7
2. Model description	9
3. Test program	11
4. Test results	13
4.1. Optical tests	14
4.2. Pressure distribution in the separation zone	15
upstream of the flap	
4.3. Balance tests	15
Conclusions	17
References	18

1

page

NOMENCLATURE

- d_p probe tube diameter
- h_f flap height
- 1_m model length
- 1_n probe tube length
- M freestream Mach number
- q freestream dynamic pressure

Re freestream Reynolds number, Re = f(T_{oo})

- Re_0 Reynolds number, $Re_0 = f(T_0)$
- S_m reference model base area
- T₀ total temperature
- T_w model wall temperature
- t_w temperature factor, $t_w = T_w / T_0$
- x_m longitudinal model coordinate
- $x_{c.m}$ conditional mass center position, $x_{c.m} = 2/3 l_m$
- C_x drag coefficient, $C_x = F_x / (qS_m)$
- C_y lift coefficient, $C_y = F_y / (qS_m)$
- Cm_z pitching-moment coefficient, $Cm_z = M_z / (qS_m l_m)$
- α angle of attack
- χ azimuth angle in the transverse model plane
- θ cone half angle
- % specific heat ratio
- X hypersonic interaction parameter

INTRODUCTION

For the flight of a hypersonic maneuverable vehicle at velocities of M_>>1 and altitudes higher than 40 km there arises the problem of increasing the effectiveness of control surfaces, especially when the control surfaces are near the vehicle base where a relatively thick hypersonic boundary layer develops on the vehicle surface when its thickness becomes of the same order as the control span. The effectiveness of the control surfaces in such a hypersonic boundary layer depends on local dynamic pressure, i.e., on relation $\sim 1/M^2_{\sim o}$.

Another important point is that the hypersonic boundary layer flow condition is acted upon considerably by temperature factor in two ways. First, this parameter exerts an influence on the boundary layer thickness. Second, temperature factor influences the upstream propagation of disturbances and, thereby, the extent of the separation zone ahead of a control surface. Therefore, along with the Mach and Reynolds numbers, the temperature factor t_w is one more parameter influencing the control surface effectiveness.

In conventional hypersonic wind tunnels, the temperature factor is $t_w \sim 0.15$ to 0.3 and higher, while in full-scale conditions this quantity is less almost by an order. Consequently, it is impossible to evaluate reliably the effectiveness of the control surfaces of hypersonic maneuverable vehicles in conventional hypersonic wind tunnels although the parameter $M_{\infty}/\sqrt{Re_{\infty}}$ is simulated correctly.

TsAGI is in possession of hypersonic facilities capable of simulating not only the parameter $M_{\infty}/\sqrt{Re_{\infty}}$ but also the parameter t_{w} ; among these is, for example, a cryogenic wind tunnel VAT-3 in which the model surface can be cooled down to cryogenic temperatures with temperature factor t_{w} ranging from 0.04 to 0.3.

A model in the form of a 5° -cone with a flap was designed and manufactured to test the control surface effectiveness in this

wind tunnel.

The spoiler-type flap as a control surface was chosen based on the fact that in the tests the effectiveness of the flap, i.e., the property of producing aerodynamic loads, is mostly exhibited precisely at zero angle of attack since the model body in the form of a circular cone without a flap does not produce any normal force and longitudinal moment at $\alpha = 0$. In this case, the influence of temperature factor on the effectiveness of the flap itself can be judged from the behavior of variations in coefficients C_y and Cm_z of the model with varying parameter t_w . The present report contains the description of the wind tunnel, the model, the test program and the test results obtained.

5 -

1. Wind tunnel VAT-3

6 -

The vacuum wind tunnel VAT-3 is designed for investigating aerodynamic and thermal characteristics of models of such vehicles as aerospace planes and others (Figs. 1, 2).

This wind tunnel may be used for:

- evaluation of integral aerodynamic characteristics and disturbances caused by interference of vehicle-induced jets;
- evaluation of local aerodynamic and thermal characteristics of vehicle components;
- flow visualization by glow discharge method;

- physical investigations.

VAT-3 is an intermittent wind tunnel featuring cryogenic pumping of test gas. The cryopanels are cooled by gaseous helium being passed through a cooling gas-cycle unit.

The flow is produced by contoured and conical hypersonic nozzles. Test gas condensation is precluded by using Cowper electric heaters. The facility has two test sections to investigate external aerodynamics of winged vehicles and gas-dynamics of orbiter jets.

The wind tunnel parameters enable simulation of aerogasdynamic effects in orbital descent of such vehicles as aerospace planes from altitudes of 100 to 75 km.

