Variation of Elastic Constants of Hardened 1 per cent Carbon Steels on Tempering

IT was shown some years ago that changes in elastic constants accompany the hardening process in steel[1] and can be measured by ultrasonic techniques. More detailed experiments have been made recently on two commercial steels containing about 1 per cent carbon. The steels were quenched in oil from 780° C. and then tempered for one hour at temperatures between 100° C. and 650° C., in steps of 50° C. Young's modulus, E, and the rigidity modulus, G, were measured after each heat treatment by the ultrasonic-pulse method. The rigidity modulus was also measured by static loading, the same specimens being used.

The specimens were 7 in. long and 0·5 in. in diameter with enlarged ends of square section for the application of the static torque. The square ends were used for the ultrasonic tests in which the phase velocities for pulses in the longitudinal and transverse modes were measured. The values of E determined from these velocities are estimated to be accurate to within ± 0·2 per cent and those for G to be within ± 0·1 per cent.

The static values of G were measured in a special rig designed to apply a pure torque and the maximum shear stress did not exceed 4,000 lb./in.² The twist was measured over a length of 3 in. by means of two mirrors which were observed simultaneously with an autocollimator. The static values of G are considered to be accurate to within ± 0·3 per cent.
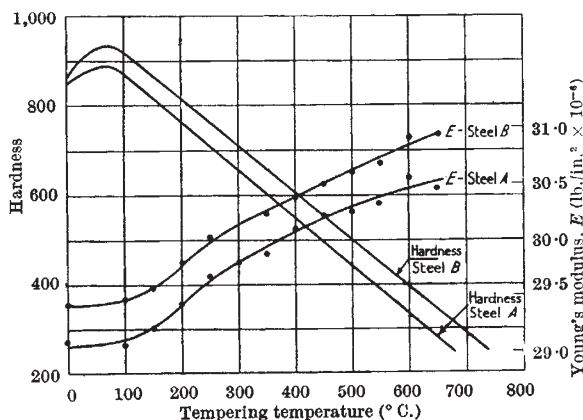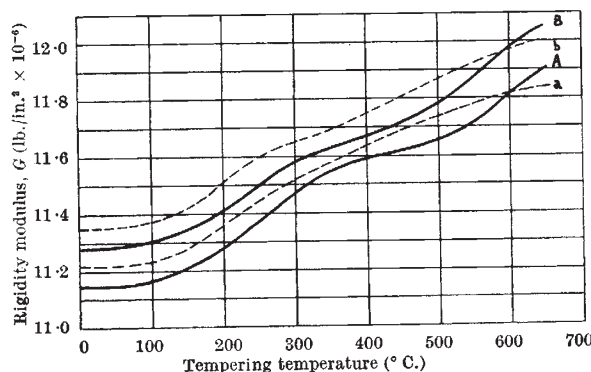

Fig. 1

Fig. 2. Rigidity modulus vs. temperature of tempering. For steel A : (a) by the ultrasonic method, (A) by the static method ; and for steel B : (b) by the ultrasonic method, (B) by the static method
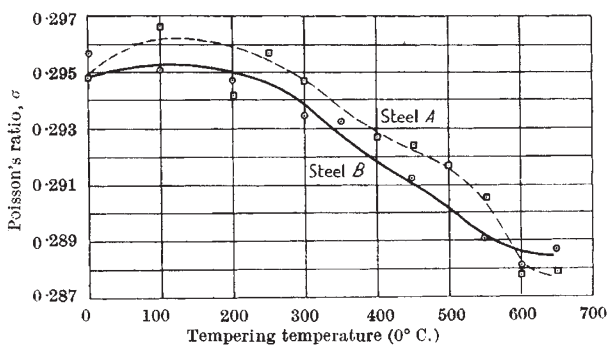

Fig. 3

Fig. 1 shows the ultrasonic values of E for the two steels as a function of tempering temperature, the corresponding values of the hardness being also plotted. Fig. 2 shows the values of G determined by ultrasonic and static methods, again as a function of tempering temperature. In Fig. 3 the values of Poisson's ratio derived from the ultrasonic figures are given. It can be seen that the total increase from the hardened to the fully tempered state is about 4·5 per cent for E and 6 per cent for G.

The static values of G are about 1 per cent lower than the ultrasonic values for hardened steel for tempering temperatures up to 450° C. At higher tempering temperatures the difference is insignificant.

A possible explanation is based on the supposition that the bars were not fully quenched through their thickness. If the surface were harder it would have more effect on the static measurements because of the stress gradient, whereas the ultrasonic tests are based on the average wave velocities in a radial direction. Further work would be needed to prove the validity of this effect.

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[1] *Engineer*, **191**, 318 (1951).

A Surface Electroluminescence Effect in Diamonds

TEN diamonds, all of type I, have been found to luminesce with bright green spots of light when a potential difference is applied to them. The luminescence is often intense enough to be seen in daylight. This effect was first noticed while investigating some aspects of the counting properties of the diamonds, and only after the diamond had been coated with a thin layer of graphite and annealed in this condition.

All the stones so far tested are of the conventional rhombohedral form and with a maximum dimension of about 1 mm. Before being coated with 'Aquadag', the diamonds were good insulators with a resistance greater than 10^{12} ohms : after coating, the resistance between opposite faces fell to 10^6 ohms or thereabouts.

