of the finest particles of Sahara sand, while others looked for its origin on laterite ground.

The value of the occurrences of falls of dust is of special moment meteorologically, because they afford us a means of obtaining further knowledge of the actual movements of the air currents in the higher reaches of our atmosphere which cannot be gained by any other such direct methods. Much valuable information was obtained of the movement of the air at great heights by the dust that was ejected during the eruption of Krakatoa, and as this volcano is situated near the equator, where the air currents have a great tendency to rise directly away from the earth's surface, the conditions were favourable for the dust reaching an extraordinary elevation.

Nevertheless, whether the falls owe their origin to dust storms in a desert or eruptions of large volcanoes, it is of great importance to meteorological science that they should be, not only accurately observed, but recorded and discussed. Fortunately, the fall in the present instance occurred where a great amount of useful data could be, and was, secured. In the handling of this material the authors are to be congratulated, for besides considerably increasing our knowledge of the way in which the dust is transported and enlightening us on other peculiarities of this interesting phenomenon, they have given us a volume which will serve as an excellent example for future recorders and observers. W. J. S. L.

BRITISH VERSUS AMERICAN LOCOMOTIVES.

A NOTEWORTHY Parlimentary paper has recently been issued containing correspondence respecting the comparative merits of British, Belgian and American built locomotives running on the Egyptian railways. The paper is full of interest to the locomotive engineer, bearing out as it does the unsatisfactory results obtained with American locomotives on British, Colonial and Indian railways when compared with the English design of engine, and, what is more, these unsatisfactory results are in all cases certified by the representative of the American firm of locomotive builders, as well as by an official appointed by the Egyptian railway authority, so there can be little doubt as to their accuracy.

Probably the most interesting report in the series is that by Mr. Trevithick, the locomotive engineer, who says:—

"The Mechanical Department of the Egyptian State Railways has recently made some interesting comparative trials between British and American locomotives of the same weight and power. These comparisons have been carried out under exceptionally favourable circumstances, inasmuch as the locomotives employed were typical of their respective countries in design and manufacture, and the trials were personally conducted, and the results conjointly signed, by a representative sent out by the American builders and a locomotive inspector of the Egyptian Railway Administration.

"The first set of trials, consisting of eight runs extending over 1034 miles, was between goods engines, and, in order to secure similar loads and to be able to gradually increase the weight of trains to the maximum that the respective engines could satisfactorily draw, the material transported consisted chiefly of coal.

"The total amount of coal consumed in the eight trips by the British engines was 22·84 tons, which works out at an average of 49·4lbs. per mile, whilst the American engines consumed 28·69 tons, an average of 62 lbs. per mile; in other words, for every 100 tons of coal consumed by the British engines the American engines burnt 125·4 tons, *i.e.* an excess of 25·4 per cent. This economy was effected by the British engines, although they drew a heavier average load, to the extent of 14·2 per cent. than the American, the average train taken by the British engines being 57 trucks, or 868 tons, as against 54 trucks, or 760 tons, the average train taken by the American. The maximum load taken by each make of engine was 61 trucks.

"These trials were followed by others between passenger types of engines, extending over 1345 miles; each make ran an equal number of trips with practically similar formation of trains, with the result that the British engines consumed a total of 18·47 tons of coal, or an average of 30·7 lbs. per mile, as against a total of 27·8 tons, or an average of 46·3 lbs. per mile, in the case of the American engines, which means that where the British engine consumed 100 tons, the American engine consumed 150 tons, or 50 per cent. more. Such a difference at 1*l*. 14*s*. 2*d*. per ton, the average price paid last year by the Railway Administration, represents an additional yearly cost per engine of 400*l*.; which is to say that these ten American engines would cost in coal in one year 4000*l*. more than the ten British engines, an amount almost sufficient to buy two new ones."

The above extract from Mr. Trevithick's report conclusively proves that the British type of locomotive is well able to hold its own in the three important matters of fuel and oil consumption, and cost of repairs. Much has been written lately on the standardisation of the locomotive, but in a progressive age this appears to be unnecessary, since the locomotive of yesterday must always be out of date. Much can, however be done to assist locomotive builders in the way of standardisation of specifications and, more particularly, of the test requirements for the material.

It is absurd to think that consulting engineers cannot agree as to the best test requirements for, say, a crank axle or a steel boiler plate. With standard tests the locomotive builders could buy the material more cheaply, obtain quicker deliveries from the makers, and, probably, in their turn take less time to complete an order.

