DISCUSSION

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This article describes a careful study of the condensation of mercury vapor under conditions similar to those of Misra's wetted-wall runs [35, 36].[3] For instance, both used a double-tube bayonet condenser with a nickel condensing surface centered axially and directed vertically downward into a large vapor chamber. Both also attempted to eliminate noncondensable gas scrupulously by continuous evacuation. The speed of Misra's reflux-condenser diffusion-pump was evidently much greater, but in compensation Sukhatme had a reduced-pressure jacket around his chamber. Some other differences were only minor. According to Wilhelm's detailed analysis [37], Sukhatme's vapor was some 6 to 38 F superheated. Misra's was saturated, due to the addition of traces of Mg and Ti to promote good wetting of the boiler wall and eliminate bumping. However, this small superheat should not be significant. Also, Sukhatme's pressure range of 1 to 17 mm, which is rather low, did not quite reach Misra's range of 26 to 760 mm. However, this gap is fairly small, considered as a ratio.

It is thus not surprising that, contrary to the impression gained from the paper, very similar results were obtained. Both demonstrated that condensate flow was predominantly laminar, Sukhatme by gamma ray attenuation and Misra by observation and photography. Both also carried out runs in which noncondensable gas was intentionally added at various concentrations—Misra by continuously adding and removing H_2 or N_2 at steady state at 4 or 5 flow rates, and Sukhatme by adding and trapping two different partial pressures of an unstated inert gas in the apparatus. Qualitatively, both workers saw a similar fall-off in the coefficient of heat transfer with increase in inert gas.

Both studies also recognized and applied the concept of "temperature jump," which of course is mandatory and calculable by the kinetic theory of gases, to interpret their results. In fact, both studies give very similar values of accommodation coefficient. Taking the evaporation and condensation coefficients, for simplicity, as equal, Sukhatme obtains their average value, σ, as 0.45. The average of Misra's 20 lowest pressure points—those under 52 mm—is 0.40 [37]. Since Misra shows σ decreasing toward higher pressures this small change is quite expected.

Quoting from Misra [36]: "The overall values of h, uncorrected for "temperature jump," vary from about 10 percent of (the Nusselt equation) at atmospheric pressure to about 50 percent at 1 lb/sq in abs. When (the temperature jump) correction is applied, the results vary from about 10 to 70 percent, respectively. The various surfaces (copper, steel, and nickel) yielded the same order of magnitude of h, although the surfaces were visibly wetted to quite different degrees." It is evident that using an accommodation coefficient below unity to decrease the theoretical h values to the observed ones will require a very wide variation in σ; for Misra's atmospheric pressure runs σ thus calculated ranges from 0.01 to 0.03 [37]. Such low values are certainly contrary to expectations for a continuously cleaned surface such as flowing condensate, and are the reason that this concept was not carried further by Misra. In fact, Subbotin [38] recently studied the condensation of potassium vapor onto a horizontal pool of liquid potassium at 1 to 7 mm absolute, obtaining condensation coefficients averaging exactly 1.00, with an average deviation of 4 percent. His one higher pressure point is at 230 mm, too high to show whether σ has remained at 1, or fallen off.

Although many specific questions come up on reading this paper, the principal one is probably as to the novelty and reliability of attempting "to resolve the discrepancy between theory and experiment for the case of heat transfer during film condensation of liquid metal vapors" by temperature jump analysis of Sukhatme's low pressure tests, when all available higher pressure work, and particularly Misra's, since it agrees with Sukhatme, indicates that this model is grossly inadequate. No doubt additional light could be thrown on this problem merely by replacing the special manometer, which can only read up to 18 mm [39], with a simpler but longer one!

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[3] Numbers in brackets designate Additional References at end of this discussion.

Additional References

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39 S. P. Sukhatme and W. M. Rohsenow, "Heat Transfer During Film Condensation of a Liquid Metal Vapor," Dept. of Mech. Eng., Mass. Inst. of Technology report 9167-27 (A.E.C. report MIT-2995-1, 1964).

Authors' Closure

We are grateful for Dr. Bonilla's remarks in pointing out the issues in question.

We emphasize that the apparatus in this experiment was vacuum jacketted preventing, or greatly minimizing, inward leakage of air. In our discussion of Fig. 1 we suggested the data of previous investigators most likely had unsuspected amounts of noncondensible gas present because a plot of their data (Misra's included) showed that at essentially constant heat flux the data of h versus p decreased in the manner shown in our Fig. 8 when we intentionally introduced air into our system.

The presence of unsuspected noncondensible could readily account for the low values of σ deduced from Misra's data.

The data of Subbotin, et al. [38], suggest magnitudes of unity for σ in the pressure range of 1 to 6 mm Hg. The values of σ in the present paper are around 0.45 for the pressure range 2.3 to 17 mm Hg. At our lower pressures of 1.4 and 1.04 mm Hg the corresponding magnitudes of σ are 0.516 and 0.605 suggesting that σ may rise to unity at very low pressures.

Another possible cause of the significant decrease in the value of σ as pressure is increased could be the inapplicability at the higher pressures of the molecular theory leading to equation (6). The magnitudes of the σ may well result from a combination effect of the departure from the molecular theory as wel as the actual condensation coefficient magnitude at the surface