(*Continued from p. 1254*)

A potential difference, applied between two electrodes on the diamond, produces luminescence over a wide range of potential values. Due to the high refractive index the whole diamond appears to luminesce, with a band of wave-lengths in the 5400-A. region, but closer microscopic inspection shows that the luminescence is in fact confined to small spots on the diamond. There may be a dozen of these which are not necessarily in the immediate neighbourhood of the electrodes and seem to be independent of the precise form of the potential probe, but are sensitive to its position. If the graphite layer is scratched off in the vicinity of one of these luminescent centres, the effect is destroyed for that particular one.

The intensity increases with an increase in the applied voltage, and in one particular case could be observed from 30 volts to 1,500 volts. Changing the polarity of the electrodes makes no difference to the locality, colour or intensity of the spots. They are equally unaffected by a temperature variation from that of liquid air to 300° C. ; by immersion in oil, or a sprayed plastic sheath ; or by ultra-violet or infra-red irradiation.

None of these diamonds exhibits counting properties ; only one of them shows fluorescence under ultra-violet irradiation, but all of them show blue luminescence when bombarded by electrons.

Unlike some of the effects reported by Wolfe and Woods[1] the diamonds return to their normal state when the surface is cleaned and display no luminescence. Neither quartz nor glass was found to display luminescence after similar treatment.

The investigation is far from complete ; but this communication is prompted by a recent observation of Fischer[2] that when the dielectric properties of the diamond have been broken down by sufficiently high currents and fields, a green luminescence is observed. The breakdown process may produce graphitization of parts of the diamond and the effect may be of the same nature as that reported here.

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[1] Wolfe, R., and Woods, J., *Phys. Rev.*, 105, 921 (1957).
[2] Fischer, A., *Z. Phys.*, 149, 107 (1957).

Ranque Vortex-Tube Combustion Chamber

RECENT experiments carried out here lead to the conclusion that the vortex tube of Georges Ranque[1] may form an extremely useful compact combustion chamber and also a possible research tool for the investigation of cool flames. Many applications of the vortex tube have appeared during the past fifteen years, as shown by Westley[2], but, so far as it has been possible to ascertain, the nearest approach to the burner described here is due to Moore and Martin[3] and Martin (private communication). Moore and Martin, using a single-outlet vortex tube made of 'Pyrex' glass, discovered the peculiar behaviour of premixed propane-air flames in this burner, together with the extreme flame stability obtained over a wide range of ratios of air to fuel. Owing to the limitations of their air supply, and to the size of the glass tube they were apparently unable to obtain the rates of flow needed for some of the behaviour described here.

The burner used in this Department consists of a standard vortex tube of the type described by Ranque, with a range of orifices to restrict the flow in one direction. The main tube has an inside diameter of one inch, and was fed by a tangential nozzle, of rectangular cross-section, 0·017 in. × 2·30 in. Orifices of diameter $\frac{5}{8}$ in., $\frac{1}{2}$ in., $\frac{3}{8}$ in. and $\frac{1}{4}$ in. are available, and the burner is also run with both ends open, and with the orifice end closed off, when it resembles that of Martin and Moore. Due to the high temperatures involved, the complete burner is made of steel.

With both ends open, and with all the orifices, the striking-back phenomenon of Moore and Martin is encountered, but it is found to be even more stable when there is a double exit from the tube than under the conditions which they used. When the ratio of air to fuel is increased, however, two further forms of combustion are found to exist. The first, a detonating or howling combustion with a very high heat release occurs at the lower ratios of air to fuel, while the second, a quiet mode of combustion with relatively small heat release and very steep temperature gradients across the flame-front occurs at the higher ratios of air to fuel. The latter flame also produces large quantities of formaldehyde, acetaldehyde and propionaldehyde.

The upper and lower limits of these forms of combustion have been established, the upper limit of the aldehyde-producing flame being complete extinction. It is apparent that the function of the orifice is to allow the induction of a large quantity of air into the system, since the change from one form of combustion to another occurs at lower ratios of air to fuel for the premixed gases as the orifice size is increased. The change from one mode to the next is also affected to a very great extent by the temperature of the tube ; as tube temperature increases, so the ratio of air to fuel at which any flame occurs also increases (Fig. 1).

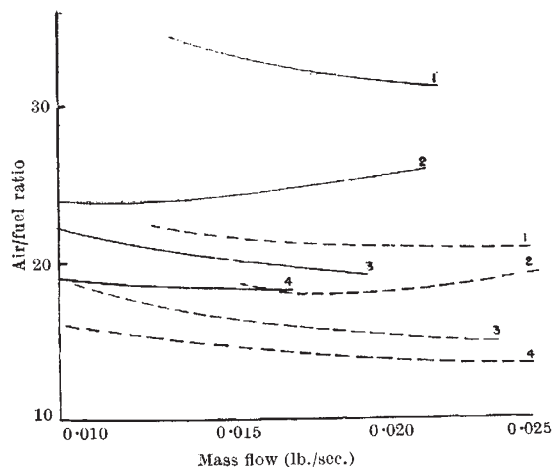The various aldehydes in the flame were detected by means of the semicarbazide–hydrochloride reaction,

Fig. 1. Sample performance curves : (1) Extinction, tube temperature 1,100° F. ; (2) extinction, tube temperature 500° F. ; (3) detonation to aldehyde-producing flame, tube temperature 1,100° F. ; (4) detonation to aldehyde-producing flame, tube temperature 500° F. Orifice end closed, ———— ; $\frac{1}{8}$ in. orifice, - - - -