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by

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SUMMARY

Flow visualization techniques, which have been successfully used in flight tests, are described.

One indicates boundary-layer transition on a wing with a "china clay" coating, that is wetted at high altitude with a liquid of suitable volatility emitted by another aircraft; the result is photographed at altitude.

The second shows the shock-wave position by the differential rippling of a viscous oil coating on the wing; it also reveals laminar flow areas by unrippled oil, at the same time. It relies on direct sunlight but is not over-sensitive to the direction of this, within quite wide limits

Comparative shock-wave results are given using an earlier direct sun-shadowgraph method which requires precise sun alignment and has been little used.

*Replaces R.A.E. Technical Report 68188 - A.R.C. 30837.

CONTENTS

1 INTRODUCTION

The aim of this brief paper is to record two visual flow techniques that were used successfully in flight some years ago, lest they get lost to posterity.

The first technique described relates to the visualization of the transition from laminar to turbulent flow within the boundary layer. It is particularly designed for use at high altitudes, where contrary to what was thought at one time the sublimation method cannot hope to work due to its sensitive dependence on temperature.

The second was aimed at locating a shockwave on a wing by virtue of the abrupt change in skin friction at the shock; it was thought that a viscous oil film would be rippled by the friction in a differential manner ahead of and behind the shock. Not only was this so but the areas of laminar flow, ahead of the shock, were not rippled at all; this was a bonus result that makes the method a double indicator.

2 LOCATION OF BOUNDARY LAYER TRANSITION

Up to 1948 the only flight testing for flow transition in the boundary layer was by the author's original chemical method[1], using a chlorine gas trail and a sensitized wing. An alternative technique developed by Pringle[2] and which became known as the sublimation method had been used but only in wind-tunnels. It had, moreover, run into difficulties as regards the smoothness of the coating. In 1948/9 it was decided to try the sublimation technique in flight and considerable flying was done[3], including tests at altitude. What was not appreciated in that work was that very little sublimation took place in the intense cold and the records were produced at the lower levels only.

Early in 1951 the author demonstrated that it was barely possible, after using all a Vampire's fuel in level flight, to get a genuine test record at 18000 ft down to ground level and photograph it. This theme and the tricks used, in an attempt to overcome the difficulties were later taken up by P.R. Owen[4].

To overcome the temperature difficulty the author decided to try a method developed by the N.P.L.[5] from the original chemical one, i.e. to coat the wing with a porous white china clay coating over a dark undercoat and to use liquid evaporation instead of a chemical action. This gives an excellent contrast for demonstration work - and for photography in flight.

The key to the application of the method was to wet the wing at altitude with a suitable kerosene 'fraction' to suit the temperature, by spilling it from another aeroplane which would then photograph the wing to be tested from above and below after it had dried out to give a black and white picture of transition. The dry white areas of such pictures correspond, of course, to those regions of the wing over which the flow was turbulent.

In the tests just mentioned a Meteor aircraft was used for the wetting process and the flow over the wings of both a Vampire and a Canberra aircraft were successfully observed and photographed with little difficulty. To illustrate the sort of result obtained the transition patterns over the outer upper and lower portions of the wing of the Canberra aircraft when flying level at a Mach number of 0.74 and an altitude of 35000 ft are shown in Fig.1.

3 AN INDICATION OF THE SHOCK-WAVE POSITION

It was highly desirable that there should exist relatively simple but effective visualization techniques, which would give the position of the shock wave when this was present on a wing. Such a technique, which used a coating of high viscosity silicone oil spread over the wing, was tried in the autumn of 1955 as an alternative to the very complicated travelling light interference method of Dr. Lamplough[6]. The test aircraft was a Venom and as it could only sustain a shock wave at altitude the oil coating had to be viscous enough and thick enough applied to blow gradually back on the climb, and become smooth, and to retain enough oil to form ripples under test. This was successful on the first and only attempt. Photographs of the wing upper surface inboard of the 'fence' were taken from the fuselage, and the direction of the sun in any test is shown by the shadow cast by a knob on a short mast on the wing. The rippling differential at the shock was not very sensitive to sun position, although without the sun no ripples could be seen at all. Fig.2 shows examples of the appearance of the surface with two different sun positions. It will be seen that the rippling in the high-drag area ahead of the shock is much more pronounced than behind the shock. Further forward on the wing, that is to the right in the photos, areas of turbulence can be seen spreading in the now classical manner first seen in the author's

