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HEAT-TRANSFER MEASUREMENTS DURING DROPWISE CONDENSATION OF STEAM

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THE greatly enhanced heat-transfer coefficient obtainable in the presence of dropwise condensation has long engaged the interest of research workers. Hitherto, lack of precise measurements has hindered basic studies of the mechanism. The present investigation had, as its original aim, the provision of precise data relating to heat-flux and steamside temperature difference. It is briefly reported here in order to render available the *results*. These may be briefly summarized thus:

For each of four different promoters, runs were made using three different effective plate heights. Observations of hitherto unexcelled consistency were obtained and found reproducible on different days. These results are thought to have enhanced precision and, in particular, their relation to earlier work supports the view that the effect of "non-condensables" has been avoided. Differences between promoters were clearly established.

Thermocouples, accurately located and spaced through the test plates served to measure:

(1) by extrapolation—the "mean" surface temperature at a known point on the condensing surface;
(2) from the temperature gradient—the heat flux.

Each of two copper test plates was 0·5 in thick and the dimensions of the condensing surfaces were:

	Horizontal	*Vertical*
Plate 1	2·750 in	2·44 in
Plate 2	0·875 in	5·00 in

Using Plate 1, the measurements were made at a point 1·12 in below the top of the condensing surface. Using Plate 2, measurements were made at depths of 1 in and 4 in from the top of the condensing surface. The plates, in all cases were vertical and the steam pressure was approximately 1·03 atm. In all three cases the measuring point was laterally central.

The promoters used were:

(1) Dioctadecyl disulphide [$C_{18}H_{37}SSC_{18}H_{37}$]
(2) "No. 1 Amine"† [chiefly octadecylamine $C_{18}H_{37}NH_2$]
(3) Di-S-octadecyl 00 — 1, 10-decanedixanthate [$C_{18}H_{37}SSCO(CH_2)_{10}OCSSC_{18}H_{37}$]
(4) Dodecanetris (ethanethio) silane [$C_{12}H_{25}Si(SC_2H_5)_3$]

The graphs presented (see Fig. 1) relate to the condensation of clean steam, free from "non-condensable" gases, on vertical copper surfaces operating under steady conditions a few hours after promotion.

It was found that when a plate had been newly promoted, the surface temperature (after the removal of "non-condensables") increased for some time. In most cases an interval of at least 4 h was required to attain a steady and reproducible value. The increase in surface temperature during this interval was between 1 and 2 degC. No further change was detected over the duration of the test. Presumably, during the preliminary interval "excess" promoter is removed by the condensate.

Fig. 1 indicates that for all four promoters, the steam-to-surface temperature difference is an approximately linear function of heat flux over the range of heat flux investigated. It was also found that the position of the measuring point did not affect the results over the range used (1 in to 4 in from the top of the condensing surface).

It may also be seen that although promoters 1 and 2 give very nearly the same results, 3, and particularly 4, give results that are evidently different.

† "No. 1 Amine" is a commercial product of Houseman Thomson and Co. Ltd., and is used as a corrosion inhibitor.

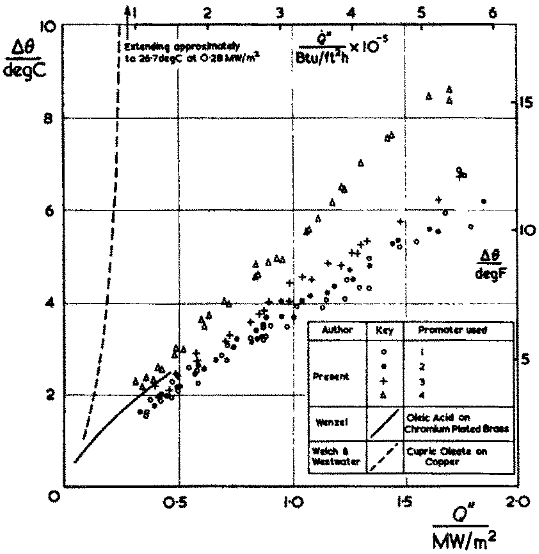

FIG. 1. Variation of steam-to-surface temperature difference with heat flux.

There exists a wide range of published results. The approximate extremes are given by the present work together with that of Wenzel [1] and by the results of Westwater and Welch [2]. These earlier observations are included in Fig. 1. Inaccuracies in past work may be partially attributed, in many cases, to unsatisfactory methods for measuring the condensing surface temperature. It is considered however that the errors, scatter and diversity of previous results are due largely to varying and unknown "non-condensable" gas content in the steam. Evidently the effect of such gases would be to cause deviation towards the results of Westwater and Welch [2].

In agreement with various previous workers it has been the present authors' experience that the steam-to-surface temperature difference during dropwise condensation is extremely sensitive to even minute traces of "non-condensables". Boiling for several hours while simply "blowing off" a considerable proportion of the steam did not reduce this effect to an insignificant level. Arrangements eventually adopted in the present work for the removal of "non-condensable" gases from the immediate neighbourhood of the plate were operated at a series of settings until, in the limit, results were obtained which were independent of the setting. Moreover, it was established that the final results were not thereby vitiated by any effect that steam velocity might be thought to have and that these results are thus the same as those for steam initially at rest.

The foregoing brief report relates to results recently obtained at Queen Mary College (University of London). It is intended that experimental details and a review of the background will later be prepared for publication.

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