INTERFERENCE OF SOUND.[1]

FOR the purposes of laboratory or lecture experiments it is convenient to use a pitch so high that the sounds are nearly or altogether inaudible. The wave-lengths (1 to 3 cm.) are then tolerably small, and it becomes possible to imitate many interesting optical phenomena. The ear as the percipient is replaced by the high-pressure sensitive flame, introduced for this purpose by Tyndall, with the advantage that the effects are visible to a large audience.

As a source of sound a "bird-call" is usually convenient. A stream of air from a circular hole in a thin plate impinges centrically upon a similar hole in a parallel plate held at a little distance. Bird-calls are very easily made. The first plate, of 1 or 2 cm. in diameter, is cemented, or soldered, to the end of a short supply tube. The second plate may conveniently be made triangular, the turned-down corners being soldered to the first plate. For calls of medium pitch the holes may be made in tin plate. They may be as small as ½ mm. in diameter, and the distance between them as little as 1 mm. In any case the edges of the holes should be sharp and clean. There is no difficulty in obtaining wave-lengths (complete) as low as 1 cm., and with care wave-lengths of 0·6 cm. may be reached, corresponding to about 50,000 vibrations per second. In experimenting upon minimum wave-lengths, the distance between the call and the flame should not exceed 50 cm., and the flame should be adjusted to the verge of flaring ("Theory of Sound," 2nd ed., § 371). As most bird-calls are very dependent upon the precise pressure of the wind, a manometer in immediate connection is practically a necessity. The pressure, originally somewhat in excess, may be controlled by a screw pinch-cock operating on a rubber connecting tube.

In the experiments with conical horns or trumpets, it is important that no sound should issue except through these channels. The horns end in short lengths of brass tubing which fit tightly to a short length of tubing (A) soldered air-tight on the face of the front plate of the bird-call. So far there is no difficulty; but if the space between the plates be boxed in air-tight, the action of the call is interfered with. To meet this objection a tin-plate box is soldered air-tight to A, and is stuffed with cotton-wool kept in position by a *loosely* fitting lid at C. In this way very little sound can escape except through the tube A, and yet the call speaks much as usual. The manometer is connected at the side tube D. The wind is best supplied from a gas-holder.

With the steadily maintained sound of the bird-call there is no difficulty in measuring accurately the wave-lengths by the method of nodes and loops. A glass plate behind the flame, and mounted so as to be capable of sliding backwards and forwards, serves as reflecting wall. At the plate, and at any distance from it measured by an *even* number of quarter wave-lengths, there are nodes, where the flame does not respond. At intermediate distances, equal to *odd* multiples of the quarter wave-length, the effect upon the flame is a maximum. For the present purpose it is best to use nodes, so adjusting the sensitiveness of the flame that it only just recovers its height at the

[1] A Discourse delivered at the Royal Institution on Friday, January 17, by the Right Hon. Lord Rayleigh, F.R.S.

minimum. The movement of the screen required to pass over ten intervals from minimum to minimum may be measured, and gives at once the length of five complete progressive waves. For the bird-call used in the experiments of this lecture the wave-length is 2 cm. very nearly.

When the sound the wave-length of which is required is not maintained, the application of the method is, of course, more difficult. Nevertheless, results of considerable accuracy may be arrived at. A steel bar, about 22 cm. long, was so mounted as to be struck longitudinally every two or three seconds by a small hammer. Although in every position the flame shows some uneasiness at the stroke of the hammer, the distinction of loops and nodes is perfectly evident, and the measurement of wave-length can be effected with an accuracy of about 1 per cent. In the actual experiment the wave-length was nearly 3 cm.

The formation of stationary waves with nodes and loops by perpendicular reflection illustrates interference to a certain extent, but for the full development of the phenomenon the interfering sounds should be travelling in the same, or nearly the same, direction. The next example illustrates the theory of Huyghens' zones. Between the bird-call and the flame is placed a glass screen perforated with a circular hole. The size of the hole, the distances and the wave-length are so related to one another that the aperture just includes the first and second zones. The operation of the sounds passing these zones is antagonistic, and the flame shows no response until a part of the aperture is blocked off. The part blocked off may be either the central circle or the annular region defined as the second zone. In either case the flame flares, affording complete proof of interference of the parts of the sound transmitted by the aperture.

