since they are somewhat indicative of the vinyl resins, nylons and cellulose derivative plastics. The diffuse conductor reflectivities of 0·75 and 0·25 cover the range from bright to heavily oxidized metals.

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TETRAFLUORETHYLENE COATINGS ON CONDENSER TUBES

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MIZUSHINA *et al.* [1] report the failure of a tetrafluorethylene coating to promote dropwise condensation of organic vapours and confirm its success with steam. This behaviour illustrates an important principle of surface chemistry which, although recognized at least qualitatively by Topper and Baer [2], is sometimes ignored in condensation studies. It is a necessary condition for dropwise condensation that the energy of the solid heat-transfer surface be less than the liquid–vapour surface tension of the condensate. The concept of a "critical surface tension, γ_c", has been used by Zisman *et al.* [3–5]. These workers have investigated the reduction in surface energy of an initially high energy surface achieved by adsorption of long chain fluorocarbon acids on to the surface as well as surface studies of polyfluorethylenes. In particular Zisman made a careful study of the contact angle, θ, of drops of liquid from a homologous series placed on the surface. He observed a linear relationship between the surface tension, γ_{LV}, of the liquid and cos θ (see Fig. 1). The critical surface tension is defined as the surface tension at which $\theta = 0$, i.e. the liquid completely wets the surface. The long chain fluorocarbon acids orientate themselves with their carboxyl group towards the metal substrate and their tails perpendicular to the surface. An acid such as n-perfluorolauric acid will display an effective surface of —CF_3 groups (and a critical wetting tension of ~6 dyn/cm at 20°C) whilst P.T.F.E. will have a structure of —CF_2–CF_2— (and a critical surface tension of 18·5 dyn/cm at 20°C). In general the degree of non-wetting is proportional to the degree of fluorination of the surface. In Table 1 the

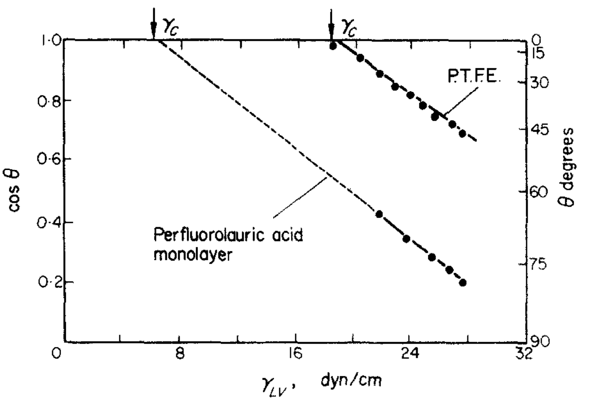

FIG. 1.

Table 1. Condensation on tetrafluorethylene-coated surfaces

Investigator	Condensate	Surface tension dyn/cm	Mode of condensation
Mizushina *et al.*	water	58·9 (at N.B.P.)	drop
	CCl_4	19·7 (at N.B.P.)	film
	CH_3OH	19·4 (at N.B.P.)	film
Topper and Baer	water	58·9	drop
	ethylene glycol	37·8	drop
	nitrobenzene	33·3	drop
	aniline	32·5	drop
	benzene	21·3	film

surface tension of the condensate and the mode of condensation of the materials studied by Mizushina *et al.* and by Topper and Baer are listed. It is noted that only when the surface tension of the condensate is well above the 18·5 dyn/cm critical surface tension for P.T.F.E. (which may be expected to be only slightly temperature dependent [5]) does dropwise condensation occur.

The use of adsorbed films of fluorocarbons would greatly extend the regions of interest for drop-wise condensation. In addition the adsorbed film would offer negligible additional thermal resistance. One major difficulty to be overcome is that the adsorbed layers are hydrophilic so that polar compounds will remove them; however useful heat-transfer data could be readily obtained for aromatic hydrocarbons, the higher aliphatic hydrocarbons and similar compounds.

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THE PREDICTION OF THE MECHANISM OF CONDENSATION ON CONDENSER TUBES COATED WITH TETRAFLUOROETHYLENE

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NOMENCLATURE

M = mass L = length T = time t = temperature

- T, temperature [t];
- θ, contact angle;
- γ, surface free energy [$ML^{-2}T^{-2}$];
- γ_c, critical surface tension [MT^{-2}];
- π_e, equilibrium film pressure [ML^{-2}];
- S, spreading coefficient [$ML^{-2}T^{-2}$].

Subscripts

- L, liquid;
- S, solid;
- SL, solid–liquid;
- V, vapour.

In a recent communication Mizushina *et al.* [1] reported data on condensation of steam and organic vapours on tubes coated with tetrafluoroethylene (T.F.E.). Previous workers [2, 3, 4] have observed that dropwise condensation of steam can be achieved on these coatings resulting in a higher heat-transfer coefficient. Topper and Baer [4] also reported dropwise condensation of ethylene glycol, nitrobenzene and aniline on this surface but noted that benzene did not exhibit this phenomenon and that film condensation occurred with a resulting lower heat-transfer coefficient. Mizushina also observed film condensation of carbon tetrachloride and methanol vapours on surfaces coated with T.F.E. These experimental findings leave some doubt on the mode of condensation exhibited by a particular system. The mechanism of condensation can however be predicted from the surface properties of the solid and liquid phases.

The conditions governing the equilibrium of a liquid droplet on a solid surface are expressed by Young's equation [5]:

$$\gamma_S - \gamma_{SL} = \gamma_L \cos\theta + \pi_e \qquad (1)$$