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EFFECTS OF THE INITIAL SIZE OF WATER DROPLET ON ITS EVAPORATION ON HEATED SURFACES

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NOMENCLATURE

A, projected base area of droplet [m^2];
$\bar{A}$, time-averaged projected base area of droplet [m^2];
D_0, initial diameter of droplet [m];
T_F, temperature T_{w0} having the maximum evaporation time, i.e. Leidenfrost temperature [°C];
T_{sat}, saturation temperature [°C];
T_{w0}, initial surface temperature [°C];
T_{ws}, time-averaged surface temperature [°C];
ΔT_{sat}, $= T_{ws} - T_{sat}$ [K];
Q, heat required to evaporate completely one droplet [J];
q, time-averaged heat flux, $q = \dfrac{Q}{\bar{A}\tau}$ [W/m^2];
τ, total evaporation time [s].

IN THE previous paper [1], we discussed the heat-transfer characteristic of evaporation of a single droplet of pure water on various heated plates (materials: copper, brass, carbon steel and stainless steel), by correlating the time-averaged heat flux q with the time-averaged surface superheating of plate ΔT_{sat}, which were obtained from time-dependent measurements of the surface temperature of plate just below the droplet and the projected base area A of the droplet. In that case, we dealt with the droplet whose initial diameter D_0 was 3.29 mm in the range of initial surface temperature T_{w0} less than the Leidenfrost temperature T_F, while we used four initial droplet sizes, 2.54, 2.78, 2.86 and 3.29 mm dia in the range of $T_{w0} > T_F$.

In this note, three initial droplet sizes, 2.54, 2.86 and 4.50 mm dia, are dealt with in addition to 3.29 mm in the range of $T_{w0} < T_F$. The initial temperature of water droplet is about 20°C. The experimental apparatus and procedure, and also the correlation technique are the same as those described in the previous paper [1]. Recent works [2–10] are concerned with the evaporation of liquid droplet on the heating surface and with the liquid–liquid thermal interaction.

Examples of the total evaporation time τ correlated with the initial surface temperature T_{w0} are shown in Fig. 1(a) and (b). Measurements of τ are conducted by increasing stepwise the initial surface temperature T_{w0} from room temperature to higher temperature, which is called UP, and thereafter they are conducted by decreasing stepwise from the high temperature to lower temperature, which is called DOWN. If we represent the same data as those in Fig. 1 on the q vs T_{ws} diagram after the correlation technique treated in the previous paper, we can get Fig. 2(a) and (b). It can be seen that two figures coincide very well when the temperature T_{ws} is less than about 120°C, regardless of UP and DOWN, material of heated plate and initial droplet diameter D_0.

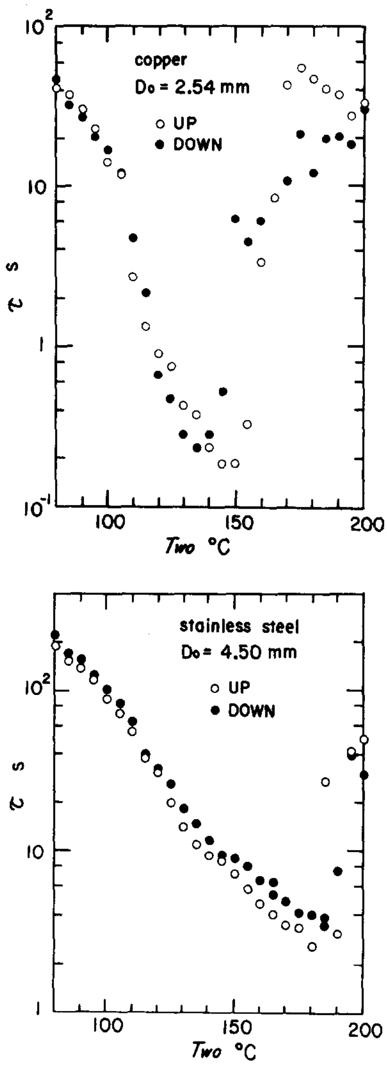

FIG. 1. Total evaporation time τ vs initial surface temperature T_{w0}: (a) copper, $D_0 = 2.54$ mm; (b) stainless steel, $D_0 = 4.50$ mm.

Figure 3(a) and (b) illustrate the so-called boiling curve (q vs ΔT_{sat} diagram) and they show the nucleate boiling and transition boiling regions. Although there is a little scatter of experimental data, the effect of D_0 on the boiling curve can not be recognized.

