ICAS-98-3,7,4

A98-31558

WIND TUNNEL INVESTIGATIONS ON RPV WING GLOVE CONFIGURATION

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ABSTRACT

A wind tunnel test investigation was conducted to evaluate the downwash effect of the flow around an RPV wing/glove combination and to build confidence in its pressure data acquisition system. The wing is part of an RPV (Remotely Piloted Vehicle) which the Department of Aerospace Engineering at the Glasgow University plans to use as a flying laboratory for laminar aerofoil research. The wind tunnel tests used three glove endplates configurations and a wing extension to obtain pressure data. Pressure measurements were taken near the glove mid section. Data suggest that the downwash effect cannot be eliminated by screening the flow over the glove with endplates, although the flow might be nominally two-dimensional if there is negligible crossflow with endplates and wing extension on. The pressure sensing equipment and its software code operated satisfactorily and as a consequence such a data acquisition system might be installed on board of the RPV in the near future.

INTRODUCTION

A wing glove arrangement for in-flight experiments in subsonic laminar flow research is an excellent test bed for designing new aerofoils with improved laminar flow characteristics and hence significant drag reduction. In fact such an approach requires the minimum of modifications to the test aircraft whilst permitting a number of different aerofoil sections to be tested. Although such a research has also been conducted in wind tunnels, with valuable results, in-flight testing has often permitted higher Reynolds numbers to be attained [1].

Today, advances in miniature electronics have reduced cost and size of data acquisition equipment only dreamed of in the past, thus allowing the conception of a new breed of experiments and test beds.

The University of Glasgow in 1995 initiated a programme of research by purchasing an existing RPV airframe [2] in a view of adapting it into a flying laboratory. The aim is to demonstrate the potential use of an RPV system [3] fitted with an outsized and removable aerofoil section attached to the wing, for in-flight subsonic laminar flow research at a fraction of the cost for a wing glove employed on a manned aircraft [4].

The research programme was organized as follows :

Phase 1 - Creation of a CFD model of the RPV wing/glove combination and initial feasibility study on this basis. Design of the wing glove and its data acquisition system using guidelines from the CFD study [4,5].

Phase 2 - Wind tunnel testing of the RPV wing/glove combination to assess the three-dimensional aerodynamic effects upon the wing glove configuration and build confidence in its pressure sensing equipment. Optimisation of the wing glove configuration on the basis of the wind tunnel results.

Phase 3 - Modification of the air vehicle to aerofoil research standard, which includes revision of the control system and performance, as well as structural modifications and provision of an onboard data acquisition system. Flight testing to qualify the air vehicle as a reliable airborne aerofoil research platform (Fig.1).

Presently the RPV is envisaged fitted with two wing gloves, because a single glove would induce a rolling moment about the longitudinal axis. Consequently, a permanent aileron deflection would be likely to be needed to trim the moment out above certain speeds. This would affect the flow over the glove and it might affect test data. A constant aileron deflection

21st ICAS Congress
13-18 September 1998
Melbourne, Australia

also might have an associated aeroelastic effect known as divergence.
This paper deals with the pressure data measurements conducted on the RPV wing/glove combination fitted with various types of endplates and it presents the results.

WIND TUNNEL TEST SETUP

Tests were carried out in the Glasgow University "Handley Page" low-speed closed-return wind tunnel. The RPV wing/glove combination was located horizontally in its 2.13X1.61 metre octagonal working section (Fig.2) and supported by a rig which held the wing in place at the tunnel (Fig.3). Variation of the angle of attack of the wing between 0 and 6 degrees was produced by manually moving a saddle at the top of the rig. An aperture closer closed the gap between the wing and the wind tunnel wall. There were two sections : the moving section attached to the upper and lower surface of the wing and slid through the fixed section when the wing was tilted. The two sections overlap somewhat to effect a seal.
The experiments were conducted at a speed of 30 m/s. The Reynolds number was 2.3×10^6.

GLOVE MODEL

The glove incorporates a NACA 0012 aerofoil section and is 0.83 m wide (Fig.4). The chord is 1.05 m long to make room for the sixty tubes which connect thirty pressure tappings on the upper surface and another thirty on the lower surface (Fig.5) to two pressure scanners located inside the RPV wing, underneath the glove. The glove contains tubes only and no instrumentation, and it is removable from the wing in 15 minutes if endplates are not fitted. The endplates are in turn fully removable, thus permitting tests to be performed with or without endplates. The glove has a balsa core covered by two layers of mohogany plywood, and its chord is aligned with the chord of the wing. Its surface is painted in matt black to facilitate surface flow visualization [6]. The glove model weighs about 7.6 Kg without endplates.

