LOW-SPEED SURFACE PRESSURE AND BOUNDARY LAYER MEASUREMENT DATA FOR THE NLR 7301 AIRFOIL SECTION WITH TRAILING EDGE FLAP

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0. INTRODUCTION

Test data are given for a two-dimensional wing flap configuration, which has been so designed that nowhere flow separations occur, apart from a small laminar separation bubble on the wing nose. The 32% chord trailing edge flap is deflected 20°. Two widths of the gap between wing and flap have been applied, with mixing of the wing wake and flap boundary layer occurring with the smaller gap. The experiment has been carried out at a Reynolds number $Re,c = 2.51 * E6$ and a Mach number of about $Ma = 0.185$.

The measurements comprise surface pressure data, from which lift and pitching moment coefficients were calculated, at various angles of attack from zero up to beyond stall. At three angles of attack the drag has been determined from wake traverses. At these angles mean flow measurements in the boundary layer and wake have been executed at 16 stations. In addition turbulence data were obtained at 5 stations in the wing wake above the flap. Surface flow visualization data are also available.

1 GENERAL DESCRIPTION

1.1	Model designation	NLR 7301 with flap.
1.2	Model type	Two-dimensional.
1.3	Design requirement	Model was designed to provide an as simple as possible test case for low-speed multi-element airfoil calculation methods.
1.4	Dominant flow physics	Interaction between the two airfoil elements, both inviscid and viscous.

2 DETAILS OF MODEL

2.1	General geometry	Cylindrical model of wing with trailing edge flap (see fig. 1). Basic-airfoil chord = 0.57 m.
2.2	Configurations	Test have been done at one flap angle, 20°, and two flap gap widths, 2.6% and 1.3% chord.
2.3	Airfoil data	Basic airfoil section is NLR 7301.
2.4	Model support details	Model was mounted vertically from wall to wall, spanning the tunnel test section.

2.5	Model deformation	The position of the flap relative to the main wing is affected slightly by airloads, due to the limited stiffness of the flap brackets. Measurements showed that the flap gap decreases with wind-on by approximately 0.2% chord and the flap angle by about 0.2 or 0.3 degrees.

3 GENERAL TUNNEL INFORMATION

3.1	Tunnel designation	Most of the tests have been carried out in the NLR LST 3*2m in Amsterdam; some additional data were obtained later in the new NLR LST 3*2.25m in the North-East Polder.
3.2	Organization running tunnel	NLR, The Netherlands.
3.3	Tunnel characteristics	Low-speed wind tunnel of conventional design.
3.4	Test section	Closed-wall test section. Width: 3m; height: 2.1m/2.25m; length: 4m/8.75m for old/new tunnel, respectively. Blowing boundary layer control was applied on tunnel walls to avoid premature stall at model tunnel wall junctions.
3.5	Flow quality	NLR LST 3*2m wind tunnel in Amsterdam (used for most of the measurements): variation of mean velocity across test section: 0.5%. Free-stream turbulence level: < 0.2%. NLR LST 3*2.25m wind tunnel in the North-East Polder (used for the turbulence measurements in the wing wake above the flap): variation of mean velocity across test section: < 0.2%. Free-stream turbulence level: < 0.04%.

4 INSTRUMENTATION

4.1	Model position	Accuracy of geometrical angle of attack of main wing: ± .05°.
4.2	Model pressures	Surface pressure hole positions are indicated in fig. 1. Typical measured surface pressure distributions are shown in fig. 2. Estimated accuracy of pressure coefficients: ± 0.01 or ± 0.5%.

4.3 Forces and moments

Lift and pitching moment have been obtained from integration of the model surface pressures. Drag has been determined from wake traverses at several spanwise positions at one chord distance behind the model trailing edge. Estimated accuracy: lift coefficient: ± 0.01. Pitching moment coefficient: ± 0.005. Drag coefficient: ± 2%. (Spanwise variation in local wake drag traverse data: < 5%.)

4.4 Skin friction

Skin friction coefficients, determined with various indirect methods, are plotted in fig. 3 for the wing upper surface. Accuracy estimate: ± 10%.

