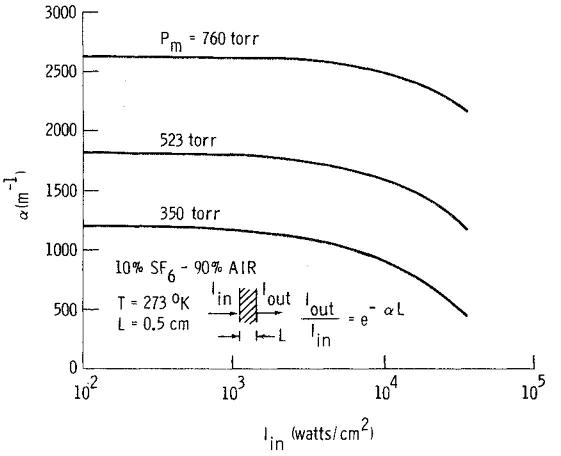

Fig. 4 Predicted saturation effects in a constant temperature SF_6-air mixture at near-atmospheric pressures.

the influence of bulk heating.[10] The vibrational relaxation times used in this analysis are from Ref. 1, where $p\tau_{SF_6-SF_6} = 122$ μsec-torr, and $p\tau_{SF_6-N_2} = 103$ μsec-torr. This latter value is adopted for $p\tau_{SF_6\text{-air}}$. The results shown in Fig. 4 suggest that saturation effects for a typical SF_6-air mixture at near-atmospheric pressure are not important until I_{in} exceeds 10^4 w/cm^2.

IV. Conclusions

From the results given in this Note, and from the extensive data shown in Refs. 10 and 12 (on which this Note is based), the following conclusions are made.

1) Pure SF_6 is a powerful absorber of 10.6μ radiation. For example, the small-signal absorption coefficient, α_0 for SF_6 is on the order of 3540 m^{-1} at $p = 100$ torr.

2) SF_6-air *mixtures* are also strong absorbers of 10.6μ radiation. For example, $\alpha_0 = 2740$ m^{-1} in a 10% SF_6-90% air mixture at 1 atm.

3) The experimental variation of α_0 with p is linear. This is consistent with the theoretical prediction for absorption due to a large number of closely spaced overlapping lines.

4) Comparison between experimental data and theory imply that additional (and as yet unidentified) hot band transitions are contributing to SF_6 absorption at room temperature and above.

5) At pressures near atmospheric, the onset of saturation for a 10% SF_6-90% air mixture occurs above intensities of 10^4 w/cm^2.

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Reattachment of a Separated Boundary Layer to a Convex Surface

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EXPERIMENTS on simplified models of the interaction between a transverse two-dimensional jet and an enveloping supersonic flow have been conducted at the Gas Dynamics Labs. of The Univ. of Michigan.[1] One of the simplified models consisted of a flat plate upon which was mounted a solid obstacle representing the jet (see Fig. 1). The shape chosen for this obstacle was a cylinder of semicircular cross section, the flat side of which was placed against the flat plate, with the cylinder axis perpendicular to the flow direction. The forward part of this circular cylinder thus represents a portion of the dividing stream surface between an imagined two-dimensional transverse jet and the main airstream. The flow ahead of this simulated jet behaves very much like that ahead of a real jet, in that it separates from the plate at some distance ahead of the jet, and then reattaches to the convex (jet) surface while undergoing a strong interaction shock. The flow pattern is also quite similar to that ahead of a forward-facing step, with the important difference that reattachment is not constrained to occur at a fixed point (the corner of the step). This Note describes experimental determinations of the location of reattachment on the curved surface, and correlation with a simple theory.

The tests were conducted at Mach number 3.9 and Reynolds number 120,000 per inch in the 8- by 13-in. supersonic wind tunnel of The Univ. of Michigan, on the two-dimensional model shown in cross section in Fig. 1. The semicircular cylinder had a diameter of 1 in. and a span of 3 in. The flat plate on which it

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Index categories: Boundary Layers and Convective Heat Transfer—Laminar; Boundary Layers and Convective Heat Transfer—Turbulent; Supersonic Flow.

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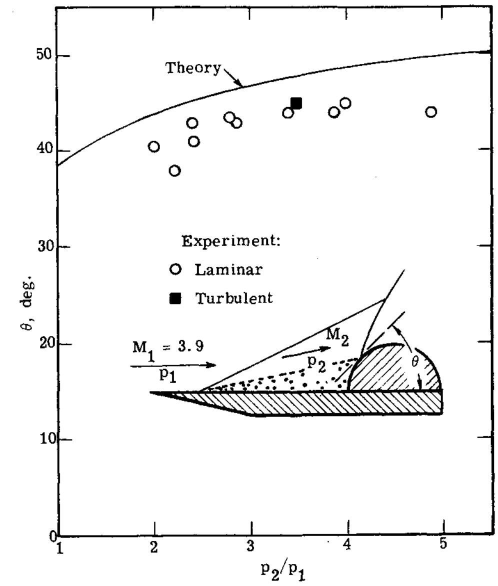

Fig. 1 Measured slope at reattachment point on convex surface, compared with maximum deflection for an attached shock.

was mounted had a sharp 15°-beveled leading edge, and its span was also 3 in. Large endplates were used to assure two-dimensional flow. These extended from the leading edge downstream beyond the cylinder. They had flat inner surfaces and leading edges beveled on their outsides to produce attached flow.