PRESSURE SENSING EQUIPMENT

A series of two diaphragm type differential pressure transducers were used, each fitted into a scanivalve and ganged to a stepping motor. The 48 ports per valve were used to cover both surfaces of the wing glove with a total of 60 tappings (Fig.6). The two scanivalves were installed inside the RPV wing, feeding an ADC card plugged to a notebook computer. A solenoid controller was also necessary to set the speed of the stepping motor, which was 20 ports/sec.
Transducers were calibrated when mounted on the model prior to commencing tests by using a water gauge. During testing port 8 was not functioning.
The pressure sensing equipment is shown in Figure 7.

TEST SERIES

Four configurations were tested, with the baseline being the wing/glove combination with no endplates and the wing extension on. The other configurations were produced by mounting different types of endplates (Fig.8). Further tests were made to verify that the tip-vortex effect was stronger with no wing extension installed and to better evaluate the magnitude of this effect on the configuration being tested.

PRESSURE MEASUREMENTS

A selection of pressure distributions at the measurement station near the mid glove are shown in figures 9-10-11 where experimental pressure coefficients are compared against a two-dimensional incompressible numerical solution at the same (measured) angle of attack. These figures suggest that the downwash effect from the tip vortex is present in all configurations and it reduces the local angle of attack. Indeed, this difference between measured and calculated pressure distribution is absent at low angles of attack (Fig.9) and becomes stronger and stronger as the angle of attack increases to six degrees. In particular, Figure 11 shows that the viscous angle is one degree since this is the difference berween measured and calculated angle of attack. The fact that such a difference gets larger as the angle of attack increases excludes that this is simply due to a mis-measurement of the angle of attack which the glove is set at, and it suggests that is owing to the downwash from the tip vortex. This is also visible in Figures 12-13-14, and in Fig.14 in particular, where the peak of pressure at the glove leading edge decreases dramatically with the wing extension off.
It is therefore concluded, in accordance with a previous study [4], that the downwash effect cannot be eliminated in the current wing/glove combination, even in the event of employment of endplates. The pressure sensing equipment performed well and no problems were experienced during testing, thus qualifying the system and its software code for flight testing in the future.

CONCLUDING REMARKS

A wind tunnel investigation was conducted to evaluate the downwash effect on an RPV wing/glove combination. The tunnel tests used three sets of endplates of different shape and size. Pressure values were measured near the glove mid section.

Results of the investigation can be summarized as follows :
1) Measured pressure distributions suggest that the downwash effect from the tip vortex cannot be eliminated, even by using endplates;
2)The compact pressure data acquisition system operated correctly along with its software code, therefore such a system is qualified for test-flying;
3) Endplates 5 cm high are associated with a downwash effect on the local angle of attack comparable with the other tested configurations, which is what a previous CFD study showed.
The 5 cm endplates are preferred for their reduced size, as large surface areas ahead of the aircraft center of gravity could compromise directional stability.

ACKNOLEDGMENTS
The authors would like to thank Dr. F.N.Coton for his help and advice, Mr R.Gilmour and Mr T. Smedley for their assistance in the wind tunnel, and Dr R. Gatiganti for providing the two-dimensional incompressible numerical solutions.

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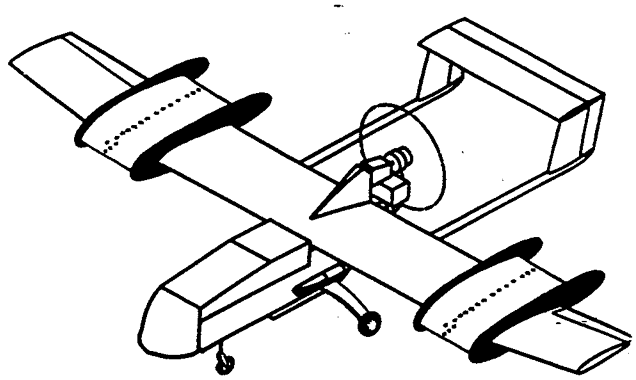
CONDOR - UNIVERSITY OF GLASGOW RPV SYSTEM



Wing Span	4100 mm
Wing Span (With Extensions)	5930 mm
Overall Lenght	4070 mm
Max. Take-Off Weight	145 kg
Max. Payload	30 kg
Engine Power	20.5 kW

