Acoustical Problems.

By Major W. S. TUCKER, D.Sc.

OF all branches of physics, acoustics has probably been the most neglected of recent years; and although a good deal of work is being done in America, the number of investigators working in acoustics in Great Britain is surprisingly small. The War caused a temporary revival of interest in certain aspects of the subject, and a number of papers of scientific value were produced as the result of the application of acoustical methods to the location of submarines, guns, aeroplanes, and mining activities. Very few of the large personnel, however, who were engaged in these problems have continued in this work. Return to the universities of those engaged in teaching and research resulted in a resumption of their pre-War activities.

Yet there are many problems well deserving of systematic study. To give one illustration, the study of the properties of collectors of sound such as trumpets —and all those aspects of sound distribution in which the wave-length is comparable with the dimensions of the object—require further development by the mathematician, although the cases of obstacles large or small as compared with the wave-length have been adequately dealt with. In experimental acoustics many physical laboratories used for instruction are only equipped with apparatus of a very elementary character, and after a brief course in the first year, the students cease to take any further interest in that branch of physics. The shortage of text-books on the subject is another feature, and it is scarcely possible to appreciate how much work has been done in recent years, except by a laborious study of scientific journals, few of which are available in the average college library. Yet there is a growing demand for the solution of problems which are beginning to affect our everyday life, and the calling of "acoustical engineer," or "consultant in acoustics," should be among the professions worthy of a more definite place.

Our mode of locomotion largely involves the production of rapid explosions—only too often inadequately silenced—and our main roads are more noisy than the railroad tracks. In the neighbourhood of our busy aerodromes, noise is continuously distracting, and our quiet countryside has been invaded by the sounds of the low-flying continental traffic.

Our halls and council chambers, now that wood ceases to be an indispensable part of the walls and ceilings, are so resonant that much expense has been entailed in remedying their poor acoustical properties, and if further problems need be cited, the distortion of our speech and music by "loud speakers" is surely a matter requiring something more than the experimental investigations undertaken by commercial firms.

These are only a few of the problems the solution of which will almost certainly be found in the physical laboratory, but in order that they may be dealt with effectively, some attention must be paid to the perfecting of acoustical measurements. The researches of Harvey Fletcher, Knudsen, Minton, and other American physicists have shown what are the limitations of the ear, and although no instrument could be devised combining the extreme sensitivity and large musical range of that organ at the same time, there is ample evidence to show that the ear either for absolute or relative measurements should not be relied upon. Electrical methods of comparison must ultimately be used, and microphones must be devised in which some simple law must connect the intensity of the measured sound with the effect it produces. There is a great need for a source of sound which can be accurately reproduced, and can serve as an arbitrary unit, worthy to be included among the standards as a basis of physical measurement.

One of the chief problems in acoustical research is the provision of an acoustical laboratory. If a closed room is chosen, the distribution of sound in the room is so strongly affected by reflexions of the walls that nearly all experiments involving sound measurement are vitiated. If a siren be employed as a source of sound, and the pitch is gradually raised, a given point in the room may give a maximum of intensity for one note and a minimum for a note of another pitch. This effect is overcome to some extent by "lagging" the walls of the room with sound-absorbent material, but the effect can still be distinguished, and if one attempts to obtain resonance curves for any acoustical apparatus, these curves will be distorted.

The only means of working satisfactorily is to do experiments in the open air, and in spite of difficulties with wind and varying temperature, and possible extraneous noises, good results can be obtained. Measurements of absorbing powers of different materials have been made, by Wallace Sabine and his associates, by employing rooms in which elaborate precautions have been taken to insulate them from the outer air. In this case values have been deduced from the period of reverberation, the ear being employed as the means of estimating the duration of the effect. Not only have absorbing powers been measured, but also the experiments have been developed to such an extent as to measure deafness, and quite recently to estimate the amount of energy given out by various musical instruments, and by the human voice. Values of absorbing power for different materials have been obtained with sufficient accuracy to enable architects and builders to improve effectively the acoustic properties of halls and churches. Tests of reverberation are difficult to carry out if there are disturbing sounds in the neighbourhood. It is reasonable to anticipate that with a pure note source of sound and a tuned microphone for reception, more accurate methods could be devised for measuring reverberation periods—methods which will ignore the "jamming" effect of outside noises.

One of the chief problems in acoustical measurement is the design of a source of sound in which the note is pure, and the output is fairly uniform throughout a reasonable range of musical notes. Developments in wireless have introduced to us a very useful generator of sound in the thermionic valve and its appropriate electric circuits. Alternating currents closely approaching a simple harmonic character have been generated, and the alteration in pitch is accomplished by the simple adjustment of inductance or capacity. By a process of "heterodyning" familiar to the wireless expert, Cohen has been able to produce a very constant output for cycles varying from 50 to 5000 per second, and these oscillatory currents can be used to actuate "loud speakers." If only the loud speaker were devoid of resonance properties, the problem above referred to would be effectively solved.