1944 tests; the laminar areas appear dark owing to the blue sky, yellow filter, and smooth reflecting film of oil. The flight conditions were the same in both photographs, being M = 0.82 in turning flight, to study the effect of sun angle.

Another simple method for the visualization of the shock position is that described in Ref.7 whereby a shadowgraph picture of the shock location is obtained using the sun. It remained largely unexploited, but was used in the present tests to obtain an approximate confirmation of the shock position. For this picture the sun is in the plane of the shock, that is, on the starboard beam, as indicated by the mast's shadow. Fig.3a shows the shock-wave position to be at 66.5 per cent wing chord; this was in straight flight, whereas in Fig.2a and 2b the shock locations are at 65 and 64 per cent in turning flight. The effect of added incidence is to bring the shock wave forward, and an exact comparison is not possible from the photographs.

Fig.3b shows another example of the results that are obtainable by this method. This shock-wave position corresponds to a higher speed, Mach number 0.84, in straight flight.

4 CONCLUSIONS

Both the "wetting at altitude" method for transition, and also the oil-ripple method for shock wave plus transition are simple and straightforward in use. The same can be said of the use of the sun to cast shock-wave shadows - certainly when these can be observed by the pilot or crew during test.

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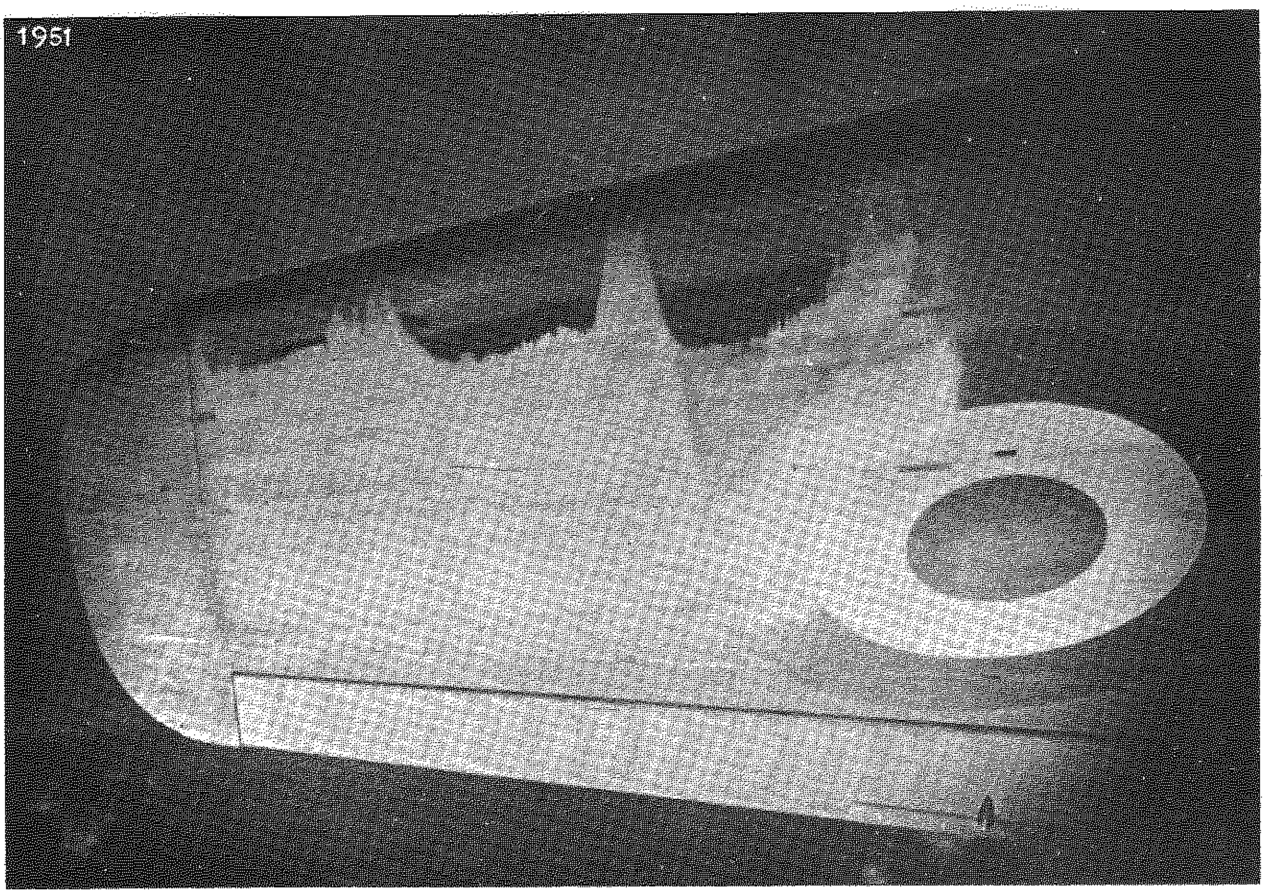