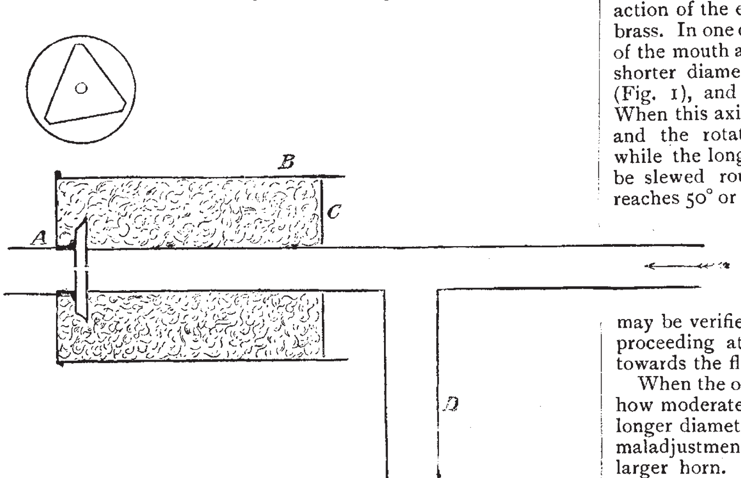

FIG. 1.

From a practical point of view, the passage of sound through apertures in walls is not of importance, but similar considerations apply to its issue from the mouths of horns, at least when the diameter of the mouth exceeds the half wave-length. The various parts of the sound are approximately in the same phase when they leave the aperture, but the effect upon an observer depends upon the phases of the sounds, not as they leave, but as they arrive. If one part has further to go than another, a phase discrepancy sets in. To a point in the axis of the horn, supposed to be directed horizontally, the distances to be travelled are the same, so that here the full effect is produced, but in oblique directions it is otherwise. When the obliquity is such that the nearest and furthest parts of the mouth differ in distance by rather more than one complete wave-length, the sound may disappear altogether through antagonism of equal and opposite effects. In practice the attainment of a complete silence would be interfered with by reflections, and in many cases by a composite character of sound, viz. by the simultaneous occurrence of more than one wave-length.

In the fog signals established on our coasts, the sound of powerful sirens issues from conical horns of circular cross-section. The influence of obliquity is usually very marked. When the sound is observed from a sufficient distance at sea, a deviation of even 20° from the axial line entails a considerable loss, to be further increased as the deviation rises to 40° or 60°. The difficulty thence arising is met, in the practice of the Trinity House, by the use of two distinct sirens and horns, the axes of the latter being inclined to one another at 120°. In this way an arc of 180° or more can be efficiently guarded, but a more equable distribution of the sound from a single horn remains a desideratum.

Guided by the considerations already explained, I ventured to recommend to the Trinity House the construction of horns of novel design, in which an attempt should be made to spread the sound out horizontally over the sea, and to prevent so much of it from being lost in an upward direction. The solution of the problem is found in a departure from the usual circular section and the substitution of an elliptical or elongated section, of which the short diameter, placed horizontally, does not exceed the half wave-length; while the long diameter, placed vertically, may amount to two wave-lengths or more. Obliquity in the *horizontal plane* does not now entail much difference of phase, but when the horizontal plane is departed from, such differences enter rapidly.

Horns upon this principle were constructed under the supervision of Mr. Matthews, and were tried in the course of the recent experiments off St. Catherine's. The results were considered promising, but want of time and the numerous obstacles which beset large-scale operations prevented an exhaustive examination.

On a laboratory scale there is no difficulty in illustrating the action of the elliptical horns. They may be made of thin sheet brass. In one case the total length is 20 cm., while the dimensions of the mouth are 5 cm. for the long diameter and $1\frac{1}{4}$ cm. for the shorter diameter. The horn is fitted at its narrow end to A (Fig. 1), and can rotate about the common horizontal axis. When this axis is pointed directly at the flame, flaring ensues; and the rotation of the horn has no visible effect. If now, while the long diameter of the section remains vertical, the axis be slewed round in the horizontal plane until the obliquity reaches 50° or 60°, there is no important falling off in the response of the flame. But if at obliquities exceeding 20° or 30° the horn is rotated through a right angle, so as to bring the long diameter horizontal, the flame recovers as if the horn had ceased sounding. The fact that there is really no falling off may be verified with the aid of a reflector, by which the sound proceeding at first in the direction of the axis may be sent towards the flame.