Another useful piece of apparatus has been designed by E. A. Milne and Fowler in which the simple Seebeck siren is converted into a pure tone generator by so shaping the holes of the disc as to cause the flow of air to alter in quantity by a simple harmonic relation with time. If the pipes supplying the air can be made non-resonant this source of sound is probably the best available. An attempt is being made to devise pure tone centrifugal sirens in which pipes for conducting the air past the ports of the rotating part are dispensed with, but here we have the disadvantage of acoustical output increasing with the frequency of the note. With apparatus of this character and with suitable microphones, accurate resonance curves can be obtained for various sound receivers.

There are problems of sound transmission through the air which involve large scale experiments and the accurate knowledge of upper winds and temperatures. These might be considered under the heading of meteorological acoustics, and they are of increasing importance in long-range listening for aeroplanes. The work of Tyndall, Osborne Reynolds, Rayleigh, and, more recently, Van Everdingen and E. A. Milne, have resulted in the explanation of those phenomena of variation of range for sounds up-wind and down-wind. Milne has obtained expressions for range and corrections for refraction due to variations of upper wind and upper temperature when these follow a linear law. Explanations of zones of silence at some distance from the source have also been afforded. The Acoustical Section, working for the three Fighting Services and the Department of Scientific and Industrial Research, has been able to verify experimentally some of these laws, and the latter have been very helpful in the design of directional sound-receiving apparatus.

One of the features of recent developments in acoustics has been the production and improvement of the Service sound locators for detection and location of aeroplanes. These instruments will not in general point to the source of sound owing to (1) lag of sound, if the source is a moving one, and (2) the departure of the wave front from the spherical owing to refraction due to wind and temperature variations. The ease with which these instruments can be used depends on the structure of the atmosphere in which, apart from refraction due to the above causes, there are irregularities due to local temperature and humidity variations, and local whirls and eddies.

These variations in the medium have all been grouped under the heading of "acoustic clouds." Contrary to what might be expected, these acoustic clouds are most in evidence on a warm sunny day of good visibility, and are undoubtedly due to unequal heating from the sun's radiation. After sunset these clouds dissipate, and we get, not only good listening as regards range, but also greatly improved powers of finding direction. The blurred acoustical image becomes well defined. On the other hand, a uniform fog is acoustically clear and it is only on the fringes of the fog that sound absorption takes place. Experiments have recently been performed with aeroplanes in which some idea of the dimensions of the acoustic clouds has been deduced. These have been obtained by taking a photographic record of the sound obtained from an aeroplane in flight, and observing the periodicity of the sound fluctuations.

One of the outcomes of the study of meteorological conditions has been the fixing of an "acoustic sky-line," which, under adverse wind conditions, always lies above the visual skyline. A source of sound moving through the air may be observed to rise or set over the skyline, with a definiteness almost as complete as the rising and setting of the sun, and when the sound is below the skyline a kind of acoustic twilight is produced. At this stage sense of direction is lost, the sound is diffused, and only arrives at the observer or microphone by scattering.

Other problems involving big scale experiments are connected with the production of powerful directive sources of sound, and include the breakdown of the air as a medium of sound transmission when the displacements due to the source of sound become large.

The foregoing statement merely provides a summary of those problems which are engaging the attention of research workers in acoustics, but they may serve to indicate how very fruitful is this field of investigation for the expert experimental physicist.

Obituary.

MR. A. E. CRAWLEY.

THE death took place on October 21 of Alfred Ernest Crawley, who was well known as the author of several works on anthropological matters. He was born in 1869, the son of the Rev. Samuel Crawley, Rector of Oddington, Oxford, was educated at Sedbergh and Cambridge, and entered the scholastic profession; he abandoned this for journalism in 1908. An adept in several branches of sport, his works on tennis and ball games are of recognised authority. In anthropology, besides contributing to the journals of several scientific societies, to NATURE, and to Hastings's "Dictionary of Religion and Ethics," he was the author of three books of some importance—"The Mystic Rose, a Study of Primitive Marriage," published in 1902; "The Tree of Life, a Study of Religion," published in 1905, and "The Idea of the Soul," which appeared in 1909. Of these "The Mystic Rose" was the best known—it undoubtedly exercised no inconsiderable influence on the anthropological thought of that day, especially in so far as it emphasised the importance of marriage ceremonies, a side of the subject to which Westermarck had then paid too little attention in his monumental study of human marriage.

Certain characteristic lines of thought are common to all Crawley's books, and indeed so early as 1895 he had outlined in the Journal of the Anthropological