1.1. Technical characteristics of VAT-3 VAT-3 is an impulse wind tunnel with cryopumping of test gas. Test section dimensions: diameter, m 1.0 length, m 1.7 volume, cub.m 1.5 Mach number range: contoured nozzle M=12 conical nozzle M=20 nozzle diameter, m 0.15 to 0.3 Reference model dimension, m: aerospace plane-type vehicles 0.1 to 0.2 orbiters up to 0.3 Reynolds number range (per 1m): 0.5×10^6 to 1.5×10^6 at M=12 10^4 to 10^5 at M=20Adiabatically retarded gas parameters: pressure, MPa 2 to 6 temperature, K 1000 to 2000

- 7 -

```
Gas flow rates, kg/s:
```

maximum	1.0
nominal	0.2
Wind tunnel efficiency:	
run time at maximum gas flow rate, s	0.07
same at nominal gas flow rate, s	3 to 5
between-runs-interval, min	no more than 5
runs per cycle	up to 100
cycles per week	2 to 3
Consumed electric power, kW	up to 100

· 8 -

2. Model description

The hypersonic maneuverable vehicle model is a thin axisymmetric cone with a half angle of $\Theta = 5^{\circ}$; one or two spoiler-type flaps were placed on the model afterbody. The geometric dimensions of the flaps, the model and its components are given in Figs. 3, 4.

A base sting made of heat-insulated material to reduce heat transfer to the model was used to suspend the model. In the balance tests, the sting was attached to a strain-gage balance placed in a thermostatically-controlled container on a three-component traversing gear creating displacements along the x-axis up to 600 mm, along the y-axis up to 100 mm at angles of attack up to 45° .

Temperatures of the side model surface and of the flap (a total of 5 points) were measured during the balance tests using thermocouples; the thermocouple wire diameter was not more than 0.1 mm to reduce the thermocouple influence on the balance test results.

The three-component semiconductor strain-gage balance was used to measure frontal drag F_x , lift F_y and pitch moment M_z over the ranges: 1 to 200 g for F_x and F_y and $M_z < 200$ g*cm. The balance was thermostatically-controlled at $10\pm5^{\circ}$ C. The amplifier of the AH4-21 type was used to amplify signals; the measurement error was ~ 1%.

The model was tested at zero angle of attack (α =0); the maximum model deflection under the action of the model weight and aerody-namic loads was not exceed ~1[°].

The pressure in the flow separation zone upstream of the flap was measured by a probe (Fig.5); its capillar part was made in the form of a tube with the wall thickness of 0.5 mm and the dimensions of $l_p * d_p = 50 \text{ mm} * 2 \text{ mm}$. The probe was fixed on the traversing gear guide so that the capillar part ($d_p = 2 \text{ mm}$) was in the longitudinal vertical model plane and oriented in a downward di-

- 9 -

rection. The gap between the model surface and the probe was ~ 1 mm; a low-inertia pressure tap capable of measuring pressure up to 0.1 atm was used as a measuring element.

The model flow visualization system based on the glow discharge technique involved 2 copper electrodes with the potential of 3 to 10 kV from a high-voltage constant-current source (Fig.1). The most part of the plate surfaces was shielded to focus the discharge into the model location region.

The flow patterns over the model were recorded by a special photographic unit mounted on the side test section window. It consisted of a photo camera, an electromagnet with a pusher and a relay controlling the electromagnet switching-on delay. An impulse to initiate the photo camera operation was supplied by the data acquisition system during a run.

3. Test program

The evaluation of the effectiveness of a control surface in the form of a spoiler-type flap on a hypersonic maneuverable vehicle included two stages.

First, the free-stream hypersonic flow (Mach number M_{∞} = 12) over the model with two flaps of different heights ($h_{\rm f}$ = 5 and 10 mm) was visualized by the glow discharge technique at different temperature factors $t_{\rm W}$ = 0.06 to 0.3. The model flow pattern, shock system configuration upstream of the flap, separation zone dimensions on the side model surface and aerodynamic characteristics were determined. The data obtained made it possible to improve the test procedure and test equipment operation and to choose the dimensions of a spoiler-type flap at which the temperature factor influence would be appreciable.

At the second stage, optical tests of the model with one flap $(h_f = 10 \text{ mm})$, pressure measurements in the flow separation zone and then balance tests were conducted in a given range of the parameter t_w .

In contrast to the previously adopted test program, the pressure in the separation zone upstream of the flap was measured simultaneously with optical tests using a probe rather than on a single tapped model. This alteration introduced in the test program was caused, on the one hand, by a considerable rise in the manufacturing cost of the models themselves and, on the other hand, by a drastic rise in the cost of wind tunnel runs that would be required for testing a special tapped model. Unfortunately, the accuracy of static pressures in the separation zone measured by using a probe was, of course, lower than that in the case of applying a special tapped model; therefore, the model pressure distributions obtained are of a qualitative nature.

