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EFFECT OF ENERGY INPUT ON THE PROPERTIES OF FOAM
MADE FROM VARIOUS COMPOUNDS

by

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Introduction

The process of making foam for fire-fighting use is one in which an aqueous solution of a foaming agent or compound is mixed with a chosen proportion of air, and the whole is worked together until the typical "bubble structure" of foam appears. The properties of the resultant foam will depend upon the type and concentration of foaming agent, the degree of aeration or "expansion" and the amount of the applied energy converted into surface energy in the foam. This surface energy may be related⁽¹⁾ directly to the "stiffness" of the foam, as measured by its critical shear stress, and to its rate of drainage, properties which are both important to the fire-fighting qualities of the foam. It is of interest that in practical fire-fighting equipment, about 1 per cent of the applied energy is converted into surface energy, about 7 per cent into kinetic energy for projection of the foam, and the remainder is dissipated as heat.

This note describes an investigation into the relationship between applied energy and critical shear stress, for foams produced from wetting agent and protein based compounds in a range of concentrations at two levels of expansion.

Energy balance

In this study, the foam was produced from the laboratory foam generator⁽²⁾ in which pressure tappings at inlet and outlet to the improver (Fig.1) gave a measure of the energy input to the foam solution. The suffixes 0, 1, 2, 3 in the equations below relate to the appropriate station in Fig.1.

The total energy available for the production and projection of the foam is that contained in the solution and air supplies to the generator. Thus, using the notation

- p = gauge pressure in Lb/ft²
- p_a = atmospheric pressure in Lb/ft²
- P = Absolute pressure in Lb/ft²
- E = foam expansion so that volume of air per cubic foot of solution = (E-1)ft³

Energy of solution stream = p₀ ft. Lb/ft³ of solution.

In the presence of foaming solution, with its comparatively large heat capacity, it can be assumed that the air will expand isothermally; thus the energy available from the air stream is p_a(E-1)log_e P₀/p_a ft Lb/ft³ of foaming solution. Hence the total energy input = p₀ + p_a(E-1)log_e P₀/p_a ft Lb/ft³.

In the investigation described here, the operating pressure of the solution and the air supply was 100 Lb/in², whence

$$\begin{aligned} \text{Total energy input} &= 14,400 + 14.7 \cdot 144 (E-1) \log_e \frac{114.7}{14.7} \\ &= 14,400 + 4350 (E-1) \text{ ft Lb/ft}^3 \end{aligned}$$

Hence for the two expansions used:

Total energy = 40,500 ft Lb/ft³ for E = 7

70,900 ft Lb/ft³ for E = 14.

This energy will be converted to surface energy, kinetic energy and heat as the fluids flow through the mixing chamber, improver and delivery pipe. The only part of the process that can be readily controlled is that which occurs in the improver, but, of course, the foam will absorb more energy as it passes through the delivery pipe to an extent depending on the characteristics of the foam leaving the improver itself.

It was considered that the most useful information would be obtained by relating the amount of energy dissipated in the improver and delivery pipe to the critical shear stress of the foam, as this is a direct measure of its surface energy⁽¹⁾. The energy input from (1) to (3) (Fig.1) used to increase the surface and heat energy of the foam is

$$(P_1 - p_a) + (E - 1)p_a \log_e P_1/p_a - (\text{Increase in kinetic energy (1) to (3)})$$

The rate of flow of foaming solutions for these tests was 0.2 gal/min. and the outlet area at (3) was 0.008 ft², giving an outlet velocity for the foam with the higher expansion of 14 of about 1 ft/s. so that the kinetic energy per ft³ of solution is about 1 ft Lb., which is negligible in comparison with the total energy. The expression then becomes

$$(P_1 - p_a) + (E - 1)p_a \log_e P_1/p_a \text{ ft Lb/ft}^3 \text{ of foaming solution.}$$

Compounds used

Laboratory identification	Type of compound	Remarks
A	Protein	Produced by one manufacturer from similar basic materials to give high (A) and low (B) viscosity compounds
B	Protein	
C	Protein	Manufactured to Chemical Research Laboratory formula, using blood.
N	Protein	Meets same specification as A, B & C.
E	Wetting agent	Not generally accepted as suitable for fire-fighting, but will deal with fires under some circumstances.

Compounds tested

Tests were made on compounds A, B and N at 1½, 3 and 10 per cent concentration, and compounds E and C at 3 per cent concentration only. All compounds were tested at an expansion of 7, and some at an expansion of 14 also. A range of critical shear stresses up to 600-700 dynes/cm² was covered.