Fig. 1- The RPV Flying Laboratory as it is envisaged

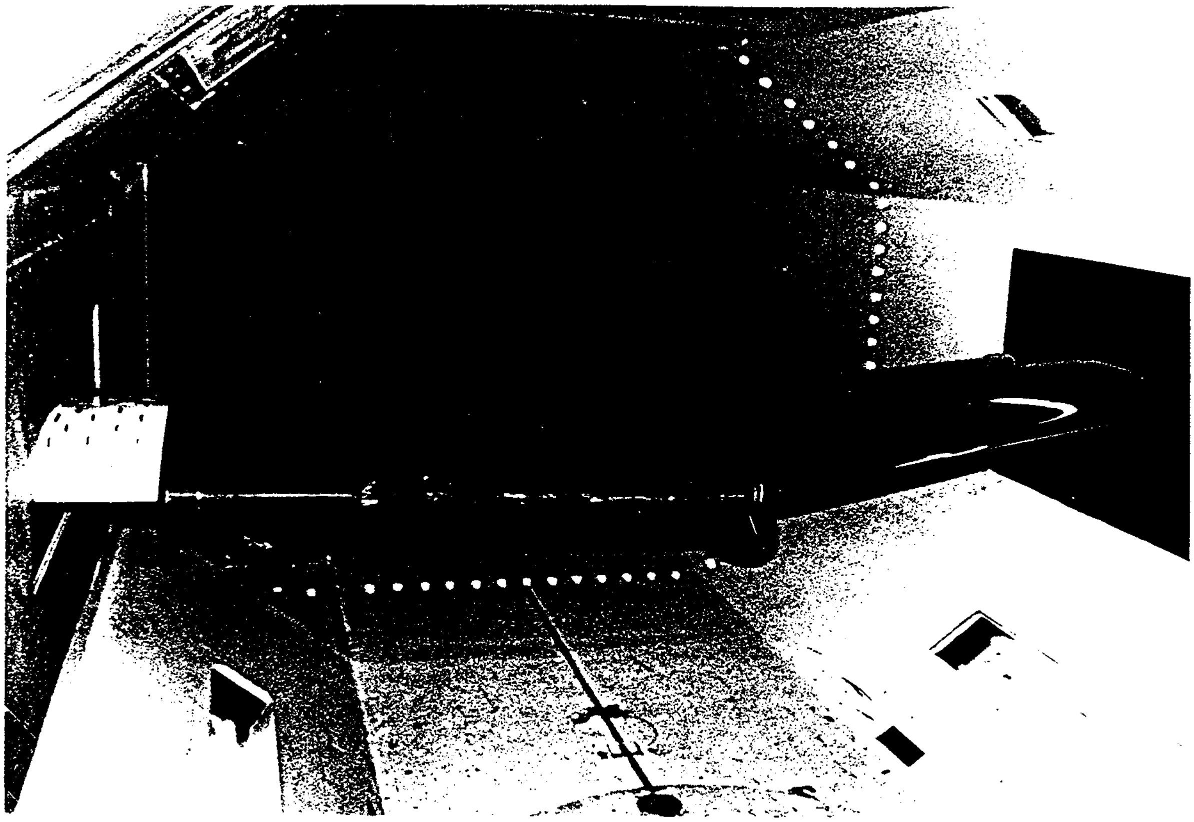


Fig. 2 - The RPV wing/glove combination in the octagonal working section

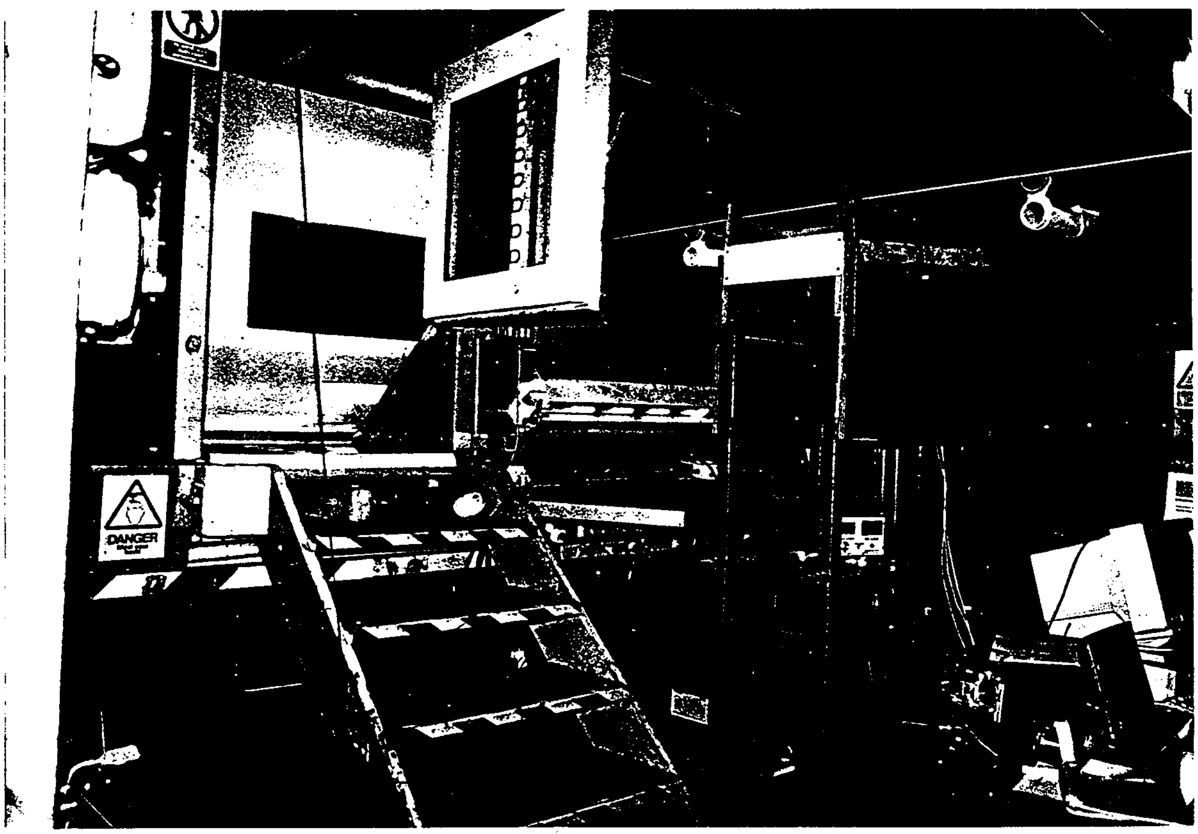


Fig. 3 - The Wind Tunnel Test Rig

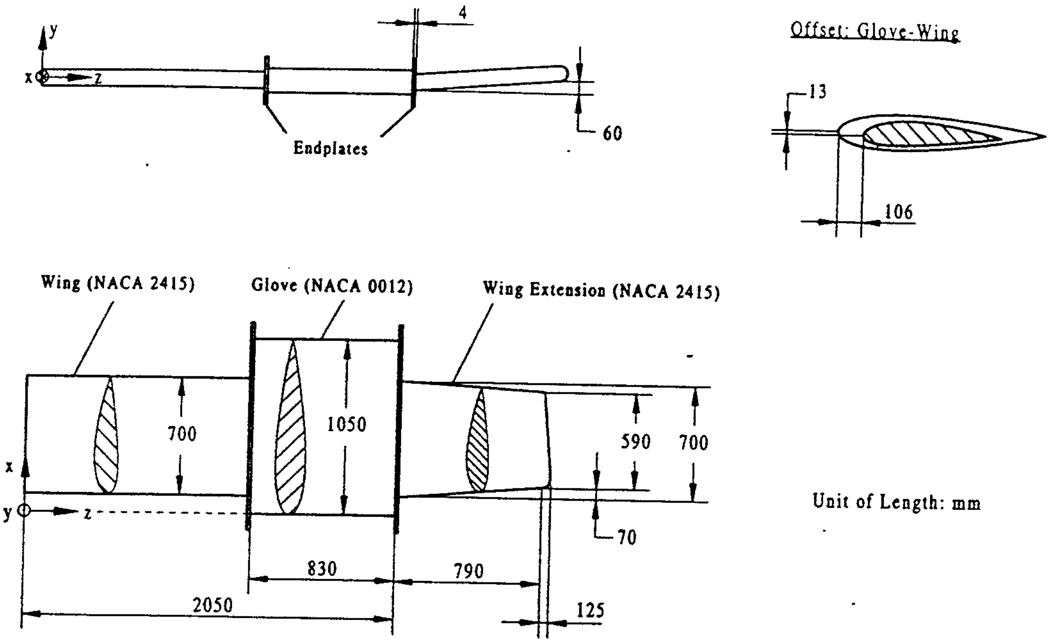


Fig. 4 - RPV wing/glove geometry