4.5 Boundary layers

Boundary layer and wake measurements have been performed at 16 stations, using a small, movable, external traversing mechanism, specially built for the purpose. The mean velocity measurements have been made with pressure probes. Hot-wire measurements to determine the turbulence properties have been carried out at station 8, 12, 13, 14 and 16 (see fig. 1). Typical boundary layer mean velocity profiles are depicted in fig. 4. Fig. 5 and 6 show mean velocities measured in the wing wake above the flap, at a flap gap of 2.6% and 1.3% c respectively. Some turbulence measurement results are plotted in fig. 7. Boundary and wake data accuracy estimate: mean velocities: ± 2%. Turbulence quantities: ± 15%.

4.6 Flow visualization

Surface flow was visualized using the oil flow technique to detect flow separation and attachment lines, and the sublimation technique to determine transition positions.

5 <u>TEST MATRICS AND CONDITIONS</u>

5.1 Detailed test matrix

Surface pressure measurements have been carried out at angles of attack between 0 tot 16° at intervals of 1°. Wake traverses and detailed boundary layer measurements have been done at 6.0°, 10.1°, 13.1°. The free-stream Mach number was about 0.185 and the Reynolds number 2.51 * E6.

5.2	Model/tunnel relations	Tunnel "height/ basic-airfoil chord ratio is 5.26. Tunnel "width"/ chord ratio is about 3.8.
5.3	Transition details	Tests were made with free transition. Transition positions and position and extent of laminar separation bubbles have been determined at 6.0°, 10.1° and 13.1° angle of attack.

6 DATA

6.1	Availability of data	The data set is freely available.
6.2	Suitability of data	Data are well suited for CFD validation, and have already been used for this purpose. Tunnel wall interference effects are small and consequently the data can be used for "free air" calculations. Also "in tunnel" calculations can be made, assuming a two-dimensional tunnel test section of infinite length with the tunnel walls at 2.63 chord distance from the model center.
6.3	Form of data	Data are available in tables and on floppy disk.
6.4	Corrections applied	Classical tunnel wall interference corrections have been applied. Lift interference correction on lift is less than 1%. Blockage correction on velocity is about 0.5%.

7 DATA ACCURACY

7.1	Accuracy	Angle of attack: ± 0.05°. Free-stream velocity: ± 0.2%. Lift coefficient: ± 0.01. Pitching moment coefficient: ± 0.005. Drag coefficient: ± 2%. Surface pressure coefficients: ± 0.01 or ± 0.5%. Skin friction coefficient: ± 10%. Boundary layer and wake mean velocity data: ± 2%. Wake turbulence data: ± 15%.
7.2	Repeat measurements	Surface pressure and boundary layer measurements have been done in two different tunnels with good agreement.

8 REFERENCES

B. van den Berg - "Boundary layer measurements on a two-dimensional wing with flap". NLR TR 79009 U (1979).

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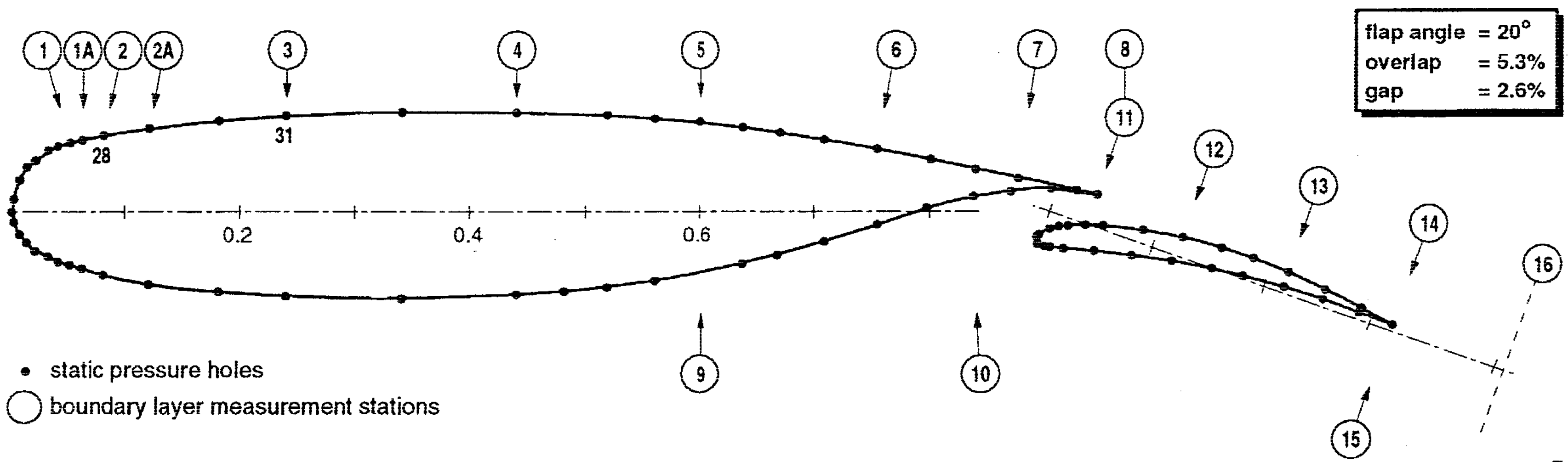