Fig.1a. Upper surface

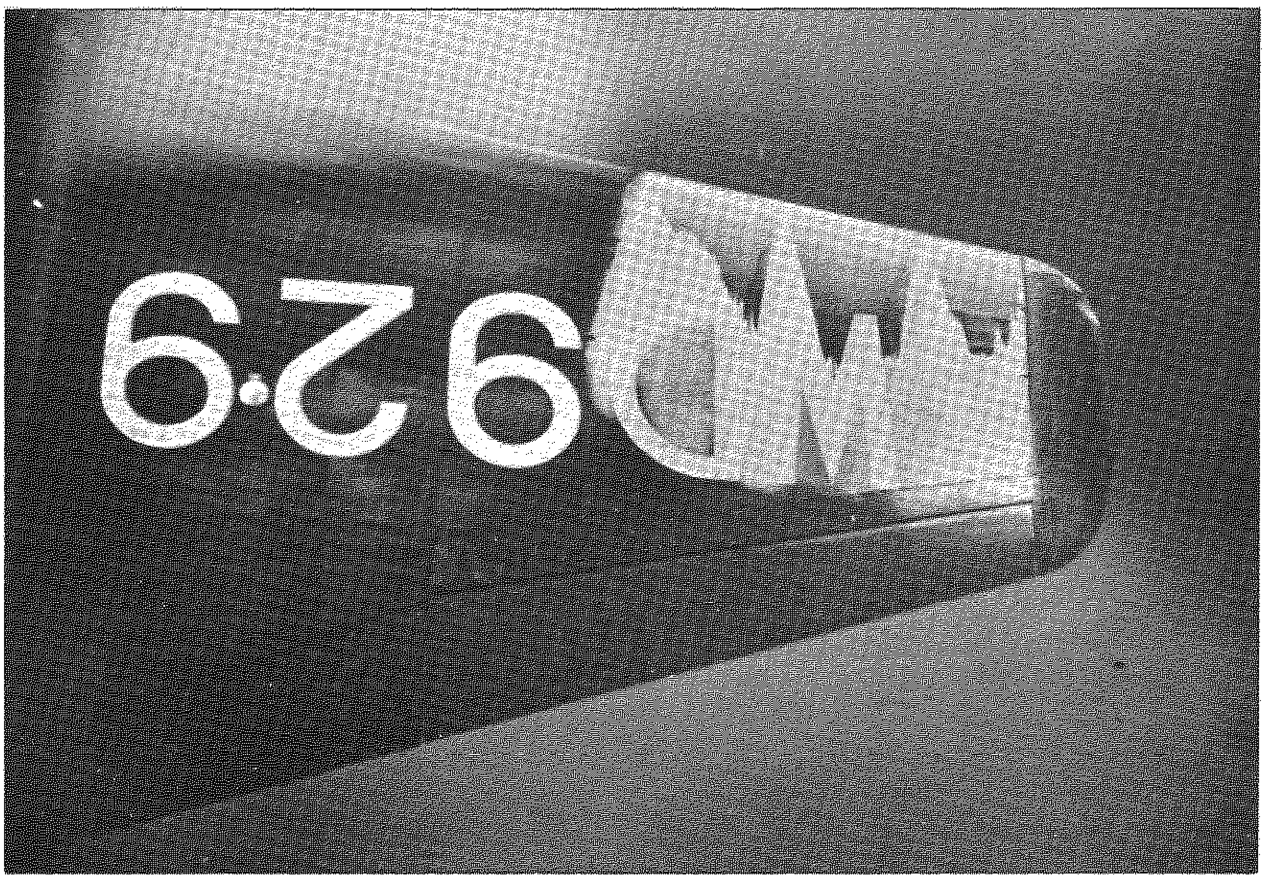

Fig.1b. Lower surface

Fig.1. Transition from laminar to turbulent flow in the boundary layer on the wing of the Canberra aircraft. ($M=0.74$ at 35,000ft, $R_e=6\times10^6$)

