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WING-BODY INTERFERENCE

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In order to insure the most compact and efficient design of models and instrumentation for both part (a) and (b) of the contract as outlined in the January, 1951, Proposal, attention was first directed towards the checking and development of the methods of approach, both theoretical and experimental. Preliminary survey of the literature on wing-body interference indicated that there are three (approximate) analytical methods which might predict the local flow characteristics sought: the Ferrari, Morikawa, and NACA (Ames-Cleveland) methods (all linearized). It is proposed to "calibrate" these computational methods against each other on the simplest case of wing influence on body and simultaneously to "get the feel" for these methods (i.e., organization of computing, short cuts, approximations, etc.).

Concurrently, the same problem (if linearization is valid) of wedge at 4° influencing a cylindrical body was placed into the UMERI Supersonic Wind Tunnel (See Fig. 1). The experimental results should help in evaluation of the three computational methods. However, emphasis in the tunnel was placed on checking out details of techniques, such as total head probing and boundary-layer flow visualization as well as blocking characteristics of model and heat transfer effects on the boundary layer during the runs. Some of the results of more general interest are given below.

1) Streamlines in the inner portion of the boundary layer and shock-surface intersection can be made visible by a mixture of china clay and oil of wintergreen spread over the blackened surfaces. The pattern appears not to be affected by the unsteady flow during the starting and closing of the tunnel if the ingredients are properly mixed and spread.

2) Even weak shock waves impinging obliquely on a surface cause appreciable boundary-layer cross flow. Fig. 1 exhibits the visibility of streamlines and the boundary-layer cross flow with local angle of over 30° for a weak shock deflection of 4°. Fig. 1 shows also usage of the technique for studying blocking characteristics (vortices on the floor).

Other tentative conclusions from the application of this technique may have importance beyond the immediate objectives of the present problem. (a) Expansion waves create little boundary-layer cross flow on surfaces they affect (in contrast to shock waves). (b) The flow visualization technique developed gives excellent means for judging the extent of tip effects on wings. (c) Squarely cut tips of finite-thickness wings indicate undesirable separation at angles of attack. (d) Juncture between a body and a swept-forward wing exhibits highly undesirable boundary-layer flow, which probably causes a detached shock wave.

3) Since the boundary layer may indeed have a strong influence, it is important to keep it the same from run to run and thus minimize the scatter of pressure data. During the preliminary experiments, therefore, a short study of the motion of the transition point on the body during the run and of the effect of this motion due to heat transfer from model to tunnel air was made. It was found that the location of the transition point moves little during a run and that over 50 per cent of the cooling of the model occurs in the first three seconds after the butterfly valve is opened. By

the end of the run thermal equilibrium between model and air is essentially established. However, it was also found that on the unusually long pointed body the location of the transition point was influenced by secondary uncontrollable factors, some of which are not fully understood. It was decided therefore, that the model for the wing-body interference proper should not have a long nose ahead of the region of pressure probing and that the condition and thickness of the boundary layer should be standardized by introducing fixed artificial roughness elements forward of the probable location of the transition point.

4) Fig. 2 shows the spatial distribution of pressure for the configuration of Fig. 1, namely,a wave corresponding to a "wing" incidence of 4° influencing the flow over the body (p_o = free stream total pressure; Mach number = 1.90). The linearized potential flow method of Ferrari has now been set up and computations started for the case of Fig. 2. Simultaneously the NACA (Nielsen) method is being prepared for the same problem to check the experiment and Ferrari's method. Indications are that the boundary-layer cross flow visible in Fig. 1 influences the pressures on the lee side ($\omega = 180°$) a great deal. Test for large wing incidences such as $\delta = 11°$ show that this effect probably makes the linearized methods inapplicable.

5) The flow of the accumulated boundary layer on the body may be strongly affected by total head rakes in the presence of rear-support sting and strut. This fact indicates the desirability of using a hollow body supported from the floor for the wing body interference tests.

6) The total head rakes must be made very sturdy and may require nonstandard hypodermic tubing with thicker walls and smaller inner diameter. A special design in which five small tubes run inside a larger hypodermic tube and flare out from it has been developed.

7) The basic design and first drawings of the complete wing-body interference model are completed. As a precaution, an old hollow model with various noses, tail shapes, and inner area restrictions was checked out for internal and over-all tunnel blocking in presence of simulated wings. The use of a straight circular channel (outside diameter = 2.00 inches, inside diameter starting from 2.00 inches at the sharp lip, decreasing to 1.75 inches in 2 axial inches) supported at the rear top by a strut that can be set in ten axial floor positions indicated the feasibility of these tests. The total head rake support is an integral part of a rotatable afterbody. The wings are supported through special (now available) side windows and merely abut at the body.