Results

The energy input to the foam in the improver and delivery pipe was calculated from the pressures measured at inlet to the improver, and was

plotted against the critical shear stress of the foam, as shown in Figs 2-5.

Discussion of results

The results shown in Figs 2-5 have been replotted in Fig.7 to give the relationship between the energy input and the compound concentration at various levels of critical stress. This is a good indication of the difference between foams produced from compounds A, B and N, although these compounds are of a very similar basic composition and meet the same specification. For example, with this particular foam generator, compounds A, B and N in 3 per cent concentration require an energy input of 1500, 2100 and 1700 ft Lb/ft³ to produce foams of 300 dyne/cm² critical shear stress, at an expansion of 7. For a fixed energy input of 2400 ft Lb/ft³ foams of expansion 7 and critical shear stresses 450, 330 and 270 dynes/cm² respectively, are produced from compounds A, B and N at 3 per cent concentration.

By comparison with the above results, compounds A, B and N at 3 per cent concentration in a typical foam-making branchpipe were found to produce foams of approximate expansion 7 and critical shear stresses of 450, 170 and 450 dynes/cm² respectively, although the branchpipe is virtually a constant energy device at a chosen input pressure.

It may be inferred that a comparison of foams produced from different compounds should be related, in some degree at least, to the actual foam-producing equipment used.

References

- (1) CLARKE, N. O. A study of mechanically produced foam for combating petrol fires. Department of Scientific and Industrial Research Chemistry Special Report No. 6. London, 1947. H.M. Stationery Office.
- (2) FRY, J. F. and FRENCH, R. J. A mechanical foam generator for use in laboratories. J. Appl. Chem., 1951, 1 (10) 425-9.