Fig.2a. Shockwave location with Sun in first position

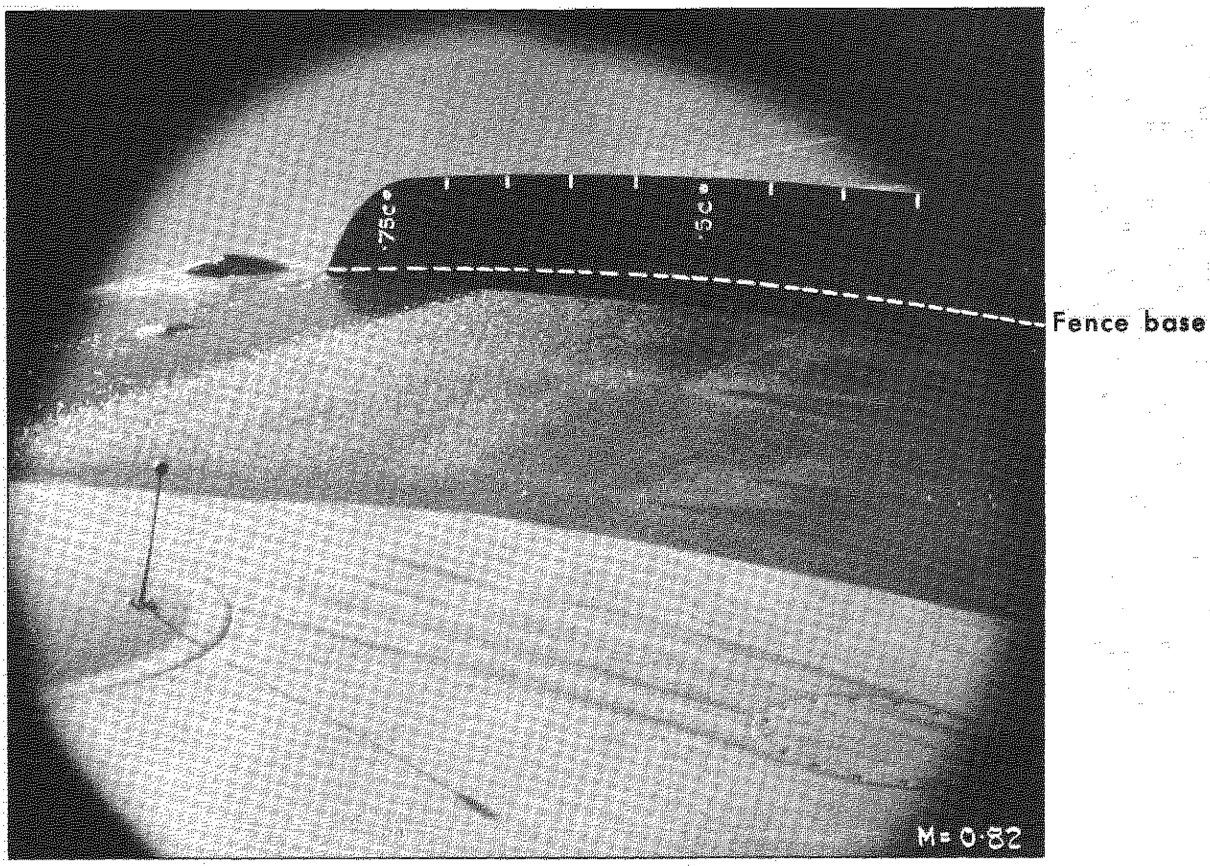

Fig.2b. Shockwave location with Sun in second position