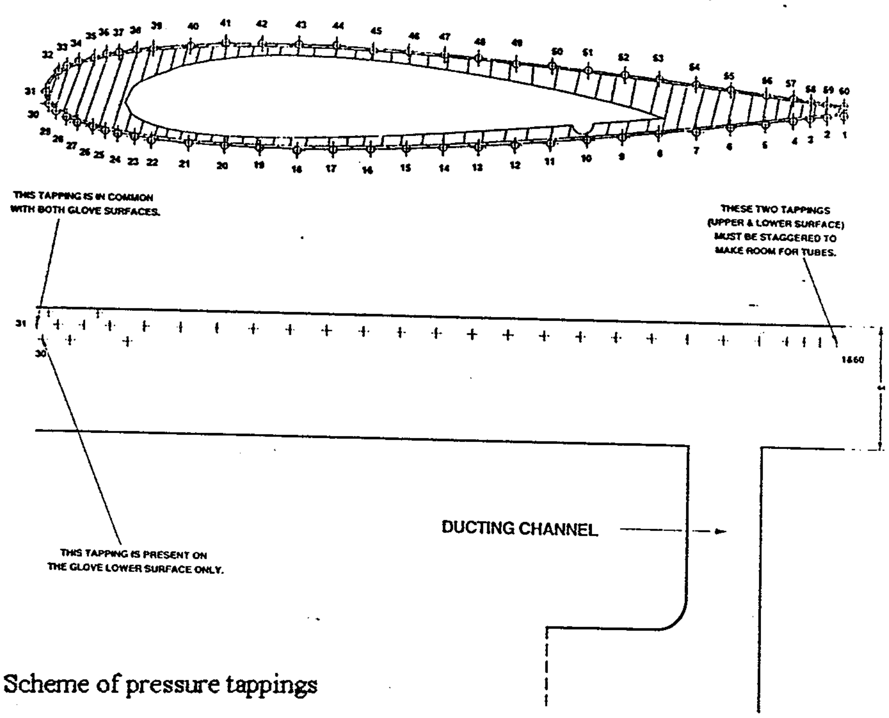


Fig. 5 - Scheme of pressure tappings

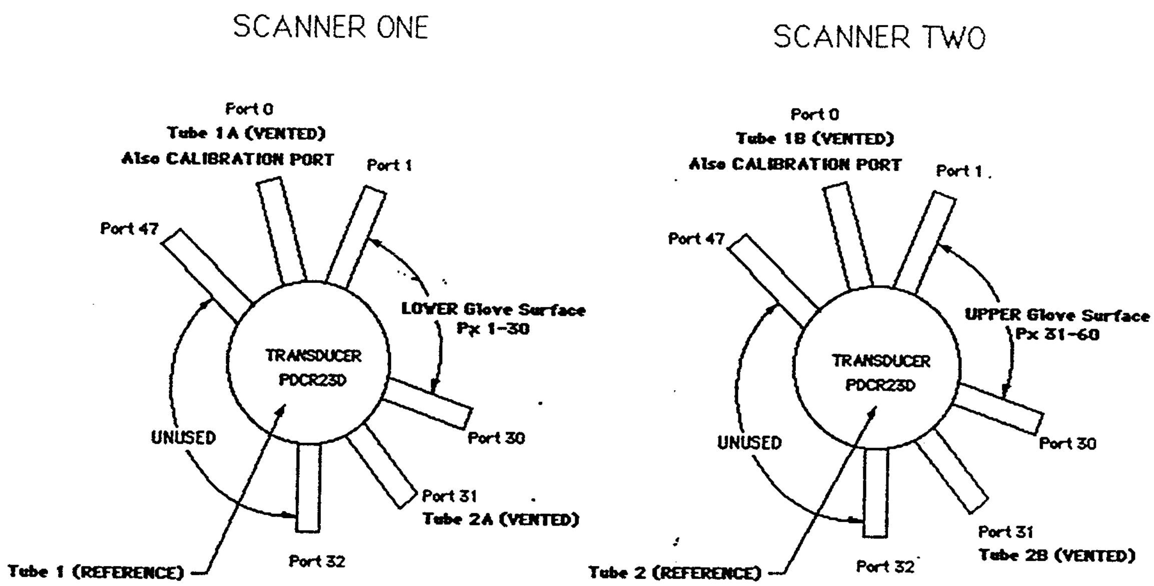


Fig. 6 - Scanivalve SGM module arrangement

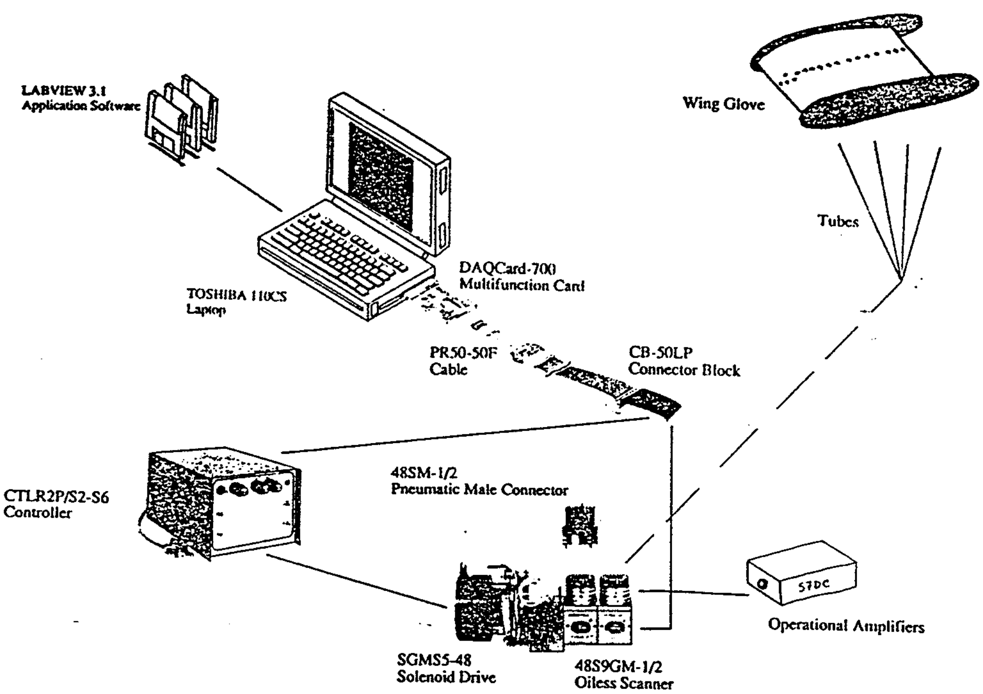


Fig. 7 - The Data Acquisition System

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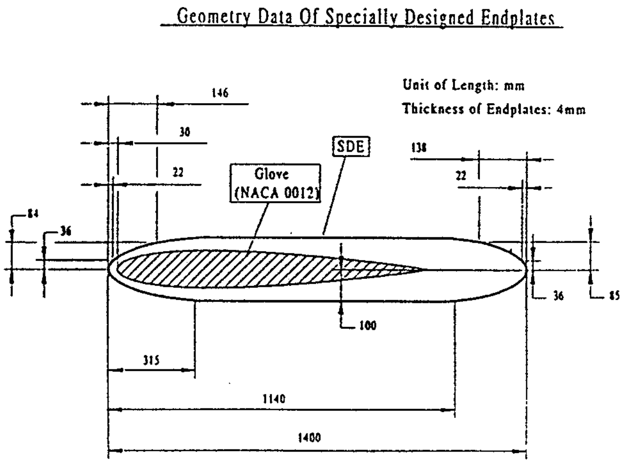
