ULTRASONICS IN FLUIDS

DURING the recent meeting of the British Association at Newcastle upon Tyne, Section A (Mathematics and Physics) held a symposium on ultrasonics in fluids. Most of the papers read at this symposium concerned applications of the ultrasonic interferometer, which may be regarded as a modern development of the familiar Kundt's tube into a precision instrument for studying those properties of gases and liquids which come into play when the molecules are set into vibration as a whole. In essence, the instrument consists of a quartz crystal in piezo-electric vibration, sending out plane waves into the fluid which are reflected back to the crystal, there to react upon the circuit which maintains the piezo-electric oscillations. The reflector usually consists of a plate mounted on a micrometer screw which is carried parallel to itself in a direction perpendicular to the ultrasonic wave-front, thereby recalling several types of optical interferometer. In the original method of Pierce, the magnitude of the resonance, as indicated by the maintaining circuit, at each half wave-length shift of the screw is observed through the change in the anode current of the circuit. With some precautions, the magnitudes of these current changes may be used to calculate the absorption coefficient of the radiation in the fluid, and, of course, the screw settings for these resonances enable the velocity in the fluid to be calculated if the frequency of the crystal oscillations can be accurately measured.

Prof. A. van Itterbeek submitted a paper in which the work recently done in the low temperature laboratory in the University of Louvain was described. There they have been making measurements in liquids and condensed gases, particularly hydrogen and the constituents of air together with some organic liquids, which they have studied down to the temperatures attainable with liquid hydrogen, that is, down to 16° K. In all these liquids, the velocity of sound was found to be a linear function of the temperature. The adiabatic compressibility and the ratio of specific heats were also calculated for each substance. During measurements on liquid hydrogen some unexpected difficulties were encountered, for the velocity of sound continually increased to an asymptotic limit (during the course of half an hour) which was about eight per cent higher than the initial value. This result is ascribed to a continual change in the constitution of a mixture of ortho- and para-hydrogen into the pure para variety under the ultrasonic radiation, for if the latter was turned off for a while, on resumption the same value for the velocity as at the intermission was obtained (see *Nature*, March 12, p. 399).

Prof. van Itterbeek and his colleagues do not use the interferometer for absorption measurements. For this they are developing a method involving the radiation pressure on a vane suspended in the liquid at various heights above the source, so that the attenuation is determined in terms of the force on the vane and its variation with distance along the ultrasonic beam.

The remaining work on interferometry described at the meeting concerned measurements in gases carried out at King's College, Newcastle. Dr. J. F. W. Bell dealt with the effect of pressure on the coefficient of absorption, as determined in the gas contained in an interferometer. In most gases, theory would predict an attenuation coefficient proportional inversely to pressure. In fact, straight lines are obtained if the coefficient as measured is plotted against the reciprocal of the pressure, but they do not pass through the origin. Dr. Bell quoted some results of Prof. van Itterbeek in various gases contained in the *same* interferometer which demonstrated this. All these values of the absorption coefficient are in excess of those given by the Stokes–Kirchhoff theory by a constant amount—for each gas—which is ascribed to a breakdown in the simple theory of the interferometer which, as has been mentioned, supposes a plane wave system. At high frequencies, radial resonances may be set up in the tube containing the gas by inequalities in the wave-front just before the crystal —as with electromagnetic waves entering wave-guides—and these cross-modes, which are, of course, functions of the tube width, distort the wave-front and produce additional absorption not envisaged in the treatment of the interferometer as a plane wave system, which must likewise involve a 'correction' to be subtracted from the measured value if the absorption due to the gas alone is to be derived. This correction, on Krashnooshkin's theory, is equal to the value extrapolated to infinite pressure of the absorption when plotted against the reciprocal of the pressure; it is found to be proportional to the ultrasonic velocity in each gas.

Mr. H. D. Parbrook has been carrying out experiments in gases such as carbon dioxide and ethylene in the neighbourhood of their critical points. For this work, an interferometer has been built into a bomb capable of withstanding pressures of 150 atmospheres, in such a fashion that the screw may be moved by a motor while its position relative to the source and the reaction on the latter are automatically and continuously recorded on a moving sensitive film. A series of results for several frequencies and temperatures over a range of pressures surrounding the critical state has been obtained in carbon dioxide. This gas is of special interest because it shows at N.T.P. a dispersion of velocity with frequency in the neighbourhood of 100 kc./sec. It has been possible to 'chase' this region of dispersion to still higher frequencies as the pressure is raised and, near the critical point, to link up the absorption in this region with viscosities as determined thirty years ago by Phillips. Some results for ethylene are also being obtained, although, so far as is known, this gas does not exhibit a dispersion with frequency.

It is important to be able to tell in all this work precisely how much of the absorption to be shown by a dispersive gas is to be ascribed to viscosity. Some ideas on this point can be explored if the gas is submitted to an excessive—and, therefore, easily measured—absorption by placing the interferometer in a narrow tube. This can be done by setting up a miniature interferometer in a capillary glass tube, using a nickel needle in magneto-striction oscillation as source and a tight-fitting non-magnetic piston as reflector. Demonstrations of this effect were given by Mr. T. E. Lawley. Results so far obtained confirm the Kirchhoff theory of viscous absorption of sound in tubes containing air, even at frequencies of the order of 100 kc./sec.