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Fig. 1 Airfoil and flap section with the positions of static-pressure holes and boundary layer measuring stations

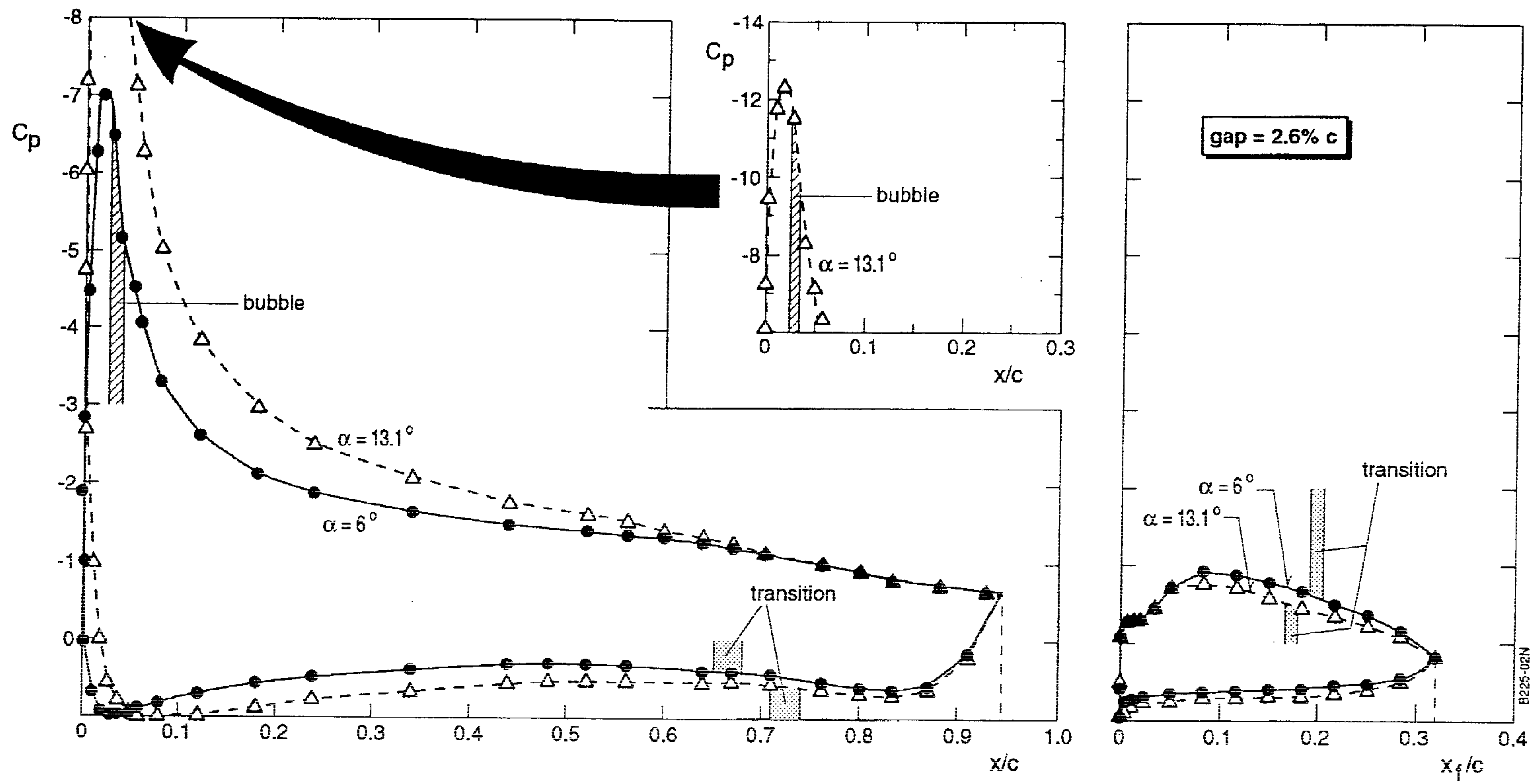

Fig. 2 Measured surface pressure distribution and position of laminar separation bubbles and transition regions

