pointed out that, although solar radiation torques are an order of magnitude smaller than gravity gradient torques, solar radiation torques are nearly always oscillatory for earth satellites and may act as a forcing function to drive a gravity gradient stabilized satellite beyond its designed attitude envelope

Note also that, for an interplanetary craft, i e , one for which gravity gradient, magnetic, and aerodynamic torques are absent, solar radiation torque is the dominant space environment effect

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Boundary-Layer Transition on a Slender Cone in Hypersonic Flow

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IN this note the author presents new experimental data on boundary-layer transition on a slender flared cone in hypersonic flow The importance of the knowledge of the state of the boundary layer (i e , laminar, transitional, or turbulent) hardly can be overemphasized Drag, performance, and heat-transfer rates depend on the location of transition on the surface of a body in flight While the effects of freestream turbulence, pressure gradients, surface curvature, surface roughness, and heat transfer on transition are at least known qualitatively, the effect of compressibility in the high Mach number range is still a subject of speculation At low supersonic Mach numbers various wind tunnel tests indicate a general decrease of transition Reynolds number with increasing Mach number [1, 2]

Korkegi[3] conducted some transition studies on an insulated flat plate $M = 5\ 8$ which give some insight as to the effects of compressibility In particular, a very high transition Reynolds number based on distance along the plate, in excess of 5×10^6, was noted along with the inability of various disturbances to trip transition at low Reynolds numbers This appears to indicate greater stability of the laminar boundary layer in hypersonic flow than at lower speeds Zakkay et al [4] have investigated the effects of surface discontinuities on transition However, upstream of the discontinuity, for the range of test conditions considered, transition Reynolds numbers based on momentum thickness Re_θ on cones at Mach numbers of 3–5 were observed to be in the range of 600–700

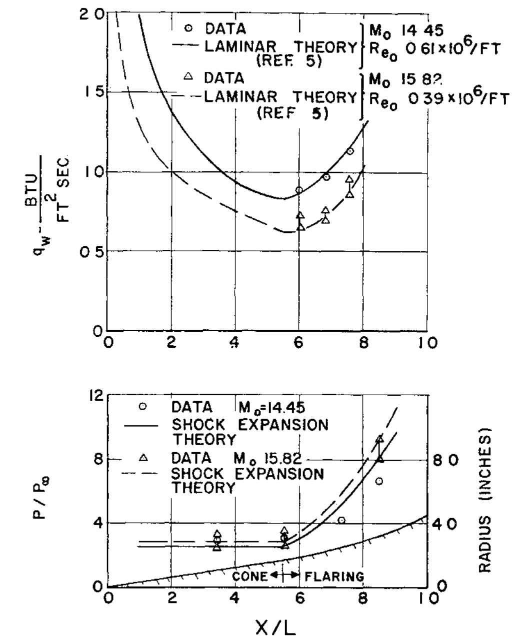

Fig 1 **Pressure and heat-transfer distribution for M = 14 45 and 15 82**

The data presented in this note are the partial results of more complete model tests The data were taken on a slightly blunted (ratio of base to-nose radius $R_0/R_N = 150$) 3 5° half-angle cone with a flared skirt (Fig 1) and a model length of 52 in Thus, for all practical purposes, the cone can be considered as pointed Surface pressures and transient temperatures giving heat flux were measured The fore-

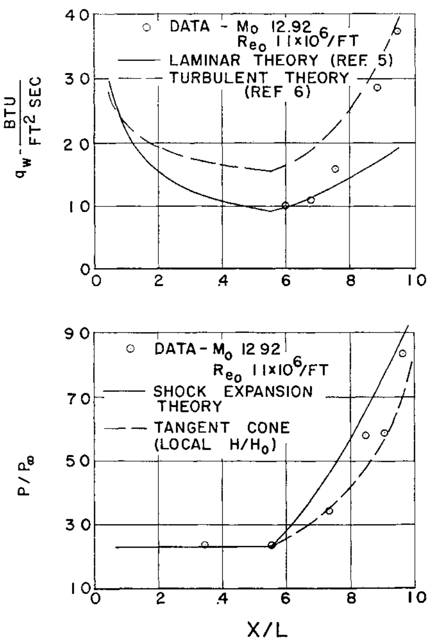

Fig 2 **Pressure and heat-transfer distribution for M = 12 92**

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Table 1 Test conditions

Mach no	Re/ft × 10^{-6}	Stagnation Pressure, psia	Stagnation Temperature, °R	Wall temperature, °R
15 82	0 387	4032	3500	530
14 45	0 612	4051	3230	530
12 92	1 124	4102	2840	530
12 58	3 045	4165	1800	530

