F.R. Note No. 143/1955

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

A NOTE ON THE APPLICATION OF FOAM TO VERTICAL SURFACES

by

P. H. Thomas

Summary

In this note, some of the features of the behaviour of foam on
a vertical surface are discussed, and an estimate is made of the
velocity at which a layer of foam will slide.   This velocity is shown
to be less than that of a water film giving equivalent protection against
radiant heat.   By applying water as foam, it may therefore be possible
to disperse it over a greater area and thus use it more economically in
the protection of the surface from radiant heat.

February, 1955.

Fire Research Station,
Boreham Wood,
Herts.

A NOTE ON THE APPLICATION OF FOAM TO VERTICAL SURFACES

by

P. H. Thomas

Introduction

In certain circumstances foam is observed to stick to a vertical surface and in others to slide slowly over it. If the layer is not too thick it will slide in bulk over the liquid layer between the foam layer and the solid surface. One would expect the nature of the solid to be an important factor influencing the foam behaviour. For example if the solid absorbs water or has an adsorbed film on it, the characteristic of the liquid film adjacent to it may be considerably affected. The present note discusses only the ideal case of a clean, smooth surface, which might be expected to result in an overestimate of the sliding velocity in practical cases.

Liquid film thickness

The thickness of the water film between the foam and the surface would be expected to be of the order of the bubble wall thickness which may be estimated as follows. If E is the expansion of the foam and S is the specific surface of the foam, the quantity of water per unit surface is $\frac{1}{ES}$. Since each layer has two sides we have the bubble wall thickness as

$$T = \frac{2}{ES} \qquad --- (1)$$

This gives values of T of order $10^{-3} - 10^{-4}$ cm and agrees approximately with the values found by Penney and Blackman [1] for the boundary liquid layer in pipe flow. Clearly the effect of surface roughness is important when such small thicknesses are involved and it is not surprising that foam which may slip on glass can adhere to a rough metal or brick surface.

Maximum thickness of foam layers moving in bulk

If the equilibrium of a vertical foam layer of thickness "D" and weight $\frac{D\rho_w g}{E}$ per unit cross-section is considered (Figure 1)
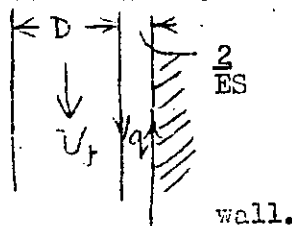

Figure 1

we have, for steady flow, the shearing stress at the wall

$$q = \frac{D \rho_w g}{E} \qquad --- (2)$$

where g is the gravitional constant
and ρ_w is the density of foam solution.

If the foam moves as a whole on the surface we have

$$q < q_c \qquad --- (3)$$

where q_{rc} is the critical shearing stress of the foam,
i.e. with q_c = 400 dynes/sq cm

and $E = 8$

we have from equation (2) $D < \dfrac{q_c \cdot E}{\rho \omega \cdot g} < 3 \cdot 3$ cm with the above values (4)

Velocity of falling foam layer

Assuming a linear velocity gradient in the liquid layer we have the shear
stress q given by

$$q = \frac{\eta \, v_f}{T}$$

where η is the viscosity of foam solution
and v_f is the velocity of the foam layer.
From equation (1) we then have

$$q = \frac{\eta \, E \, S \cdot v_f}{2} \qquad\qquad - - - (5)$$

Clark [2] gives the relation between S and q_c , the critical shearing
stress of foam, as

$$2 \; \gamma \, S = q_c \qquad\qquad - - - (6)$$

where γ is the superficial critical shearing stress solution of foam so
that from equations (2), (5), and (6)

$$v_f = \frac{4 \, D \cdot \gamma \, \rho \omega \; g}{q_c \, E^2 \, \eta} \qquad\qquad - - - (7)$$

If we put

$D = 3 \cdot 3$ cm — the maximum value calculated from equation (4) for a
foam layer moving in bulk

γ = 3 dynes/cm (Clark gives some values of this order for solutions
of blood compound)

$\rho\omega = 1$

$g = 981$ cm/sec^2

$E = 8$

$\eta = 0 \cdot 010$ gm cm^{-1} sec^{-1} (the viscosity of water at 20°C)
and $\quad$ = 400 dynes/sq cm
we have

$$v = 150 \text{ cm/sec}$$

The velocity in some experiments made using a glass surface with a layer
about 1 cm thick was observed to be about 15 cm/sec. or about a quarter
of that calculated from equation (3) with $D = 1$ cm.

Application to protection of surfaces from radiant heat

The velocity calculated above is much less than the falling velocities
of liquid layers containing the same quantities of water. The mean steady

falling velocity of a water layer of thickness D/E, equivalent to a foam layer of thickness D and expansion E, may be taken as equal to that of a layer of thickness $\frac{2D}{E}$ following under gravity between two parallel plates (3)

$$V_w = \frac{g}{3\nu}\left(\frac{D}{E}\right)^2 \qquad \qquad \text{- - - (8)}$$

where ν is the kinematic viscosity of water

Hence for D = 1 cm, Vw is calculated as 1.5×10^3 cm/sec. This is about twice the free falling velocity $\sqrt{2g \ H}$ attained after falling 10 ft. so that it is clear that a water film will flow much more rapidly than a foam layer of equal protection to radiant heat. (4)   It may therefore be possible to use water more economically if applied as foam since there will be less tendency to "run off".   If the glass surface is roughened by the crust of dried foam, it is possible that foams may adhere to it.   It must be remembered, however, that the minimum amount of water required to give protection from radiation is the same whether applied as water or as foam and it is the problem of coverage that is critical.   Since the thickness of a water film will be determined by the local rate of application it is necessary to achieve a high degree of dispersion for the coverage to be sufficiently large for the layer to be thin enough not to produce excessive run off. Application as foam may make this problem easier of solution.

(1)   Penney, W. G. and Blackman, M.   "Mechanical properties of foam and the flow of foam through pipes".   R.E.N. 282.

(2)   Clark, N. O.   "A study of mechanically produced foam for combating petrol fires".   H.M.S.O.

(3)   Lewitt   "Hydraulics" Pitman.   p. 348   7th edit or similar standard text work".

(4)   R. J French,   "Resistance of Fire-fighting foams to destruction by radiant heat".   J. App. Chem. (2) 1952.   60-64.

ERH