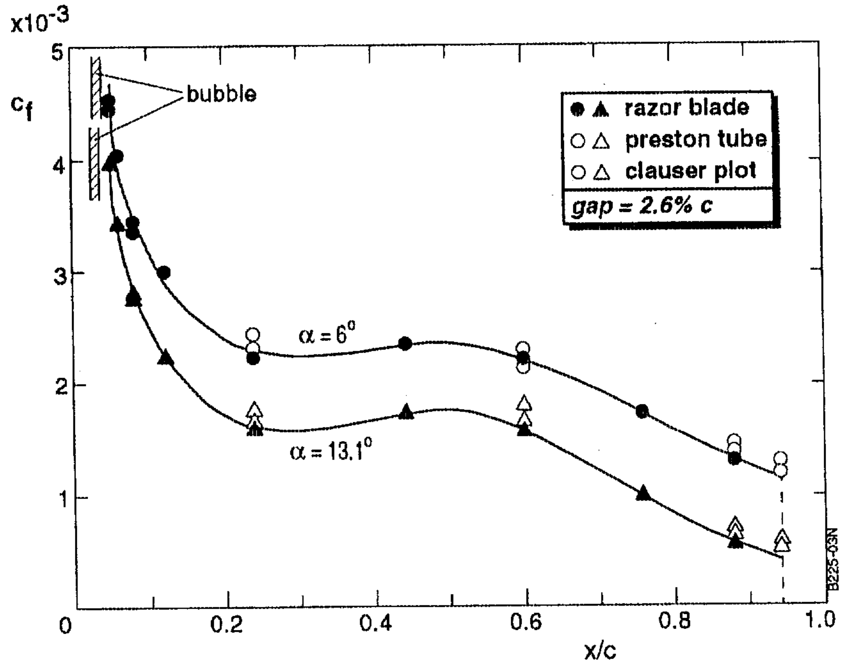

Fig. 3 Measured wall shear stress variation on wing upper surface

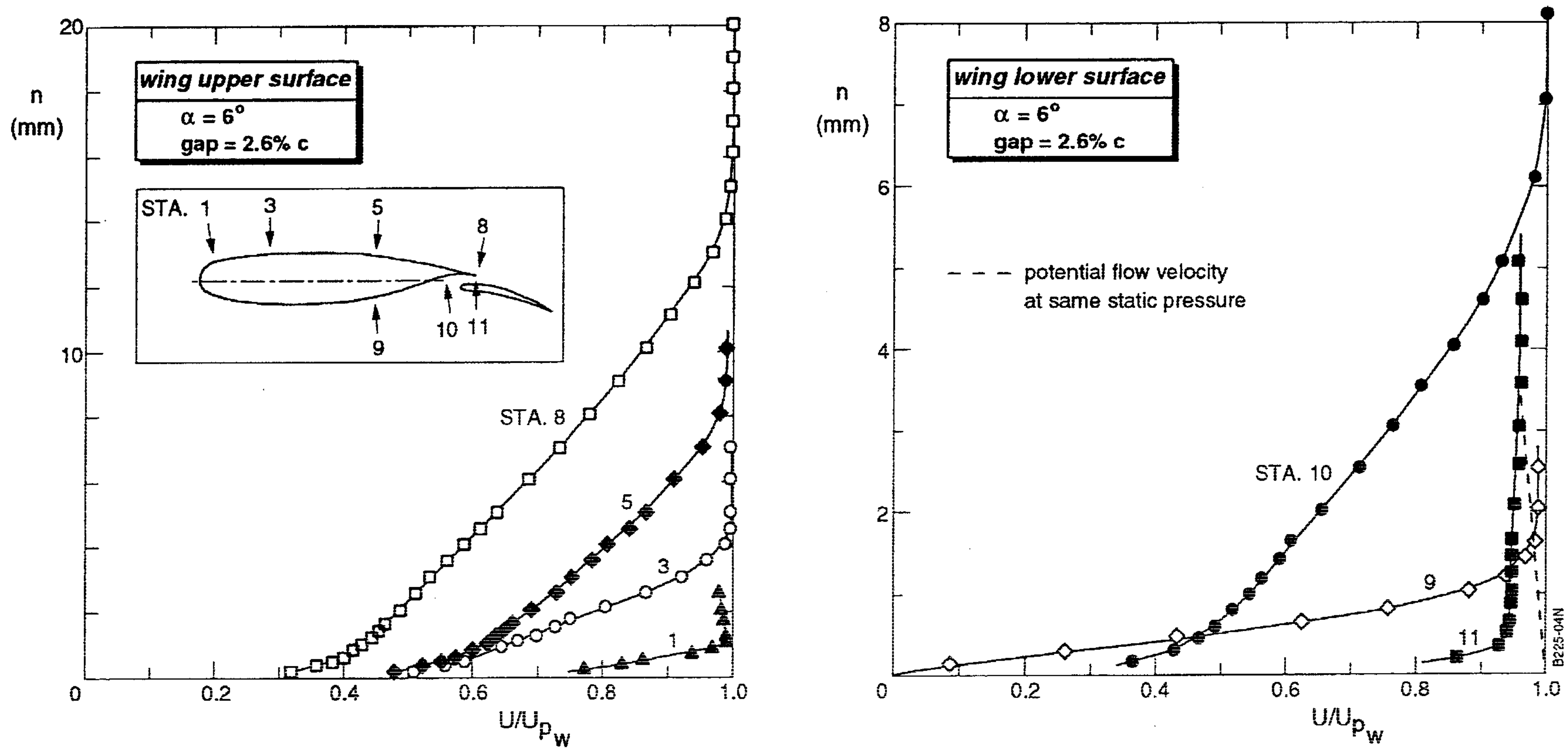