When the obliquity is 60° or 70°, it is of great interest to observe how moderate a departure from the vertical adjustment of the longer diameter causes a cessation of effect. The influence of maladjustment is shown even more strikingly in the case of a larger horn. According to theory and observation, a serious falling off commences when the tilt is such that the difference of distances from the flame of the two extremities of the long diameter reaches the half wave-length—in this case 1 cm. It is thus abundantly proved that the sound issuing from the properly adjusted elliptical cone is confined to a comparatively narrow belt round the horizontal plane and that in this plane it covers efficiently an arc of 150° or 160°.

Another experiment, very easily executed with the apparatus already described, illustrates what are known in optics as Lloyd's bands. These bands are formed by the interference of the direct vibration with its very oblique reflection. If the bird-call is pointed toward the flame, flaring ensues. It is only necessary to hold a long board horizontally under the direct line to obtain a reflection. The effect depends upon the precise height at which the board is held. In some positions the direct and reflected vibrations cooperate at the flame, and the flaring is more pronounced than when the board is away. In other positions the waves are antagonistic, and the flame recovers as if no sound were reaching it at all. This experiment was made many years ago by Tyndall, who instituted it in order to explain the very puzzling phenomenon of the "silent area." In listening to fog signals from the sea it is not unfrequently found that the signal is lost at a distance of a mile or two and recovered at a greater distance in the same direction. During the recent experiments, the Committee of the Elder Brethren of the Trinity House had several opportunities of making this observation. That the surface of the sea must act in the manner supposed by Tyndall cannot be doubted, but there are two difficulties in the way of accepting the simple explanation as complete. According to it the interference should always be the same, which is certainly not the case. Usually there is no silent area. Again, although according to the analogy of Lloyd's bands there might be a dark or silent place at a particular height above the water, say on the bridge of the *Irene*, the effect should be limited to the neighbourhood of the particular height. At a height above the water twice as great, or near the water level itself, the sound should be heard again. In the latter case there were some difficulties, arising from disturbing noises, in making a satisfactory trial; but as a matter of fact, neither by an observer up the mast nor by one near the water level was a sound lost on the bridge ever recovered.

The interference bands of Fresnel's experiment may be imitated by a bifurcation of the sound issuing from A (Fig. 1). For this purpose a sort of T-tube is fitted, the free ends being provided with small elliptical cones, similar to that already described, the axes of which are parallel and distant from one another by about 40 cm. The whole is constructed with regard to symmetry, so that sounds of equal intensity and of the same phase issue from the two cones the long diameters of which are vertical. If the distances of the burner from the mouths of the cones be precisely equal, the sounds arrive in the same phase and the flame flares vigorously. If, as by the hand held between, one of the sounds is cut off. the flaring is reduced, showing that with this adjustment the two sounds are more powerful than one. By an almost imperceptible slewing round of the apparatus on its base-board, the adjustment above spoken of is upset and the flame is induced to recover its tall equilibrium condition. The sounds now reach the flame in opposition of phase and practically neutralise one another. That this is so is proved in a moment. If the hand be introduced between either orifice and the flame, flaring ensues, the sound not intercepted being free to produce its proper effect.

The analogy with Fresnel's bands would be most complete if we kept the sources of sound at rest and caused the burner to move transversely so as to occupy in succession places of maximum and minimum effect. It is more convenient with our apparatus and comes to the same thing, if we keep the burner fixed and move the sources transversely, sliding the base-board without rotation. In this way we may verify the formula, connecting the width of a band with the wave-length and the other geometrical data of the experiment.

The phase discrepancy necessary for interference may be introduced, without disturbing the equality of distances, by inserting in the path of one of the sounds a layer of gas having different acoustical properties from air. In the lecture carbonic acid was employed. This gas is about half as heavy again as air, so that the velocity of sound is less in the proportion of 1:1·25. If l be the thickness of the layer, the *retardation* is ·25l; and if this be equal to the half wave-length, the interposition of the layer causes a transition from complete agreement to complete opposition of phase. Two cells of tin plate were employed, fitted with tubes above and below, and closed with films of collodion. The films most convenient for this purpose are those formed upon water by the evaporation of a few drops of a solution of celluloid in pear-oil. These cells were placed one in the path of each sound, and the distances of the cones adjusted to maximum flaring. The insertion of carbonic acid into *one* cell quieted the flame, which flared again when the second cell was charged so as to restore symmetry. Similar effects were produced as the gas was allowed to run out at the lower tubes, so as to be replaced by air entering above.[1]