The test program for the 5° -cone model is given in Table 1.

- 11 -

				Table 1
Test stage	Test stage scope	e Model configuration	Parameters measured	Results obtained
I	Optical and ba- lance tests	Cone ($\Theta = 5^{\circ}$) with two flaps ($h_f = 5.0$ and 10.0mm, $\gamma = 0$ and 180 [°])	1)Flow spectra 2)Aerodynamic characteristics	Model flow pattern, aerodynamic characte- ristics
II	Optical tests, pressure measure- ments (probe), balance tests	Cone (Θ =5 ⁰) with one flap (h_f =10mm, γ =0)	1)Flow spectra 2)pressure distribution upstream of flap 3)aerodynamic characteristics	Evaluation of control surface(flap) effectiveness using balance measurements

Here $\boldsymbol{\gamma}$ is the azimuth angle in the transverse model plane

- 12 -

4. Test results

At hypersonic velocities, pressure disturbances for a flow over a flat plate propagate, in the condition of moderate or strong viscous interaction, upstream along the boundary layer for distances comparable with the body length [1-4]. As for weak viscous interaction, the disturbance influence is limited by a small vicinity of a disturbance source [1]. The disturbance propagation in flows over slender axisymmetric bodies in the case of weak interaction is similar to that for a two-dimensional case.

When viscous interaction is moderate or strong, the increase in the interaction level causes the cross dimension of the zone, through which the disturbances propagate, to tend to zero [5], and variations in flow parameters are concentrated in the vicinity of a disturbance source. Temperature factor t_W and specific heat ratio \Re are also important parameters that exert some influence on the upstream disturbance propagation [6-8]. When tw tends to zero, the interaction region contracts to a disturbance source. A similar situation also exists as $\Re \rightarrow 1$.

The case when disturbances propagate upstream along the boundary layer is known as a supercritical flow condition in a hypersonic boundary layer [7]. This boundary layer is characterized by a Mach number averaged over the boundary layer thickness. If there is three-dimensional disturbance source in such a boundary layer, the disturbance propagation in this boundary layer begins in the azimuth direction inside characteristic disturbance lines, i.e., analogs of Mach numbers.

In this investigation, values of hypersonic interaction parameter $X=1/(\alpha^2 * \sqrt{Re_0})$ were close to 1 when $M_{\infty}= 12$ and $Re_0 = 1.6 * 10^4$ which indicated the existence of a moderate viscous interaction condition and the possibility of propagating appreciable disturbances in a flow over a flap both upstream and in the azimuth direction.

From the analysis of the results obtained in the present investi-

- 13 -

gation for a 5° -cone with a spoiler-type flap at hypersonic velocities with temperature factor t_w ranging from 0.30 to 0.06 it is inferred that the flap effectiveness depends considerably on parameter t_w in the case of moderate interaction.

4.1. Optical tests

Figs. 6 to 8 present pictures of flow spectra for a 5° -cone model with one spoiler-type flap at three temperature factors: $t_w = 0.06$, 0.095, and 0.3.

These pictures show clearly a shock system characteristic of a flow over a body of revolution with a flap: a bow shock (N1,4), an oblique shock upstream of the flap initiating at the boundary layer separation point (N2), and a shock wake immediately upstream of the flap (N3).

In addition, one more oblique shock (N5) occurs on the model side opposite to that where the flap is placed (γ =180⁰); the longitudinal coordinate of the shock onset corresponds approximately to the coordinate of the flow separation point upstream of the flap.

This shock is likely to be caused by a strong disturbance or even by the boundary layer separation on the opposite model side due to the extension of the influence of the separation zone upstream of the flap.

As a result of the treatment of the pictures obtained on a densitometer (of the Pericolour type) it is evident that the model boundary layer thickness decreases as temperature factor reduces, while the shock system configuration changes slightly (Figs. 9 to 12), but no appreciable variations in the boundary layer separation point position were observed.

- 14 -

4.2. Pressure distribution in the separation zone upstream of the flap

Pressure coefficients measured by a probe along the cone model generatrix upstream of the flap at two temperature factors $t_w =$ 0.06 and 0.3 are given in Fig. 13. Possible influence of the probe itself on the pressure distribution over the side model surface implies only qualitative nature of the dependence $C_p = f(x, t_w)$. But it is clearly seen that pressure values in the separation zone upstream of the flap vary considerably with varying temperature factor, while the separation zone dimensions vary slightly.

4.3 Balance tests

Fig. 14 shows main aerodynamic characteristics of a 5° -cone model with a flap, that is longitudinal and normal force coefficients and pitching moment coefficients as functions of temperature factor tw.

It is seen that these aerodynamic coefficients increase by 30-40% as parameter t_w decreases especially in the range of $t_w = 0.20 - 0.06$.

