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DISCUSSION

A. M. O. Smith

It is remarkable that the influence of concave curvature on heat transfer rates was not studied long ago. Professor McCormack and his co-workers are to be congratulated for their efforts in this area.

The paper brings forth several questions. The first one concerns the increased net heat transfer rate, which is contrary to linear theory. Why has it occurred? Are you sure you were measuring a true average for the entire plate? In the paper you say the heating elements were 0.1-in. wide, spaced 0.03-in. apart, and located parallel to the flow. Something is not clear. There appears to be interference. I presume you mean the elements are transverse to the flow, and if so, the 14 elements cover about one cycle. This extent may not be enough to obtain a good average. Another point arises; the flow is highly unstable. Perhaps, it is transitional, thus explaining the increased heat transfer rate, although your hot-wire measurements seem to deny this possibility.

I am curious how much the vortices have been amplified at your measurement station. Have you tried to make such calculations, as I did in your reference [3]?

The evaporation rate for naphthalene is proportional to the rate of heat transfer. This fact suggests a possible experiment with respect to the gross heat transfer rate. This fact suggests a possible experiment with respect to the gross heat transfer rate. Under carefully controlled conditions, run the channel for a short period of time, learn the loss in weight $w$ of naphthalene, and hence $dw/dt$ either for the complete model or for an insert. For the same velocity, temperature and other conditions with naphthalene evaporate from a curved plate at the same rate as from a flat plate, or at a different average rate?

A statement is made in the paper as follows: "Since the existence of the phenomenon (Görtler vortices) to be studied had at best been shown indirectly by Liepmann and McGahan, it was first desired to demonstrate their existence with some visual technique." Tani has demonstrated their existence (Proceedings, International Council of the Aero Sciences, Stockholm, 1962).

Authors' Closure

As mentioned in the paper, the temperature of each heating element (on the curved duct) was taken as the average of 6 measurements taken along the element. A sample is given in Table 1—the average is 258 deg F and the spread is about ±9 percent.

The flow was, in fact, very stable and the free stream turbulence fluctuations were always well under 3 percent of the free stream velocity—that is, less than 10 percent of the longitudinal velocity fluctuations associated with the Görtler vortices.

We did not measure the amplification factor of the vortices. However, our observations indicated that these reach a constant maximum strength at a certain distance along the curved plate (as expected from Kirchgassner's work) and our heat measurements were made in this region.

The suggestions for a further naphthalene experiment are appreciated.

We are now aware of the work of Tani and Wortman on demonstrating the formation and nature of Görtler vortices.

We agree that it is likely that Görtler vortices are present in the sublaminar layer in turbulent flow on concave plates and probably turbulent heat transfer. These and other unanswered problems associated with this interesting phenomenon are worthy of continued attention.