Fig. 4 Typical measured velocity profiles of boundary layer on wing surface

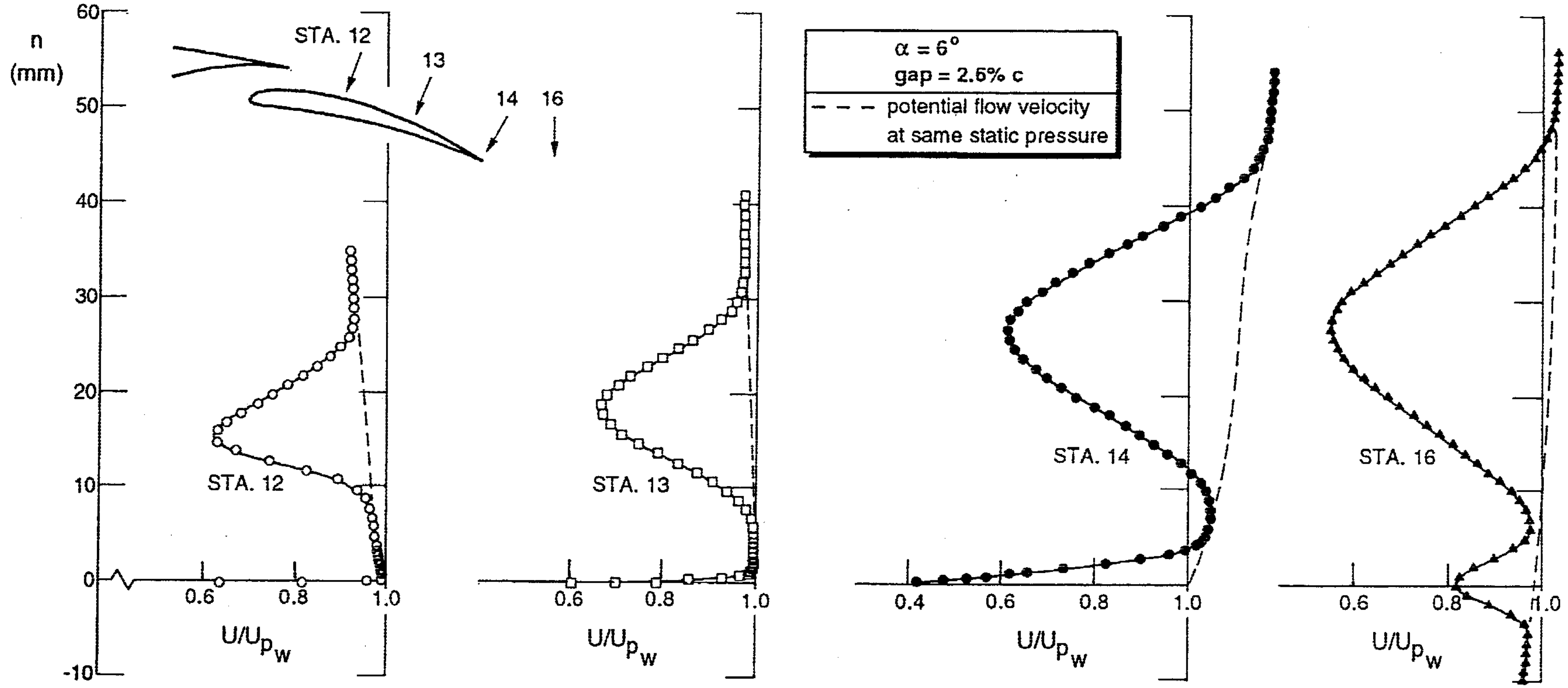

Fig. 5 Typical measured velocity