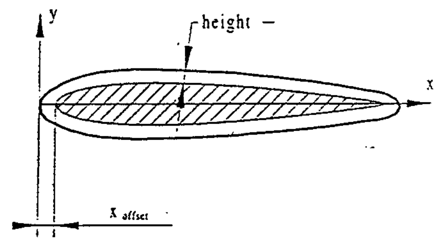


Geometry Data Of Endplates With Constant Height

Endplates Height = 5cm	
x [mm]	y [mm]
0	0
14.0	30.5
57.0	56.0
85.0	68.5
113.5	77.0
170.5	90.0
227.0	96.0
283.5	99.0
340.5	100.0
567.5	92.5
681.0	84.0
794.5	74.0
908.0	62.0
1021.5	46.0
1078.0	38.0
1112.0	30.0
1125.0	18.0
1135.0	0
chord = 1135 mm	
x_{offset} = 48 mm	

Enplates Height = 10cm	
x [mm]	y [mm]
0	0
15.5	46.0
31.0	62.5
62.0	84.0
92.5	103.0
123.5	115.5
185.5	135.0
247.0	144.0
370.5	150.0
617.5	139.0
741.0	126.0
864.5	111.0
988.0	93.0
1111.0	70.0
1173.0	57.0
1210.0	45.0
1224.0	27.0
1235.0	0
chord = 1235 mm	
x_{offset} = 100 mm	



