

The points 1, 2, 3, 4 on  $AA'$  in the diagram are joined by straight lines to the point  $O$  on the parallel line  $CC'$ . The intersections, 1', 2', 3', 4', on some intermediate parallel line  $BB'$  are marked. A line is then drawn from each point on  $AA'$  to each point on  $BB'$  and produced to  $CC'$ . The array of points on  $CC'$  is then the vector map of the points on  $AA'$ . The construction is equally valid in two dimensions, with the points distributed on planes at  $AA'$ ,  $BB'$ , and  $CC'$ .

If the points 1, 2, 3, . . . are movable light sources connected by thin elastic threads to  $O$ , and each thread carries a small light sphere at  $BB'$ , then the shadow pattern produced on the screen at  $CC'$  corresponds to the Patterson projection of the structure at  $AA'$ . The shadows will overlap and merge in some places, and in particular there will always be an intense shadow at the origin  $O$ , as in the Patterson distributions. The shadows can be adjusted to correspond very roughly to atomic contours by varying the size and intensities of the light sources.

The advantage of the method lies in the fact that as the atomic positions on  $AA'$  are varied, the resulting Patterson projection can be followed continuously. Now, the Patterson projection of any unknown structure can be calculated directly. To solve the structure, therefore, we have to vary the possible atomic positions until a good 'fit' is obtained. It is only rarely, of course, that one can deal with a small isolated group of atoms, as shown in the diagram. In general, parts of the adjoining unit cells will have to be included.

The method seems to have distinct possibilities in dealing with structures containing moderate numbers of similar atoms, and it is also an interesting lecture experiment. It is possible to abolish the rather troublesome threads and small spheres by using properly placed photographic plates and negatives, and the method outlined above also has the virtue of continuous variation.

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<sup>1</sup> Patterson, A. L., *Phys. Rev.*, **46**, 372 (1934); *Z. Krist.*, **90**, 517 (1935).

<sup>2</sup> See NATURE, **142**, 581, 955, 994 (1938); **143**, 75 (1939); **149**, 491 (1942); **150**, 324 (1942).

<sup>3</sup> Warren, B. E., and Gingrich, N. S., *Phys. Rev.*, **46**, 368 (1934).

## A New Criterion for Expressing the 'Intensity of Firmness' of Soft Bodies

Nutting<sup>1,2</sup> has proposed, and Scott Blair and Coppen<sup>3,4</sup>, Broome and Bilmes<sup>5,6</sup>, Couzens and Wearmouth<sup>7</sup>, Lethersich<sup>8</sup> and Haward<sup>9</sup> have developed and applied, an equation expressing the shear strain ( $\sigma$ ) in soft materials as proportional to a power ( $\beta$ ) of the shear stress ( $S$ ) and also to a power ( $k$ ) of the time ( $t$ ) of its application. This equation may be written:

$$\sigma = \psi^{-1} S^\beta t^k, \quad (1)$$

where  $\psi$  is an intensity or proportionality factor which, unlike  $\beta$  and  $k$ , has complex dimensions.

Since  $1/\psi$  is defined as the strain produced by unit stress in unit time, a comparison of the firmness of materials having different  $\beta$  and/or  $k$  values in terms of  $\psi$  is in any case arbitrary. Moreover, the usual unit of force (1 dyne) being very small compared with the stresses normally required, these values of  $\psi$

are not only arbitrary but are apt also to be misleading. Although this latter difficulty can be obviated by using a larger unit of force,  $\psi$  still represents no more than a point within a three-dimensional diagram.

The intensity factor cannot, in the nature of things, be expressed in terms entirely independent of arbitrary conditions: but a great improvement can be effected if we use, for purposes of comparison, instead of  $\psi$ , a property  $\zeta$ , defined as the reciprocal of the volume of the  $S : \sigma : t$  figure integrated between the limits of the greatest ranges of stress and time likely to be used in practical testing.

As an example, for materials which are readily deformed by squeezing in the hands ('soft bodies'), Scott Blair and Coppen<sup>10</sup> have shown that stresses of the order of  $10^6$  dynes/cm.<sup>2</sup> are normally exerted. For studying such materials, a convenient range of stress would be 0- $10^6$  dynes/cm.<sup>2</sup> and of time 0-100 sec.

Indicating these limits by their logarithms as suffixes, we have, for the volume of the selected figures:

$$1/\zeta = \int_0^{S_6} \int_0^{t_2} \sigma \cdot dS \cdot dt. \quad (2)$$

Substituting from equation (1) and integrating:

$$1/\zeta = \psi^{-1} \frac{1}{\beta+1} \frac{1}{k+1} S_6^{\beta+1} t_2^{k+1};$$

or, writing  $\sigma_m$  for maximum strain and taking logarithms:

$$\log \zeta = \log(\beta+1) + \log(k+1) - 8 - \log \sigma_m \quad (3)$$

$\log \sigma_m$  can either be determined experimentally or, more usually, calculated from experimental data for lower values of  $S$  and  $t$ , using equation (1).

Scott Blair and Caffyn's<sup>11</sup> suggestion that the deformation properties of soft materials should be described by plotting  $\log \psi$  vertically on the base of a 'Nutting square' having  $\beta$  and  $k$  as horizontal co-ordinates is thus improved by substituting  $\log \zeta$  for  $\log \psi$ .

For the special cases of an elastic solid ( $\beta = 1$ ,  $k = 0$ ) and a viscous fluid ( $\beta = 1$ ,  $k = 1$ ) it is easy to express  $\zeta$  in terms of shear modulus and viscosity. It is not, of course, a fluidity, in spite of its dimensions ( $M^{-1}LT$ ), which are independent of equation (1). Notwithstanding the necessity for fixing limits in the integration defining  $\zeta$ , this treatment often provides better criteria of the behaviour of complex materials under stress than do viscosities and shear moduli, since the former usually fall in a complex manner with rising stress and rise with increasing strain, and the latter are frequently dependent on the stress history of the sample.

I am indebted to Dr. F. M. V. Coppen and to Mr. L. Bilmes for helpful discussions.

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<sup>1</sup> *J. Franklin Inst.*, **191**, 679 (1921).

<sup>2</sup> *Proc. Amer. Soc. Test. Materials*, **21**, 1162 (1921).

<sup>3</sup> *Proc. Roy. Soc.*, B, **128**, 109 (1939).

<sup>4</sup> *J. Soc. Chem. Ind.*, **60**, 190 (1941).

<sup>5</sup> *J. Soc. Chem. Ind.*, **60**, 184 (1941).

<sup>6</sup> NATURE, **147**, 176 (1941); **149**, 412 (1942).

<sup>7</sup> *J. Soc. Chem. Ind.*, **61**, 69 (1942).

<sup>8</sup> Brit. Elec. and Allied Ind. Res. Assoc. Report No. L/T 14.

<sup>9</sup> *Trans. Farad. Soc.*, **38**, 394 (1942).

<sup>10</sup> *Amer. J. Psychol.*, **55**, 215 (1942).

<sup>11</sup> *J. Sci. Instr.*, **19**, 88 (1942).