Many vibrating bodies give rise to sounds which are powerful in some directions but fail in others—a phenomenon that may be regarded as due to interference. The case of tuning forks (unmounted) is well known. In the lecture a small and thick wine-glass was vibrated, after the manner of a bell, with the aid of a violin bow. When any one of the four vibrating segments was presented to the flame, flaring ensued; but the response failed when the glass was so held at the same distance that its *axis* pointed to the flame. In this position the effects of adjacent segments neutralise one another and the aggregate is zero. Another example, which, strangely enough, does not appear to have been noticed, is afforded by the familiar open organ pipe. The vibrations issuing from the two ends are in the same phase as they start, so that if the two ends are equally distant from the percipient, the effects conspire. If, however, the pipe be pointed towards the percipient, there is a great falling off, inasmuch as the length of the pipe approximates to the half wave-length of the sound. The experiment may be made in the lecture-room with the sensitive flame and one of the highest pipes of an organ, but it succeeds better and is more striking when carried out in the open air with a pipe of lower pitch, simply listened to with the unaided ear of the observer. Within doors reflections complicate all experiments of this kind.

[1] In a still atmosphere the hot gases arising from lighted candles may be substituted for the layers of CO_2.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—The 235th meeting of the Junior Scientific Club was held on May 2 in the physiological lecture room at the Museum. Two papers were read, "A New Type of Vertebrate Kidney," by Mr. E. S. Goodrich, Merton College, and "The Prussic Acid Problem," by Mr. J. M. Wadmore, Trinity College.

The ninth Robert Boyle lecture of the Junior Scientific Club will be delivered by Prof. T. Clifford Allbutt, F.R.S., in Balliol College Hall on Tuesday next, May 13. The subject will be "The Growth of the Experimental Method in Oxford."

THE honorary degree of LL.D. was conferred on Lord Kelvin on Monday by the University of Yale.

A MEETING will be held at the Mansion House to-morrow, May 9, at 3 p.m., with the Lord Mayor in the chair, in support of higher university education and research in London, with special reference to the fund being raised for the endowment of University College and its incorporation in the University of London. All who are interested in national progress and the advancement of knowledge are invited to take part in this movement for making up in some degree the gaps in our educational system, and in the endeavour to place at the disposal of the inhabitants of London facilities for mental training at any rate equal to those enjoyed by our continental neighbours. Among the speakers at the Mansion House meeting will be the Duke of Devonshire, Lord Brassey (chairman of the Appeal Committee), Lord Avebury, Mr. Ritchie, M.P., the Hon. Alban Gibbs, M.P., Sir Michael Foster, M.P., Principal Rücker, F.R.S., Mr. Lionel Phillips, and Mr. H. R. Beeton.

THE debate on the second reading of the Education Bill of the Government was opened in the House of Commons on Monday. Mr. Bryce gave reasons for believing that the Bill would not establish satisfactory local authorities, secure educational improvement, or effect a final settlement of the education question. Referring to secondary education, Mr. Bryce said that the Bill promises to do nothing for it, though secondary education is the most urgent of all our educational wants. "It does not direct any inquiry or any scheme to be made for the reorganisation of secondary education. It does not impose any duty upon the new authorities to provide secondary education, however great the local need may be. It is purely permissive. It does not contain any suggestion for dealing with endowments or for the reorganisation of schools. It does not set apart the grant under the Act of 1890 as only applicable to secondary education. It gives a rating power up to 2*d.*, with the possibility of increase by the consent of the Local Government Board. Secondary education ought to have had a Bill to itself, and it ought to have had a start of two or three years before primary education is thrown upon the same authority, if ever it is to be thrown upon it. Now, the probability is that secondary education will go to the wall." Sir John Gorst urged in reply that the Bill creates an authority, or it gives to the authority already existing for technical education full powers for secondary education, and so may be said to do something for secondary education. As to the inadequacy of the funds available under the Bill, it was held that the County Councils had enough to begin with, "and," added Sir John Gorst, "if this Bill is passed it will, at all events, make a beginning of secondary education, and when the authorities of counties and county boroughs see what sum of money is really required, I have no doubt the representations made by them to this House will be received with very fair consideration." The debate was continued on Tuesday, and among the points discussed were the comparative merits of School Boards and County Councils as local authorities for education, need for better training of teachers, the extension of the limit of a 2*d.* rate, and the need for generous grants from the Exchequer for secondary education.