The plateau pressure ratio, p_2/p_1, in the separated flow region ahead of the semicircular cylinder was measured by means of orifices on the flat plate. The reattachment point of the separated boundary layer, assumed to be the maximum pressure location, was deduced from pressures measured at 15° intervals along the circular-arc contour of the cylinder.

Most of the tests were made under conditions that gave pure laminar separation. For these tests, a wide range of plateau pressure ratios was obtained by mounting the cylinder with its leading edge either 2.25 or 2.75 in. downstream of the leading edge of the flat plate, and by varying the height of the obstruction by inserting spacers of various thicknesses up to $\frac{1}{2}$ in. between the cylinder and the plate.

For the one test with a turbulent boundary layer, the cylinder was mounted 10.75 in. from the plate leading edge, in order to produce a natural turbulent boundary layer ahead of separation. Endplates for this test consisted of a combination of lower endplates and small end wedges. The lower endplates had sharp, supersonic leading edges, beveled on the inside, and their outer surfaces were flat. When mounted below the plate they prevented any propagation of high pressures from the beveled lower surface of the plate to the upper surface. The small end wedges closed off the ends of the separated flow region, their upper surfaces being approximately aligned with the plane of the separated shear layer (see Fig. 2). In this case, as well as in the laminar boundary-layer case, the conditions of the experiment met the requirements of Werle[2] for two-dimensionality, namely, that side plates enclose the ends of the separation bubble and that the separation bubble aspect ratio be greater than one.

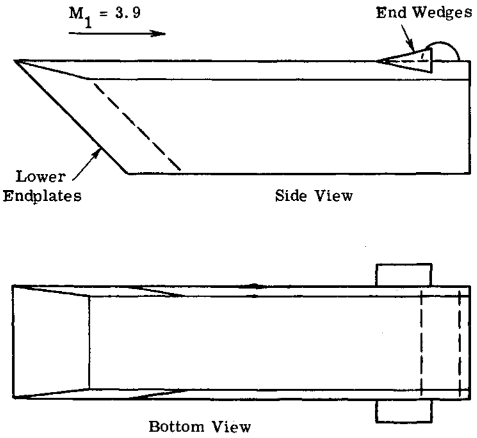

Fig. 2 Arrangement of lower endplates and wedges for turbulent boundary-layer test.

Measured values of the slope θ at the reattachment point are plotted in Fig. 1 as a function of the plateau pressure ratio p_2/p_1. Also shown is a theoretical curve based on the simple assumption that the deflected mainstream, in reattaching to the cylinder, undergoes a maximum-deflection shock, as given by the oblique shock theory. Thus, the calculated slope at reattachment is the sum of the angle of deflection of the mainstream in going through the shock caused by separation ahead of the cylinder (a function of the plateau pressure ratio) plus the maximum theoretical deflection angle for an attached shock that this already-deflected mainstream can undergo.

Reasonable agreement is seen between the simple maximum-deflection theory and the experimental results. At least part of the discrepancy between the two can be attributed to boundary-layer build-up downstream of the reattachment point.

A maximum-deflection shock at reattachment can be explained on a simple inviscid basis. The deflected mainstream entrains mass from the separated flow region, tending to reduce the size of the region of separation and to cause the reattachment shock to become stronger. But as soon as the shock becomes so strong that it detaches from the cylinder, it allows flow behind it to be diverted into the separation region, which enlarges the separation region and weakens the reattachment shock. Thus, an equilibrium would be expected where the reattachment shock is just slightly detached.

Of course this inviscid theory neglects the fact that even with an attached shock some flow will be diverted into the separation region through the subsonic part of the boundary layer. However, the inviscid theory of reattachment can serve as an upper limit and, as seen in Fig. 1, provides a fairly close approximation to the actual experimental results.

A trial-and-error procedure can be used to apply this theory to a particular flow. A separation point is first arbitrarily chosen. The plateau pressure ratio p_2/p_1 is computed from empirical separation relations involving local Mach number and Reynolds number. From oblique shock relations the Mach number M_2 and direction of the deflected flow are obtained. Then, where the shear layer intersects the convex surface the angle of deflection required to turn the flow tangent to the surface is noted. If this angle is less than the maximum deflection possible for an attached oblique shock at the Mach number M_2, then the separation point is too far upstream; if greater than the maximum deflection, too far downstream. After several trials the proper separation point can be located such that the deflected flow above the separation region has to undergo a maximum-deflection attached shock in order to flow tangentially along the convex surface.

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