An interesting sidelight (which may be applicable to wings on guided missiles) was checked for the wing supports at the windows. It was corroborated that a .25-inch gap between wings and window (except for main support shaft, of course) produces little interference with the boundary layer upstream of the wing leading edge. Thus, the danger of blocking by the complex model is somewhat relieved, and, simultaneously, the region on body free from extraneous flow interference due to tunnel walls and supports is increased.

Fig. 1

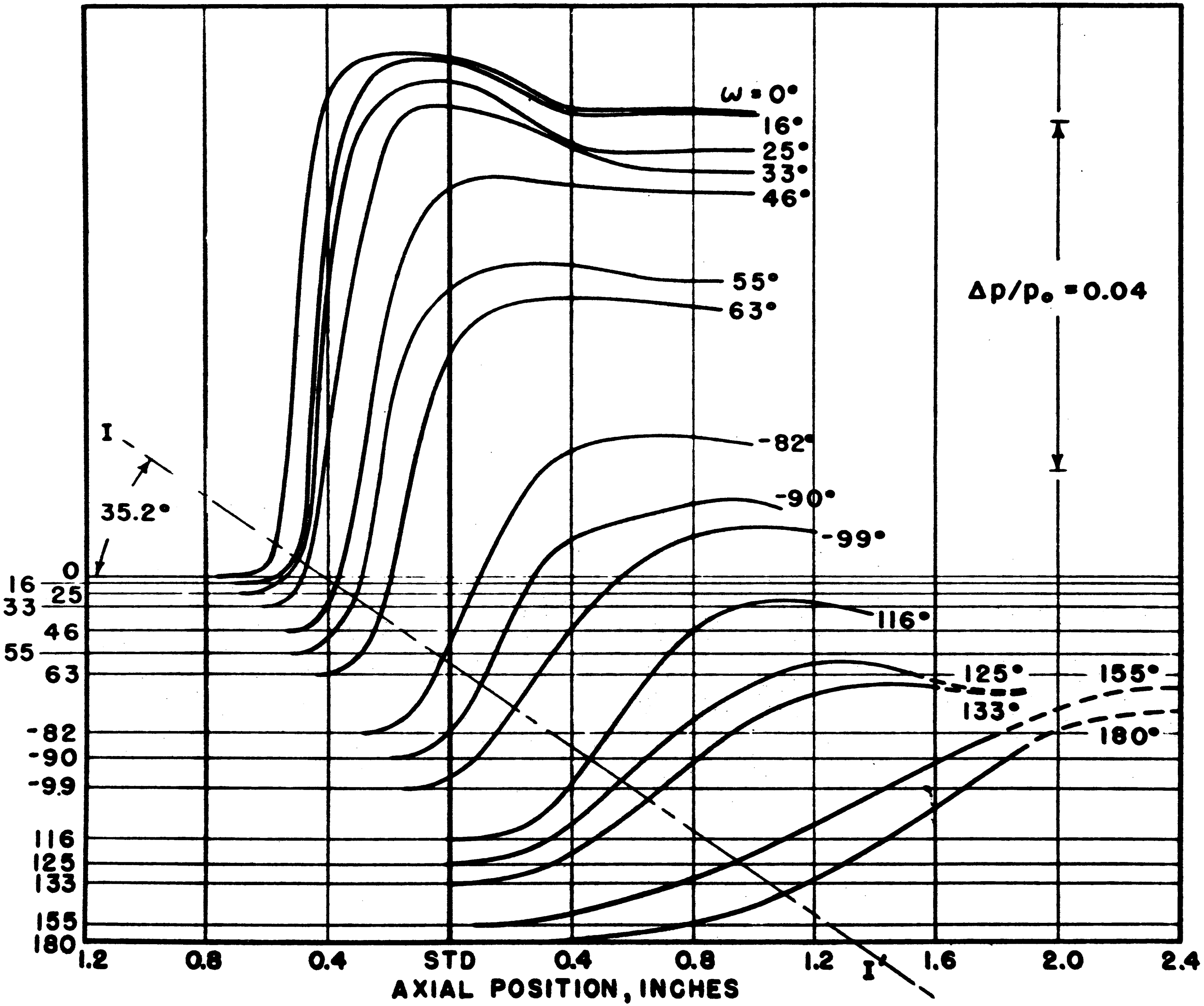

FIG. 2 COMPOSITE ARRANGEMENT OF THE PRESSURE DISTRIBUTIONS.
$\delta = 4.0°$