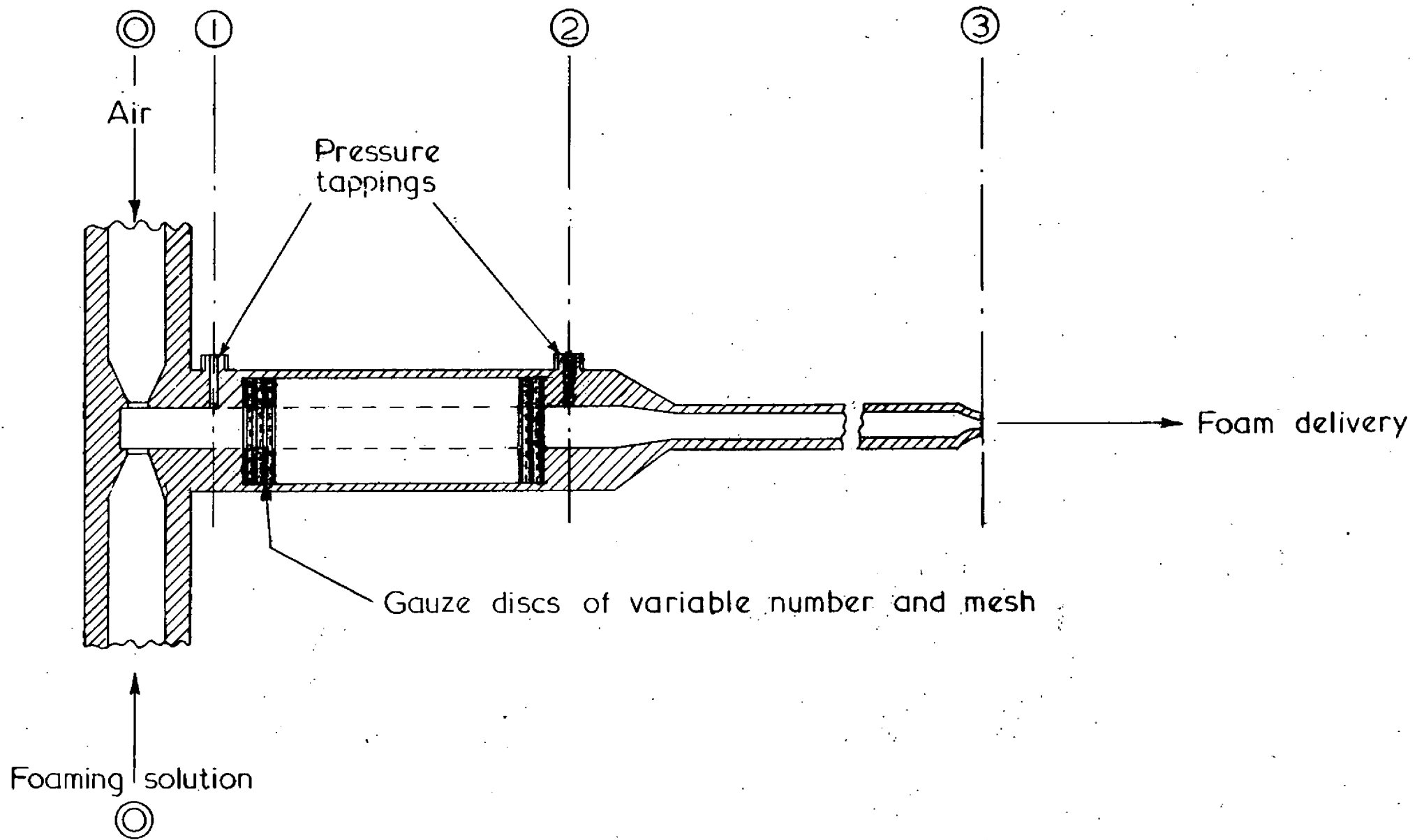


FIG. 1. DIAGRAMMATIC ARRANGEMENT OF FOAM GENERATOR

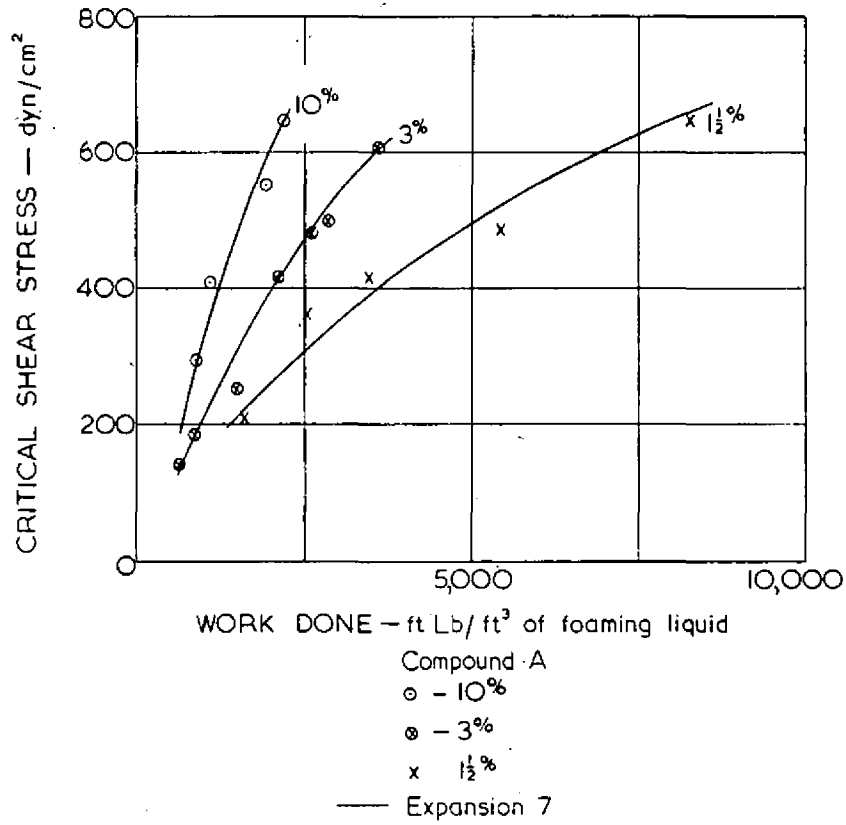


