by another method[1]. Another notable feature of the figure is that the parallel section is followed by a constriction in which the film thickness falls by approximately 10 per cent. These features confirm qualitatively theoretical ideas propounded in an approximate analysis by Grubin[2] and recently by Dowson and Higginson[3] and Archard, Gair and Hirst[4] in more exact analyses. The parallel section confirms that the pressure distribution is approximately Hertzian, while the constriction implies that somewhere towards the recess edge the pressure exceeds that of the Hertzian distribution. The practical implication of the excess pressure is that the material of the disks might be more severely stressed than is suggested by the Hertzian analysis on which design is at present based. The practical implication of the constriction is that it is the most probable site for breakdown of the oil film and the initiation of surface damage. A fuller account of the results will be published later.

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[1] Crook, A. W., *Phil. Trans. Roy. Soc.*, A, **250**, 387 (1958).
[2] Grubin, A. N., Central Scientific Research Institute for Technology and Mechanical Engineering, Book No. 30 (Moscow, 1949). (D.S.I.R. Translation No. 337.)
[3] Dowson, D., and Higginson, G. R., *J. Mech. Eng. Sci.*, **1**, 6 (1959); **2**, 188 (1960).
[4] Archard, G. D., Gair, F., and Hirst, W., *Proc. Roy. Soc.* (in the press).

Phase-Velocity of Ultra-sound in the Primary Aliphatic Amines

CONTINUOUS-WAVE electronic measurements of the speed of sound in liquids commonly depend on the presence of appreciable standing-waves in paths of low absorption, the half-wave-length being determined by detection of successive resonances as the path-length[1] or frequency[2] is changed. Alternatively, for liquids of high absorption in which the energy content of the standing-wave is necessarily small, the wave-length may be found by direct comparison of the phases of the transmitted and received signals. In conditions of very high absorption it has been necessary to use pulse techniques to obtain adequate acoustic intensity at the receiving transducer consistent with tolerable energy dissipation in the medium.

I have devised an alternative method of measurement employing continuous-wave frequency-modulated ultra-sound. The lower permissible signal/noise ratio in a frequency-modulation system allows operation at much-reduced acoustic intensities. The path occupied by a complete period of the modulation in a liquid sample is determined. The liquid is contained in an interferometer having separate transmitting and receiving quartz transducers. The frequency of the ultra-sound is varied sinusoidally by approximately ±40 kc./sec. about a mean of 10·7 Mc./sec. The modulation of the received ultra-sound is detected by a ratio discriminator preceded by a limiting stage. The observed absence of distortion of the detected modulation indicates that any dispersive effect in the liquids tested is too small to have appreciable effect for the frequency deviation used. Phase-lag of the received modulation is measured by inversion and linear addition to a sample of the transmitted modulation of equal amplitude. In the absence of phase-shift of electronic origin, the resultant is zero when the time of transit is an integral number of periods of the modulation, a condition obtained by adjustment of the modulating frequency. The phase-velocity is then given by :

$$v = Lf/N$$

where L is the length of the column, f is the modulating frequency and N is an integer. A range of path-lengths is used as a check on diffraction effects, and N-values are varied up to 4 as a check on consistency of behaviour of the electronic equipment. The temperature of the liquid is stabilized at $19\cdot3 \pm 0\cdot1°$ C.

The first application of the method has been to the homologous series of primary aliphatic amines. Measured phase-velocities (v) appear in Table 1, the uncertainties being about 3 m.sec.$^{-1}$.

Table 1

Liquid	v (m.sec.$^{-1}$)	$\frac{R}{\text{cm.}^3}$ $\left(\frac{\text{m.}}{\text{sec.}}\right)^{1/3}$ mole	$\frac{\Delta R}{\text{cm.}^3}$ $\left(\frac{\text{m.}}{\text{sec.}}\right)^{1/3}$ mole
n-Propylamine	1,234	877	
n-Butylamine	1,269	1,071	194
n-Amylamine	1,296	1,258	187
n-Hexylamine	1,317	1,444	186
n-Heptylamine	1,345	1,635	189
n-Octylamine	1,354	1,826	191
n-Nonylamine	1,372	2,024	198

Values of the molecular velocity defined in ref. 3 as:

$$R = v^{1/3}\, M/\rho$$

appear in the second column, M being the molecular weight and ρ the density. The increments ΔR with addition of successive —CH_2— groups are tabulated in the third column. It is evident these are approximately constant, the mean being 190.

The constancy of ΔR was demonstrated by Rao[4] for six homologous series, an overall average of 195 being obtained. Weissler[1] obtains 190 for series of alcohols including branched isomers and ring molecules. More recently, Leon[5] quotes Mikhailov and Nizhin (1947) as obtaining 189 for the l-olefines, and gives an average of 188 for some higher paraffins.

It is hoped to publish a detailed account of the research elsewhere.

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[1] Weissler, G., *J. Amer. Chem. Soc.*, **70**, 1634 (1948).
[2] Rao, B. R., and Rao, K. S., *Acustica*, **8**, 63 (1958).
[3] Rao, M. R., *Ind. J. Phys.*, **14**, 109 (1940).
[4] Rao, M. R., *J. Chem. Phys.*, **9**, 682 (1941).
[5] Leon, H. I., *J. Chem. Phys.*, **28**, 748 (1958).

METALLURGY

Effect of a Thin Oxide Film on the Reaction of Iodine Vapour with Copper

IN experimental work on the oxidation of metals the preparation of specimens is directed to the removal of contaminants such as grease, the production of a consistently smooth or rough surface and the realization of a stable metallurgical structure defined by the grain size and texture. The congenital