Fig.2. Oil method of visualization of shockwave location

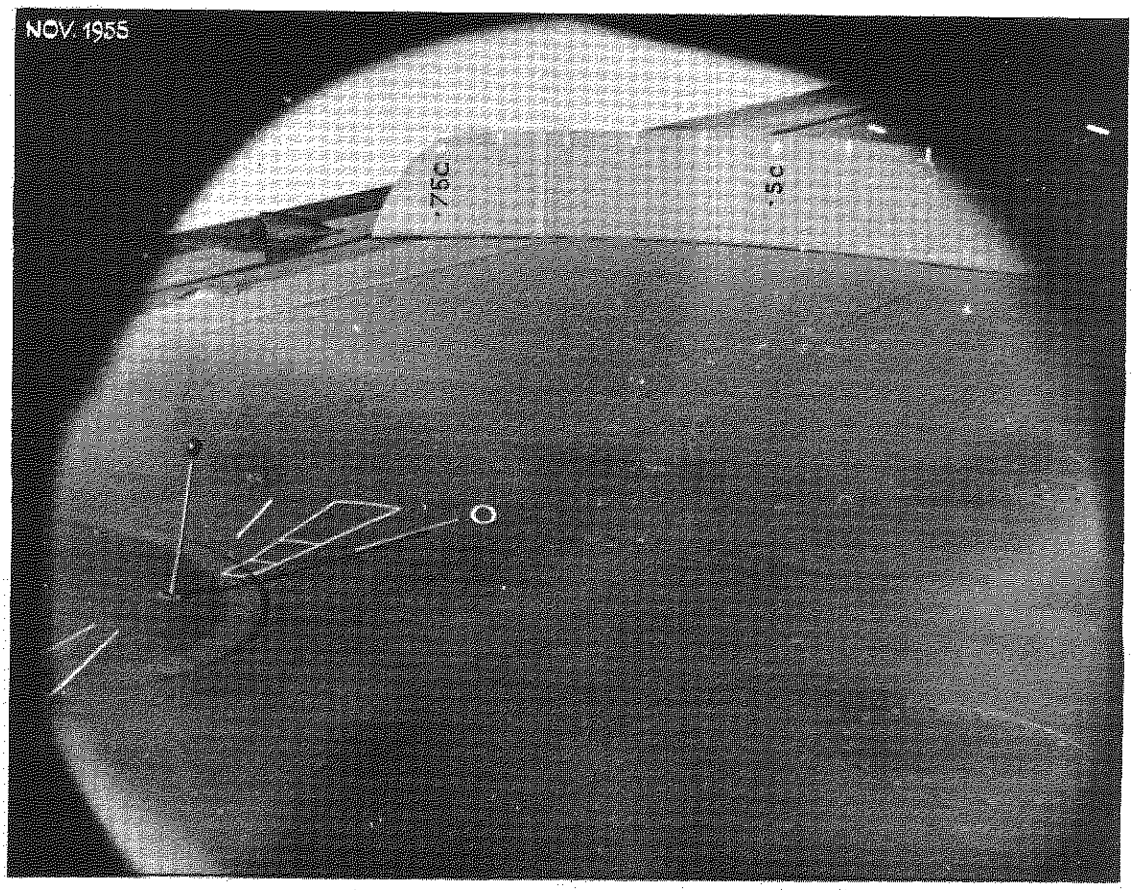

Fig.3a. Shockwave location as shown by shadow method for M=0.82

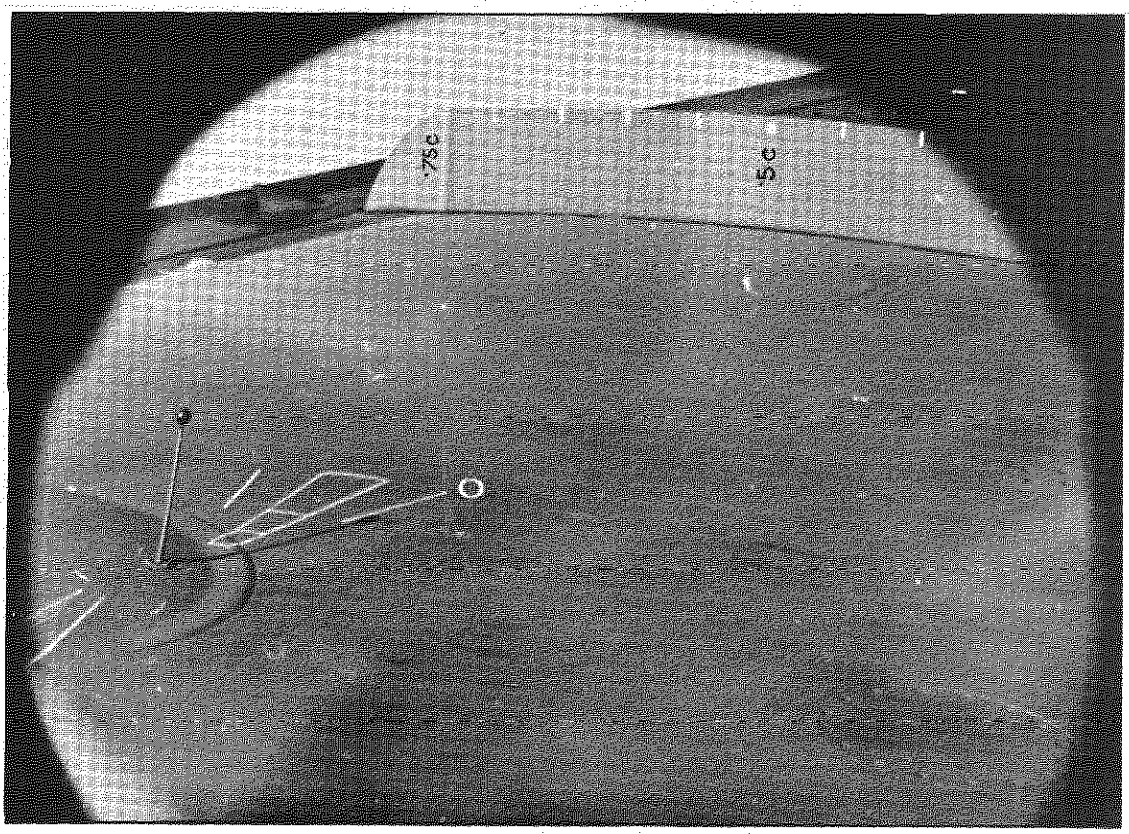

Fig.3b. Shockwave location for M=0.84

Fig.3. Shockwave locations as obtained by the use of the shadow method

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