An alternative to the Pierce type of interferometer used in all the above experiments is the 'fixed path' interferometer in which the column of gas between source and reflector is invariable, being held at a resonant length, while the stationary wave system so maintained is explored by a detector traversed along the beam. An electrically heated thin platinum wire used as an anemometer is suitable for this purpose, since it is cooled to an extent dependent on the local particle velocity amplitude. In this way, velocities and absorption coefficients in a number of organic vapours are being measured. A modification of this technique, in which the wire is traversed in planes parallel to the face of the crystal but at different distances in front of it, serves to show to what extent at the lower ultrasonic frequencies diffraction from a forthright beam of plane waves occurs, and permits of correction to the attenuation as observed to be made in order to derive that proper to the vapour alone. This was demonstrated by Mr. K. Matta.

The remaining paper, by Dr. E. A. Alexander, of H.M. Underwater Detection Establishment, dealt with a different aspect of the propagation of ultrasonics in liquids, that is, the formation of cavities. When a sound wave passes through water, the water is alternately subjected to positive and negative pressures in the respective half-periods of the wave. As the intensity is increased and the point is reached where the negative pressure equals the external pressure acting on the water plus its cohesive force, the water breaks into a cavity, consisting of water vapour together with air which comes out of solution. As the pressure starts to increase again the cavity collapses rapidly with the production of the characteristic noise which accompanies all cavitation.

Owing to the difference in acoustic impedance between air (or a vacuum) and water or solid materials, this onset of cavitation limits the efficiency of a high-power ultrasonic transducer as an underwater signal source. The object of these experiments is to investigate this limitation in terms of hydrostatic pressure, air content and signal duration. The transducer is mounted in a tank of water with a hydrophone at a certain distance to pick up the signal. In the absence of cavitation, the signal sent out, that is, the potential applied to the transducer, is of the same form, as seen on a cathode-ray oscillograph, as that picked up by the hydrophone. When the power applied is increased to the point at which cavitation sets in, bubbles are seen in the water, the signal is distorted and an audible noise, apparently due to the collapse of the bubbles, is produced. The cavities often form at a nucleus near the transducer surface, with a 'meteor tail' spreading away from the 'head'. These may persist for the duration of the signal.

Some interesting demonstrations of ultrasonic cavitation induced in flasks of water and a high-speed ciné-film of bubble formation were shown by Mr. R. Hall.

E. G. RICHARDSON

THE COAL INDUSTRY IN GREAT BRITAIN

A JOINT session of Sections B (Chemistry), C (Geology) and F (Economics and Statistics) of the British Association was held at Newcastle upon Tyne on September 5 to discuss the present position of the coal industry in Great Britain. Prof. A. Beacham of Cardiff opened the discussion on behalf of the Section of Economics, and Mr. I. G. C. Dryden (British Coal Utilisation Research Association) and Prof. H. G. A. Hickling of Newcastle followed on behalf of the Sections of Chemistry and Geology, respectively. The proceedings closed with a contribution from Mr. W. Maclean (deputy labour director, Northern Division, National Coal Board), who took the place of Mr. Sam Watson of the National Union of Mineworkers.

Prof. Beacham argued that the task of the Coal Board has been made difficult, if not impossible, by reason of the vagueness and inconsistency of the Act by which it was constituted and by its subjection to political control. The effect of this is to be seen most clearly in the approach of the Board to its long-term technical reorganisation programme. The Board seems to be unable to make up its mind whether the 'national plan' should be dominated by efficiency factors or social factors. The Coal Mines Nationalization Act laid considerable stress on both, and in any event the last word on capital reorganisation schemes lies with the Minister of Fuel. Prof. Beacham then referred to the disappointment of expectations that nationalization would inaugurate a new era in industrial relations in the industry. The reasons for this are deep-seated, but two points have been generally overlooked. First, the men, with long and bitter experience of over-production behind them, are unlikely to respond to the call for increased productivity on the facts as presented to them; and secondly, the antiquated, anomalous and almost unintelligible wages structure of the industry is a prolific cause of friction between management and men.

On price policy, Prof. Beacham emphasized the fundamental importance of proper grading of coals, and suggested that economists, chemists and geologists would need to put their heads together before these problems could be solved. In conclusion, he entered a plea for lower output targets in the next few years. High output targets are responsible for keeping costs and prices high, and signs are not lacking that Great Britain may have difficulty in disposing of her export surplus before the long-term technical reorganisation programme has produced any marked effect.

Mr. Dryden agreed with the general tenor of the preceding remarks and underlined the possibility of high costs and prices, together with competition, permanently restricting the demand for coal. As a measure of insurance against this, and (taking a shorter-term view) as a means of introducing flexibility and possibly reducing the price of fuel while maintaining or increasing the gross revenue from a ton of coal, he suggested that a greater proportion of scientific research in the coal industry should be directed towards the establishment of new chemical industries based on direct production (that is, using coal, not carbonization products) from low-grade coal residues, at present discarded. Such industries could also process a small proportion of the salable output in times of reduced demand. Mr. Dryden emphasized that coal is a complex organic substance of largely unknown constitution. A knowledge of its constitution would greatly accelerate progress, yet very little is being done. Advantage should be taken of this complex chemical nature by endeavouring to produce under mild and controlled conditions substances which are expensive to synthesize from petroleum. The biggest potential market probably lies in the field of constructional materials. Export of high-priced coal products in preference to raw coal should be encouraged when conditions allow; preparation should be made for sacrificing part of the fuel load to other sources of power in order to conserve our relatively meagre resources—compensation for this being sought in alternative markets for the new chemical products. Mr. Dryden advocated a flexible