profiles of shear layer above flap

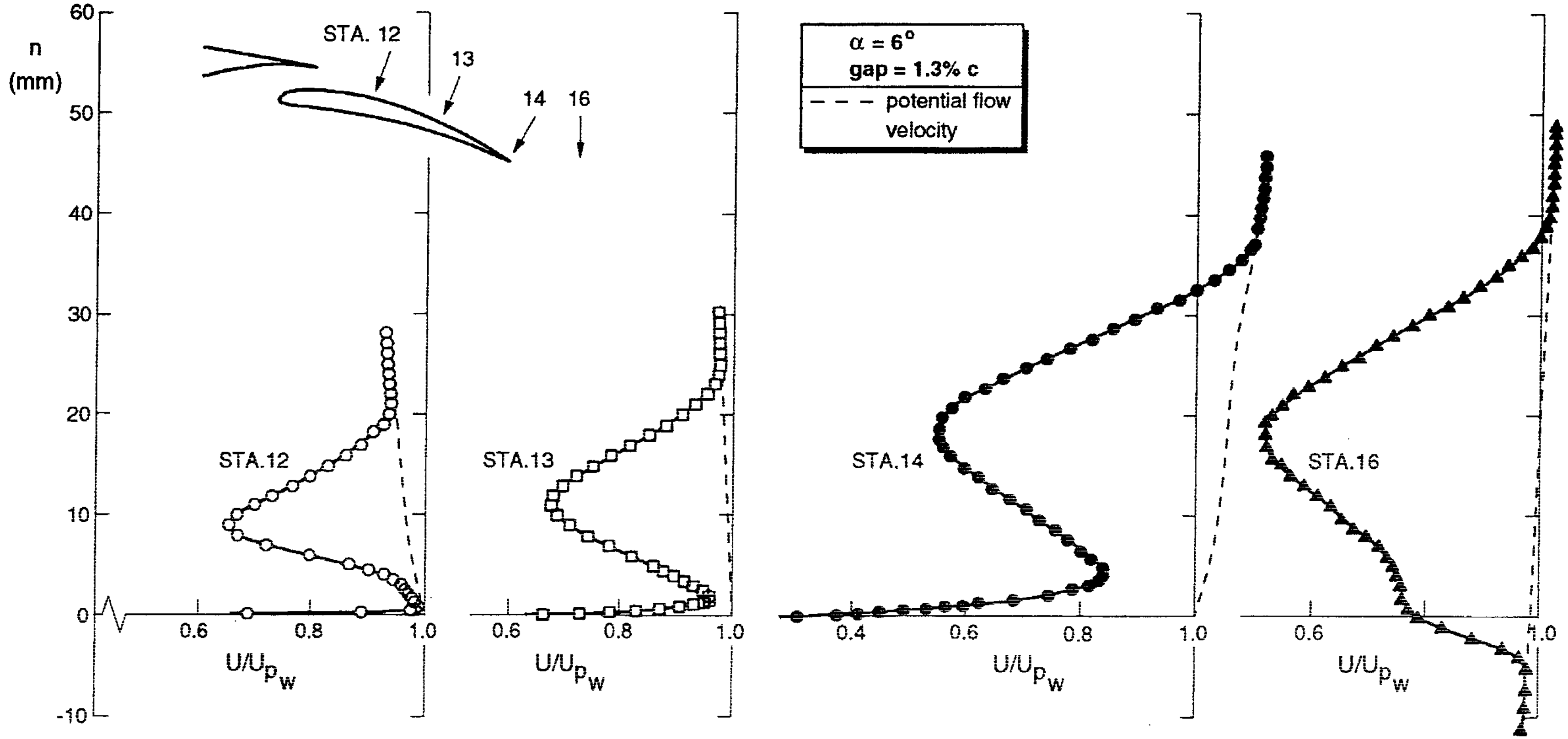

Fig. 6 Measured velocity profiles of shear layer above flap, small gap