Thickness of Endplates: 4mm

Fig. 8 - Endplates Geometry

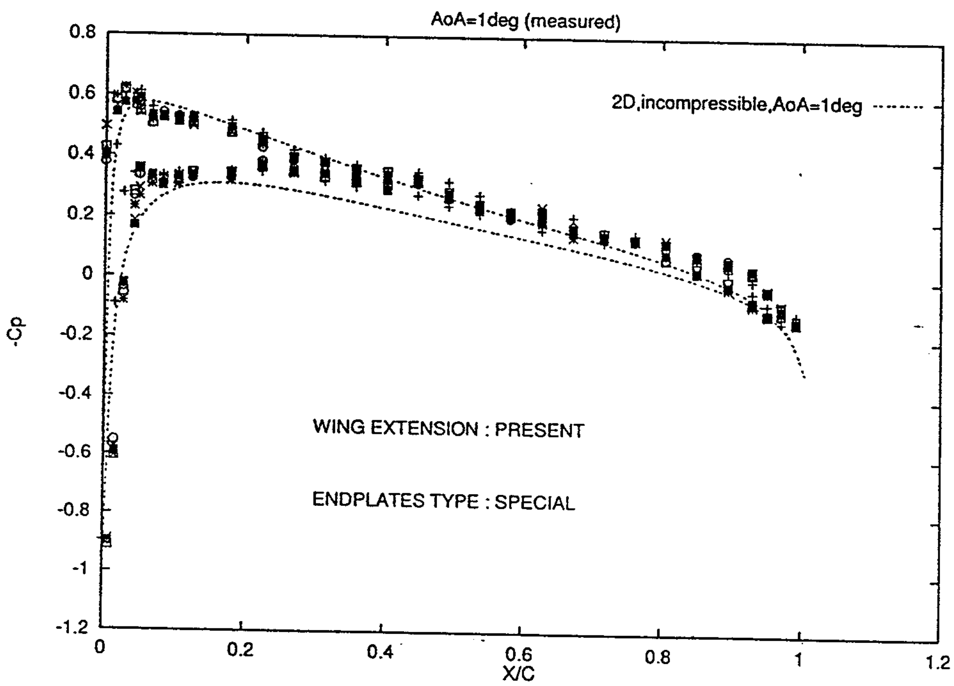


Fig. 9 - Pressure distribution near the glove mid section at AoA=1 degree

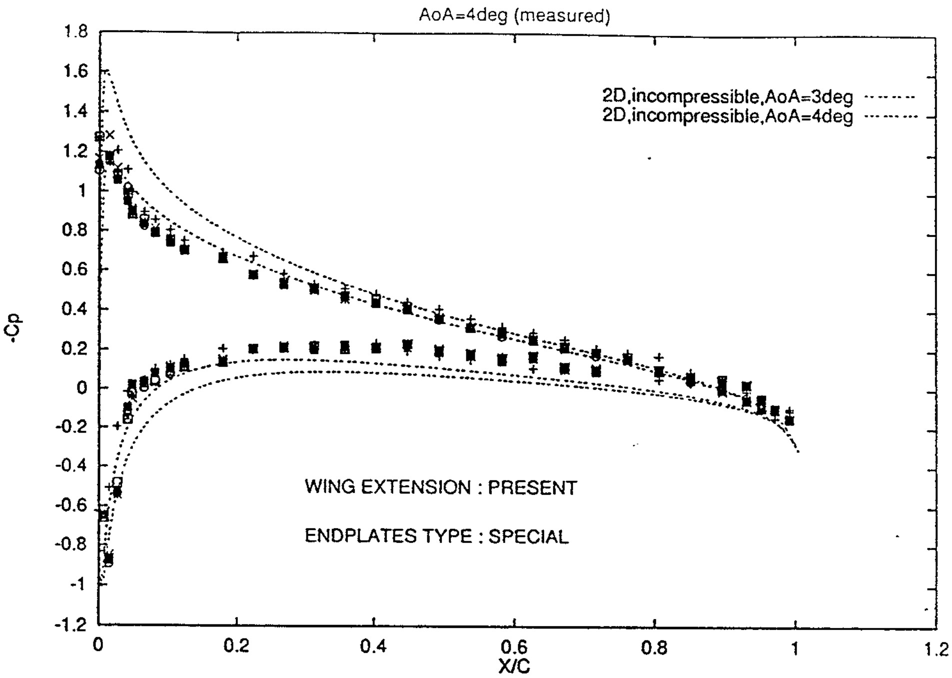


Fig. 10 Pressure distribution near the glove mid section at AoA=4 degrees

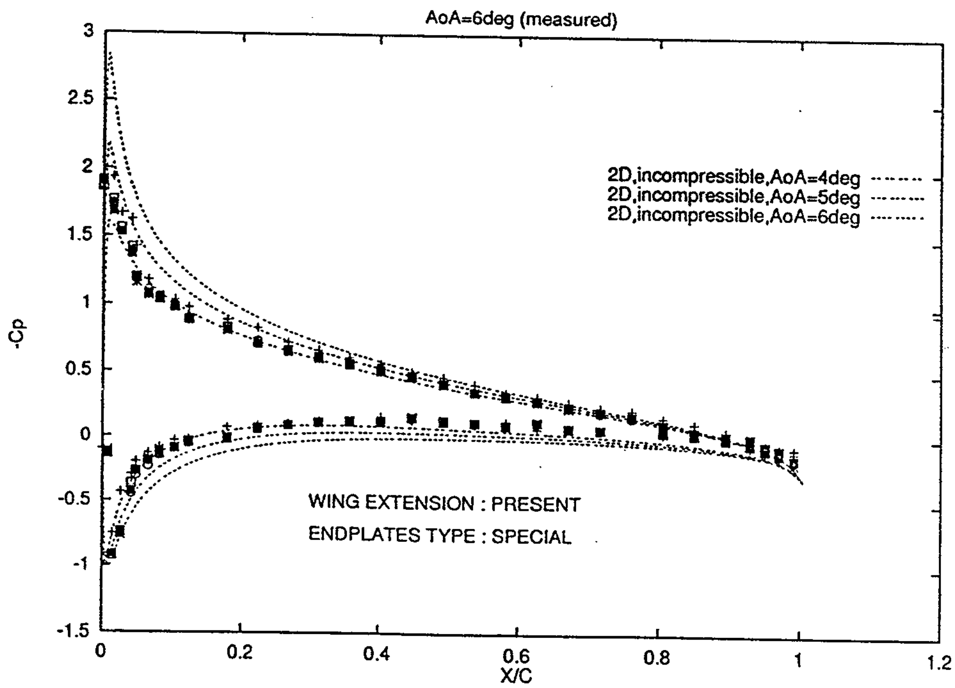


Fig. 11- Pressure distribution near the glove mid section at AoA=6 degrees