Table 2 Roughness element parameters

Mach no	k, in	k/δ	l, in	R_k
15 82	0 030	0 15	0 040	1,690
	0 150	0 72	0 072	8,450
14 45	0 050	0 37	0 072	4 000
12 92	0 050	0 55	0 072	6,870
12.58	0.030	0.46	0.040	12,580

most model pressure tap is at $X/R_N = 600$ and the foremost heat gage is at $X/R_N = 1030$

Tests were conducted in the 48-in -diam shock tunnel at the Cornell Aeronautical Laboratory, Buffalo, New York The test conditions for the data presented are listed in Table 1

The purpose of instrumenting the model with heat gages was to determine the state of the boundary layer for the various freestream test conditions Transition was assumed to occur when the measured heat rates departed from the estimated laminar level Since a turbulent boundary layer was desired for the tests, boundary-layer trips were employed These trips consisted of rectangular protuberances extending above the cone surface with the initial protuberance axially located 6 in from the apex Tabulated in Table 2 are k, the vertical height of the rectangular element above the cone surface; the roughness parameter k/δ, where δ is the calculated boundary-layer thickness at the roughness location; l, the lateral spacing between elements; and R_k, the Reynolds number based on flow conditions at the edge of the boundary layer at the roughness station and the roughness height

Conclusions

The measured pressures shown in Figs 1–3 agree well with predictions based on shock-expansion and tangent cone

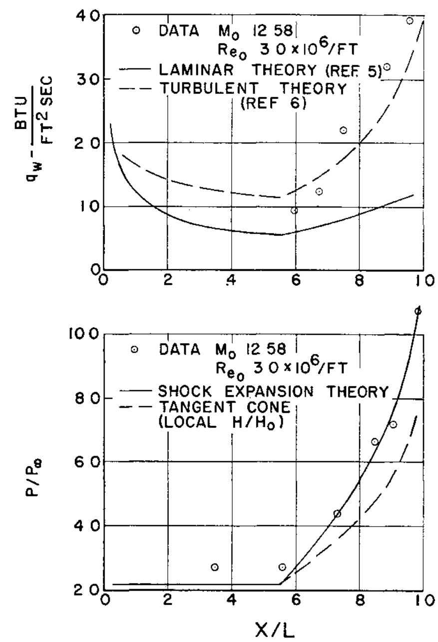

Fig 3 Pressure and heat-transfer distribution for M = 12 58

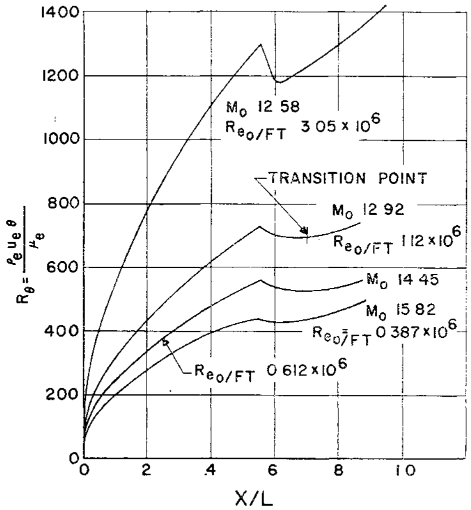

Fig 4 Variation of momentum thickness Reynolds numbei

theories Also shown on Figs 1–3 are the experimental heat rates along with the estimated laminar and turbulent levels The variation of the momentum thickness Reynolds number is shown on Fig 4 For $M = 15\ 82$, the data were obtained with two different trip sizes as specified in Table 2 From Fig 1 it is evident that the boundary layer remained laminar independent of the trip geometry or the variation of freestream Mach and Reynolds number It is interesting to note that laminar flows were present where the values of R_x were on the order of 2–3 million At Mach 12 92, transition occurred at a position $x/L \approx 0\ 7$, where the value of R_θ was on the order of 700 and $R_{e_x} = 5\ 0 \times 10^6$; whereas at Mach 12 58 transition occurred prior to $x/L = 0\ 6$

The present data confirm the greater stability of a boundary layer in hypersonic flow and the inability of the roughness in the form of protuberances to cause transition for values of $R_x < 5\ 0 \times 10^6$ and values of $R_\theta < 700$ A transition Reynolds number R_θ of 700 ($R_x \approx 5\ 0 \times 10^6$) was noted on a slender pointed cone Turbulent boundary layers were achieved where the value of R_θ was in excess of 700 with the corresponding R_x in excess of 5 million

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