movement of the two elements until near the bending failure loads. Therefore, a BI-STEM section acts almost as a rigid section and the above results are valid for design.

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Vortex-Induced Heating to a Cone-Cylinder Body at Mach 6

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RECENT experimental studies have shown that vortices can strongly influence heating on the leeward surface of conceptual hypersonic vehicles.[1–6] The interaction of these vortices with the leeward surface creates relatively high shear regions in otherwise low shear or separated flow regions. Oil flow studies show that this high shear, which is created by the scrubbing action of the vortices on the surface, creates a featherlike oil smear. Comparisons of heat transfer data with oil flow studies show that the heating levels corresponding to the featherlike oil smears are elevated above the heating levels found in the areas adjacent to the oil smear. Previous studies on early design space shuttle orbiters[1–3,6] have shown that the most severe vortex-induced lee-surface heating occurred in a region along the lee meridian where the interaction of the primary vortices with the lee surface created a relatively large, well defined featherlike oil smear. The present Note presents data on a blunt three-dimensional body which shows that the most severe vortex-induced lee-surface heating need not occur as a result of the interaction of the primary vortices with the lee surface even though this interaction produces a large, well defined featherlike oil smear.

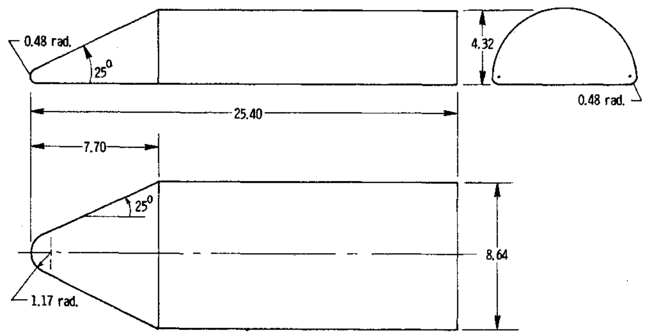

Fig. 1 Sketch of flat-bottom 25° half angle cone-cylinder model.

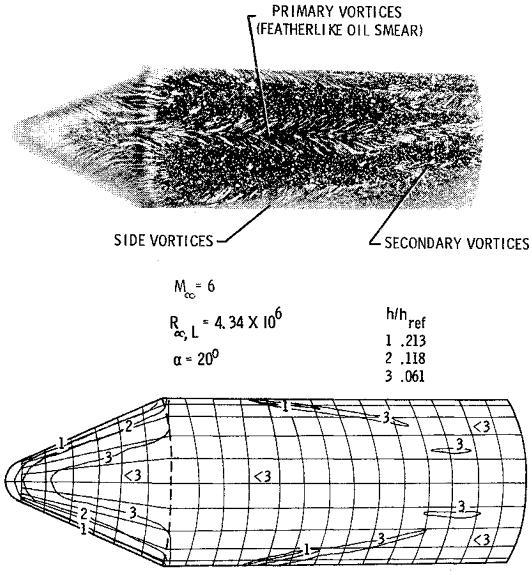

Fig. 2 Heat transfer and surface oil flow.

Heat transfer and oil flow studies were conducted on a flat bottom 25° half angle cone-cylinder body at 20° angle of attack in the Langley 20 in. Mach 6 wind tunnel[7] at a freestream Reynolds number based on model length ($R_{\infty,L}$) of 4.34×10^6. A sketch of the model is presented in Fig. 1. The heat transfer data were obtained by using the phase-change paint technique[8] with an assumed laminar recovery factor of 0.86 based on freestream conditions. The measured local heat transfer coefficient (h) was normalized by the calculated stagnation heat transfer coefficient[9] on a sphere having a 0.31 cm radius (h_{ref}). Oil flow studies were obtained by distributing a mixture of silicon oil and lampblack in random dots of varying sizes over the entire upper surface and taking photographs of the model after each test.

The oil flow photograph of Fig. 2 shows a highly complex lee-surface flow containing a number of vortices. The flow separating over the model forebody forms a primary vortex pair that interacts with the afterbody surface along the vertical plane of symmetry. Secondary vortices, which are smaller in size than the primary vortices, are formed outboard to either side of the primary vortices and interact with the afterbody lee surface. In addition to these primary and secondary vortices, side vortices, generated on the sides of the leeward afterbody at the abrupt change in planform area, also interact with the afterbody surface.

The secondary and side vortex-induced heating levels on the afterbody of the flat bottom cone-cylinder body are greater than was measured for the primary vortices even though the featherlike oil smear generated by the primary vortices was larger and much better defined than those generated by either the secondary or side vortices. This result is in contrast to that reported in Refs. 1–3 and 6 where the most severe vortex induced heating was generated by the primary vortices along the lee meridian. The heating due to the primary vortices in the present study is probably elevated above that found for the separated flow surrounding the feather pattern but was not measured for the present test times and phase-change paint temperature.

These results together with the work in Refs. 1–6 lead to the conclusion that the existence of a well defined featherlike oil smear generated along the lee meridian by the interaction of the primary lee side vortices with the surface does not necessarily indicate the region of the most severe vortex-induced heating. It should be remembered that Ref. 3 showed that the severity of vortex-induced heating is extremely sensitive to Reynolds

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number and geometry and that there exists a "threshold Reynolds number" below which vortex-induced heating decreases abruptly.

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