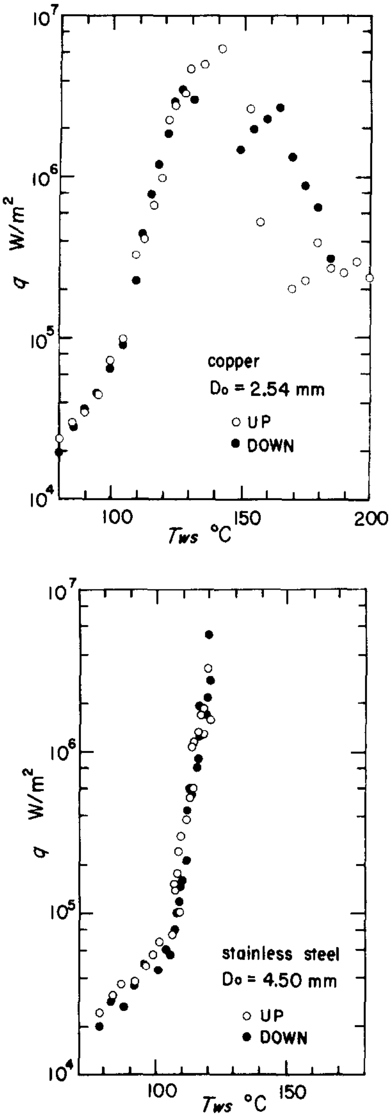

Fig. 2. Time-averaged heat flux q vs time-averaged surface temperature T_{ws}: (a) copper, $D_0 = 2.54$ mm; (b) stainless steel, $D_0 = 4.50$ mm.

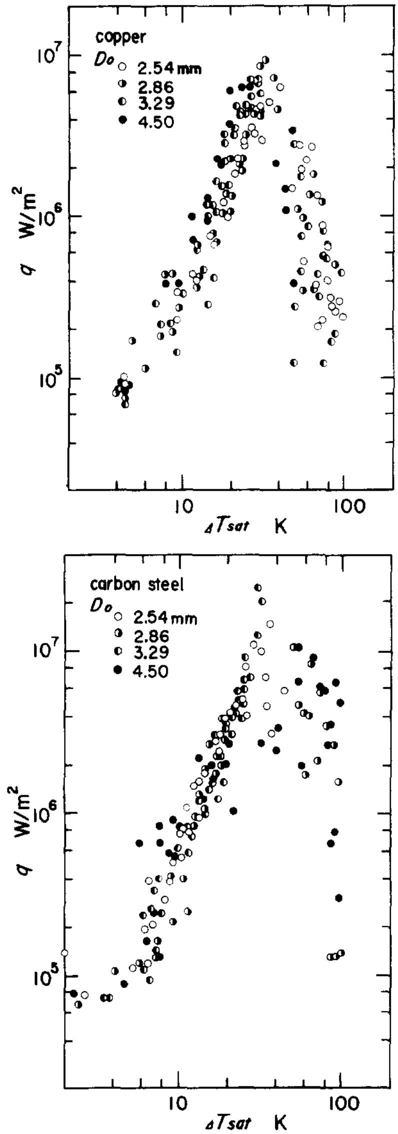

Fig. 3. Effects of initial droplet diameter D_0 on the boiling curve: (a) copper; (b) carbon steel.

Corresponding to Fig. 13 in the previous paper, all of our data are represented in Fig. 4 without distinction of D_0. From this figure, the following conclusion can be derived. In the nucleate boiling region, our present data obtained by using the droplet of $D_0 = 2.54$–4.50 mm seem to provide a straight line parallel to the nucleate pool boiling curve for thin water film (see [11–13]), no matter what material is used for heated plate and no matter which size of droplet is used for the initial diameter. Our present data are more close to Shibayama *et al.*'s recent experimental data [11], which were obtained by using thin water film of 2 mm thickness on the horizontal heating surface of 22 mm dia. than other investigators' data [12, 13]. This might be due to the fact that Shibayama *et al.* conducted the experiment of nucleate boiling on the heating surface of small area as compared with other investigators'.

In the transition boiling region, the curve for the heated plate of lower thermal diffusivity (stainless steel) comes to higher ΔT_{sat} than for higher thermal diffusivity (copper) independently of D_0. This corresponds to the fact that the higher the thermal diffusivity of the plate, the lower the Leidenfrost temperature T_F (see Fig. 2 in [1]).

In the film boiling region, the effect of initial droplet diameter on the heat-transfer characteristic has been already discussed in the previous paper, and the relation between q and ΔT_{sat} is almost independent of D_0.

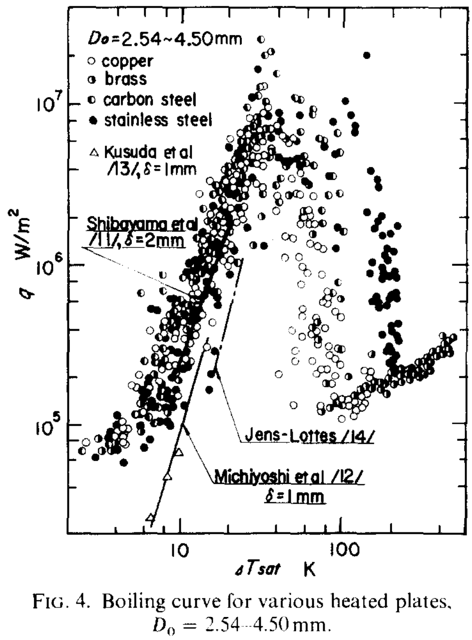

Fig. 4. Boiling curve for various heated plates, $D_0 = 2.54$–4.50 mm.

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