FIG. 2. ENERGY/CRITICAL SHEAR STRESS CURVES

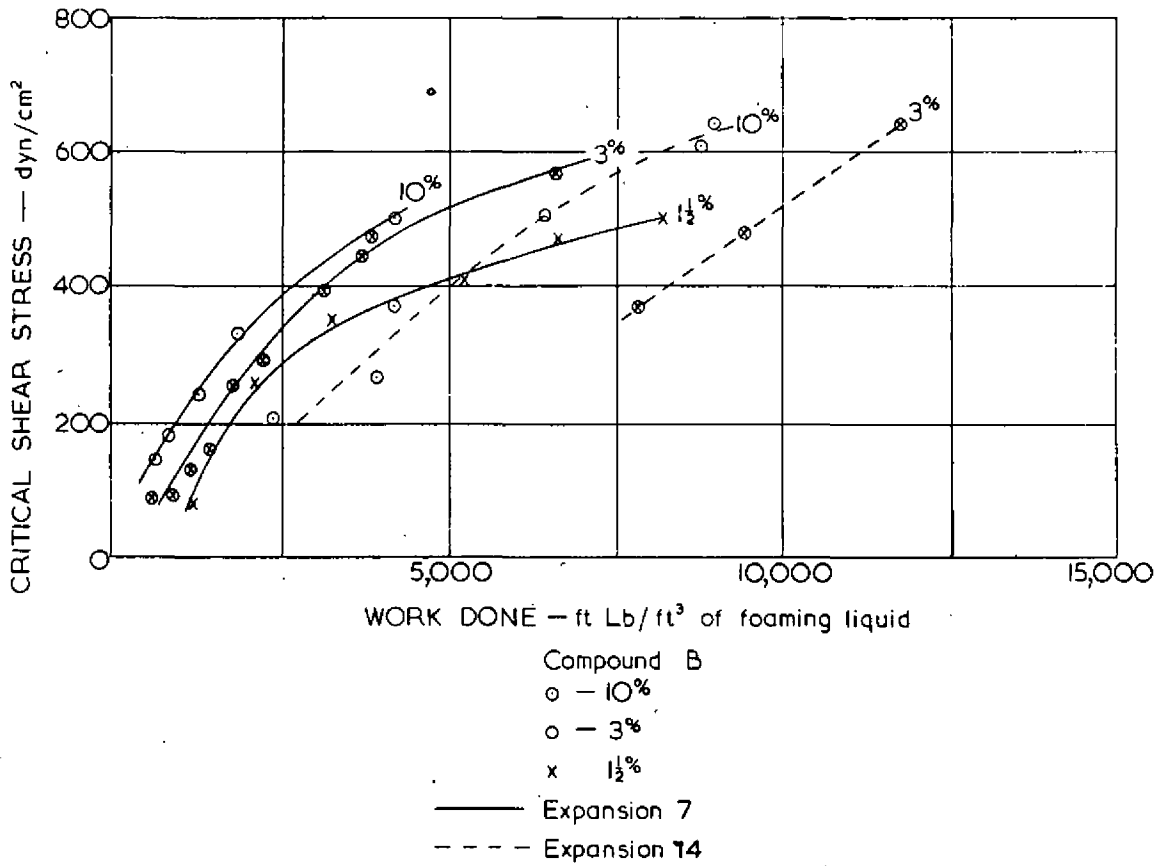


FIG. 3. ENERGY/CRITICAL SHEAR STRESS CURVES

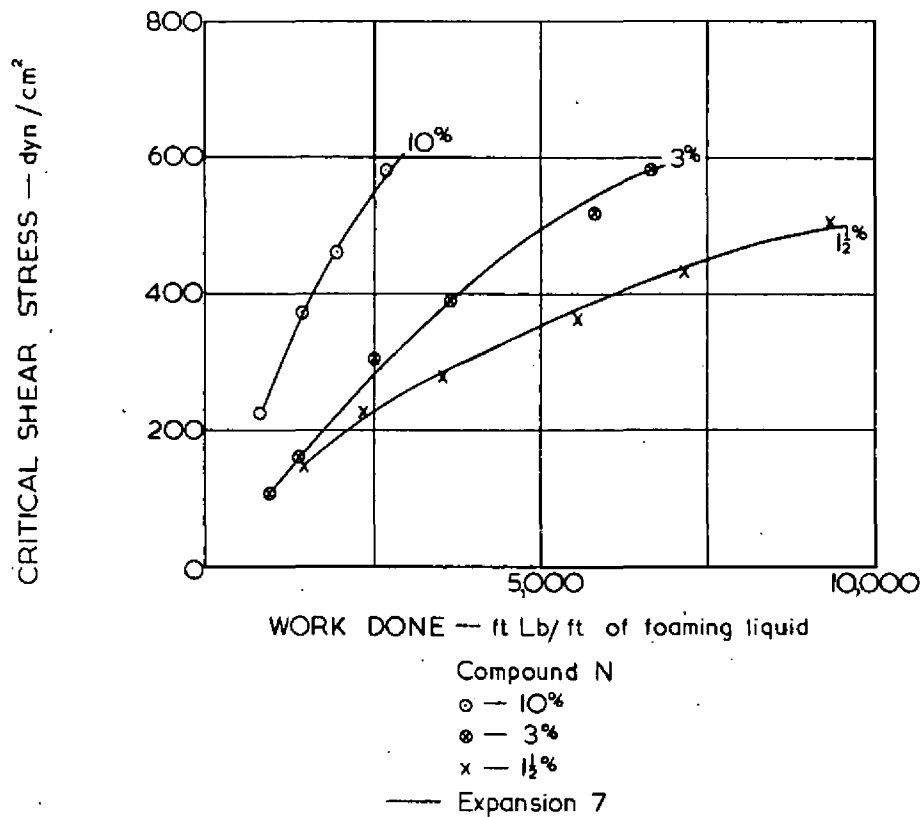


