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EFFECT OF SURFACE MATERIALS ON PURE MERCURY BOILING HEAT TRANSFER

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THE WETTABILITY of a heating surface by a liquid metal, especially in the case of pure mercury, is of great importance in determining the boiling heat transfer rate. It is frequently assumed that pure mercury does not wet steel surfaces [1]. Therefore, it is also believed that this causes film boiling of pure mercury at low heat fluxes ($\sim$ 4000 Btu/hft^2) and small temperature differences ($\Delta T \sim 10$°F), such as those reported by Lyon *et al.* [2]. However, Bonilla *et al.* [3] and Lee [4] have reported otherwise.

In the absence of adequate information on the interfacial energy conditions in pure mercury boiling, an experimental study was necessary to establish heat transfer performance parameters for different surface materials.

The survey of literature concerned with pool boiling heat transfer with mercury and mercury with additives can be found in [4] and [5]. It seems that the surface material affects the pool boiling heat transfer characteristics of pure mercury. However, no systematic study on the problem has been reported. In this note, new data are reported for pool boiling heat transfer of pure mercury from horizontal cylinders made of two different surface materials.

The experiments were conducted in the liquid metal pool boiling facility at Chalk River Nuclear Laboratories. The facility has been described in detail in [4]. In the present study, an 8 in long $\times$ $\frac{3}{4}$ in o.d. electrically heated test section of low-carbon steel surface was manufactured according to the same procedure developed for the type 304 S.S. test heater used in the previous experiment. Briefly, the test section consists of an X-750 Inconel tube placed inside boron nitride electrical-insulation sleeves and swaged into a low-carbon steel tube. Five iron-constantan thermocouples insulated with alumina and sheather in S.S. 316 tubing of 0·020 in o.d. were embedded in grooves machined on the inner wall of the test tube. Six voltage tappings were provided along the heater test section for the accurate measurement of power dissipation. The test heater extended completely across the long dimension in the lower part of a 4 $\times$ 8 $\times$ 24 in high boiling vessel. The surface finishing, cleaning method and experimental procedure were identical in both cases. The temperature difference ΔT in the present note is that between the average bulk liquid temperature measured by three thermocouples in the liquid pool and the average of five

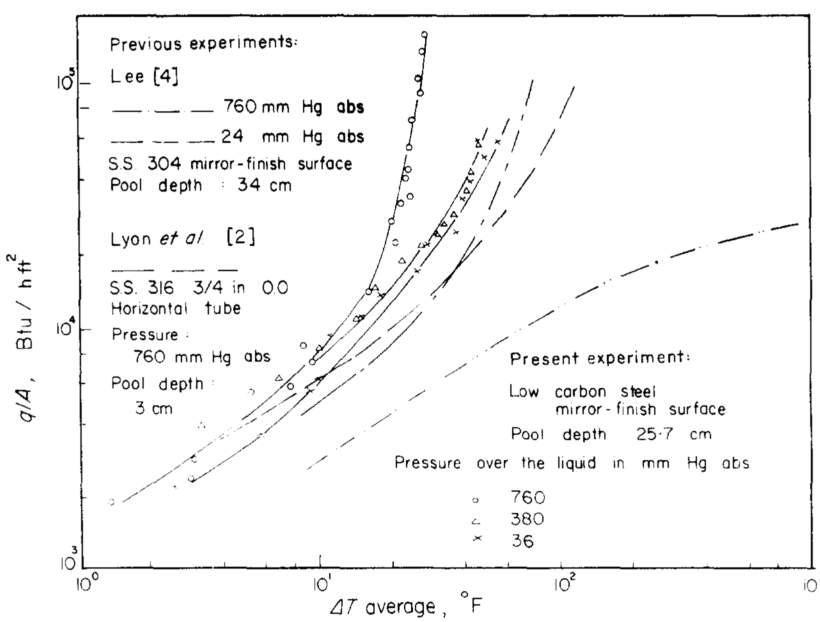

FIG. 1. Effects of system pressure and surface material on pool boiling of pure mercury.

temperature readings obtained circumferentially around the test heater, corrected to the values at the heating surface.

The test liquids were analyzed by spectrophotometry before and after the tests and the results of the analyses were generally in accord with those reported previously [4]. Care was taken so that no other contamination was allowed during the test.

The present experimental results, as shown in Fig. 1, indicate that heat transfer is much improved with the carbon-steel surface compared with the stainless steel type 304 surface studied previously. The boiling curves in Fig. 1 also seem to indicate that nucleate boiling was obtained at atmospheric pressure. However, the heat transfer rate seemed to deteriorate with a decrease in the system pressure above the liquid. This may be due to the increase of the surface tension (with the decrease in vapor pressure) acting between the liquid and vapor during the bubble formation, which in turn could change the contact angle which depends on the relative magnitude of the different surface energies.

The effect of system pressure was an increase in ΔT with decreasing system pressure for a given heat flux, just as for the previous case [4].

At atmospheric pressure, the greater pool depths seem to require larger ΔT values. This is in accord, as illustrated in Fig. 2, with the findings of Bonilla *et al.* [3] who boiled pure mercury on a horizontal low-carbon steel plate. However, at system pressures of less than 380 mm Hg abs., the greater depths require smaller ΔT, which is expected. As previously reported [4], it may be assumed that the effect of pool depth is a minor factor.

The visual observation of the degree to which the test heat surface was wetted at the room temperature was made after each series of tests but the phenomena of completely tinned surface as reported by Shimazaki [5] was not observed. The burn-out heat flux at atmospheric pressure was not reached at $2{\cdot}6 \times 10^5$ Btu/hft^2, which was the limit set by the power supply.

The present results lead to the conclusion that the relative magnitude of interfacial energies significantly affect the pool boiling heat transfer process, and that the several predictions available for liquid metal nucleate boiling does not correlate the pool boiling of pure mercury with different surface materials.

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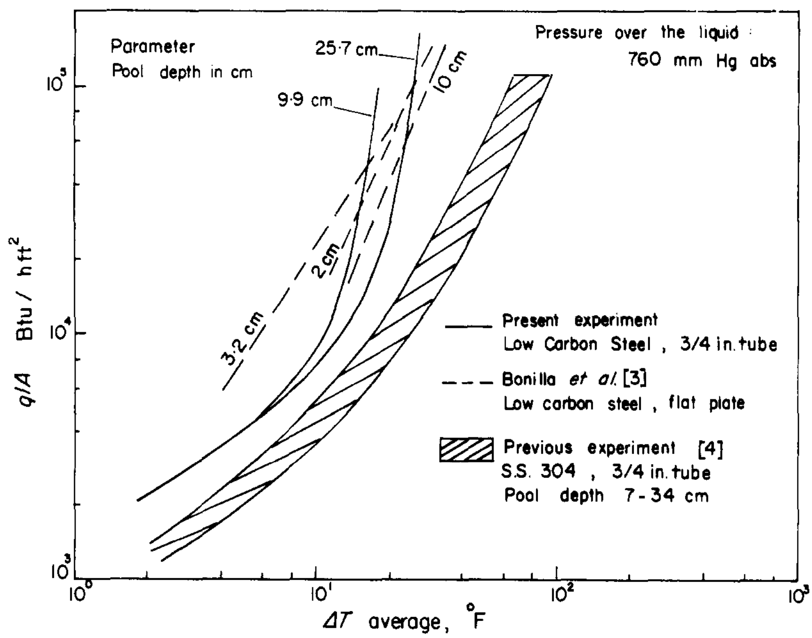

FIG. 2. Effects of pool depth and surface material on pool boiling of pure mercury.

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