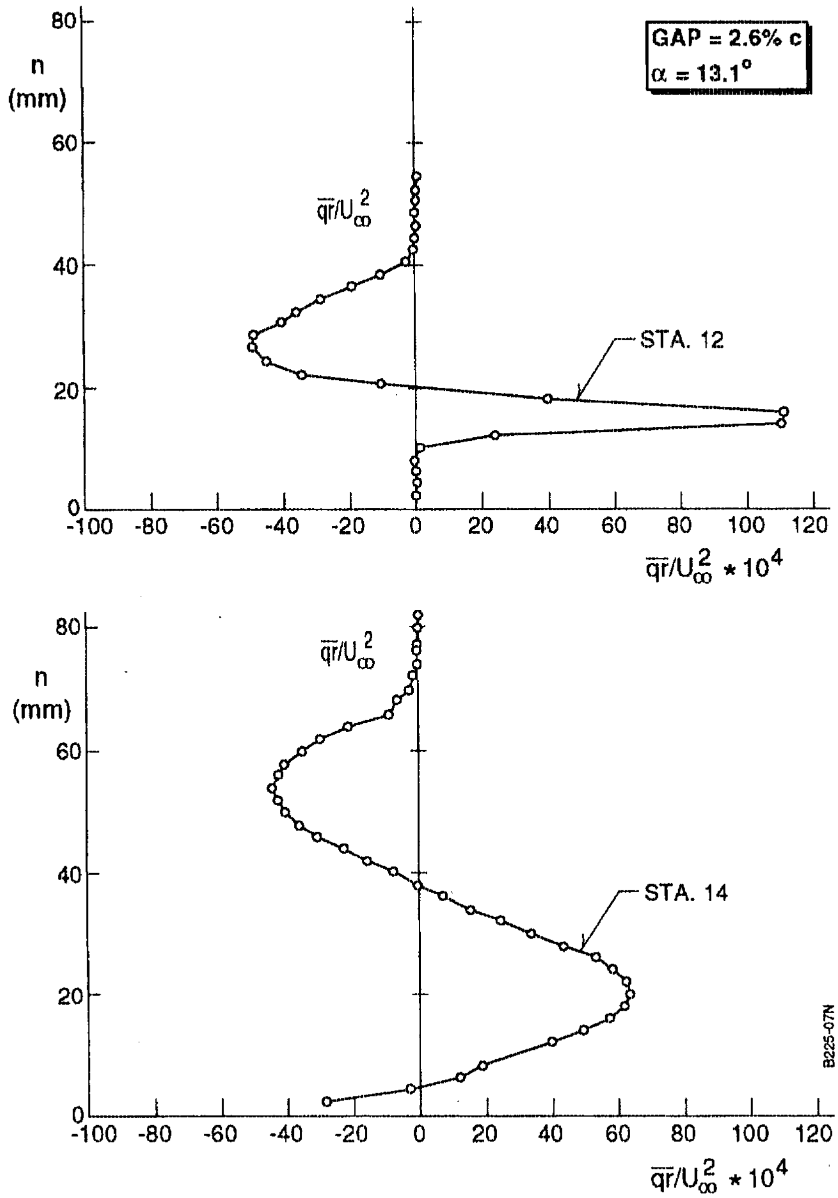

Fig. 7 Hot-wire results: measured streamwise Reynolds stresses, $\overline{qr}/U_\infty^2$, at two stations