FIG. 4. ENERGY/CRITICAL SHEAR STRESS CURVES

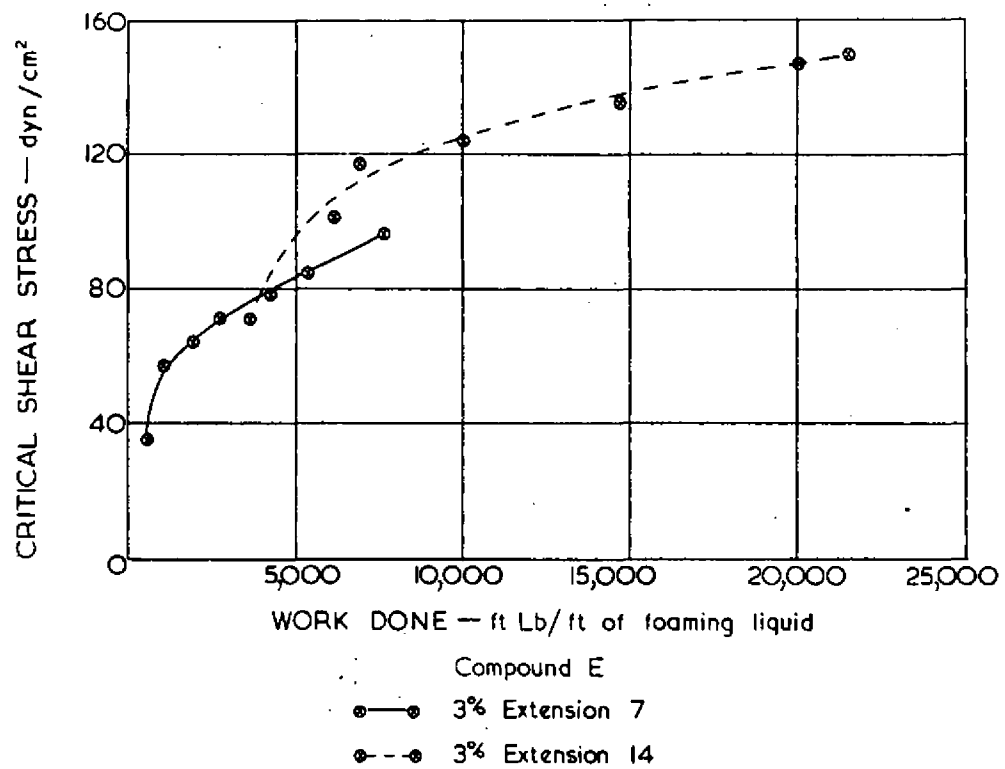


FIG. 5 ENERGY/CRITICAL SHEAR STRESS CURVES