It should be noted that in the case of moderate interaction, temperature factor influences insignificantly the total drag of a cone without a flap since the increase in its wave drag with a rise of the hypersonic boundary layer thickness due to increased temperature factor is counteracted by a respective friction drag decrease.

The behavior of the aerodynamic characteristics of a 5° -cone with a flap observed in the experiment is explained basically by an increased interaction of the flap with the flow when the boundary layer thickness decreases as parameter t_w reduces.

The flap exerts the most influence on the aerodynamic characte-

- 15 -

ristics of the model under consideration; therefore, the influence of variations in the flow conditions over the flap on the characteristics of the whole model as parameter t_w decreases is so considerable.

CONCLUSIONS

Based on the present investigation carried out at M_{ω} = 12 using a 5⁰-cone model with a flap the following tentative concluding remarks can be drawn:

1. The decrease in the hypersonic boundary layer thickness with reducing temperature factor makes a basic contribution to the effectiveness of a spoiler-type flap. For example, the longitudinal moment acting on the model increases by 30 to 40% when t_W varies from 0.3 to 0.065.

2. The variation in temperature factor in the range under investigation exerts a weak influence on the variation in the boundary layer separation point position upstream of the flap.

3. It is important that pressure distributions on the side cone surface and on the flap be investigated in more detail using a special tapped model.

4. It is desirable to continue the investigation of the temperature factor influence on the effectiveness of aerodynamic control surfaces with varying viscous interaction parameter X and specific heat ratio \mathfrak{R} .

- 17 -

REFERENCES

1. V.Ya. Neiland, Upstream Disturbance Propagation in the Case of Hypersonic Flow-Boundary Layer Interaction, MZhG, N4, 1970 (in Russian)

2. I.G. Kozlova, V.V. Mikhailov, On the Influence of Boundary Layer Disturbances on Hypersonic Flows with Viscous Interaction, MZhG, N4, 1971 (in Russian)

3. V.Ya. Neiland, On Asymptotic Theory of the Supersonic Flow-Boundary Layer Interaction, MZhG, N4, 1971 (in Russian)

4. N.G.Kozlova, V.V.Mikhailov, On Strong Viscous Interaction on Delta and Yawing Wings, NZhG, N6, 1970 (in Russian)

5. V.P. Provotorov, On Disturbance Propagation through an Axisymmetric Hypersonic Boundary Layer, Uchenye Zapiski TsAGI, vol. III, N6, 1972 (in Russian)

6. Yu.N. Yermak, V.Ya. Neiland, The Influence of Thermodynamic Gas Properties on the Hypersonic Flow-Boundary Layer Interaction, Trudy TsAGI, issue 2079, 1980 (in Russian)

7. V.Ya. Neiland, Features of Boundary Layer Separation on a Cooled Body, MZhG, N6, 1973 (in Russian)

8. P.I. Gorenbukh, V. P. Provotorov, Experimental Investigation of Hypersonic Flow over an Axisymmetric-Type Body with the Generatrix Break, Uchenye Zapiski TsAGI, vol IY, N1, 1973 (in Russian)

- 18 -



.









Fig.5 Schematic presentation of technique to measure side model surface pressure upstream of flap using probe



Fig.6 Flow spectrum over 5°-cone model with flap at $t_w = 0.3^{\circ}$



'Fig.7 Flow spectrum over 5°-cone model with flap at $t_{\rm w}$ = 0.093



Fig.8 Flow spectrum over 5°-cone model with flap at $t_w = 0.065$

Flow pattern over 5°-cone model with flap at $t_{\rm w}$ = 0.3

N утла	ф, град.	
1	~ 70	M∞=12
2	~/3°	$Re_o = 0.16 \times 10^5$
3	- 0	$Re_{\infty} = 0.385^{*}10^{6}$
4	~850	t _w =0.3
5 ·	~/35°	



N пуска 41006

Fig.9

Flow pattern over 5°-cone model with flap at $t_w = 0.093$

N пуска 41012

N угл	а ф, град.	
1	~6,5°	M _∞ =12
2	~ 12.8°	$Re_o = 0.16 \times 10^5$
3	_ 0	$Re_{\infty} = 0.385^{*}10^{6}$
4	~8 °	$t_w = 0.093$
5	~13 °	



Fig.10

IN ПУСКА 4.	L	11	I
-------------	---	----	---

N утла	ф, град.	
1	~6°	M _∞ =12
2	~/2,5°	$Re_o = 0.16 \times 10^5$
3	_ 0	$Re_{\infty} = 0.385^{*}10^{6}$
4	~7.5 °	$t_w = 0.065$
5	-12°	



Flow patterns over 5°-cone model flap at different t_w