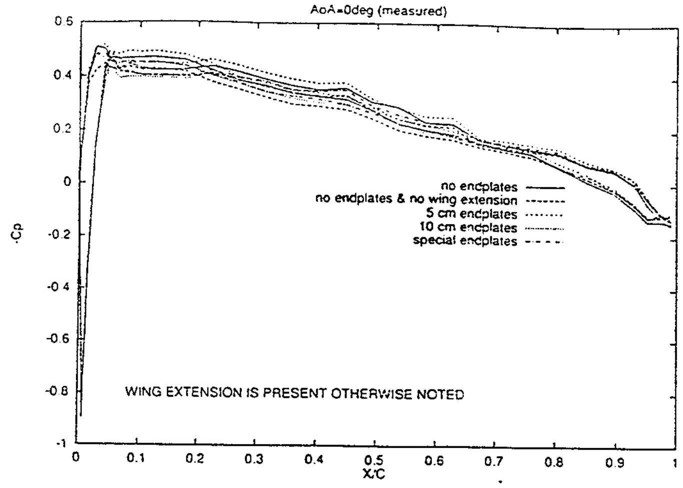


Fig. 12 - Comparison of pressure distributions for different configurations at AoA= 0 degrees

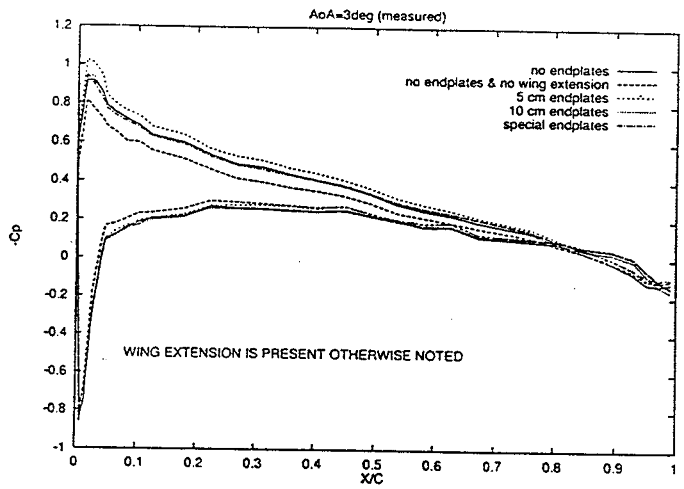


Fig. 13 - Comparison of pressure distributions for different configurations at AoA= 3 degrees

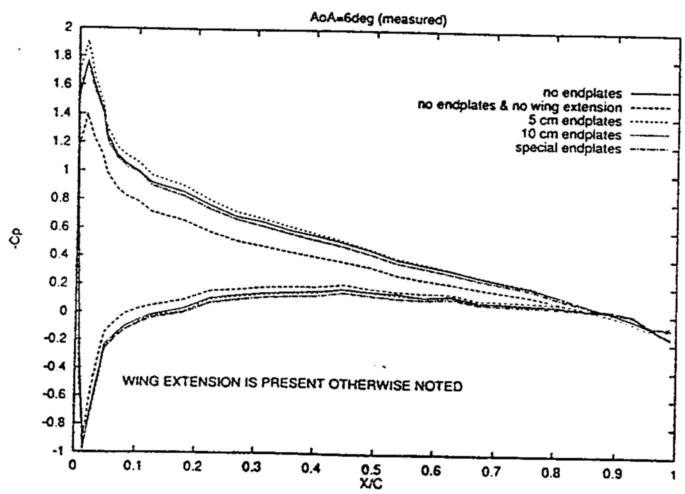


Fig. 14 - Comparison of pressure distributions for different configurations at AoA= 6 degrees