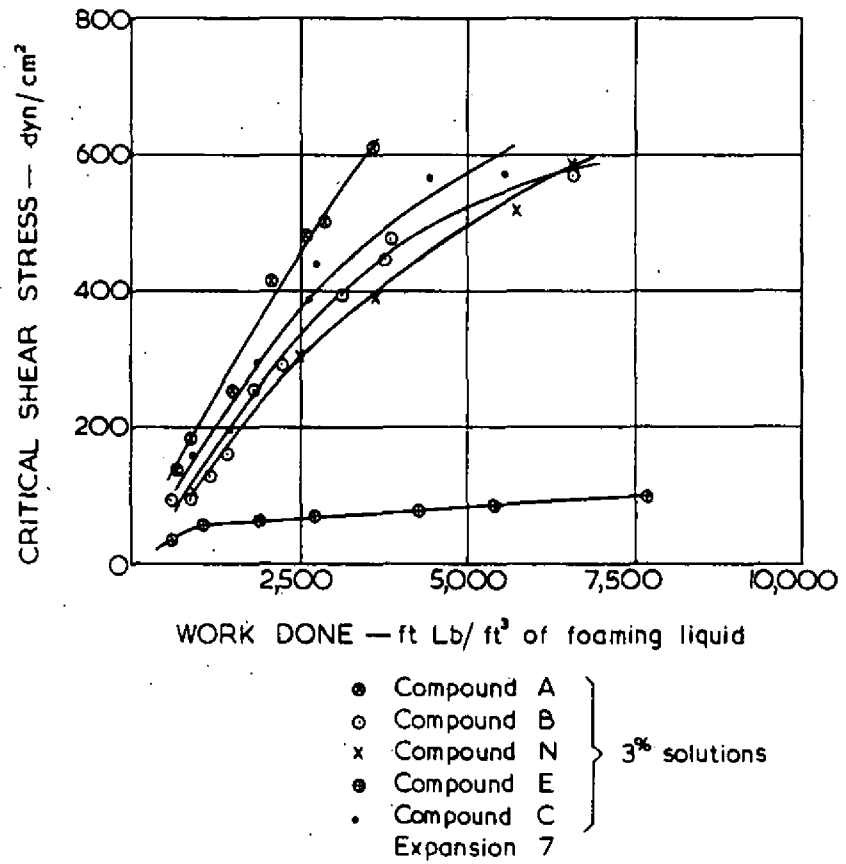


FIG.6. ENERGY CRITICAL SHEAR STRESS CURVES

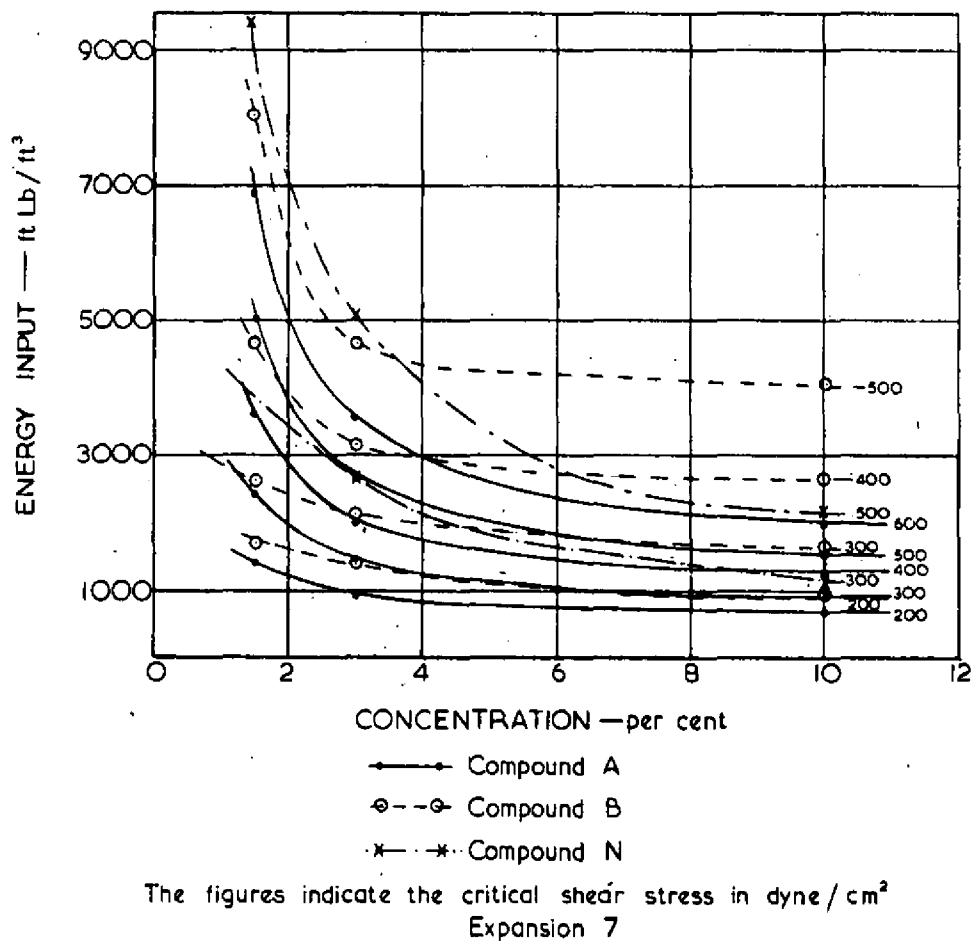


FIG.7. ENERGY/COMPOUND CONCENTRATION CURVES